Climate variability: Human management response to environmental changes in Touws River valley and Makolokwe

By

Semakaleng Llale
3275768

UNIVERSITY *of the*
WESTERN CAPE

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Supervisor: Dr Suzanne Grenfell

Co- Supervisor: Professor Shirley Brooks

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DECLARATION

I declare that *'Climate variability: Human management response to environmental changes in Touws River valley and Makolokwe'* is my own work, that it has not been submitted for any degree or examination in any other university, and that all the sources I have used or quoted have been indicated and acknowledged by complete reference. This thesis has been submitted to turnitin and the report checked by my supervisor.

Signed _____ Date 05 December 2019

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All the glory belongs to my redeemer and saviour Jesus.

"But seek first the kingdom of God and His righteousness, and all these things shall be added to you. Therefore, do not worry about tomorrow, for tomorrow will worry about its own things. Sufficient for the day is its own trouble" (Matthew 6:34-35)

ABBREVIATIONS & ACRONYMS

SAWS	South African Weather Services
DEA	Department of Environmental Affairs
DWS	Department of Water and Sanitation
WHO	World Health Organisation
NDVI	Normalised Difference Vegetation Index
ENSO	El Niño Southern Oscillation

ABSTRACT

Climate has been changing significantly around the globe; hence climate variability is of great interest to researchers. The changes in climate have caused variances in rainfall and temperature, both elements of paramount importance in farming, whether commercial or communal farming. As these fluctuations in temperature and rainfall occur, they cause direct impacts on different livelihoods, fauna and flora. The aim of this thesis is to investigate the human management responses of farmers in two different contexts of communal farming (Makolokwe) and commercial farming (Touws River valley), with a focus investigation on the adaptation and coping strategies of the farmers, as well as spatial analysis of the vegetation and rainfall variability. Farmers were asked to discuss climate and adaptation based on the rainfall data available as well as far as they could remember the occurrence of changes. Rainfall data was available between 1988 and 2017 for Touws River, while the data utilised for Makolokwe was available between 1928 and 2016. The link between the local knowledge of the farmers and scientific knowledge is an important aspect of this research. The Normalised Difference Vegetation Index (NDVI) was used to analyse the vegetation changes on a temporal and spatial scale in the context of Makolokwe and Touws River valley respectively. The differing variations in climate variability and change experienced by the two farming communities are placed alongside an exploration of the adaptation and coping measures which are put in place by farmers as a response to the changes evident in climate, as it allows for better and thorough understanding of the occurring changes in the two communities.

The study found that perceptions about climate variability vary in the two communities although there are some common factors. Farmers' perceptions about climate variability are drawn from their own observations at a local level as well as knowledge from the media regarding terms such as El Niño and drought. Farmers in both communities indicated that they experienced insufficient rain in the winter months which had an impact on the grazing areas and the management of the livestock. These months also threatened livelihoods, especially for farmers who depend on their livestock for their livelihood, in particular communal farmers.

Perceptions of factors such as decreasing grazing and vegetation in their environments have led to the adoption of adaptation and coping strategies on the part of farmers. Commercial farmers have more choices in this regard than communal farmers, such as converting to game farming. Common coping strategies include: (1) farmers have had to subsidise and use alternative food sources for the livestock, (2) livestock numbers have been reduced in order to adapt to climate variability, with an impact on livelihoods (3) farmers have had to rely on their hope and faith that things will get better.

Planning for climate variability is challenging for land managers. Knowledge and access to resources is therefore essential in ensuring that farmers are kept on track with the changing environment.

Key words: climate variability, communal farming, commercial farming, adaptation and coping strategies, NDVI

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CHAPTER 1: INTRODUCTION

1.1 Background to study

The emergence of variable trends in climate have caused tension in farming communities as livelihoods are affected. Communal and commercial farmers in South Africa are faced with environmental challenges daily, and these have the potential to often impact upon their farming practices (Ayal and Filho, 2017). As the harsh realities of coping with climate variability and climate change occur, farmers suffer fatigue and stress. Changes in rainfall trends and available grazing areas often leaves farmers vulnerable, especially if adaptation and coping strategies are not put in place. Therefore, it is important for farmers to have knowledge about their environment as that gives them the upper hand as opposed to not understanding all the changes linked to climate change and variability. Dang *et al.* (2014) suggest that the way in which information about adaptation is interpreted is important because of the different experiences, as well as personal and societal values that people may have. The knowledge allows them to be better prepared for the future. Thus, merging local knowledge and scientific knowledge will allow for better understanding of these environmental phenomena. Archer *et al.* (2008) argue that local knowledge and external (scientific) knowledge could co-exist to understand adaptive strategies in agriculture. As knowledge travels through these channels it may allow for better understanding and for better solutions and results.

Variability in climate is predicted to increase as a result of climate change in Southern Africa causing severe storms and droughts associated (Adler *et al*., 2006). This concept has been contested globally by different sectors, because many people still do not understand the term or what it means to the different communities. Farmers may associate variability with changing rainfall trends, El Niño, variations in cold and hot temperatures, and drought. These perceptions and understanding of climate variability differ from farmer to farmer. Thomas *et al.* (2007) suggests that concepts such as drought and extreme rainfall are not enough for farmers to fully understand climate variability. A farmer's perception and understanding of how their immediate environment is changing is important, as it may determine how they cope and the adaptation and coping strategies that they put in place in order to survive. Because coping and adaptation

strategies are not equivalent, a strategy used by one community may not necessarily work for the next. These perceptions that people have about climate change and variability are rooted in socio-economic and cultural understandings, as well as material interests (Ayal and Filho, 2017).

There is evidence that climate change will strongly affect the African continent (DEA, 2017; Serdeczng *et al.,* 2017). As the climate warms, it will become more variable causing more frequent droughts and storms (Adler *et al*., 2006). Such changes will require adaptation methods to be taken into consideration in order to cope with the different environmental variations which may affect livelihoods. Elum *et al*. (2017) suggest that adaptation is as a result of the level of exposure and vulnerability to climate change impacts which an area may face. Additionally, mitigation and adaptation strategies complement one another. Ideally this should be the case, but it is often not the case.

1.2 Problem statement

Farmers' knowledge of climate variability impacts on the environment as well as the adaptation and coping strategies they adopt, need to be understood in order to ensure that proper strategies are put in place. Sarr *et al*. (2015) proposes that the level of knowledge that farmers have about climate change and adaptation strategies can assist with future agricultural plans of development. When proper strategies are put in place farming practices can also function effectively. The reality is that most farmers are not aware of how all the changes which occur relate to their environment and how that may have an impact on their farming activities. Because farmers depend on their farming for their livelihood, this often puts them in a vulnerable position. In South Africa, about 69 % of the land surface is suitable for livestock farming. From an agricultural point of view, livestock farming is the biggest sector (Kotze and Rose, 2015).

A study by Mapfumo *et al*. (2013) revealed that lack of knowledge and new technological advancements has placed a strain on local farming. Kotze and Rose (2015) have pointed that the agricultural sector in South Africa is greatly dependent on sustainable farming methods in order to ensure that this sector remains in good shape. Therefore, sustainability is an essential part of good farming practices, which should be utilised by both commercial and communal farmers. Kotze and Rose (2015) further stated that sustainable farming would ensure the needs of South Africa currently and for the future. A large part of farming in South Africa is dependent on

water, which is a scarce resource (DEA, 2011). The knowledge from officials and scientists to assist both commercial farmers and communal farmers could be beneficial not only for livelihoods but for the betterment of South Africa's economy

The vulnerability differs in different provinces in South Africa. A study by Gbetibouo *et al.* (2010) showed that the most vulnerable provinces are characterised by high percentages of small-scale farming, soil degradation, rural population density, unemployment, literacy levels and other socio-economic factors. Therefore, adaptation strategies as well as policy that is available needs to consider each region separately. If a blanket approach or policy is adopted, selected strategies may not applicable for all regions and farmers' individual needs. Therefore, external help will be especially useful in areas most affected by climate variability and change. Chikosi *et al.* (2019) said that indigenous communities are often not included in policy decisions related to climate change. Therefore, policies are often published without knowledge, perceptions, and opinions of these indigenous communities.

Often local knowledge and scientific knowledge are treated separately and are seen to not be used interchangeably. In the farming sector in South Africa, especially with the environmental changes which are occurring, it is imperative to have a system that allows for the human-environment relationship. When information from local communities and scientific knowledge are used together, most of the challenges regarding the human responses to environmental changes can be explained. Wiid and Ziervogel (2012) noted that the relationship between perceptions and climate change is not a simple one to explain. Thus, the relationship between local and scientific knowledge can facilitate growth to these difficult sectors related to environmental changes.

1.3 Rationale for the study

Communal and commercial farmers are often faced with challenges in their industry. Climate variability and climate change have had a significant impact on farming communities. Research has focused on how climate variability has affected farming, and on the perceptions that farmers have about climate variability and climate change in various parts of the world including South Africa (Clarke *et al*., 2012; Fosu-Mensah *et al*., 2012; Elum *et al*., 2017; Chikosi *et al*., 2019). The perceptions that farmers have on climate change and variability are vital in understanding

the adaptation and coping strategies of the farmers (Sarr *et al*., 2015). Despite all the research that has been conducted, the link between local knowledge of the farmers and scientific knowledge needs to be looked at in order to understand how the two could be intertwined. Research on how the two components could facilitate new ways of looking at adaptation and coping strategies is vital. Awareness on climate viability and change also needs more emphasis in the farming communities in order to alert other farmers who may not understand the changes which are occurring in their immediate environments and the adaptation measures thereof. Responses to climate variability and change from a communal and commercial context could mean better decision making and a better understanding of how these communities adapt to the changes.

1.4 Research aims and objectives

1.4.1 Aim

To understand and explore how human management respond to climate variability and livestock grazing in Makolokwe and Touws River valley.

1.4.2 Objectives

1. To understand adaptation strategies of communities and how they differ.
2. To explore variability in rainfall and vegetation productivity in grazing lands of the communities.
3. To investigate whether the local knowledge mirrors the scientific knowledge.

1.5 Study areas

Two study areas in vastly different regions of South Africa were selected for this research project. In both regions, livestock rearing is locally important in sustaining rural livelihoods. The first is Makolokwe, a small community in the North West Province with a total population of 1574 and consists of 648 households (Statistics South Africa, 2016). North of the community is the small town of Bethanie, while toward the south is Segwaelane (Figure 1). It is situated in the Rustenburg local municipality, which also forms part of the Bojanala district municipality. The settlement type in the community is 100% tribal/traditional, classified by stats SA (Statistics South Africa, 2016).

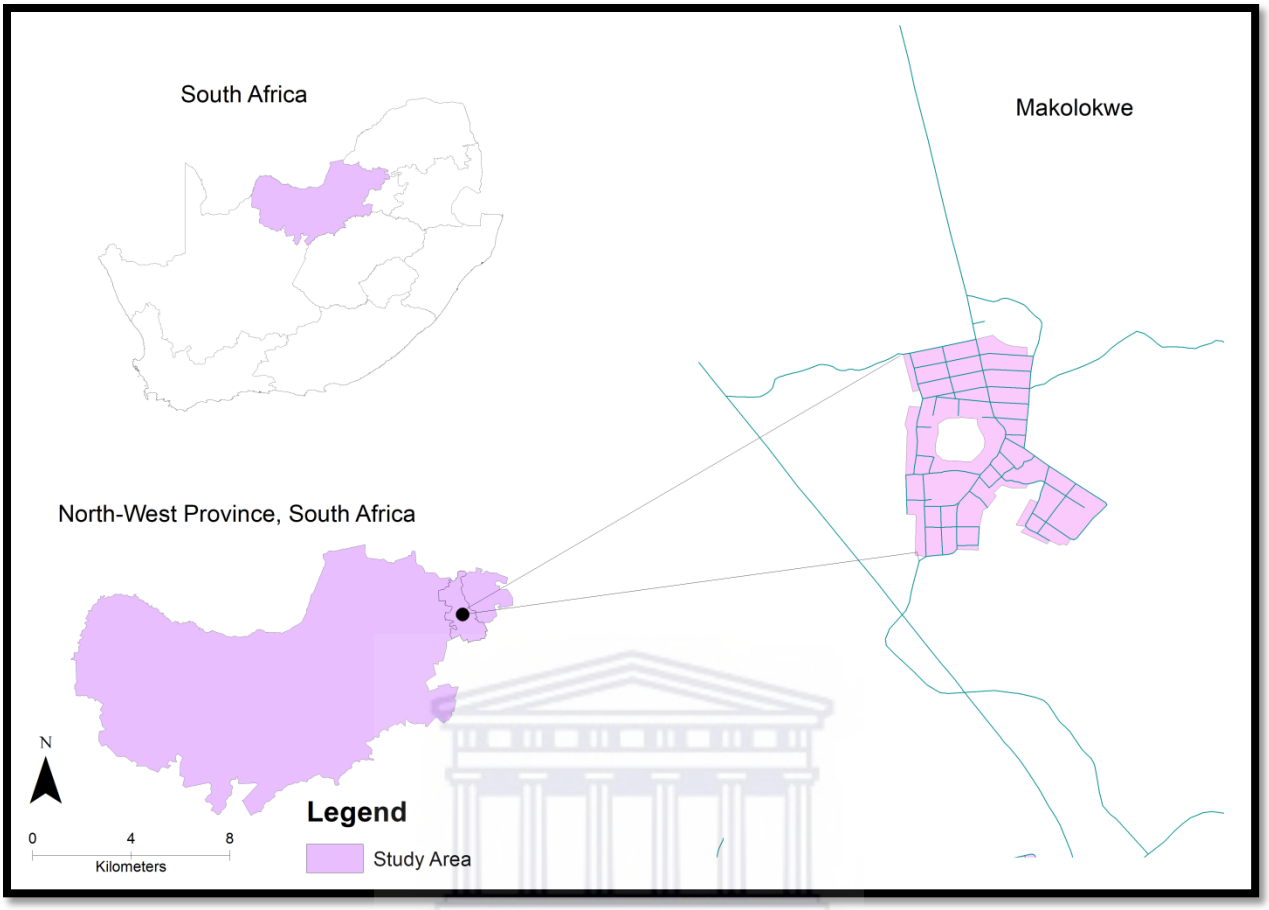

Figure 1: Study area map of Makolokwe.

The topography of the area consists of undulating terrain which is interspersed with hills. The hills average a height of 100m (see Figure 2a). The average maximum temperature is 26.6 ºC, with the average minimum temperature from about 11 ºC to 17 ºC. Maximum temperatures in summer reached over 30 ºC with minimum temperatures reaching 0 ºC (Knight Piesold, 2006 in Pistorius, 2012). The community falls in the savanna biome (SANBI, 2019). Farmers in the community keep livestock such as cattle and goats (See Figure 2b, 2c). The kraals which are used for the livestock are in close proximity to the homesteads and some are located within the village. Farmers in the community are employed except for a minority of farmers who are 60 years and above. Of these, some have started to receiving government grants and others have retired from formal employment and become pensioners.

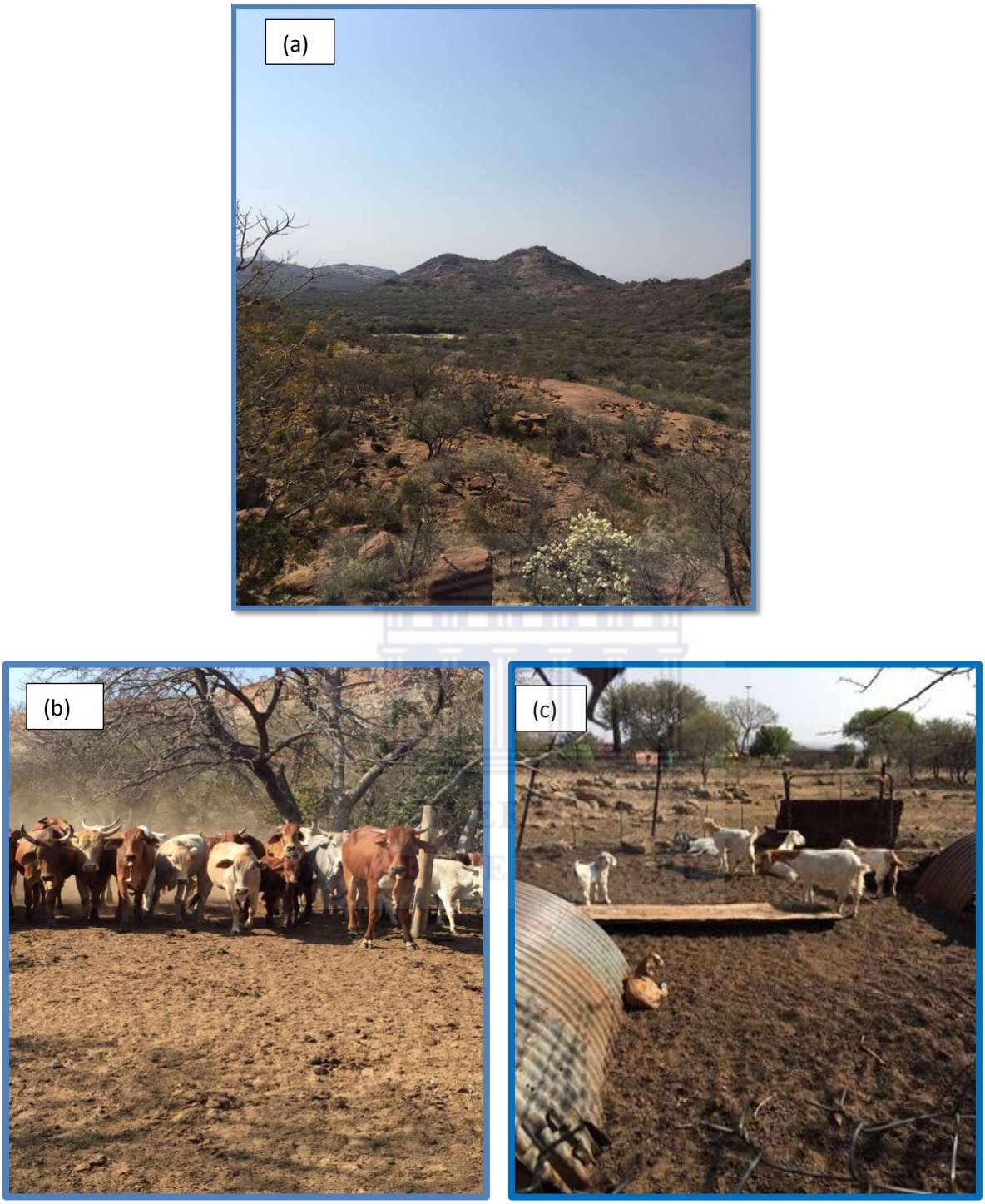

Figure 2: Images of Makolokwe, (a) area around the village, (b) and (c) show some of the livestock kept by the farmers in the community.

The second region selected was Plathuis, located within the Touws River valley near Ladismith in the Western Cape. This small community consisting of farms is situated along the Touws River and the southern slopes of the Touwsberg Mountain (Figure 3). Rainfall in the region occurs all year round with highest annual rainfall of about 270 mm (Kannaland Municipality, 2017). The biomes present in the area are the succulent karoo and fynbos biome (SANBI, 2019).

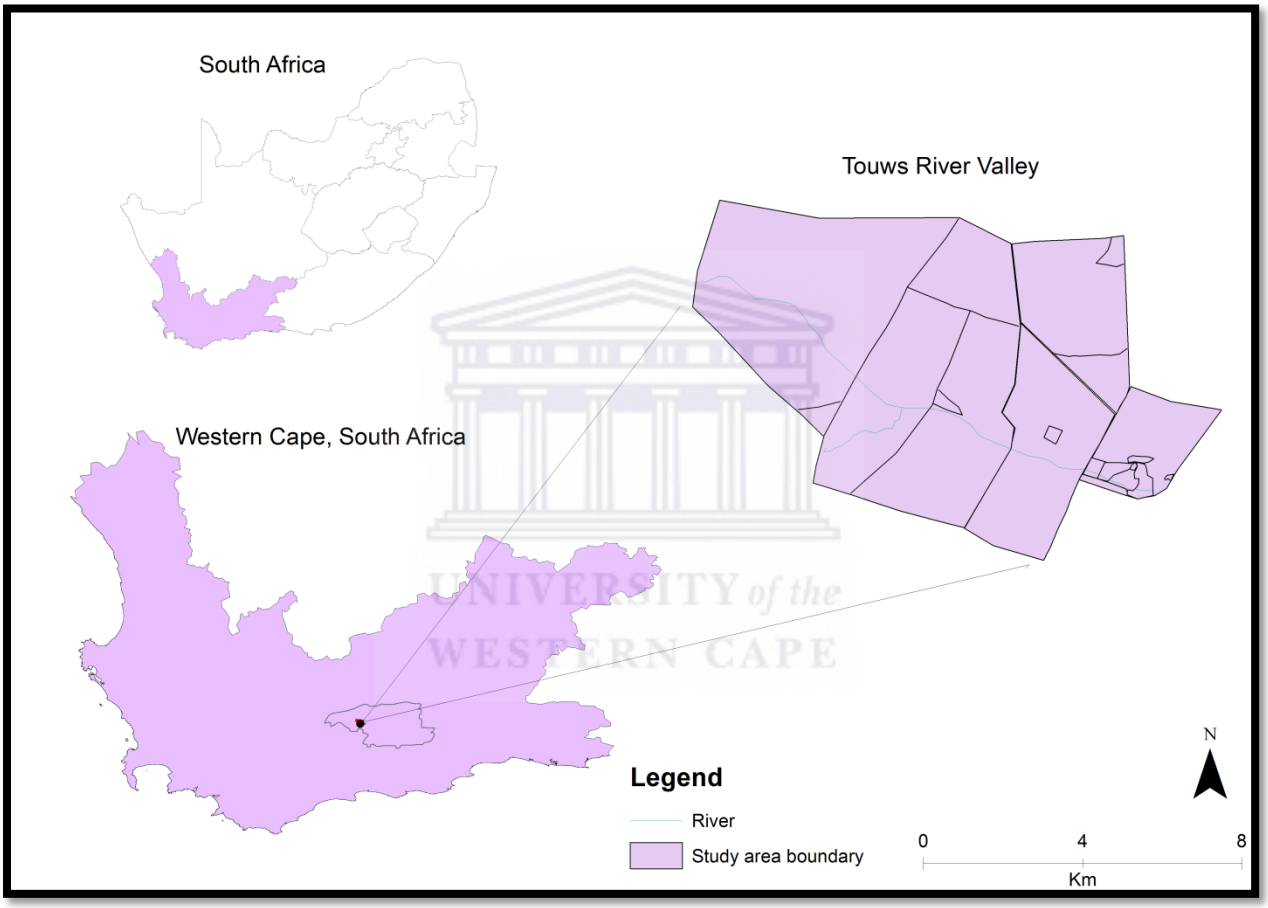

Figure 3: Study area map of Touws River valley

The topography of the wider landscape is characterized by flat terrain interrupted by subtle hills and koppies (Figure 4a). The natural undisturbed parts are characterized by steep and stony vegetated slopes, with some having rocky features.

Figure 4: Area photos of the Touws River valley, with (a) area around Plathuis guesthouse at Wolwekraal, (b) pig pans in one of the farms, (c) bare area in one of the farms and a few planted trees.

1.6 Structure of thesis

Chapter 1 introduced the research, its aims and objectives and rationale. The study areas were also introduced. Chapter 2 presents relevant literature on climate variability and climate change, farmers' perceptions of climate variability and change, and adaptation strategies. In addition, the NDVI is explained in order to provide a backbone for the research. Chapter 3 focuses on the methodological decisions made in undertaking this research. It describes the mixed method approach that utilized for this study and discusses the research design in detail.

Chapters 4 gives a detailed description of the perceptions of farmers in Touws River valley and Makolokwe on climate variability and change. Chapter 5 presents detailed results of adaptation and coping strategies, as well as the link between the scientific and local knowledge. Chapter 6 provides concluding thoughts and recommendations of the study.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

This study is located within the field of human-environment relations, which inspired and served as a basis for conducting research. Before discussing this conceptual framework in more detail, this chapter reviews recent research on climatic variability and climate change, a topic which has gained greater importance in the context of world-wide climate change. Scholars have discussed climate change in the context of South Africa. A large body of research is concerned with the perceptions of people (especially farmers) towards climatic variability and adaptation and coping strategies. Measuring changes in vegetation is important for the scientific study of land-use change, and this chapter provides an introduction to the NVDI. The chapter begins by considering the topic of rainfall and temperature variability in South Africa.

2.2 Rainfall and temperature variability

Climatic variability is a term that has been contested by many people (Thomas *et.al.*, 2007). It encompasses many factors that can differ from region to region. The World Meteorological Organization (2017) defines climate variability as variations that occur in a specific climate over a short period of time such as a month, season or year. In South Africa, changes in solar insolation and north-south displacement of the Hadley cell can cause fluctuations in the rainfall. The World Meteorological Organization (2017) further points out that Zonal circulations as well as the El Niño Southern Oscillation (ENSO) also play a key role in climatic variation. This pervasive oscillation is associated with the largest amount of interannual variation in rainfall (Lukhraj-Govender and Grab, 2018). In the north-eastern half of South Africa, the quasi 20-year oscillation is prominent, while in the southern coastal region and the inland area the10-12 year oscillation is most common (Kane, 2009).

Vogel (2000) suggests that in Southern Africa the factor most commonly observed to influence human activities is rainfall. Therefore, analyses of rainfall are imperative as livelihoods can be affected by insufficient rains. The El Niño Southern Oscillation, neighbouring sea surface temperatures and the Southern Annular Mode are the three factors most commonly linked to

South African rainfall variability (Ambrosino *et al.*, 2012). Furthermore, in order to understand the effects that rainfall has on agriculturally dependent sectors, it is important to also look at the daily rainfall data (Ambrosino *et al.*, 2012). There is a strong relationship between rainfall and the different agricultural sectors that are dependent on rainfall as it ultimately determines whether these sectors thrive.

According to Dettinger and Diaz (2000), rainfall variability has implications for stream flow variability, which in turn has an additional impact on farming. The conversion from rainfall to run off in stream flow varies globally, and is affected by the seasonality of precipitation, the occurrence of snowmelt, the amount of evapotranspiration, vegetation type and coverage, as well as the duration of time the water takes to travels from runoff source regions through surface and subsurface reservoirs (Dettinger and Diaz, 2000). The coefficient of variation of annual precipitation and stream flow which was mapped in a study by Dettinger and Diaz (2000) indicated that cooler/wetter regions and drier regions exhibit different variability in annual river flows. Temperate Europe, North America, South America and central Africa experience less variability in rainfall and stream flows than do drier settings such as the North American Southwest, Chile, Sahel, South Africa, and Australia (Dettinger and Diaz, 2000). Furthermore, DWAF (2002); DEA (2011) and Tibesigwa *et al.*, (2017) indicate that although water supply and shortage are issues in South Africa, high evapotranspiration and low surface run-off are significant contributing factors to water scarcity in the country. Locally, research has shown that South Africa's mean annual precipitation has been historically variable (Tyson, 1986; Mason and Jury, 1997; Schulze, 2016). Despite variability, there is some evidence to suggest that annual rainfall totals are increasing in the central interior of South Africa (DEA, 2016).

According to DEA (2016), trends in annual rainfall in the Western Cape are not statistically significant. In contrast, Du Plessis and Schloms (2017) indicated that in the Karoo and Southern Cape Coast there will be warmer but wetter weather as the rainfall season is lengthening. In Gauteng, the Free State and North-West, annual rainfall totals have been increasing, although this was of limited statistical significance. The western parts of North-West and the Free State have been experiencing significant increases in rainfall days, whereas Gauteng and the eastern part of Free State and North West have been experiencing a negative trend in rainfall days. (DEA, 2016).

The eastern regions of South Africa experience summer rainfall mainly due to penetration of moisture from sources in the southwest Indian Ocean associated with movement of the Inter Tropical Convergence Zone, as well as moisture penetration from the southeast tropical Atlantic (Reason, 2001; Cook *et al.,* 2004). Rainfall in the wet season also varies as dry spells are visible with the changing patterns in temperature, especially over a particular region (Thomas *et al.*, 2007). Therefore, based on the location of a particular region, temperature will play a role in the dry spell season.

Decadal variability in rainfall have caused significant concerns. During 2000, South Africa also experienced significant flooding under La Niña (DEA,2016). The 2015/2016 El Niño drought conditions in South Africa have led to significant impact on socio-economic conditions in the country. Hendricks & Witbooi (2016) stated that South Africa is recovering from the worst drought on record which it experienced in the year 2015. A report conducted by the Department of Water and Sanitation (DWS) (2017) said that in the year 2015/2016 South Africa experienced rainfall patterns which were below normal during the summer rainfall season, which resulted in the meteorological, socio-economic and agricultural drought. In addition, Richman and Leslie (2018) said that while the 2014 wet season was fruitful as all the six major dams were filled in Cape Town, however, 2015-2017 were severe drought periods. Not only was Cape Town affected, but from 2015 onward, South Africa as a whole experienced a severe reduction in rainfall.

As a result of the drought and inadequate rainfall, the African Farmers Association of South Africa in the Northern Cape reported that approximately 30 farmers had quit the farming sector. Similarly, fluctuations in temperature have also contributed to the drought. Data released by the World Meteorological Organisation (WMO) indicated that from 2011-2015, temperatures were at their warmest on a global scale (McGrath, 2016). The reports from the organisation also claim that globally the year 2015 was exceeded by the year 2016. Midgley *et al.* (2008) mentioned that there have been tremendous and fast increases in temperatures, which have made it difficult to explain these changing natural phenomena. Temperatures are expected to increase in South Africa in the 21st century, with January showing the greatest increase especially in areas such as the Northern Cape and the central interior of South Africa. The least hot areas will be those located on the coast (Midgley *et al.*, 2008).

2.3 Perceptions of climate variability

Climate predictions or forecasts relate to seasonal precipitation and other aspects of seasonal climates, such as temperature extremes. Climate prediction is used to reduce risk and to optimise gains (Roncoli, 2006). Thomas *et al.* (2007) further explain that individual communities have had to deal with different changes associated with climate variability. Regions are different and therefore people in one area will not necessarily cope the same as individuals in other communities as people have different world views. Thomas *et al.* (2007) further points out that those communities which make use of natural resources for their livelihoods will be profoundly affected by an increase in climate variability in the 21st century. Similarly, Calder and Ziervogel (2003) suggest that climate variability has contributed to stresses which rural livelihoods face, and as a result shocks and stresses which have increased household vulnerability. McKune *et al.* (2015) said that climate change affects livelihoods and is an unpredictable force which affects communities globally with aspects such as unpredictable weather patterns.

It is crucial to manage the risks posed by climate change and variability. By the same token, understanding farmers' perceptions is imperative in understanding climate variability as this will help to explain the different decisions they make (Ayal and Filho, 2017). A farmer's coping and adaptation strategies are governed by the quality of their perceptions, while the adaptation options that farmers' use are based on their understanding and processing of the environmental impacts around them (Ayal and Filho, 2017). Therefore, perceptions play an important role in how farmers react to impacts of climate variability and climate change and the success of their adaptation strategies. Clarke *et al*. (2012) take this notion of perceptions and adaptations a step further, noting that the relationship farmers have with their land impacts on the perceptions of environmental changes, and these then contribute to how farmers respond to their coping strategies. Vedwan and Rhodes, 2001 cited in Wiid and Ziervogel (2012) said that the knowledge that farmers have on perceptions and response to climate change is rooted in first-hand experiences on the impacts of climate on farming practices.

Research on risk communication indicates that people have different perceptions of climate and that these perceptions further manifest in the knowledge that they attain (Roncoli, 2006). Thus, local knowledge is important because it embodies all the elements of the ideas individuals and

communities may have. Turner (1999) stresses the role played by livestock in terms of social status, as well as financial wellbeing. Livestock are often regarded as social commodities we well as units of production. It is therefore evident that although people in urban areas may not view these aspects as important, rural communities and livestock keepers have a different perception. Moreover, not all livestock holds the same value for everyone, as different species do not possess standalone significances. Influenced by culture, origin, social class and gender, the meanings of livestock are connected and interwoven in numerous ways (Turner, 1999). It can then be said that the perception that people have about the significance of different livestock and other animals kept by farmers will determine their status and significance.

Our environment and all that is in it is intertwined in such a way that all the different elements play their own parts. Questions relating to humans and climate variability therefore incorporate both human centred and non-human centred variables. Moreover, Turner (1999) says that during the past ten years, there has been an increase in apprehension regarding global and locally scaled differences in the use of land and the environment. Thus, climate variability is not the only contributing factor to the changes in the physical environment, but human beings also play a role in bringing forth the different changes and stresses to which the environment is subject. For farmers, climate change and climate variability are extremely important because they need to understand the different variations which are occurring on a temporal scale. Turner (1999) further points out that change in land use and environmental related problems such as deforestation, soil erosion, and desertification are often discussed on a global scale although these effects are local.

A study conducted by Benhin (2006) on climate change and South African agriculture showed that farmers in different parts of the country had differing perceptions. For example, in the North West Province, 75 % of farmers suggested that there had been changes in climate with decreases in rainfall and increases in temperature. Furthermore, these farmers had experienced shifts in the timing and length of winter and summer. However, in the Western Cape Province, 50 % of farmers indicated that there had not been significant changes in the climate, but that it has been more or less the same. The other 50 % indicated that they thought the climate had become drier and hotter, and that winter rains come later than expected.

2.4 Adaptation and coping strategies

There have been many definitions of adaptation in climate change literature. Adaptation as a term originates from evolutionary science and has been used in other fields, such as the social sciences. Smit and Wandel (2006) define adaptation as adjustments in the ecological-socio-economic aspect which acts as a way to cope with the expected impacts of the environment. Moreover, Brooks (2003: 282) define adaptation as "adjustments in a systems behavior and characteristics that enhance its ability to cope with external stress". Therefore, the ability to cope with external stress will also be determined by how easily a system may adjust to new conditions. Elum *et al*. (2017) suggest that adaptations vary from place to place and over time depending on the type of resources an individual or a group may possess. Adaptation strategies followed by one area may not necessarily be relevant or be effective in another area.

In a study conducted in South Africa and Ethiopia, research showed that perceptions and especially education level is important as it creates an individual's awareness of potential adaptation strategies (Bryan *et al.,* 2009). Therefore, it is as important for farmers to be equipped with the relevant knowledge and resources which will facilitate their awareness of adaptation strategies.

According to Grothmann and Patt (2005), some people show adaptive behaviour while others do not, leading to the development of a model of private proactive adaptation which is based on protection motivation theory. The two main processes in the model are risk appraisal (assessment of the risk to valuable things and the magnitude of that risk) and adaptation appraisal (how one could avoid being harmed by the threat and the costs of those actions thereof).

In a study by Campbell (1999), traditional herders in Kenya depended greatly on their livestock to provide them with meat and milk, but because of food shortages, they have had to supplement their diets with grains and legumes through either livestock exchanges or through money from the sale of livestock. Data from a survey conducted between 1977 and 1996 indicated that farmers and herders employed a variety of strategies to combat food strategies such as moving livestock to better areas for grazing and water, sale of livestock, hunting and use of wild foods (Campbell, 1999). These strategies which are employed by farmers and herders, could guide farmers in difficult times.

In a study by Antwi-Agyei *et al.* (2014) in Ghana, it was indicated that the households of the study area were aware of climate change and they observed changing trends in temperature. Households also mentioned that selling livestock was profitable (Antwi-Agyei *et al.*, 2014). It is a way to ensure that the farm functions properly without other related farming activities being affected by climatic changes. Thomas *et al.* (2007) says that adaptability to climate variance may be closely linked to the capability to survive the pressures placed on livelihoods. Khan *et al.* (2009) further indicate that the inability to adapt to climate variance differs across areas, sectors and social classes. Therefore, a thorough understanding of the vulnerability in a region is imperative for adaptation methods. This not only assures more knowledge and understanding, but it ensures durability and sustainability. Furthermore, Thomas *et al.* (2007) mentioned that it is important to recognise that there are limitations to scientific knowledge. For this reason, it is important to understand how people in different communities live their lives and what variability and uncertainty mean to them. Local knowledge may be as useful as scientific knowledge, and it is therefore important to investigate whether scientific knowledge mirrors the local knowledge and vice-versa.

Thomas *et al.* (2007) note that for farmers and those who make use of the land, the notions of intense rainfall and drought do not need to be fully comprehended to understand that climate inconsistency is crucial to decision making. However, it is not enough to automatically assume that all the changes which occur in the environment are caused by climate change and climate variability. Different people hold different views of the changes which occur in their environments. In a study by Thomas *et al.* (2007: 310) conducted in South Africa, 80 % of the respondents showed that they were "aware of the changing trends around them". Moreover, another respondent who has been coping with the changes said that "It has been some years since I farmed [grew crops] and I think the rains are too unpredictable to farm here. I think that livestock farming is more important, and I will increase my goats if I can" (Thomas *et al.*, 2007: 314). Thus, people are focused on investing in activities that will likely be profitable and take into consideration the changes that are happening in the environment, applying them to their different livelihoods. Although this is the case, Rust and Rust (2013) stress that in local communities, loosing livestock also puts a strain on livelihoods.

Jordaan *et al.* (2013) indicated that there is a big difference in coping and vulnerability between commercial farmers and communal small-scale farmers. These differences affect the decisions and actions taken by farmers. The study conducted in the Northern Cape province by Jordaan *et al.* (2013) further indicated that communal farmers experience the negative effects of drought more regularly than commercial farmers. This is caused by their high vulnerability and low coping capacity with respect to drought conditions. Rust and Rust (2013) argue as follows with regard to African conditions: "The effects of higher precipitation on large farms on net animal revenue shows a linear increase, whereas the effects for small farms diminishes with precipitation, so that the net revenue from these two types of farms converges at high levels of precipitation" (Rust and Rust, 2013: 259). This is so because (1) farmers shift from crops with an increase in rainfall, (2) grasslands change to forest as rainfall increases, which affect grazing, and (3), rainfall increases certain animal diseases (Rust and Rust, 2013). The huge disparity of the carrying capacity between summer and winter is huge, which pushes farmers to be prepared and to always ensure that they come up with economically sound solutions. In a study conducted by Lunde and Lindtjorn (2013), the results indicated that in most African countries, an increase in annual rainfall resulted in an increase in cattle numbers. Rainfall therefore plays a significant role in farming, whether it is commercial or communal.

Sarr *et al.* (2015) further suggest that understanding the level of knowledge that local farmers have about climate change will help integrate climate adaptations and strategies to agricultural development plans. According to Mandleni (2011), said that adaptation and mitigation strategies are not sufficient to avoid all climate change impacts. Both commercial and communal farmers have put in place adaptation and mitigation measures and strategies, but awareness still is an important aspect which needs to be taken into consideration. Farmers need to be aware that livestock do better with the changing climate than do crops, as they are able to move around (Mannion, 1997; Meyer, 1996; Nisbet, 1991; Wackernagel, and Rees, 1996). However, Mapfumo *et al.* (2013) note that the response of local farming communities is often constrained because of a lack of resources, information and new technologies.

A study conducted in the North West province (South Africa) by Hudson (2002) mentioned that commercial and communal farmers coped in similar ways to the stress of drought. The main

adaptations found in the study were selling off animals and buying fodder. Commercial farmers tended to sell their livestock, while communal farmers would often buy fodder for their livestock. Similarly, farmers livelihoods were supported by selling livestock or farm equipment (Eakin, 2000). Rust and Rust (2013) emphasize that farmers in Africa often keep livestock as insurance for periods of drought. It is therefore very significant for both commercial and commercial farmers to keep livestock as it contributes to their livelihoods. Long- and short-term adjustments to climate change have been reviewed by Benhin (2006) who mentioned that farmers made adjustments in farming operations, such as changing dates of planting season of some plants. Makhado *et al.* (2014: 268) lists adaptation strategies as well as the limitations of these practices (Table 1).

Table 1: Adaptation practices used around Africa with consultation from different authors but adopted from Makhado et al. (2014: 268).

Adaptation practices	Limitations
Pastoralism: looking after livestock by the owner or hired person. **Taking livestock to areas where there is fodder and water.**	Labour intensive and high cost implication.
Loaning cattle: loaning of cattle to poor households or relatives to take care of them while they are benefiting from animal labour, milk and sometimes can be rewarded with a heifer after the agreed period.	High risk of losing more cattle through theft and negligence.
Culling: reducing the number of livestock mainly through selling. **Money earned can be used to buy fodder during drought.**	Lack of knowledge on stocking rate and grazing capacity.
Feed and water supplement: harvesting of grasses and residuals and storing them to feed animals during drought. Also supply of water.	Labour intensive and costly.
Rotational grazing: dividing the rangeland into grazing camps so as to	Require more land. Lack of coordination in rural areas.

promote rotational grazing.	Over-crowding of camps
Breeding livestock with drought resistant breeds: it includes breeding of indigenous livestock, e.g. Nguni cattle in South Africa and N'Damani cattle in Western Africa.	Lack of funds to breed indigenous stock. Low market value.
Shifts in farming practice: from less drought resistance cattle farming to more drought resistance sheep, goats, camels or donkeys.	Low market value.

Marotz-Baden and Colvin (1986) found that spiritual support and faith was an important strategy for rural farmers. Similarly, a study conducted in Midwest state of America by Light *et al.* (1990), found that 87% of farmers who took part in the study mentioned that faith and God was a coping strategy to problems and difficulties. Furthermore, 62% of farmers stated that they participated in church activities and 70% of farmers reported that they attended church services (Light *et al.*, 1990). In an article by Saal (2018) titled "A farmer who loses hope is dead", a farmer said that he has come to terms with the new changes and is hopeful that the rain will return. Similar perspectives were noted by farmers in an article by Etheridge (2018). Hope remained a standalone strategy that farmers possessed especially through trying times.

2.5 Remote sensing indices and vegetation cover

Scientists have developed methodologies for assessing vegetation and land cover change. Satellite sensors have been available since the 1980s and are useful for measuring the earth's vegetation density and productivity. The NDVI has been used to measure vegetation productivity and looks at the radiation absorption in the red band as well as in the near infrared (Ghobani *et al*., 2012). This measure assists in understanding climate-vegetation responses on a temporal scale (Chamaille-Jammes *et al*., 2006). Since soil moisture variability is partially driven by vegetation, the NDVI is able to explain soil moisture variability that might occur (Bellocchi and Diodato, 2007). Furthermore, Park *et al.* (2004) revealed that there is a connection between vegetation and the holding capacity of soil-water (using the NDVI) and thermal bands.

According to Richard and Poccard (1998), vegetation cover is strongly related to climatic conditions and creates feedbacks with respect to roughness, evaporation and albedo.

The NDVI is calculated by looking at the difference between the near infrared reflectance and the red band reflectance over the near infrared reflectance plus the red band reflectance. (Chamaille-Jammes *et al*., 2006). The NDVI measure absorbs photosynthetically active radiation and uses it to determine healthy green biomass (Chamaille-Jammes *et al*., 2006). Variations in climatic factors, in particular precipitation and temperature, have a strong influence on variation in NDVI for a given site (Wang *et al.,* 2003: 2346). The NDVI can ultimately be seen as a vegetation production index (Chamaille- Jammes *et al.,* 2006) as well as a measure that uses radiation penetration and absorption in order to determine green leaf and chlorophyll densities (Tucker and Sellers 1986).

Only one leaf layer or less can be seen by the red channel on the account of the effective chlorophyll absorption near 0.067 μm, compared to that of the near-infrared channel, which sees around eight leaf layers (Gao, 1996). At a leaf area index of three or more, the NDVI is considered close to saturated. Environmental aspects that may have a large impact on NDVI values include geomorphology, vegetation and soil. The variability of certain climatic aspects, with emphasis on temperature and precipitation, have a strong effect on the range in NDVI for a specific site (Wang *et al.,* 2003).

2.5.1 Vegetation productivity as a measure of grazing potential

The NDVI follows rainfall with different time delays depending on certain environmental aspects, for example, soil types (Richard and Poccard 1998). Similarly, Wang *et al.* (2003) found that water balance is directly affected by temperature and precipitation, which affects changes in soil moisture regime, which in turn affects plant growth. Thus, the key factor that connects NDVI, temperature and precipitation is soil moisture, as is broadly accepted; even though temperature also influences plant growth and phenology directly. There have also been other studies in Africa which supports the conclusion that net primary production is closely related to the mean annual precipitation. There has also been a close relation and temporal association between climate and vegetation production (Chamaille-Jammes *et al.,* 2006). More research is

required to understanding atmospheric processes and vegetation in different African environments (Pielke *et al.*, 2002).

In terms of grazing potential, a study conducted by Toombs *et al.* (2010) showed that in order to promote vegetation heterogeneity; (1) stocking rates would need to be reduced in order to ensure sustainability in pastures, (2) vegetation heterogeneity could be enhanced by introducing a rest rotation system where one part of a land remains ungrazed for a period of about a year, and (3) there should be more than one source of water to allow pastures of land, which have been heavily used recover. In a study conducted by Du Pisanie (2018), farmers suggested that in the Karoo the land had always been under grazed, and because of that, the carrying capacity is relatively high. What the farmers said worked for them is a three-camp system where they let at least one camp to rest for an entire season in order to let it recover. Despite the farmer's perceptions on their land, there is evidence that the Karoo has been faced with land degradation (Seymour *et al*., 2010; Wheeler *et al*., 2015), with ostrich farming considered one of the greatest agents of veld degradation in the Karoo (Wheeler *et al*., 2015).

2.6 Conceptual framework

The environment within which we live consists of both living and non-living components. Variability in climate can be more fully understood when scientific and local knowledge are used collectively. It is therefore important to acknowledge that people see things differently, therefore the knowledge people have about their culture, social status as well as stresses, shocks and adaptation strategies about the environment make up the perceptions that they have concerning climate variability and climate change. Local knowledge is as valuable as scientific knowledge, as the two complement one another although they may sometimes be contradictory. Scientific knowledge importantly brings forth evidence about factors which further frame the human-environment relations.

Smithers and Smit (1997) suggest that dimensions of adaptation serve as another basis from which to consider human-environment relations. The framework focuses on three pivotal characteristics; climatic disturbances, system characteristics and adaptive responses. The first, climatic disturbances, includes properties such as the scale of events (magnitude and areal extent). Thus, the extent of the response for local or concentrated areas will differ from the

responses of widespread areas. The second property which focuses on the frequency, duration and suddenness of climatic events also has great influence on adaptation. The frequency of a climatic occurrences has an impact on how a system recovers from climatic disturbances. Similarly, the duration of stress will greatly determine the extent of the outcome. Therefore, climatic events which happen over a long period of time will cause a greater damage than those that happen over a short period of time.

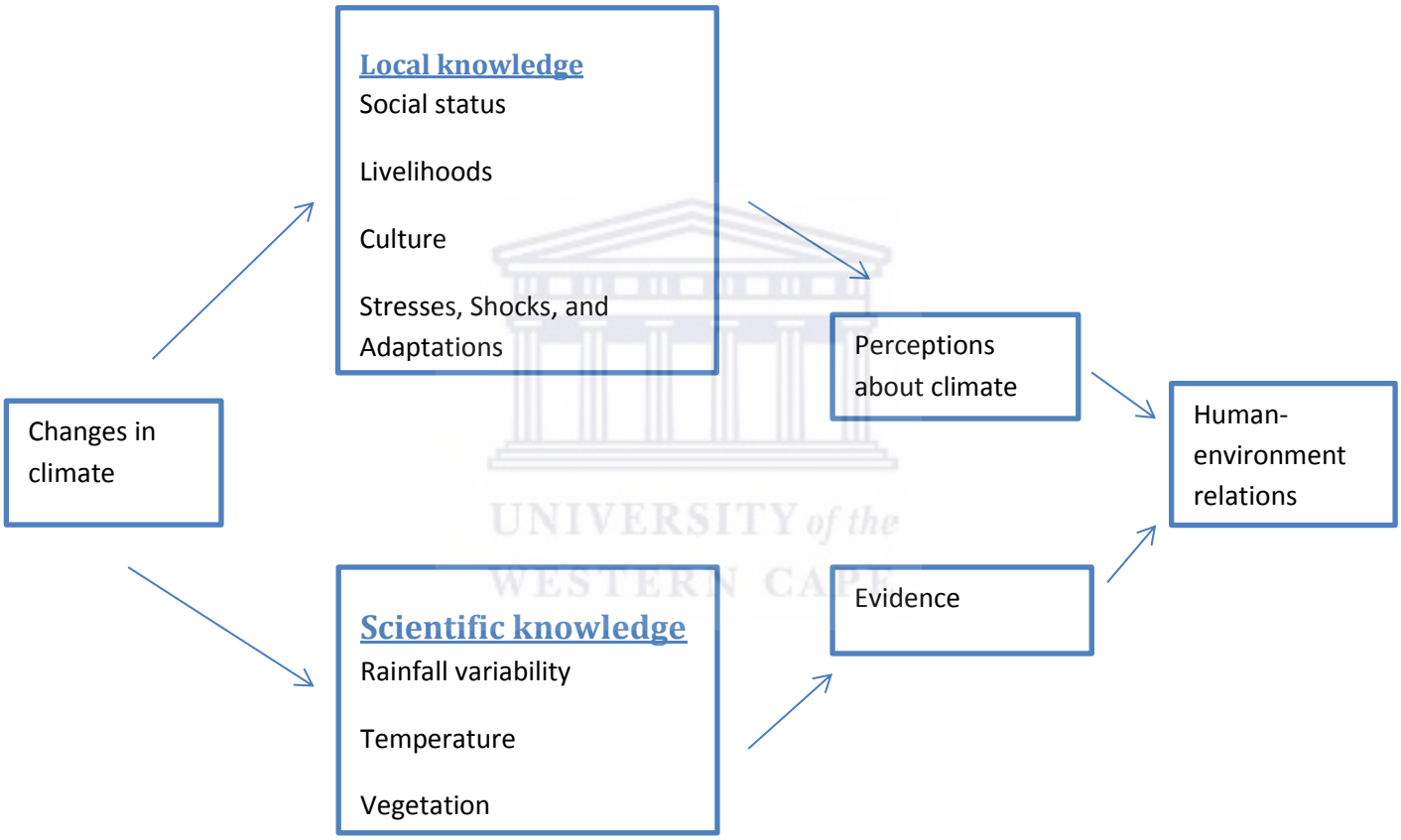

Figure 5: Relationship of humans and the environment which build perceptions about climate variability.

The second characteristic described by Smithers and Smith (1997) is system characteristics. The properties in this characteristic include stability (the ability of a system to remain fixed over a long period of time) and, resilience (how a system recovers or returns to a previous state after

climatic events and conditions). Resilience is a term that was first introduced by Holling (1973) and has been further adapted by other authors. Resilience in his paper emphasised the capacity persistence with regards to fluctuations (Holling, 1973). Other properties in this characteristic include vulnerability (how susceptible a system is to variances in climatic events and conditions), flexibility (how changeable systems and activities are), and scale. Thirdly, adaptive responses are thus pivotal for prevention and mitigation purposes to climatic disturbances. The responses include intent, role of government, scale, timing, duration, form, and effect. These responses together form attributes that distinguish how climatic disturbances could further be used for mitigation and adaptation.

2.7 Summary

Rainfall and temperature have been variable over the years. Because of the variability, analysis of rainfall has been important as livelihoods can be affected by insufficient rains (Vogel, 2000). People have held different perceptions about climate variability and change and how that affects their livelihoods. These perceptions vary from person to person. This has therefore resulted in varying adaptation and coping strategies (Ayal and Filho, 2017; Thomas *et.al*., 2007). These adaptation and coping strategies are also based on the environmental impacts around them (Ayal and Filho, 2017). Satellites are a way to measure used to assess the environmental changes (which have impacted on negatively or positively on livelihoods) through vegetation and landcover change. Thus, local knowledge and scientific knowledge can both be used to determine human-environment relations and to help understand the different changes occurring in our environment.

CHAPTER 3: METHODS

3.1 Introduction

A mixed method approach, employing both qualitative and quantitative methods, was utilized in this study. The research was carried out at two locations, the first in Makolokwe, North-West province, and the second in Touws River valley near Ladismith in the Karoo, Western Cape. The approach, using qualitative and quantitative methods, in each area was the same. Further detail on each approach is given below.

3.2 Mixed methods approach

Applied Geography has been critiqued since the 1980s. Yeager and Steiger (2013) argue that a mixed method approach is appropriate for research for this nature because Geography as a discipline looks at the human-physical interface. Yeager and Steiger (2013) further suggest that a wide array of methods needs to be applied by geographers because of the real-world impacts that occur. Mixed methods research has therefore become a separate methodological approach, one which has been seen to: (1) ensure accuracy of data, (2) ensure that there are no biases in research, (3) ensure complementarily of different data sources in research, (4) ensures inclusion of all the human-physical interface, and (5) enable different ways of developing research findings (Denscombe, 2008). Therefore, this approach is an exceptional binder of local and scientific knowledge and will especially facilitate the formation of findings in this study, which is also concerned with the way local and scientific knowledge of farmers influence management responses of the farmers to environmental changes. The different datasets were combined to expand and give more meaning and understanding of the human-nature relationship.

3.3 Qualitative methods

3.3.1Research sample

In farming communities, it is important to know and understand how a community may or may not withstand the environmental changes occurring around them. For the purpose of answering the research question, participants from two different farming communities were interviewed.

Ten communal farmers from Makolokwe participated in the research. Of the ten farmers interviewed, nine were male and one was female. In the Touws River valley five male commercial farmers were interviewed. Carrying capacity on the veld in Touws River valley is fairly low, with a few large farms. Because there was uncertainty about the number of participants who would be willing to participate in the research, the number of participants was solely based on the availability and willingness to participate.

Thus, a snowball sampling was the main method of finding research participants in the data collection process. Faugier and Sargeant (1997) in Lewis-Beck *et al*. (2004), describe it as a technique that sees possibilities to expand a web of contact and acts as a bridge for social differences and exclusion in the process of communication. A sample consent form and information sheet appear in Appendix A and B.

3.3.2 Field data collection

Semi-structured interviews were undertaken with each of the participants. According to Wilkinson and Birmingham (2003) there are a number of stages which are developed in order to effectively conduct interviews (Figure 6). The stages are as follows:

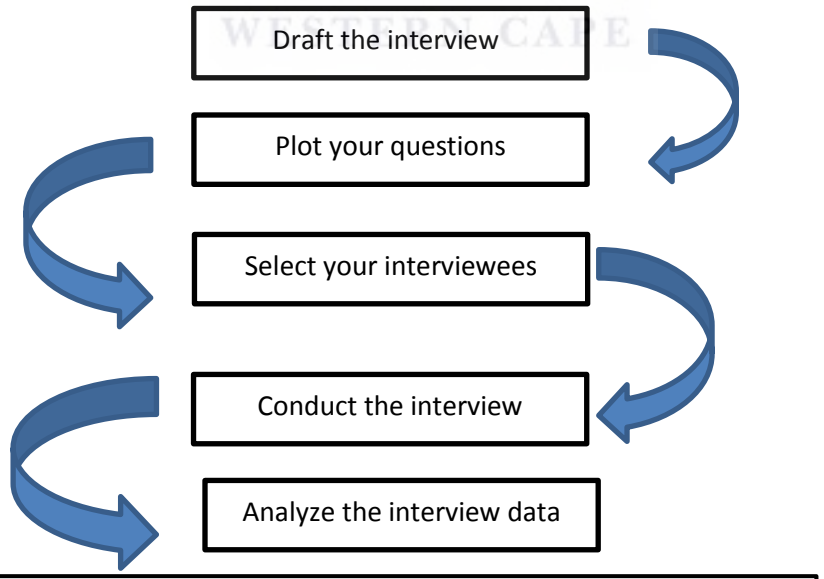

Figure 6: Stages used to develop and to ensure proper conduct of interviews. (Adopted from Birmingham and Wilkinson, 2003)

In Makolokwe, the interview sessions took place in July-August of 2016, while interviews in the Touws River valley were conducted in November 2017. The interviews were used to gain a deep understanding of the processes which affect farmers and how they in turn cope with the environmental changes which may or may not occur. Furthermore, interviews with each of the farmers brought out individual perspectives and personal experiences. This therefore gave an opportunity for the interviewer to be responsive to the individual, to ensure that all the ideas and perspectives were noted. Interviews are also rich in data because the participants/respondents' exact words were highlighted in the research findings.

The questionnaire consisted of open ended and closed ended questions. Questions were based on topics such as climate variability, coping and adaptation strategies, rainfall variability and the overall experiences of the farmers. While in Touws River valley interviews were recorded, in Makolokwe, the participants were not comfortable with being recorded. In such a case the data was recorded verbatim. Setswana and English were used in Makolokwe to clarify some of the questions. However, in Touws River valley, the respondents were Afrikaans and English. Discussions conducted in Afrikaans were translated into English.

3.3.3 Data Analysis

Once the data had been collected, the next step was to interpret the data. The main method of data analysis and interpretation was thematic analysis. Alhojailan (2012) mentioned that there is a profound dependence on interpretation in qualitative data. Furthermore, it was important to look for any patterns which arose in the data. With the patterns which arose, it was also then possible to discern and find possible appropriate explanations for the behaviours of the participants as well as why they may have certain perceptions. The data was highlighted in order to identify all the different themes and patterns. Categories and sections were then identified as a way to visualise and make sense of the data The themes and patterns which arose were centred on terms such as 'environmental awareness', 'climate variability and climate change', and 'adaption and coping strategies. Alhojailan (2012) notes that with thematic analysis certain factors and variables can be identified with regards to the participants' concerns and issues.

It was important not to approach the interviews with a particular hypothesis in mind, rather an inductive approach was utilized. With this approach analysis begins with specific thoughts about

the content of the interviews, then moves to generalisations and lastly theories may emerge (Alhojailan, 2012). Furthermore, codes and categories were adopted in order to fully make sense of the data. With this, themes emerge which are linked to the approach of the research. Alhojailan (2012) states that the coding and categorising process as well as noting patterns reveals relevant relationships in the data in order to construct logical evidence. Thus, once the process of identifying codes and categories was completed, the data analysis was simpler because relevant data was extracted and used. I was then able to come up with specific themes related to adaptation and coping strategies, rainfall variability, perceptions of climate variability and vegetation changes.

3.3.4 Challenges and experiences in the field

The data collection process for both study areas was intriguing and full of surprises. That was to be expected as individuals and communities are different including how they respond to an interviewer, especially if the researcher is an outsider as there may be uncertainties which exist in those types of relationships. In the Touws River valley, there was a lot of uncertainty as I was not familiar with the community. A local gatekeeper or facilitator was of great importance because that allowed for other community members to be open to the interview process. Throughout the week in that community, the biggest challenge was time constraints and the availability of the farmers at certain times. However, once appointments were made with various farmers, the interview process ran smoothly. In Makolokwe, a gatekeeper was used to understand the relationships between the farmers and the relevant farmers who would be available to assist and participate in the study. Once all the addresses of the farmers were noted, the interview process began. Time in this area was not a constraint as most of the farmers were retired.

3.3.5 Ethical considerations

In both study areas informed consent was a priority as it allowed trust to be the basis of the research. Ethical clearance was given at the university level. Respondents were made aware of the research aims and objectives and were free to choose to participate or withdraw at any point. Information sheets together with a consent form were made available to the participants who were interested in taking part in the research. By doing this, it provided the participants with full autonomy to decide about their ongoing participation. Furthermore, a sense of security with

regard to the participant's information was of crucial importance in order to assure them that taking part would not pose any risk to them. The recordings and research information were password protected online and kept in a folder on my personal computer.

3.4 Quantitative methods

3.4.1Data sources

3.4.1.1Rainfall Data

For the purpose of the research, data from the Agricultural Research Council (ARC) and the South African Weather Services (SAWS) were used. For the Touws River valley, rainfall data was available between 1988 and 2017, while data utilised for Makolokwe was available for a longer period, from between 1928 and 2016.

3.4.1.2 Satellite data

Over the past 40 years, satellite images have been taken using Landsat satellites. Landsat was designed as a joint initiative by the National Aeronautics and Space Administration (NASA) and the United States Geological Survey (USGS) in the year 1972 (Rosenberg, 2015). The space-based land remotely sensed data has since been used in different disciplines such as agriculture, geology, forestry, education, regional planning, mapping, and global change research (USGS, 2013).

For the purpose of this research, Landsat 4-5 TM and Landsat 8 OLI satellite scenes were obtained from the USGS website (see Table 2 for more information). The images were selected based on (1) the extent of cloud cover over the region of interest, and (2) specific years mentioned by respondents in the interview session. Altogether 59 images were used. The images were not pre-processed as the surface reflectance had already been calculated.

Table 2: Summary of Landsat satellite (4-5 and 8) and resolution. Table is adapted from Young et al. (2017).

Landsat sensor	Landsat 4-5 TM	Landsat 8 OLI/TIRS	Pixel size (m)
Coastal aerosol		B1 (0.43–0.45)	30
Blue	B1 (0.45–0.52)	B2 (0.45–0.51)	30
Green	B2 (0.52–0.60)	B3 (0.53–0.59)	30 (60† for MSS)
Red	B3 (0.63–0.69)	B4 (0.64–0.67)	30 (60† for MSS)
NIR 1			60
NIR	B4 (0.76–0.90)	B5 (0.85–0.88)	30 (60† for MSS)
SWIR 1	B5 (1.55–1.75)	B6 (1.57–1.65)	30
SWIR 2	B7 (2.08–2.35)	B7 (2.11–2.29)	30
Thermal	B6 (10.40–12.50)	B10 (10.60–11.19) B11 (11.50–12.51)	30†
Pan-Chromatic		B8 (0.50–0.68)	15
Cirrus		B9 (1.36–1.38)	30

3.4.2 Vegetation productivity

3.4.2.1 Extraction of the normalised difference vegetation index (NDVI)

According to Richard and Poccard (1998) the National Ocean Atmosphere Administration (NOAA) and the Advanced Very High-Resolution Radiometer (AVHRR) have been giving spatial cover on a regular time scale since 1983, mainly of the photosynthetic activity on the Earth's surface. This activity can be expressed by indices such as the NDVI. The NDVI index according to Richard and Poccard (1998) and Gao (1996) can be captured as follows:

$$\text{NDVI} \quad \frac{(\rho\text{NIR} - \rho\text{RED})}{(\rho\text{NIR} + \rho\text{RED})}$$

Where ρNIR and ρRED are the reflectance of the near- infrared (band 4 in TM, and band 5 in OLI) and visible red (band 3 in TM, and band 4 in OLI data) bands, respectively.

The NDVI has been predominantly used in agriculture, such as estimating crop yields and end of season above ground dry biomass (Gao, 1996). The bands used in the NDVI such as the near-infrared see roughly eight leaf layers while the red band only sees one band layer or less. In Southern Africa, one of the limitations is that bare soil reflectance causes variations in the NDVI. This is mainly caused by the brightness in the soil components such as iron and organic matter. Using a 1° by 1° resolution reduces these variations which may occur (Richard and Poccard, 1998). However, for this study, this resolution was not used as pasture lands were smaller than 1 degree in size. The purpose of the research is a time series comparison for one area, so errors caused by bare soil reflectance are likely to be similar over time.

3.4.2.2 Image Threshold Segmentation

Escuin *et al.* (2008) indicates that NDVI values range from -1 and +1. The positive (+) values are vegetated areas, whereas negative (-) values resemble water. Furthermore, values between 0.2-0.5 are usually mixed and between rock and soil cover. Values exceeding 0.5 represent dense vegetation.

The values in an NDVI index will vary depending on the amount of absorption of red light by the chlorophyll, as well as reflectance in the infrared position of the electromagnetic by variable amounts of water inside the leaf cell. The NDVI formula used for the different satellite sensors is given below in Figure 7.

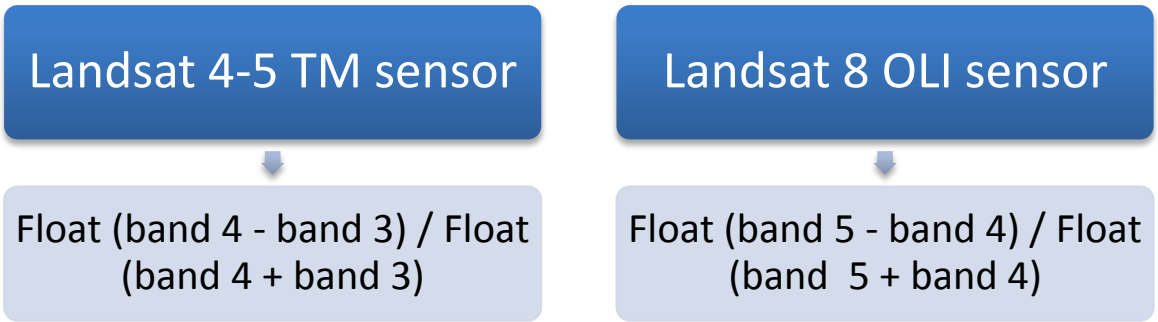

Figure 7: NDVI algorithm used for the sensors

The flowchart of the methodology used to process the images is presented in Figure 8 below:

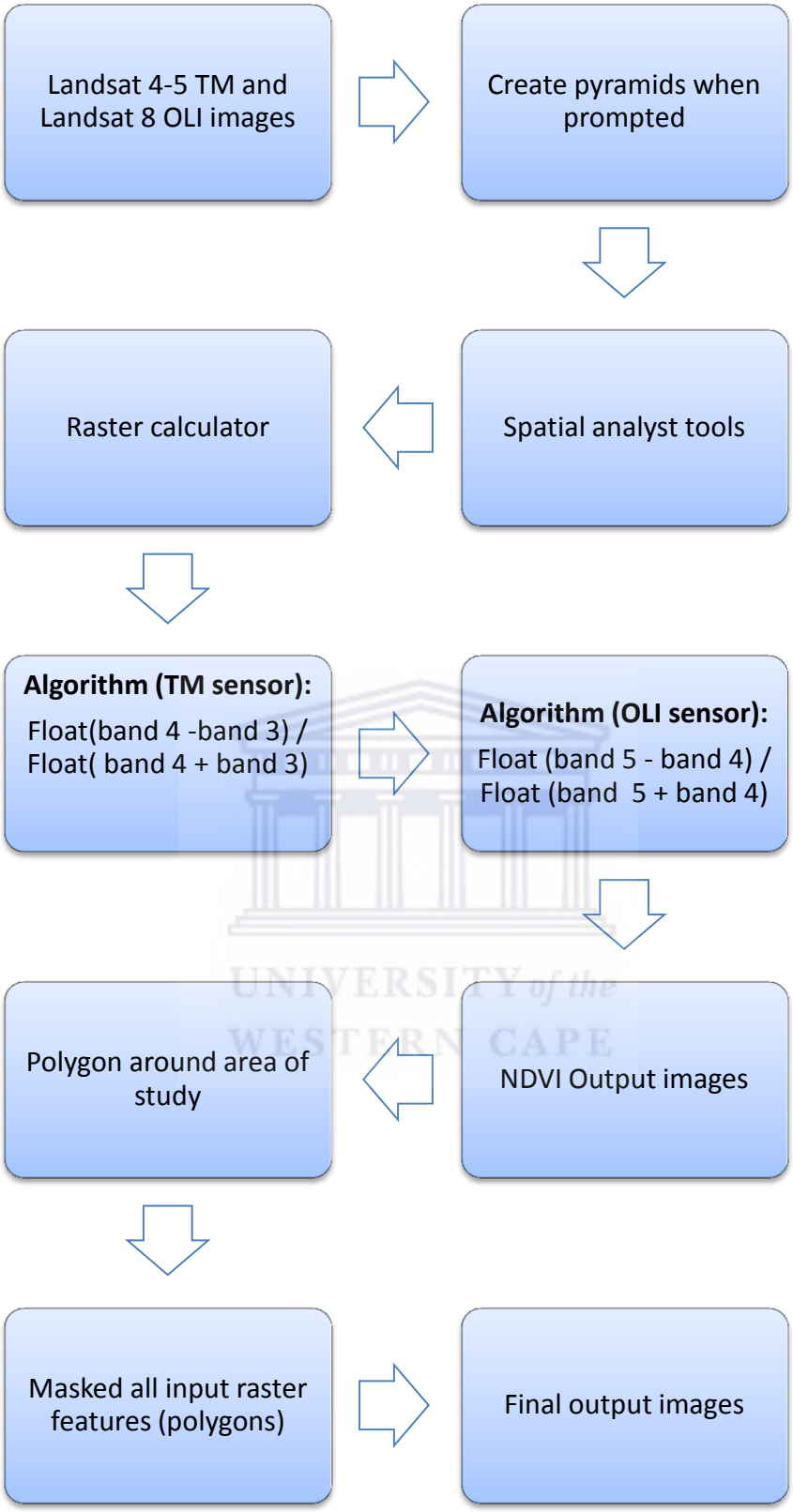

Figure 8: Workflow summary

3.4.3 Rainfall analysis

Rainfall data was analyzed to determine annual and monthly mean values, as well as identify any long-term trends. In addition, annual anomalies above and below the long-term annual mean were also calculated.

3.5 Summary

A mixed method approach was used in order to analyse the human-physical interface in this research. This approach has been seen to be accurate, inclusive, ensures research is fair and without prejudices, uses different data sources, and different research findings can be developed. For the qualitative method, semi-structured interviews were conducted, with 10 participants interviewed in Makolokwe, and 5 participants in Touws River valley. Participation was voluntary and solely based on the availability of farmers to participate in this research. For the qualitative method, rainfall data and satellite data were used to further make sense of the research objectives.

CHAPTER 4: PERCEPTIONS OF FARMERS ON CLIMATIC CHANGES

4.1 Introduction

This chapter presents results from the qualitative interviews conducted with farmers in Makolokwe and Touws River valley, aiming to draw out differences and similarities between the two contexts. In the farming community, both commercial and communal farmers have put forward perceptions about climate variability and how it has affected their livelihoods. While coping strategies differ, the farmers all show significant awareness of the issue of climate change and variability. Farmers in both the communal and private land ownership settings are aware of how climate has been changing and how it has affected farming practices and have had to come up with alternative ways of dealing with the changes. The interview analysis is followed by a comparison of observed rainfall and pastureland productivity as measured by Landsat satellite data.

4.2 Farmers' perceptions of climate change and variability

Climate change has received a lot of media attention in South Africa and globally in the last decade. McKune *et al.* (2015) said that climate change affects livelihoods and is an unpredictable force which affects communities globally with aspects such as unpredictable weather patterns. According to Elum *et al.* (2017) people have different perceptions of climate based on their experiences as well as the local knowledge of that specific region. The research question was asked using the term 'climate variability' in order to allow the emergence of perceptions of change in a specific context. A range of responses was generated, illustrating the understanding of farmers of their environments. Some embraced the global narrative of 'climate change' while others focused more on variability and seemed sceptical about the reality of human-induced climate change.

> *"Climate will vary from area to area and time to time due to climatic changes. For example, El Niño effect has passed our area. During the El-Niño period there was less*

rain. This El Niño could also result in floods if we experience heavy rains." (Respondent 6- Makolokwe)

"I would say that that would mean that climate isn't consistent. We go through cycles. I think that's what you're referring to. Uhm, that climate can vary, and it has been doing it for thousands of years and we go through different cycles and it's not so much as people think it would be climate change."

(Respondent 5- Touws River valley)

For Respondent 6, there was an embodied relationship between climatic changes such as, El Niño, temperature and rainfall. Other farmers did not venture into this debate but gave a simple explanation of the term 'climate'.

"Climate of a specific area. An area will have a different climate compared to other areas. There might also be high temperatures or low temperature or low or high rainfall. (Respondent 3- Makolokwe)

Respondent 3 is aware that climates "vary from area to area and time to time", therefore the climatic changes and different cycles occurring and experienced by one community will not necessarily be the same as those of another community. Thomas *et al.* (2007) explains that communities have had to deal with the different changes associated with climate variability. Thus, regions differ and people in one area will not necessarily cope to the same degree as individuals in other communities as people have different world views.

Some of the farmers in Touws River valley struggled to determine what exactly was meant by climate variability. Take for example the following excerpt:

"Oooh, ek weet nie (I don't know) … (paus)] Climate variability? Like hot and cold?

Yah. Klimat (climate)…(pause). Uhm like climate change?" (Respondent 4- Touws River valley)

Before the respondent could come up with an answer, he asked questions in order to try to clarify the term. What was significant with this respondent was that he was very honest about his response. Although he may have not been sure about the term of climate variability and climate change, he had some insight based on personal experience on variations of hot and cold weather. While other respondents acknowledged that climate variability is a big concern in our environment, their understanding of the term was followed with uncertainty. What they understood by the term was the difference between wet and dry seasons of rainfall. Take for example the excerpt below which also speaks of the need for experts to intervene and for assistance:

> *"Hmm, that is now when it rains, and it does not rain. Climate variability?*
>
> *I think that is one of the biggest concerns that we've got but what do we do?*
>
> *We can manage it, if you help me manage it, I will appreciate [laugh]." (Respondent 1- Touws River)*

Madison, 2006 cited in Clarke *et al.* (2012: 18) said that what is limiting farmers' knowledge of climate variability is "availability of resources, and the ability to access useful and user-friendly resources". In some instances, people may lack of knowledge about a certain subject because of the availability of resources, which also applies for farmers. Sustainability is a perspective that was projected by a game farmer in Touws River valley, who said that:

> *"The habitat is far more important than the species it is sustaining. Protection has to start as soil level, because without your soil, your grass, vegetation is dead. It's an old story, a major cycle." (Respondent 3- Touws River valley)*

From the conservation perspective, Respondent 3 strongly believes that it is important to ensure that the environment which is used for farming purposes is sustained. Du Pisanie (2018: 20) supports this perspective by adding that farmers need to take into consideration the factors such as "consumer preference, production of natural resources, biodiversity and natural resources, welfare and social development". There can be a thin line between climate variability and climate change and very often the two are confused rather than clearly defined. All the excerpts above show that farmers are aware of the climate variability and climate change. However,

because perceptions differ, the farmers had their own understanding of how they saw the world around them. Clarke *et al.* (2012) also found in his study on climate change perceptions that farmers in the Eastern Cape, were aware of climatic changes and patterns, and showed concern with regards to what these variations meant for their farming activities. This can also be said about the farmers in Makolokwe and Touws River valley interviewed for this study. Most farmers in the two regions were very aware of climate variability and climate change.

The knowledge that farmers have on perceptions and response to climate change is rooted in first-hand experiences on the impacts of climate on farming practices (Vedwan and Rhodes, 2001 cited in Wiid and Ziervogel, 2012). Perceptions vary, as shown in Tables 3 and 4.

Table 3: Grouped responses from a questionnaire used in the community of Makolokwe (n=10)

Questions	**Yes**	**No**	**Maybe**	**I don't know**
There has been little rain in the area	9			1
The streams and canals are drying up	8		1	1
There is less vegetation as compared to the past	7		2	1
There are high numbers of livestock dying due to starvation	3	6		1
Humans are responsible for the vegetation changes occurring in the area	4	3	3	
There has been increasing temperatures throughout the past years	9		1	
Livestock could be influenced by climate variability induced diseases	9	1		
An increase in temperatures could have an influence on the lives of livestock	9			1

Table 4: Grouped responses from a questionnaire used in Touws River valley (n =5).

Questions	Yes	No	Maybe	I don't know
There has been little rain in the area	5			
The streams and canals are drying up	5			
There is less vegetation as compared to the past	4	1		
There are high numbers of livestock dying due to starvation	4	1		
Humans are responsible for the vegetation changes occurring in the area	1	2		2
There has been increasing temperatures throughout the past years	3	1	1	
Livestock could be influenced by climate variability induced diseases	1	1	2	1
An increase in temperatures could have an influence on the lives of livestock	1	1	2	1

Both communities answered the questions based on their knowledge and past experiences from their respective farming activities in their different communities. It is striking that the Touws River farmers are less concerned about decreasing vegetation, increasing temperatures, and climate variability induced diseases than the farmers in Makolokwe. Most or all farmers who answered the questionnaire noted that rain as a concern in their communities. Because of the decreases in rainfall, all farmers, except those who answered with "I don't know", both communities agreed that streams and canals are drying up. Farmers showed understanding between the availability of rainfall and the availability of water in canals

4.3 Environmental changes

4.3.1 Water consciousness

Water is a natural resource of important value to all inhabitants on earth, both living and non-living. With the recent strain on water resources in the Western Cape, residents have been left with uncertainty about the future of water sustainability in the province. Richman and Leslie (2018) confirm that the 2014 wet season was fruitful as all the six major dams were filled in Cape Town, however, 2015-2017 were severe drought periods. As a result, livelihoods were vulnerable. Farmers in the Karoo indicated that water is a limiting resource because without it businesses and livelihoods suffer. One of the respondents said that:

"Water is a major issue for this part of the world. The biggest limiting factor is water in the Klein Karoo" (Respondent 3- Touws River valley)

Although this is the case for the farmers in the little Karoo, the North West is also facing water challenges. The magnitude of the challenges is not as substantial as the 2015-2017 water crisis in Cape Town because the consequences and the effects of depreciating water resources due to lack of rainfall are only seen after long periods of time. However, farmers have outlined water and insufficient rain as one of many challenges and issues they face. In Table 3 and 4, respondents said that there has certainly been less rainfall in their respective communities with 90% in Makolokwe and 100 % in Touws River valley. In a report conducted by the Department of Water and Sanitation (2017), in the years 2015/2016 South Africa experienced rainfall patterns which were below normal during the summer rainfall season, which resulted in meteorological, socio-economic and agricultural drought. Challenges outlined by respondents were as follows:

"Water; boreholes have dried out. Because of the drought, with turf soils, the effects are not that much as they have got grass, however areas which have red soil, there termites eat the grass to such an extent that there is nothing left for grazing." (Respondent 6- Makolokwe)

"Before there was sufficient rain. In the year 1957, from July to October it would rain even in winter. Now rain is decreasing." (Respondent 1- Makolokwe)

"We've had less than, you can say we've had about 40% of our rainfall for the last 3 years. So, it's definitely uhm poor. Water resources have dropped" (Respondent 4- Touws River valley)

According to the respondents in Makolokwe and Touws River valley, rainfall patterns have been changing throughout the years. This close attention to the years and seasons of rainfall variability clearly indicates that farmers are observant of their surroundings and are aware of the different kinds of the changes which may or may not be occurring in their environment.

As expressed by Respondent 4, water resources are under strain in the Karoo. Because of this stress on the environment, animals have had to opt for alternative food available to them such as reeds or any other vegetation. Animals do not have choices in food options available to them,

therefore what is available is what they consume. Farmers in the Touws River valley supplement with lucerne in order to help their livestock survive. Similarly, farmers in Makolokwe have also had to look at alternative ways of dealing with the water issue as indicated in previous sections. Thus, it can therefore be observed that water consciousness does not only affect one particular environment because water is a major issue in dryland environments.

4.3.2 Rainfall patterns

Some farmers felt that there have been significant changes to rainfall patterns, while others did not see any significant changes. Rainfall was observed to be a factor that affected farming (Vogel, 2000). Take for example the following quotes in two different communities. Clearly the recent period of drought has had a major impact on farmers in Makolokwe:

> *"Environment has been changing. In the past 3 or 4 years there has been insufficient. We have had to give the cattle chicken manure and orange pulp. It was dangerous to give them the chicken manure as some get sick. The cattle have also had to eat other vegetation such as tree leaves and shrubs. We experienced rain last year in March, but it was very late last year December." (Respondent 3- Makolokwe)*

The Touws River farmers also referred to the drought, but Respondent 1 did not see it as part of climate change:

> *"The only challenge we've got is the drought periods. You will never get a Karoo farmer that overstocks, that you will never get. We know if the capacity of the farm is for instance 10 hectare per sheep that mean for a 100 hectare you can have 10 sheep that we will not have more that 6-7 sheep. So, we under utilize our capacity. But during drought obviously the field cannot even carry 6-7 sheep per hectare, so it's less. During drought period we've got big problems. Then we've got sheep that do a lot of damage to our vegetables, our fields and that's one. We can feed them but what about the game during the drought period? I think drought is our biggest problem. Not climate change but climate fluctuations." (Respondent 1-Touws River valley)*

Conditions which have been caused by the changes in the environment have been life threatening, especially for the livestock. Because of insufficient rain and drought periods, both

the farmers in the community of Makolokwe and Touws River valley have had to look at alternative ways to feed the livestock. Farmers are aware of what is suitable for the environment and what is not, which is why they often adjust and make specific adaptation changes. It is also important to acknowledge that farmers do make sacrifices along the way because of the changes which are occurring as they constantly adjust their adaptation strategies. Insufficient rainfall has caused farmers to look at alternative ways of feeding the livestock. In the communal farming context this has meant that, even though these were dangerous for the livestock, they still took the chance in order to try to ensure that their livestock makes it through the trying times.

The inconsistency in rain patterns and seasons put farmers in a tough predicament because these changes affect their financial situation as well.

> *"Post 1960s it used to rain in the north during winter. Winter rains have disappeared. It became dryer as the years advanced. This year we experienced an unseasonal rainfall. It rained in winter. We could then go back to how it used to be in the 1960s." (Respondent 6- Makolokwe)*

> *"We wet our lucerne beds out of the rivers and we cut a lot of lucerne and sold it but now with the drought we had to make a lot of adjustments. The last time the rivers flowed was in 2014. We don't have water in the river." (Respondent 2- Touws River valley)*

The respondents indicate that these variances in the rainfall patterns caused winter rainfall in the north-west of South Africa, which is something that rarely occurs; however, unseasonal rainfall was experienced in the year 2016. This gave farmers hope that rainfall patterns were returning to how they used to be, as they see it, some fifty years ago. In a study on intra seasonal precipitation in South Africa, Thomas *et al.*, (2007) suggested that while the September and October rainfall season in the last 50 years had been increasing, during the wet season inter-annual variability in rainfall had been evident.

Rainfall variabilities are evident in both Makokwe and Touws River. Long-term monthly rainfall data indicates that Makolokwe experiences summer rainfall, peaking in the month of January (Figure 9). However, according to Respondent 6 (Makolokwe), winter rainfall was common during the 1960s. Interestingly, scientific data confirms this perception to some extent, indicating

that there has been a decline in winter rainfall since 1990, with winter rainfall peaking during the 1950's (Figure 10).

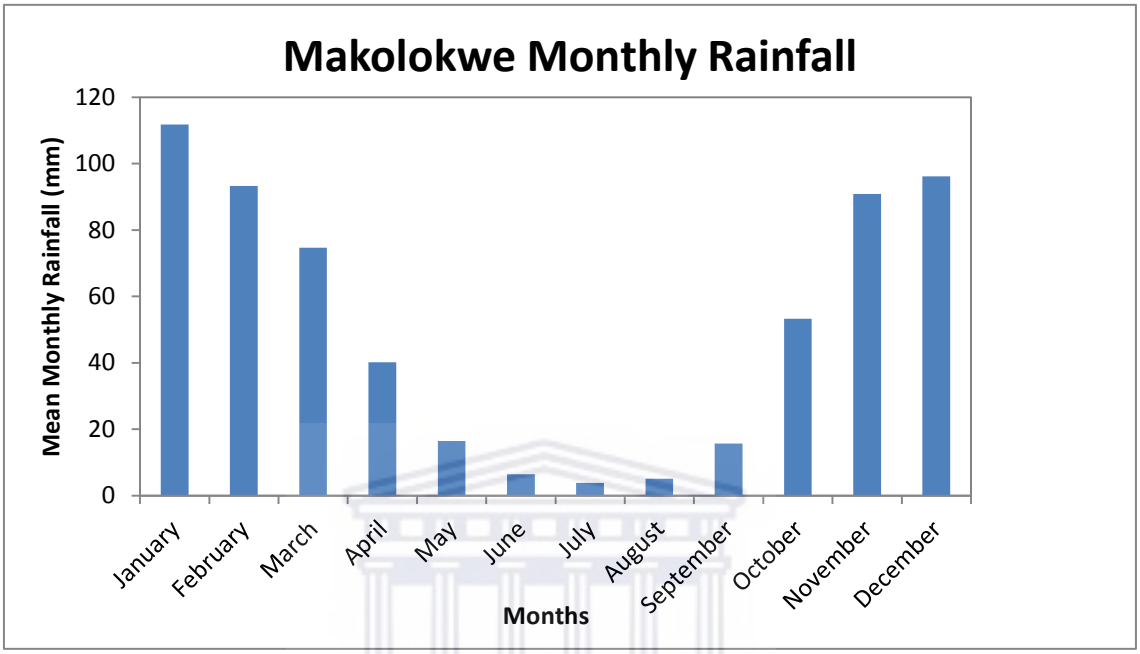

Figure 9: Monthly rainfall in Makolokwe recorded from 1928-2016. Area experiences most of its rainfall in summer and autumn. Winter (June- August) has the lowest rainfall.

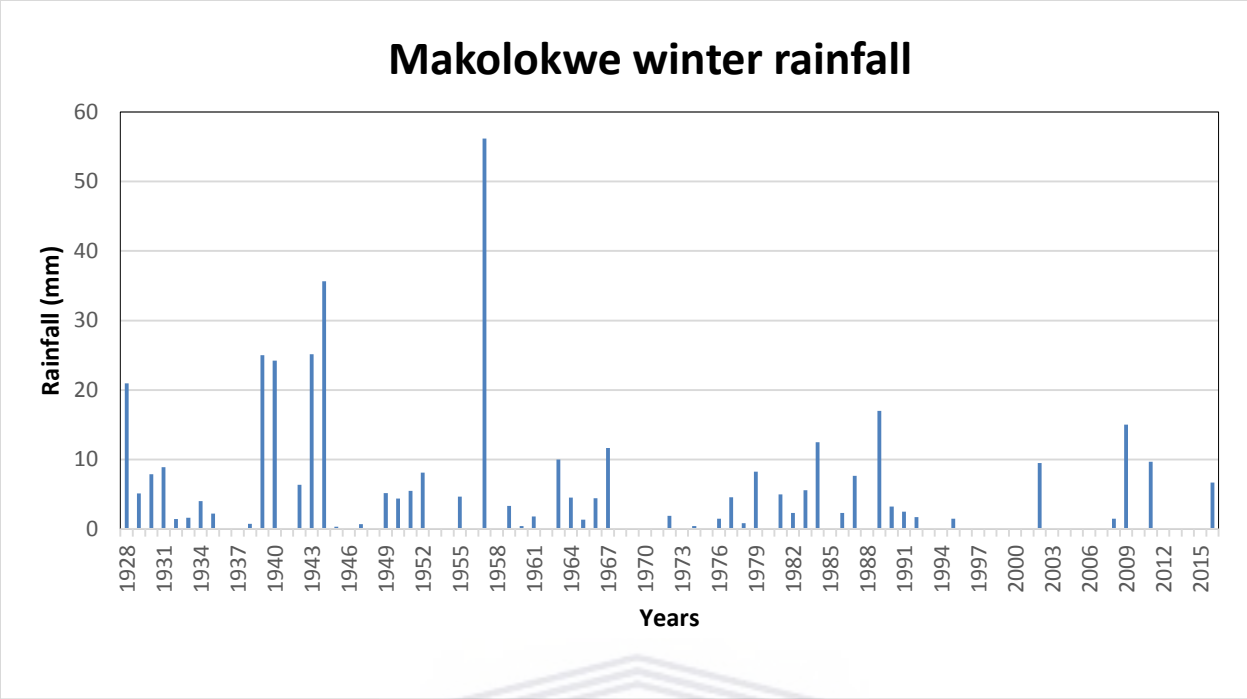

Figure 10: Winter rainfall in Makolokwe from 1928- 2015. The year 1939, 1940, 1943, 1944, and 1957 show high peaks in winter rainfall as compared to other years from June to August.

Farmers in the Touws River valley also face serious challenges with rainfall patterns as rivers have run dry because of the inconsistency and even absence of rainfall in the Western Cape. Richman and Leslie (2018) mentioned that there has been a reduction in rainfall in Cape Town since 2015 to 2017. Farmers are clearly attaching a symbolism to rainfall because they keep a record of all these changes which occur, which could have a positive or a negative impact on their livestock. What is illuminated from the interviews conducted is that rain is an important source of life for both livestock and the farmers. Touws River valley receives rainfall throughout the year without a pronounced dry season (Figure 11). The highest rainfall seasons are winter, and spring and the lowest rainfall season is summer.

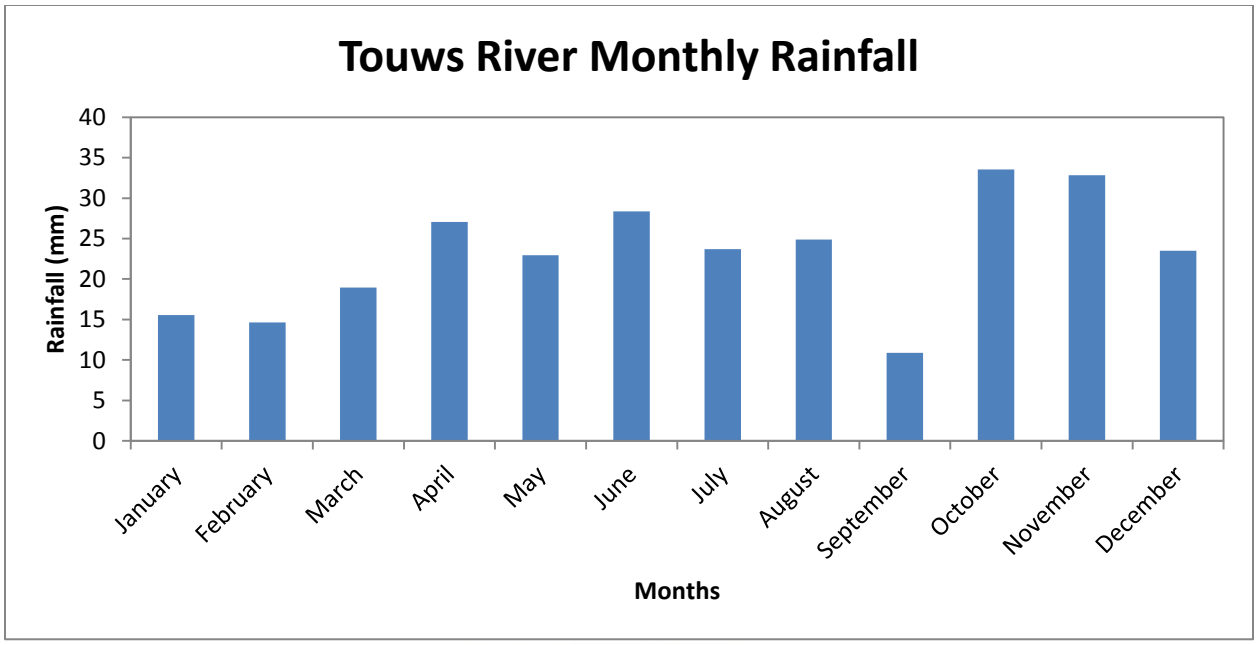

Figure 11: Monthly rainfall in Touws River recorded from 1988-2017. Area receives rainfall all year long.

Although respondents in both communities indicated that there has been a decrease in rainfall, the onset and cessation of rainfall is also another factor that may have misled their perception on rainfall patterns. Long-term rainfall records can be assessed to determine levels of variability. The mean annual rainfall for Makolokwe (Figure 12) is 569mm/a. The highest rainfall year is 2000 with 1000mm, while the lowest rainfall year was in 1999 with 196mm. A plot of annual rainfall anomalies indicates that there were more wet years prior to 1979 (Figure 13). While there is a long-term trend of decreasing rainfall, this trend was found to not be statistically significant. Nevertheless, the farmers' accounts of the past being wetter than more recently are consistent with climate data.

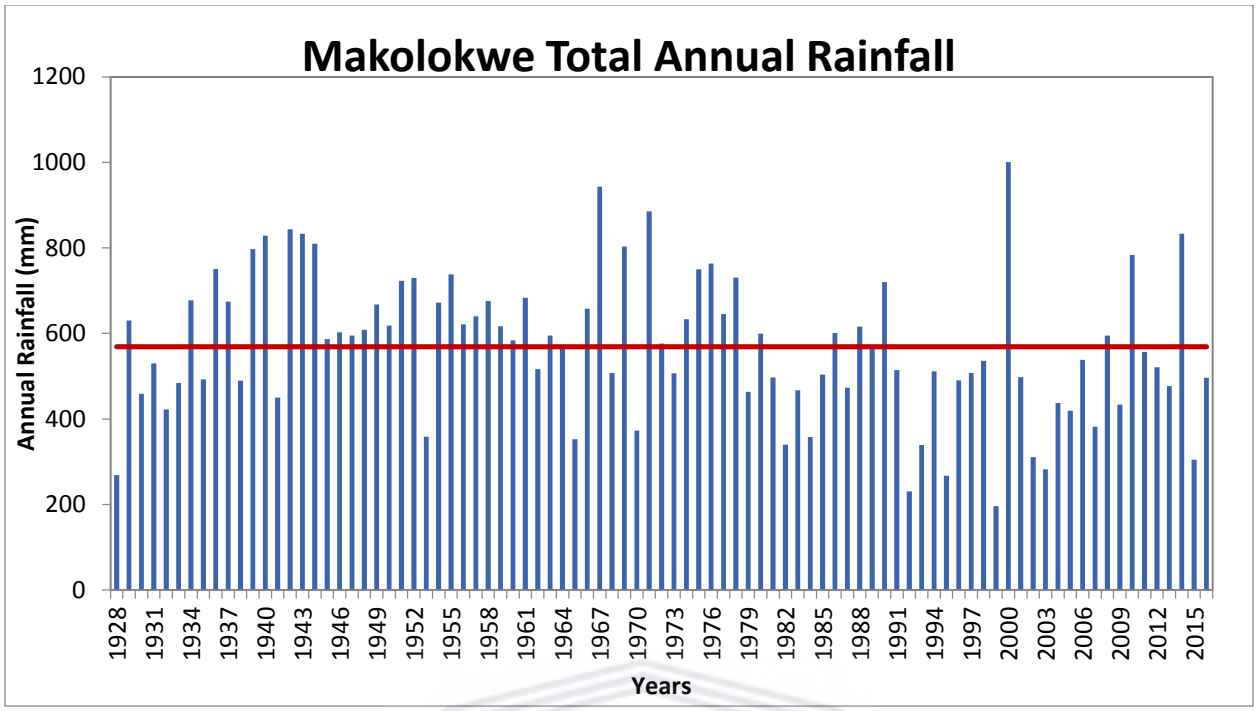

Figure 12: Total annual rainfall in Makolokwe recorded from 1928-2016. The mean value is indicated by the red line.

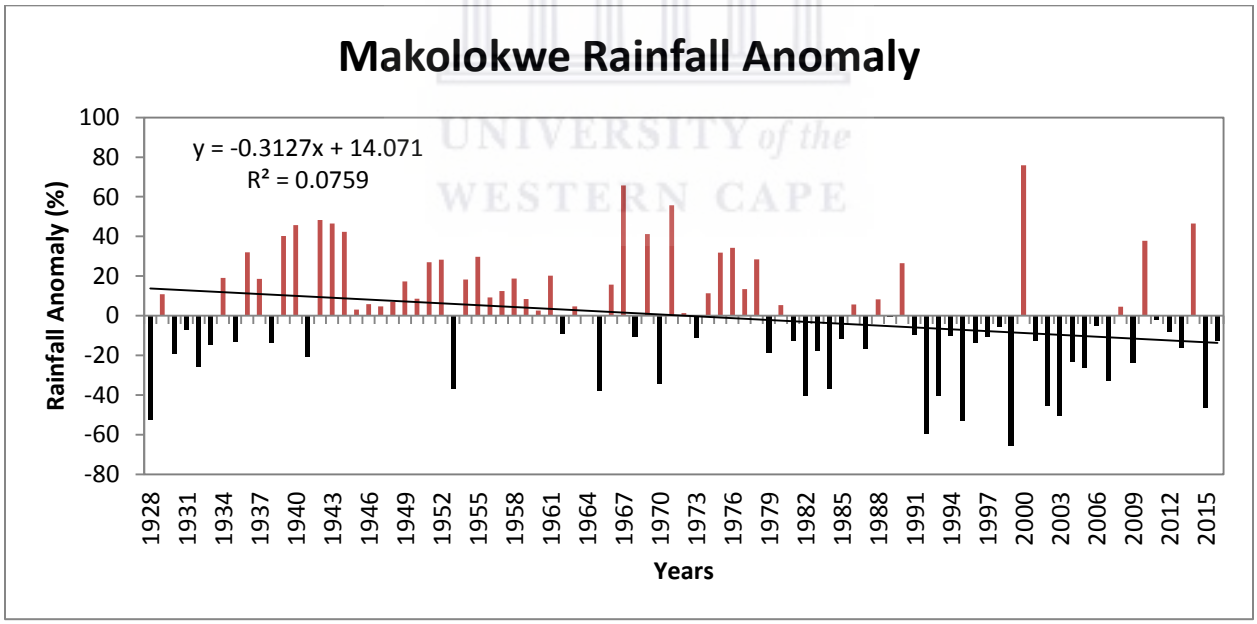

Figure 13: Rainfall anomalies relative to the mean at Makolokwe between 1928 and 2016. The trend indicates a negative trend which is not statistically significant.

The Touws River valley (Figure 14) has a mean annual rainfall of 276mm. Over the period of record, there were more years below the annual mean than those above (Figure 15). The longest wet period was just 3 years and occurred between 2011 and 2013, with a rainfall of 488mm in 2011. This was closely followed by the lowest annual rainfall on record in 2016 at 139mm. From the local data that the farmers provided in the interviews, Respondent 4 spoke about drought years which occurred as well as a drop in the rainfall.

> *"I don't think the grazing area changes the capacity of it, but the quality of it changes, because of the drought. I mean we should have like rain in the fall or, uhm, in the early winter and maybe August as well, then our veldts this time should be almost full of flowers, but we haven't had that in the last 2-3 years." (Respondent 4- Touws River valley)*

> *"We've had a drought since I came here. So, it's difficult to say, but uhm, we've had less than, you can say we've had about 40% of our rainfall for the last 3 years. So, it's definitely uhm poor. Water resources have dropped." (Respondent 4- Touws River valley)*

As indicated in Figure 14 and Figure 15, the years following the longest wet period (between 2011 and 2013) show a decrease in the annual rainfall with the years 2015, 2016 and 2017 falling below the mean annual rainfall. The data clearly indicates major variability in annual rainfall from year to year. With regard to the drought that Respondent 4 has spoken about, he has also mentioned its impact on the vegetation in the area, particularly with flowers that occur during the summertime. This variability in annual rainfall has affected natural vegetation that grows in the area.

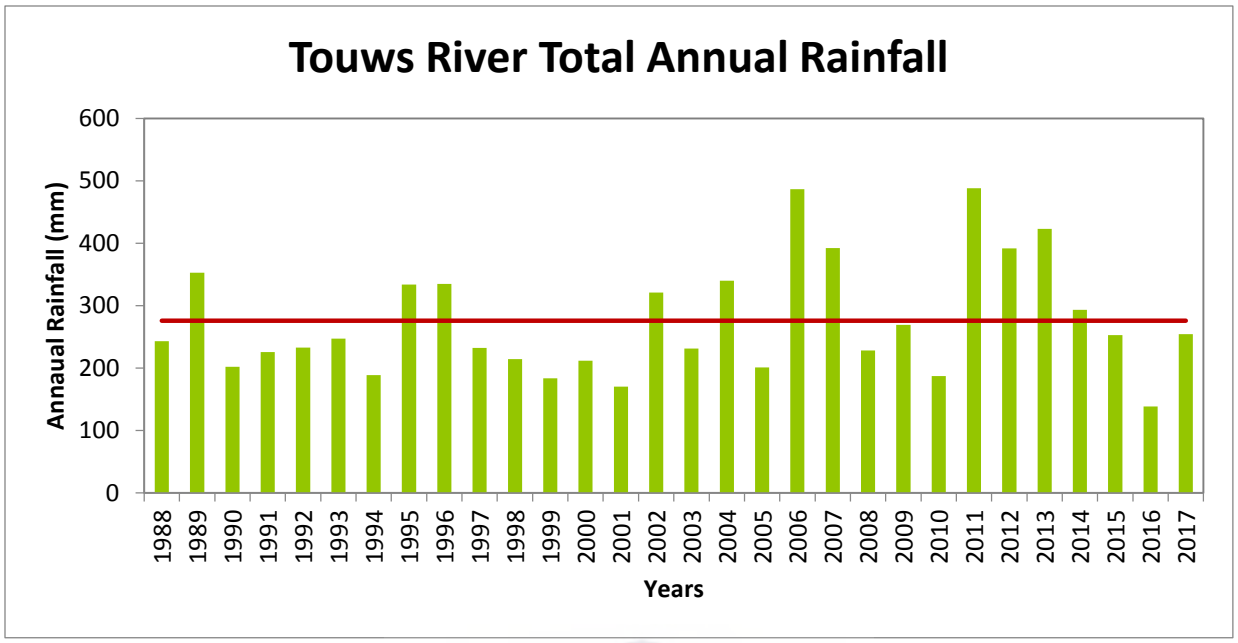

Figure 14: Annual rainfall in Touws River has been fluctuating from 1988-2017. The mean value is indicated by the red line.

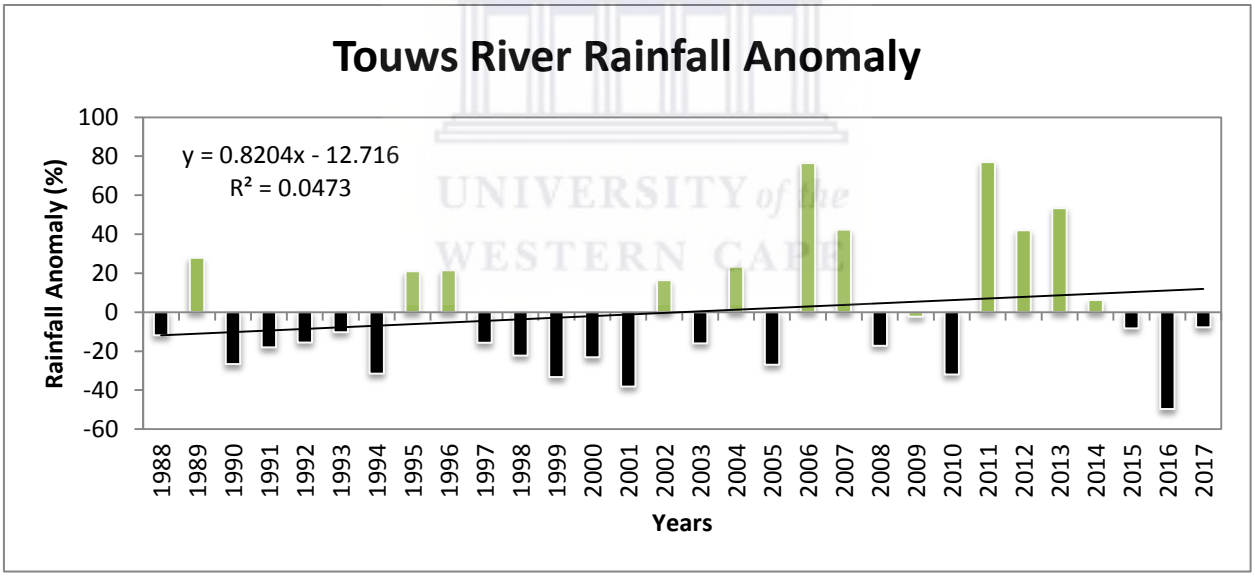

Figure 15: Rainfall anomalies relative to the mean at Touws River valley between 1988 and 2017. The trend line indicates a positive long-term trend that is not statistically significant.

4.3.3 Vegetation cover and grazing potential

Vegetation cover around farming communities plays a pivotal role in the lifespan of livestock. As grazing takes place the livestock is sustained, which in turn has a positive impact on the livelihood of the farmers. In contrast when vegetation cover decreases, pressure is put on the available and existing pastures. Furthermore, a decrease in vegetation also threatens the lifespan of the livestock as well as the livelihoods of the farmers. From some of the perceptions of the farmers, grazing areas do not decrease in capacity but the quality of the grazing area changes. For example, Respondent 4 said the following:

> *"I don't think the grazing area changes the capacity of it, but the quality of it changes, because of the drought. I mean we should have like rain in the fall or, uhm, in the early winter and maybe August as well, then our veldts this time should be almost full of flowers, but we haven't had that in the last 2-3 years." (Respondent 4- Touws River valley)*

According to Respondent 4 drought has played a major role in the quality of the grazing area in Touws River valley. The quality of grazing area has also caused delays in the time that vegetation would take to grow. Other farmers indicated that there had been decrease in vegetation in their surrounding areas. Some of them said the following:

> *"I would say decrease. Decrease for the simple reason of the grazers asopposed to browsers that we've got. The Karoo always has a shortage of grasslands, and that is our biggest problem. People tend to, because we've got a biggest problem with jackal, rooikat (karakal), and farmers go for bigger animals like game, cattle, because smaller predators cannot get the bigger game. But bigger game are more bound to graze grasses and smaller animals are more browsers, so it's the load that we put on the field, is very heavy on the Karoo." (Respondent 1- Touws River valley)*

> *"Grasslands have been decreasing. It is mostly influenced by rain. In the past years it was better. A lot of people have started owning livestock which then has resulted in less vegetation for the livestock." (Respondent 3- Makolokwe)*

"Definitely a decrease in viable grazing. It's been raped by bad farming practices in the past. It's been totally raped, that's why they called them "trek boere". They would come into a place, totally overstock it, uhm, totally overgraze it. Back then they didn't know any better. The word conservation didn't exist in their minds; I'm talking now 1800, 1700, 1600 that was common farming practices. We've learned as we come along." (Respondent 3-Touws River valley)

What is significantly illuminated from all the extracts of the farmers is that the number one contributing factor to changes in the vegetation is drought caused by insufficient rainfall. According to the farmers, drought equals less vegetation and less vegetation equals less carrying capacity of animals (Figure 16).

Figure 16: Consequences of drought suggested by respondents. (Source: Author, 2019)

Nearly all the farmers spoke about the past years of flourishing grazing areas. This has gotten the farmers to subconsciously take note of the different changes which had been occurring in their grazing areas in order to fully ascertain and assess the severity of the changes. While grazing area for livestock has been decreasing because of less rainfall, Respondent 3 notes that not only has drought affected grazing areas, but that bad farming practices have also resulted in a decline of viable grazing area. The farmers in the past abused the land without any regard to sustainability of the resources that they were using, which is now pertinent in today's farming processes (Respondent 3, Touws River Valley, 2017)

There is a heavy load on grazing lands in Makolokwe as stated by Respondent 3 as well as in Touws River valley, a point also highlighted by Respondent 3. In Makolokwe the somewhat

surprising finding is that even though people are aware that there are significant changes in the rainfall patterns, they have opted to increase their livestock. Commercial farmers in the Touws River valley also accept that rainfall patterns have been changing and that decreasing livestock assists grazing areas to recover, but because they are private landowners with resources they have more options available to them, not only decreasing the livestock but also having an opportunity to introduce game as an option to support their livelihoods. This option is different and not available to communal farmers who would not consider changing to game farming in part due to the cultural and economic significance of livestock. Figures 17 and 18 indicate a significant increase over a 10-year period in the amount of livestock at Makolokwe.

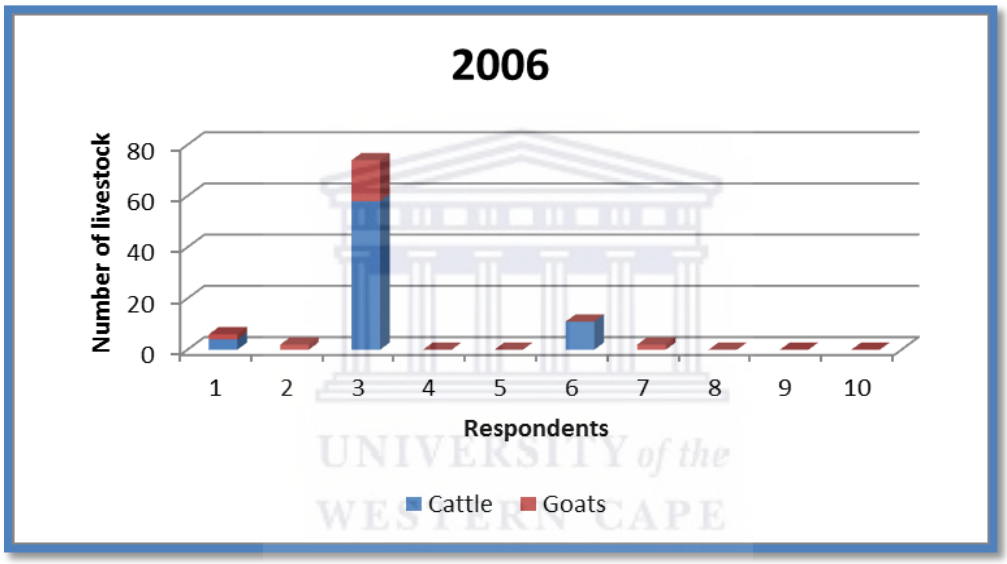

Figure 17: Number of livestock in 2006 owned by respondents in Makolokwe. (Source, Fieldwork, 2016)

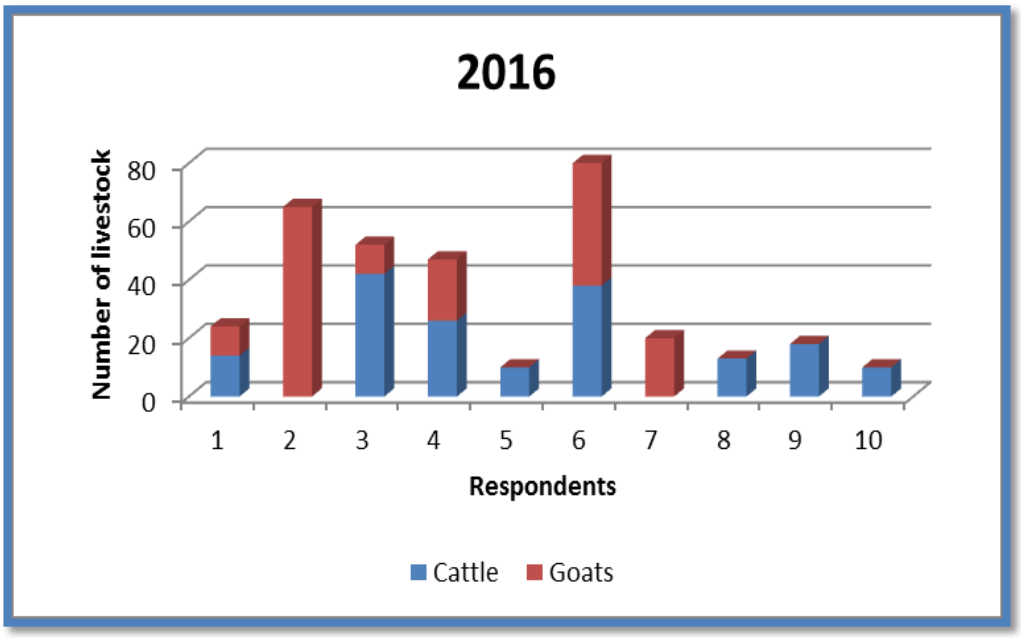

Figure 18: Number of livestock in 2016 owned by respondents in Makolokwe. (Source, Fieldwork, 2016)

This not only creates contestations, but it creates problems over grazing as communal farmers must share land. It is therefore essential to look at this relationship between changing rainfall patterns and the strong interest in investing in livestock farming. One other important aspect which was considered is the connection between the number of livestock and the increase or decrease in grazing area. Take for example the following response:

> *"For livestock farmers there have been contestations. When there is more livestock, there will be a decrease in grasslands. But now as people are decreasing the number of livestock they have, the number of livestock grazing is not affected. Even though there is global warming, grazing has become easier." (Respondent 4- Makolokwe)*

This then suggests that although rainfall plays an important role in vegetation, there are other factors that come into play such as (1) the farming practices of the farmer, (2) the perceptions that the farmer has about sustainability of resources, and (3) the farmer's livelihood. Thus, if a farmer uses poor farming practices, or is not taking into consideration the sustainably of the resources they use for farming, that may result in environmental degradation and long-term reduction in carrying capacity. Similarly, when the livelihood of the farmer is threatened, farmers

will use whichever method they think best fits options to support their livelihood, whether it be bad or good in the long-term.

Generally speaking, the more the livestock there is, the less vegetation there will be available for grazing. Toombs *et al.* (2010) showed in their study that one of the ways to promote vegetation productivity is that stocking rates would be to decrease in order to ensure sustainability. It is also important to acknowledge that although some livestock farmers see significant decreases in the vegetation with the decreasing numbers of livestock by farmers, others note that it has made grazing easier as overgrazing has lessened. Therefore, it is important to continue to learn and seek better ways to conserve and sustain the environment.The NDVI images of the year 2013 (Figure 19) show that the wet seasons (April and December) had patches of vegetation cover which indicated that there were grazing areas available for the livestock. Rainfall data from the area indicates that it was a dry year (See Figure 12 and 13). According to farmers in Makolokwe, rainfall had been decreasing. As Respondent 3 said:

> *"In the past 3 or 4 years there has been insufficient rain. It was extreme because we now had to make other arrangements and feed the cattle." (Respondent 3- Makolokwe)*

In addition to insufficient rainfall, vegetation cover was also found to be fluctuating throughout the years. One farmer in Makolokwe said the following:

> *"It has been increasing and decreasing throughout the years." (Respondent 2- Makolokwe)*

These fluctuations in the vegetation are clearly linked to rainfall patterns (Figure 12 and 13) with areas experiencing less rainfall showing fewer grazing areas and areas experiencing more rain showing more grazing area.

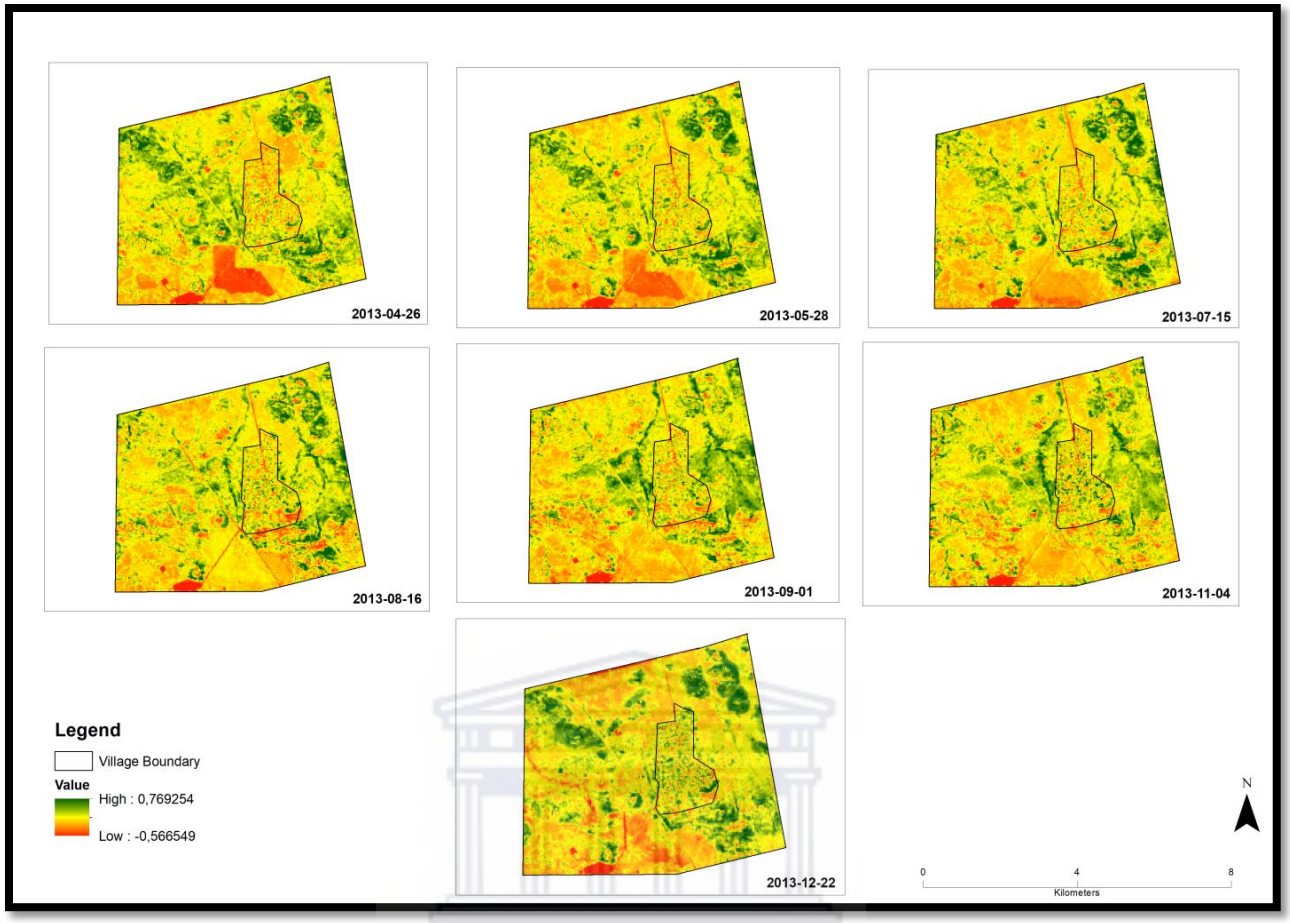

Figure 19: NDVI images of Makolokwe dated from 2013-04-26 to 2013-12-22. The green colour indicates areas with dense vegetation cover, with yellow indicating medium vegetated areas and red indicating areas with low vegetation cover.

The results for 2014 in the months of May, June and, July, show many patches with healthy vegetation (Figure 20). Although Makolokwe receives its highest rainfall in summer and autumn, Figure 20 is striking in that June and July were well vegetated. Figure 21 and 22 also show that April, May, June, October, and November have some parts with dense vegetation cover. Overall, although the vegetation cover in Makolokwe has been decreasing, some of the respondents indicated that they would increase their livestock. As aforementioned, the farmers' livelihoods have a role in the increase and decrease of livestock, as that determines a farmer's wealth.

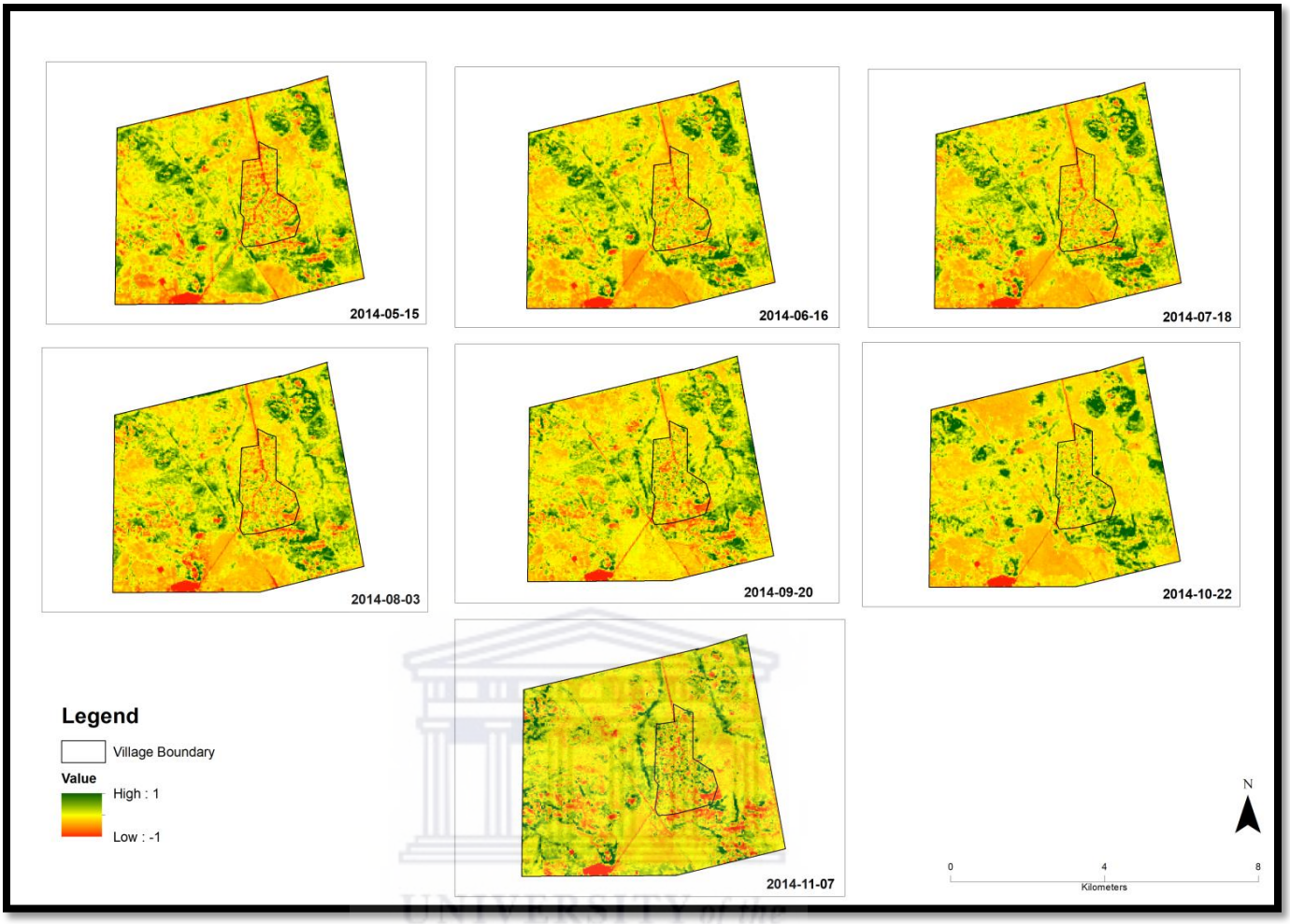

Figure 20: NDVI images of Makolokwe from 2014-05-15 to 2014-11-07. The green colour indicates areas with dense vegetation cover, with yellow indicating medium vegetated areas and red indicating areas with low vegetation cover

According to Respondent 3 (Makolokwe), not only have grasslands decreased but the carrying capacity also plays an important role in the vegetation. Where the carrying capacity increases, vegetation lessens (Vogel, 2000) especially in communal communities like Makolokwe. Although vegetation cover was low in 2013, 2014 and 2015, a report by DEA (2016) indicated that despite rainfall variability, annual rainfall totals are increasing in the central interior of South Africa. This increase in annual rainfall total is not statistically significant (DEA, 2016).

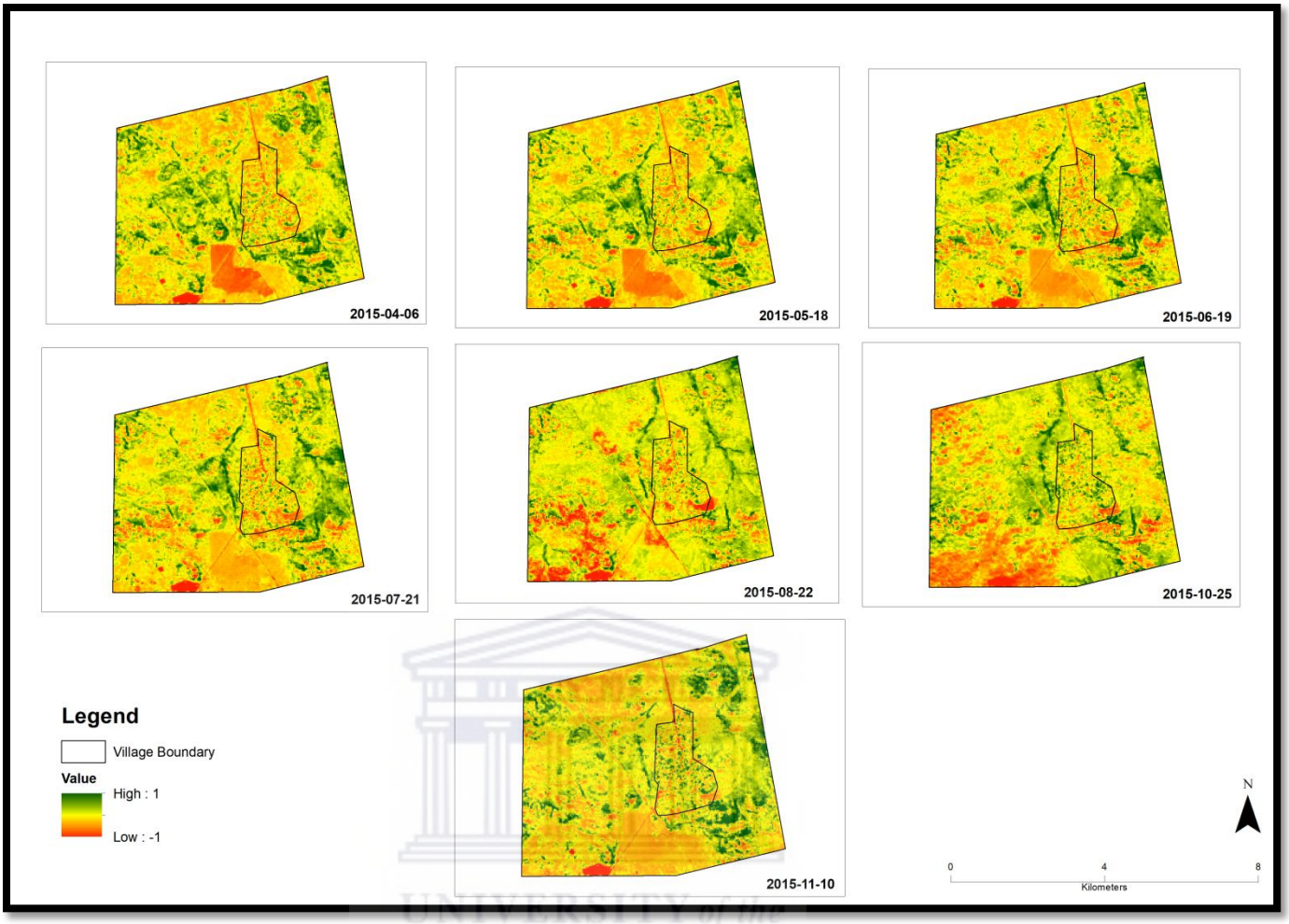

Figure 21: NDVI images of Makolokwe dated from 2016-04-16 to 2015-11-10. The green colour indicates areas with dense vegetation cover, with yellow indicating medium vegetated areas and red indicating areas with low vegetation cover.

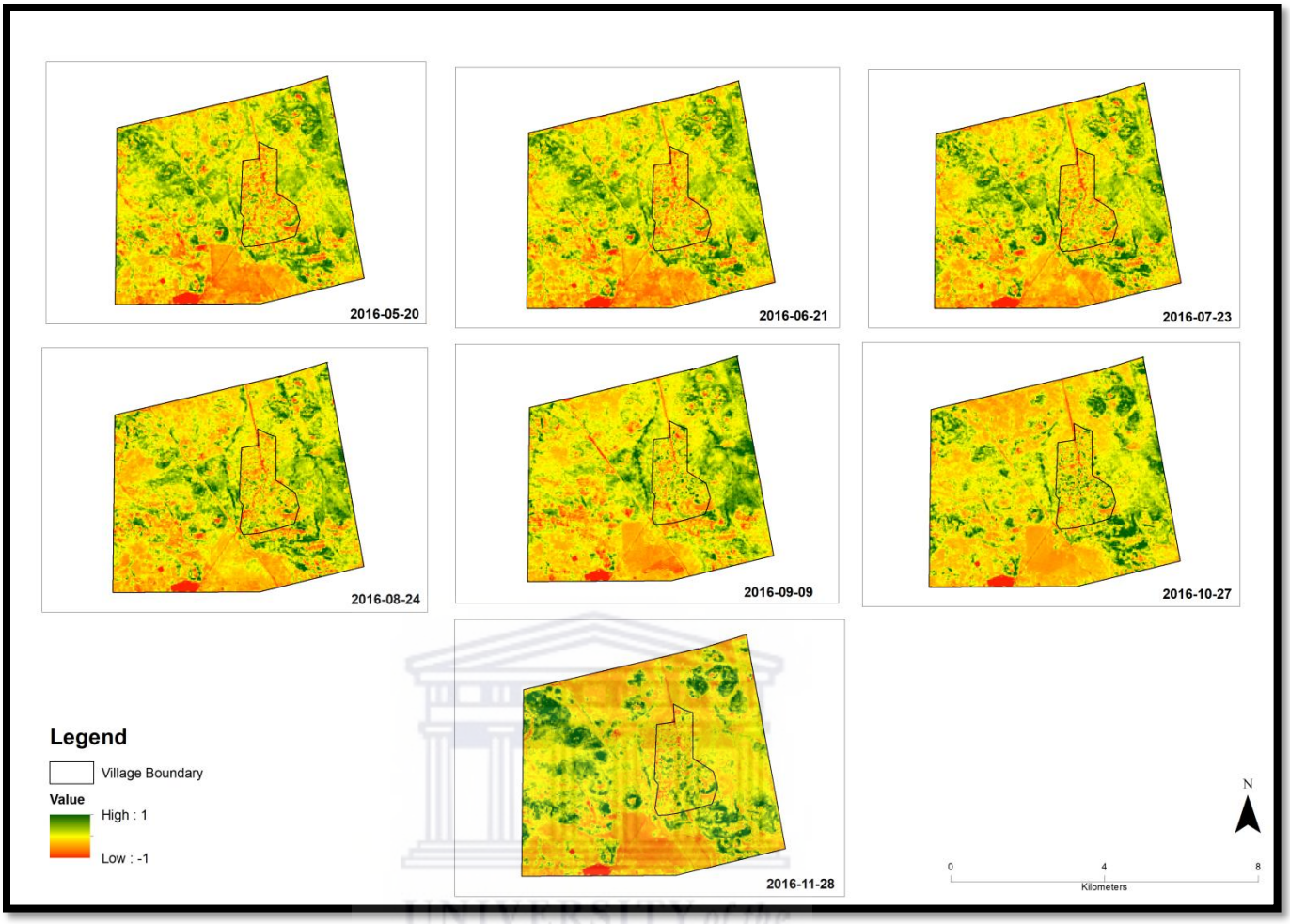

Figure 22: NDVI images of Makolokwe dated from 2016-05-20 to 2016-11-28. The green colour indicates areas with dense vegetation cover, with yellow indicating medium vegetated areas and red indicating areas with low vegetation cover.

Figures 23, 24, 25 and 26 show that in Touws River valley, the area with good vegetation is the hills and the rivers, with everything else having sparse vegetation cover. There is a drainage line which is very green, indicating that these farms are irrigated. Farmers find themselves in a vulnerable position as the availability of resources has become compromised. However, commercial farmers may use borehole water to supplement their farming practices, as Respondent 2 has mentioned below:

> *"In the beginning it's still fresh but even if it becomes a little brackish then the animals still drink the water, it doesn't affect them. However now that the rivers do not flow*

anymore or flow very little, we are dependent only on our bore holes. We have for example if we have a bore hole under the mountains, we build a pipe going from the bore hole to the different livestock camps and into a water trough for the animals' drinking water." (Respondent 2- Touws Tiver valley)

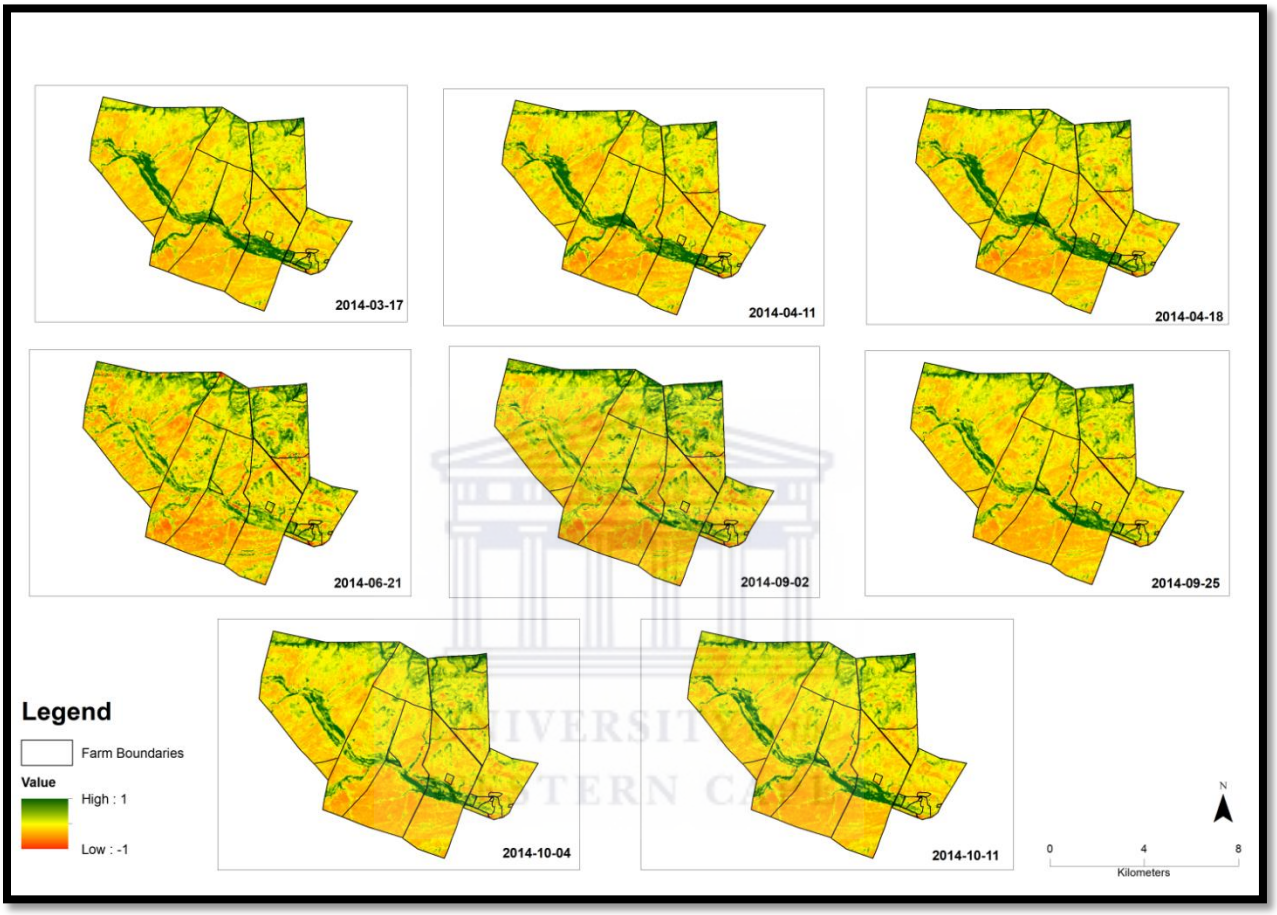

Figure 23: NDVI images of Touws River valley dated from 2014-03-17 to 2014-10-11. The green colour indicates highly vegetated areas, with yellow indicating medium vegetated area and red-orangish colour indicating areas with low vegetation

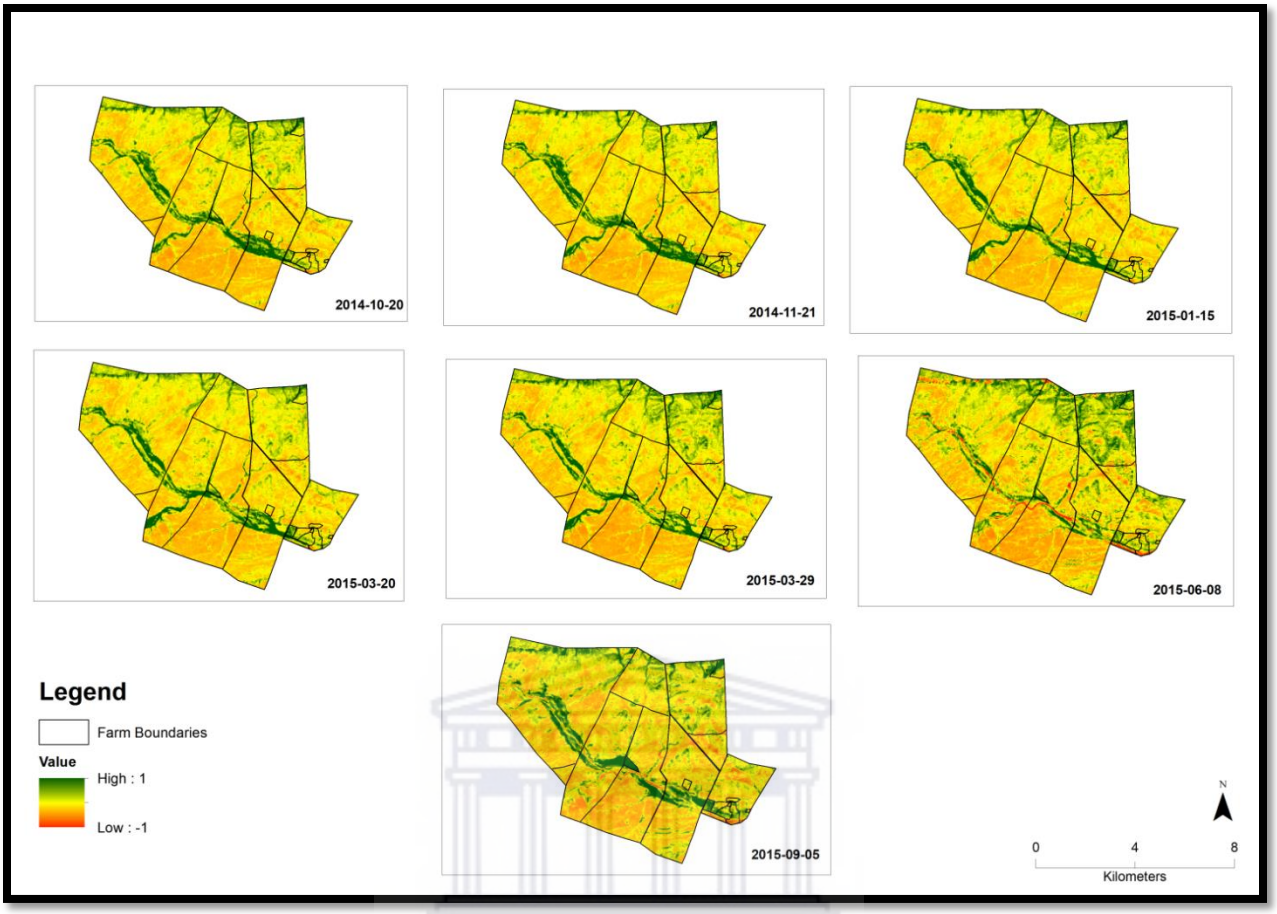

Figure 24: NDVI images of Touws River valley dated from 2014-10-20 to 2015-09-05. The green colour indicates highly vegetated areas, with yellow indicating medium vegetated areas and red-orangish colour indicating areas with low vegetation.

Respondent 1 and Respondent 4 in Touws River valley as aforementioned indicated that availability of suitable grazing vegetation has always been a problem in the Karoo. The images show that although there is rainfall all year round, the vegetation cover remained low throughout the year except around the drainage line. According to Richman and Leslie (2018) 2014 was a wet season as all the dams were filled in Cape Town, which may have affected the drainage lines in Touws River valley during that same year. Figure 14 and 15 further attests that the year 2014 was above mean annual rainfall and was an anomalous year. The NDVI images of this year also give an indication of the drainage lines green all year long.

Farmers indicated that there have been rainfall fluctuations in the area. One farmer said the following:

> *"We had bad dry periods for about 2-3 years then it gets up again. So, it goes up and comes down again. So that is how it works. If you can get a trend that goes up up up, then we can say there's earth warming or there's something happening. But that's not what I found. I think the patterns, or the past is just repeating itself over a period of time." (Respondent 1- Touws River valley)*

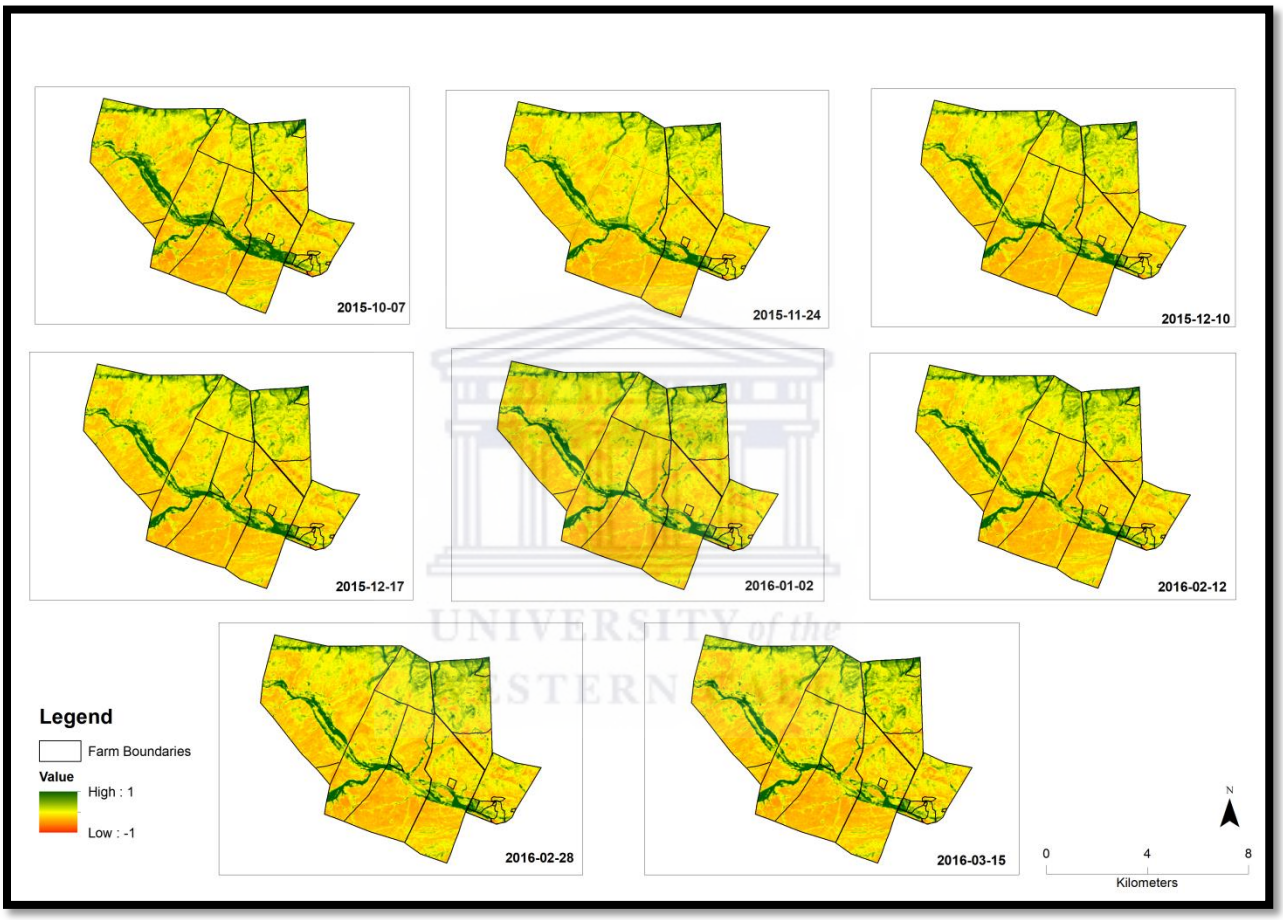

Figure 25: NDVI images of Touws River dated from 2015-10-07 to 2016-03-15. The green colour indicates highly vegetated areas, with yellow indicating medium vegetated areas and red-orangish colour indicating areas with low vegetation.

Taking a further look at Figure 14 and Figure 15, 2014 was a good year which was above the mean rainfall in Touws River valley. This is also backed by Richman and Leslie (2018). However, the years 2015, 2016, and 2017 that followed were below mean annual rainfall.

Richman and Leslie (2018) reported that the years 2015-2017 was a severe drought period. Although there was a drought in the area during that period, the area around the drainage lines was still green, but had decreased because of a drop in the water levels.

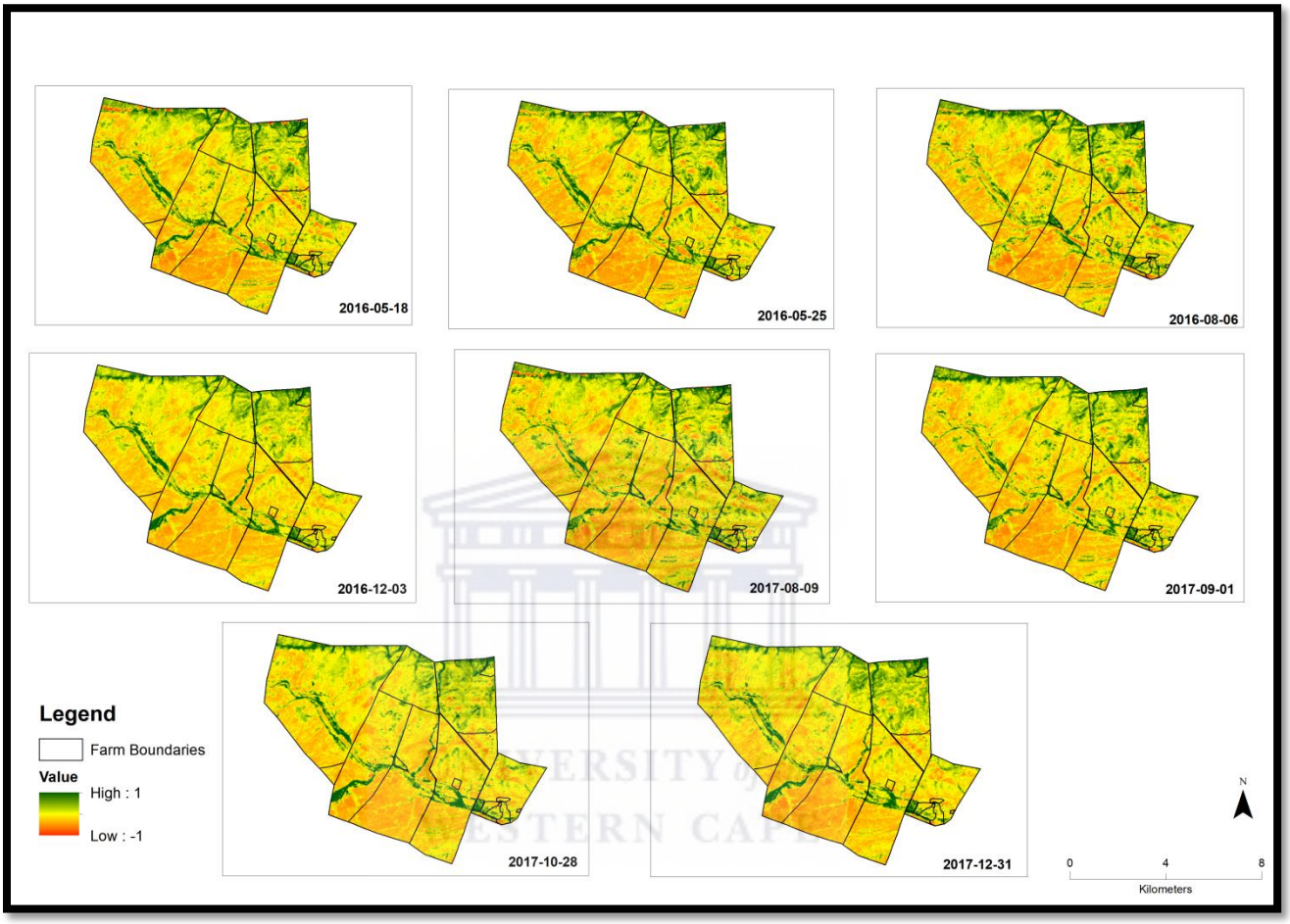

Figure 26: NDVI images of Touws River dated from 2016-05-18 to 2017-12-31. The green colour indicates highly vegetated areas, with yellow indicating medium vegetated areas and red-orangish colour indicating areas with low vegetation.

4.4 Summary

Majority of farmers in both communities understood what climatic variability is, and they have a good understanding of local rainfall patterns (for example, the fact that without any rainfall data, some farmers in Makolokwe remember winter rainfall use to be higher). However, where the farmers differ is in the adaptation options available to them. Commercial farmers have boreholes, control their own land so that they can reduce grazing in certain areas, grow lucerne, and may choose to switch to game. Communal farmers share their grazing land and may choose not to decrease livestock as it affects their livelihoods. These strategies are highlighted and expanded upon in the next chapter.

CHAPTER 5: ADAPTATION STRATEGIES AND THE LINK BETWEEN LOCAL AND SCIENTIFIC KNOWLEDGE

5.1 Introduction

The main purpose of this chapter is to consider the different ways that farmers in Makolokwe and Touws River valley cope with climatic variability. The chapter begins by looking in detail at adaptation strategies adopted by the farmers. Adaptation strategies are organised under two themes: subsidising and stock reduction, which are practical responses. They were identified as common when it came to adaptations and are described sequentially. The second part of the chapter reflects the relationship between the local knowledge provided by farmer's narratives and the scientific knowledge are outlined.

5.2 Adaptation Strategies

5.2.1 Subsidising

With all the environmental changes in our environments, farmers are left with difficult decisions to make on how to best take care of their farming activities and their livelihoods in this context. Thus, adaptations as Elum *et al.* (2017) have described, vary from place to place, and over time depending on the type of resources an individual or group may possess. Perceptions that farmers have about climate change and variability are also important in decision making processes. Ayal and Filho (2017) support this notion as they argue that the quality of the perceptions of farmers impacts on the ability to cope and adapt.

It is evident from the excerpts below that although farmers in Makolokwe and Touws River valley live in different regions, they followed similar adaptation and coping strategies and had similar concerns. There are farmers who use available natural resources from the land to subsidize the diet of their livestock. This was most evident in the interviews with farmers from Touws River valley.

"We use the rivers quite a lot for the reeds…

That's how the cattle and a lot of these sheep survive the winter now. Here by our place, here up, where the Brak River connects, down there the reeds are 3m high, green right now, and down here as well. And in this river from my house down there, there is a lot of reeds, a lot, a lot, a lot. So, we are very fortunate to have that and the grass as well, 'kweet gras'. It's hard grass but they eat it." (Respondent 4- Touws River valley)

Farmers in both study areas also take more active measures. It is evident that communal farmers in Makolokwe were forced to use more risky methods such as using chicken manure for feed.

'When in winter we support the cattle. We buy them food, for example 'lesereng', chicken manure and orange pulp. Sometimes we have to sell the cattle in order to support others or buy them food." (Respondent 3-Makolokwe)

"For example, for water I have a tanker and carry the water for the cattle. Then the dry grass that the cattle feed on in winter we supplement with Lucerne and other nutrient animal feed that we buy" (Respondent 6- Makolokwe)

"In the wintertime we need a lot of external feed to give to the animals and in the summer time it's the other way around, then there's more natural grazing, like there where the sheep are grazing. That's Lucerne and mixed grazing. So, they walk in that and they eat. You just give them a little of chop, dry feed or pellets just for additional feed" (Respondent 4-Touws River valley)

Because Touws River valley and Makolokwe are located in two different provinces with differing environmental concerns, their adaptation strategies sometimes differ. Some of the options available in one context are not available in the other. Take for example in the excerpts above where reeds are used as a natural resource to supplement for the livestock and game in the Touws River valley area. What is important to note is that Touws River valley has drainage lines in the farming communities. The Touwsberg Mountain also creates runoff which facilitates most of the water that runs along the farming communities. Respondent 4 in Touws River valley displays a lot of gratitude for the reeds that grow in the area. He also mentions that although the reeds may be hard, the animals seem to not have a problem with it. Commercial farmers in Touws River valley use borehole water to grow lucerne to subsidise their livestock, and they also

use rotational grazing to manage vegetation Both these strategies are not available to communal farmers in Makolokwe. Drainage lines and canals are present in Makolokwe, but they are all dry and have been like that for years, which causes farmers to also rely on more risky forms of keeping the livestock alive such as using chicken manure. Livestock may not thrive and may die consuming this.

Subsidising is a costly process because not only does it take up time, but it requires one to spend money in order to further invest in the farming process. In this study, one respondent in particular mentioned that although he was aware of the unpredictable rains in his community, he was willing to still increase his livestock. He was aware that this would require further supplementary feeding. In rural communities, the loss of livestock could mean that they fall into poverty and this in turn affects their livelihoods (Rust and Rust, 2013).

It can be seen from the above excerpts that responses to the seasonal climatic changes are taken seriously. Clarke *et al.* (2012) mentioned that the relationship farmers have to their land shapes the perceptions that they have about the environmental changes which in turn can contribute to their coping strategies. Thus, context specific reference to climate change and variability perceptions is imperative in proper decision making about adaptation and coping strategies. In a study conducted by Thomas *et al.* (2007), 80% of the respondents were aware of the changing rainfall trends around them.

During the summer months, livelihoods are not threatened leaving farmers less vulnerable as there is less support for livestock (Figure 27) for both communities. According to Lunde and Lindtjorn (2013) annual rainfall plays a significant role in cattle numbers. Rust and Rust (2013) also showed that there is a huge disparity in the carrying capacity in winter and summer. During the summer months in the two study areas, livelihoods are not as threatened leaving farmers less vulnerable as there is less need to support livestock (See Figure 27). Differences between the two farming communities are evident in terms of their experience of drought periods. However, winter months pose a significant threat to the livelihoods of farmers in both Touws River valley and Makolokwe. For farmers in Makolokwe there is less rain in this season and conditions are drier. Farmers have had to rely more on external food such as lucerne in order to support the livestock through the winter. Although Touws River valley may receive rainfall all year round,

feed availability was reduced as well in winter. The respondents are concerned about the environmental changes which are occurring and the costs thereof. Farmers said the following:

> *"We don't control climate, then it becomes difficult. We then have to decrease livestock. The livestock have to drink water in the community and not in the field; this can be costly." (Respondent 4-Makolokwe)*

> *"The last time the rivers flowed was in 2014. We don't have water in the river. I have a few bore holes but in the earlier years we only used it for drinking water for our animals but now we had to use it for something else. On my land I have a hectare that I've cordoned it off so that the kudus do not not come in and destroy the crop. We've started planting carrot and onion seeds and watered it with the borehole water. This was so that we could have an income as farmers. We have made many adjustments because of the drought" (Respondent 2-Touws River valley)*

> *"I've got a couple of boreholes in the veld, which during the dry periods I've been monitoring, running and maintaining for the game. The water is brak, this whole area's water is quite brak. It's got mineral salts in the ground, so it's not the most palatable of water, but we are fortunate. Along Touwsberg is a massive catchment. I've got a big catchment behind the house, which I can't wait for it to be filled. We just repaired the wall a couple of years ago after the two very serious floods a couple of years ago." (Respondent 3-Touws River valley)*

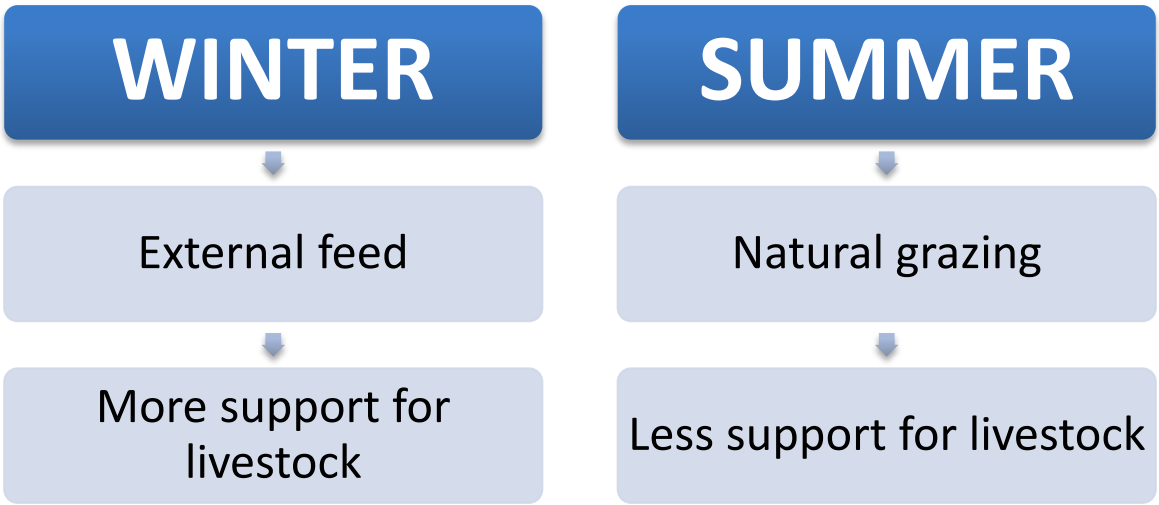

Figure 27: Support given to livestock in Makolokwe and Touws River valley in winter and summer. (Source: Author, 2019).

A study conducted by Campbell (1999) showed that farmers moved livestock to better grazing areas and water in order to support the animals. Farmers in Makolokwe use the community as a means to provide water for the livestock. What they have done to help livestock is to use the water provided by the windmill, and if water is not available, they also have pipes running from the community to the kraals. Other farmers have also installed taps closer to the kraals so that water is readily available for the livestock at all times (Figure 28). One farmer indicated that they use a tanker to support the livestock, especially if the kraal is located far from any water points in the community and the farmers' household. On the other hand, farmers in Touws River valley utilise boreholes and the river as ways to adjust with the water concerns in the area. The water in the boreholes has not been palatable for human and animal consumption. Movement of animals off-farm is not an option for private landowners such as those in Touws River valley.

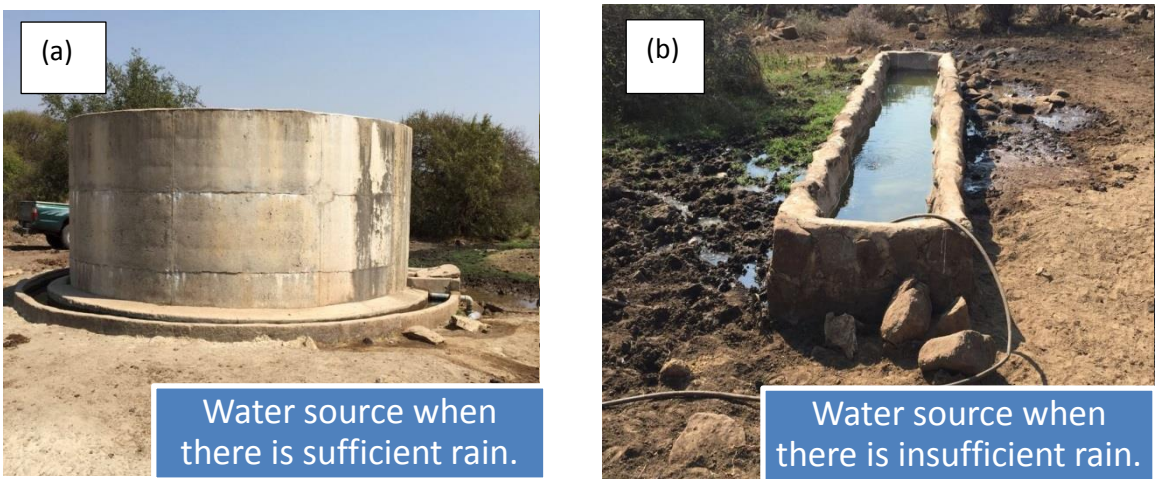

Figure 28: Water sources for the livestock (a) when there is sufficient rain in the community and (b) when there is insufficient rain in community of Makolowe. (Source: Author, 2019)

The options available to farmers also differ because of the resources they have at their disposal. For farmers in Touws River valley, they have possible options to opt for in order to support them such as (1) game farming, and (2) diversifying into crops. Because of these available and possible sectors, the livelihoods of commercial farmers may not be as vulnerable as those of communal farmers to climate variability. In Makolokwe, livestock is a part of the livelihoods of the communal farmers and is a support structure for most of them. Although they could go into farming crops, because of funding issues and the lack of necessary resources, most of the livestock farmers in the community do not venture into this sector.

As was indicated previously, there is an embodied relationship between environmental changes and livelihoods. Livestock form an important component of livelihood strategies, especially in communal areas. Commercial farmers in the Touws River valley have also historically relied on the ability to keep livestock. In both cases, livestock represent a considerable investment. Rust and Rust (2013) mentioned that precipitation does indeed affect net animal revenue. In a study conducted by Thomas *et al.* (2007), respondents focused on farming activities such as livestock farming, which are profitable during periods of unpredictable rains. When environmental changes such as rain impacts negatively on the environment it also causes adverse impacts for livelihoods as livestock may need more care or investment in order to survive. Commercial

farmers may diversify into other areas of production, but this is not easy for communal farmers who rely on their cattle. A study on the impacts on the impacts of climate change on livestock by Mandleni (2011) mentioned that adaptation and mitigation strategies are not enough to combat and avoid impacts of climate.

5.2.2 Stock reduction

With the decline in habitats due to climate change, as hard as it may be, a decision must sometimes be taken to and adapt to the changes which occur in ways that are difficult and costly. Stock reductions have occurred in both communities with very similar intentions. Take for example the following excerpts:

> *"I've got 20+ km of Touws River on my side. But in summer you find a lot of reeds and things in the river bed, but in winter there's nothing. So that means in summer I can carry a stock of 1000 cattle but in winter I can carry about 120. That means I have to fluctuate between that and make sure that my increases, calving season is more in the beginning of summer, so that I can make it before the winter. I sell those calves, the small ones. Or otherwise you must feed them, and if you feed them it's too expensive. There's no way you can feed them and survive economically, that is what I can say. We sell them off. We manage our stock levels." (Respondent 1- Touws River valley)*

> *"Sometimes we have to sell the cattle in order to support others or buy them food." (Respondent 3-Makolokwe)*

> *"We don't control climate, then it becomes difficult. We then have to decrease livestock." (Respondent 4 – Makolokwe)*

> *"Because of the drought, with turf soils, the effects are not that much as they have got grass, however areas that have red soil there, termites eat the grass to such an extent that there is nothing left for grazing. They take the grass underground. It therefore means that one must sell other cattle to maintain your size. This then forces you to maintain a manageable size of the livestock, because if you do not do that they are going to die of hunger, starvation. It does not help you to boast and say you have 100 cattle but come winter they all perish." (Respondent 6-Makolokwe)*

"I personally believe when the drought comes you have to make your herd smaller as quick as possible otherwise if you keep you totals the same you will reach a point where your fields are over grazed. Your grass will be eaten until it is level with the ground. What we do to protect our fields and grass is when the drought comes, we make the herd less and we try to, I personally try to, have some of my camps rest meaning the flock does not graze there. For example, if you decide for the next eight months you will let this specific camp rest and it's not grazed at all. Just to give the grass a chance to give seed and get larger otherwise if you have too much animals in the dry season then you'll over graze your fields. Your bush and grass will not get a chance to produce seedlings." (Respondent 2- Touws River valley)

According to Respondent 1 (Touws River valley) and Respondent 3 (Makolokwe) there is a difference in the carrying capacity in the different seasons. In winter, the carrying capacity is low, whereas in summer the carrying capacity is much higher (see Figure 29). The disparity of the carrying capacity between summer and winter is huge, which pushes farmers to be prepared and to always ensure that they come up with economically sound solutions.

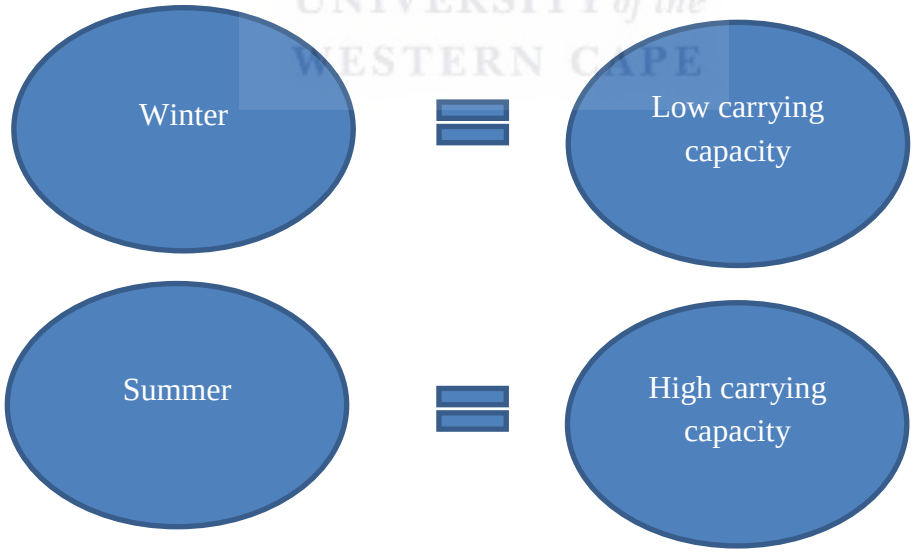

Figure 29: Carrying capacity of livestock in Maklokwe and Touws River valley in winter and summer. (Source: Author, 2019).

Reducing the herd size (as mentioned in the excerpts above) into a manageable size not only releases some of the pressure on the livestock owners and farmers but it can also be used to support livelihoods. This support can be in the form of selling livestock, or farm equipment to get food for the livestock or selling the animals to support the farmers' livelihood (Eakin, 2000). Therefore, the livelihood as well as the severity of the climatic changes plays a role in the choices that the farmers make with regards to the carrying capacity. Stock reduction as a coping strategy may also be beneficial for the grazing area. Respondent 4 indicated that during the drought season they let some of the camps rest for months in order to allow it to recover and to alleviate further land degradation.

Farmers in Makolokwe and Touws River valley have different views on how land degradation in their communities related to livestock grazing. In Makolokwe, farmers do not put emphasis on resting pasture of land in order to avoid degradation. This communal community has had to rotate and move about their livestock for grazing which has meant less degradation on pastures of land. However, Touws River valley as a commercial farming community relies on assuring that they constantly rotate their livestock as the area experiences degradation.

Although in communal areas a large herd of livestock is normally associated with wealth, farmers emphasize the importance of knowing when to increase and decrease livestock. As Respondent 6 said *"It does not help you to boast and say you have 100 cattle but come winter they all perish".* Therefore, it is important to be flexible and to use the best strategies to ensure sustainability of the grazing area and longevity of the livestock. Wealth alone should not be the driver of how to run a successful farming experience. Although farmers in Makolokwe and Touws River valley have different experiences in farming, they may want to be sustainable in their farming practices.

5.2.3 Hope and faith

The attitude of farmers was also of interest in this study. In addition to practical strategies such as subsidizing food and reducing carrying capacities of livestock, farmers talk about the importance of hope and faith. It is important to acknowledge that there are some coping methods which seem daunting to those that may not understand them. Together with hope and faith, plans are just as important because they assure that there is progress in a situation. Therefore, the better

the plan of action, the greater chance there is for the sustainability of resources. In an article by Saal (2018) titled "A farmer who loses hope is dead", a farmer said that he has come to terms with the new changes and is hopeful that the rain will return. This is similar to what respondent 4 in the above excerpt has also stated. Marotz-Baden and Colvin (1986) found that spiritual support and faith was an important strategy for rural farmers. Similarly, a study conducted by Light *et al.* (1990), found that 87% of farmers in the midwest state of America who took part in the study mentioned that faith and God was a coping strategy to problems and difficulties. Furthermore, 62% of farmers stated that they participated in church activities and 70% of farmers reported that they attended church services (Light *et al.*, 1990). Therefore, although farmers have practical adaptive strategies, faith and plans (not schemes) according to respondent 4 work hand in hand.

Believing and having faith and hope requires patience and a long-term approach. Most of the farmers in the current study outlined numerous ways in which they cope with the winter and summer months and what they do to sustain their livestock (and in other instances game), but respondent 4 emphasized the importance of an attitude of hope and faith in the future.

> *"Nee (no), [laugh], faith. You know you can't do nothing without faith. It's difficult, but we try to stay on our feet every day. Doesn't matter what challenges you get, you must just face it and move forward. Some days you don't even wanna get out of bed in the morning, cos what you gonna do? But then the next day something nice happens or positive and then you get some energy to go forward again. So, your plans must never dry up. You must always have a new plan, but not schemes, PLANS." (Respondent 4- Touws River)*

5.3 Relationship between local and scientific knowledge

According to Calder and Ziervogel (2003) and Thomas *et al*. (2007), rural livelihoods have been affected by climate variability. Bryan *et al.* (2009) further pointed out that perceptions and education build on the individual's awareness of the various adaptation strategies available. Therefore, the quality of the perception that farmers may have is of importance (Ayal and Filho, 2017). Furthermore, Roncoli (2006) explains that the knowledge that people have presently about climate directly relates to the perceptions that they have.

5.3.1 Rainfall variability and perceptions of communal and commercial farmers

Farmers in Touws River valley and Makolokwe have all indicated that climate has been changing in their environment and that their livelihoods have been affected. Farmers have used the knowledge that they have gathered over the years to facilitate future planning for their farming practices.

There is a strong relationship between the perceptions of the respondents and their experiences. Sustainability and protection of our environment are also important aspects which a respondent mentioned. Although environmental changes are occurring, it is still the land user's responsibility to ensure that the process of sustainability is maintained. "Sustainability has to start at the soil level" said Respondent 3 from Touws River valley.

Multiple oscillations are known to impact upon rainfall patterns in southern Africa, such as El Niño and the Southern Annular Mode (Ambrosino *et al.*, 2013). Most of the farmers in the study associate El Niño and drought with climate variability. The experiences that the farmers in Makolokwe and Touws River valley have had with regards to rainfall patterns has also built on the perceptions that they have about the significance of rainfall as well as the changes that have occurred as a result of the availability of water and lack of rainfall. Water is an important resource as well as a limiting factor as mentioned by some of the respondents, affecting livelihoods, livestock and natural vegetation.

Rainfall in Makolokwe and Touws River valley has been very variable in the past 20-30 years. When looking at the scientific data at first glance it might seem like the dry seasons which are shown in Figure 13 and Figure 15 are significant. In Makolokwe, the respondents mentioned that rainfall during the winter season (June, July, August) has decreased since the 1960s. What is important here is that the change is real as reflected in the data. Statistical significance tells us the likelihood of whether the change is as a result of random chance, or major shift such as climate change. In this case, it is not statistically significant because there is no long-term shift. A report by DEA (2016) showed that there was no statistically significant long-term trend in

rainfall in the North-West province. However, there has been a reduction in winter rainfall over the respondent's lifetime. So, despite not measuring rainfall, their perceptions are borne out by the data. Furthermore, Lunde and Lindtjorn (2013) said that an increase in annual rainfall resulted in an increase in cattle numbers, however with a decrease in rainfall it would be expected that there would be a decrease in cattle or livestock, but Figure 17 and Figure 18 show that farmers in Makolokwe were willing to increase livestock with a decrease in rainfall.

In Touws River valley, respondents indicated that water is a limiting factor in their environment. These farmers have also taken rainfall seriously which is reflected in their detailed record of rainfall and their consideration of how to respond to drought in such a way as to fully sustain their livestock and game. Farmers further mentioned the drought period (2015-2017) year which is also reflected in the rainfall data (Figure 15). Similarly, Richman and Leslie (2018) indicated that there was a severe drought period of 2015-2017. Temperatures from 2011-2015 were the warmest globally, which may have had an impact on precipitation in the different regions of South Africa. Furthermore, data from Richman and Leslie (2018) also showed that there has been a reduction in rainfall in South Africa as whole.

5.3.2 Environmental changes facilitate adaptation and coping strategies

The local knowledge of livestock owners and herders about the changing trends in their environment as well as the culture of the area they live also add up to the perceptions that they have about climate variability. At the same time, Turner (1999) adds that, the composition of farming practices in a particular area is not only a result of "ecological imperatives", but that the economic and social statuses of livestock owners also play a role. In Makolokwe in 2006 the number of livestock was considerably lower than today (See Figure 11and Figure 12); however, in 2016 there were increases in the number of livestock for both cattle and goats. Thus, although there were environmental constraints, farmers were still willing to increase the number of livestock.

Therefore, the environmental changes in the area of Makolokwe did not merely alone affect the composition of the livestock. Local knowledge, culture, and social status played a role in the farmers increasing their number of livestock throughout the years. Social status is also an

important element in any community as there is a great association with livestock and wealth. Thus, livestock farming is seen as a good investment by the farmers.

At the same time, individual farmers in both contexts have adapted to changing environmental conditions by decreasing their number of livestock in order to keep the size manageable. Adaptive responses such as intent, role of government, scale, timing, duration, form, and effect are imperative for prevention and mitigation purposes to climatic disturbances (Smithers and Smit, 1997). Subsidising as an adaptation method seems to have been taken on board by all farmers due to the environmental changes that have been occurring. In describing this, the word 'support' may be better than 'subsidize' as it is a word that broadens thinking about methods of subsidising. The winter months as mentioned by the respondents posed significant challenges. Financially and emotionally, subsidising or support has taken a toll on the farmers in both Makolokwe and Touws River valley. It was interesting to see how a change in climate could cause farmers in Makolokwe to feed the livestock chicken manure knowing that it might be dangerous. Mapfumo *et al.* (2013) said that communities often struggle to respond appropriately to climate change impacts because of lack of resources, information, and new technologies. Thus, with the correct and sufficient support farmers could potentially avoid dangerous methods which affect their livelihoods.

In the Touws River valley, farmers have had to change their livelihoods and adapt their lifestyle, with some even moving away from livestock to vegetables or game. They also actively support their livestock (and game) animals during dry seasons. There was a sense that expert or scientific knowledge could be helpful. As one of the respondents in the Touws River valley stated "I think that is one of the biggest concerns that we've got, but what do we do? We can manage it if you help me manage it. I will appreciate it. "(Respondent 1- Touws River valley). This suggests that (1) they may be struggling tremendously and need extra help which could help them cope with the changes, and (2) that although they have some support it is not enough.

Not only are farmers using practical adaptation methods, but farmers also lean on their hope and faith as a way to cope with challenges in the farming process. Although the interviewed farmers did not focus intensely on this topic, it was clear that they did lean on their hope and faith to cope with the environmental changes. Literature does not cover this extensively as an adaptation

method, however reports by Saal (2018) and Etheridge (2018) focused on how hope helped farmers through the trying times.

5.4 Summary

The adaptation strategies adopted by farmers in the two areas were similar in some ways, with differences as well because they are located in different environments and have different options available to them. Commercial farmers had more options than communal farmers, although not necessarily better knowledge of climate variability science. Both communities subsidised with alternative food such as Lucerne in the dry winter months. Natural feeds such as reeds were common in Touws River valley, whereas in Makolokwe drastic and potentially dangerous measures were used to support the livestock. Farmers also opted to reduce their livestock in winter. This strategy allowed for farmers to sustain their grazing areas. A significant finding is that although there was insufficient rain, some respondents in Makolokwe did not reduce their livestock but rather kept increasing it as this is their livelihood. There is an embodied relationship between the local and scientific knowledge as their ideas are imbedded.

CHAPTER 6: CONCLUSION AND RECOMMENDATIONS

6.1 Summary of Findings

Across southern Africa, water is a limiting factor in the farming industry (DEA, 2011). Without sufficient water during the growing season, plant growth is affected (Wang et al., 2013), and as net primary production of vegetation is closely related to precipitation (Chamaille-Jammes *et al.*, 2006) water scarcity can have a major impact on rural livelihoods associated with agriculture. According to Thomas *et al.* (2007), rainfall variability is common in South Africa, and these changes in rainfall patterns impact socio-economics and the agricultural sector. Hendricks and Witbooi (2016) described 2015 as the worst drought year that South Africa has ever experienced, while farmers also indicated that they had been experiencing insufficient rainfall and high temperatures.

Livelihoods are affected by the variability of rainfall, with wet years leaving farmers less vulnerable and dry years leaving farmers more vulnerable. Calder and Ziervogel (2003) suggest that climate variability has affected rural livelihoods, and as a result of these shocks and stresses households have become vulnerable. Farmers in Touws River valley and Makolokwe used subsidising and stock reduction as the main adaptation and coping strategy. Both farmers could support their livestock during dry periods using Lucerne. However, there were some differences in natural resource availability as cattle in the Touws River valley often grazed reeds, while communal farmers rotated in their region to find new grazing areas. Because of their socio-economic status, dangerous methods were sometimes used to support the animals in Makolokwe. Communal farmers have to rotate livestock grazing land due to communal land tenure, while this option is not available to commercial farmers on private land.

Farmers in both regions indicated that insufficient rainfall and less suitable grazing affected their livelihoods. Furthermore, Turmer (1999) showed that livestock plays an important role in finances, social status, commodities and units of production. Figure 30 below provides a summary of the different aspects that were affected by environmental changes in Makolokwe and Touws River valley, and how these changes cascade through the farming community in

terms of impact on farming and adaptation strategies. These environmental changes affect precipitation, grazing potential, livelihoods and the adaptation strategies selected to ensure survival.

As adaptations may differ from place to place over time, the strategies utilised by one community may not necessarily be effective and relevant to the next (Elum *et al.*, 2017). Touws River valley and Makolokwe are testament to this theory. The carrying capacity of livestock in both communities differed in summer and in winter. Furthermore, the support that farmers gave to livestock was also different in summer and winter. Thus, the adaptive ability to climate variances may be closely linked to the capabilities to cope with stress placed on livelihoods (Thomas *et al.*, 2007). Consequently, Rust and Rust (2013) mentioned that precipitation affects net animal revenue, with linear revenue in large farms and a decrease in revenue for small farms. What is significant in the study is that there are human-environmental relations which are intertwined in the different farming activities. Therefore, adaptive responses which often stem from the perceptions that people have can prevent further climatic disturbances (Smithers and Smit, 1997).

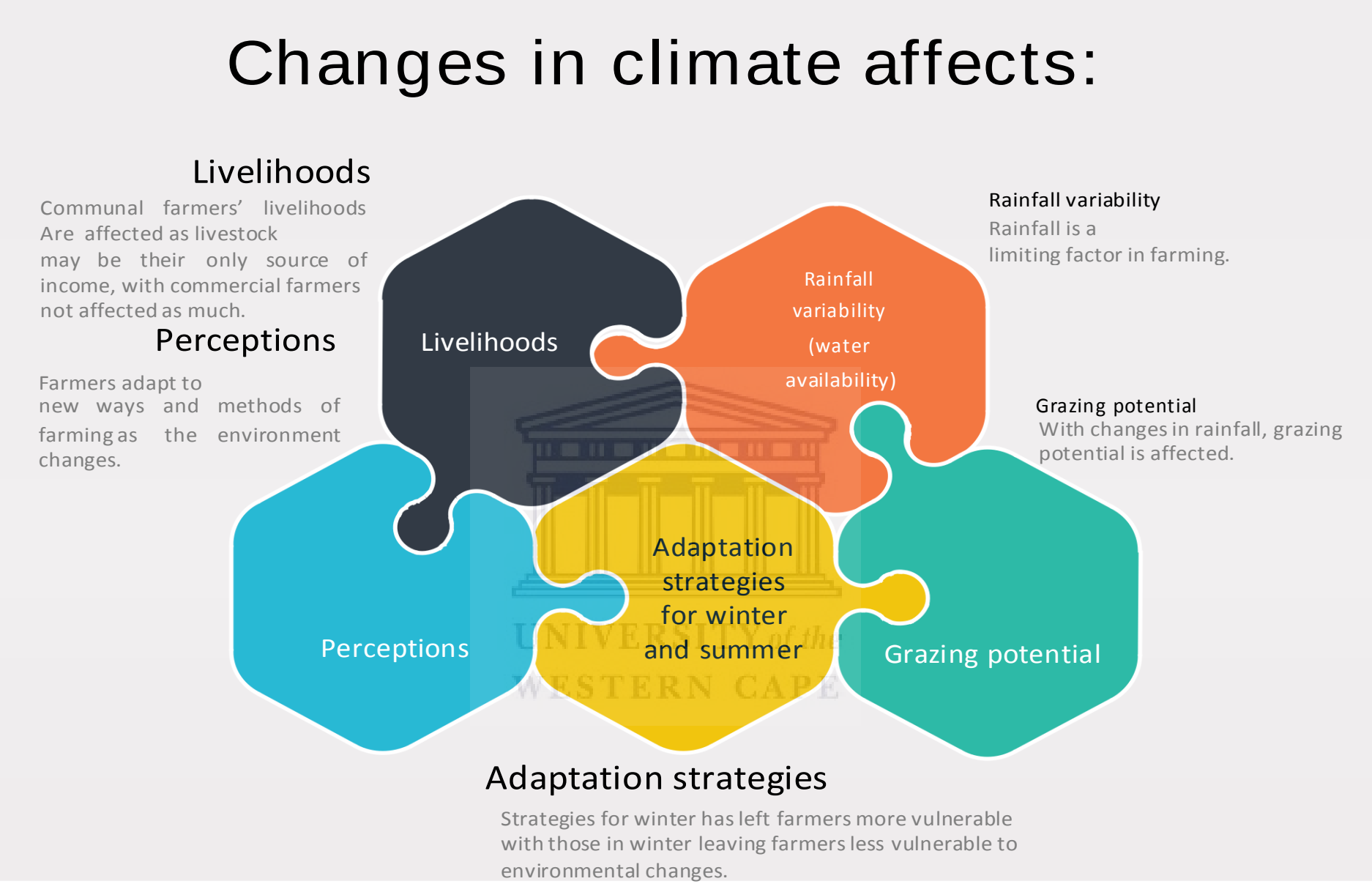

Figure 30: Different aspects that were affected by environmental changes in Makolokwe and Touws River valley. (Source: Author, 2019)

6.2 Conclusion

The findings of the study contribute to discourse on applied geography on human management responses to environmental changes in South Africa. The findings show that there is an inherent and apparent human-environment relationship in the local and scientific knowledge. The local and scientific knowledge build on the understanding that people have about their environmental changes (Ayal and Filho, 2017). What was apparent in that study is the study is that socio-economic aspects played a role in how farmers understood and adapted to environmental changes. Generally, all farmers indicated that environmental changes were present and represented a challenge to their livelihoods. Rain was most commonly the cause for concern and was said to have been variable (Thomas *et al.*, 2007). Unfortunately, farming practices were greatly affected by insufficient rainfall as it had an impact on vegetation productivity and therefore the carrying capacity of livestock in communal and commercial farms.

Despite the differences in resource availability, communal farmers in Makolokwe were as well (or potentially even more) aware of variations in rainfall patterns than the commercial farmers. The study showed that they have an intuitive, long term understanding of the land they farm. In contrast, the commercial farmers were more likely to collect their own rainfall data but did not necessarily reflect on it in terms of change.

Farmers from both regions indicated that in the winter months there was a requirement for more external feed, which consequently meant more costs in terms of keeping the livestock. However, in the summer months there is more natural grazing, with less support required for the livestock. Where the carrying capacity is concerned, in the winter months respondents indicated that there is low carrying capacity, whereas in the summer months, there is high carrying capacity for livestock.

Interestingly, culture and lack of opportunities play a major role in determining stock patterns in communal area and is potentially tempered by socio-economic circumstances. Due to high unemployment rates at the time of the study, people may be increasingly dependent of traditional livelihood strategies such as communal farming. As a result, despite limited grazing land, people within Makolokwe elected to increase their livestock numbers. In this case, culture was even more important than environmental factors in terms of decision making. This potentially

increases the vulnerability of communal farmers to climatic variability and climate change as they cannot respond logically by reducing stock when environmental conditions are not favourable. Furthermore, the vulnerability of communal farmers is further exacerbated by the use and access to common lands. The success of individuals is ultimately determined by the actions of the group because grazing land is shared.

When considering both commercial and communal farmers, it becomes clear that vulnerability to climatic variability is affected by land tenure and resource availability (Figure 31). While communal farmers may be negatively affected by increases in livestock numbers, they are able to move their livestock to new areas when grazing is depleted. In contrast, commercial farmers cannot do this because of private land ownership. On the other hand, communal land is open to abuse, and it can be difficult for a farmer to decide to increase their herd or to improve the land (e.g. by putting in a borehole or growing pasture) (Figure 31).

There are different adaptation strategies and while both farming communities may supplement feed at cost, access to capital gave commercial farmers more options. Commercial famers could respond more quickly to adversity by diversifying into other farming sectors such as crops and could also invest in game farming. Other strategies for commercial farmers included using borehole water to feed animals or to irrigate land to grow their own Lucerne. Some farmers in the Karoo used solar power and reverse osmosis systems to desalinate non-potable borehole.

Although communal and commercial farmers in this study are located in different environments, there is a significant relationship between their perceptions about their environment, the experiences they have had in the past, livelihoods, and how they respond to the environmental changes.

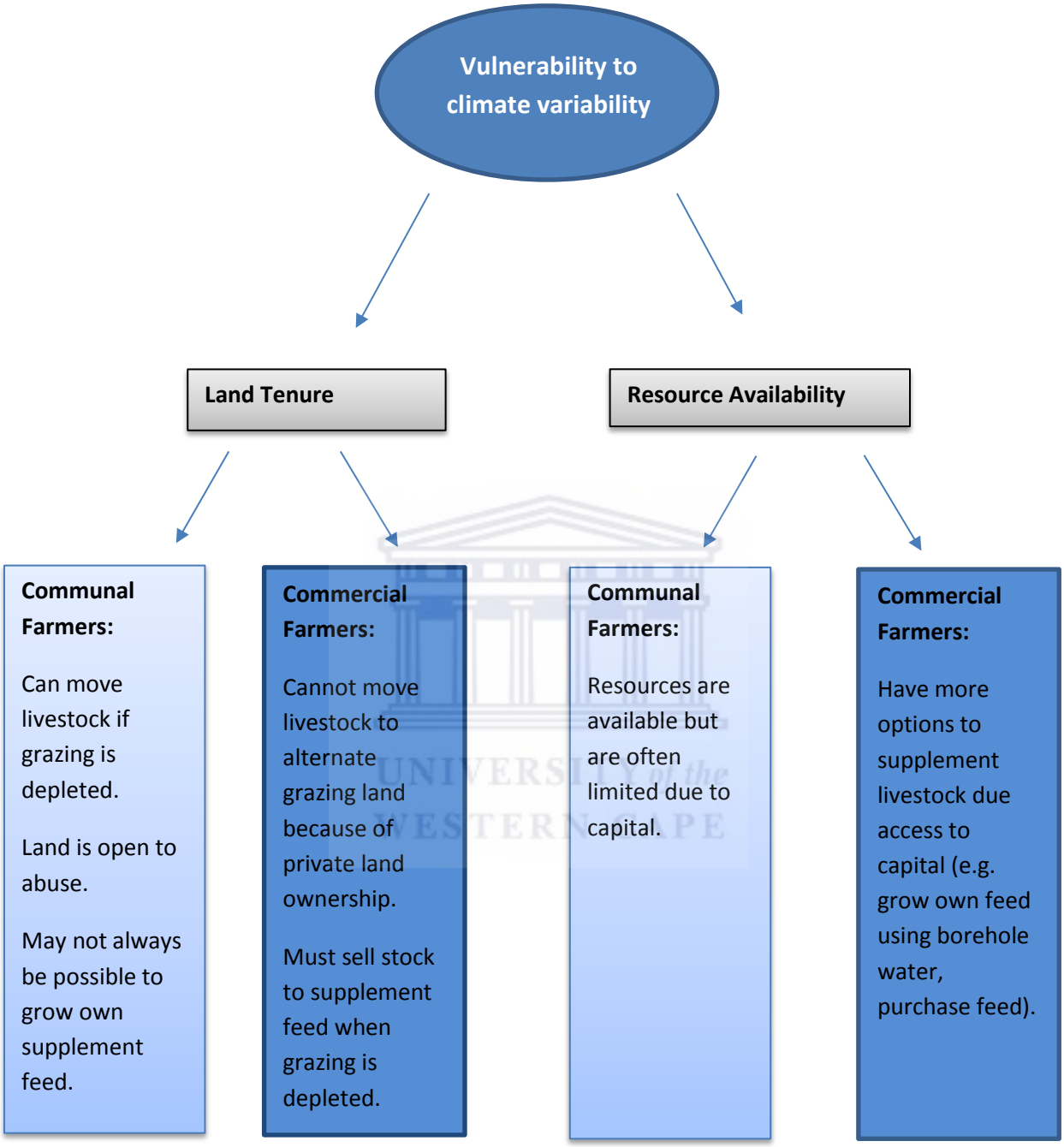

Figure 31: Schematic diagram of differences in farmer's vulnerability to climatic variability as affected by land tenure and resource availability. (Source; Author, 2019)

6.3 Recommendations

For further research purposes and to further understand the human-nature relationship, I would recommend that:

Cultural norms and how these impacts on perceptions and responses to climatic variability in other parts of South Africa could be investigated. A further look at how the age, gender, and culture of farmers in different parts of South Africa on how they understand climate variability and climate change and how it has affected them.Other biomes in South Africa could be looked at to see how coping and adaptation strategies vary. Certain parts of South Africa are likely to have better grazing opportunities; therefore, it would be interesting to see what constraints these farmers in such communities may face and how they adjust adaptation strategies. Most of the farmers in this study mentioned drought as one of the factors that affected farming practices and their livelihoods. Other impacts if droughts in other regions of South Africa could be used to see how farmers adaptations strategies change depending on the severity of the drought.

6.4 References

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Appendix A: Semi- structured questions for farmers

Please answer the questions below:

1. **Age:**

20-30☐ 30-40☐ 40-50☐ 50-60☐

60 and above ☐

2. **Gender:**

Male ☐ Female ☐

3. **How long have you stayed in the area?**

4.

Type of livestock?		**Number of livestock you have?**	**Number of livestock you have had for the past 10 years?**
Cattle			
Sheep			
Goats			
Other			

5. **How often do you take the livestock to the field for feeding purposes?**

6. **What is the main water source for the livestock?**

7. **What do you understand by the term climate variability?**

8. **How do you think the environment has been changing in the past years?**

9. **Do you think that there has been an increase or decrease in the amount of grasslands around the area?**

10. **What are the challenges that you face on a daily basis with the livestock, especially in the field?**

_____

_____

_____

_____

11. **How do you cope with climate variability?**

_____

_____

_____

_____

12. Are your coping strategies for summer and winter different?

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Appendix B: Questionnaire for farmers

Please select the correct box below:

	YES	NO	I DON'T KNOW	MAYBE
There has been little rain in the area.				
The streams and canals are drying up.				
There is less vegetation compared to the past.				
There are high numbers of livestock dying due to starvation.				
Humans are responsible for the vegetation changes occurring in the area.				
There has been increasing temperatures throughout the past years.				
Livestock could be influenced by the climate variability induced diseases.				
An increase in temperatures could have an influence on the lives of livestock.				

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Appendix C: Consent form

Consent Form

Please initial box

Project: Climate variability: Human management response to environmental changes in Makolokwe and Touws River

Researcher: Semakaleng Llale

Supervisor: Dr Suzanne Grenfell

1. I confirm that I have read and that I understand the information sheet explaining the above research project and confirm that I have had the opportunity to ask questions about the project. ☐
2. I understand that my participation is voluntary and that I am free to withdraw at any time without giving any reason or negative consequences for me. In addition, should I not wish to answer any particular question or questions, I am free to decline. ☐
3. I understand that the information given will be protected, e.g. by using pseudonyms for all the individuals interviewed and those mentioned in such interview. ☐
4. I hereby give permission for an audio-recording of the interview. ☐
5. I agree for the data collected from me to be used in this project and publications. ☐
6. I agree to take part in the above research project. ☐

I…… (full names of participant) hereby confirm that I understand the contents of this document and the nature of the research project, and I consent to participating in the research project.

_____ _____

Participant (Signature) Date

_____ _____

Researcher (Signature) Date

Copies: Each participant will receive a copy of the signed and dated version of the consent form and information sheet. A copy of these forms will be filled and kept in a secure location for research purposes only.

Appendix D: Information Sheet

Information Sheet

Project: Climate variability: Human management response to environmental changes in Makolokwe and Touws River

Researcher: Semakaleng Llale

Supervisor: Dr Suzanne Grenfell

The research mainly focuses on management as well as the adaptation strategies by different communities. What I seek to do is to understand and explore how human management responds to climatic changes which have been occurring in the community. You have been selected to participate in this research because you are a part of the community. Participation is voluntary and you are entitled to withdraw your information at any time if you do decide to take part in the research. Your name will not be used in the project without your consent. You will not receive any payment for participating in the project.

If you seek further information, do not hesitate to contact me or my supervisor.

Researcher: Semakaleng Llale
Email: 3275768@myuwc.ac.za

Supervisor: Dr Suzanne Grenfell
Email: sgrenfell@uwc.ac.za