Food security and climate change: The role of subsistence agriculture in Genadendal, Western Cape of South Africa

by

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Thesis presented in partial fulfilment of the requirements for the degree of Master of Science in Sustainable Agriculture in the Faculty of AgriSciences at Stellenbosch University

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December 2018

Declaration

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Abstract

Food security consists of four dimensions namely, availability, access, utilisation and stability as defined by the FAO. Subsistence agriculture has the potential to supplement household food security. It can increase the amount and diversity of food that is available for consumption (i.e. food availability and utilisation). Income generated through the sale of produce can be used to access additional food (i.e. food access). Stability in production can ensure that household food security remains stable (i.e. food stability). However, subsistence farmers are particularly vulnerable to climate-related hazards such as droughts, floods and extreme temperatures. With appropriate adaptation responses, households who practice subsistence agriculture can be supported in dealing with climate-related hazards. The extensive history of Genadendal in the Overberg District Municipality, Western Cape, South Africa shows that food insecurity was a common occurrence in the past, despite efforts made to develop subsistence agriculture. The Overberg District Municipality is currently vulnerable to food insecurity in the face of climate change due to impacts on crops and livestock. Households of Genadendal have low levels of income, a high dependency ratio and low levels of formal education which can exacerbate their food insecurity. The present study aimed to investigate the role of subsistence agriculture in achieving food security in a changing climate in Genadendal by analysing (1) changes in the historical climate using meteorological data and perceptions of subsistence farmers; (2) the impact of climate-related hazards on the dimensions of food security of subsistence farmers; and (3) adaptation responses used by subsistence farmers to overcome the impacts of climate-related hazards. A combination of quantitative and qualitative methods was used, although qualitative methods formed the bulk of the study. Three meteorological datasets were analysed quantitatively to determine changes in Genadendal's rainfall from 1960 and minimum and maximum temperature from 1993. Qualitative data were obtained from semi-structured interviews with twenty-three subsistence farmers. Questions relating to their perceptions of climate change, impacts of climate-related hazards on their food security and the use of adaptation responses were asked during the interviews. (1) According to the meteorological datasets, rainfall was highly unpredictable and varied from year to year. Increases and decreases in rainfall occurred in cycles of approximately four years at a time. Seasonal shifts in rainfall occurred with a decrease in autumn rainfall and an increase in winter and spring rainfall. Rainfall in early summer decreased but increased toward the end of summer. Maximum temperature increased but changes in minimum temperature were uncertain. Subsistence farmers perceived it to rain less often but more intensely. They perceived the start and end of the rainfall season as inconsistent and that the rainfall season became shorter. It was perceived that summers had gotten warmer and winters colder and that the length and intensity of heatwaves had increased. (2) Results show that food availability was not a concern because respondents either produced their own food and stored their produce for household use and/or had alternative sources of food. Accessing alternative sources of food was found to be somewhat challenging for some respondents due to transport challenges and the cost of purchasing food. Food utilisation and stability was found to be mostly unaffected by the impacts of climate-related hazards. (3) Subsistence farmers experienced at least some production losses due to the impacts of climate-related hazards despite implementing adaptation responses. However, none of the subsistence farmers experienced overall production losses. This is an indication that the adaptation responses support subsistence farmers in coping with the impact of climate-related hazards to some degree. However, subsistence farmers in Genadendal could not completely rely on subsistence agriculture to render them food secure. Subsistence agriculture rather played a supplementary role in achieving food security in Genadendal.

Keywords: food security, subsistence agriculture, climate change, adaptation, Western Cape, Genadendal

Opsomming

Voedselsekuriteit bestaan uit vier dimensies, naamlik beskikbaarheid, toegang, benutting en stabiliteit, soos beskryf deur die FAO. Bestaansboerdery besit die potensiaal om voedselsekuriteit aan te vul. Dit kan die hoeveelheid en diversiteit van voedsel in ‘n huishouding verhoog. Inkomste wat genereer word deur die verkoop van produksie kan gebruik word om addisionele voedsel te koop. Stabiele produksie kan die voedselsekuriteit van ‘n huishouding verseker. Bestaansboere is egter veral kwesbaar vir klimaatsverwante bedreigings soos droogte en vloede. Toepaslike aanpassings kan bestaansboere ondersteun om klimaatsverwante bedreigings te hanteer. Die geskiedenis van Genadendal in die Overberg Distrik Munisipaliteit, Wes-Kaap, Suid Afrika wys dat voedselonsekerheid algemeen was, ten spyte van pogings om bestaansboerdery te ontwikkel. Die Overberg Distrik Munisipaliteit is tans kwesbaar vir voedselonsekerheid in die konteks van klimaatsverandering. Baie huishoudings in Genadendal het lae vlakke van inkomste en formele opvoeding en hoë afhanklikheidsverhoudings wat hul voedselonsekerheid kan vererger. Die huidige studie se doel was om die rol van bestaansboerdery in die behoud van voedselsekuriteit binne die konteks van ‘n veranderende klimaat te ondersoek deur (1) veranderinge in die historiese klimaat te analiseer deur die gebruik van meteorologiese data en persepsies van bestaansboere; (2) die impak van klimaatsverwante bedreigings op die dimensies van voedselsekuriteit; en (3) aanpassings wat deur bestaansboere gemaak was ten opsigte van klimaatsverandering. ‘n Kombinasie van kwalitatiewe en kwantitatiewe metodes was gebruik. Drie meteorologiese datastelle was geanaliseer om veranderinge in Genadendal se reënval vanaf 1960 en temperatuur vanaf 1993 te bepaal. Onderhoude was gedoen met drie-en-twintig bestaansboere om inligting oor hul persepsies van klimaatverandering, die impakte daarvan en hul aanpassings uit te vind. (1) Volgens die meteorologiese datastelle was die reënval hoogs onvoorspelbaar en gevarieerd van jaar tot jaar. Toename en afname in reënval gebeur in siklusse van vier jaar op ‘n slag. Seisoenale verskuiwings in reënval het gebeur met afname in herfs reënval en toename in winter en lente reënval. Reënval in vroeë somer het afgeneem, maar verhoog teenoor die einde van die somer. Maksimum temperature het verhoog, maar veranderinge in minimum temperature was onseker. Bestaansboere het waargeneem dat dit minder gereeld reën, maar harder reën. Hul het waargeneem dat die begin en einde van die reënseisoen onvoorspelbaar geraak het, maar dat die reënseisoen wel verkort het.. Dit was ook waargeneem dat somers warmer en winters kouer geword het en dat die lengte en intensiteit van hittegolwe verhoog het. (2) Resultate wys dat voedsel beskikbaarheid nie ‘n bekommernis was nie, omdat respondente óf hul eie voedsel geproduseer het, óf voedsel by alternatiewe bronne gekry het. Toegang tot alternatiewe bronne van voedsel was soms uitdagend vir sommige respondente as gevolg van vervoer uitdagings en koste van die aankoop van voedsel. Voedsel benutting en stabiliteit was meestal onaangeraak deur klimaatsverwante bedreigings. (3) Bestaansboere het wel in sommige aspekte ‘n afname in produksie ervaar as gevolg van klimaatsverwante bedreigings, ten spyte van aanpassings wat geïmplementeer was. Nie een van die bestaansboere het egter ‘n algehele afname in produksie ervaar nie. Dit is ‘n aanduiding dat die aanpassings wat deur bestaansboere gemaak was hulle tot 'n sekere mate ondersteun het. Bestaansboere in Genadendal kon egter nie heeltemal staatmaak op bestaansboerdery vir voedselsekuriteit nie. Bestaansboerdery in Genadendal het eerder ‘n aanvullende rol in die bereik van voedselsekuriteit gespeel.

Sleutelwoorde: voedselsekuriteit, bestaansboerdery, klimaatverandering, aanpassings, Wes-Kaap, Genadendal

Acknowledgements

I would firstly like to thank my supervisor, Rhoda Malgas for taking this journey with me. I would like to thank her for all her exciting ideas, support, motivation and wisdom. She is an encouraging supervisor who brings out the best in her students. I would then like to thank Dave Ogier for his consistent help throughout this thesis. Without him the climate analysis would not even have been possible. His help and advice has been greatly appreciated.

Next, I would like to say thank you to my colleagues at Aurecon. I would like to thank Daniël Brink and Johan Minnie for understanding why I needed to take so many leave days. Without their understanding I would still be writing my thesis. I would also like to thank Daniël Brink for his inputs and advice. Thanks to Riano Mabie for also writing a thesis and so being able to share the frustrations and successes with me. I need to thank Caron Booysen, Jill Jansen and Michelle Leaner for their motivational talks and emotional support that kept me going. I would also like to thank my classmates for the two years that I got to share with them. They are an innovative group who I really enjoyed being around.

A big thank you needs to be given to Harry van der Berg, not only for his patience, continuous support and encouragement but for translating my work into Afrikaans. I would especially like to thank him for his support during my last few weeks of writing. Without him by my side it would have been a lot more challenging. I would also like to thank my Cape Town family for giving me a quiet and supporting environment in which I could work. I also need to thank Steve Rubell. I am grateful that I had him to kick me through my thesis.

I have saved the most important thank you for last. Thank you to my dad, mom and brother for being my pillars of strength not only while writing my thesis but always. My brother said to me one evening when I was feeling overwhelmed, ‘as long as a bird has wind beneath its wings it can glide.’ They are that wind and without them I would not have gotten this far. Their support and encouragement carried me through right to the end. I also need to thank my mom and dad for my passion in agriculture. If they had chosen different professions I might not have embarked on this journey.

Preface

The present study explores the role of subsistence agriculture in achieving food security in a changing climate in Genadendal in the Overberg District Municipality, Western Cape of South Africa. It is presented as a compilation of six chapters. Chapters 4 and 5 are introduced separately and will be submitted for publication.

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List of Acronyms and Abbreviations

ARC	African Rainfall Climatology Version 2 Satellite
CRU	Climate Research Unit
CSAG	Climate Systems Analysis Group
ETD	South African Theses and Dissertations Portal
FAO	Food and Agriculture Organisation
HDI	Human Development Index
IDP	Integrated Development Plan
IPCC	Intergovernmental Panel on Climate Change
LTAS	Long-Term Adaptation Scenarios
SAWS	South African Weather Service
SDG	Sustainable Development Goal
SUN Search	Stellenbosch University Online Library
WB	World Bank
WMO	World Meteorological Organisation

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Chapter 1 – Introduction

1.1. Introduction

The present study explores the role of subsistence agriculture for household food security in a changing climate in Genadendal, Overberg District Municipality, Western Cape of South Africa. The terms *food security*, *subsistence agriculture*, *climate change*, and *adaptation* are defined, and a brief overview is given in Chapter 1 for the baseline of the present study.

1.2. Food security and subsistence agriculture: an overview of definitions

Food security was initially defined at the World Food Summit in 1974. Food security was then defined as the availability of global basic food supplies to support the steady expansion of food consumption and to offset fluctuations in food production and food prices (Cowley and Gouws, 1996). In keeping with changing policy environments, food security was redefined on numerous occasions. In 1996, at the World Food Summit, food security was redefined as "when all people, at all times, have physical and economic access to sufficient safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life" (FAO, 1996). From this definition the Food and Agriculture Organisation (FAO) formulated four dimensions of food security which are food availability, access, utilisation and stability.

Food availability refers to the physical availability of food (Swaminathan and Bhavani, 2013). It is associated with supply and is determined by food production and net trade (FAO, 2008). Food availability is achieved when people have adequate food at their disposal (Gross *et al.*, 2000). It often depends on storage, transportation and market integration (Swaminathan and Bhavani, 2013). In the early 1970s, food security was considered to be a national food supply issue. A country was considered food secure if there were no shortfalls in national food supply (Sijm, 1997 in Martens, 2015). However, from the mid-1970s it became known that food availability does not necessarily translate into food access (FAO, 2008; Sen, 1982) making food availability on its own a poor indicator of food insecurity.

Food access is ensured when all households and all members within households have sufficient resources to obtain food by means of production, purchase or donation (Gross *et al.*, 2000). Food access depends on income, expenditure, prices and markets (FAO, 2008; Godfray *et al.*, 2016). Increased purchasing power may also increase the capability of households to purchase more nutritious and diverse foods (Dillon, McGee and Oseni, 2015). A household is therefore insecure if entitlement to the food that is needed is not established, as was first captured by Sen's entitlement theory (Sen, 1982).

Research has mostly focused on food availability and access (Burchi, Fanzo and Frison, 2011) as they were historically considered the major contributors of food security. However, food utilisation emerged as a third dimension after it was recognised that having access to available food was still not enough to achieve an active and healthy life. Food utilisation refers to the preparation and consumption of food in a manner that is safe and will ensure proper nutrition (FAO, 2008). It also involves the way the body makes use of nutrients in the food, diversity in the diet and food preparation (FAO, 2008). Intrahousehold distribution of food is also important in determining food utilisation (FAO, 2008). It may not be uniform across different household members (Dillon, McGee and Oseni, 2015). Food utilisation therefore determines the nutritional status of households and individuals (FAO, 2008).

Stability of the abovementioned dimensions over time is critical in achieving food security (FAO, 2008). The FAO states that households may be vulnerable to food insecurity when at least one of the dimensions are unstable (FAO, 2008). The stability of food security is impacted by factors such as poverty, lack of education, food price increases, unemployment, lack of tenure rights, poor market access, climate and environment (Scholes and Biggs, 2004).

The ability of households to achieve food security is affected by institutional, economic and social factors of vulnerability (Connolly-Boutin and Smit, 2016). For example, De Cock *et al.* (2013) found that education, age of household head, size of household, dependency ratio, income and locale are the most important contributing factors to food security in Limpopo, South Africa. Many households in sub-Saharan African regions are already constrained by the aforementioned vulnerability factors which affect the regions' capacity to cope with scarcity, poverty (Connolly-Boutin and Smit, 2016) and changing environments (Westerhoff and Smit, 2009). As a result, most households may be left severely food insecure (e.g. 53% of households in De Cock *et al.* (2013)).

Household food security can be supplemented if the household engages in subsistence agriculture (Mashamaite, 2014). Subsistence agriculture is defined as agricultural production for consumption and/or sale by households who have limited resources and small plots of land that are usually less than one hectare in size (Wenhold *et al.*, 2007). It has the potential to increase the amount of food that is available for use by the household through the production of food (Martens, 2015). Income generated through the sale of produce can also be used to access additional food (Tiwari and Joshi, 2012). Subsistence agriculture also has the potential to improve the nutritional status of households by increasing their diversity of food (Dillon, McGee and Oseni, 2015; Patterson *et al.*, 2017). If stability in the production of subsistence agriculture is achieved, the food security of households can be maintained (Bodin *et al.*, 2016).

However, literature states that subsistence farmers in developing countries are particularly vulnerable to climate change (Aase, Chaudhary and Vetaas, 2010; Maponya, 2012; Martens, 2015; Midgley and Methner, 2016; Muhire, 2012; Novas, 2015; Seaman *et al.*, 2014; Sieber *et al.*, 2015; Thorlakson and Neufeldt, 2012). This is often a result of climate-related hazards such as droughts and floods pushing them beyond their capacity to implement climate change adaptation responses (Maponya, 2012). As a result, their production is disturbed causing losses in yields and income (Brown and Funk, 2008). With production losses, the cost for subsistence land-users to maintain their basic consumption increases (Brown and Funk, 2008) as they have to purchase more food.

1.3. Climate change: Global context and South African perspective

Climate change is a prominent driver of food insecurity (Masipa, 2017; Tibesigwa *et al.*, 2015). Results from previous studies show that climate change affects food security directly and indirectly (Gregory *et al.*, 2005). Direct effects include changes in crop production and changes in growing seasons whereas indirect effects include changes in markets and food prices (Denton *et al.*, 2015; Gregory *et al.*, 2005). Climate change also places pressure on resources such as water that subsistence land-users depend on for food security (United Nations, 2015).

About 10% of climate projections for 2030-2049 predict that global crop yields will increase by 10%. However, 10% of climate projections also predict that they will decrease by 25% (IPCC, 2014). Therefore, there is a possibility that climate change will generate benefits or detriment to agriculture. If the latter is the case, the detrimental impacts are expected to largely outweigh the benefits. Climate projections for the period after 2050 predict that decreases in crop yields will become even more severe (IPCC, 2014). However, the effect on production is expected to be differentiated geographically. The Intergovernmental Panel on Climate Change (IPCC) projected that in sub-Saharan Africa there will be a 30-50% decrease in production if temperatures are to increase by 2°C.

Literature shows that the impacts of climate change are significant, and that South Africa is no exception (Masipa, 2017; Tibesigwa *et al.*, 2015). According to South Africa's Third National Communication under the United Nations Framework Convention on Climate Change (DEA, 2017), the top priority climatic drivers concerning agriculture in South Africa are decreasing precipitation, changes in the distribution of rainfall and increasing occurrence of heatwaves. Reduced rainfall is particularly a concern in the KwaZulu-Natal, Mpumalanga and Western Cape Provinces (DEA, 2017). The Western Cape Province which experiences winter rainfall, has been plagued by a severe 3-year winter rainfall drought (Conradie, 2018). These climate drivers cause a reduction in yields, impacts crop production and increases demand for water resources. Increasing temperature is expected to increase irrigation demands and also have a direct effect on labour and livestock through heat stress (DEA, 2017).

Due to the severe drought in 2014 and 2015 only 13.8% of all households in South Africa were classified as agricultural households in 2016 compared to 19.9% in 2011 (Statistics South Africa, 2017). These severe drought conditions also impacted the economy of South Africa mainly due to the decrease in the production of field crops (maize, sunflower and sugar cane) and horticulture (citrus subtropical fruit). The decrease in agricultural production in 2015 was the largest annual decrease since 1995 (Statistics South Africa, 2015) and had a knock-on effect on other industries in 2016 such as transportation due to less demand for transportation of freight (Statistics South Africa, 2016b).

The drought forced South Africa to import maize which caused food prices to rise. Households who depend on grain-based products were most affected (Statistics South Africa, 2016a). By 2017, the agriculture sector bounced back from the severe drought with a bumper maize harvest and a rise in animal products which strengthened the economy once again (Statistics South Africa, 2018). The Western Cape had good rains in 2018 although it was still drier than usual (Conradie, 2018).

Current stresses to South Africa's agriculture sector in the context of climate change are land use change, land degradation, water stress and invasive alien plants (DEA, 2017). These are dilemmas not only experienced by South Africa but globally. In recent decades, portions of productive agricultural land around the world have been lost to the consequences of climate change such as rural-urban migration, spread of alien invasive species and land degradation. Land use change such as expanding urban areas and land degradation increases competition for land with soil in good condition that can be cultivated. Changes in climate alters the conditions needed for certain plants to grow which could result in the spread of alien invasive plants. In addition, the aforementioned impacts on agriculture will be intensified by water stresses (DEA, 2017).

Furthermore, the aforementioned factors (i.e. land use change, land degradation, water stress and invasive alien plants) worsen each other. For example, water stress in an area is worsened by alien invasive plants that use more water than indigenous plants. As a result of these multiple and confounding stresses, a decrease in world food production is expected to occur this century if appropriate climate change adaptation responses are not implemented (Bryan *et al.*, 2009; Teng and Wolf, 2017; United Nations Environment Programme, 2009).

1.4. Climate change adaptation: South African context

Climate change adaptation refers to the adjustments made in structures, processes and practices in response to climatic drivers and impacts to moderate damages and/or to benefit from arising opportunities (UNFCCC, 2014). Climate change adaptation is critical to protecting the livelihoods of households who practice subsistence agriculture (Bryan *et al.*, 2009).

Literature shows that climate change adaptation responses vary in different locations due to differing agro-ecological zones and climate variability (Maponya, 2012). Climate change adaptation responses have been studied widely across South Africa (e.g. Calzadilla *et al.*, 2014; Senyolo *et al.*, 2018; Tibesigwa, Visser and Turpie, 2014). Studies have been conducted in the Limpopo (e.g. Bryan *et al.*, 2009; Maponya, 2012), North West (e.g. van der Merwe, Cloete and van der Hoeven, 2016), Mpumalanga (e.g. Tibesigwa *et al.*, 2016), Eastern Cape (e.g. Dassanayake *et al.*, 2018), Kwa-Zulu Natal (e.g. Wilk, Andersson and Warburton, 2013) and Northern Cape (e.g. Archer *et al.*, 2008) Provinces. Some examples of the climate adaptation responses used by subsistence farmers in each province are tabulated in Table 1.

Table 1: Brief overview of some examples of adaptation responses according to Province in South Arica

Province	**Adaptation responses**	**Author(s)**
Limpopo Province	Changing crop types and varieties used, planting trees, changing planting dates, irrigating and conserving soil	Bryan *et al.* (2009)
	Improving irrigation	Maponya (2012)
North West Province	Make use of indigenous and traditional food crops	van der Merwe, Cloete and van der Hoeven (2016)
Mpumalanga Province	Best not to specialise in a type of farming (e.g. crop or livestock farming) but rather to engage in mixed farming systems	Tibesigwa *et al.* (2016)
Eastern Cape Province	Increased off-farm activities like small business	Dassanayake *et al.* (2018)
KwaZulu-Natal Province	Transfer of knowledge, government directives and local adapted financial programmes	Wilk, Andersson and Warburton (2013)
Northern Cape Province	Earlier ground preparation, deeper ploughing, ploughing numerous times, changes in harvest times, bush strips in lands to prevent wind erosion, wind breaks, conserving water, reducing livestock numbers, moved livestock to fields with higher carrying capacities, supplemental feed given to livestock, livestock were taken to water sources or extra water was given to them in the field	Archer *et al.* (2008)

The Department of Environmental Affairs suggested that the actions needed by South Africa's agriculture sector to cope with the top priority climatic drivers are, climate smart agriculture, conservation agriculture, appropriate water management as well as monitoring and early warning systems (DEA, 2017). Investments are required to enhance future food security (Hanjra and Qureshi, 2010). These investments include water conservation, land preservation and adopting climate resilient crop varieties (Hanjra and Qureshi, 2010). Agricultural households should be provided with farmer support and extension services (Warman, 2003; Department of Environmental Affairs, 2013) because with adequate support services they can significantly improve their agricultural production and productivity (Mashamaite, 2014).

Further climate change support for subsistence agriculture includes developing infrastructure for irrigation and improving water management which will render farms more drought resistant (Department of Environmental Affairs, 2013; Hanjra and Qureshi, 2010). Developing and improving road infrastructure will improve market access which will facilitate income generation from agricultural production (Department of Environmental Affairs, 2013).

1.5. Climate change and food security nexus: South African context

The link between climate change and food security has been widely researched (Gregory *et al.*, 2005) and initiatives that do not recognise the interrelationships are bound to be ineffective (Connolly-Boutin and Smit, 2016; Tibesigwa *et al.*, 2015). Thus, South Africa has developed numerous plans, projects and policies which attempt to address the impacts of climate change on agriculture. These include the National Climate Change Response White Paper (Department of Environment and Narutal Resources, 2010) and the Long-Term Adaptation Scenarios (Department of Environmental Affairs, 2013).

1.6. Climate change and food security nexus: Western Cape

The Western Cape has gone further and developed a SmartAgri Plan which explicitly acknowledges the link between climate change and food security (Western Cape Department of Agriculture, 2016). However, to date subsistence farmers within the Western Cape have not been the focus of climate change studies but rather commercial farmers have been the focus. The present study focuses on subsistence agriculture in an area in the Western Cape. The results of the present study also provide improved knowledge on climate-related impacts and adaptation responses that exist within the Western Cape. The results can assist policy-makers in better decision-making with regards to subsistence farmers in the Western Cape.

1.7. Understanding climate change

The frequency of climate-related hazards such as floods, heatwaves and droughts are increasing (EU Science Hub, 2016; Midgley and Methner, 2016 and Thomas and López, 2015). Evidence linking the occurrence of climate-related hazards to climate change has been well documented in literature (Thomas, Albert and Perez, 2013 and Thomas and López, 2015). Climate-related hazards are the most tangible manifestation of climate change and drawing attention to them could improve action against climate change (Thomas and López, 2015).

Thus, to make the term *climate change* more understandable, relatable and tangible the present study makes use of the term *climate-related hazards* (e.g. Thomas and López, 2015). In the present study climate-related hazards refers to droughts, floods, heatwaves, intense storms, hail, strong winds, frost or any other events that are related to the climate. More specifically, the present study refers to the impacts of the climate-related hazards.

The concept of climate change may be interpreted differently by different people, depending on their contexts, networks and place (Hulme, 2009). It was anticipated that subsistence farmers in the study area would be more familiar with the impacts of the aforementioned climate-related hazards on their produce than they would be with the term *climate change*. Reference to climate-related hazards would offer subsistence farmers a more clearly defined set of parameters to talk about their experiences and observations.

Chapter 2 – Methodology and research design

2.1. Introduction

Chapter 2 describes the study area and makes use of the information given in Chapter 1 to develop a problem statement, research question, aim and objectives. Thereafter the research hypotheses and methodology are briefly described. The ethical factors that were considered for the present study are outlined in this chapter as well. Lastly, the motivation for the study is given.

2.2. Study area

The study area is located in Genadendal, a small town 120 km east of Cape Town in the Western Cape of South Africa (Figure 1). Genadendal is situated in the Theewaterskloof Local Municipality which falls under jurisdiction of the Overberg District Municipality. The GPS coordinates for Genadendal are 34.0432 S, 19.5497 E.

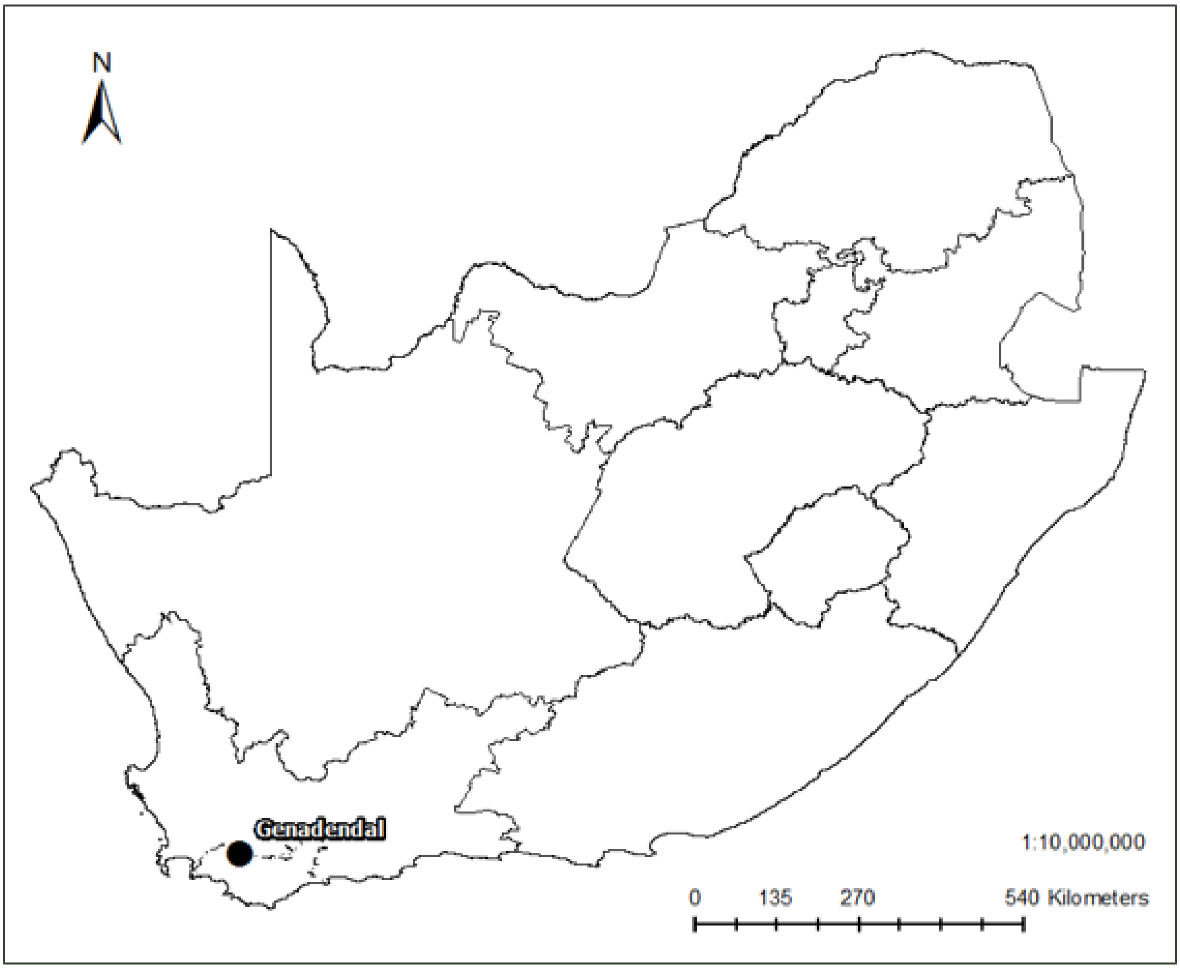

Figure 1 Location of Genadendal in the Overberg District, Western Cape Province, South Africa

At the time of the 2011 census, the total population of Genadendal was 5 663 with 1 593 households. Many (45%) of these households are headed by females. The majority of the educated population in Genadendal only has some secondary education (43.5%) with very few matriculating (15.5%) and obtaining higher education (7%) (Statistics South Africa, 2011). Approximately half (49.3%) of the population are nonworking dependents below the age of 15 or above the age of 64. This is concerning since the majority of households earn below R 76 400 per year (Statistics South Africa, 2011).

The climate change response strategy (Birch *et al.*, 2017) developed for the Overberg District Municipality, has identified food insecurity as a concern in the District, particularly under a changing climate. Municipal officials and external stakeholders in the District identified that food security would decrease due to impacts on crops and livestock as a result of increased frequency of drought, floods, wind, fires, pest infestation, changes in rainfall and increases in temperature (Birch *et al.*, 2017).

Genadendal has an extensive and well documented history dating back to 1738 (Krüger, 1966 and Krüger and Schaberg, 1966). To render Genadendal more self-sufficient, a Moravian missionary named Georg Schmidt made efforts to develop subsistence agriculture. Despite his efforts, Genadendal still regularly faced food insecurity due to climate-related impacts (e.g. droughts and floods). This often drove residents to wild harvesting or to work on neighbouring farms where their wages hardly covered their expenses. The history of Genadendal is explained in further detail in addendum A.

2.3.Problem statement

It is known that subsistence farmers are vulnerable to climate change (Aase, Chaudhary and Vetaas, 2010; Maponya, 2012; Martens, 2015; Muhire, 2012; Novas, 2015; Seaman *et al.,* 2014; Sieber *et al.*, 2015; Thorlakson and Neufeldt, 2012). The extensive history of Genadendal shows that famines were common occurrences in the past despite efforts made to develop subsistence agriculture (Krüger, 1966 and Krüger and Schaberg, 1966). In addition, Birch *et al.* (2017) found that the Overberg District Municipality within which Genadendal is located, is vulnerable to food insecurity in the face of climate change. Household climate-related food insecurity is further exacerbated by poor socio-economic conditions (Connolly-Boutin and Smit, 2016). The ability of resource-poor subsistence farmers to respond to climate-related food insecurity is likely to be limited by their socio-economic conditions (Maponya, 2012). According to Statistics South Africa (2011), households of Genadendal have low levels of income, a high dependency ratio and low levels of formal education.

2.4.Research question, aim and objectives

The purpose of the research is to answer the question of what the role of subsistence agriculture for household food security in a changing climate is. The aim of the present study is therefore to investigate the role of subsistence agriculture in achieving food security in a changing climate in Genadendal, Western Cape of South Africa.

The objectives of the research were to:

1. Analyse changes in climate using meteorological data and perceptions of subsistence farmers;
2. Investigate the impacts of climate-related hazards on the four dimensions of food security namely, availability, access, utilisation and stability with a focus on subsistence agriculture; and
3. Record and analyse climate adaptation responses used by subsistence farmers.

2.5.Hypothesis

The hypotheses of the present study are as follows:

1. Climate variables (i.e. rainfall and maximum and minimum temperatures) have changed over the years;
2. Climate-related hazards such as droughts, floods and heatwaves have an impact on the four dimensions of food security; and
3. Subsistence farmers use numerous adaptation responses to overcome the impacts of climate-related hazards.

2.6.Brief overview of methodology and research design

Relevant methodologies are made explicit in each of the chapters. However, this section serves as an overview of the methodology used in the present study. It particularly outlines information that is relevant to all the data chapters (Chapter 4 and 5). The present study used a combination of quantitative and qualitative methods, although qualitative methods formed the bulk of the study. Qualitative data were obtained from semi-structured interviews that were conducted with subsistence farmers. Quantitative data were sourced from meteorological datasets and used to analyse the climate of Genadendal in Chapter 4.

The study frame for the households who practice subsistence agriculture was identified with the assistance of knowledgeable key individuals within the community. A snowball sampling technique was then used to identify respondents who were eligible for the study by asking respondents to suggest other subsistence farmers who would be eligible for the study (e.g. Mugambiwa and Tirivangasi, 2017; Rivers III *et al*., 2017).

The households interviewed in the study include those that have at least made use of their land at some time in their lives to produce non-edible (e.g. flowers and trees) and edible (e.g. vegetables, livestock, eggs and milk) products for consumption and/or sale. The person responsible for the gardens and/or livestock was interviewed (n=20) unless they were not available, in which case the person that usually helps in the garden was interviewed (n=3).

A total of 23 subsistence farmers were interviewed during the present study. The sample number was limited by the amount of time that could be spent in the field. However, there are other studies that used similar sample sizes (e.g. Douxchamps *et al.*, 2016; Patterson *et al.*, 2017). Douxchamps *et al.* (2016) sampled 10 households per village and Patterson *et al.* (2017) sampled 13 households from each community in the study area.

2.7. Delimitations and challenges of the research

The first challenge faced during the present study was determining the sample size of households to interview. No information is available on the number of households that practice subsistence agriculture in Genadendal. A snowball sampling technique was therefore used in which key informants living in Genadendal introduced the study to households who were eligible for the study (further explained in Chapters 4 and 5). The sample size was chosen based on the sample sizes used in similar studies. Time was also a limiting factor and as a result only one week could be allocated to interviews. Thus, as many interviews as could be conducted in one week also contributed to determining the sample size. Another challenge that was encountered was making climate change understandable to the community. For this reason, the term *climate-related hazards* is used to describe climate change as described in Chapter 1.

2.8. Missing data

When data are collected by making use of questionnaires during interviews missing data can occur. There are different types of missing data which are caused by different factors. Missing data in this study are due to item nonresponse because information for some questions were not obtained for some respondents. Item nonresponse can be caused by three factors; (1) data are missing by systematic design; (2) all data are missing after a certain question; and (3) data are missing for some questions for some respondents. In this study, the most common type of missing data is (3) data that are missing for some questions for some respondents. This is a result of information not being provided or information not being useful.

2.9. Ethics

The questions asked during the interviews were designed in a manner that would avoid harm, discrimination or undue discomfort to the respondents. The intention was also to not invade the privacy of the respondents, to allow them to stay anonymous and answer on a voluntary basis. An application for ethical clearance was submitted to the Human Research Ethics Committee (REC) of the Stellenbosch University in April 2018. Ethical clearance for the research was granted on 13 April 2018.

Respondents could withdraw from the study at any time without consequences if they wished to do so. The respondents were informed of the purpose of the research, what will be asked of them, possible benefits, risks and discomforts, and the procedures followed to protect their information, confidentiality and identity. Furthermore, the interactions took place in their language of choice which was Afrikaans and later transcribed to English for analysis. Of all the respondents (n=23), verbal informed consent was received by 22 respondents on recordings. One respondent gave verbal consent but requested not to be recorded and also preferred not to give written consent.

2.10. Rationale for the study

2.10.1. Global scale

The Sustainable Development Goals (SDGs) call for action to end poverty, protect the environment and ensure that all people prosper and live in peace by 2030 (United Nations, 2015). The present study is in line with the second SDG that aims for zero hunger. To achieve zero hunger by 2030, numerous targets need to be met. The targets that are aligned with the present study are as follows; access to safe, nutritious and sufficient food by all people needs to be ensured; all forms of malnutrition need to be ended; agricultural productivity needs to be doubled in a sustainable and climate resilient manner; (United Nations, 2015).

In addition, the preamble of the Paris Agreement makes explicit reference to the fundamental importance of safeguarding food security and agriculture from the adverse impacts of climate change (United Nations Framework Convention on Climate Change, 2015). The present study is well aligned to put the Paris Agreement into action as it investigates the role of subsistence agriculture in safeguarding household food security in a changing climate.

2.10.2. National scale

South Africa's commitment to climate change and food security is reported on in the National Climate Change Response White Paper (Department of Environment and Narutal Resources, 2010) and research projects such as the Long-Term Adaptation Scenarios (LTAS) (Department of Environmental Affairs, 2013). However, the National Climate Change Response White Paper does not give detailed responses on how to improve food security in the context of climate change but rather gives a high-level overview. LTAS gives a few detailed examples on how small-scale subsistence farmers can be supported in a changing climate. However, most examples given are not options that subsistence farmers can implement themselves as they are costly and require support from external parties.

One of the objectives of the present study is to acquire local knowledge on how households have adapted their subsistence agriculture to climate-related hazards. The results of the research will therefore reveal local adaptations that could be incorporated into the review of the White Paper, the development of the National Communication or other plans and policies.

2.10.3. Provincial scale

At a provincial level, the Western Cape has shown a significant commitment to climate change and food security in the Western Cape Climate Change Response Strategy (Western Cape Government, 2014b) and the SmartAgri Plan which advocates for climate smart agriculture (Western Cape Department of Agriculture, 2016). The Western Cape Climate Change Response Strategy gives a high-level overview of options that need to be prioritised for climate resilient food production. It lists the following priority areas; conservation farming; climate smart agriculture; water efficiency; climate resilient crops and livestock; climate vulnerability and food security in the context of the resource-food nexus (Western Cape Government, 2014b).

The SmartAgri Plan provides a time-specific, spatially explicit, scale-sensitive and commodity-specific strategic roadmap to climate resilient agriculture. It mentions that it is important to capture local knowledge of climate change responses on farms to provide guidance on how to survive bad years (Western Cape Department of Agriculture, 2016). The third objective of the present study is aligned with the SmartAgri Plan, as it aims to accumulate local knowledge on climate change adaptation in subsistence agriculture.

2.10.4. District scale

The Overberg District Municipality Climate Change Response Strategy (Birch *et al.*, 2017) has identified food insecurity to be the top climate change hazard and impact in the District. The present study is therefore appropriate for the chosen study area. The strategy gives an overview of the climate change responses that the District has committed to. However, like the White Paper and Western Cape Climate Change Response Strategy, the strategy does not go into detail on how the District intends on safeguarding food security against climate change. The results of the present study can be used in the review of the strategy as it will provide further information on the link between climate change and food security in the Overberg District Municipality.

2.10.5. Local municipal scale

The Theewaterskloof Local Municipality Integrated Development Plan (IDP) (Theewaterskloof Municipality, 2017) acknowledges that agriculture, the backbone of the local economy, is impacted by climate change and needs to be protected to create jobs, wealth and social upliftment. The IDP indicates that the Theewaterskloof Agricultural Forum serves as a platform to discuss the development of subsistence farmers and household food security. To achieve sustainable, equitable and vibrant rural communities with adequate food security, the IDP has prioritised service delivery and improved social fibre. The Theewaterskloof IDP also acknowledges that agricultural development within Genadendal presents the biggest opportunities to empower emerging farmers and that land needs to be made available for this purpose. The present study contributes to the body of knowledge on climate change and food security within the Theewaterskloof Local Municipality. It provides a status quo of climate change impacts on the food security of subsistence farmers in Genadendal.

2.11. Outline of present study

The present study commenced with an introductory chapter, Chapter 1. Chapter 2 briefly outlines the methodology and research design. A systematic literature review is provided in Chapter 3. It provides an overview of the available information on subsistence agriculture, food security and climate change in South Africa and other developing countries. Chapter 3 is framed especially around small-scale, subsistence farming contexts similar to that of Genadendal. Chapter 4, which addresses objective one, follows with an analysis of historical climate data and perceptions of climate change of subsistence farmers. Chapter 5, which addresses objective two and three, investigates the impacts of climate-related hazards on the four dimensions of food security, as defined by the FAO (Chapter 1) with a focus on subsistence agriculture. It also investigates how subsistence farmers have adapted to climate-related hazards. Chapters 4 and 5 are each formatted as journal articles, each with its own introduction, aim, objectives, methodology, results and conclusion. The research then concludes the findings from each chapter and makes recommendations for further research in Chapter 6.

Chapter 3 – A systematic literature review on subsistence agriculture, food security and climate change

Keywords: Food security, climate change, subsistence agriculture, adaptations

3.1. Introduction

The overall aim of this chapter is to provide a review on available academic and grey literature on food security, subsistence agriculture and climate change in a South African context as well as on a global scale. To achieve the aim, the chapter firstly identifies which dimensions of food security has been reflected in the literature. The chapter also explores the role of subsistence agriculture in achieving food security to answer the question raised by Averbeke and Khosa (2007). The question raised by Averbeke and Khosa (2007) is whether subsistence agriculture plays an important role in achieving food security, given that income is known to be a significant factor. Impacts of climate change and climate change adaptation responses are also explored. The chapter then concludes by identifying knowledge gaps.

3.2.Methodology

To ensure that the literature review was unbiased, balanced and as impartial as possible, a systematic review was conducted (e.g. de Bruin, 2018; Williams and Tai, 2016) based on the guide developed by Gentles *et al.* (2016). Systematic literature reviews are transparent and rigorous and encompass the identification, synthesis and assessment of all available evidence to generate a robust answer to a focused research question (Mallett *et al.*, 2012).

The guide developed by Gentles *et al.* (2016) firstly suggests that a manageable set of publications must be delimited. It also suggests that alternative sources of databases should be consulted to ensure the inclusion of non-journal publications. To screen the literature found in the preliminary searches to select useful literature, the guide suggests reading abstracts, tables of contents and index sections. Thereafter, literature should be selected providing a predetermined set of criteria are met to ensure that the literature review covers adequate concepts.

The literature review was conducted using a comprehensive inquiry of keywords to search for literature dated from January 2009 to May 2018 that address topics similar to the present study (Table 2). The topic criteria included the following words and/or synonyms; food security, subsistence agriculture, subsistence farming, food gardens, climate, climate change, adaptation, climate resilience and small-scale farming. Articles that showed connections to South Africa were reviewed first followed by articles that showed connections to the global South. Rigg *et al.* (2015) described the global South as a term used to distinguish between richer and poorer countries in a globalised world. They are distinguished from one another through the use of the Human Development Index (HDI). Countries in the global South have a low HDI (United Nations Development Programme, 2018).

To capture as much data as possible literature was searched for on two academic-based databases and two organisations' publication catalogues. The databases that were used to source academic literature included the Stellenbosch University Online Library (SUN Search) and the South African Theses and Dissertations (ETD) Portal. Grey literature was sourced from the two organisations namely, the Food and Agriculture Organisation (FAO) and the World Bank (WB).

Table 2: Results of literature search

Database / organisation	**Keywords used**	**Filters**	**No. of results**	**No. included**
SUN Search	"food security" AND "subsistence agriculture" AND "climate change"	2009-2018; English	8,876	38
SUN Search	"food security" AND "subsistence agriculture" AND "climate change" AND "South Africa"	2009-2018; English; South Africa	204	19
ETD Portal	"food security" AND "subsistence agriculture" AND "climate change" AND "developing country"	2009-2018; English	65	9
FAO	"safeguarding food security in South Africa"	2009-2018; English	10	3
WB	"Role of subsistence agriculture for food security in climate change"	2009-2018; English	14	3

The abstracts and table of contents of literature found in the preliminary search was reviewed. Thereafter, literature was selected based on the practicality of the abstract and providing the secondary criteria in Table 3 were met. The present study is focused on the influence of climate change on food security. Therefore, literature on other drivers of food insecurity were excluded. It also focuses on subsistence agriculture as the method of achieving food security through consumption and/or sale. Therefore, literature on other methods of achieving food security were also excluded.

Due to the large number of results in the preliminary search of each database the search was ended after thirty consecutive publications were not relevant (e.g. de Bruin, 2018). The selected literature was read in full to ensure its applicability and to uncover themes in literature on food security, subsistence agriculture and climate change. After cross-referencing was checked and included in the literature, the reference lists of the included literature were then perused to extrapolate new literature.

Table 3: Inclusionary and exclusionary criteria for preliminary and secondary searches

	Included	**Excluded**
Date of publish	2009-2018	Published before 2009
Language	English	Any other languages
Location	South Africa and other countries in the global South	Countries in the global North
Preliminary criteria	Title and abstract contains "food security" AND "subsistence agriculture" AND "climate change" OR synonyms thereof	Does not meet preliminary criteria
Secondary criteria	Scan of paper reveals: connection to South Africa or other developing countries; dimensions of food security as defined by the FAO (Chapter 1); role of subsistence agriculture; impacts of climate change on subsistence agriculture and food security; climate change adaptations	Does not meet secondary criteria

After the exclusionary criteria in Table 3 were applied to the preliminary results (n=72) as shown in Table 2, the number of publications were reduced to n=47. Of these publications, 40 were included from SUN Search, five from ETD, none from FAO and two from WB. After using additional literature extrapolated from cross-referencing the result was n=50. The number of cross-referencing results is low. This is because the literature review focussed on the results of each study rather than information that was referenced within each publication. The information presented in the literature review is not exhaustive, nevertheless it is an attempt to document available literature.

3.3.Results

3.3.1. Dimensions of food security

Table 4 provides a list of publications that address each dimension of food security (availability, access, utilization and stability) and how they are addressed. It also provides the author(s) names and the location of the studies. Where possible, studies conducted in South Africa were listed by province as South Africa has nine provinces. Studies in other locations were listed by country and some studies were conducted at large spatial scales that included numerous locations in different countries (e.g. Sub-

Saharan Africa or East Africa). South African studies were mostly located in the Mpumalanga and Eastern Cape Provinces. Studies on food security have typically been focused on food availability, but a growing body of literature addressed other dimensions of food security as well. A part of the present study focuses on the impacts of climate change on all four of the dimensions of food security which makes it relevant to trends in food security literature.

Table 4: Dimensions of food security (FAO, 2008) addressed in the literature

Dimension of food security (FAO, 2008)	**How it is addressed in the relevant study**	**Author(s)**	**Location**
Food availability	If produce is supplied to local markets the availability of food in the study area is increased. Over time subsistence land-users have abandoned their big fields and started using small home gardens to supplement their own supply. Instead of using livestock as a continuous supply of food the community use them for cultural practices. The questionnaire included questions on food purchased and/or produced as well as storage.	Martens (2015)	Eastern Cape Province, South Africa
	Higher incomes from the sale of products produced by an agricultural household is synonymous with adequate food availability.	Tibesigwa *et al.* (2016)	Mpumalanga Province, South Africa
	Study found that food availability was influenced by the socio-economic status of respondents.	Pereira, Cuneo and Twine (2014)	Mpumalanga Province, South Africa
	Investigates the natural and socio-economic factors that affect food security. Studied the productivity of agriculture and related it to the food available to households.	Tiwari and Joshi (2012)	Kumaon Himalaya, India

	Focused on maximizing the number of calories produced. Study found that adjusting crop selection can increase crop production to improve available food.	Bodin *et al.* (2016)	Sub-Saharan Africa
	Focused on obtaining sufficient quantities and qualities of food throughout the year by testing different climate-smart adaptation responses	Douxchamps *et al.* (2016)	West Africa (Ghana, Senegal and Burkina Faso)
	States that it is necessary to improve yields to increase food availability	Funk (2011)	East Africa
	Respondents were unable to produce enough food due to insufficient equipment and poor rainfall	Rivers III *et al.* (2017)	Mali
	Studied the role of subsistence agriculture and the amount of food available at local markets. Study found that subsistence agriculture improved availability to food for short period in year.	Patterson *et al.* (2017)	Uganda
Food access	Investigates the role that the retail sector plays in rural food security. Purchasing food was found to be an important strategy to food access. It was found that low income limits food access via purchasing.	Pereira, Cuneo and Twine (2014)	Mpumalanga Province, South Africa
	Found that income generated by subsistence agriculture is small and that respondents are reliant on other sources of income for their livelihoods. Subsistence agriculture was also found to only supplement respondents' food consumption. Respondents were largely reliant on grants.	Martens (2015)	Eastern Cape Province, South Africa

	Investigates the natural and socio-economic factors that affect food security. It was found that access to food relies on numerous factors including income, employment, storage and food purchasing power.	Tiwari and Joshi (2012)	Kumaon Himalaya, India
	Respondents had to find alternative ways to generate income to purchase food because they were unable to produce enough	Rivers III *et al.* (2017)	Mali
	Investigated how people access food. During dry seasons respondents preferred to have alternative sources of income to purchase food rather than rely on subsistence agriculture. However, produce sold locally reduced food prices at local markets.	Patterson *et al.* (2017)	Uganda
Food utilization	Studied dietary diversity and found 61.7% of households had a high dietary diversity score. However, food groups containing micronutrients were consumed less than cereals, oil, sugar and beef.	Megbowon and Mushunje (2018)	Eastern Cape Province, South Africa
	The questionnaire asks about the diversity of crops and livestock produced and consumed. It was found that although respondents keep livestock they do not consume meat on a regular basis.	Martens (2015)	Eastern Cape Province, South Africa
	Study found that the nutritional quality of food eaten by respondents was influenced by the socio-economic status of respondents. Respondents were mostly consuming sweets and	Pereira, Cuneo and Twine (2014)	Mpumalanga Province, South Africa

	fats. Vegetables, fruits and meat were consumed less frequently.		
	Study focused on gender and found that young women were key in achieving food security. They were responsible for completing the tasks that other household members made decisions on. Elder men were responsible for food allocation whereas other household members were responsible for food production.	Rivers III *et al.* (2017)	Mali
	Adult hunger increased in dry periods. Children were protected to some degree. Men ate last. Variability in the diet decreased in dry periods.	Patterson *et al.* (2017)	Uganda
	Investigates impact of climate variability on dietary diversity of households via production losses. It was found that increases in income from subsistence agriculture change the composition of diets as respondents were 7.2% and 3.5% more likely to eat vegetables and fish, respectively. Thus, if production is reduced due to climate variability it was said that dietary diversity would decrease.	Dillon, McGee and Oseni (2015)	Nigeria
Stability	The questionnaire asked how often respondents experienced food shortages and how many times per day respondents eat meals. However, the study did not discuss the results in detail.	Martens (2015)	Eastern Cape Province, South Africa
	Study found that adjusting crop selection can increase crop production and improve the stability of production	Bodin *et al.* (2016)	Sub-Saharan Africa

	and food security. Stable yields are crucial to food security.		
	Study found that reducing vulnerability to climate-related hazards can improve the stability of income made by subsistence land-users.	Douxchamps *et al.* (2016)	West Africa (Ghana, Senegal and Burkina Faso)
	Found that respondents were unable to produce enough food for the whole year resulting in their food security being unstable during some months.	Rivers III *et al.* (2017)	Mali
	Majority of households reported experiencing hunger year-round.	Patterson *et al.* (2017)	Uganda

3.3.2. Role of subsistence agriculture in achieving food security

The claims listed in Table 5 were made about the role of subsistence agriculture in achieving food security. Table 5 gives evidence for each claim as well as the name of the author(s), the date and the location of the study. As was mentioned for Table 4, where possible studies in South Africa were listed according to provinces whereas studies outside of South Africa were listed according to country or region. South African studies were mostly conducted in the Limpopo, Mpumalanga and Eastern Cape Provinces. It was found that claims have been centered around income from the sale of produce as well as the consumption of produce.

Table 5: Claims made about the role of subsistence agriculture in achieving food security

Claim	**Evidence**	**Author**	**Location**
Subsistence agriculture does not make a significant difference to the food security status of households. It only supplements household food security.	About 53% of households were severely food insecure. Determinants of food security were found to include education, household size, dependency ratio and income.	De Cock *et al.* (2013)	Limpopo Province, South Africa
	In a survey 49% of respondents reported that they experienced hunger due to social and agroecological constraints such as poor access to water. The study	Hart (2011)	Limpopo Province, South Africa

	found that subsistence agriculture serves as an additional source of food to that which is purchased.		
	Due to inadequate rainfall households were unable to grow enough food. Purchasing food was important for their food security.	Pereira, Cuneo and Twine (2014)	Mpumalanga Province Province, South Africa
	Subsistence agriculture plays only a supplementary role	Martens (2015)	Eastern Cape Province, South Africa
	Only supplements household food supply but respondents attached a significant amount of importance to subsistence agriculture. It was found that off-farm activities generate very little income.	Aliber and Hart (2009)	South Africa
	Subsistence agriculture mitigates high food prices and reduces the vulnerability of households to food insecurity through a supplementary role. Used to provide the main source of food but recently only provides an extra source of food.	Baiphethi and Jacobs (2009)	Sub-Saharan Africa with focus on South Africa
	Only 48%, 18% and 55% of households were food secure in Senegal, Ghana and Burkina Faso, respectively. The main contributor to food security was found to be total land area per capita.	Douxchamps *et al.* (2016)	West Africa (Ghana, Senegal and Burkina Faso)
	Found that households were unable to produce sufficient food to last the whole year due to challenges such as climate change, traditional behaviours and lack of	Rivers III *et al.* (2017)	Mali

	easily accessible adaptation responses.		
	Found 74% of households were food insecure. Households can only consume their own production for only six months in a year. The shortfall of production was due to inadequate rainfall.	Berlie (2013)	Ethiopia
	Subsistence agriculture was only the main source of food for 46% of households. However, this could have been because staple crops had been replaced with cash crops to generate more income. Households had become more dependent on purchasing food.	Hussain *et al.* (2018)	Koshi River Basin, Nepal
	Food security primarily depends on subsistence agriculture and food purchasing power. Thus, subsistence agriculture supplements household food security.	Tiwari and Joshi (2012)	Kumaon Himalaya, India
The sale of agricultural produce is an important source of income	Sale of agricultural produce generates additional income for households making subsistence agriculture a suitable coping strategy to improve food security.	Mashamaite (2014)	Limpopo Province, South Africa
	About 58% of crops and 49% of livestock are sold to generate an extra source of income.	Tibesigwa, Visser and Turpie (2014)	South Africa
	Subsistence agriculture is the main source of income for households.	Bryan *et al.* (2009)	Africa
	In addition to off-farm income the sale of staple crops (such as millet,	Douxchamps *et al.* (2016)	West Africa (Ghana, Senegal

	cowpea, maize, sorghum and groundnut) generated income.		and Burkina Faso)
Sale of agricultural produce only supplements income	Only 15% of households stated that income from the sale of produce is their main income source.	De Cock *et al.* (2013)	Limpopo Province, South Africa
	Off-farm activities and state grants are the main source of income.	Hart (2011)	Limpopo Province, South Africa
	The contribution of subsistence agriculture to household income is small.	Baiphethi and Jacobs (2009)	Sub-Saharan Africa, focus on South Africa

3.3.3. Impacts of climate change on subsistence agriculture and food security

The claims listed in Table 6 were made about the impacts of climate change on subsistence agriculture and food security. Table 6 gives evidence for each claim as well as the name of the author, the date and the location of the study. As was mentioned for the previous tables, where possible studies in South Africa were listed according to provinces whereas studies outside of South Africa were listed according to country or region. South African studies were conducted in the Eastern Cape, Mpumalanga and KwaZulu-Natal Provinces. Numerous studies acknowledge that climate change has an impact on the food security of subsistence land-users. Impacts of climate change range from changes in crop yields and planting dates to impacts on livestock and food prices.

Table 6: Claims made about the impacts of climate change on food security

Claim	**Evidence**	**Author**	**Location**
Climate change impacts the food security of subsistence farmers	Lack of resources and reliance on subsistence agriculture renders households more vulnerable to climate change. Livestock deaths and crop failure during droughts threatens their food security.	AgriSA (2016)	South Africa
	The impact of climate change on subsistence agriculture and natural resources such as	Martens (2015)	Eastern Cape Province, South Africa

	fisheries would be detrimental. However, respondents were heavily reliant on state grants and so the impact on food security was modest.		
	Study found that climate change poses a threat to food security mainly due to water shortages.	Mugambiwa and Tirivangasi (2017)	South Africa
	Acknowledges that climate change will impact the food security of subsistence farmers.	Senyolo *et al.* (2018)	South Africa
	Study found that specialised crop farmers are the most vulnerable and mixed crop-livestock farmers to be least vulnerable to climate change. At first climate change will be mildly harmful. The negative impacts will worsen with time.	Tibesigwa, Visser and Turpie (2014)	South Africa
	Interviews with local farmers showed that farming communities are negatively impacted by changes in the climate. Perceived impacts were unpredictable rainfall, increased frequency of droughts and floods, soil degradation and increased insect pests, diseases and weeds.	Shrestha and Nepal (2016)	Makwanpur, Nepal
	Acknowledges that subsistence farmers are highly vulnerable	Sieber *et al.* (2015)	Tanzania

	to climate change and that their livelihoods are under threat.		
	Acknowledges that climate change will impact the food security of subsistence farmers.	States News Service (2017)	Latin America and Caribbean
	Acknowledges that climate change will impact the food security of subsistence farmers.	FAO (2016)	Global
	Current subsistence agriculture is highly vulnerable to fluctuations in precipitation.	States News Service (2016)	Zambia
	Floods damaged crops and swept livestock away. In addition, the rainy season began late delaying the planting season.	Bariyo (2015)	Malawi
	Acknowledges that climate change will impact the food security of subsistence farmers.	Presbyterian Record (2013)	Global South
	Fluctuations in water supply contribute to periodic food shortages.	Salman, Amer and Ward (2017)	Afghanistan
	Water availability will shift production areas. As a result, food security will be impacted.	IPCC (2014)	Global South
	Changes in climate have decreased irrigated land and therefore agricultural productivity by 25% during the last 30 years causing annual food deficits of 65%	Tiwari and Joshi (2012)	Kumaon Himalaya, India
	Study found 100% of households in one study area	Thorlakson and Neufeldt (2012)	Western Kenya

	and 70% of households in another study area experienced an additional month of hunger due to floods and droughts. Typical periods of hunger for households in each study area were 2.3 and 4.5 months respectively.		
	Reliance on subsistence agriculture may result in floods and droughts having a significant impact on food security. However, adaptation allows communities to overcome the impacts.	Davies *et al.* (2009)	Rural communities
	Combined with high food prices, decreased rainfall reduces the food security od subsistence land-users.	Funk (2011)	East Africa
	Interviews showed that food security is at risk to climate change due to insufficient rainfall.	Rivers III *et al.* (2017)	Mali
	Subsistence land-users are most food insecure during dry periods.	Patterson *et al.* (2017)	Uganda
Household food production and consumption decreases due to climate change	Consumption decreased by 33.9% when households lost most crops due to poor rainfall and hail storms and 76.5% when they lost all crops. Households made use of natural resources and purchased food so the decrease	Tibesigwa *et al.* (2016)	Mpumalanga Province, South Africa

	in consumption was only 21.3% and 47.8% respectively.		
	Food consumption decreases due to decreased crop yields. Cereal consumption is affected the least.	Amjath-Babu *et al.* (2016)	South Africa; Ethiopia; Cameroon; Zimbabwe
	Approximately 36-45% of crop growing households experienced a decline in production which was mainly due to climate-related hazards including unpredictable rainfall, extreme temperatures, frost and hailstorms. The most common climate-related hazards were droughts.	Hussain *et al.* (2018)	Koshi River Basin, Nepal
	Acknowledges that household production and consumption decrease due to climate change.	Bryan *et al.* (2009)	Africa
	Poor communities reduced or stopped purchasing expensive food products.	Tiwari and Joshi (2012)	Kumaon Himalaya, India
	Food shortages occurred due to rainfall variability, droughts and floods that decreased farm productivity by 39-60%.	Thorlakson and Neufeldt (2012)	Western Kenya
Climate change will increase crop yields	Millet and sorghum yields are expected to increase slightly due to their heat and drought tolerance.	Ringler *et al.* (2010)	Sub-Saharan Africa
Climate change will decrease crop yield	Decrease in cassava by 0.2% and 37.7% in maize in Zimbabwe. Decrease in sorghum by 4% and 18% in	Amjath-Babu *et al.* (2016)	South Africa; Ethiopia; Cameroon; Zimbabwe

	maize in Cameroon. Decrease in sorghum by 15.2% and 30.3% in maize in South Africa. Decrease in sorghum by 6.4% and 19% in maize in Ethiopia.		
	Affects crop growth and quality.	Mugambiwa and Tirivangasi (2017)	South Africa
	Cereal crop production is expected to decrease by 3.2% by 2050. Wheat, maize and rice is expected to decrease by 22%, 5% and 2%, respectively.	Hadebe, Modi and Mabhaudhi (2017)	Sub-Saharan Africa
	Crop yield to decrease by 10% by 2020.	Mohammed (2012)	Asia
	Yields of sorghum, cowpeas, maize, millet, sweet potatoes, cassava, cotton, rice, pigeon peas, pumpkin leaves and other vegetables are decreasing.	Joshua *et al.* (2016)	Malawi
Climate change affects the cropping calendar	Due to changes in the onset and distribution of rainfall.	Joshua *et al.* (2016)	Malawi
Climate change impacts livestock	Affects health of livestock.	Mugambiwa and Tirivangasi (2017)	South Africa
	During droughts subsistence farmers are concerned about livestock diseases.	Wilk, Andersson and Warburton (2013)	KwaZulu-Natal, South Africa
Climate change will increase food prices	Food prices inflated by 11% in 2016. Maize meal increased by 47% in 2016.	AgriSA (2016)	South Africa
	Sorghum prices increase due to uncertainties in precipitation.	Sassi (2013)	Sudan

	Acknowledges that climate change will result in increased food prices.	Godfray *et al.* (2010)	Globally
	Food prices increased between 2008 and 2010 which decreased the purchasing power of people by 30-35%	Tiwari and Joshi (2012)	Kumaon Himalaya, India
	Price of maize increased by 246% in 12 months due to drought.	Funk (2011)	East Africa
Climate change will reduce farm income	By 2050 farm income would have reduced by 9.7% in Ethiopia, 21.4% in Cameroon, 27% in South Africa and 38% in Zimbabwe.	Amjath-Babu *et al.* (2016)	South Africa; Ethiopia; Cameroon; Zimbabwe
	By 2080 there will be a 151% loss in net revenue of households.	Tibesigwa, Visser and Turpie (2014)	South Africa
	Farm income for dryland crops and livestock decreased with increased temperatures but farm income rose when crops were buffered from temperature by irrigation.	Kurukulasuriya *et al.* (2006)	Africa
	Value of goats halved in 12 months due to drought.	Funk (2011)	East Africa
Climate change will increase farm income	When water supply decreased, supply from production decreased which increased crop prices. As a result, farm income increased.	Salman, Amer and Ward (2017)	Afghanistan

Secondary impact of climate change is poor health and nutrition	Health and nutrition were impacted as a result of decreased consumption.	Tiwari and Joshi (2012)	Kumaon Himalaya, India
The impact of climate change on rural livelihoods and food security is insignificant	Due to reliance on state grants instead of subsistence agriculture for food security	Martens (2015)	Eastern Cape Province, South Africa

3.3.4. Climate change adaptations in subsistence agriculture

The claims listed in Table 7 were made about climate change adaptations in subsistence agriculture to achieve food security. Table 7 gives evidence for each claim as well as the name of the author, the date and the location of the study. As was mentioned for the previous tables, where possible studies in South Africa were listed according to provinces whereas studies outside of South Africa were listed according to country or region. South African studies were conducted in the Limpopo, Eastern Cape, North West, Mpumalanga and KwaZulu-Natal Provinces. The claims made by existing literature indicated that households who engage in subsistence agriculture are vulnerable to climate change but that numerous climate change adaptation responses exist that can support them in improving their resilience within the right enabling environment.

Climate resilience is referred to as the outcomes of processes that manage change and disruptions caused by climate change in order to reduce the associated impacts and enhance opportunities (Denton *et al.*, 2015). The United Nations Office for Disaster Risk Reduction defines resilience as the ability of a system, community or household exposed to disturbances and risks to withstand, absorb, adapt to and recover from the impacts of disturbances and risks in a way that is timely and efficient (UNISDR, 2017). Climate resilience depends on innovative and context-specific actions and policies to successfully develop new ideas and responses to adapt and respond to disturbances (Denton *et al.*, 2015; IITA, 2015).

Table 7: Claims made about climate change adaptation in subsistence agriculture

Claim	Evidence	Author	Location
Subsistence farmers in developing countries are more vulnerable to climate change than those in developed countries	Climate change pushes them beyond their capacity to respond	Maponya (2012)	Limpopo Province, South Africa
	Acknowledges that rural communities are particularly vulnerable to climate change	Martens (2015)	Eastern Cape Province, South Africa

	due to their reliance on natural resources for food security.		
	They are technically and financially least equipped to adapt to climate change.	Seaman *et al.* (2014)	Developing countries
	Due to their large populations and dependence on subsistence agriculture	Aase, Chaudhary and Vetaas (2010)	Manang, Nepal Himalaya
	Due to lower adaptive capacity	Sieber *et al.* (2015)	Tanzania
	Acknowledges that African countries are particularly vulnerable to climate change due to their reliance on rain-fed agriculture	Muhire (2012)	Rwanda
	Acknowledges that subsistence farmers are the most vulnerable to climate change due to their reliance on rainfall.	Novas (2015)	Zambia
	Poor general standard of living	Thorlakson and Neufeldt (2012)	Western Kenya
Barriers against climate change adaptation exist	Lack of access to credit (in South Africa) and land (in Ethiopia)	Bryan *et al.* (2009)	Limpopo Province, South Africa; Nile Basin, Ethiopia
	High initial investment costs, labour and management.	Senyolo *et al.* (2018)	South Africa
	Lack of the following: education, finances, knowledge on climate change, equipment, production inputs, skilled extension officers, water,	Maponya (2012)	Limpopo Province, South Africa

	irrigation systems and new technology.		
	Lack of land	Patterson *et al.* (2017)	Uganda
	Insufficient equipment	Rivers III *et al.* (2017)	Mali
Numerous adaptation strategies have been used to counteract the impacts of climate change	Change in crop types or varieties used, planting trees, changing planting dates, irrigation, soil conservation.	Bryan *et al.* (2009)	Limpopo Province, South Africa; Nile Basin, Ethiopia
	Climate change scenarios found that moderate to extreme increases in dry-spells increased off-farm activities like small business and decreased on-farm activities like gardening. Opposite results were found for wet-spells.	Dassanayake *et al.* (2018)	Eastern Cape Province, South Africa
	Sell or slaughter livestock in times of stress.	Martens (2015)	Eastern Cape Province, South Africa
	Water management, soil management, insurance, subsidies, shade nets to withstand heat and cold, planting cotton due to its heat-resistance, applying water and fertiliser after damage due to climate-related hazards to revive production, reduced planting space of cabbage and spinach to withstand cold.	Maponya (2012)	Limpopo Province, South Africa
	Study found that conservation agriculture, rainwater	Senyolo *et al.* (2018)	South Africa

	harvesting as well as drought tolerant and early maturing seed varieties are the most suited adaptation responses for South African smallholder farmers.		
	Use of indigenous and traditional food crops such as sorghum, sweet potato and amaranth.	van der Merwe, Cloete and van der Hoeven (2016)	North West Province, South Africa
	Mixed crop-livestock farming, Crop farmers earn more income when the household owns the land. Livestock farmers earn more money on communal land. Reduced consumption is counteracted if households have access to social capital and natural resources such as wild edible foods. Study found that specialised crop farmers are the most vulnerable and mixed crop-livestock farmers to be least vulnerable.	Tibesigwa, Visser and Turpie (2014)	South Africa
	Informal social capital and natural resources sustain food security. Study found mixed farming systems to be less vulnerable to climate change.	Tibesigwa *et al.* (2016)	Mpumalanga Province, South Africa
	Knowledge transfer, government directives, locally adapted financial programmes.	Wilk, Andersson and Warburton (2013)	KwaZulu-Natal Province, South Africa

	Use of drought-tolerant crops such as sorghum. Increase area under cereal production by 2.1% to compensate for yield losses.	Hadebe, Modi and Mabhaudhi (2017)	Sub-Saharan Africa
	Irrigation	Kurukulasuriya *et al.* (2006)	Africa
	Diversify livestock, agroforestry, crop diversity	Berlie (2013)	Ethiopia
	Conservation agriculture, particularly minimum tillage.	Novas (2015)	Zambia
	Water sharing methods such as water trading amongst different locations overcomes the impacts of drought.	Salman, Amer and Ward (2017)	Afghanistan
	Off-farm employment	Tiwari and Joshi (2012)	Kumaon Himalaya, India
	Reclaim abandoned land, make use of barley, relocate farming	Aase, Chaudhary and Vetaas (2010)	Manang, Nepal Himalaya
	Reduce dependence on climate-sensitive livelihoods	Davies *et al.* (2009)	Rural communities
	Staggered planting to adapt to changes in the onset and distribution of rainfall. Increased use of sorghum instead of maize.	Joshua *et al.* (2016)	Malawi
	Agroforestry	Jerneck and Olsson (2013)	Kenya
	Employment at other farms, crop rotation, crop diversity, keeping of livestock, cash cropping, increased inputs,	Patterson *et al.* (2017)	Uganda

	storing during harvest season, long-term planning.		
Some farmers do not make any adjustments to their farming practices	Survey found they did not make any adjustments.	Bryan *et al.* (2009)	Limpopo Province, South Africa; Nile Basin, Ethiopia
Some adaptation strategies will not be sufficient to overcome the impacts of climate change	A doubling of development in irrigation will not be sufficient.	Calzadilla *et al.* (2014)	South Africa
	Social protection and disaster risk reduction are not sufficient in the long-term.	Davies *et al.* (2009)	Rural communities

3.4.Discussion and conclusion

3.4.1. Literature with connections to developing countries

The results revealed that there is valuable literature on the link between food security, subsistence agriculture and climate change. Research on food security has mostly focussed on food availability (e.g. Bodin *et al.*, 2016; Funk, 2011). These results are consistent with the observations of other authors (e.g. Burchi, Fanzo and Frison, 2011; Gross *et al.*, 2000). Food access has also been widely researched (Martens, 2015; Pereira, Cuneo and Twine, 2014; Patterson *et al.*, 2017; Tiwari and Joshi, 2012; Rivers III *et al.*, 2017). The results of the literature review show that a broader and more complex analysis of food utilisation is necessary. This was also noted by Burchi, Fanzo and Frison (2011). It was found that the stability of food security is usually studied together with food availability (Bodin *et al.*, 2016; Douxchamps *et al.*, 2016). However, stability needs to be studied together with the other dimensions of food security as well to be coherent with the definition of food security. There are very few publications that focus on all four dimensions of food security simultaneously. However, Patterson *et al.* (2017), Rivers III *et al.* (2017) and Martens (2015) touched on all the dimensions of food security.

Available literature shows that subsistence agriculture does not render households completely food secure throughout the year (Douxchamps *et al.*, 2016; Pereira, Cuneo and Twine, 2014; Rivers III *et al.*, 2017). Instead, subsistence agriculture only supplements food security by supplying households with an additional source of food and/or income (De Cock *et al.*, 2013; Hart, 2011; Martens, 2015; Aliber and Hart, 2009; Baiphethi and Jacobs, 2009; Tiwari and Joshi, 2012).

The amount of income generated by subsistence agriculture has been found to be small (Baiphethi and Jacobs, 2009). Therefore, subsistence land-users usually have multiple and diverse ways of making their income (Bryan *et al.*, 2009; Douxchamps *et al.*, 2016; Mashamaite, 2014; Tibesigwa, Visser and

Turpie, 2014). Income generated from off-farm activities is commonly the main source of income for households (Baiphethi and Jacobs, 2009; Bryan *et al.*, 2009; De Cock *et al.*, 2013; Hart, 2011).

Thus, Averbeke and Khosa (2007) questioned the role that subsistence agriculture plays in achieving food security when income has been found to play such an important role. However, it is important to note that the importance of subsistence agriculture is much greater than usually appreciated (Baiphethi and Jacobs, 2009). The results of a study conducted by Aliber and Hart (2009), found that respondents still attached a significant amount of importance to subsistence agriculture even though it only makes a small contribution to household food security.

There is an abundant body of literature acknowledging that climate change has a negative impact on the food security of subsistence land-users (AgriSA, 2016; Bariyo, 2015; Martens, 2015; FAO, 2016; Mugambiwa and Tirivangasi, 2017; Senyolo *et al.*, 2018; Shrestha and Nepal, 2016; Sieber *et al.*, 2015; States News Service, 2016; States News Service, 2017; Tibesigwa, Visser and Turpie, 2014). This is largely due to the reliance of subsistence farmers on rainfall for their agriculture (Muhire, 2012; Novas, 2015; States News Service, 2016). Food insecurity due to droughts and unpredictable rainfall has been more frequently cited (e.g. AgriSA, 2016; Funk, 2011; Thorlakson and Neufeldt, 2012) than any other climate-related hazard. Some studies found that climate change will present opportunities for agriculture such as increased crop yields and farm income (e.g. Ringler *et al.*, 2010; Salman, Amer and Ward, 2017).

Most studies focus on the immediate impacts of climate change (Amjath-Babu *et al.*, 2016) such as changes in crop yields (e.g. Hadebe, Modi and Mabhaudhi, 2017; Ringler *et al.*, 2010) and the cropping calendar (e.g. Joshua *et al.*, 2016). However, there is a growing body of literature that focusses on the secondary impacts of climate change such as poor health and nutrition (e.g. Tiwari and Joshi, 2012) as well as increased food prices (e.g. AgriSA, 2016; Funk, 2011; Sassi, 2013).

There is a gap in literature studying the impacts of climate-related hazards together with local adaptations in agriculture (Hussain *et al.*, 2018). Barriers that prevent subsistence farmers from adapting to climate change have been widely studied (e.g. Bryan *et al.*, 2009; Maponya, 2012; Patterson *et al.*, 2017; Senyolo *et al.*, 2018; and). It has been found that access to finances (Bryan *et al.*, 2009), land (Bryan *et al.*, 2009; Patterson *et al.*, 2017), knowledge (Maponya, 2012), equipment (Rivers III *et al.*, 2017), labour and technology (Maponya, 2012; Senyolo *et al.*, 2018) pose as barriers. Some subsistence farmers do not make any adjustments to their farming practices (e.g. Bryan *et al.*, 2009). But others have used numerous adaptation strategies to improve their resilience and counteract of the impacts of climate change at least to some degree. These adaptation strategies have been captured in the results of many studies (e.g. Bryan *et al.*, 2009; Dassanayake *et al.*, 2018; Maponya, 2012; Martens, 2015; Senyolo *et al.*, 2018). Martens (2015), goes as far as saying that the impact of climate change on rural livelihoods and food security is insignificant due to reliance on state grants.

3.4.2. Literature with connections to South Africa

Numerous studies have been conducted in South Africa to understand the issues relating to subsistence agriculture, food security and climate change (e.g. Amjath-Babu *et al.*, 2016; Bryan *et al.*, 2009; Dassanayake *et al.*, 2018; Maponya, 2012; Martens, 2015; Mugambiwa and Tirivangasi, 2017; Senyolo *et al.*, 2018; Tibesigwa, Visser and Turpie, 2014; Tibesigwa *et al.*, 2016; Wilk, Andersson and Warburton, 2013). However, after consulting available literature using the aforementioned selection criteria, it can be said that the Western Cape is not the focus of studies researching the food security of subsistence land-users.

This could be because at the time of the 2016 Community Survey only 3.0% of the Western Cape's households were found to be agricultural households. Although it is an increase of 0.1% since 2011, it remains low compared to the rest of South Africa. Almost two thirds of South African agricultural households are in KwaZulu-Natal (24.4%), Eastern Cape (20.7%) and Limpopo (16.3%) combined (Statistics South Africa, 2017).

Other reasons for the gap in literature on subsistence land-users in the Western Cape may be due to grain-based food prices and the ability to buy food. According to Statistics South Africa (2016a), the Western Cape does not appear as one of the provinces vulnerable to rising grain-based food prices. This is because for every R100.00 spent on food, households in the Western Cape only spend R21.00 on grain-based food. Households in Limpopo (the most vulnerable province to rising grain-based food prices) spend R39.00 for every R100.00 spent on food. Statistics South Africa (2016a) also found that households in the North West and the Eastern Cape Provinces struggled the most to buy food. In the North West 41% and in the Eastern Cape 32% of households ran out of money during the 12 months prior to the survey. Fewer households in the Western Cape (25%) run out of money to buy food.

However, it is concerning that, so few studies have focussed on the food security of subsistence land-users in the Western Cape. Many of the households are headed by the elderly (people aged 65 and up) who are already considered to be a part of the vulnerable groups (Statistics South Africa, 2017). Adding to the concern, is the fact that the main purposes of these agricultural households are to provide the household with their main source of food or an additional source of food. Most of these agricultural households engage in back yard farming (80.9% of households), 15.3% farm on farm land, 0.9% on communal land and three percent at schools, churches or other land (Statistics South Africa, 2017). This is an indication that these households do not have the luxury of access to large plots of land.

3.4.3. Literature with connections to the Western Cape

Literature was selected for the present study with strict selection criteria as mentioned in Table 3. As was discussed above, the results did not include many studies from the Western Cape. Another search was done briefly to find literature on agriculture and climate change in the Western Cape that may have been excluded by the selection criteria. The results of this search showed that there are studies addressing food security, agriculture and climate change in the Western Cape (e.g. Archer *et al.*, 2009; David and Thomas, 2015; Midgley and Methner, 2016 and Ziervogel *et al.*, 2014).

However, most of this literature was found to have a focus on intensive commercial farming (e.g. Archer *et al.*, 2009 and Ziervogel *et al.*, 2014) or urban agriculture (e.g. David and Thomas, 2015). The focus of these studies were not on the food security of subsistence farmers in rural areas. Midgley and Methner (2016) reflected on the climate adaptation readiness of agriculture in the Western Cape and lessons that were learnt from the 2016 drought. However, the study did not address the impact of climate change on the food security of subsistence farmers in the Western Cape in detail. It focussed on institutional arrangements and policies that may support the agriculture sector as a whole in adapting to climate change.

3.4.4. Filling the gaps: The present study

The present study contributes to filling two main gaps in literature. As mentioned above, the link between climate change and the food security of subsistence farmers in the Western Cape has not been studied in detail. Studies addressing this topic that have been conducted in other provinces such as Limpopo and the Eastern Cape have addressed the topic in far greater detail than studies in the Western Cape have. The present study is therefore conducted in the Western Cape to contribute to the gap that currently exists. In addition, the present study addresses the need to research food security holistically by including all four of its dimensions.

Chapter 4 – Climate change in Genadendal, Western Cape of South Africa: Perceptions of subsistence farmers and meteorological data

Keywords: Historical climate, meteorological data, perceptions, subsistence farmers, Western Cape, Genadendal

Abstract

In this chapter, meteorological data and the perceptions of subsistence farmers are explored to analyse the historical climate of Genadendal, Western Cape of South Africa. The Climate System Analysis Group conducted a climate analysis for the Western Cape Province but to date no climate analysis has been developed at a scale that is more appropriate for decision-making within Genadendal. Climate changes in a specific place can be better understood using a comprehensive network of data consisting of a combination of meteorological data and perceptions. Understanding the changes in the climate of an area is particularly important for subsistence farmers who are reliant on the climate for their production. The results of this chapter provide improved knowledge on the historical climate of Genadendal dating back to 1960. They also contribute to the growing body of literature that investigates farmer perceptions of climate changes with meteorological data found in historical climate datasets. The present study makes use of subjective qualitative data (i.e. farmer perceptions) to support the results of objective quantitative data (i.e. meteorological data). However, the results from the qualitative data and quantitative data do not always agree with one another and variation also exists within each dataset.

4.1.Introduction

Climate, in a narrow sense, can be defined as the average of weather over a period of time (IPCC, 2014). According to the World Meteorological Organisation, the classical period for averaging weather to determine climate is 30 years (World Meteorological Organisation, 2017). Changes in the means of climate variables such as precipitation and temperature that persist for extended periods of time, typically decades or longer, can be defined as climate change (IPCC, 2014).

Since the 1950s, observed climate changes are unprecedented over decades to millennia (IPCC, 2014). These changes have been well documented in meteorological databases by weather services such as the South African Weather Service (SAWS, 2018) and projected by climate models (IPCC, 2014). Analysing trends in historical climate is key in understanding possible future changes in climate (Climate System Analysis Group, 2014).

However, in some cases, the availability of long-term climate data is limited even though there is a wide network of weather stations (Goodall, 2009). This is particularly true for rural areas where weather stations are not always present (Goodall, 2009). To understand trends in climate, a comprehensive network of data is required (Goodall, 2009). Thus, integrating meteorological data with observations and perceptions develops a thorough analysis of the changes in climate for a specific location (Marin, 2010).

Literature studying agriculture and climate change are increasingly taking farmers' perceptions of climate change into account (e.g. Elum, Modise and Marr, 2017; Gbetibouo, 2009; Mafongoya, 2015; Mulenga, Wineman and Sitko, 2017 and Ubisi, 2016). Furthermore, literature that explores farmers' perceptions of climate change together with meteorological databases is increasing (e.g. Shrestha and Nepal, 2016; Marin, 2010; Mulenga, Wineman and Sitko, 2017; Joshua *et al.*, 2016; Gbetibouo, 2009; Niles and Mueller, 2016). Some studies found that the perceptions of farmers could be validated by meteorological data (e.g. Shrestha and Nepal, 2016). However, other studies found that they do not always coincide (e.g. Mulenga, Wineman and Sitko, 2017 and Niles and Mueller, 2016).

The aim of this chapter was to analyse historical climate changes by analysing historical meteorological data and exploring the perceptions of subsistence farmers of changes in the climate. The hypothesis that was tested by this chapter was that the climate had changed over the years according to meteorological data and farmers' perceptions.

4.2.Methodology

4.2.1. Study area

The present study was conducted at Genadendal in the Western Cape, South Africa. The coordinates used to locate Genadendal in the extraction of the climate data were -34.041744, 19.558194. Genadendal experiences a Mediterranean climate as it is a winter rainfall area and receives an average annual rainfall of 342mm (SA Explorer, 2017). December is Genadendal's driest month receiving 13mm and August is the wettest month receiving 48mm. The average midday temperatures in Genadendal range from 15.5℃ in July to 26℃ in February. Average minimum temperatures drop to 5℃ in July (SA Explorer, 2017).

According to climate analysts, the Western Cape has gone through changes in rainfall and temperature, with temperature changes being more obvious (Climate System Analysis Group, 2014). The climate projections developed by CSAG show that an increase in temperatures is most likely to have the greatest impact in summer. Most of the climate models predict that maximum temperatures in summer will increase by 1.5°C and 2.25°C. One model does however predict that maximum temperatures will increase by up to 3°C (Climate System Analysis Group, 2014).

One of the most noticeable trends in historical rainfall in the Western Cape has been the decrease in monthly rainfall at the beginning of spring and end of summer (Climate System Analysis Group, 2014). Different climate models showing future projections of rainfall for the Western Province do not show an agreement as to the change in rainfall. Global Climate Models show a decrease in rainfall whereas the downscaled models show a slight increase in rainfall. Rainfall is more challenging to model than temperature and therefore different climate models do not always give the same prediction of changes in rainfall (Climate System Analysis Group, 2014).

4.2.2. Data collection: Sources of meteorological data

During the initial visit to Genadendal the research was introduced to the community during an induction meeting with a group of local community members. It became apparent that changes in rainfall and temperature impacts the subsistence agriculture of the community. Therefore, the climate variables to be assessed in the present study are precipitation and minimum and maximum temperature.

Multiple datasets were analysed in the present study to get a more robust outlook of the historical climate of Genadendal. The datasets used were sourced from the African Rainfall Climatology version 2 (ARC) satellite (International Research Institute for Climate and Society, 2017) the Climate Research Unit (CRU) Reanalysis v. 3.23 (Harris *et al.*, 2014), and the South African Weather Service (SAWS) (SAWS, 2018).

The ARC satellite dataset is presented at 0.1° by 0.1° spatial resolution and consists of daily temporal resolution from 1983 to 2018. The data are created by assessing infrared measures, cloud temperatures and microwave soundings. Where possible, the data are then validated against station observations to remove biases. The CRU Reanalysis dataset is presented at 0.5° by 0.5° spatial resolution and consists of monthly temporal resolution from 1960 to 2016. The data are created by modelling the climate over time and detecting station observations where applicable. Datasets recorded by the Tygerhoek weather station were requested from SAWS (SAWS, 2018) as it is the closest weather station to Genadendal. The SAWS dataset consists of monthly temporal resolution with maximum and minimum temperature data recorded from 1990 to 2018 and rainfall data recorded from 1993 to 2018. The SAWS dataset does not include a period of 30 years which may limit the results of the present study since the WMO states that climate needs to be analysed in 30 year periods (World Meteorological Organisation, 2017).

4.2.3. Data collection: Perceptions of subsistence farmers

To explore the perceptions of subsistence farmers, 23 respondents were asked whether they experienced a change in the climate since the time they started farming. Questions related to the number of rainy days per year, the intensity of rainfall, shifting rainy seasons, length of rainy seasons, average temperatures and the intensity or length of heatwaves. The questions can be seen in further detail in Addendum B: Interview questionnaire.

4.2.4. Data analysis

Linux, an operating system, was run in VirtualBox Graphical User Interface Version 5.2.6 in which National Oceanic and Atmospheric Administration Ferret Analysis and Visualisation Software was used to extract the necessary data from the datasets. After the data were extracted from the relevant datasets, Excel was used to analyse the data.

The demographic data collected during the interviews were analysed using Excel where a frequency table was created (Table 8). The data collected regarding the perceptions of subsistence farmers on climate change were analysed using SPSS Statistical 25. A correspondence analysis was carried out to determine the perceptions of subsistence farmers on climate change from the time they started farming (Table 9).

The present study lacked daily meteorological data therefore trends in frequency and intensity of rainfall events as well as heatwaves were not analysed. Conclusions were made about them based on the results of the perceptions of subsistence farmers. It is important to understand changes in severe weather events such as heatwaves and intense rainfall to assist farmers in planning for future seasons. For example, if heatwaves have been frequent in the recent past, it would be worthwhile for farmers to invest in adapting to heatwaves.

4.3.Results

4.3.1. Demographic information

Of the 23 respondents, 74% were male and 26% were female. Most respondents (n= 21) were older than 40 years of age. The youngest and oldest respondents were between 18 and 19 (n=1) and 70 and 79 (n=1), respectively (Table 8). The questions were answered by all of the respondents (n=23) meaning that the table below contains no missing data.

Table 8: Demographic information related to climate change (n=23)

Demographic	Category	Count (no.)	Count (%)
Gender	Male	17	74%
	Female	6	26%
Age	18-19	1	4%
	20-29	1	4%
	30-39	0	0%
	40-49	6	26%
	50-59	4	17%
	60-69	10	43%
	70-79	1	4%
Years of experience in farming	0-9	2	9%
	10-19	0	0%
	20-29	4	17%
	30-39	6	26%

	>40	11	48%
Source of climate information	News (on TV or radio)	17	74%
	Phone app	1	4%
	Look at clouds	4	17%
	Look at the moon and sun	1	4%
	Research institution distributed information	1	4%
	Old knowledge of weather patterns	2	9%
	Informed by someone	1	4%
	No access to information	0	0%
	Knew there would be a drought in 2016/17	4	17%

Many respondents who said that they started helping their parents in their gardens when they were children could not recall the age that they were. To calculate the number of years of experience each of these respondents have in farming, it was assumed that they started helping their parents at the age of 16. Almost 50% (n= 11) of the respondents have more than 40 years of experience. Very few respondents reported having less than 30 years of experience (n=6). This is consistent with the fact that 91% of respondents reported that their knowledge on farming had been passed on to them from older generations in their families. Most respondents had been farming since they were children and helped their parents in their gardens.

Respondents were also asked where they obtained information on the climate for short-, medium- and long-term planning. The sources of information may also have an influence on how they perceive changes in the climate. Most respondents (n=17) make use of the news broadcast on TV or radio. Two participants mentioned that the news is not reliable because predictions are not always accurate. Respondents (n=4) also look at the clouds coming over the surrounding mountains to determine whether it will rain. It was found that respondents mostly have access to information that can only be used for short-term planning. Only four respondents stated that they knew that there was a drought coming in 2016/17.

4.3.2. Meteorological data

4.3.2.1. Changes in rainfall

Figure 2 illustrates changes in rainfall per dataset by analysing the slope of the trendlines of each dataset as well as by analysing changes in anomalies per dataset. It also illustrates the correlation between the anomalies of the datasets. Due to the SAWS data only dating back to 1993 and the CRU data only dating up to 2016, Figure 2 only displays data from 1993 to 2016. The slopes of the trendlines of the

ARC and SAWS anomalies indicate that rainfall is increasing. ARC shows a larger increase than SAWS. However, the slope of the trendline of ARC anomalies may be strongly influenced by the rainfall that occurred from 2005 to 2008. According to ARC anomalies for the years 2005 to 2008, the increase in rainfall during those years was much higher than any other years. The slope of the trendline of CRU anomalies indicates that rainfall is decreasing. The largest increase in rainfall is shown by the ARC anomaly in 2008 and is approximately 500mm. The largest decrease is shown by the SAWS anomaly in 2009 and is approximately 180mm. Figure 2 also illustrates that increases and decreases in rainfall occur in cycles of a few consecutive years at a time as shown by the anomalies. For instance, the average of the anomalies for the years 2005 to 2008 indicate an increase in rainfall each year whereas the average of the anomalies for the years 2009 to 2012 indicate a decrease in rainfall each year. This is then followed by a cycle of increased rainfall from the years 2013 to 2016.

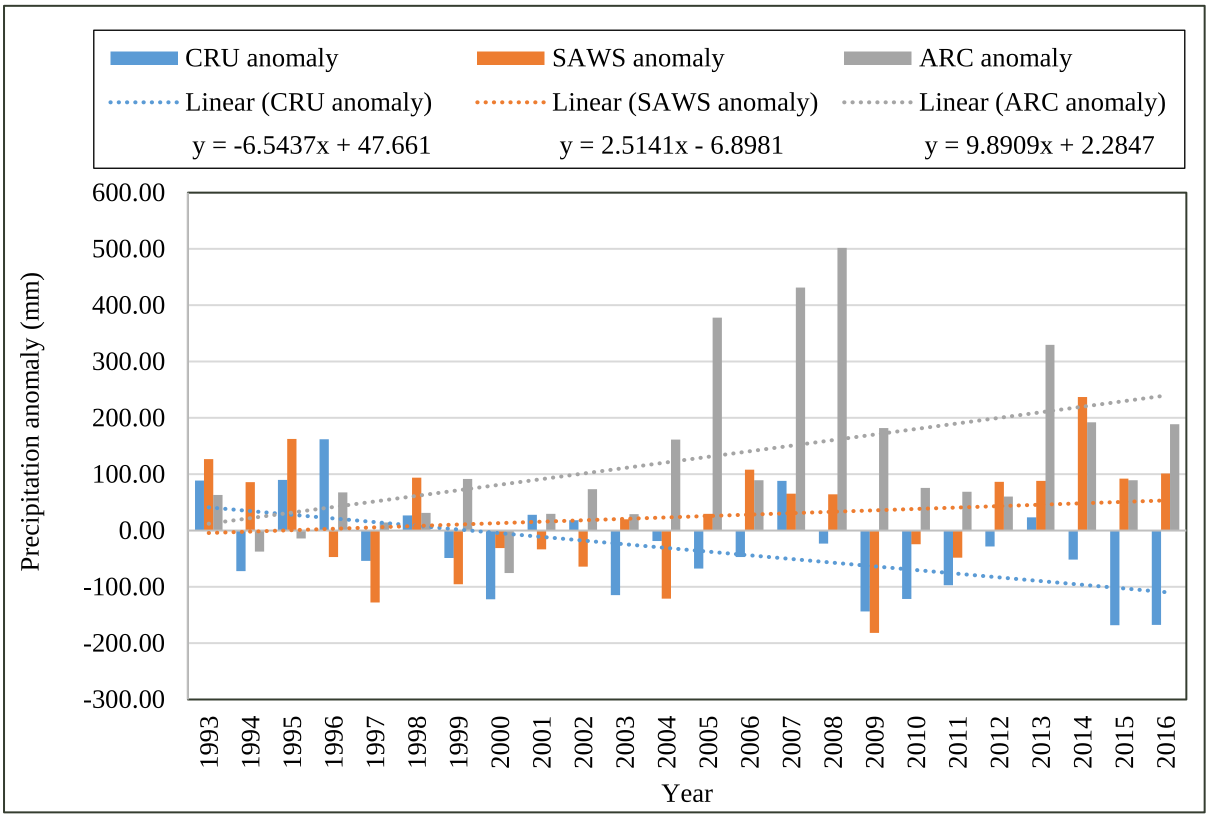

Figure 2 Changes in rainfall per dataset derived from the African Rainfall Climatology version 2 (ARC) satellite, the Climate Research Unit (CRU), and the South African Weather Service (SAWS) for the years 1993 - 2016

Figure 3 illustrates which years are dry or wet years for each dataset. SAWS data are shown from 1993 to 2017. ARC data are shown from 1983 to 2017 and CRU data are shown from 1960 to 2016. According to Figure 3 dry years occur consecutively and so do wet years. This again indicates that cycles of increased and decreased rainfall occur. The occurrence of dry and wet years is mostly different amongst datasets. However, more than one dataset agrees that 2000 and 2009 were dry years and that 1995 and 2007 were wet years.

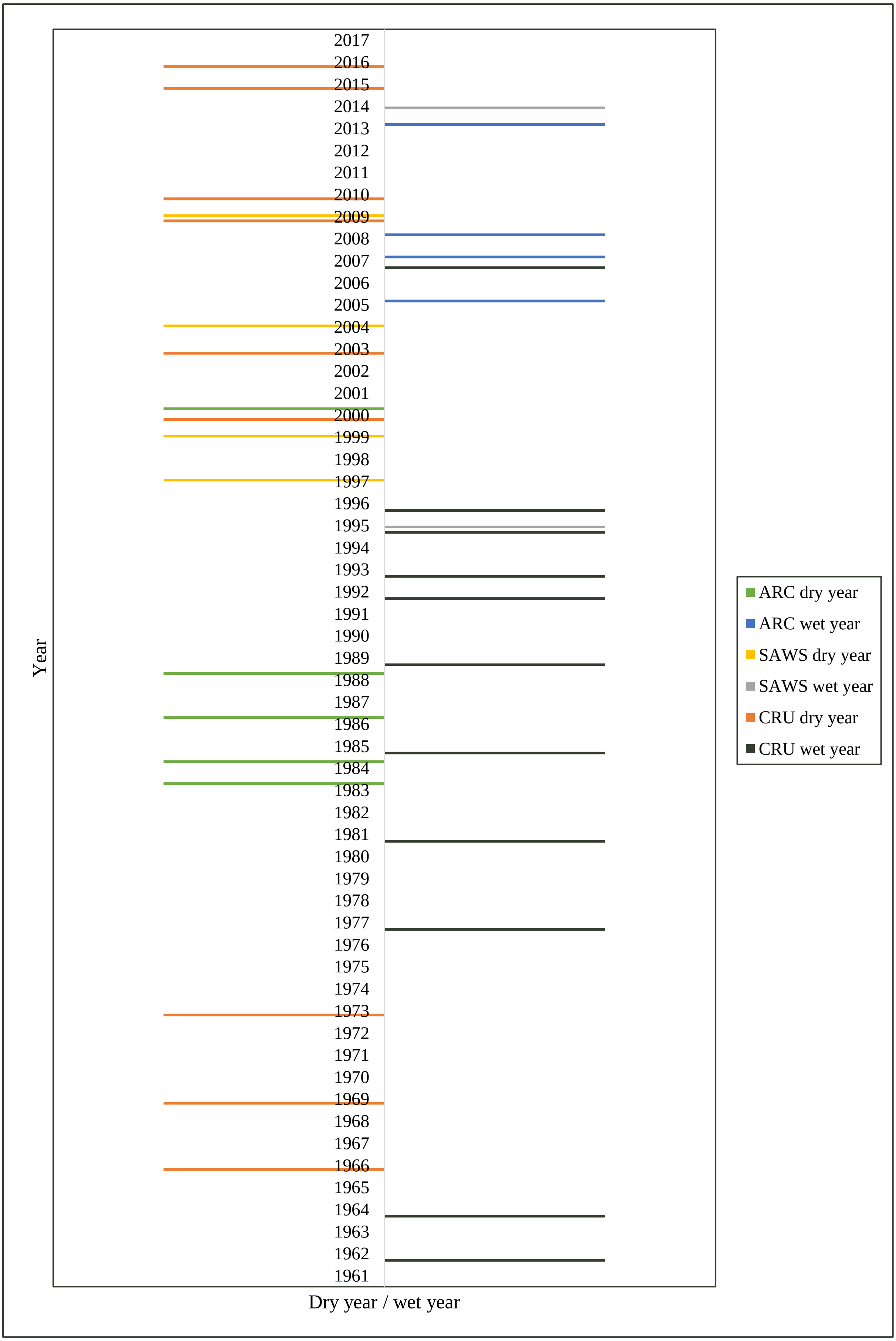

Figure 3 Dry and wet years per dataset

Figure 4, Figure 5 and Figure 6 illustrate changes in rainfall data per half decade by plotting their anomalies. The dates shown in the legend represent the start of each half decade (i.e. 1990 includes 1990-1994). These figures focus on the individual anomalies per dataset. Figure 4 indicates that January and June experienced an increase in rainfall from 1990 to 2015. It also indicates that April, May and December experienced a decrease in rainfall from 1990 to 2015. According to the graph, rainfall experienced in the other months was inconsistent or did not undergo a significant change. Figure 4 shows that the largest increase and decrease was approximately 60mm and -40mm.

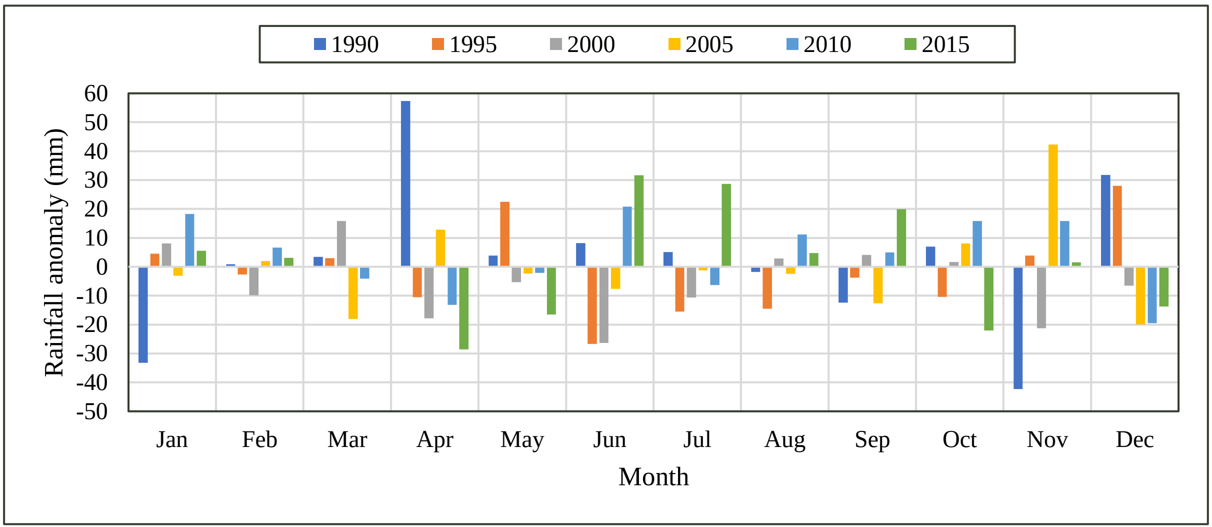

Figure 4 Changes in SAWS rainfall data per half decade from 1993 – 2017. Dates shown in the legend reflect the start of the half decade.

Figure 5 indicates that rainfall received in July and November increased. It indicates that rainfall received in January, March and December decreased. Rainfall received in September and October increased until 2005 and thereafter it decreased. It increased in February until 1995 and decreased thereafter. Rainfall received in May, June and August had an inconsistent trend throughout the years. It also shows that the largest increase and decrease was approximately 30mm.

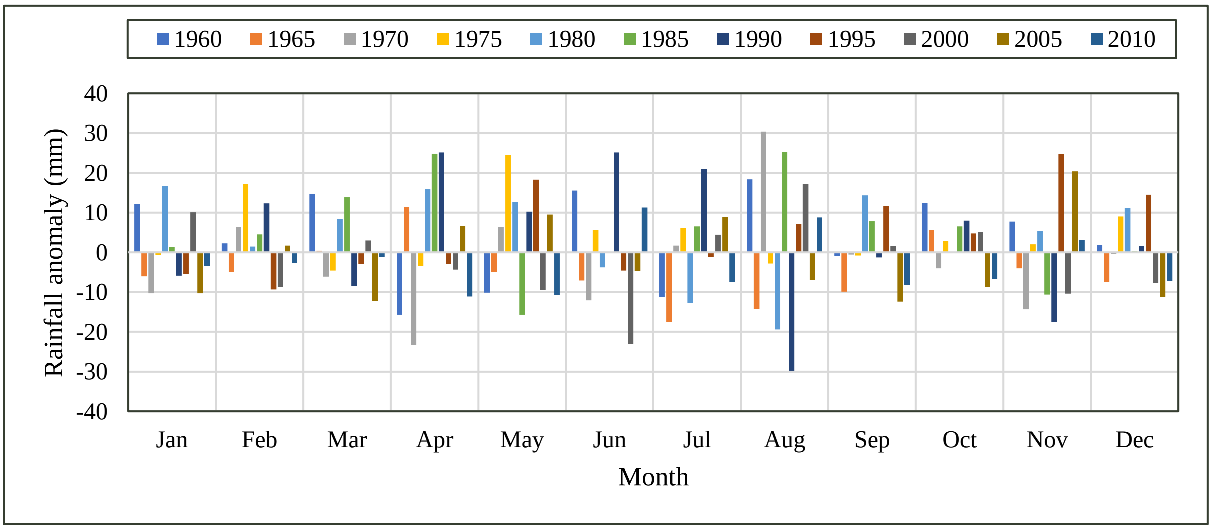

Figure 5 Changes in CRU rainfall data per half decade from 1960 – 2016. Dates shown in the legend reflect the start of the half decade.

Figure 6 indicates that the rainfall received in January increased from 1980. February and March show little change. Rainfall received in April increased until 2010 and thereafter it decreased. Except for 2005, rainfall received in May decreased. Rainfall received in June, August, September and October increased. Rainfall received in July was inconsistent. Rainfall received in November decreased until 2005 and thereafter it increased. Rainfall received in December decreased at first. It then increased from 1990 until 2005 after which it decreased. Figure 6 also indicates that increases in rainfall are larger than decreases in rainfall. It also shows that the largest increase and decrease was approximately 65mm and -35mm.

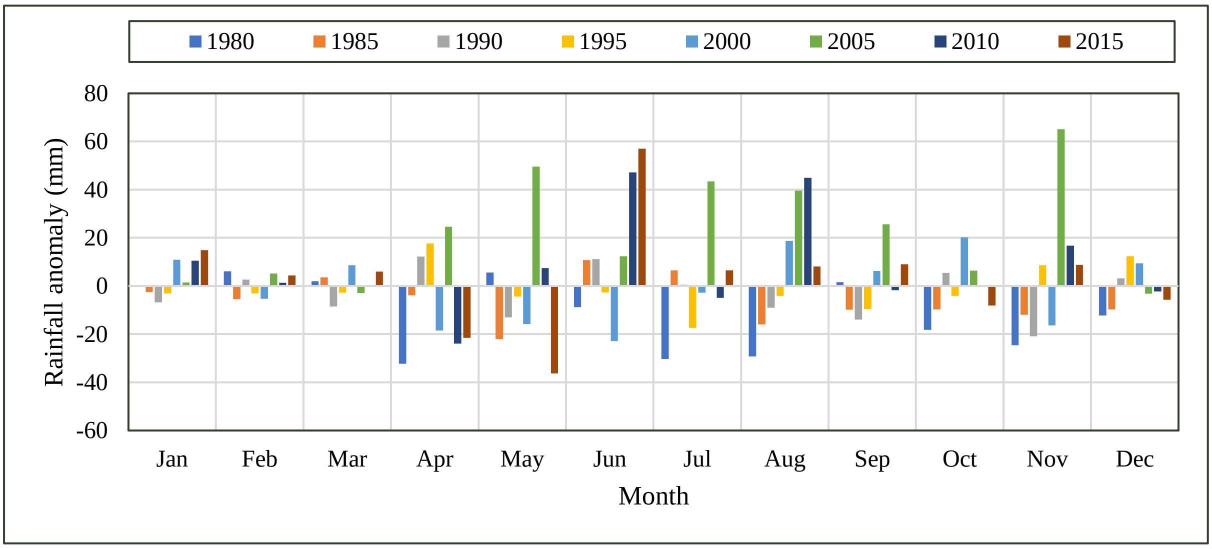

Figure 6 Changes in ARC rainfall data per half decade from 1983 – 2017. Dates shown in the legend reflect the start of the half decade.

Figure 7 illustrates changes in rainfall per month by plotting the slope of the regression lines of monthly data points for each year. Figure 7 was included in the present study to confirm the results of Figure 4, Figure 5 and Figure 6 which focuses on individual anomalies. Figure 7 illustrates that rainfall experienced in January, February, June, July, August, September, October and November is increasing. It also shows that rainfall experienced in March, April May and December is decreasing. All datasets agree that rainfall received in July and November has increased.

Changes in summer rainfall are assessed by analysing rainfall over December, January and February (DJF). Autumn is analysed from March, April and May (MAM), winter as June, July and August (JJA) and spring as September, October and November (SON). According to Figure 7, rainfall experienced in autumn (MAM) is decreasing and rainfall during winter (JJA) and spring (SON) is increasing. This is an indication that the rainfall season is starting later and ending later. Rainfall experienced in early summer (December) is decreasing but increasing towards the end of summer (January and February).

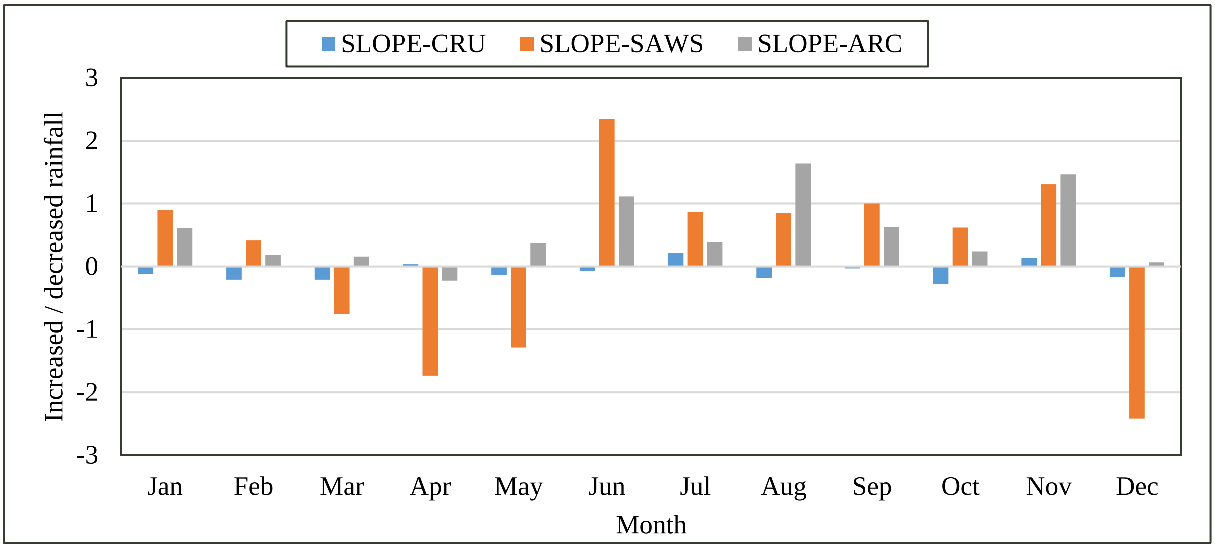

Figure 7 Changes in rainfall per month per dataset

4.3.2.2.Changes in maximum temperature

Figure 8 illustrates changes in temperature per year per dataset by analysing the slope of the trendlines of each dataset as well as individual anomalies. It also illustrates the correlation between the anomalies of the SAWS and CRU datasets. Anomalies from both datasets are mostly in agreeance that temperature has increased. However, SAWS anomalies more frequently indicate that there are some years that have been colder than usual. Anomalies from both datasets indicate that 1996 was colder than usual. The CRU dataset shows a larger magnitude of increase in temperature than SAWS. The largest increase in maximum temperature has been approximately 1.5℃ as indicated by CRU in 2016. The largest decrease in maximum temperature has been approximately 1.1℃ as indicated by SAWS in 1995.

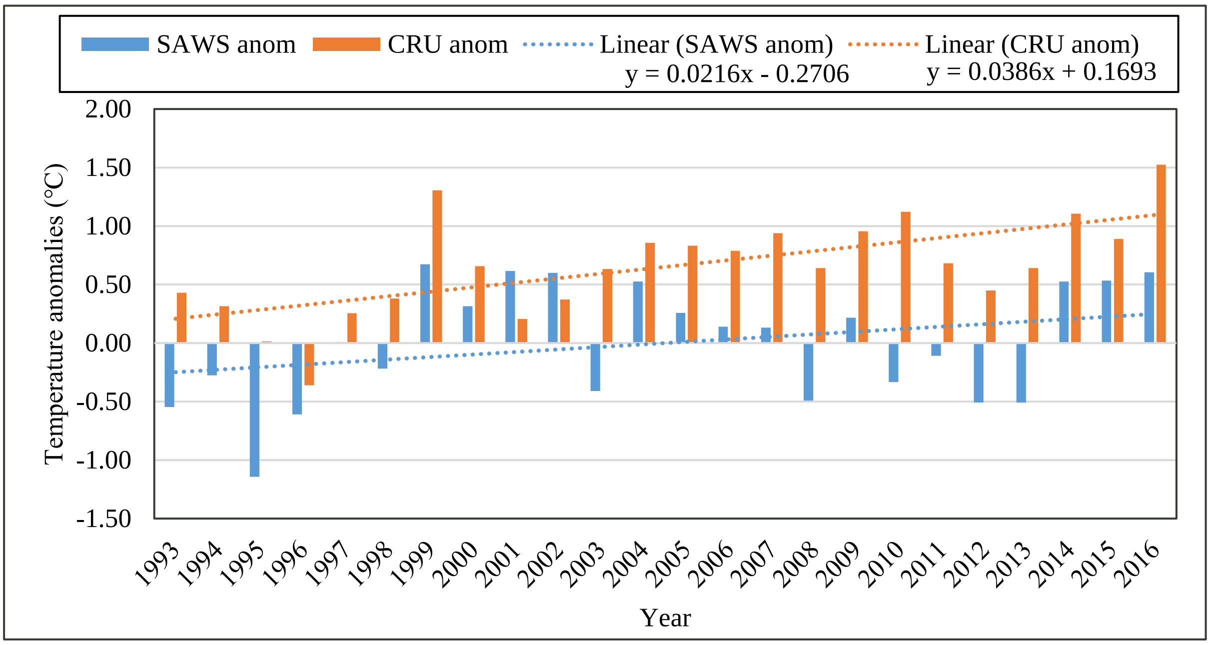

Figure 8 Changes in maximum temperature per dataset from 1993 - 2016

4.3.2.3.Changes in minimum temperature

Figure 9 illustrates the changes in temperature per year per dataset by analysing the slope of the trendlines of each dataset as well as individual anomalies. It also illustrates the correlation between the anomalies of the SAWS and CRU datasets. The slope of the trendline of SAWS data indicates that the minimum temperature has decreased whereas the slope of the trendline of CRU data indicates an increase. The largest increase in minimum temperature has been approximately 1.2℃ as indicated by both SAWS and CRU anomalies. The largest decrease in minimum temperature has been approximately 1.1℃ as indicated by the SAWS anomaly in 2016.

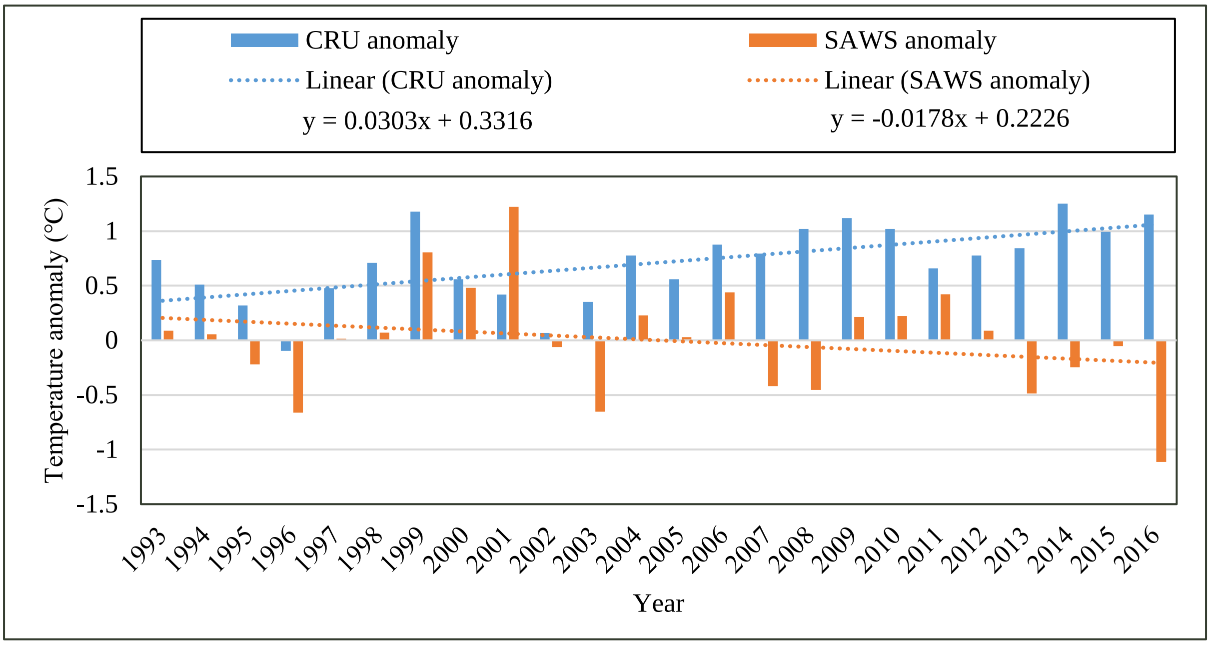

Figure 9 Changes in minimum temperature per dataset from 1993 - 2016

4.3.3. Perceptions of subsistence farmers

The perceptions of subsistence farmers with differing years of experience of farming are shown in Table 9. There are some missing data as indicated by the number of respondents (n) in the last column. Most of these data are missing due to respondents giving answers that were not useful in answering the question. This could possibly be a result of respondents not fully understanding the question that was asked. Therefore, it would be recommended that researchers undertaking any future studies on climate change refine their questionnaire to make it fully understandable by people with varying levels of climate change knowledge.

Table 9: Perceptions of subsistence farmers of climate change according to years of farming experience

Years of experience		0-9	10-19	20-29	30-39	>40	No. of respondents (n)
Rainfall frequency	Rains more often	**1**	0	1	0	1	3
	Rains less often	**1**	**1**	**2**	**5**	**5**	**14**
	No change	0	0	0	1	1	2
	Inconsistent	0	0	1	1	2	4
	Unsure	0	0	0	0	0	0
	Total no. of respondents (n)	*2*	*1*	*4*	*7*	*9*	*23*
Intensity of rainfall events	**More intense**	0	0	**4**	2	**3**	**9**
	Less intense	0	0	0	1	2	3
	No change	**1**	0	0	**3**	2	6
	Inconsistent	0	**1**	0	1	1	3
	Unsure	**1**	0	0	0	1	2
	Total no. of respondents (n)	*2*	*1*	*4*	*7*	*9*	*23*
Start of rainfall season	Starts earlier	**1**	0	0	1	1	3
	Starts later	0	0	**2**	1	**2**	5
	Starts at same time	0	0	0	1	**2**	3
	Inconsistent	0	**1**	**2**	**2**	**2**	**7**
	Unsure	**1**	0	0	0	1	2
	Total no. of respondents (n)	*2*	*1*	*4*	*5*	*8*	*20*
End of rainfall season	Ends earlier	**1**	0	0	1	0	2
	Ends later	0	0	0	1	**3**	4
	Ends at same time	0	0	1	**2**	2	5
	Inconsistent	0	**1**	**2**	1	2	**6**
	Unsure	**1**	0	0	0	1	2
	Total no. of respondents (n)	*2*	*1*	*3*	*5*	*8*	*19*
Length of rainfall season	Longer	0	0	0	0	2	2
	Shorter	**2**	**1**	**3**	**5**	**3**	**14**
	No change	0	0	0	1	2	3
	Inconsistent	0	0	1	0	1	2
	Unsure	0	0	0	0	0	0
	Total no. of respondents (n)	*2*	*1*	*4*	*6*	*8*	*21*
Changes in temperature	**Increased**	**2**	**1**	0	**3**	**3**	**9**
	Decreased	0	0	1	0	1	2
	No change	0	0	0	1	1	2
	Inconsistent	0	0	**3**	**3**	**3**	**9**
	Unsure	0	0	0	0	1	1
	Total no. of respondents (n)	*2*	*1*	*4*	*7*	*9*	*23*
Length and intensity of heatwaves	**Increased**	0	**1**	**3**	**2**	**3**	**9**
	Decreased	0	0	0	0	0	0
	No change	**2**	0	1	**2**	**3**	8
	Inconsistent	0	0	0	1	2	3
	Unsure	0	0	0	0	1	1
	Total no. of respondents (n)	*2*	*1*	*4*	*5*	*9*	*21*

The number of years of experience have been made a focal point in Table 9 due to the way the questions were asked in the questionnaire. Respondents were asked how they perceived the changes in climate from the time they started farming. The results were grouped according to the years of experience that respondents had because changes in climate differ temporally. As a result, the perceptions of farmers may vary according to the temporal scale they are referring to. For example, respondents with less than 19 years of farming experience may perceive increases in temperature but respondents with more than 19 years of experience may perceive temperatures to be inconsistent.

There is consensus amongst respondents (n=14 out of 23) that it rains less often per year now as compared to when they started farming, regardless of the number of years of farming experience. Most respondents (n=9 out of 23) perceived the intensity of rainfall events to be more intense than before. However, there was not a strong consensus of the intensity of rainfall events across years of farming experience. Only farmers with 20 to 29 and more than 40 years of experienced agreed that the intensity of rainfall had increased.

Most respondents (n= 7 out of 20) agreed that the start of the rainy season had an inconsistent pattern, regardless of the number of years of experience. Although most respondents (n=6 out of 19) said that the end of the rainy season had an inconsistent pattern, there was not a strong consensus between respondents across the number of years of experience. Only respondents with 10-19 and 20-29 years of experience agreed with one another. Most respondents (n=14 out of 21), regardless of the number of years of experience agree that the length of the rainy season has shortened since the time they started farming.

Nine of the 23 respondents stated that temperatures have increased. Farmers with 0-9, 10-19, 30-39 and more than 40 years of experience agreed that temperatures have increased. However, respondents (n=9 out of 23) also perceived them as being inconsistent since they perceive winters as being colder and summers as being warmer than before. Farmers with more than 20 years of experience agreed that temperatures have become inconsistent. Most respondents perceived the length and intensity of heatwaves as having increased (n=9 out of 21), regardless of the number of years of experience. None of the respondents perceived heatwaves as having decreased in length and intensity. The perceptions of farmers according to the number of years of farming experience is discussed in further detail in the sections below.

4.3.3.1.Years of experience: 0-9

Respondents with 0-9 years of experience (n=2) either said it rains more often or less often. They also indicated that there was no change in rainfall intensity or that they were unsure of how the rainfall intensity had changed over the last decade. They also either indicated that the rainfall seasons now start earlier and end earlier or that they were unsure of when they started and ended. Both respondents agreed that the rainfall seasons are shorter now and that temperatures had increased. Both respondents also agreed that there is no change in the length and intensity of heatwaves over the last decade.

4.3.3.2.Years of experience: 10-19

There was only one respondent with 10-19 years of experience. This respondent perceived rainfall as being less often. He/she also perceived the intensity of rainfall events as well as the start and end of rainfall events to be inconsistent. This respondent perceived rainfall events to be shorter and temperatures and length and intensity of heatwaves to have increased.

4.3.3.3.Years of experience: 20-29

Half of the respondents with 20-29 years of experience (n=4) perceived it to rain less often now as compared to when they started farming. They all agreed that rainfall events had become more intense. Half of the respondents (n=2) perceived the rainfall season to start later and the other half (n=2) perceived it as being inconsistent. They also perceived (n=2 out of 3) the rainfall season as ending inconsistently, and that the rainfall season had become shorter (n=3). They perceived the changes in temperature to be inconsistent (n=3) but the length and intensity of heatwaves as having increased (n=3).

4.3.3.4.Years of experience: 30-39

Seven respondents had 30-39 years of experience in farming, however not all of them answered all of the questions. They (n=5 out of 7) agreed that it rains less often now than in the past. They (n=3 out of 7) also perceived no change in the intensity of rainfall. There was no strong consensus on the start and end of the rainfall season amongst these respondents as it was perceived as being inconsistent. Five of the respondents perceived that the length of the rainfall season had shortened (n=5 out of 6). Changes in temperature were either perceived as having increased (n=3 out of 7) or being inconsistent (n=3 out of 7). The length and intensity of heatwaves was either perceived as having increased (n=2 out of 5) or as no change (n=2 out of 5).

4.3.3.5.Years of experience: more than 40

Nine respondents had more than 40 years of experience in farming. However, one of the respondents was not able to answer all the questions. There was a strong consensus amongst these respondents (n=5 out of 9) that it rains less often now than in the past. There was not a strong consensus amongst them of the intensity of rainfall events. However, the most common response was that they are more intense (n=3 out of 9). Similarly, there was also not a strong consensus about the start and end of the rainfall season. Respondents perceived the start of the rainfall season as starting later (n=2 out of 8), at the same time (n=2 out of 8) and inconsistent (n=2 out of 8). The most common response for the end of the rainfall season was that it ends later (n=3 out of 8). Similar responses were given for the length of the rainfall season as there was no strong consensus about the length of the rainfall season. The most common response was that it had shortened (n=3 out of 8). Respondents either perceived temperatures as having increased (n=3 out of 9) or as being inconsistent (n=3 out of 9). They perceived the length and intensity of heatwaves as having increased (n=3 out of 9) or having no change (n=3 out of 9).

4.4.Discussion

The results of the present study were based on three different meteorological datasets and the perceptions of 23 subsistence farmers. It was found that the results from the meteorological datasets are not always in agreement with one another. Furthermore, the perceptions of the subsistence farmers are also not always in agreement with one another. Thus, it is challenging to make conclusions about historical changes in the climate of Genadendal with certainty. However, it is common for meteorological datasets to show results that are inconsistent with one another (e.g. Jack *et al.*, 2016, Novella and Thiaw, 2013). There are numerous reasons for the inconsistency.

Firstly, the datasets used in the present study are of different resolutions i.e. different spatial scales. ARC data is captured at approximately 5km resolution whereas CRU data is at a lower resolution than ARC. The SAWS data was captured by a weather station at a single point. Large landscapes cover regions that have varying potential for climate-related hazards such as droughts, floods and extreme weather events (World Climate Research Programme, 2018). This prevents higher resolution models from capturing local characteristics that modulate the local climate (Giorgi, Jones and Asrar, 2009).

Secondly, inconsistency may exist in the present study due to the datasets being captured in different manners. As mentioned in Section 4.2.2, CRU data is modelled over time but is enforced by over 4000 station observations globally. Therefore, CRU contains major deviations in areas that have sparser observational data (Harris *et al.*, 2014). ARC data consist of infrared measures, cloud temperatures and microwave soundings (International Research Institute for Climate and Society, 2017). SAWS data are actual observed data at a single point (SAWS, 2018).

Thirdly, climate variables contain natural variation and are challenging to model (Climate System Analysis Group, 2014). Rainfall is particularly challenging to model due to its temporal and spatial variation. It varies over very short distances due to microclimate and topography (Kidd, 2001). As a result, weather stations may not always accurately record rainfall of surrounding areas (Kidd, 2001).

To make more informed decisions on climate change adaptations at national and regional scales, climate models need to provide greater detail (World Climate Research Programme, 2018). Therefore, it can be said that a spatial scale gap exists between the climate information provided by high resolution models (such as the climate analysis provided by CSAG (2014) for the Western Cape Province) and the climate information needed for climate change responses (Giorgi, Jones and Asrar, 2009). It can also be said that there is a need to present climate change information at a local scale to assess the impacts of climate change specific to certain human and natural systems. The development of suitable adaptation responses can then be guided (Giorgi, Jones and Asrar, 2009).

The results of the present study show that variability in the rainfall data does not only exist between datasets but within them as well. Rainfall in Genadendal is highly variable from decade to decade and even from year to year. Such unpredictable changes in rainfall can make it challenging for subsistence farmers to adapt their production accordingly. However, respondents perceived that rainfall frequency and intensity had changed and they recognised new trends (i.e. less frequent and more intense rainfall). Climate adaptation responses may differ amongst farmers who perceive new trends in rainfall as compared to those who do not.

The results derived from the meteorological data indicate that the rainfall season has been shifting. There has been an increase in rainfall in winter, spring and late summer and a decrease in early summer and autumn. These results are contrary to the trends in the Western Cape's rainfall as found by CSAG (2014). The Western Cape's rainfall trends indicate that there has been a decrease in rainfall at the beginning of spring and end of summer (Climate System Analysis Group, 2014). The contrast could be because the meteorological data used in the present study is of a resolution more suitable to take local topology into account. Respondents perceived the changes in the start and end of the rainfall season to be inconsistent and the length of the rainfall season to be shorter.

Changes in Genadendal's maximum temperature according to the meteorological datasets show an increase from 1993 to 2016 for the CRU and SAWS datasets. These results are consistent with those found by CSAG (2014). Respondents also agreed that temperatures have been increasing (particularly summer temperatures). Conclusions about the changes in Genadendal's minimum temperature according to the meteorological datasets can be made with less certainty than the maximum temperature. This is because the two datasets disagree with one another. CRU indicates an increase in minimum temperature from 1993 whereas SAWS indicates a decrease. CSAG (2014) found that there has been an increase in minimum temperatures at some weather stations whereas others show a decrease. However, respondents perceived minimum temperatures to have decreased (particularly winter temperatures).

Many of the subsistence farmers who felt that climate is changing found it challenging to explain exactly how it has changed. When asking respondents about their perception of changes in climate from the time they started farming they were easily able to recall the recent changes in climate for the last two to five years. Recalling changes in climate before the last five years became more challenging for respondents. It is therefore recommended that an alternative method to interviews is used to help respondents better remember past climate-related events. One example of an alternative method is a participatory calendar-making process where respondents are asked to recall the occurrence of past climate-related hazards.

Furthermore, the recent drought in the Western Cape may have influenced respondents' perceptions of changes in climate. Due to it being a recent event, respondents were easily able to recall its impacts. Respondents often spoke about the last two years. For example, one respondent said that it has gotten hotter now since the time he/she started farming. This respondent also emphasised that last summer was very dry and hot.

The source of climate information accessed by each respondent may also influence their perceptions. Having access to climate information also assists subsistence farmers in planning. Every respondent had access to at least one source of climate information. Most of the respondents reported that they accessed climate information via the news broadcast on TV or radio. This indicates the importance of having access to appliances such as TV and radios. However, these respondents reported only being informed of short term weather forecasts. Very few respondents had access to information regarding long-term future climate trends.

For subsistence farmers in Genadendal to plan for upcoming seasons it is important for them to access information regarding future predictions. This can help them plan what to plant or which livestock to keep, sell or slaughter. This information would be particularly important for the respondents that said they are sometimes or always reliant on the climate for production. However, one respondent that has access to irrigation stated that climate information was not necessary for him/her because he/she looks at the individual needs of the plants. He/she monitored the colour of the plants and watered them accordingly. However, planning becomes increasingly necessary as water restrictions limit the amount of irrigation permitted.

4.5. Conclusion

The results of the present study show that the historical climate of Genadendal has changed according to meteorological data and the perceptions of subsistence farmers. However, conclusions about how they have changed cannot be made with certainty. This is because the meteorological datasets used in the present study do not always agree with one another and the perceptions of subsistence farmers also differ from one another. It can therefore be said that the results of both the subjective qualitative data (i.e. perceptions of farmers) and the objective quantitative data (i.e. meteorological data) vary.

Future climate change studies in Genadendal should analyse meteorological data dating back further than 30 years to be consistent with the definition of climate change given by the WMO. An alternative method of obtaining information on the perceptions of subsistence farmers should also be used in future climate change studies. A participatory calendar-making process is one example of an alternative method that can be used to assist subsistence farmers in better recalling the occurrence of past climate-related hazards.

Chapter 5 – Impacts of climate change on the four dimensions of food security in Genadendal, Western Cape of South Africa

Keywords: Climate change impacts, subsistence agriculture, dimensions of food security, Western Cape, Genadendal

Abstract

In this chapter, results obtained during interviews with subsistence farmers are analysed to determine the impact of climate change on the four dimensions of food security (Chapter 1), namely food availability, food access, food utilisation and food stability, in Genadendal, Western Cape of South Africa.

5.1.Introduction

As mentioned in Chapter 1, the definition of food security is "when all people, at all times, have physical and economic access to sufficient safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life" (FAO, 1996). From this definition, the FAO identified four dimensions of food security which are food availability, stability, access and utilisation, and states that households may be food insecure when at least one of the four dimensions are uncertain (FAO, 2008). Figure 10 summarises the definitions of each dimension of food security as was explained in Chapter 1. The bolded bullet points are the factors that were addressed by the present study.

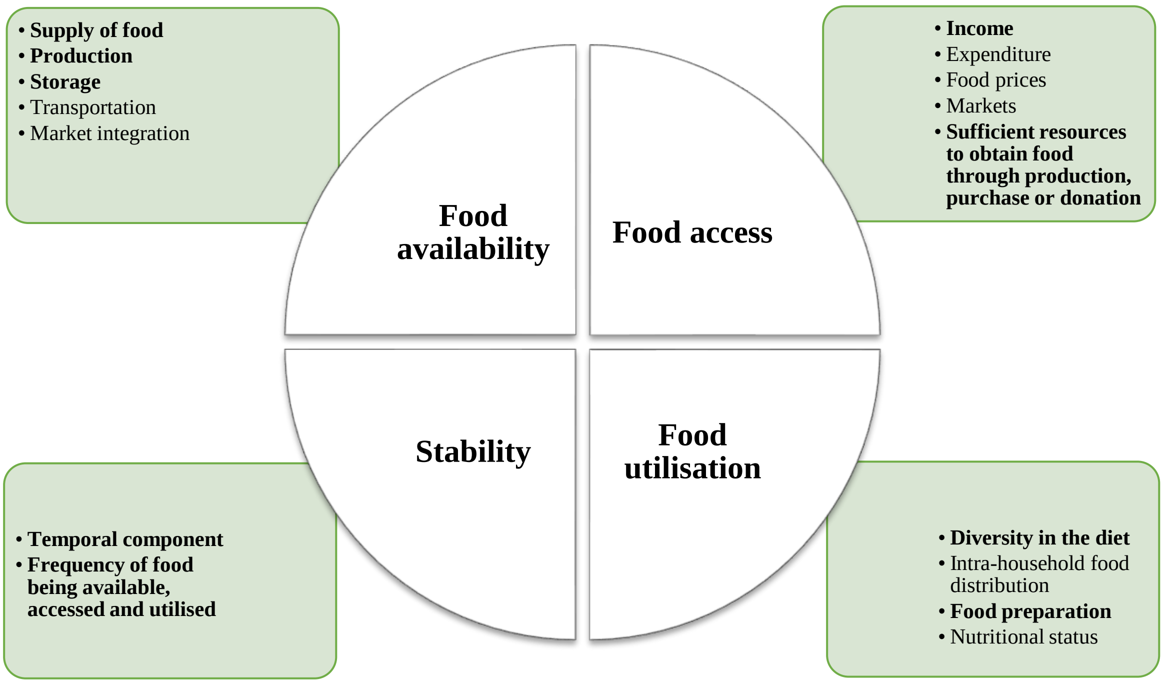

Figure 10 Schematic of the four dimensions of food security as defined by the FAO (2008)

Subsistence agriculture supplements household food security through consumption and/or sale of produce (Averbeke and Khosa, 2007; Aliber and Hart, 2009; Baiphethi and Jacobs, 2009; Hart, 2011; Mashamaite, 2014). It assists households in mitigating high food prices and reduces the risk of households being food insecure (Baiphethi and Jacobs, 2009). In the past, rural households produced the majority of their food, but recent studies show that they are increasingly becoming dependent on market purchases (Baiphethi and Jacobs, 2009).

Moreover, there is a large body of literature stating that climate change impacts the food security of subsistence farmers (e.g. AgriSA, 2016; Martens, 2015; Midgley and Methner, 2016; Mugambiwa and Tirivangasi, 2017; Senyolo *et al.*, 2018; Shrestha and Nepal, 2016; Tibesigwa, Visser and Turpie, 2014). This is partly a result of the quality and yields of crops being affected (Mugambiwa and Tirivangasi, 2017) and the health of livestock being put at risk (Wilk, Andersson and Warburton, 2013). Furthermore, food prices increase (AgriSA, 2016; Funk, 2011; Godfray *et al.*, 2010) in some cases by up to 47%, as was seen for the price of maize meal during South Africa's severe drought of 2016 (AgriSA, 2016).

However, implementing climate change adaptation responses can make subsistence farmers more resilient to the impacts of climate-related hazards (Bryan *et al.*, 2009; Dassanayake *et al.*, 2018; Maponya, 2012 Senyolo *et al.*, 2018). For example, the severity of climate-related hazards on a household that practices subsistence agriculture depends on the amount of income the household earns and its ability to compensate loss in production (Seaman *et al.*, 2014). In addition, households may make use of natural resources such as irrigation or purchase additional food to compensate for production losses (Tibesigwa *et al.*, 2016).

Thus, the aim of this chapter was to investigate the impacts of climate-related hazards on the dimensions of food security for households who practice subsistence agriculture. The first hypothesis tested by this chapter was that climate-related hazards have an impact on the four dimensions of food security. The second hypothesis was that subsistence farmers use numerous adaptation responses to overcome impacts of climate-related hazards. To test these hypotheses, the objectives of this chapter were to investigate:

1. The manner in which subsistence agriculture achieves food security with a focus on consumption and income;
2. The impacts of climate-related hazards on each dimension of food security namely, availability, access, utilisation and stability; and
3. The responses that subsistence farmers adopt to overcome climate-related hazards.

5.2.Methodology

5.2.1. Study area

The present study was conducted at Genadendal in the Overberg District Municipality, Western Cape of South Africa.

In this province, 27.5% of agricultural households engage in animal farming only, 58% in crops only, 10.2% in mixed farming and 4.3% in other types of farming (Statistics South Africa, 2017). Although the aforementioned percentages may not apply to Genadendal, subsistence farmers in Genadendal are known to engage in different types of farming with many having engaged in mixed farming at some point in time (Krüger, 1966; Krüger and Schaberg, 1966). Plots of land in Genadendal that are used for agriculture are often small in size. The locals refer to them as '*tuine*' in Afrikaans which translates to 'gardens'. Most subsistence farmers in Genadendal fence off their vegetable gardens and allow their livestock to graze freely in open areas.

The Overberg District Municipality Climate Change Response Strategy (Birch *et al.*, 2017) states that food security in the District will decrease with climate change due to increased frequency of drought, flood, fire, wind and extreme weather events. It also states that rainfall patterns are becoming more variable. The strategy highlights that May, the usual planting month is becoming drier. It also states that pest occurrence and distribution is changing and that higher temperatures will impact crop yield and quality and cause heat stress in livestock.

In addition, the extensive history of Genadendal as documented by Krüger (1966) and Krüger and Schaberg (1966) documents many climate-related hazards that occurred in the town. These climate-related hazards caused famines in the past despite efforts to develop agriculture. Thus, Genadendal is a suitable location for studies focusing on subsistence agriculture and climate change in the Western Cape.

5.2.2. Data collection

Similar to van der Merwe, Cloete and van der Hoeven (2016), the present study uses the definition of food security as defined by the FAO as a framework to develop the questions that would be asked during the interviews. Questions focussed on the impacts of climate change on the four dimensions of food security namely food availability, access, utilisation and stability. The first dimension, food availability, was computed by determining the supply levels of food in each household. This was done by determining if products were produced in the gardens (production levels) as well as identifying alternative sources of food (supply levels) that are used when production in the garden is poor.

The second dimension, food access, was computed by determining if each household had sufficient resources (such as income or social networks) to obtain food. Therefore, the questionnaire included questions on whether the income made from the sale of crops was used to buy other food or whether the household received income from off-farm activities. The present study focused on the role of subsistence agriculture in achieving food security therefore did not go into detail about the income made from off-farm activities. Respondents were also not asked to report on the amount of income made from subsistence agriculture but rather emphasised the importance of the income to each respondent.

The third dimension, food utilisation, was computed by exploring the diversity of production, food preparation and food storage. The fourth dimension, stability, was computed by determining how often the household experienced production losses due to the impacts of climate-related hazards and the frequency of climate-related hazards. If respondents reported that production losses were due to other causes instead of the impacts of climate-related hazards, they were not asked about the frequency of climate-related hazards. The study also collected data on how households usually overcome the impacts of climate-related hazards to explore the climate change adaptation responses used in Genadendal. The questions that were asked during the interviews can be seen in further detail in Addendum B: Interview questionnaire.

5.3. Data analysis

The demographic information collected during the interviews was analysed using Excel where a frequency table was created (Table 10). The data collected regarding the impact of climate change on the food security of households were analysed using software package SPSS Statistical 25. Descriptive statistics were generated using SPSS to explore the role of subsistence agriculture in providing food security. A correspondence analysis was carried out to determine whether respondents rely on subsistence agriculture for income (Table 12). Lists of the crops planted (List 1), livestock kept (List 2), impacts of climate-related hazards (List 3) and adaptation responses (List 4) resulted from thematic analysis of responses to questions.

5.4.Results

5.4.1. Missing data

As explained in Chapter 2, missing data can occur during interviews. In this chapter, data are missing for some questions for some respondents because some of the information obtained is not useful. Respondents often answered with information that was needed to answer the question. In addition, if respondents reported not being impacted by climate-related hazards, questions relating to climate-related production losses were not asked.

5.4.2. Demographic information

The following section describes Table 10: Demographic information. Some of the questions tabulated below were not answered by all the respondents (n=23). Therefore, the number of responses is indicated in the table to show how many respondents answered each question. The questions that have missing data relate to the number of dependents in the household and the respondents' role in the household.

Table 10: Demographic information for interview respondents (n=23). Not all questions were answered in every instance, resulting in variable number of responses.

Measure	Category	No. of responses (n)	Count (no.)	Count (%)
Gender	Male	23	17	74%
	Female		6	26%
Age	18-19	23	1	4%
	20-29		1	4%
	30-39		0	0%
	40-49		6	26%
	50-59		4	17%
	60-69		10	43%
	70-79		1	4%
Number of people in household	1	23	0	0%
	2		3	13%
	3		5	22%
	4		9	39%
	5		3	13%
	6		3	13%
Number of dependents in household	0	20	2	10%
	1		4	20%
	2		2	10%
	3		5	25%
	4		4	20%
	5		2	10%
	6		1	5%
Role in household	House wife	20	2	10%
	Father / husband		7	35%
	Breadwinner		1	5%
	Mother		2	10%
	Son, helps dad in garden		2	10%
	Grandmother		1	5%
	Ensure everything in the house is going well		3	15%

	Granddaughter, looks after children		1	5%
	Head of household		1	5%
Source of information needed for farming	Extension services	23	2	9%
	Family or friends		4	17%
	Passed on from generation-to-generation		21	91%
	Own experience		4	17%
	Internet		1	4%
	Books		3	13%
	Courses		6	26%
	Agriculture Committee		1	4%
	Agriculture Department		1	4%
	Other farmers		4	17%
	Research		1	4%
	Talks		1	4%
	Learns from things that are taught to kids at school		2	9%
	Small farmer initiative		1	4%
	Worked on farms		1	4%

As already discussed in Chapter 3, 74% and 26% of the respondents were male and female, respectively. Many respondents (n=11) were pensioners above the age of 60. The largest household size was six. Four people per household was the most common household size followed by three. Most households had three dependents. The information obtained for the roles that respondents play in the household is also presented in Table 10: Demographic information. This was an open-ended question in the questionnaire, so respondents responded (n=20) with their own definition of their roles. As most respondents were male, most respondents saw themselves as the father and husband in the household.

The respondents reported having numerous sources for the information they need for farming. Almost all the respondents (n=21) obtained information that was passed on from generation-to-generation. Many also obtained information through courses that they studied (n=6), from family or friends (n=4), their own experience (n=4) and other farmers (n=4). Very few respondents relied on extension services as a source of information. Other governmental sources such as the Agriculture Committee and the Agriculture Department also played a small role in providing information to the subsistence farmers.

Respondents were also asked what size their farms are. However, most participants did not know the size in hectares and so expressed the size as being a reasonably big piece of land. This is a very subjective response and may mean different sizes for different respondents. Therefore, the question was excluded from the results of the study. It is recommended that the land be measured by researchers in any future studies that may be wanting to investigate this question further. Sizes given by respondents who did know the size of their land in hectares ranged from less than one hectare to 20 hectares, with most being one or two hectares in size.

5.4.3. Manner in which subsistence agriculture contributes to food security

The following section describes Table 11 which contains information related to the manner in which subsistence agriculture contributes to food security. The questions asked were answered by all of the respondents that were applicable. All respondents (n=23) used their production in the household and almost all of them (n=22) sold their produce, but sharing was also quite important (n=14). Only one respondent stated that the purpose of the production was for household use and/or to give away and not to sell. This respondent stated that he/she had an alternative source of income. Of the respondents that sell their produce (n=22), 18 said that the income is important in the household. Most of these respondents (95%) also said that they use the income to buy other food for the household. Only one respondent said that the income is not used to buy other food but rather covers the expenses of farming such as buying seed.

Table 11: Manner in which subsistence agriculture contributes to food security

Measure	**Category**	**Count (no.)**	**No. of applicable respondents (n)**	**% of applicable respondents**
Purpose of production	Use in household	23	23	100%
	Sell	22		96%
	Give away	14		61%
Important source of food	Yes	23	23	100%
	No	0		0%
Important source of income	Yes	18	22	82%
	No	4		18%
	Not applicable (do not sell produce)	1		-
Use income to buy other food	Yes	21	22	95%
	No	1		5%
	Not applicable (do not make an income from produce)	1		-
Have other source of income	Always	17	23	74%
	Sometimes	3		13%
	Never	3		13%

A correspondence analysis was carried out (Table 12) to determine whether respondents rely on subsistence agriculture for income. Three respondents stated that they do not have another source of income but only two of these said that the income from the produce was an important source of income. The other respondent said that it was not an important source of income. Another three respondents only sometimes have other sources of income. Only one of these respondents said the income from the sale of produce is not an important source of income, the other two said it is. Fourteen respondents said the income from the sale of produce is important for the household even though they have another source of income. Two respondents said that it was not an important source of income and stated that they have other sources of income.

Table 12: Correspondence analysis showing reliance on subsistence agriculture for income

Sale of produce is an important source of income	**Other sources of income**			
	Always	**Sometimes**	**Never**	**No. of respondents (n)**
Not applicable (do not sell produce)	1	0	0	1
Yes	14	2	2	18
No	2	1	1	4
No. of respondents (n)	17	3	3	23

Correspondence analyses were also carried out to determine the effect of production losses due to climate-related hazards on the manner in which subsistence agriculture contributes to food security (Table 13). Of the 23 respondents that stated that the food they produced was an important source of food, 16 experienced at least some losses in production due to climate-related hazards. The 12 respondents who stated that the sale of produce was an important source of income experienced some losses. Of the 21 respondents that said they used their income from the sale of produce to buy other food, 15 experienced at least some losses in production due to climate-related hazards. Only two respondents who experience some production losses do not have another source of income.

Table 13: Correspondence analyses to determine effect of production losses on the food security of interview respondents (n=23)

Production losses	**Important source of food**			**Important source of income**			**Use income from sale of produce to buy other food**			**Other source of income**			
	Yes	**No**	**No. of responses (n)**	**Yes**	**No**	**No. of responses (n)**	**Yes**	**No**	**No. of responses (n)**	**Always**	**Sometimes**	**Never**	**No. of responses (n)**
Overall losses	0	0	**0**	0	0	**0**	0	0	**0**	0	0	0	**0**
Some losses	16	0	**16**	12	4	**16**	15	1	**16**	12	2	2	**16**

No losses	3	0	**3**	3	0	**3**	3	0	**3**	2	0	1	**3**
Other causes	4	0	**4**	3	0	**3**	3	0	**3**	3	1	0	**4**
No. of responses (n)	23	0	**23**	18	4	**22** (1 not applicable)	21	1	**22** (1 not applicable)	17	3	3	**23**

A list of the crops planted (List 1) and livestock kept (List 2) as mentioned by respondents during the interviews is given below. The lists are not exhaustive as respondents would mention another type of crop and/or livestock later in the interview. This was taken to be an indication that some respondents may not have mentioned all the crops and livestock that they produce. Respondents would also mention a few crops and then follow with 'etcetera'.

List 1: Crops planted as mentioned by respondents

Peas	Lemons	Berries
Onions	Patty Pans	Peaches
Potatoes	Parsley	Tomatoes
Pumpkin	Celery	Bananas
Gem Squash	Fig Trees	Sweet potato
Spinach	Cucumber	Butternut
Carrots	Lettuce	Corn
Turnips	Garlic	Oats
Cabbage	Chilli	Broccoli
Cauliflower	Rocket	Sunflowers
Honey Bush Tea	Beetroot	
Green Beans	Leaks	

List 2: Livestock kept as mentioned by respondents

Pigs	Chickens
Cattle	Horses (for trail rides or ploughing)
Dairy cows	Donkeys (for ploughing)

5.4.4. Impacts of climate change on subsistence agriculture

Most respondents (n=15 out of 23) reported that they were not reliant on the climate for their production. This was because they had access to water for irrigation. Some respondents reported that they irrigated on hot days to overcome high temperatures. Some respondents reported having water for irrigation but stated that they experienced challenges (n=3 out 23). These challenges included water losses caused by flood irrigation due to degrading infrastructure. They also experienced challenges due to the irrigation channels being blocked by debris or being closed off by other subsistence farmers. The rest of the respondents (n=5) had no access to water for irrigation and were reliant on rainwater harvesting.

The following is a list of all the impacts of climate-related hazards that respondents mentioned during the interviews (List 3). The list may not be exhaustive because it is possible that respondents may have forgotten to mention impacts on the day of the interview. In addition, some of the impacts below were mentioned more than once by different respondents. However, for the sake of recording local knowledge on the impacts of climate change in Genadendal a list was generated.

List 3: Impacts of climate-related hazards on subsistence agriculture as mentioned by respondents

- Wind blows the trees over and blows plants out of the ground
- Wind causes crops to be covered by sand
- Cannot plant throughout the year anymore
- Stress on vegetables
- Soil erosion caused by rain and wind (land degradation)
- Hail damages vegetables and fruit
- Have to replant if crops get damaged which increases expenses
- Frost burns crops and causes rusting of plants
- Drought reduces available grazing
- Change in planting seasons due to changing rainfall
- Harsh climate (such as frost, hail, floods and hot days) kills seedlings
- Crops ripen faster
- Sun burns crops
- Crops grow slowly in winter months and are smaller or the seedlings are killed so the crops do not grow at all

Table 14 contains information on how the aforementioned impacts of climate-related hazards (List 3) affect the food security of households in Genadendal. Each question was asked to understand how climate change affects the dimensions of food security namely, availability, access, utilization and stability (defined in Chapter 1). The results presented in Table 14 are discussed in sections 5.4.4.1. to 5.4.4.4. according to the food security dimension addressed.

Table 14: Impacts of climate change on the food security of interview respondents (n=23)

Measure	**Food security dimension addressed**	**Category**	**Count (no.)**	**No. of applicable responses**	**% of applicable responses**
Frequency of climate-related hazards and impacts	Stability	Often	1	23	4%
		Sometimes	7		30%
		Rarely	15		66%
Occurrence of production losses due to impacts of climate-related hazards	Availability	Overall losses	0	23	0%
		Some losses	16		70%
		No losses	3		13%
		Due to other causes	4		17%
Frequency of climate-related production losses	Stability	Often	3	16	19%
		Sometimes	11		68%
		Rarely	2		13%
		Not applicable (production losses due to other causes / no losses experienced so question was not asked)	7		-
Alternative sources of food if production losses are experienced	Availability / Access	Shop	20	20	100%
		Buy from neighbour / friend / family	1		5%
		Trade with neighbour / friend / family	8		40%
		Neighbour / friend / family gives you food for free	1		5%
		Not applicable (do not experience production losses so question was not asked)	3		-
Food from alternative source is similar to production	Utilisation	Yes	16	20	80%
		Some food	4		20%
		No	0		0%
		Not applicable (do not experience production losses so question was not asked)	3		-

Production losses affect grocery budget	Access	Always	17	18	95%
		Sometimes	0		0%
		Never	1		5%
		Not applicable (do not experience production losses so question was not asked)	3		-
		Missing data	2		-
Storage for harvests	Availability	Yes	20	20	100%
		No	0		0%
		Missing data	3		-
Change in food preparation due to impacts of climate-related hazards	Utilisation	Yes	2	20	10%
		No	18		90%
		Missing data	3		-

5.4.4.1.Availability

All the respondents (n=23) said that their subsistence agriculture was an important source of food for their households. Therefore, food availability was firstly assessed by investigating the occurrence of production losses due to the impacts of climate-related hazards. This was investigated by determining whether respondents experience overall production losses, only some losses, no losses or losses due to causes other than climate change. No one reported experiencing overall production losses. Most respondents (n=16) stated that they experienced some losses. Three respondents experienced no losses and four others experienced losses but due to causes other than climate-related hazards.

Food availability was secondly assessed by asking respondents if they have alternative sources of food such as shops, neighbours, friends or family. All of the respondents (n=20) reported that there was food available at shops. Respondents could also buy (n=1), trade (n=8) or get food for free (n=1) from their friends, neighbours or family. Their ability to access the food available at the abovementioned sources is discussed in Section 5.4.4.2. below. Food availability was also assessed by whether respondents had storage for their harvests. All of the respondents (n=20) reported that they did have storage for their harvests.

5.4.4.2.Access

Food access was assessed by asking respondents questions about their income. Of all the respondents (n=22), 82% said that the income made from selling produce was an important source of income. Only 74% of respondents always had another source of income other than their farming activities. Pension was included as an alternative source of income. Ninety-five percent of respondents stated that production losses affected their grocery budgets.

5.4.4.3.Utilisation

Utilisation was assessed by determining if food that was obtained from alternative sources during times of production losses, were similar to those that would have been produced. Of all the respondents (n=20), 16 said that the food that they obtained from other sources was similar to what they would have produced themselves. The other respondents (n=4) said that they obtain some of the same products from alternative sources but also obtain products such as sugar and coffee. Utilisation was also assessed by determining whether the impacts of climate-related hazards changed the way food was prepared. Only two respondents felt that their food preparation methods had changed.

5.4.4.4.Stability

To assess the stability of food security respondents were asked about the frequency of climate-related impacts and the frequency of production losses. A correspondence analysis was also conducted to determine the combined impact of the frequency of climate-related hazards and occurrence of production losses. Most respondents said that the impacts of climate-related hazards occurred rarely (n=15). Nine of these respondents reported experiencing some losses when climate-related hazards occurred. Therefore, if climate-related hazards occurred more frequently, these respondents would experience some production losses more often. Only one respondent reported that the impacts of climate-related hazards occurred often. This respondent reported that when they do occur some production losses are experienced. Respondents also reported that climate-related hazards only occur sometimes (n=7). Most of these respondents also experienced some losses (n=6).

When asking respondents about the frequency of climate-related production losses, seven respondents were reported as not applicable. This was either because they experienced losses due to other causes or they said that they do not experience production losses. Most respondents (n=11) experience production losses sometimes, three experienced them often and only two said rarely.

5.4.5. Climate change adaptation responses

The following list is a list of all the climate change adaptation responses implemented that respondents mentioned during the interviews. Some of the adaptation responses below were mentioned more than once by different respondents. However, for the sake of recording local knowledge on climate change adaptation responses used in Genadendal a list was generated of the different responses.

List 4: Climate change adaptation responses implemented as mentioned by respondents

- Fertiliser made of chicken manure mixed with cow and horse manure or with compost to suppoprt crop growth
- Shade nets to protect their nursery from the heat (although on some extremely hot days they have to open the nets to allow heat to escape from the nursery)

- Irrigation overcomes heat and drought impacts
- Use municipal water from the taps in their houses to irrigate crops during droughts (however the chlorine in the water hardens the soil and then plants struggle to grow)
- Rainwater harvesting for irrigation using tanks and/or buckets underneath the gutters
- Greywater harvesting (e.g. dishwashing water) for irrigation
- Flood irrigation
- Use water from the dam or river to irrigate using a petrol pump
- Irrigate seedlings immediately after being replanted
- Seasonal cropping to ensure selected crops are adapted to climate
- Frost resistant crops
- Avoiding the planting of crops during winter to avoid impacts such as frost and floods
- No tilling to prevent soil erosion
- Slaughter or sell livestock when there is too little grazing for them
- Irrigate crops in the mornings before the sun rises to wash frost off the leaves of crops thereby preventing any frost damage
- Channels to divert flood water away from farmland
- Plant a stick from a bush next to tomato plants while they are young to shade them from the sun. Once they are old enough to withstand the heat then the bush is pulled out.
- Weeding
- Leave land fallow to recover for a year or two
- Plant seedlings in the house garden that is close to where respondents live so that they can easily water them and then replant them in the big farmland when they are older.
- Use bushes to cover the crops like a roof to protect them from frost
- Planting crops against a wall so that it is protected from frost (frost usually comes from the direction of the river, so they make sure the wall is in between the crops and the river)
- Making their own seed to minimise expenses. The seeds that respondents make from their own crops are also better adapted to local climate.
- Planting oats that can be eaten by livestock when grazing is poor (e.g. during a drought)
- Give damaged crops to livestock to eat

- Plant corn or sunflowers amongst other crops to provide them with shade
- Mulching (made of compost or straw) to prevent moisture from evaporating from the soil
- Monitor colour of leaves to know how much water they should get
- Plant seedlings on a hill so that when it rains a lot the water runs off. This way seedlings do not get saturated with too much water or get rained flat.

5.5. Discussion

Subsistence agriculture in Genadendal was found to contribute towards food security through household use and providing an income to the household. This income was used to cover household expenses such as electricity but was also used primarily to buy other food. Very few respondents reported that subsistence agriculture was their only source of income. It was found that subsistence farmers in Genadendal diversify their sources of income and do not rely only on one source. However, most respondents were pensioners. It is therefore recommended that future studies be done in which more detailed questions are asked regarding the income sources of respondents.

In terms of stability of food security, the present study found that the impacts of climate-related hazards do not occur often. It was also found that the impacts of climate-related hazards did not cause subsistence farmers to have overall losses of all of their produce. Instead, most subsistence farmers only experienced some losses of production. This finding is consistent with existing literature claiming that climate change will at least decrease crop yield and affect the health of livestock by some degree (e.g. Amjath-Babu *et al*., 2016, Mugambiwa and Tirivangasi, 2017 and Joshua *et al.*, 2016).

The present study also found that climate-related production losses negatively impacts the manner in which subsistence agriculture achieves food security in Genadendal. Most respondents who experience at least some production losses also reported that subsistence agriculture was an important source of food and income and that they used the income to purchase other food. However, very few of these respondents did not have another source of income.

Some of the practices in subsistence agriculture have been adapted to overcome the impacts of climate-related hazards, which are becoming even more unpredictable. For example, a few respondents reported having to intercrop with taller crops to create shade for shorter crops even though they would prefer to engage in monocropping. Adaptation strategies implemented by subsistence farmers have been well documented by literature (e.g. Bryan *et al.*, 2009, Dassanayake *et al.*, 2018, Maponya, 2012 and Senyolo *et al.*, 2018). The results of the present study further expand this body of knowledge, particularly for the Western Cape. It is important to note that there were a few respondents who felt they could not overcome the impacts of climate-related hazards because they did not have access to irrigation or coping mechanisms such as insurance.

Irrigation has been reported as an important climate adaptation option for subsistence farmers in Genadendal. However, changes in rainfall influence the amount of water that is available for irrigation (WWF, 2018). In addition, water restrictions implemented by the municipality during droughts could have drastic impacts on agriculture (WWF, 2018). It is therefore recommended that future studies in Genadendal assess the sustainability of the different irrigation methods used by subsistence farmers.

The present study found that food availability is influenced by climate-related production losses as well as other causes including theft and cattle breaking into farmlands to graze on crops. Respondents continued to explain that cattle break into farmlands because of poor management by their owners. Theft, as explained by respondents, has been on the rise in Genadendal. Most respondents were able to overcome the impacts of climate-related hazards through different climate adaptation responses such as irrigation. Respondents were not asked if and how they overcome other causes of production losses. Therefore, it is recommended that future studies research other causes of production losses in more detail.

A few respondents said that they still traded food with a few of their neighbours, but trading had become a rare occurrence. They also reported that they engage with family, friends or other farmers to seek information on farming methods. This is an indication that social networks are an important coping mechanism to some in Genadendal.

Very few respondents relied on governmental sources of information such as extension services, the Agriculture Committee and the Agriculture Department. This is consistent with the results of Martens (2015), who found that visits from extension officers were few. One respondent reported that extension services only benefit subsistence farmers that are currently farming and do not assist new farmers. This could make it challenging for new farmers to enter the agriculture industry in Genadendal. It may also restrict the knowledge and skills of local subsistence farmers (Martens, 2015). The Department of Environmental Affairs (2013) encourages adequate farmer support through extension services to improve agricultural production. It is therefore recommended that the Department of Environmental Affairs increase the presence of extension officers in Genadendal.

There seems to be a high interest from subsistence farmers to upskill themselves in agriculture by attending courses, using the internet, reading books, attending courses, learning from their own experience or even learning from the things that are taught to kids at school. Therefore, it is recommended that these sources of information are made available more easily to subsistence farmers in Genadendal.

Although it was not asked during the questionnaire, one important observation is that many subsistence farmers in Genadendal do not farm throughout the year anymore. Many respondents reported that they used to plant throughout the year in the past but are now limited to summer months. This observation is consistent with results from the literature review that state that subsistence agriculture improves food availability for a short period of the year (e.g. Patterson *et al.*, 2017). Although restricting planting to summer months was also listed as an adaptation to frost, there are also other reasons for not planting throughout the year anymore.

One reason that was given was that certain respondents were too old to work as hard in their gardens as in the past. Furthermore, many of the youths did not seem to be interested in farming. As a result, they seemed to be reluctant to assist the elderly with continuing their production, even though the elderly wanted to pass on their knowledge to the younger generation. This could potentially result in the loss of knowledge of subsistence agriculture in Genadendal. It is therefore recommended that practices developed by older generations be well documented by future studies.

As a result of some subsistence farmers only planting in summer, food availability and access may be challenging during winter months as alternative sources of food need to be accessed. This is also the case for subsistence farmers who experience production losses. Purchasing food from shops is an important source of food for many households in Genadendal. These results are consistent with those found in literature that claim that subsistence farmers are becoming more reliant on the purchasing of food (e.g. Baiphethi and Jacobs, 2009 and Pereira, Cuneo and Twine, 2014).

Shops in Genadendal are mostly small convenience stores and do not stock a wide variety of fresh produce. Therefore, residents must travel to the nearest large town, which is approximately 30km away, to access fresh food. However, transport in Genadendal is limited as every household does not own a vehicle. Therefore, some residents need to take a taxi to Caledon which costs R60.00 per person for a one-way trip. As a result, additional expenses are incurred by households who do not produce their own food.

Respondents reported producing a wide variety of products. Other than the things that subsistence farmers could not produce in Genadendal (e.g. sugar and coffee), most respondents reported that they purchased similar products to those that they would have produced if they had not experienced production losses. This is an indication that food utilisation may not have changed significantly due to production losses. However, respondents reported that it was costly to purchase products from the shop. Consequently, their grocery budgets were affected by production losses possibly making food access even more challenging.

All the respondents reported that they had adequate means of storing their produce for future use. The most common means of storage was to steam vegetables for two minutes and then freeze them. One respondent also reported canning the cooked vegetables and storing it in an airtight container to avoid oxygen from getting in. Many respondents reported having storage rooms that they built out of metal sheets that they use to dry out their produce to increase shelf life.

Only one respondent felt that changes in the climate had changed the way he/she stored produce. This respondent said that he/she would have liked to pick some produce from the garden everyday but can no longer do so. The respondent explained that the climate is too unpredictable in recent years and that produce may become damaged in a short period of time. Therefore, the respondent felt that he/she had no choice but to harvest the products and store them in a freezer. As a result of having to freeze produce, this respondent also felt that the impacts of climate-related hazards changed the manner in which he/she prepared food. Another respondent also reported that the impacts of climate-related hazards changed the way he/she prepared food but did not give a reason why.

The present study explored the impacts of climate change on subsistence agriculture by studying all the dimensions of food security. However, food availability and access had more of a focus than utilisation and stability. It is recommended that future studies focus more on utilisation by studying the diversity of the diet and intrahousehold food distribution. There is also room for more emphasis on stability in future studies.

5.6. Conclusion

It was found that food availability is not a concern in Genadendal as respondents either produced their own food and stored their produce for household use and/or had alternative sources of food. Although accessing alternative sources of food was found to be somewhat challenging for some respondents due to transportation expenses and high food prices affecting grocery budgets. Food utilisation and stability was found to be mostly unaffected by the impacts of climate-related hazards.

Subsistence farmers in Genadendal experienced at least some production losses due to the impacts of climate-related hazards despite implementing adaptation responses. However, none of the subsistence farmers experienced overall production losses. This could either be a result of the adaptation responses being implemented successfully, or because the climate-related hazards are not severe. However, the present study did not take the severity of climate-related hazards into account. It is recommended that future studies research the severity in more detail.

It is also recommended that future studies take additional factors into consideration and explore the ones from the present study in further detail to fully investigate each dimension of food security. Transportation and market integration should be studied in further detail when analysing food availability. Household expenditures, food prices and market access should be studied in further detail when analysing food access. In addition to the factors studied in the present study, intra-household food distribution and nutritional status should be investigated when analysing food utilisation. It is also recommended that future studies research the water, food and climate nexus in Genadendal because irrigation was found to be an important adaptation in the present study.

Chapter 6 – Conclusion

6.1. General discussions

The present study aimed to explore the role of subsistence agriculture in achieving food security in Genadendal in the Western Cape Province of South Africa in a changing climate. The body of research comprises of six chapters. After the introductory chapter (Chapter 1), the methodology and research design were briefly described in Chapter 2. Chapter 3 consists of a systematic literature review which was followed by two research chapters that were introduced separately and written for publication. The concluding chapter (Chapter 6), presents a general discussion of each of the chapters, makes recommendations based on the results of the present study and makes suggestions for further research.

Chapter 3, the systematic literature review firstly aimed to determine the focus of existing literature on food security. Food security consists of four dimensions as defined by the FAO namely, food availability, access, utilisation and stability. It was found that studies have typically focussed on the food availability and access dimensions of food security. A distorted comprehension of food security can have arisen due to the poor integration of all four dimensions into research. A review of the literature on the role of subsistence agriculture in achieving food security revealed that subsistence agriculture supplements food security by generating additional income and food for households. The impact of climate change on subsistence agriculture and ultimately food security was found to be well documented by existing literature. Climate change adaptation responses implemented in subsistence agriculture is well presented in the literature, and include irrigation and using drought-tolerant varieties, to name a few.

Chapter 4 analysed the historical changes in the climate of Genadendal. The chapter analysed historical meteorological datasets from three different sources namely, ARC, CRU and SAWS. Rainfall data were analysed from 1960 to 2017. Minimum and maximum temperature data from CRU and SAWS were analysed from 1993 to 2017. Chapter 4 also investigated and analysed the perceptions of subsistence farmers of the changes in climate from the time they started farming. The hypothesis tested in this chapter was that the climate variables (i.e. rainfall and maximum and minimum temperature) had changed over the years.

The results of Chapter 4 show that the climate of Genadendal has changed over the years according to meteorological data and the perceptions of subsistence farmers. Conclusions about how the climate has changed could not be made with certainty as the meteorological datasets and perceptions of subsistence farmers were not always consistent, neither within those categories, nor between them. Rainfall and minimum temperatures were highly variable amongst and within datasets. There was agreement between the meteorological datasets, however, that maximum temperature did increase. Perceptions of changes in climate also varied amongst subsistence farmers across and within groups of differing years of farming experience. Although conclusions on how the climate variables (i.e. rainfall, maximum and minimum temperature) had changed could not be made with certainty, it is evident that they have not remained unchanged. The hypothesis tested in Chapter 4 should therefore not be rejected. In Chapter 4 it was recommended that meteorological data dating back further than 1960 and 1993 be analysed in future studies to be consistent with the definition of climate change as defined by the WMO (2017).

Chapter 5 investigated the impacts of climate change on the four dimensions of food security (defined in Chapter 1) for households who practice subsistence agriculture in Genadendal. The chapter also explored the climate change adaptation responses implemented by subsistence farmers in Genadendal. The first hypothesis tested by this chapter was that climate-related hazards such as droughts, floods and heatwaves have an impact on the four dimensions of food security (i.e. availability, access, utilisation and stability). The second hypothesis was that subsistence farmers use numerous adaptation responses to overcome the impacts of climate-related hazards.

Results from Chapter 5 show that climate-related hazards affect each dimension of food security (i.e. availability, access, utilisation and stability) to a different degree. Food availability was found not to be a concern as food was produced, stored or available at alternative sources. Climate-related hazards mostly have an impact on food access when production losses occur due to food needing to be accessed at alternative sources. This is due to expenses being incurred for transportation to shops and the cost of purchasing food. Food utilisation and stability was mostly unaffected by climate-related hazards. Climate-related hazards caused at least some production losses for most subsistence farmers in Genadendal despite adaptation responses. However, none of the subsistence farmers who participated in the study experienced overall production losses (i.e. none of the respondents reported losing all of their crops and/or livestock due to climate-related hazards). Adaptation responses made subsistence farmers in Genadendal somewhat more resilient to climate-related hazards. This means that they were able to withstand, absorb and reduce the impact of climate-related hazards at least to some degree.

6.2. Conclusions

The present study makes a contribution towards research on the impacts of climate change on the food security of households who engage in subsistence agriculture, particularly in the Western Cape. Results show that in most cases subsistence farmers in Genadendal could not completely rely on subsistence agriculture to render them food secure. These results are consistent with existing literature that claims that subsistence agriculture does not make a significant difference to the food security of households, but rather supplements food security (e.g. Aliber and Hart, 2009; Baiphethi and Jacobs, 2009 and Martens, 2015).

6.3. Recommendations

Results from the present study suggest that irrigation is an important adaptation response. Subsistence farmers in the present study irrigated on hot days as well as during dry periods. The Western Cape has recently been overwhelmed by a severe drought which restricted water usage throughout the province by a large degree. As a result, many farmers were unable to irrigate due to water restrictions. Thus, water can also be seen as a key limiting factor for subsistence farmers in Genadendal. Without sufficient water supply for irrigation subsistence farmers can be left vulnerable to the impacts of climate-related hazards such as droughts and heatwaves. It is therefore recommended that investments be made to maintain water infrastructure in Genadendal to avoid water losses and maximise water storage that can be used during future droughts. This will contribute to safeguarding subsistence farmers' resilience and ability to adapt to climate-related hazards such as heatwaves and droughts.

The present study found that subsistence farmers in Genadendal rely largely on their networks of friends, family and neighbours as coping mechanisms. This demonstrates that subsistence agriculture in one household may well contribute to the food security of other households in the community, based on an ethic of sharing within the community and amongst families. It was also found that governmental services such as extension services play a small role in Genadendal. It is therefore recommended that provincial plans and policies such as the Western Cape Climate Change Response Strategy (Western Cape Government, 2014b) and the SmartAgri Plan (Western Cape Department of Agriculture, 2016) be reviewed to support the development and preservation of social networks amongst subsistence farmers in towns similar to Genadendal. This will also contribute towards achieving one of the Theewaterskloof Local Municipality IDP (Theewaterskloof Municipality, 2017) goals of improved social fibre.

Furthermore, the Theewaterskloof Local Municipality IDP suggests making land available for subsistence agriculture. Although Genadendal is characterised by complex tenure security issues expressed in the Rural Areas Act 9 of 1987, the subsistence farmers that took part in this study already had land available. Further actions are required to support subsistence farmers in Genadendal. Actions include increasing access to more affordable transport, access to drought and heat-tolerant seed varieties and access to long-term climate information.

6.5. Suggestions for further research

Although the results of the present study contribute towards climate change and subsistence agriculture studies within the Western Cape, it only covers one area of the Western Cape. It is therefore suggested that additional research be conducted in other areas of the Western Cape to expand the body of knowledge further. One area that can be recommended for research is Elim in the Cape Agulhas Local Municipality because the history of Elim is similar to that of Genadendal.

Different irrigation methods used by subsistence farmers as adaptation responses in Genadendal were briefly mentioned in Chapter 5 (List 4). However, it is recommended that future studies research the sustainability of each irrigation method in further detail. This is particularly important if the frequency of climate-related hazards such as droughts increase. It is also suggested that further research be conducted on other causes of production losses such as the impact of pests like moles. Respondents also reported that alien invasive clearing causes changes in local climate which causes production losses. It is suggested that further research be conducted on the impacts of alien invasive clearing on the local climate of Genadendal.

The present study did not address the tenure security of subsistence farmers in Genadendal. Subsistence farmers who took part in the present study, did not mention tenure security as an issue. However, the questionnaire did not include any questions on tenure security and so did not give respondents the opportunity to express their opinions on the matter. It is therefore suggested that future studies investigate the impacts of tenure security on the food security of subsistence farmers in Genadendal.

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Addendum A: History of Genadendal

The beginning of Genadendal was a product of the work of Georg Schmidt, a Moravian missionary. Despite being ridiculed and posed with numerous challenges by the Council in Cape Town and Holland, Schmidt aimed to teach the First Nations people about the Saviour. On 23 April 1738, he moved to the end of the Baviaanskloof (to be renamed Genadendal in 1806) with eighteen First Nations people and three soldiers where they erected a hut, a water furrow and a garden. This was the beginning of Genadendal (Krüger, 1966, pp. 21).

Schmidt did not receive financial support from the Council but rather had to earn a living for himself by working on neighbouring farms. Schmidt also spent time improving his garden. It produced vegetables such as beans, peas, onions, lettuce and parsley as well as grapes and other fruit, tobacco, barley, wheat and oats. He built an oven in which to bake bread and bought six oxen. He also had two pigs, dogs, a horse and 76 goats (Krüger, 1966, pp. 27, 28). While working in the gardens he used metaphors to preach the Gospel, for example, when the peach trees were being pruned he explained that man is like a tree, which must be pruned (Krüger, 1966, pp. 27).

Other than teaching the First Nations people about the Saviour, the missionary station served as a safe haven to its community. The missionaries therefore constantly experimented with ways in which the livelihoods of the residents could be improved. An example thereof is the corn mill that was built in 1797 to relieve farm labourers from their slave labour they had to do on neighbouring farms. Without the corn mill inhabitants had to take their corn to neighbouring farms to be milled where they had to work for the farmer in return (Krüger, 1966, pp. 77). The mill was particularly profitable in times of drought (Krüger, 1966, pp. 85).

In the winter of 1740, the community suffered from hunger as food was scarce, however, the shooting of a hippopotamus in the river brought with it some relief (Krüger, 1966, pp. 28). In 1796, food was scarce again after the men of Genadendal left for the military causing work to cease. The women and young girls were then driven to neighbouring farms by hunger (Krüger, 1966, pp. 79). By 1798, every household of Genadendal had a vegetable garden which would supply food throughout the year (Krüger, 1966, pp. 80). Shortly thereafter, Genadendal experienced a severe famine. Crops failed throughout the year of 1801 causing food to become very scarce. People survived off of roots and berries that they collected in the veld (Krüger, 1966, pp. 89).

By 1808, the economy of Genadendal was partly financed by agriculture (Krüger, 1966, pp. 111) and residents became more and more fond of working the ground (Krüger, 1966, pp. 114). Still, the majority of the residents were farm labourers on neighbouring farms and were hired by the week and some by the month and year. However, their wages hardly covered their daily expenses (Krüger, 1966, pp. 112).

Again in 1822, many people in Genadendal died of famine. Food was so scarce that crops had to be guarded at night against thieving (Krüger, 1966, pp. 145). From 1861 to 1869, Genadendal and the rest of the country suffered from catastrophes of nature, droughts, crop failures and pest invasions which threatened the food security of communities (Krüger, 1966, pp. 272). The beginning of the 1880s were again a period of economic crisis due to droughts and other difficulties (Krüger and Schaberg, 1966, pp. 16).

From 1877 to 1893, efforts were made to establish industries at Genadendal to create work locally. This included sowing seeds for castor oil plants to produce castor oil. Mulberry trees were also planted to feed silk-worms for the production of raw silk. Next came the planting of hop plants that would be cultivated for the breweries in Cape Town. Cotton seed and tobacco was also experimented with (Krüger and Schaberg, 1966, pp. 29). While these industries were establishing and growing to make profit, people collected buchu and harvested flowers to be exported to Europe (Krüger and Schaberg, 1966, pp. 30). In the end, attempts to bring industries to Genadendal failed for various reasons (Krüger and Schaberg, 1966, pp. 31).

Devastating floods in 1913, 1921, 1936, 1941 and 1945 caused major damage to the crops and to the land (Western Cape Government, 2003).

The inhabitants of Genadendal regarded the mission station as their property. The mission on the other hand, acted as the owner although the government was the legal owner and the mission was the trustee. (Krüger and Schaberg, 1966, pp. 42).

The land in Genadendal was initially owned by the Moravian Church but was later transferred to the state in order to be held in a trust for the community (Western Cape Government, n.d.). Genadendal now falls under the Rural Areas Act 9 of 1987. This Act was implemented to provide control, improvement and development of rural areas that were reserved for the benefit of coloured people (Republic of South Africa, 1987).

The main objective of the Transformation of Certain Rural Areas Act 94 of 1999 is to transfer the common property to a legal entity (Theewaterskloof Municiplaity, 2012). The Department of Land Affairs and the relevant municipalities are now responsible for the transformations which entail land audits, approval of plans, subdivisions and the issuing of Deeds. Once all of these processes have been completed and the areas have been successfully transformed it is expected that the Rural Areas Act 9 of 1987 will be repealed (Western Cape Government, 2014a).

The Theewaterskloof Municipality Spatial Development Framework of 2012 states that the Minister of Rural Development and Land Reform would have made a decision regarding the transfer during 2011 (Theewaterskloof Municiplaity, 2012). However, the ownership of the land has still not been transferred and remains in the trust for the community. However, the land has been subdivided into individual plots and farming units that have been surveyed and registered at the Chief Surveyor-General under various general plans dating as far back as 1984 (Western Cape Government, 2017; Government of South Africa, n.d.).

Local Advisory Councils used to enforce law and order in the Act 9 areas and were responsible for development. The Local Advisory Councils were replaced in later years by Management Councils and Transitional Local Councils. However, due to developmental backlogs the new councils fed most funding into the townships and neglected agriculture which together with lack of tenure rights has caused the stagnation of agriculture (Western Cape Government, 2014a).

Addendum B: Interview questionnaire

Name of Participant: ____

Questionnaire reference number: _________ **Date and time:** __________________

* In this questionnaire 'products' refer to flowers, fruits, vegetables, livestock, eggs or any other things that participants produce in their gardens / farms.

* Please note that table 1 and table 2 can be found at the end of the questionnaire.

* Participants are allowed to give multiple answers for questions marked with *.

Section A: Introduction

1) How long have you been living in Genadendal for? ______________________________

2) How long have you been farming? ______________________________

3) *Where did you learn to farm / keep a garden?

   a) Your parents / other family
   b) Friends
   c) Extension services
   d) Other (please specify): ____

4) *Where do you get the information that you need for farming?

   a) Extension services
   b) Family / friends
   c) Passed on from generation-to-generation
   d) Own experience
   e) Internet
   f) Books
   g) Other (please specify): ____

Section B: Purpose of food production

5) *The products that you produce in your garden – what do you do with them?

   a) Use it in the household
   b) Sell it
   c) Give it away
   d) Other (please specify): ____

6) *What products do you usually produce in your garden? Which of these do you eat? Which of these do you sell? How long does it take to produce each product? Please complete table 1.

7) Would you say that the products produced in your garden that your household eats is an important source of food for your household?

   a) Yes
   b) No

8) Would you say that the money made from the products that are sold is an important source of income for your household?

   a) Yes
   b) No

9) Do you ever use the income made from selling the products to buy other food?

   a) Yes
   b) No

Section B: Introduction to climate change

10) Do you rely on the climate/weather (e.g. rainfall or temperature) to produce products in your garden?

a) Yes, for all of the products

b) Yes, for at least some of the products

c) No

11) *Where do you get information on the weather for the day, week and season? Please complete the table below.

Source of information	**For the day** *(mark with an X)*	**For the week** *(mark with an X)*	**For the season** *(mark with an X)*

12) How has the number of times it rains per year changed since the time you started farming? *E.g. It used to rain four times a week in the rainy season but now it only rains once a week in the rainy season.*

a) It rains more often

b) It rains less often

c) No change

13) Has the intensity of rainfall events changed since the time you started farming? *E.g. It never used to hail and now it does hail sometimes.*

a) More intense (it rains harder)

b) Less intense (the rain is gentler)

c) No change (the rain is the same)

d) Inconsistent / variable (the rain is different every time)

14) *Has the rainy season shifted to different times since the time you started farming? *E.g. It used to rain from March to August but now it only starts raining in April.*

a) Starts earlier

b) Starts later

c) Starts at the same time

d) Inconsistent / variable

e) Ends earlier

f) Ends later

g) Ends at the same time

h) Inconsistent

15) How would you describe the change in the length of the rainy season since the time you started farming?

a) Longer

b) Shorter

c) No change

16) How have temperatures changed since the time you started farming?

a) Increased

b) Decreased

c) No change

d) Inconsistent / variable

17) How has the length / intensity of heatwaves changed since the time you started farming? *E.g. It gets a lot hotter now than it ever used to before and it stays hotter for a few days.*

a) Increased
b) Decreased
c) No change
d) Inconsistent / variable

Section C: Impacts of climate change

18) *How do (i) water shortages (ii) floods (iii) shifting rainy seasons (iv) hail / storms / strong winds and (v) heatwaves impact your production of products? Do you do anything to try and overcome the impacts? If so, how do you overcome the impacts? Please complete table 2.

19) *How often would you say the impacts mentioned in table 2 occur?

a) Daily
b) Weekly
c) Monthly
d) Every season
e) Only some seasons

20) *Would you say you experience overall production losses due to the impacts mentioned in table 2 or would you say the production losses are due to other causes?

a) Yes, often
b) Yes, sometimes
c) Yes, but rarely
d) No, never experience production losses
e) Other causes (please specify): ______________________________

21) *How often would you say you have overall production losses?

a) Daily
b) Weekly
c) Monthly
d) Every season
e) Only some seasons

22) *When you have production losses due to the impacts mentioned in table 2, how else do you get food?

a) Buy from shop
b) Buy from neighbour / friend / family
c) Trade with neighbour / friend / family
d) Neighbour / friend / family gives you food for free
e) Other (please specify): ______________________________

23) *When you have losses of production due to the impacts mentioned in table 2, does it affect…

a) Your household's grocery budget for the month
b) The amount of food your household has
c) The amount of food each household member eats
d) Your household's health
e) Other (please specify): ______________________________
f) No affect

24) *When you have losses of production due to the impacts mentioned in table 2, and you have to get alternative sources of food, which foods do you get? Please complete the table below.

25) Do the impacts mentioned in table 2, affect the way you have to store your products? If yes, please specify how.

a) Yes, all of the products because ___________________________________

b) Yes, at least some of the products because ___________________________

____

c) No

26) Do the impacts mentioned in table 2, affect the way you have to prepare the products that you eat? If yes, please specify how.

a) Yes, all of the products because ___________________________________

b) Yes, at least some of the products because ___________________________

c) No

Table 1: Products that are eaten in the household or sold and how long they take to produce

Product	**Eat** *(Mark with X)*	**Sell** *(Mark with X)*

Table 2: Impacts of climate change on production and how they are overcome

Product	**How do (i) water shortages (ii) floods (iii) shifting rainy seasons (iv) hail / storms / strong winds and (v) heatwaves impact the products?**	**How do you overcome these impacts?**