Climate change perceptions, knowledge and adaptation responses of smallholder, crop-livestock farmers in Mediterranean-type ecosystems: case studies from the Overberg District, South Africa

by

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Declaration

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Abstract

Smallholder farmers must adapt their farming practices to sustain livelihoods, as a result of the changing climate. It is known that climate change may cause significant adverse effects on the agricultural sector. Smallholder farmers are particularly vulnerable to the effects caused by extreme weather events such as droughts and flooding as their farms are often located in areas that are prone to these environmental risks. It is known that it is necessary to establish the perceptions and knowledge of smallholder farmers, regarding climate change to ensure appropriate context-based adaptation strategies are implemented. Climate change adaptation methods have been extensively researched in recent literature, but there is a need to investigate context-specific adaptation methods for smallholder farmers, especially in Mediterranean-type ecosystems as it is expected that precipitation will decrease and increasing temperatures will increase drought risk in these ecosystems. This current study aimed to investigate the climate change perceptions, knowledge, and adaptation methods of smallholder farmers in two former mission stations, namely Elim and Genadendal, located in the Overberg District of the Western Cape Province of South Africa. The perceptions of the farmers were also compared to long-term meteorological data from the Overberg District. A mixed-method approach was used in this study. Structured telephonic interviews were held with 9 smallholder farmers in Elim and 4 in Genadendal. Qualitative data obtained from the interviews were coded and analysed using qualitative data analysis software ATLAS.ti and quantitative data were analysed in Statistical Package for Social Sciences (SPSS). Minimum and maximum daily temperatures, as well as daily rainfall data, were analysed using simple linear regression analyses ($p < 0.05$) in STATISTICA. Results from this study indicated that smallholder farmers in the Overberg District perceived and experienced a change in climatic conditions, especially in the case of extreme weather events such as flooding (Elim) and drought (Genadendal and Elim). The meteorological data confirmed the perceptions of the farmers, as significant results were obtained regarding the minimum temperature and rainfall data in the Genadendal region and maximum temperatures in the Elim region. Adaptation methods utilised by smallholder farmers in the Overberg region included changing planting dates, increasing irrigation, mulching, selling livestock, and an increase in fungicide use. Due to the relatively small number of participants, statistically, sound conclusions cannot be drawn - however,

the study does provide insight into the perceptions and adaptation methods regarding climate change, of smallholder farmers in the Overberg District. This may be beneficial to stakeholders involved in climate change adaptation planning, as well as smallholder farmers in other Mediterranean-type ecosystems.

Opsomming

Kleinboere moet hul boerderypraktyke aanpas vir 'n volhoubare lewensbestaan as gevolg van veranderde klimaatstoestande. Dit is bekend dat klimaatsverandering merkbare nadelige gevolge kan inhou vir die landbousektor. Kleinboere is veral kwesbaar vir die gevolge wat veroorsaak word deur die effek van uiterste weerstoestande soos droogte en vloede omdat, hul plase dikwels in areas geleë is wat geneig is tot hierdie omgewings-risiko's. Dit is bekend dat dit ook nodig is om waarnemings en kennis van kleinboere aangaande klimaatsverandering te vestig om te verseker dat toepaslike konteks-gebasseerde aanpassings en strategieë implementeer word. Klimaatsverandering aanpassings-metodes is reeds omvattend nagevors in onlangse literatuur maar, daar is 'n behoefte om konteks-spesifieke aanpassingsmetodes vir kleinboere te ondersoek veral in die Mediterreense-tipe ekosisteme waar dit verwag word dat reënval sal afneem en stygende temperature, droogte-risiko's sal laat toeneem in hierdie ekosisteme. Hierdie huidige studie het gemik om klimaatsveranderings-aannames, kennis en aanpassings-metodes van kleinboere in twee voormalige sendingstasies, naamlik Elim en Genadendal, geleë in die Overbergdistrik van die Wes-Kaap Provinsie van Suid-Afrika te ondersoek. Die aannames van hierdie boere was ook vergelyk met die langtermyn meteorologiese data van die Overbergdistrik. 'n "Gemengde- metode" benadering is in hierdie studie gebruik. Gestruktureerde telefoniese onderhoude is gevoer met 9 kleinboere in Elim en 4 in Genadendal. Kwalitatiewe data verkry uit hierdie onderhoude is gekodeer en geanaliseer in ATLAS.ti en kwantitatiewe data is ook ge-analiseer in "Statistical Package for Social Sciences" (SPSS). Minimum en maksimum daaglikse temperature, asook daaglikse reënvaldata is geanaliseer (ontleed) waar gebruik gemaak is van lineêre regressie analises ($p<0.05$) in STASTISTIKA. Resultate van hierdie studie het aangedui dat dat kleinboere in die Overbergdistrik 'n verandering in klimaatstoestande waargeneem en ervaar het, veral in gevalle van uiterste weersomstandighede soos vloede (Elim) en droogte (Genadendal en Elim). Die meteorologiese data wat verkry is, het bevestig dat die aannames van die boerebetekenisvolle resultate is,aangaande die minimum temperature en -reënvaldata in die Genadendalstreek en maksimum temperature in die Elimstreek. Aanpassingsmetodes wat deur die kleinboere in die Overbergstreek benut word, het ingesluit: die verandering in plantdatums, toenemende besproeiing, deklaag

bewerking, verkoop van vee en vermeerdering in swamdoder gebruik. As gevolg van ‘n klein hoeveelheid deelnemers, kon gesonde gevolgtrekkings statisties nie opgeteken word nie, alhoewel die studie insig verleen het in die aannames- en aanpassingsmetodes wat betref klimaatsverandering by kleinboere in die Overbergdistrik. Dit mag voordelig wees vir aandeelhouers wat betref klimaatsverandering-beplanning sowel as vir kleinboere in ander Meditereense-tipe ekosisteme.

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List of Acronyms and Abbreviations

ACDI - African Climate and Development Initiative

CSA – Climate-smart agriculture

DAFF - Department of Agriculture, Forestry and Fisheries

DEA & DP - Department of Environmental Affairs and Development Planning

DOA – Department of Agriculture

EU - European Union

FAO - Food and Agriculture Organization

FGD – Focus group discussion

IPCC - Intergovernmental Panel on Climate Change

NGO - Non-governmental organization

NUS - Neglected and underutilized crops

PRISMA - Preferred Reporting Items for Systematic review and Meta-Analysis

REC: SBE - Research Ethics Committee: Social Behavioural and Education Research

SDGs - Sustainable Development Goals

SmartAgri - Smart Agriculture for Climate Resilience

SPSS - Statistical Package for the Social Sciences

TRANCAA - Transformation of Certain Rural Areas Act of 1998

UN – United Nations

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Chapter 1 – Introduction

1.1. Introduction

The chapter provides an overview of the current literature regarding smallholder farmer perceptions of climate change, and those perceptions compared with meteorological data. This chapter examines responses amongst smallholder farmers globally: it considers the influences and determinates of adaptation responses to climate change as well as the challenges associated with regards to adaptation responses. An overview of the United Nations (UN) Sustainable Development Goals (SDGs) is presented as the backdrop to climate change adaptations both globally and locally. Bringing the focus back to the South African context, adaptation responses are reviewed in the context of Climate-Smart Agriculture (CSA) and Smart Agriculture for Climate Resilience (SmartAgri) programmes linked to the SDGs. The literature review culminates in a problem statement, followed by the research aims and objectives, as well as the questions, that guided the research process. The chapter concludes with a thesis outline, briefly introducing each of the chapters that follow.

1.2. Background

1.2.1. Defining climate change

The UN recognizes climate change as the defining challenge of the twenty-first century for human development (Davis-Reddy and Vincent, 2017). Definitions for climate change has slightly changed over time. The Intergovernmental Panel on Climate Change (IPCC) defined climate change in 2007, as a phenomenon referring to any changes in climatic conditions, as a result of human activity or due to natural variability, over an extended period (IPCC, 2007). Climate change was defined by Leiserowitz *et al.* (2014), as the long-term (over several decades or longer) rainfall, temperature, and wind pattern changes of the earth's climate. More recently the UN defined climate change as shifts in long-term weather and temperature patterns (UN, 2021) caused by greenhouse gas emissions from human activities from natural systems and human activities (Fawzy *et al*. 2020). Changes in the mean and/or variability of climatic properties over an extended period, that are identified using statistical analyses can also be defined as climate change (IPCC, 2018). The observed warming since the mid-20th century, has been predominately caused by human influence (IPCC, 2018). In this thesis, referring to climate change includes both natural variability and anthropogenic climate change.

Global temperatures continue to rise and there has been an increase in extreme weather events, such as droughts floods, temperature increases as well as natural disasters such as hurricanes, tornados, and cyclones, which will result in global repercussions (IPCC, 2014). According to Adebisi-Adelani and Oyesola (2014), Christensen *et al*. (2007), as well as Abegaz and Wims (2015), it is projected that climate change will affect the subtropical and tropical ecosystems of Africa, with extreme warming and drying occurring in subtropical regions and slight increases of rainfall in tropical regions. Climate change models also project an increase in drying in Southern African regions as a result of the El Niño–Southern Oscillation, causing an increase in temperatures (IPCC, 2007, 2014a).

1.2.2. Defining the term "smallholder farmers"

There is no universal definition of the term smallholder (Bosc *et al*., 2013). Some authors may subject the term of "smallholder" to farms that are of a certain size e.g., farms that are the size of 2 ha or smaller are often referred to as smallholder farms, but some authors make use of the term when referring to farms that are up to 200 ha in size (Davidson *et al*., 2012). The term of "smallholder" may also depend on the production system of the farm, and according to Swai *et al*. (2014), smallholder farmers in many localities, are involved in mixed-cropping systems. According to Cohn *et al*. (2017), smallholder farming systems can also be identified by the percentage of the production that is consumed on the farm, the quantity of the economic output as well as the reliance on family labour. The South African Department of Agriculture Forestry and Fisheries (DAFF) (2013) and Cousins and Chikazunga (2013), defines smallholder farmers as farmers who produce for household consumption as well as for markets, thus earning an ongoing revenue from farming. The definition presented by the DAFF (2013) and Cousins and Chikazunga (2013), will also be used to define the term "smallholders" for this current project.

1.2.3. Smallholder farmers in the Overberg District

The agricultural sector is a key sector for food security and employment for the Overberg district and contributes to 11% of the Western Cape's total agricultural production (Overberg District Municipality, 2017). According to Statistics South Africa (2011), 8.62% of households are involved in agricultural activities in the Overberg district. Smallholder producers in the Overberg District, contribute in a limited manner, financially, to the formal agricultural economy of the district according to the Department of Agriculture, Forestry, and Fisheries (DAFF) (2013). Despite risks associated with agricultural activities, such as drought, flooding, theft, and pests as well as limiting market access for smallholder producers, it can be argued that agriculture can play a key role in elevating poverty and improving food security in rural areas of the Overberg District (DAFF, 2013), and certainly on household level.

Presently, information with regards to the total number of smallholder farmers in the Overberg District is not readily available. A status report conducted by Tshintsha Amakhaya in 2012, with regards to the livelihoods, land use, and rights of citizens in certain sites in the Eastern Cape, Limpopo, KwaZulu-Natal, and Western Cape provinces, however, identified that there were 654 smallholder projects on 14 000 ha, with less than 2000 ha cultivated, and 96 food garden projects on 401 ha in the Overberg district (Tshintsha Amakhaya, 2012). According to Tshintsha Amakhaya (2012), 37% of these projects were produced for informal markets and 56% produced for household consumption. Smallholder farmers in the Overberg District mainly operate within the former "Act 9 rural areas", municipal commonages, or in their gardens (DAFF, 2013). Former "Act 9 rural areas" refers to areas that fell under the now repealed Rural Areas Act (Act 9 of 1987) passed in the Apartheid era by the House of Representatives in the tricameral parliament. The Transformation of Certain Rural Areas Act (No. 94 of 1998) also known as TRANCRAA was drafted after the abolishment of Apartheid to replace Act 9 of 1987.

1.2.4. Smallholder farmers' perceptions of climate change

It is useful to assess farmer's perceptions with regards to climate change, in achieving sustainable management of smallholder farming systems. This is so because farmer insights can provide an understanding into the state of farmers' awareness of climatic patterns such as temperature and rainfall variability (Mkuhlani *et al*., 2020). A range of authors have considered the value of examining smallholder farmer's perceptions of climate change in Africa (for example, Ntombela et al., 2017; Shisanya and Mafongoya, 2016; Mkuhlani *et al*., 2020; Ayanlade *et al*., 2017; Zake and Hauser, 2014; Antwi-Agyei *et al*., 2017; Popoola *et al*., 2018; Pauline and Grab, 2018; Bedeke *et al*., 2018; Kerr *et al*., 2017; Talanow *et al*., 2021). Farmer's perceptions of climatic change, generally include decreased rainfall, increased temperatures, and increased drought.

Climate change has varying direct and indirect effects on smallholder farmer' households. Ntombela (2017), studied the climate change perceptions of smallholder farmers in two former Act 9 areas in the Namaqualand region of South Africa, namely Leliefontein and Steinkopf, and found that farmers in both areas perceived a late onset of rains and increased temperatures. A study by Shisanya and Mafongoya (2016), was carried out in the uMzinyathi District of Kwazulu-Natal in South Africa and concluded that, due to past experiences, the households interviewed in the study, were anxious that they will face recurrent floods and drought; a decline in soil fertility; a shorter rainy season; as well as general climate variability. The study however focused on, whether households had anxiety with regards to only certain impacts of climate change such as extreme weather events, impacts on crops and livestock, soil fertility, and rainfall occurrences, and did not consider other climatic conditions such as temperature fluctuations, that might also impact the production of smallholder farmers in the district.

Similar, to Shisanya and Mafongoya, (2016), Popoola *et al*., (2018), focused on the perceived agricultural impacts of climate change in smallholder farming communities. The study by Popoola *et al*., (2018), was conducted in the Amathole District Municipality in the Eastern Cape province of South Africa. The methodological approach utilised by the authors was different to the approach utilised by Shisanya and Mafongoya (2016). The authors used a cross-sectional household survey together with mean scores to describe how severe the households perceived climate change to be on the three-point Likert-type scale (Farauta *et al*., 2011). Findings showed that participating farmers perceived a decrease in the amount of rainfall as well as an increase in temperature levels over the last 25 years before the study was conducted. The authors also indicated that farmers perceived drought as the most pronounced climate risk in the area, and that threats of heatwaves and fire were also perceived as risks (Popoola *et al*., 2018). Similar results were obtained by Rapholo and Makia (2020), who also made use of a four-point Likert-type scale, to analyse the perceptions of smallholder farmers in Botlokwa, which is a semi-arid region in South Africa. The authors concluded that most farmers perceived a decrease in rainfall, an increase in temperatures, and an increase in dry spells (Rapholo and Makia, 2020).

Apart from decreasing rainfall, increasing temperatures and more frequent dry spells, several South Africa studies have reported small-scale farmer experiences of higher rainfall variability and a frequency in high-temperature events. This was reported amongst small-scale farmers in both the Lambani and Nkonkobe communities of the Limpopo and Eastern Cape Provinces, respectively (Mkuhlani *et al*., 2020). Kom et al. (2020) similarly found that smallholder farmers in the Vhembe District (Limpopo Province) noticed that the rainfall season is getting shorter as well as perceiving a late on-set in rainfall, compared to 30 years before. Kom *et al*. (2020), also reported that smallholder farmers perceived an increase in temperatures and a decrease in rainfall in the area. Farmers in the Western Cape province of South Africa perceived long-term climate changes in the region, such as increasing temperatures, changes in rainfall patterns as well as extreme weather events (Talanow *et al*., 2021). It is clear from evidence based on the studies performed in South Africa that smallholder farmers perceive climatic changes, especially an increase in temperature and a decrease in rainfall or an increase in rainfall variability. The study by Talanow *et al*. (2021), however, focused on commercial farmers, and there is thus, a need to focus on smallholder farmers in the Western Cape, as smallholder farmers tend to be more vulnerable to climatic changes (Harvey *et al*., 2018).

Climate change studies elsewhere in Africa show trends similar to those reported in South Africa, despite obvious differences in topography, ecosystems, governance systems and cultures. In southwestern Nigeria, both crop and livestock farmers perceived a change in climate, specifically the recurrence of drought, increasing temperatures, prolonged dry spells, rainfall ceasing halfway into the end of growing seasons, and the late onset of rainfall compared to 20 years ago (Ayanlade *et al*., 2017). The study by Zake and Hauser (2014), which was conducted in the Mpigi district Uganda concluded that the respondents' perceptions of climate change disasters were similarly based on gender as well as wealth status, and that respondents perceived an increased incidence of disease and pest outbreaks, as well as prolonged droughts due to climate change. The authors also concluded that there was a significant relationship between respondents' perceptions of climate change disasters and engaging in off-farm income-generating activities, as participants who perceived the occurrence of heavy rains with hailstones were more likely to engage in off-farm income-generating activities (Zake and Hauser, 2014).

A study by Antwi-Agyei *et al*. (2017), which was conducted in three farming communities in the Gonja District of the Northern region of Ghana, not only focused and analysed climatic stressors that might affect livelihood vulnerability, on household and community levels, but also non-climatic stressors. What was interesting was that the study indicated that households perceived climatic stressors such as an increase in temperature, drought, as well as a decrease in rainfall, as not the most critical stressors that influence household and community livelihood vulnerability (Antwi-Agyei *et al*., 2017). The study revealed that non-climatic stressors such as poverty, poor village infrastructure, limited market access, high cost of healthcare, high cost of farm inputs as well as a lack of storage facilities, as the most important stressors that affect livelihood vulnerability with the most prominent non-climatic stressor being a lack of money (Antwi-Agyei *et al*., 2017). It is, thus of importance to analyse not only climatic stressors, but consider non-climatic stressors when analysing smallholder farmers perceptions.

Farmers in south-western Tanzania, the Wolaita Zone of Ethiopia as well as central and northern Malawi perceive similar climatic perceptions including a decrease in rainfall quantity and variability, a delay in rainfall onsets (Kerr *et al*., 2017), frequent dry spells mid-season, an increased length and frequency of droughts, as well as an increase in average temperature (Pauline and Grab, 2018; Bedeke *et al*. 2018). The study by Kerr *et al*. (2017) did not, however, include responses of respondents with regards to the perceptions of temperature changes. Bedeke *et al*. (2018), also analysed whether smallholder farmers believed in the occurrence of climate change and the cause thereof and found that 61% of smallholder farmers who perceived climatic trends such as a decrease in precipitation, an increase in temperature and a shorter rainfall duration, believed in the occurrence of climate change and also that it was attributed to human action. Similarly, to Bedeke *et al*. (2018), Kerr *et al*. (2017) also analysed farmers' views of the underlying causes of climate change and found that people perceived deforestation to be a significant cause of climate change.

Despite biophysical differences across regions, studies across the African continent suggest that smallholder farmers generally perceive an increase in temperatures, a decrease in precipitation, an increase in drought occurrences and an increase in rainfall variability. For smallholder farmers who are vulnerable to climate change because they may lack financial or technical support, cultivate in marginal areas and depend on rain-fed agriculture (Holland *et al*., 2017; Donatti *et al*., 2018), analysing climatic perceptions are useful, as studies indicate that farmers cope with climatic change based on their perceptions thereof (Li *et al*., 2013; Abid *et al*., 2015). Meteorological data combined with local farmer perceptions can be useful because context-based adaptation decisions can be made based on the climatic changes perceived in their respective areas. The following section reviews studies that compared smallholder farmer's perceptions of climate change to analysed meteorological data.

1.2.5. Climate change: smallholder farmer' perceptions compared with meteorological data

In as much as farmer perceptions are central to local adaptations and policy, researchers have cautioned that when analysing the perceptions of smallholder farmers, with regards to rainfall patterns, the perceptions may be compromised as farmers may recall more recent climatic or extreme events (Pauline and Grab, 2018) or events that may have impacted them more negatively. Studies that compared farmer's climate change perceptions to meteorological data were conducted by Salerno *et al*. (2019); Pauline and Grab (2018), as well as Bedeke *et al*. (2018). Salerno *et al*. (2019), obtained meteorological data, which included daily satellite-based rainfall data. The authors concluded that in general, the rainfall perceptions of smallholder farmers in the Ugandan Albertine Rift corresponds to the satellite-based estimates, which suggested that the wet seasons are becoming wetter and that the dry seasons are becoming dryer (Salerno *et al*., 2019). Similarly, the rainfall perceptions of smallholder farmers in the Great Ruaha River Sub-Basin in Tanzania, correspond to the meteorological data obtained (Pauline and Grab, 2018).

The studies by Salerno *et al*. (2019) and Pauline and Grab (2018), only focused on comparing smallholder farmer's perceptions to precipitation data obtained; whereas Bedeke *et al*. (2018), included observed precipitation- as well as temperature data, in their study based in Ethiopia. The authors concluded that, there was an increasing trend with regards to a minimum as well as a maximum annual temperature and a decline in annual rainfall, and that farmer's perceptions correspond with the trends analysed (Bedeke *et al*., 2018).

Similarly, results of a study conducted in Nigeria that analysed meteorological data indicated that there were years that experienced lower rainfall than normal together with late-onset and early cessation in that area, confirming the perceptions of the farmers in that area(Ayanlade *et al*., 2017). The findings of a study also confirmed that the perceptions of farmers and extension officers of the Vhembe District in South Africa, with regards to long-term rainfall and temperature changes correspond to the meteorological data analysed (Kom *et al*., 2020).

It is imperative that smallholder farmers' perceptions of climatic changes correspond to meteorological trends of their respective areas to implement suitable and context-based adaptation responses. From the studies in this review, farmers perceptions of climatic changes such as increasing temperatures and lower rainfall, generally corresponds to meteorological data analysed.

1.2.6. Adaptation responses implemented by smallholder farmers

Climate vulnerability and extreme climatic disasters that impact smallholder farmers can be remedied through evidence-based adaptation responses when farmers are aware and can identify climatic factors affecting their livelihoods (Kom *et al*., 2020). Multi-stakeholder evaluations have been gradual in including the vulnerabilities and the local knowledge of smallholder farmers (IPCC, 2014). Apata (2011) and Obayela *et al*. (2014), indicate that the level of climate change knowledge of smallholder farmers is paramount to implementing climate change adaptation and coping strategies.

According to a study conducted by Atube *et al*. (2021), in two districts in northern Uganda, namely the Amuru and Apac districts, smallholder farmers utilize several adaptation strategies to mitigate climate change-induced effects on agricultural activities. The adaptation strategies revealed-, were mostly related to reducing the effects of drought. The most widely adopted adaptation strategy amongst smallholder farmers in both districts, was to plant different crop varieties, to test improved crop productivity (Atube *et al*., 2021). Smallholder farmers in Uganda indicated that they planted drought-resistant crops such as cassava (*Manihot esculenta*), which is an indigenous plant, to mitigate challenges associated with prolonged droughts (Zake and Hauser, 2014). Further responses included planting early maturing crop varieties and constructing trenches to conserve water and soil, respectively. Farmers respond to climate change disasters, based on indigenous knowledge and earlier experience of climate change disaster management, which has been transferred to farmers throughout generations (Zake and Hauser, 2014).

Smallholder farmers in the uMzinyathi District of Kwazulu-Natal in South Africa, also referenced eight other adaptations, besides increasing crop variety. These included, cover cropping, using organic manure for crop fertilization, planting of different fields at different times, fallowing, minimum tillage practices, the planting of trees alongside some of the crops, mixed cropping as well as the use of cropping in the moist bottom of the valley (Shisanya and Mafongoya, 2016). Smallholder farmers responded to climatic risks by adjusting the cropping date to allow the crops to better cope with variations in the timing and duration of the rainy season, as farmers who implemented cropping date adjustments, perceived high temperatures and low soil moisture volumes (Bedeke *et al*., 2018). Smallholder farmers also mentioned that to mitigate climatic risks, they used improved crop varieties and utilized open-pollinated crop varieties, which were less costly than hybrid varieties that are drought-resistant and provide higher yields (Bedeke *et al*., 2018). In response to drought stress, farmers reported that they had made a shift from only producing maize, to producing multiple crops in mixed systems, such as maize and tuber or maize and legumes (Bedeke *et al*., 2018). Crop diversification, choosing crops with drought-resistant attributes and experimenting to test costing of various adaptations seem to be common amongst smallholder farmers.

1.2.7. Adaptation response influences to climate change effects

Factors such as farm size, access to extension services, land ownership, and household size, were determinants of smallholder farmers with regards to decisions of climate change adaptation practices (Menghistu *et al*., 2020). Similarly, Atube *et al*. (2021), found that household size does have a significant effect with regards to determining adaptation strategies. According to Menghistu *et al*. (2020), farmers that have access to climate change information, such as temperature and rainfall data, are more likely to adapt to climate change, than farmers that are without such information. Koelle and Oettle (2009), that focused on smallholder adaptation in the Suid Bokkeveld region of the Northern Cape, found that farmers may be more readily prepared to adapt to climate change if stakeholders such as researchers engage with farmers through participatory action research. It was also determined that the gender of the household head has a significant influence on adaptation strategies and that male household heads were more likely to use pesticides and chemical fertilizers as adaptation strategies, compared to female household heads (Atube *et al*., 2021).

Years of farming experience obtained, also determines decisions with regards to implementing climate change adaptation strategies, as farmers with more years of experience are more likely to plant trees as well as implementing fallowing as adaptation strategies (Atube *et al*., 2021). Other factors, that have a significant influence in determining adaptation strategies of smallholder farmers include the marital status of the household head, the availability of extension services, quantity of land available for production, travel time to markets, annual income as well as access to credit (Atube *et al*., 2021).

1.2.8. Challenges with adaptation responses

There is a gap involving climate change adaptation planning with regards to understanding and accessing climate change information (Girvetz *et al*., 2009). According to Mkuhlani *et al*. (2020), smallholder farmers and especially horticulture-dependent farmers and enterprising pensioners, also mentioned that climate change adaptation has been challenging due to limited climate information, affecting managing planting dates accordingly. In a study conducted by Popoola *et al*. (2020), it was discovered that the failure to adapt to climate change was mainly attributed to the lack of access to agricultural extension services. According to Popoola *et al*. (2020), smallholder farmers in the area noted that there is a serious lack of knowledge regarding appropriate climate change response and adaptation strategies as well as a lack of climate change information, available. Although smallholder farmers perceive changes in climatic patterns, not all smallholder farmers make the necessary adjustments to their respective agricultural systems or reassess their management decisions in coping with the varying climatic conditions (Gbetibouo, 2009). Appropriate agricultural extension and other knowledge-brokering pathways (e.g., peer support, mentor farming) plays a key role in transferring information with regards to agricultural technologies and improved varieties to farmers (Zamasiya *et al*., 2014) as well as linking farmers and stakeholders that provide information such as policymakers and researchers (Zamasiya *et al*., 2017).

Apart from extension services and information, one other constraint smallholder farmers face regarding climate change is access to financial resources to effect change. Mkuhlani *et al*. (2020), found that the most critical constraint that smallholders face with regards to climate change adaptation, is the lack of financial resources, especially amongst horticulture-farming and mixed-farming households in Limpopo and Eastern Cape provinces of South Africa. Climate change adaptation is mainly limited by the lack of financial resources as farmers require finances for irrigation as well as for seed (Mkuhlani *et al*., 2020). Other constraints to climate change adaptation mentioned by smallholder farmers in the study by Popoola *et al*. (2020), also includes a lack of savings or credit facilities as well as poor health, low levels of education, gender, a lack of property rights, or access to land that is secure and limited access to markets for selling produce. Bedeke *et al*. (2018), concluded that smallholder farmers face four main challenges with regards to climate change adaptation. The main challenge was reported to be financial constraints concerning purchasing water pumps. Other constraints included increased temperatures which have led to increased water evaporation rates, high prices of polythene plastic to conserve rainwater as well as high water infiltration rates due to poor quality pond construction materials (Bedeke *et al*., 2018).

1.2.9. Climate-Smart Agriculture and SmartAgri

In response to climate change threats, stakeholders such as the World Bank and the Food and Agriculture Organization of the United Nations (FAO) have identified Climate-smart agriculture as an approach to potentially cope with and/or mitigate such threats (Taylor, 2018). Climate-smart agriculture is a governance framework, that was designed to transform agricultural systems when challenged with the risks associated with climate change, to ensure food security and support sustainable development (FAO, 2019). According to the FAO (2013) and the World Bank (2015), CSA should be acknowledged as a framework for reference and should be adopted to suit the local context-specific situation. The climate-smart agriculture framework broadly aims to reduce greenhouse gas emissions, improve, or maintain productivity as well as contributing to climate change adaptation including soil conservation practices (FAO, 2013; World Bank, 2015).

The SmartAgri project was developed in 2014 in response to risks associated with climate change in the Western Cape. The SmartAgri plan was implemented in 2016 and is a collaborative project between stakeholders such as the Western Cape Department of Environmental Affairs & Development Planning (DEA&DP), the Western Cape Department of Agriculture (DOA) and the University of Cape Town's African Climate and Development Initiative (ACDI) (DOA and Greencape, 2021). According to the Western Cape Government (2016), the objective of the SmartAgri plan was to provide a plan to ensure that the agricultural sector of the Western Cape becomes more climate-resilient, and that the amount of carbon that is produced by the sector is low. From November 2019 to April 2020 the DOA commissioned an evaluation report titled, "Evaluation of the Diagnostic, Design, and Implementation of the Western Cape Agricultural Sector Climate Change Framework and Implementation Plan" (SmartAgri), in which the DOA evaluated the SmartAgri plan by interviewing multiple stakeholders (DOA, 2020). As ultimate beneficiaries of the SmartAgri plan, the evaluation included six focus group discussions with various farmers throughout the Western Cape (DOA, 2020). Two focus group discussions (FGD's) were held in the general Southern Cape region. One FGD was held for grain-producing farmers, with 7 farmers participating and the other FGD was held for dairy farmers with two farmers participating. There is, thus, a gap in research with regards to the state of awareness of smallholder farmers in the Overberg district, with regards to the SmartAgri plan, as well as awareness with regards to the CSA framework.

1.3. Problem statement

Smallholder agricultural systems may be vulnerable to climate change, since such systems often have a low capacity to adapt to changes (Adger *et al*., 2003); are located in areas that may be subjected to climatic hazards such are deserts and hillsides (Morton, 2007; UNEP, 2013); are often dependent on rainfed crops (Eakin, 2005; Lobell *et al*., 2008), and may rely on crops that are not suited for productivity (Lobell *et al*., 2008), because of the direct effect of climate change. As a result of increasing temperatures and considering the recent drought, the population, economy, and ecosystems of the Western Cape are highly vulnerable to climate change. It is thus, critical that the province moves towards land use practices that are more resilient to climatic hazards. Food security and food production in the Western Cape can suffer (and may already be suffering) detrimental effects if adaptation strategies are not utilized.

The vulnerability of agriculture in South Africa to climate change was examined in a nation-wide study across a range of sectors of the industry (Gbetibouo and Ringler, 2009). It is, however, of importance to provide interdisciplinary and participatory research with regards to adaptation strategies to context specific risks that are associated with climate change. According to Ayanlade *et al*. (2017), the success of adaptation largely depends on how smallholder farmers perceive changes relating to the climate, as well as the successful understanding of climate change. Climate change literature, as reviewed by Ayanlade *et al*. (2017), has largely focused on the impact thereof, modelling systems and risk and adaptation assessment. Comparatively fewer studies have been devoted to addressing and analysing the perceptions of those experiencing climate change. There is an apparent gap between climate change research, and rural farmers' perceptions thereof (Ayanlade *et al*., 2017).

There is a need to investigate context specific adaptation efforts in terms of how smallholder farmers respond and experience climate change (Harvey *et al*., 2018). Information regarding the characterisation of the vulnerability of smallholder farmers in the Western Cape, and how these farmers perceive and responded to climate change may have significant value for policy makers and practitioners. It is of importance to provide context specific information to policy makers for them to be able to develop policies and strategies for climate change adaptation for smallholder farmers (Castellanos *et al*., 2013; Donatti *et al*., 2017) and thus channel funds to implement these policies.

The Overberg District Municipality compiled the Overberg District Municipality Climate Change Response Strategy (Birch *et al*., 2017), which includes a district-wide framework in response to climate change. The framework fails, however, to include a vulnerability assessment, as well as adaptation methods specifically related to smallholder farmers in the district. The present study would, thus be able to help to fill this specific gap in research in this study area.

The climatic conditions of Mediterranean type ecosystems are defined by warm or hot dry summers and temperate, wet winters (Seageretal *et al*., 2019). It is projected that areas with Mediterranean climates are getting hotter and drier (Semenov *et al*., 2014; Senapati *et al*., 2018). According to Polade *et al*. (2017), a decrease in precipitation is expected in Mediterranean climatic regions as a result of climate change caused by rising greenhouse gases. There is also an increase of drought risk in these regions (Cook *et al*., 2014). These projections indicate that Mediterranean regions are becoming increasingly arid (IPCC, 2013). Future predictions indicate that it is plausible that the Cape region of southern Africa may lose its Mediterranean-type climate, classification completely as a result of the encroaching subtropical aridity (Seageretal *et al*., 2019). These changing climatic conditions may impact smallholder farmers, whose livelihoods depend on farming systems that are located in the Mediterranean climatic region of South Africa. It is, thus of importance to analyse the perceptions and adaptation strategies of farmers located in this climatic region.

1.4. Sustainable Development Goals

This study may contribute to the United Nations' Sustainable Development Goal (SDG) 1 (No Poverty); 2 (Zero Hunger) and 13 (Climate Action). The study specifically correspond to target 1.5, of SDG 1, which is to build the resilience of those in vulnerable situations and reduce their risk and vulnerability to climate-related extreme events and other disasters. It will also contribute specifically to target's 2.3, which is to double the agricultural productivity and incomes of small-scale food producers through secure and equal access to land, knowledge, financial services, markets and other resources for value addition and non-farm employment and 2.a. which is to increase investment opportunities through agricultural research and extension services among others to enhance the productivity of agriculture in developing countries. This study may finally also contribute to targets 13.1 and 13.2, which are respectively, to strengthen the resilience and the adaptive capacity to climate related disasters of regions and integrate climate change measures into planning and policy.

1.5. Research questions

The research in this study attempted to answer the following questions:

1. How do smallholder farmers perceive climate change and the effects thereof?

2. How does the perceptions with regards to long term temperature and rainfall patterns as well as extreme weather events, of farmers compare to long term climate trends obtained from meteorological stations from the district?

3. How are smallholder farmers currently responding to climate change?

1.6. Research objectives

This study aimed to evaluate the following research objectives:

1. Assess the perceptions, knowledge and attitudes of smallholder farmers in the district with regards to climate change.

2. To compare the perceptions with regards to long term temperature and rainfall patterns as well as extreme weather events, of smallholder farmers to the Overberg district's long term meteorological data.

3. Assess smallholder farmers in the district's current and probable typology of adaptation responses and strategies on coping with climate related risks.

1.7. Thesis outline

This chapter offered an overview of the perceptions and adaptations of smallholder farmers with regards to climate change as well as an overview of determinants and challenges regarding implementing strategies for adaptation. Chapter 2 includes a systematic review of adaptation responses of smallholder farmers globally. Followed by Chapter 3, which includes a study with regards to comparing climatic data that was analysed to the perceptions of smallholder farmers in two former mission stations in the Overberg district in the Western Cape. Chapter 3 aims to evaluate Objective 1, 2, and 3. Chapter 4 includes general conclusions drawn from Chapter 2 and Chapter 3, and also includes recommendations for future studies as well as recommendations for smallholder farmers.

Chapter 2 – A global perspective of climate change adaptation strategies of smallholder farmers: a systematic review

2.1. Introduction

Globally, the effects of climate change are experienced in phenomena including increasing temperatures, decrease in rainfall, and extreme weather events such as floods and drought. Due to climate change, there will be a decrease in biodiversity and natural resources such as land and fresh water, which will exacerbate known vulnerabilities of regions highly dependent on such resources (Arneth *et al*., 2019). Food and livelihood security can decrease due to climate change which has detrimental impacts on the agricultural sectors of developing countries (Cholo *et al*., 2013). Rural farmers in developing countries, particularly African countries, are especially more vulnerable to the impacts associated with climate change (Williams *et al*., 2015; Serdeczny *et al*., 2017; Abegunde and Sibanda, 2018), because of their high reliance on rainfed agriculture and low technological and infrastructural development (Lipper *et al*., 2014; Ericksen *et al*., 2011; Nelson *et al*., 2014; Adimassu and Kessler, 2016).

About 2.5 billion people live in rural areas globally, are dependent on the income generated by farming (FAO, 2013). Smallholder farmers constitute about 85% of the world's farmers (Graeub *et al*., 2016; Lowder *et al*., 2016; Nagayet, 2005). According to research, smallholder farmers have suffered a substantial loss in welfare as a result of climate change (Komba and Muchapondwa, 2018). Smallholder farmers are especially vulnerable to climate change, as they may have limited resources that may aid in adapting to shocks associated with climatic change (Frank and Penrose-Buckley, 2012; Harvey *et al*., 2014). Climate change adaptation can be defined as an ongoing process that shifts livelihood practices to help respond to and cope with the changing climatic conditions (Otitoju and Enete, 2016). It is, thus, imperative for smallholder farmers to adapt to climatic changes to increase resilience and reduce the vulnerability of their livelihoods.

Five regions on Earth are classified as Mediterranean-type ecosystems, namely, Central Chile, Mediterranean Basin, Southwest Australia, California, and the Cape region of South Africa (Cowling *et al*., 1996). Mediterranean-type ecosystems regularly experience a winter-rainfall and summer drought precipitation cycle (Blumler 2005; Rebelo *et al*. 2006). Mediterranean regions are experiencing an increase in temperature and decrease in precipitation long-term, which also leads to such regions becoming increasingly arid (Penuelas *et al*., 2005; IPCC, 2013). This change in climatic conditions is accompanied by extreme weather events such as floods, drought, and heatwaves (Penuelas *et al*., 2013).

As stated in Chapter 1, this present study aims to investigate how smallholder farmers, particularly crop-livestock farmers, are adapting to climate change in Mediterranean-type ecosystems, especially in the Cape region of South Africa, as a smallholder in Africa may be more likely to experience the vulnerabilities associated with climatic change. The study will also provide insight regarding smallholder adaptation responses to climate change, globally, through analysing empirical studies focussing on smallholder climate change adaptation responses.

2.2. Methodology

The focus of this review was on empirical studies that focused on smallholder farmer adaptation responses to climate change. The papers included in this review were searched according to a protocol developed using the PRISMA (Preferred Reporting Items for Systematic review and Meta-Analysis) guidelines (Moher *et al*., 2015) for systematic review writing as shown in Figure 2.1. A literature search was conducted on 10 June 2021 using the search string: TITLE-ABS-KEY ((("Climate change" OR "climate variability" OR "global warming") AND (adaptation) AND (responses OR strategies OR efforts) AND ("smallholder farmers" OR "small scale farmers")) in the search databases, Scopus, Web of Science and CAB Abstracts. There were no date restrictions set on the search, to ensure that all relevant studies would be included in this review.

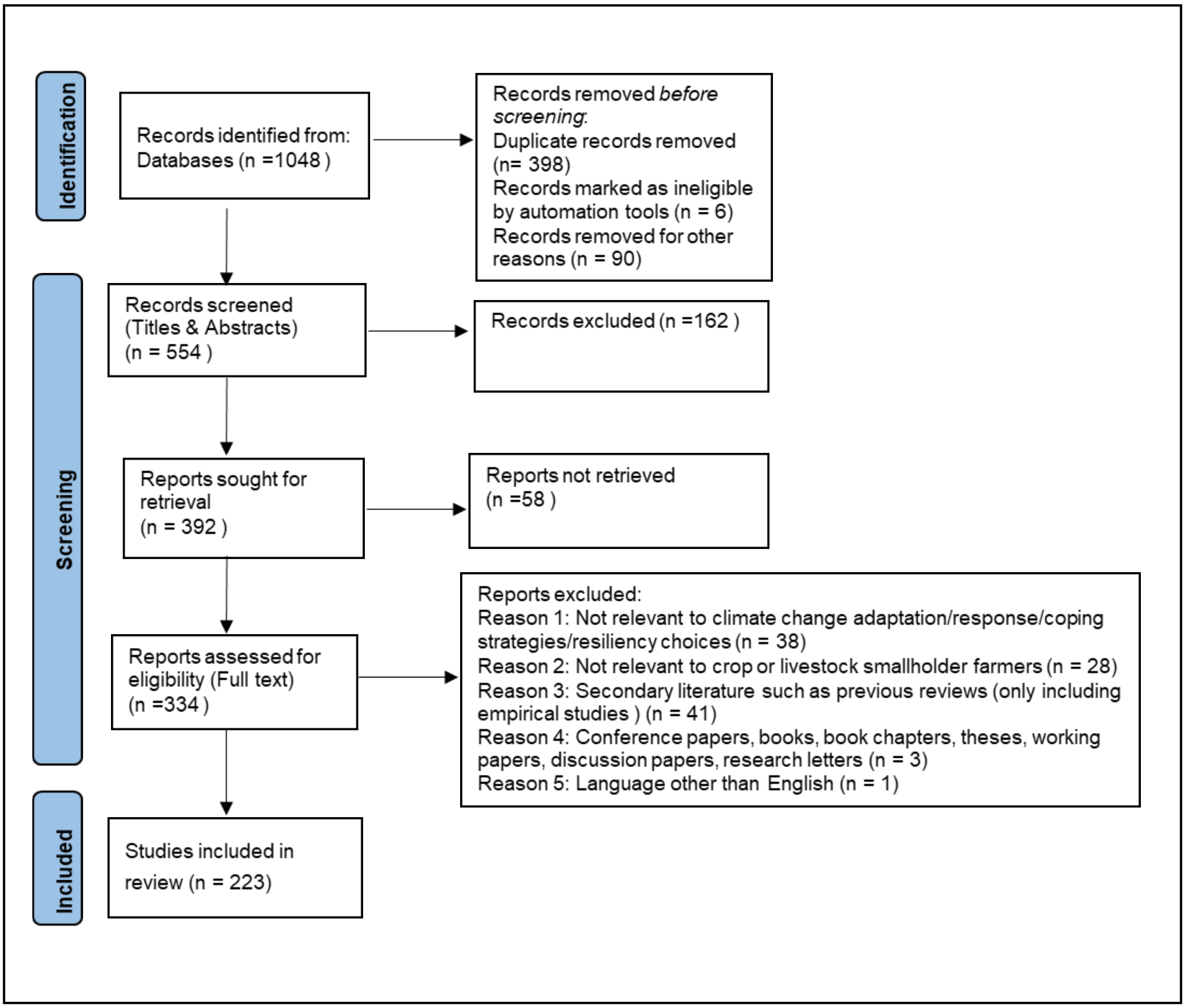


Figure 2. 1 PRISMA flow diagram of the PRISMA systematic review process (Moher *et al*., 2015).

The papers were exported to the reference manager, Zotero desktop application version 5.0.96.3 (2021). Duplicates were then removed. Records were also removed that were marked as ineligible by automation tools of the Zotero desktop application. Conference papers, books, book chapters, theses, working papers, discussion papers, and research letters were also not included in this study and were removed. Titles and abstracts of papers were then screened, and any papers that were not relevant to climate change adaptation/ responses, smallholder farmers, or crop or livestock farming were removed. Reports were then sought for retrieval, and full reports then scanned for eligibility of this study. Again, studies were removed that were not relevant to climate change adaptation responses and typologies thereof and crop or livestock smallholder farmers. As this study explicitly deals with empirical studies, secondary literature such as previous reviews were also removed. Conference papers, books, book chapters, theses, working papers, discussion papers, and research letters that were missed during the title and abstract screening were also removed. Papers in languages other than English were also not included in this study and were removed.

Finally, the full text of 223 studies focusing on adaptation strategies of smallholder crop/livestock farmers was considered for final review. The adaptation strategies of smallholder farmers in each paper were analysed concerning region, country, and continent. The Köppen–Geiger climate classification for each of the regions represented in the papers was searched to analyse the climate type of each region homogeneously. These analyses allowed the current adaptation methods used by smallholder farmers globally in the different climatic types to be described and represented in this study.

2.3. Results

The majority of papers (N=167) relating to climate change adaptation responses and typologies thereof of smallholder farmers, focused on countries in Africa (Fig 2.2). The number of papers that included studies that were conducted in Asia, included in this review was 42 (Fig 2.2). Very few studies (N=12) and (N=6) included study sites that were represented by North America and South America respectively. It is also indicated in Figure 2.2, that no studies with regards to smallholder climate change adaptation were conducted in Europe or Australia that met the inclusion requirements for this study. Although no studies are included in this review, examples of studies with regards to climate change adaptation of farmers in Europe include Reidsma *et al*. (2010), Ricart *et al*. (2019) and Leclère *et al*. (2013), and in Australia, include Thamo *et al*. (2017) and Wheeler *et al*. (2013).

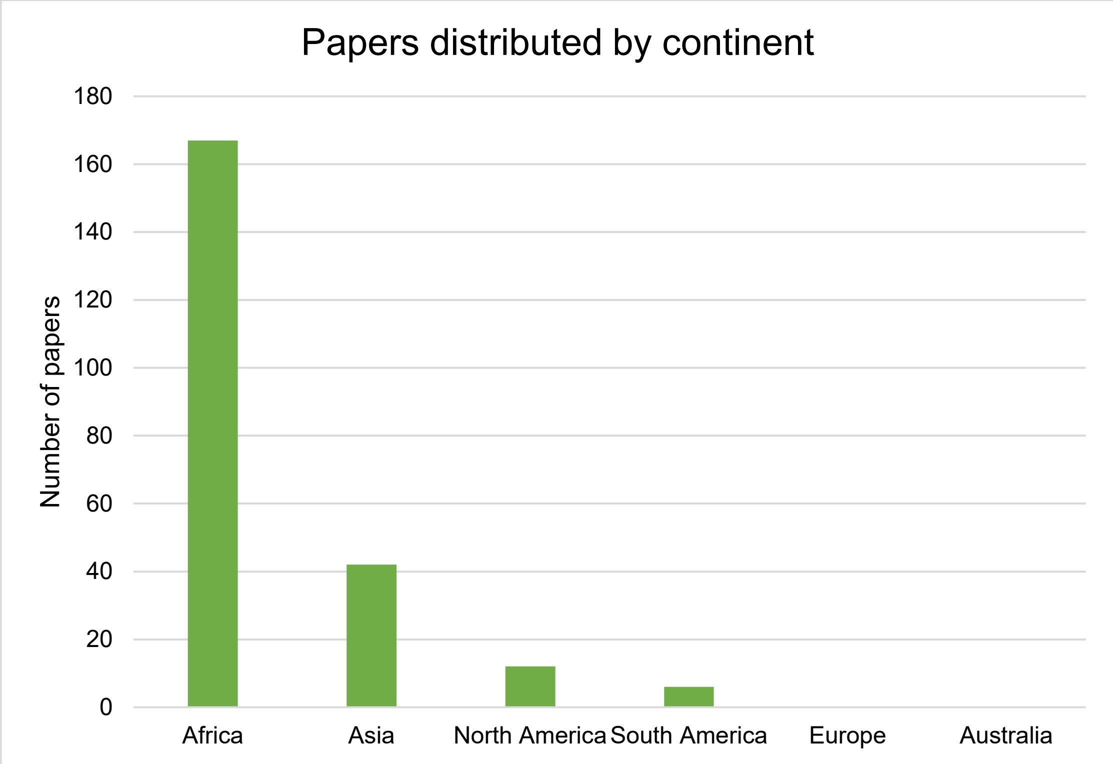


Figure 2. 2 The number of papers distributed by continent.

Countries that were favoured for studies that analysed smallholder farmers, climate change adaptation responses included in this review, included the African countries of Kenya (N=27), Ethiopia (N=26), Ghana (N=24), Zimbabwe (N=17), South Africa (N=16), and Nigeria (N=12) (Fig. 2.3). Followed by the Asian countries of China (N=6), Nepal (N=6), Vietnam (N=6), Bangladesh (N=5), and India (N=5). North American countries represented by the papers in Figure 2.3 include Mexico (N=3), Honduras (N=3), Guatemala (N=2), Costa Rica (N=2), Nicaragua (N=1), and El Salvador (N=1). South American countries included in this review included Brazil (N=2), Bolivia (N=1), Chile (N=1), Colombia (N=1), and Peru (N=1) (Fig.2.3).

Papers in this study focused on the tropical savanna climatic zone (Fig. 2.4). Studies were also readily conducted in the hot semi-arid and subtropical highland climatic zones. Climatic regions that have received little consideration included the arid hot desert -, Mediterranean (cool summer) -, humid subtropical -, tropical savanna (dry summer) -, Mediterranean (hot summer) -, continental (dry winter) - and humid continental climatic zones (Fig. 2.4).

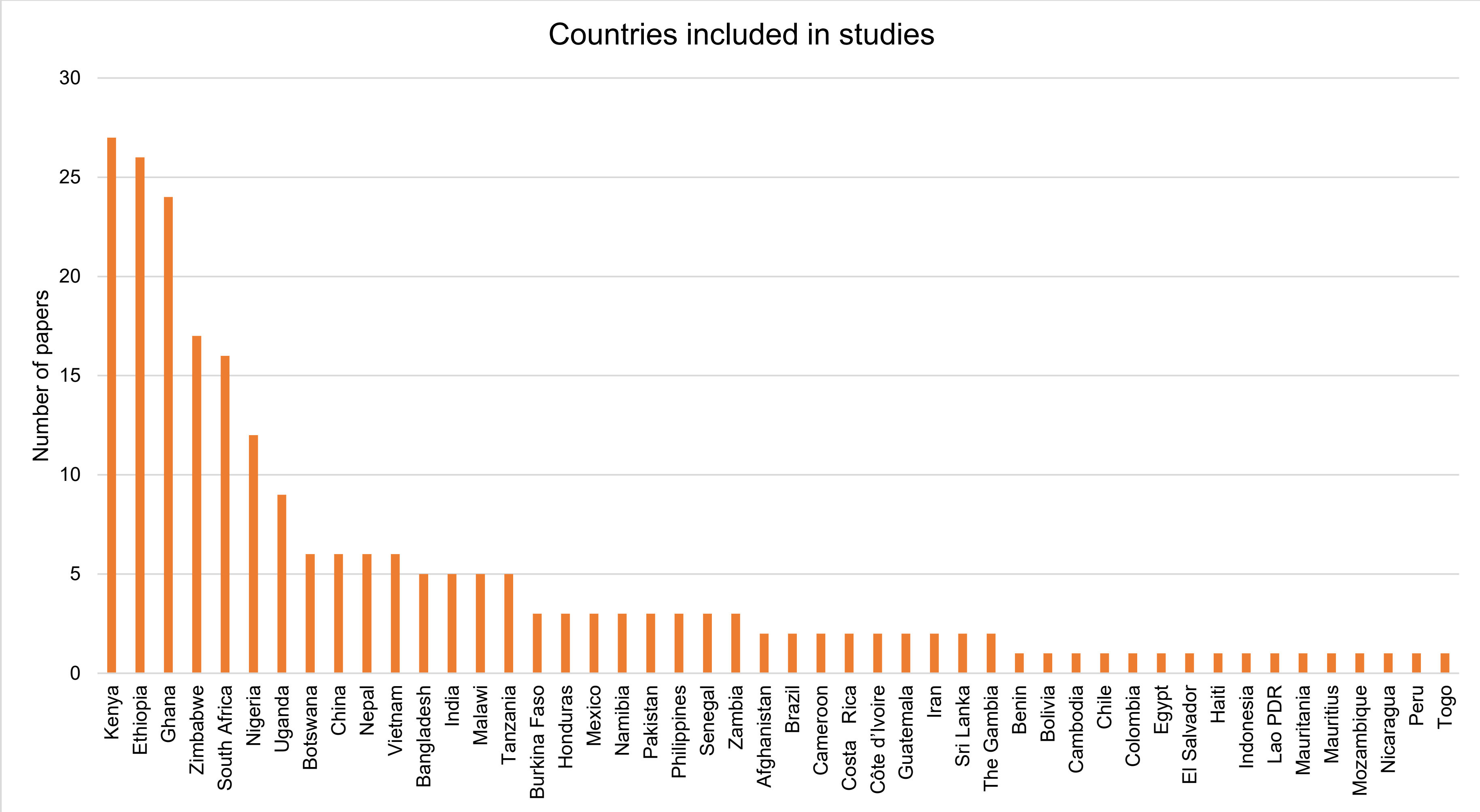


Figure 2. 3 Countries studies in papers included in this review.

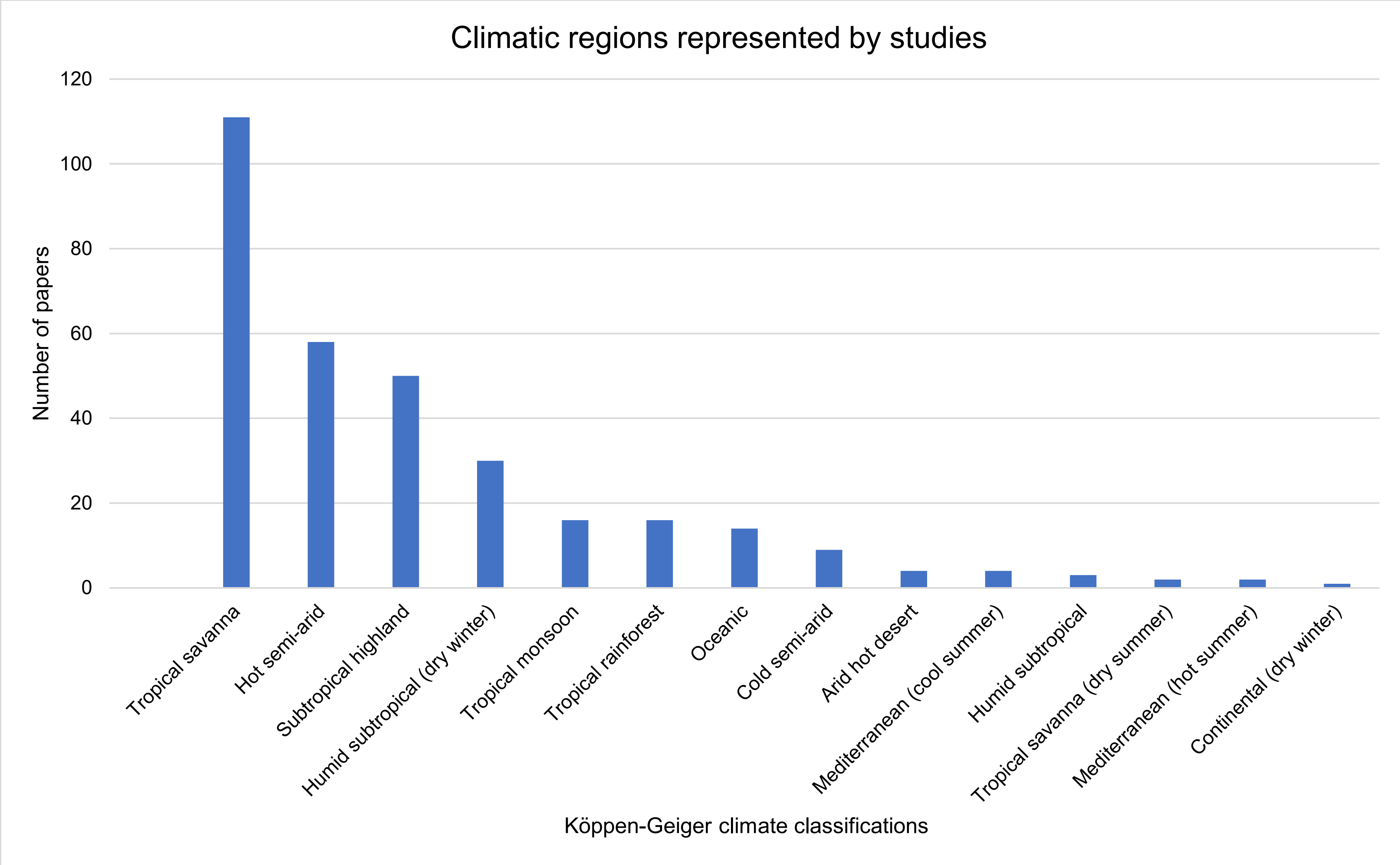


Figure 2. 4 The Köppen–Geiger climate classifications of the regions studied in the papers included for this review.

Tables 2.1, 2.2, 2.3 and 2.4 represent the preferred climate adaptation methods of smallholder farmers if mentioned in papers included in this review of the different countries in Africa, Asia, North America, and South America respectively. The predominant adaptation methods used by smallholder crop farmers in Africa included, planting drought resistant crops; changes in planting dates; implementing intercropping; using irrigation; implementing crop rotation and diversifying crops planted on farms (Table 2.1). Livestock farmers in Africa adapted to climate change by migrating to better suited areas, supplementing feed, and diversifying livestock on farms (Table 2.1).

Table 2. 1 Climate change adaptation responses implemented by smallholder farmers in Africa as reported in the literature.

Authors	**Country**	**Adaptation responses reported**
Baudoin *et al*. (2014)	Benin	Taking out loans; working in town and using improved seed varieties.
Akinyemi (2017); Kgosikoma *et al.* (2017); Mugari *et al.* (2020); Sekelemani *et al.* (2020); Bosekeng *et al.* (2020)	Botswana	Planting drought resistant crops; supplementing livestock feeds; reducing herd size; moving livestock to areas with better forage; changing planting dates; sequencing cropping; crop diversification; using improved hybrid seeds and planting early maturing crops.
Barbier *et al*. (2009)	Burkina Faso	Using micro water harvesting techniques; improving fields with stone lines; storing hay and sorghum residues for animal feed during dry season and fattening bull and sheep.

Awazi *et al.* (2019); Ngoe *et al*. (2019)	Cameroon	Shifting planting dates; implementing soil conservation measures; intercropping; irrigation; using improved varieties; off-farm practices; mono-tree plantations; joining community groups; non-farm activities; implementing agroforestry practices; using improved fallows; increasing land area under cultivation; using external inputs and crop diversification.
Comoé *et al*. (2014); Comoé and Siegrist (2015)	Côte d'Ivoire	Using new crop varieties; mixed cropping; adjusting the agricultural calendar; changing the planting method; watering crops; livestock watering; enclosing livestock; implementing sanitary treatments for animals; dietary changes such as eating more cassava that is more suitable to climatic conditions; implementing repeated sowing; using more seeds during sowing; changing the size of hillocks; keeping trees on the field; and making large holes for seedbeds.
Kassem *et al*. (2019)	Egypt	Using manure; crop rotation and changing crop patterns.
Destaw and Fenta (2021); Alemayehu and Bewket (2017); Alemayehu and	Ethiopia	Implementing terracing; changing planting dates; applying fertilizer; crop diversification; income

Bewket (2017a); Etana *et al.* (2020); Gebru *et al.* (2020); Hirpha *et al*. (2020); Kahsay *et al*. (2019); Belay *et al.* (2017); Lemessa *et al.* (2019); Mesfin and Bekele (2018); Temesgen *et al.* (2014); Tesfaye and Seifu (2015); Tessema and Simane (2021); Tessema *et al*. (2013)		diversification; livestock diversification; soil and water conservation; planting trees; irrigation; using drought tolerant and fast maturing crops; using improved seed varieties; earing an off farm income; seasonal migration; changing consumption patterns; taking credit; getting support from government programmes; renting land; decreasing livestock numbers; using cross-bred animals; crop rotation and increasing the intensity of input use; using improved varieties and intercropping; engaging in non-farm activities; incorporation of crop residue and water harvesting.
Adam *et al*. (2020); Dapilah and Nielsen (2020); Aniah *et al.* (2019); Fagariba *et al.* (2018); Fagariba *et al.* (2018a); Fagariba *et al.* (2018b); Osei (2017); Guodaar *et al.* (2021); Azumah *et al.* (2020); Lawson *et al.* (2020); Zakaria and Matsui (2020); Williams *et al.* (2017); Williams *et al.* (2019);	Ghana	Using drought tolerant crop varieties; selling household assets; household migrating; decreasing food consumption; changing diets; changing planting dates/ early planting; using soil and water conservation strategies; selling livestock; providing extra water and feed for livestock in the dry season; reducing the quantity of feed; rearing other kinds of livestock; increasing the number of local

Yamba *et al*. (2019); Yiridomoh *et al*. (2020)		breeds; mixed farming; practicing agroforestry; mulching; land rotation; crop diversification; diversification to non-farming activities; rainwater harvesting, relocating farms to water sources; using neem leaf extract and organic manure applications; irrigation; using pesticides and herbicides; crop rotation; using improved seeds; row planting; field bunding and using agrochemicals.
Atsiaya *et al*. (2019); Kirimi *et al.* (2019); Kichamu *et al*. (2018); Ombogoh *et al*. (2016); Otieno *et al*. (2017); Lydia *et al*. (2021); Mburu *et al*. (2015); McCord *et al*. (2015); Quandt (2020); Mutunga *et al*. (2017); Mwenda *et al*. (2019); Nyang'au *et al*. (2021); Ochieng *et al*. (2017)	Kenya	Increasing use of organic fertilizers; planting date changes; rainwater harvesting; irrigation; replanting; fenced paddocks; crop rotation; intercropping; reducing herd numbers; increasing herd numbers; farming with more climate adaptable species; zero grazing; improved fodder; mulching; abandoning livestock; changing crop varieties; planting trees/agro-forestry; using soil and water conservation measures; water harvesting; culling and selling livestock; planting drought tolerant crops; practising drip irrigation; keeping small stock; crop diversification; planting crops that thrive well in flooded areas; ploughing across

		contours for drainage; terracing; planting grass on embankments; off-farm employment; using insecticides; crop diversification; vaccinating animals and charcoal burning and using manure
Tarchiani *et al*. (2018)	Mauritania	Choosing specific seed varieties; choosing the most appropriate planting date, and cultural operations are also practiced at favourable periods.
Ramborun *et al.* (2019)	Mauritius	Increasing use of pesticides and fertilizers.
Chichongue *et al.* (2015)	Mozambique	Changing crop varieties.
Angula and Kaundjua (2015)	Namibia	Migrating to areas not affected by floods; digging trenches in and around crop fields to reduce inundation; supplementing agriculturally based livelihood with cash income, remittances, or pension; destocking livestock; purchasing food to enhance food security; using drought resistant crop varieties and migrating to land better suited for grazing.
Falaki *et al*. (2010); Jellason *et al*. (2020); Ayanlade *et al.* (2017); Tambo and Abdoulaye (2013); Tarfa *et al*. (2019); Yila and Resurreccion (2014)	Nigeria	Changing planting dates; planting trees; crop diversification; using early maturing varieties; economic diversification; changing the planting pattern of crops; livestock farmers migrate to green pasture; diversifying water sources to supplement

		supply; using drought tolerant varieties; planting trees; soil and water conservation; implementing irrigation; intercropping; crop rotation; using high-yield varieties and replanting.
Gandure *et al*. (2013); Kom *et al*. (2020); Magombeyi and Taigbenu (2008); Popoola *et al*. (2018); Myeni and Moeletsi (2020); Samuel and Sylvia (2019); Tesfuhuney and Mbeletshie (2020); Thinda *et al.* (2020)	South Africa	Rainwater harvesting techniques; changing planting dates; changing crop varieties; using drought-tolerant seeds; planting improved seedlings; using shorter cycle crops; diversifying crops; implementing irrigation practices; migrating to urban area; supplementing income by being involved in petty business; applying supplementary irrigation; improving soil fertility; soil and water conservation; minimum tillage and camp rotation; obtaining insurance; mulching; reducing livestock numbers; planting trees.
Kihupi *et al*. (2015); Brüssow *et al*. (2017); Ojoyi and Mwenge Kahinda (2014); Van Aelst and Holvoet (2017)	Tanzania	Irrigation; crop diversification; planting early maturing maize varieties; planting drought resistant crops; changing of planting dates; agriculture diversification; involvement in non-farm activities and planting cover crops.

Bagagnan *et al*. (2019); Sonko *et al*. (2020)	The Gambia	Using chemical fertilizers; planting trees; crop diversification; crop rotation; using early maturing crops; contour farming; zero-tillage; temporary migration and integrated pest management.
Ali *et al.* (2020)	Togo	Using selected seeds and adjusting sowing times.
Diem *et al.* (2017); Atube *et al.* (2021); Ombogoh *et al.* (2016); Mfitumukiza *et al*. (2017); Mubiru *et al*. (2018); Tiyo *et al*. (2015); Tiyo *et al*. (2015a)	Uganda	Expanding croplands; crop diversification; planting drought-resistant varieties; fallowing; planting trees; changing planting and harvesting dates; implementing micro-irrigation; rainwater harvesting; applying organic manure; selling livestock; growing additional feed; hiring shelter for protecting livestock; mulching; intercropping; soil conservation and using fertilizers.
Dumenu and Tiamgne (2020); Arslan *et al*. (2013); Kuntashula *et al*. (2014)	Zambia	Using drought tolerant crop varieties; changing planting times; crop diversification; relying on government assistance; engaging in non-farm jobs; conservation agriculture; implementing minimum tillage and crop rotation.

Dube *et al.* (2018); Grey *et al*. (2020); Jiri *et al*. (2015); Jiri *et al*. (2017); Rusinga *et al*. (2014); Zinyemba *et al*. (2020); Mupakati and Tanyanyiwa (2017); Mutandwa *et al*. (2018); Ndlovu *et al*. (2020)	Zimbabwe	Using drought and heat resistant crops; constructing contour ridges; harvesting rainwater; implementing zero tillage; irrigation; cultivating stream bank crops; migrating livestock to other grazing grounds seasonally; stocking of grain; planting early; conservation farming; planting small grains; implementing dry planting; adjusting planting dates; crop diversification; planting short-season crop varieties; mulching; agro-forestry; gardening; increasing pesticide use; cassava production and pit planting.

Smallholder crop farmers in Asia also implemented strategies such as changing crop varieties and types of crops, changing planting dates and diversifying their livelihoods by engaging in off-farm activities (Table 2.2). Adaptation strategies such as supplementing feed; migration and selling livestock were implemented by livestock smallholder farmers in Asia (Table 2.2).

Table 2. 2 Climate change adaptation responses implemented by smallholder farmers in Asia as reported in the literature.

Authors	Country	Adaptation responses reported
Omerkhil *et al*. (2020); Omerkhil *et al*. (2020a)	Afghanistan	Applying scientific techniques to improve crop production; using drought resistant crop varieties; using new crops and gaining assistance for crop cultivation from local authorities.
Delaporte and Maurel (2018); Aryal *et al*. (2020); Islam *et al*. (2021); Roy *et al*. (2021); Billah *et al*. (2015)	Bangladesh	Changing crop varieties; changing crop type; irrigation; changing from livestock to crop production; using savings; borrowing funds from family and neighbours; periodically reducing household food consumption; engaging in off-farm employment; seeking assistance from governmental and non-governmental organizations (NGOs); using pesticides; taking out loans; using compost; crop rotation and homestead gardening.
Hageback *et al*. (2005); Kibue *et al*. (2015); Qiang-yi *et al*. (2014)	China	Diversifying livelihoods; changing crop varieties; changing crop type; implementing water and soil management measures and changing planting dates.
Funk *et al*. (2020)	India	Using information and communication technologies; farm diversification; crop diversification; social networking through cooperatives and implementing

		soil; water conservation measures and using alternative crop varieties.
Irawan and Syakir (2019)	Indonesia	Implementing mixed cropping.
Keshavarz and Moqadas (2021)	Iran	Reducing cultivated areas; decreasing furrow length; avoiding second crop; increasing fertilizer use; selective irrigation; reducing livestock numbers; changing ration ingredients; decreasing feeding frequency; implementing postharvest grazing and supplementing feeding of livestock.
Ghimire *et al*. (2016); Karki *et al.* (2020); Khanal *et al*. (2018); Khanal *et al*. (2020) and Budhathoki *et al*. (2020)	Nepal	Diversifying into mixed crop-livestock systems; switching from crops to livestock; practicing zero tillage; making ridges across farms; intercropping; changing crop varieties; changing crop types; using new technologies; implementing soil and water management measures; diversifying income sources; migration; changing planting dates; changing harvesting dates; diversification of crops and varieties; manure; increasing irrigation; changing fertilizer applications; changes in timing of farm operations; engaging in off-farm activities and employment and obtaining crop insurance.

Ali *et al.* (2021); Shahbaz *et al*. (2020); Abid *et al.* (2019).	Pakistan	Changing crop varieties; changing input use; changing planting dates; irrigation; engaging in non-farm activities; implanting early planting schemes; mix farming; selling livestock; providing more water for livestock; livestock diversification and using trees for shade for livestock.
Landicho *et al.* (2015); Lasco *et al.* (2016)	Philippines	Replanting; using chemical pesticides and fertilizers; pruning; changing crops and harvesting crops earlier.
Esham and Garforth (2013)	Sri Lanka	Changing planting dates; shortening growing season; changing crop varieties and implementing crop rotation practices.
Nguyen *et al*. (2012); Vo *et al*. (2021)	Vietnam	Changing crop varieties; adjusting farming calendar; intercropping; monitoring weather forecasts; agro forestry; diversifying crops; irrigation diversifying livestock and improving soil quality.

Countries that were included in studies that mentioned the preferred adaptation strategies of smallholder farmers included El Salvador, Guatemala, Honduras, Nicaragua, Costa Rica, and Mexico (Table 2.3). The preferred adaptation responses of smallholder farmers in North America included changing planting dates, using new crops, using more fertilizers, implementing agroforestry, using fertilizers, using irrigation, taking out loans, engaging in off-farm activities to diversify their livelihoods as well as planting trees (Table 2.3).

Table 2. 3 Climate change adaptation responses implemented by smallholder farmers in North America as reported in the literature.

Author	**Country**	**Adaptation responses reported**
De Sousa *et al*. (2018)	El Salvador; Guatemala; Honduras; Nicaragua	Changing the agricultural calendar; using new crops and using more fertilizers.
Harvey *et al.* (2018)	Costa Rica; Honduras; Guatemala	Implementing agroforestry and restoration activities; adopting agroecological practices; using new crop varieties and using new technologies.
Campos *et al*. (2014); Mardero *et al*. (2015); Shinbrot *et al*. (2019)	Mexico	Shifting to intensive fertilization methods; investing in irrigation; took out loans; accessing government funding programs; seeking alternative livelihoods; tree-planting; adjustment of the agricultural calendar; storing water; diversification of crops; planting trees and soil conservation.

The preferred adaptation strategies of smallholder in the South American countries included in this study are mentioned in Table 2.4. The adaptation methods mentioned included intensifying production of cash crops; shifting to cattle and dairy farming; planting improved crop varieties; engaging in off-farm activities and relying on community institutions to cope with the climatic changes in the various areas (Table 2.4).

Table 2. 4 Climate change adaptation responses implemented by smallholder farmers in South America as reported in the literature.

Authors	**Country**	**Adaptation responses reported**
McDowell and Hess (2012)	Bolivia	Intensifying production of cash crops; relying on community institutions and engaging in off-farm activities to supplement income.
Maia *et al*. (2017)	Brazil	Shifting to cattle and dairy farming.
Zúniga *et al*. (2021)	Chile	Changing to crops with shorter growing periods and lower capital and technological costs.
Lennox (2015)	Peru	Planting improved varieties of grasses for livestock for dairy production.

2.4. Discussion

The results revealed that due to the search criteria in this study the most climate change adaptation research with regards to smallholder farmers has been conducted on the African continent. This may be because of the well-documented many stressors and reduced adaptive capacities of developing countries in Africa as a result of climate change (Parry *et al*., 2007; Gandure *et al*., 2013).

The study also, however, revealed that there have been limited attempts made to analyse smallholder adaptation with regards to climate change in European countries, although according to Kania *et al*. (2014), small farms or smallholder farms correspond to 67% of farms in the European Union (EU) and are particularly located regions including Scotland, Ireland, Northern Scandinavia, all Mediterranean countries, and South-eastern Europe (Claros, 2014). Analyses on climate change adaptation strategies of smallholder farmers in Australia are also limited. According to O’Brien (2017), Asian smallholder farmers in Australia are increasingly contributing to the agricultural sector of Australia. It is, thus of importance to investigate the impact of climate change and adaptation strategies that these farmers may be utilizing on this continent.

Results indicate that the majority of studies were conducted in developing countries specifically in Kenya, Ethiopia, Ghana, Zimbabwe, South Africa, and Nigeria. According to a study by Moghim and Garna (2019), that classified countries according to environmental resiliency; Kenya, Ghana, and Ethiopia were among countries that were classified as the least resilient countries in the world and may explain why these countries received attention with regards to climate change adaptation studies.

This current study also indicated that papers were focused on the tropical savanna climatic zone as well as semi-arid zones. According to Anderson *et al*. (2010), Boko *et al*. (2007), and Otto *et al*. (2015), climate change impacts may be more severely felt in arid and semi-arid areas. No studies included in this review have been conducted in the Mediterranean climatic region of the Western Cape in South Africa. The results of this current study suggest that more attention with regards to climate adaptation studies should be provided to climatic regions such as Mediterranean-, subtropical-, and continental climatic regions.

The study also provided insight into the preferred adaptation strategies of the different countries in Africa, Asia, and North- and South Americas. This may provide insight to smallholder farmers globally as to what adaptation strategies are currently being utilized. The information may also present as beneficial for government officials concerning policy planning for future climate change adaptation strategies.

2.5. Conclusions

Africa and Asia are the two continents with the highest number of studies on smallholder farmer adaptations to climate change across the continents. Research has also focused on the tropical savanna and semi-arid Köppen–Geiger climate regions globally. There is thus, a need to investigate the adaptation strategies of smallholder farmers in Europe and Australia, especially in Mediterranean climatic regions. There is also a need to investigate adaptation strategies of smallholder farmers concerning climate change in the Mediterranean climate region of South Africa in the Western Cape as the region is becoming increasingly arid as a result of warming and lower rainfall, as mentioned in Chapter 1. Chapter 3 will thus, aim to fill this specific gap in research by evaluating the perceptions, knowledge, and adaptation strategies with regards to climate change, of smallholder farmers in two Mediterranean- type climatic areas, i.e., Elim and Genadendal.

Chapter 3 – Climate change perceptions and responses of smallholder farmers, compared to climatic data of areas in the Overberg District

3.1. Introduction

Climate change is presently viewed as one of the most significant global challenges facing the social, environmental, and economic dimensions of humankind (Romieu *et al*., 2010; Amjath-Babu *et al*., 2016; Mitchell and Van Aalst, 2008; Clarke *et al*., 2012, IPCC, 2014). The IPCC Fifth Assessment Report mentioned that, between 1880 and 2012, the global average surface temperature warmed by 0.85°C (IPCC, 2014). According to Coumou and Rahmstorf (2012) and Hatfeld *et al.* (2011), these temperature variations give way to inevitable extreme climatic consequences such as droughts and floods. Although Africa only contributes less than 5% of the global carbon emissions, it will be significantly impacted by climate change, due to the continents' low adaptive capacity and high levels of vulnerability (Davis-Reddy and Vincent, 2017).

Sub-Saharan Africa is vulnerable to climate change as the economies of the region are highly dependent on the agricultural sector that is climate sensitive (AGRA, 2018; IPCC, 2018). Agricultural systems in southern Africa are vulnerable to climate variability as it is mainly comprised of smallholder agricultural systems and over 90% of crops farmed are rain-fed (Batino and Waswa, 2011). As a result of climate change, the Western Cape may experience higher maximum as well as minimum temperatures, higher average annual temperatures, reduced average rainfall, an increase in fire related risks, rising sea levels and an increase in extreme weather events such as droughts and floods (Western Cape Government, 2018).

Low-income smallholder producers are especially impacted by climatic shocks, such as droughts (Vermeulen *et al*., 2012). Smallholder agricultural systems are linked to climate change through climate change adaptation (Tambet and Stopnitzky, 2021), as well as through their significant role they can play in climate change mitigation (World Bank, 2015; Cohn *et al*., 2017). Developing countries must adapt to the changing climate to ensure that the livelihoods of low-income communities are secured (Belay *et* *al*., 2017; Di Falco and Veronesi, 2013). Human adaptation is defined by the IPCC, as "the adjustment-process with regards to expected or present climate variability, to mitigate adverse effects or exploit advantageous opportunities" (Field *et al*., 2012). According to Salami *et al*. (2010), researchers, policymakers and practitioners agree that climate change adaptation practices are occurring at a lagging pace.

The objectives of this study were firstly to assess the perceptions of smallholder farmers in two former mission stations in the Overberg on long term temperature and rainfall patterns as well as extreme weather events, and compare it with the Overberg district's long term meteorological data. Secondly, this chapter examined the knowledge, attitudes, and practices of smallholder farmers in the district with regards to climate change.

3.2. Methods

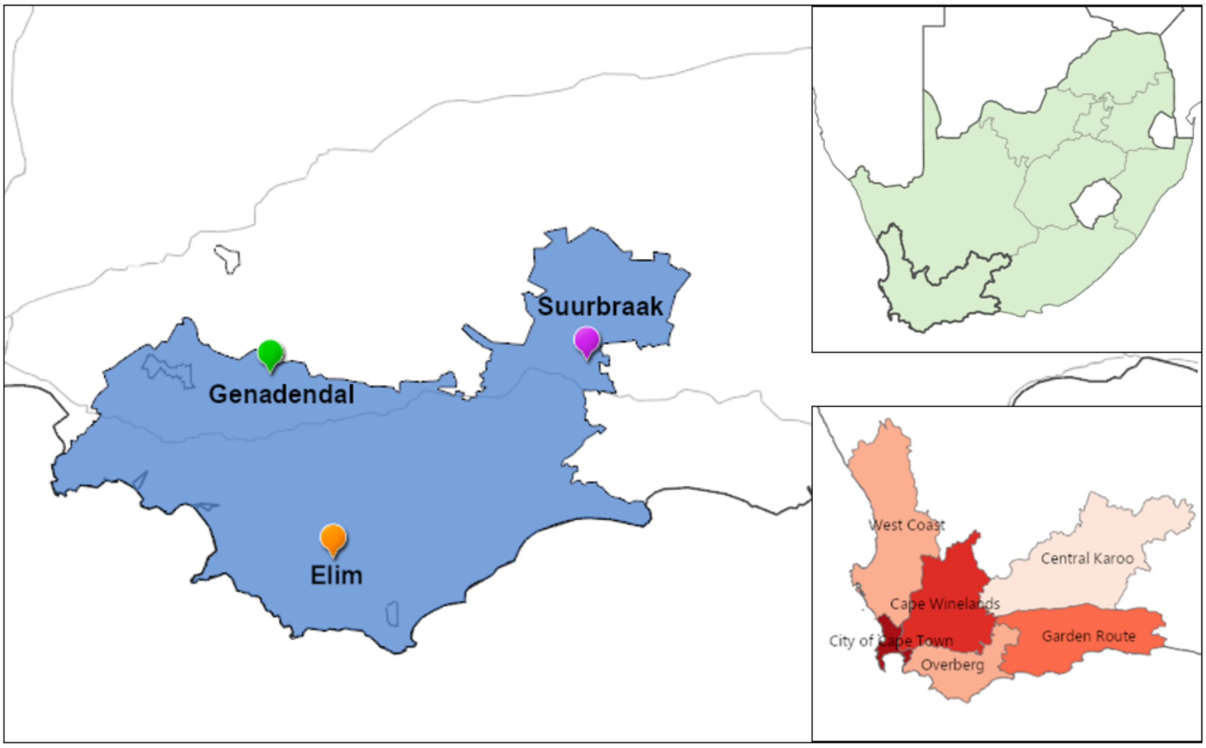
Primary data were collected from smallholder farmers in the Overberg District in the Western Cape by conducting structured interviews. Primary meteorological data were collected from meteorological stations in the Overberg District. Trends from the meteorological data were then compared to the climatic perceptions of the interviewed farmers.

3.2.1. Study Area

The Overberg District Municipality includes four local municipalities namely the Theewaterskloof, Overstrand, Cape Agulhas, and Swellendam Municipalities. The district mostly experiences Mediterranean climatic conditions, which includes typically cold and wet winters (June to August) and drier summer (December to February) conditions (Birch *et al.*, 2017). Data were collected from three purposefully chosen sites in the Overberg District, namely Genadendal, Suurbraak, and Elim (Figure 3.1).

These sites where chosen, because of their unique histories and are classified as former Act 9 rural or church land areas. "Act 9-areas" refer to areas affected by the

Rural Areas Act 1987 (Act No 9 of 1987). There are 12 such areas in the Western Cape. After slavery was abolished in 1834 in South Africa, many dispossessed people settled around mission stations. Genadendal is one such former mission station that was established in 1737 by the Moravian church and was subsequently incorporated in the Mission Stations and Communal Reserves Act, 1909 (No. 29 of 1909) and the three Group Areas Acts of the 1950's-1960's (Palchick, 2008). Suurbraak was also established as a mission station in 1812, by the London Mission Society (Western Cape Government, 2003). Genadendal and Suurbraak are classified as former Act 9 rural areas. Although Elim is not formally classified as a former Act 9 rural area, the town was similarly established by German missionaries of the Moravian church in 1824. The histories of these sites make them unique as they maintained their agrarian heritage as the policies under Apartheid protected the occupants of these mission station areas from displacement and prohibited them from migration and thus generations of families have settled in these sites for centuries (Palchick, 2008).



The population density of Elim was 1412 people in 2011, that predominantly speak Afrikaans (94.1%) (STATS SA, 2011a). Elim is located in the Cape Agulhas Local Municipality which is the most southern local municipality in South Africa. The percentage agricultural households in the Cape Agulhas Local Municipality involved in livestock farming is 24%, 23.9% engage in poultry farming, 23% engage in vegetable farming and 13% farm with other crops (STATS SA, 2011b). Genadendal is located in the Theewaterskloof Local Municipality. The total population of Genadendal was 5663 in 2011 according to STATS SA (2011c). About 95% of Genadendal's population speaks Afrikaans (STATS SA, 2011c). The main agricultural activities for agricultural households in the Theewaterskloof Local Municipality includes vegetable farming (30.1%), poultry farming (19.9%), farming with crops excluding vegetables (17.2%) and livestock farming (16.8%) (STATS SA, 2011d). There were a total of 2252 people living in Suurbraak in 2011, that predominantly speak Afrikaans (95,9%) (STATS SA, 2011e) and is located in the Swellendam Local Municipality. Agricultural households located in the Swellendam Local Municipality mainly participate in poultry farming (31.1%), followed by vegetable farming (22.9%) and livestock farming (22.5%) (STATS SA, 2011f). Only 11.3% of agricultural households in the Swellendam Local Municipality engage in crop farming (excluding vegetables) (STATS SA, 2011f).

3.2.2. Meteorological data

The minimum and maximum daily temperature, as well as daily monthly rainfall data, were obtained from three weather stations near each of the study areas and was generously supplied by the Agricultural Research Council (ARC). Meteorological data for Genadendal was obtained from the Boontjieskraal station (-34,20000076; 19,35000038) which is at an altitude of 128m and is 26km southwest from Genadendal from January 1990 to July 2006 as well as from the Boontjieskraal/ Caledon station (-34,2164;19,36132) at an altitude of 191m from August 2006 to August 2021. The Agulhas Wines station (-34,6581, 19,76496) is 7.4km south from Elim at an altitude of 92m with data available from November 2003 to August 2021, and Voorstekop station (-34,11666489; 20,73333359) is 14.3km southeast from Suurbraak and at an altitude of 250m with data available from March 1996 to August 2021.

Monthly and yearly averages of the minimum and maximum temperature and daily average rainfall, as well as the total rainfall, was analysed in STATISTICA 14.0.0.15 (2021), using basic descriptive statistics (Addendum A; Addendum B) and simple linear regression analyses (Table 3.1; Table 3.2; Table 3.3) with a significance level of 5%. The linear regression analyses would demonstrate whether there is a positive or negative trend with regards to temperature and rainfall. The minimum and maximum temperature and daily rainfall, as well as the total rainfall of each month of the different areas, were also analysed in STATISTICA 14.0.0.15 (2021), using basic descriptive statistics (Addendum C; Addendum D; Addendum E) and simple linear regression analyses (Addendum F; Addendum G; Addendum H) with a significance level of 5%.

3.2.2.1. Missing data

A simple linear adjustment calculation was used to deal with the missing data in the raw data set. Missing data from the meteorological data that was obtained included the months of May and June of 2010 from the Boontjieskraal station and the months of December and November of 2013 and January of 2014 for Agulhas wines station. Missing temperature data from the Voorstekop station included the months of May (2001), May (2002), September to December (2002), March to July (2003), January (2006), December (2006), June (2012), July (2012). Missing rainfall data for the Voorstekop station included the months of January (2000), June to August (2003), December (2003), January (2006), December (2006), June (2012), July (2012) and May (2013).

3.2.3. Interviews

Telephonic interviews were conducted due to constraints associated with the COVID-19 pandemic. Interviews were conducted with 4 smallholder farmers in Genadendal and 9 smallholder farmers Elim. No smallholder farmers from Suurbraak were interviewed, because of time and other constraints. The limited sample size was due to time and other constraints associated with telephonic interviews, such as poor internet and telecommunications infrastructure at the chosen research sites.

Participants were selected using the snowball sampling approach. Community contacts were also asked to identify eligible participants. Participants that were eligible to be included in this study were crop and/or livestock farmers farming in the mentioned study sites. Participants were called in a pre-interview to ask if they would be willing to participate in the study. If the participant agreed to participate in the study a time was scheduled for the interview that most suited the participant. The interview times varied between 30 minutes and an hour.

The questions asked in the interview protocol (Addendum I), were a combination of closed-ended and open-ended questions and were transformed into a Microsoft Forms document to capture data more easily. The interview schedule was piloted with two students in the MSc Sustainable Agriculture course and adjusted according to comments made during the pilot interviews. The questions concerned the demographics of the participant's household; their agricultural practices; knowledge, attitudes, and perceptions relating to climate change; adaptation practices and knowledge with regards to adaptation approaches and projects such as climate-smart agriculture (CSA) (FAO), and the SmartAgri (Western Cape Government).

The interviews were also conducted in the preferred language of the participants, either in English or Afrikaans. Qualitative data from the interviews were manually coded using the inductive coding approach in ATLAS.ti 9.1.6.0 (2021). The inductive coding approach was chosen as it follows a “bottom-up” coding strategy, thus coding phrases and words from the interview transcriptions. This approach is well suited to capture the diversity and the complexity of interview data (Linneberg and Korsgaard, 2019). To analyse the quantitative data in Statistical Package for the Social Sciences (SPSS) Statistics 27.0 (2021), a coding frame was first developed (Addendum J). Categorical data were analysed using percentages and frequencies. Continuous variables (age, household size, farming area size, household income) and Likert style questions that assessed the attitudes of the farmers and were analysed using descriptive statistics (minimum, maximum, mean, and standard deviation). The codes from the qualitative data as well as the descriptive statistics from the quantitative data were then grouped into associated code groups and categorized into main themes including climate change perceptions, knowledge, attitudes, adaptation, effects of weather conditions, and stakeholder involvement.

3.2.4. Ethics Statement

The interview schedule and protocol were reviewed and approved by the Research Ethics Committee: Social, Behavioural and Education Research (REC: SBE) of Stellenbosch University (project no. REC-2021-18969) on 22 April 2021. Informed consent was sought from smallholder farmers. Participants had a choice to either provide written consent through signing an electronic form or verbal consent that was recorded by the interviewer, before the interviews were conducted. The individuals were also identified using unique alphanumeric codes, to ensure their anonymity.

3.3. Results

3.3.1. Meteorological Data

The total months analysed for the Boontjieskraal station were N=380, N=214 for the Agulhas wines station and N=307 for the Voorstekop station (Addendum A). The mean monthly maximum temperatures for the Boontjieskraal station were calculated as 23.60°C, 21.58°C for the Agulhas wines station and 23.29°C for the Voorstekop station. The mean monthly minimum temperature was calculated as 11.32°C for the Boontjieskraal station, 12.54°C for the Agulhas wines station and 12.35°C for the Voorstekop station (Addendum A). The mean monthly average and mean monthly total rainfall was calculated as 1.10mm and 35.70mm respectively for the Boontjieskraal station (Addendum A). The mean daily average rainfall and mean monthly total rainfall for the Agulhas wines station were calculated at 1.63mm and 49.64mm respectively and for the Voorstekop station, the mean daily average and total rainfall was calculated as 1.31mm and 39.52mm respectively (Addendum A).

The mean yearly maximum temperatures were calculated as 23.59°C and 21.58°C for the Boontjieskraal (N=32) and Agulhas wines (N=18) stations, respectively (Addendum B). The mean yearly maximum temperature was calculated as 23.28°C for the Voorstekop station (N=26) (Addendum B). The mean yearly minimum temperature for the Boontjieskraal station was calculated as 11.32°C, 12.54°C for the Agulhas wines station and 12.35°C for the Voorstekop station. The mean yearly average and total rainfall for the Boontjieskraal station were 1.10mm and 423.95mm respectively and for the Agulhas wines station they were calculated as 1.70mm and 588.10mm respectively (Addendum B). The mean yearly average and total rainfall for the Voorstekop station were 1.32mm and 466.65mm respectively (Addendum B).

The highest mean maximum temperature for the Boontjieskraal station was calculated as 29.22°C for February and the lowest mean minimum temperature was calculated as 6.21°C for July (Addendum C). The highest mean average and total rainfall for the Boontjieskraal station was calculated as 1.85mm for June and 55.79mm for July respectively and the lowest mean average and total rainfall is indicated as 0.47mm and 13.25mm for February (Addendum C). For the Agulhas wines station, the highest mean maximum temperature was calculated as 25.69°C for February (Addendum D). The lowest mean minimum temperature for the Agulhas wines station was calculated as 8.92°C for August (Addendum D). The highest and lowest mean average rainfall was calculated as 2.75mm for June and 0.72mm for December respectively (Addendum D). The highest and lowest total mean rainfall was calculated as 83.59mm for July and 22.17mm for December for the Agulhas wines station (Addendum D). The highest mean monthly maximum temperature for the Voorstekop station was calculated as 28.23°C for the month of February (Addendum E). The lowest mean minimum temperature for the Voorstekop station was calculated as 8.36°C for the month of August (Addendum E).

Simple linear regressions were calculated to predict the variables that included maximum temperature, minimum temperature, average rainfall, and total rainfall based on months and years for the Boontjieskraal station, respectively (Table 3.1). Additional regression results including the summary statistics and analyses of variance for each of the models are included in the supportive information (Addendum K; Addendum Q).

Table 3. 1 Linear regression analysis (unstandardized and standardized regression coefficients) for variables predicting the maximum temperature, minimum temperature, average rainfall, and total rainfall for the Boontjieskraal station near Genadendal.

		Standardized Coefficients		Unstandardized Coefficients			
Model	Source	B	Std. Error	B	Std. Error	t	p
MaxTemp vs. Month	Intercept			24,89	2,56	9,71	0,00*
	Month	-0,03	0,05	0,00	0,00	-0,51	0,61
MinTemp vs. Month	Intercept			4,57	2,27	2,02	0,04*
	Month	0,15	0,05	0,0002	0,00	2,98	0,00*
AverageRain vs. Month	Intercept			1,84	0,58	3,19	0,00*
	Month	-0,07	0,05	0,00	0,00	-1,28	0,20
TotalRain vs. Month	Intercept			92,26	32,00	2,88	0,00*
	Month	-0,09	0,05	0,00	0,00	-1,77	0,08
MaxTemp vs. Year	Intercept			31,86	26,42	1,21	0,24
	Year	-0,06	0,19	0,00	0,01	-0,31	0,76
MinTemp vs. Year	Intercept			-132,40	18,26	-7,25	0,00*
	Year	0,83	0,10	0,07	0,01	7,87	0,00*
AverageRain vs. Year	Intercept			15,59	10,59	1,47	0,15
	Year	-0,25	0,18	-0,01	0,01	-1,37	0,18
TotalRain vs. Year	Intercept			1152,68	604,25	1,91	0,07
	Year	-0,32	0,18	-0,56	0,30	-1,85	0,07

A significant regression equation was found (F (1.00, 378.00) = 8.90, $p < .00$), for the minimum temperature based on months for the Boontjieskraal station with the model explaining 2% of the variance (Table 3.1). The unstandardized regression coefficient was calculated as b=0.0002, indicating that for every month that passes, the minimum temperature will increase by 0.0002°C. The relationship between the passing months and the minimum temperature for the Boontjieskraal station is also visually represented by a scatterplot (Figure 3.2).

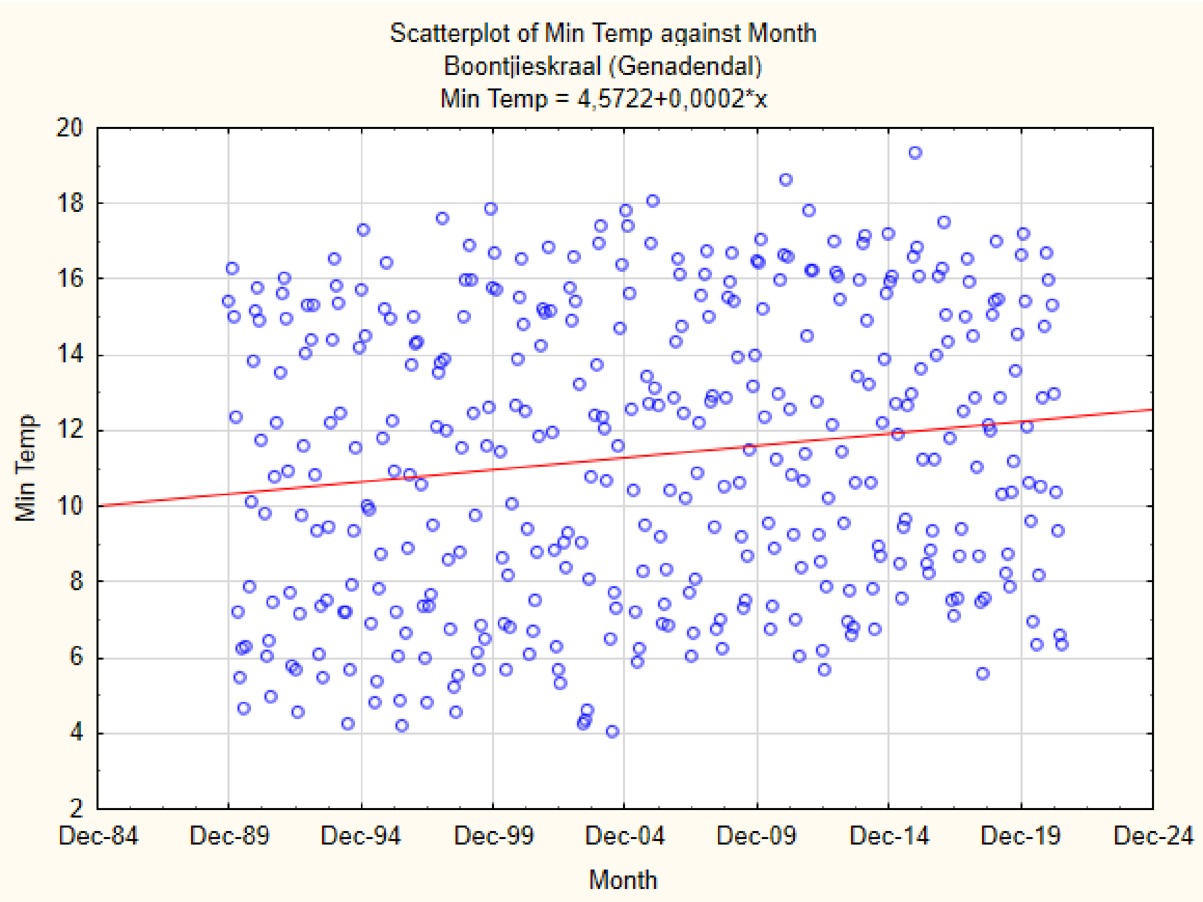


Figure 3. 2 Scatterplot illustrating the relationship of the number of months and the minimum temperatures of the Boontjieskraal station.

A significant relationship ($p < 0.00$) (Table 3.1) was found between the minimum temperature and the number of years for the Boontjieskraal station (F (1.00, 29.00) = 61.91), with the model explaining 68% of the variance. A scatterplot of the model, illustrating the regression model for minimum temperature based on the number of years for the Boontjieskraal station can be found in Figure 3.3. The unstandardized regression coefficient was calculated as b = 0.07, indicating that with an increase in years the minimum temperature will increase by 0.7 units i.e., 0.07°C.

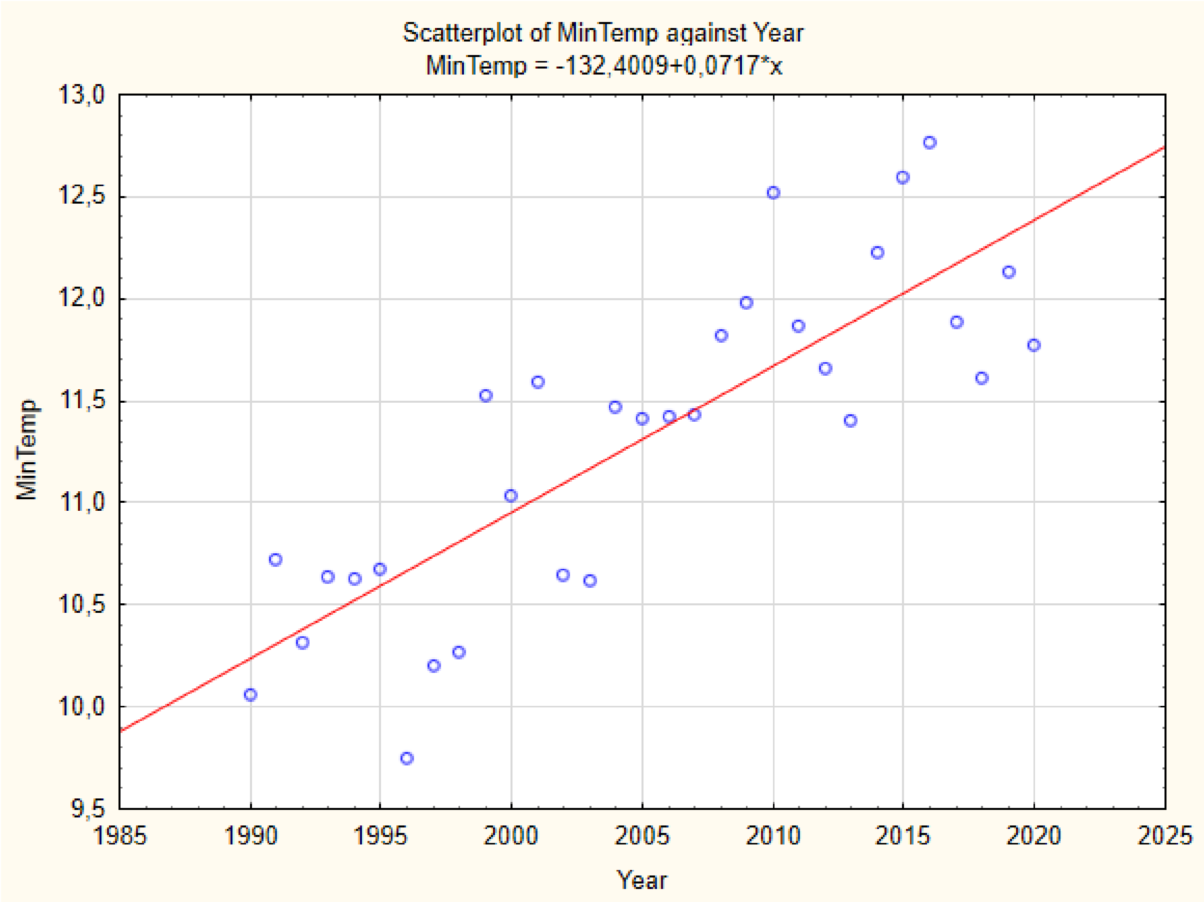


Figure 3. 3 Scatterplot illustrating the relationship of the number of years and the minimum temperatures of the Boontjieskraal station.

Simple linear regressions were also calculated to predict the variables that included maximum temperature, minimum temperature, average rainfall, and total rainfall for each of the months individually based on the number of years data were available for the specific months for the Boontjieskraal weather station (Addendum F). Significant relationships were found for the minimum temperature based on years for the models of the specific months including January (F (1.00, 30.00) = 11.12, p = .00, R^2 = 0.01, b = 0.06); April (F (1.00,30.00) = 4.84, p = .00, R^2 = 0.35, b = 0.07); May (F (1.00,30.00) = 27.36, p < .00, R^2 = 0.48, b = 0.11); June (F (1.00, 30.00) = 39.56, p < .00, b = 0.11); July (F (1.00,30.00) = 18.66, p<.00, R^2 = 0.38, b = 0.08); August (F (1.00, 30.00) = 11.94, p < .00, R^2 = 0.28, b = 0.08); September (F (1.00, 29.00) = 12.08 , p < .00, R^2 = 0.29, b = 0.07); October (F (1.00, 29.00) = 14.24, p < .00, R^2 = 0.33, b = 0.08);

November (F (1.00, 29.00) = 8.40, $p < .01$, $R^2 = 0.22$, $b = 0.06$) and December (F (1.00, 29.00) = 4.80, $p < .04$, $R^2 = 0.14$, $b = 0.05$).

Significant relationships were also found between the average rainfall and number of years for models of specific months for the Boontjieskraal station including April (F (1.00, 30.00) = 4.84, $p < .04$, $R^2 = 0.14$, $b = -0.04$), May (F (1.00, 30.00) = 11.58, $p < .00$, $R^2 = 0.28$, $b = -0.06$) and December (F (1.00, 29.00) = 6.07, $p < .02$, $R^2 = 0.17$, $b = -0.04$). The number of years were included in regression models relating to the total rainfall for the individual months of the Boontjieskraal station. Significant relationships were found for the months of April (F (1.00, 30.00) = 4.83, $p < .04$, $R^2 = 0.14$, $b = -1.22$), May (F (1.00, 30.00) = 11.62, $p < .00$, $R^2 = 0.28$, $b = -1.72$) and December (F (1.00, 29.00) = 6.10, $p < .02$, $R^2 = 0.17$, $b = -1.16$) (Addendum F). Additional regression information of the different models can be found in Addendum N and Addendum T.

To predict the variables that included maximum temperature, minimum temperature, average rainfall, and total rainfall based on months and years, respectively, for the Agulhas wines station simple linear regression analyses were performed (Table 3.2). Additional regression results including the summary statistics and an analysis of variance for each of the models for the Agulhas wines station are included in the supportive information (Addendum L; Addendum R).

Table 3. 2 Linear regression analysis (unstandardized and standardized regression coefficients) for variables predicting the maximum temperature, minimum temperature, average rainfall, and total rainfall for the Agulhas wines station near Elim.

		Standardized Coefficients		Unstandardized Coefficients			
Model	Source	B	Std. Error	B	Std. Error	t	p
MaxTemp vs. Month	Intercept			18,87	4,47	4,22	0,00*
	Month	0,04	0,07	0,00	0,00	0,61	0,54
MinTemp vs. Month	Intercept			13,61	4,21	3,23	0,00*
	Month	-0,02	0,07	0,00	0,00	-0,25	0,80
AverageRain vs. Month	Intercept			0,33	1,86	0,18	0,86
	Month	0,05	0,07	0,00	0,00	0,70	0,49
TotalRain vs. Month	Intercept			8,06	56,98	0,14	0,89
	Month	0,05	0,07	0,00	0,00	0,73	0,47
MaxTemp vs. Year	Intercept			-69,00	32,62	-2,12	0,05
	Year	0,57	0,21	0,05	0,02	2,78	0,01*
MinTemp vs. Year	Intercept			-0,47	27,61	-0,02	0,99
	Year	0,12	0,25	0,01	0,01	0,47	0,64
AverageRain vs. Year	Intercept			-22,87	29,93	-0,76	0,46
	Year	0,20	0,24	0,01	0,01	0,82	0,42
TotalRain vs. Year	Intercept			2533,12	9247,48	0,27	0,79
	Year	-0,05	0,25	-0,97	4,60	-0,21	0,84

* indicates significance at $p<0.05$

The relationship between the maximum temperature and the number of years for the Agulhas wines station was found to be significant ($p < 0.01$), F (1.00,16.00) = 7.7, with the model explaining 33% of the variance (Table 3.2). The unstandardized regression coefficient was also calculated as 0.05, indicating that for every year that passes, the maximum temperature increases with 0.05 units i.e., 0.05 °C. This regression model is also visually represented in Figure 3.4.

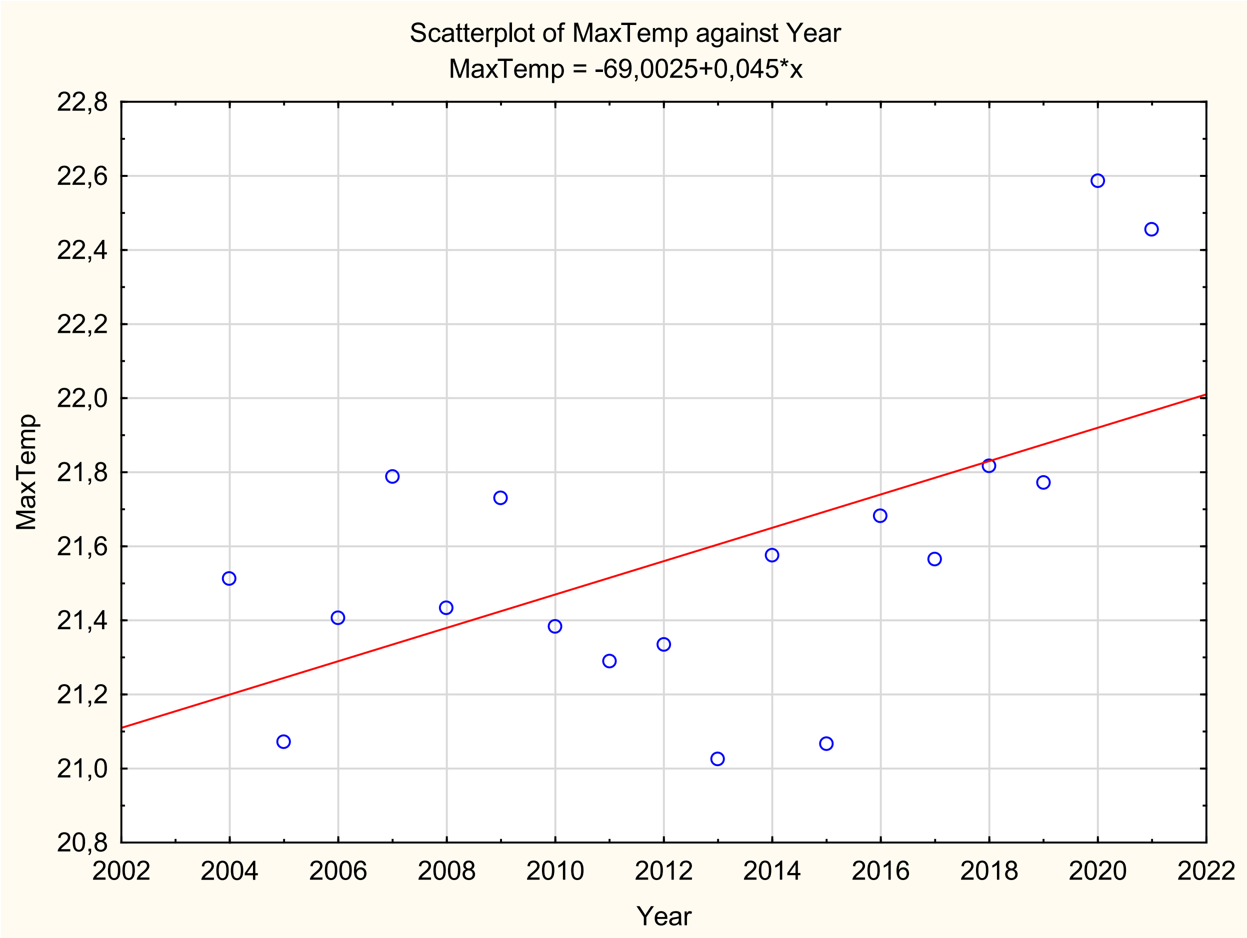


Figure 3. 4 Scatterplot illustrating the relationship of the number of years and the maximum temperatures of the Agulhas wines station.

Linear regression models were also calculated for variables (maximum temperature, minimum temperature, average rainfall and total rainfall) predicted by years for each individual month for the Agulhas wines station. Significant results ($p< 0.04$) were found for the month of April were the variable, average rainfall, was predicted by the number of years, $F(1.00, 16.00) = 5.02$, with the model explaining 24% of the variance. The unstandardized regression coefficient was calculated as $b = -0.14$. The model that included the relationship between total rainfall and the number of years for the month of April for the Agulhas wines station was also found to be significant ($p < 0.04$), F

(1.00,16.00) = 5.01, with the model explaining 24% of the variance. The model's unstandardized regression coefficient was calculated as b = -4.3. A significant relationship ($p < 0.03$) was also found for the model including maximum temperature predicted by the number of years for the month of May, F (1.00, 16.00) = 5.80, with 24% explaining the variance of the model and with an unstandardized regression coefficient of b = -4.30. Additional information with regards to the regression analyses are included in Addendum O and Addendum U.

There were no significant relationships found for the monthly or yearly data against the different variables for the Voorstekop station (Table 3.3). There was however a significant difference ($p<0.05$) for the minimum temperature variable against the years for the month of January for the Voorstekop station, F (1.00, 23.00) = 4.33, with an unstandardized regression coefficient of b = 0.05, indicating an increase in the minimum temperatures for this month (Addendum H). Tables of the summary statistics and the analyses of variance for the linear regression analyses for years predicting the maximum temperature, minimum temperature, average rainfall, and total rainfall for each month of the Voorstekop station are included in in Addendum P and Addendum W.

Table 3. 3 Linear regression analysis (unstandardized and standardized regression coefficients) for variables predicting the maximum temperature, minimum temperature, average rainfall, and total rainfall for the Voorstekop station near Suurbraak.

		Standardized Coefficients		Unstandardized Coefficients			
Model	Source	B	Std. Error	B	Std. Error	t	p
MaxTemp vs. Month	Intercept			25,25	3,21	7,87	0,00
	Month	-0,04	0,06	0,00	0,00	-0,61	0,54
MinTemp vs. Month	Intercept			11,76	2,57	4,57	0,00
	Month	0,01	0,06	0,00	0,00	0,23	0,82
AverageRain vs. Month	Intercept			1,28	0,95	1,34	0,18
	Month	0,00	0,06	0,00	0,00	0,04	0,97
TotalRain vs. Month	Intercept			31,59	28,99	1,09	0,28
	Month	0,02	0,06	0,00	0,00	0,27	0,78
MaxTemp vs. Year	Intercept			44,06	35,39	1,24	0,23
	Year	-0,12	0,20	-0,01	0,02	-0,59	0,56
MinTemp vs. Year	Intercept			-12,10	23,78	-0,51	0,62
	Year	0,21	0,20	0,01	0,01	1,03	0,31
AverageRain vs. Year	Intercept			-3,29	18,09	-0,18	0,86
	Year	0,05	0,20	0,00	0,01	0,25	0,80
TotalRain vs. Year	Intercept			1060,04	5631,05	0,19	0,85
	Year	-0,02	0,20	-0,30	2,80	-0,11	0,92

3.3.2. Interview data

In total, 13 persons were telephonically interviewed for this study from Elim and Genadendal. From Elim, 6 males that took part in the study, as well as 4 males from Genadendal. Only three respondents were female that took part in the study and all three were from Elim. The roles of the female smallholder farmers that took part in the study differ. One participant was a retired teacher as well as a member of the Elim Overseers Board, and the other female participants were not involved in any community organizations. Three of the participants from Elim and three participants from Genadendal have been engaged in farming for more than 20 years. All participants from Genadendal have been living in the community for more than 20 years, whereas 5 participants from Elim have been living in the community for more than 20 years (Table 3.4). The mean age for the participants from Elim was 39 years ranging from 20 to 68 years and 63 years for the participants from Genadendal, ranging from 53 to 72 years (Table 3.4). From Elim, there were 8 participants that farmed with livestock and 4 that farmed with crops and of these participants, 3 farmed with livestock and crops. All farmers from Genadendal that participated in the study, farmed with livestock and crops. Detailed information about the demographic characteristics of the participants can be found in Table 3.4 and 3.5, and about their types of farming activities in Table 3.6.

Table 3. 4 Demographic characteristics of the respondents in Elim and Genadendal including gender, highest level of education, years engaged in farming and years living in the community.

Category	Community	Valid	Frequency	Percent
Gender	Elim	Male	6	66.7
		Female	3	33.3
	Genadendal	Male	4	100.0
		Female	0	0
Highest level of education	Elim	Primary school	1	11.1
		Secondary school	2	22.2
		Tertiary education	6	66.7
	Genadendal	Primary school	2	50.0
		Secondary school	1	25.0
		Tertiary education	1	25.0
Years engaged in farming	Elim	Less than 5 years	4	44.4
		5-10 years	2	22.2
		More than 20 years	3	33.3
	Genadendal	11-20 years	1	25.0
		More than 20 years	3	75.0
Years living in the community	Elim	5-10 years	3	33.3
		11-20 years	1	11.1
		More than 20 years	5	55.6
	Genadendal	More than 20 years	4	100.0

Table 3. 5 Descriptive statistics of the demographic characteristics of the respondents in Elim and Genadendal including household size, size of farming area, age, and household income.

Category	Community	N	Minimum	Maximum	Mean	Std. Deviation
Age	Elim	9	20	68	39	16.84
	Genadendal	4	53	72	63	8.60
Household size	Elim	9	1	9	4	2.22
	Gendadendal	4	3	5	4	.816
Size of farming area (ha)	Elim	9	0.25	138	36.67	57.70
	Gendadendal	4	6	250	72.25	118.81
Household income (ZAR/month)	Elim	5	2900	70000	26580	26105.21
	Gendadendal	3	3600	6000	4400	1385.64

Table 3. 6 Type of farming activities respondents in Elim and Genadendal are involved in

		Responses					Responses		
Community	**Category**	**N**	**Percent**	**Percent of Cases**	**Community**	**Category**	**N**	**Percent**	**Percent of Cases**
Elim	Livestock	8	53.3%	88.9%	Genadendal	Livestock	4	44.4%	100.0%
	Crops	4	26.7%	44.4%		Crops	4	44.4%	100.0%
	Fish	1	6.7%	11.1%		Other	1	11.1%	25.0%
	Other	2	13.3%	22.2%					
	Total	15	100.0%	166.7%		Total	9	100.0%	225.0%

3.3.2.1. Climate change perceptions

Participants were asked if they perceived any long-term changes with regards to the temperature and rainfall in their respective areas, as well as any long-term changes in extreme weather events such as heatwaves and flooding. A network was created for the weather conditions perceived based on the codes that were generated from the interview analysis in ATLAS.ti v9 (2021) and can be seen in Figure 3.5.

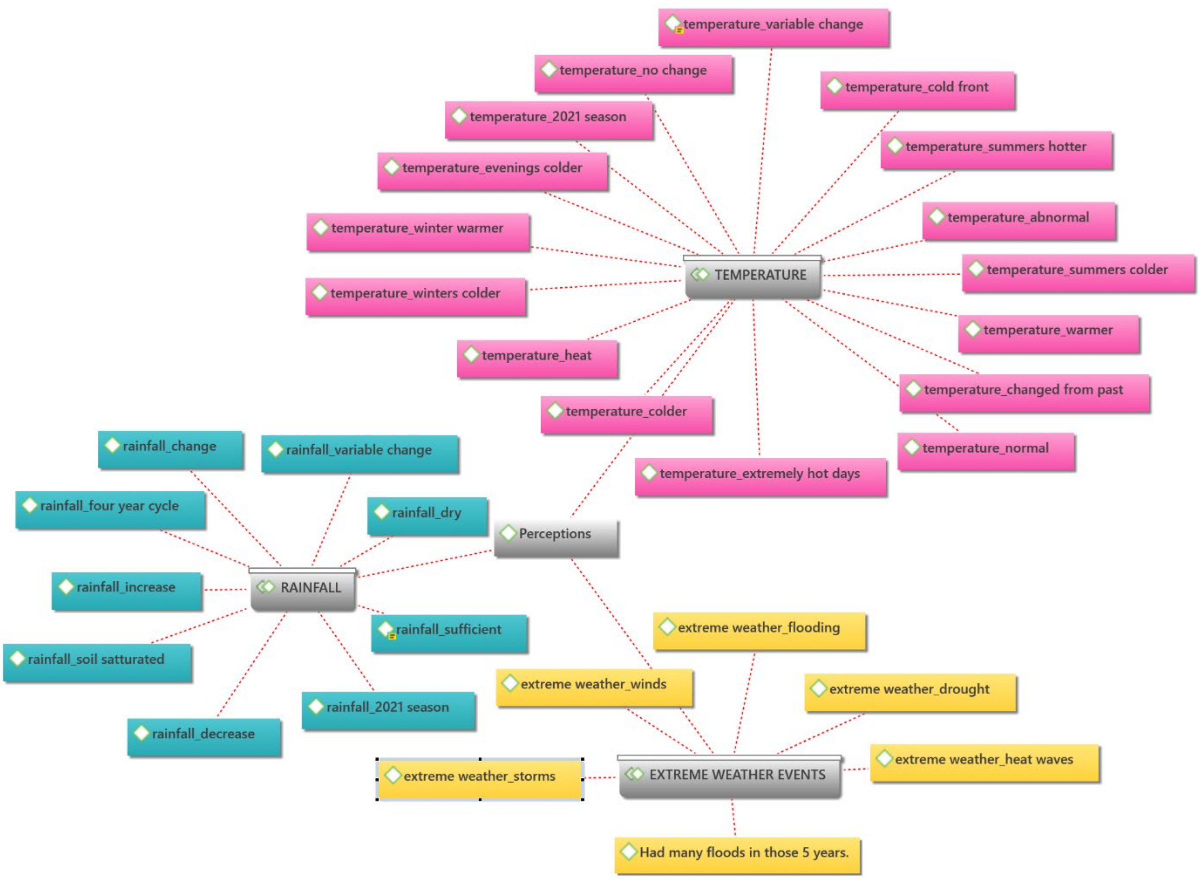


Figure 3. 5 Network of climate change perceptions including rainfall (blue), temperature(pink) and extreme weather events (yellow), of respondents generated in ATLAS.ti v9 (2021).

Participants (N=2) from Genadendal indicated that 2021 was a much colder year than previous years. Another participant noted that since 2007, in Genadendal there was a change in temperature in the area. Participants (N=2) indicated that both the summer and winter seasons are colder than normal. However, other participants (N=2) from Genadendal perceived that the recent summer seasons are warmer than usual. Some participants (N=2) also mentioned that they perceived a variable change in the temperature and one participant mentioned that it varies greatly:

The temperatures fluctuate tremendously, it sometimes gets very hot and sometimes very cold. - GEAH210621001

One participant from Genadendal mentioned that the 2021 winter season was not as cold as usual. One respondent from Elim observed that the 2021 season was the coldest and wettest they have experienced. Several participants (N=4) from Elim however noticed that the winter temperatures are much higher in recent years, compared to the past. Participants mentioned that they noticed abnormally high temperatures during the recent winter, stating that they observed temperatures of 25°C and higher for some days. They also mentioned that they perceived recent winters to be much drier than past winters. A few participants (N=2) however noticed that the evening temperatures in the winter are much colder than usual. More than half (N=6) of the respondents from Elim also mentioned that they perceived a definite overall increase in temperature. Few participants (N=2) however mentioned that they perceived no change in temperature.

Participants (N=2) from Genadendal mentioned that they noted a decrease in precipitation compared to earlier years. One participant indicated that he looked forward to the harvest season of 2021, as the area received sufficient rainfall for growing crops. A participant also mentioned that during the past 10 years, there has been a constant cycle with regards to the rainfall in Genadendal, where he noted that for four years the area receives sufficient rain and for the next four years there is drought and that currently (2021) is in the second year where there is sufficient rainfall for agricultural activities.

When asked to elaborate as to whether they noticed any long-term changes with regards to the rainfall in Elim, several participants (N=6) mentioned the 2021 winter season. Participants noted very heavy rainfall occurrences, and one participant mentioned that they have not experienced such heavy rains in the past 20 years. Few participants (N=2) also compared the 2014-2017 period with the 2019-2021, period indicating that during the 2014-2017 period, the area received very little rainfall, compared with the 2019-2021 season. Another participant also indicated that rainfall in the area decreased during the 2010-2020 period. Several participants (N=4) mentioned there has always been enough rainfall in the area for agricultural activities, such as vegetable planting. Few participants (N=2) indicated there has been a variable change in perceptions over the past years.

Several participants (N=3) from Genadendal mentioned that they experienced a three-year drought period from 2015 to 2018 when asked if they have perceived any long-term changes with regards to drought in the area. Participants (N=3) also mentioned that there was flooding in the area between 2005 and 2008. One participant however observed that the area experienced flooding around the 2015-2016 period, in contradiction to what they mentioned about experiencing drought during that period. Only one participant from Genadendal indicated that they have experienced heatwaves in the area.

Similarly, to the participants from the Genadendal community, participants (N=3) from Elim also experienced a drought during the 2015-2019 period. All participants from Elim mentioned that there has been flooding in the area and one participant specifically mentioned that the area is known for experiencing floods:

Our region is known for flooding, if you look back in history our region is known for flooding. I have experienced flooding since my childhood, thus as far back as I can remember. - ELCM260621007

Participants (N=7) especially mentioned the 2021 winter season, where many houses in the community suffered damages as a result of flash floods and heavy rainfall occurrences. One participant also mentioned that the area also experienced floods in 2005 and 2009. Only a few participants mentioned that they have recently experienced elevated temperatures in the area, whereas one participant explicitly noted that the Elim area does not experience heatwaves. One participant mentioned that they experienced strong winds in 2020.

3.3.2.2. Climate change knowledge

From the persons that participated in the study only one participant, from Elim, has not heard of the term climate change (Addendum W). Figure 3.6. represents the codes associated with climate change knowledge that was coded in ATLAS.ti v9 (2021).

Figure 3. 6 Visual representation of codes associated with climate change knowledge.

Fifty percent of the participants from the Genadendal community indicated that they heard of the term climate change from the television, radio, and other sources (Table 3.7) including courses that were offered by Elsenburg Agricultural Training Institute. Participants from Elim indicated that they mostly heard of the term climate change from watching television (50%) and from other sources (62.5%) (Table 3.7). Other sources that participants mentioned from where they heard of the term climate change included school and courses that were offered by the Department of Agriculture.

Table 3. 7 Sources from where respondents in Elim and Genadendal have heard of the term climate change.

			Responses					Responses		
Question	**Community**	**Valid**	**N**	**Percent**	**Percent of Cases**	**Community**	**Valid**	**N**	**Percent**	**Percent of Cases**
Please indicate from where you have heard of the term "climate change"?	Elim	Family member	1	5.9%	12.5%	Genadendal	Television	2	25.0%	50.0%
		Friend	1	5.9%	12.5%		Newspaper	1	12.5%	25.0%
		Television	4	23.5%	50.0%		Radio	2	25.0%	50.0%
		Newspaper	2	11.8%	25.0%		Extension officer	1	12.5%	25.0%
		Internet	2	11.8%	25.0%		Other	2	25.0%	50.0%
		Radio	1	5.9%	12.5%					
		Extension officer	1	5.9%	12.5%					
		Other	5	29.4%	62.5%					
		Total	17	100.0%	212.5%		Total	8	100.0%	200.0%

When asked to define climate change, participants from Genadendal answered that summers and winters may become warmer, farmers will have to adapt to the climate, that climate change is due to global warming and greenhouse gases and one participant indicated that they could not answer the question. Participants from Elim responded with answers such as climate change is due to the negative impact of humans and pollution, and few replied that it is the change in climatic conditions.

Participants from Genadendal indicated that the cause of climate change may be due to the cutting down of the rainforests as well as due to chemical gasses released in the atmosphere as well due to factories and coal mining. A participant from Genadendal also indicated the following:

I almost want to say it's in the Father's hands, because he is the One who is in charge. - GEPO180621004

Another indicated that the environment, trees, landfills and water contribute to climate change. When asked what the cause of climate change is, participants of Elim answered that it may be due to the overexploitation of resources, the removal of trees, as well as factories, cars and cattle that causes gasses like methane to release in the atmosphere. Three participants of Elim mentioned that pollution may be the cause of climate change.

3.3.2.3. Climate change attitudes

Participants of Genadendal and Elim were asked four Likert-style questions (choosing from 1-5 with 5 being the highest) to determine what their general attitude towards climate change is regarding the global, community and household effect thereof (Table 3.8). Of the participants from Elim, 44.4% indicated that they were highly concerned about global climate change. Only one participant from Elim indicated that they were not concerned about global climate change by choosing 1. Then, 75% of the Genadendal participants indicated that they were highly concerned about global climate change by choosing 5.

Table 3. 8 Frequencies and percentages of the attitudes of the respondents in Elim and Genadendal towards climate change.

Question	Community	Frequency (N=9)
On a scale from 1 to 5 indicate how concerned you are about global climate change	Elim	1
		1
		3
		4
	Genadendal	1
		3
On a scale from 1 to 5 how concerned you are about climate change effecting your community	Elim	1
		3
		2
		3
	Genadendal	2
		2
On a scale from 1 to 5 indicate how concerned you are about climate change effecting your livelihood/household	Elim	1
		1
		3
		1
		3
	Genadendal	1
		3
On a scale from 1 to 5 indicate how interested you would be to learn more about climate change	Elim	1
		1
		7
	Genadendal	4

The percentage of participants from Elim that indicated that they were highly concerned that climate change would affect their communities was 33.3%. Participants from Genadendal either chose 5 (50%) or 4 (50%) when asked if they were concerned about climate change effecting their communities. About 33.3% of the respondents from Elim indicated that they were highly concerned that climate change may affect their livelihoods or households, and 11.1% indicated that they were not concerned that climate change would affect their livelihoods or households by choosing 1. Seventy-five percent of participants chose 5 and 25% of participants chose 4 when asked if they were concerned if climate change may affect their household or livelihoods. From the respondents 77.8% from Elim and 100% from Genadendal indicated that they would be interested in learning more about climate change (Table 3.8).

3.3.2.4. Adaptation responses and farming practices

Adaptation strategies in response to climate change that were implemented by participants in this study were coded in ATLAS.ti v9 (2021) and visualised by creating a network (Figure 3.7). One smallholder farmer from Elim indicated, that due to the high rainfall occurrence in the 2021 winter season, the soil was too saturated, and they could not plant any crops or vegetables. As a result, the farmer used a tunnel production system to sell trays of seedlings to supplement his income. The farmer also indicated that he and his wife also sold pickled vegetables and other homemade goods at a local store to generate an extra income. Other adaptation strategies that the farmer indicated were that he started making his own compost in 2020, switched to drip irrigation in 2016 and installed water tanks to save water. Another farmer from Elim also indicated that he started using irrigation on his farm. Several participants (N=4) from Elim however indicated that they have not implemented any adaptation strategies in response to climate change.

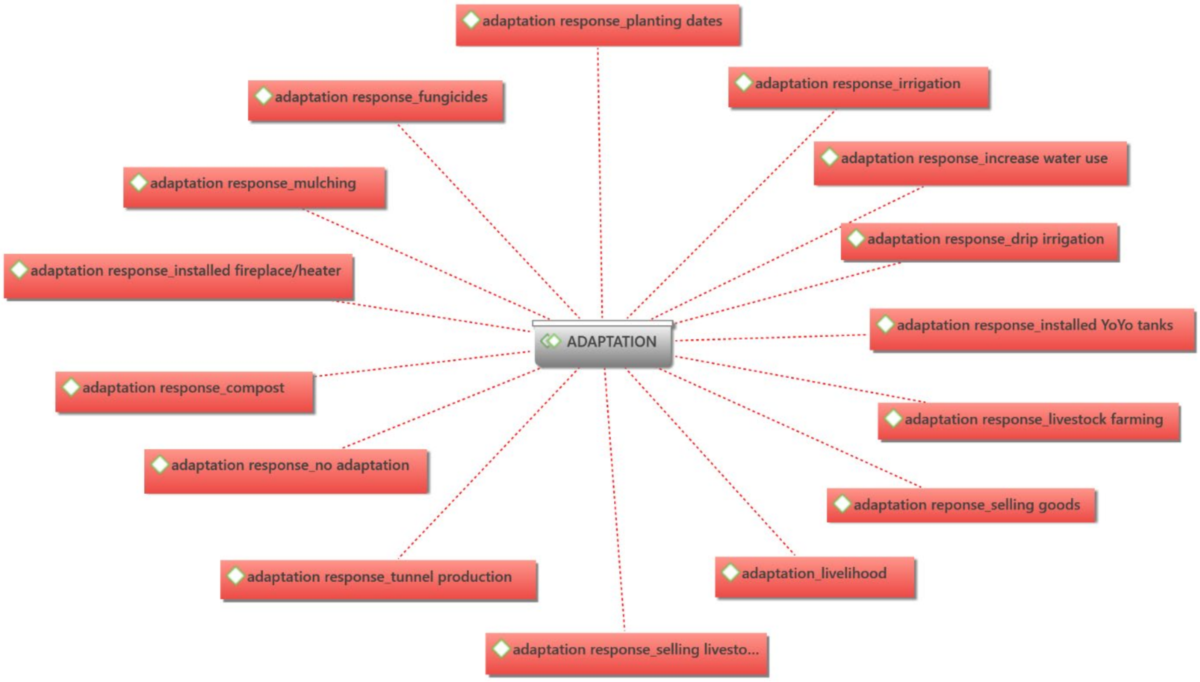


Figure 3. 7 Visual representation of codes associated with participants' adaptation responses.

Two participants from Genadendal indicated that they had to instal a fireplace in their house as a result of recent low evening temperatures in the winter. One participant indicated that he had to adapt to the three-year drought (2015-2018) by farming with livestock, as he could not plant crops for three years. He also indicated that he started implementing mulching as a practice on his farm to preserve more soil moisture and that he increased his water use to irrigate his crops more frequently. A participant also mentioned that they had to change their planting dates, in response to recent climate conditions in Genadendal. Another mentioned that they started using fungicides as a response strategy.

About 67% of smallholder farmers in Elim indicated that they make use of irrigation, conservation agriculture and contouring on their farms (Table 3.9). Approximately 44.4% of participants indicated they made use of practices such as crop rotation, mixed cropping and composting, 33.3% made use of ridging, agro-forestry, cover cropping and pesticides and 22.2% made use of mulching and fertilizers on their farms.

All participants in Genadendal indicated that they madee use of irrigation, composting, fertilizer, mulching, mixed cropping, and crop rotation on their farms. Seventy-five percent of the participants from Genadendal indicated they practice conservation agriculture on their farms, as well as making use of ridging, pesticides, contour farming and cover cropping. Fifty percent of the smallholder farmers of Genadendal indicated that they practiced agro-forestry on their farms (Table 3.9).

Table 3. 9 Farming practices of respondents in Elim and Genadendal.

			Responses				Responses	
Question	**Community**	**Valid**	**N**	**Percent of Cases**	**Community**	**Valid**	**N**	**Percent of Cases**
Which of the following farming practices do you engage in on your farm?	Elim	Irrigation	6	66.7%	Genadendal	Irrigation	4	100.0%
		Conservation agriculture	6	66.7%		Conservation agriculture	3	75.0%
		Ridging	3	33.3%		Ridging	3	75.0%
		Agro forestry	3	33.3%		Agro forestry	2	50.0%
		Contour farming	6	66.7%		Contour farming	3	75.0%
		Other	6	66.7%		Composting	4	100.0%
		Cover cropping	3	33.3%		Fertilizer	4	100.0%
		Crop rotation	4	44.4%		Pesticides	3	75.0%
		Mixed cropping	4	44.4%		Mulching	4	100.0%
		Composting	4	44.4%		Cover cropping	3	75.0%
		Mulching	2	22.2%		Mixed cropping	4	100.0%
		Fertilizer	2	22.2%		Crop rotation	4	100.0%
		Pesticides	3	33.3%				

3.3.2.5. Stakeholder involvement

Four participants from Elim indicated that they are part of community groups or organizations in Elim, whereas five participants indicated that they were not involved in any community groups. Only one participant from Genadendal indicated that they were not involved in any community groups or organizations. Other participants from Genadendal indicated that they were part of community groups such as the Church Council and the Farmers' Association.

Participants had the choice to name more than one stakeholder responsible for communicating climate change information. About 66.66% of the respondents from Elim indicated that the government should be responsible for communicating information regarding climate change to farmers, 44.44% identified non-governmental organizations (NGO's), and 33.33% indicated that community groups should be responsible for communicating such information (Table 3.10). About 22.22% of Elim respondents indicated that they and their families are also responsible for communicating climate change information and, 33.3% indicated that other stakeholders should be responsible such as researchers. One participant indicated that they do not know who should be responsible, and another mentioned that information sessions on climate change have been presented at events in the community, but people do not seem to be interested in such information.

All smallholder farmers that participated in this study from Genadendal indicated that they believe that it is the Government's responsibility to communicate information with regards to climate change to farmers, and 25% indicated that it is also the responsibility of NGO's as well as the community groups (Table 3.10). A participant also mentioned that information with regards to climate change should also be communicated at farmer's association meetings.

About 89% of respondents from Elim have not heard the term climate-smart agriculture or of the term SmartAgri (Table 3.11). All respondents from Genadendal have not heard of CSA and SmartAgri. Twenty-two percent of smallholder farmers of Elim that took part in the study indicated that they are aware of measures that were implemented by the Department of Agriculture, Land Reform and Rural Development (DALRRD) that would help ease the impacts of climate change in the agricultural sector. One participant from Elim mentioned that the Department of Agriculture, Land Reform and Rural Development's (DALRRD) involvement in their community included building dams, offering training seminars as well as providing funding to farmers in the community. Another participant also mentioned that the Department of Agriculture, Land Reform and Rural Development (DALRRD) provided a recent course regarding agriculture and climate change which he attended. Participants from Genadendal also mentioned that a recent workshop with regards to climate change for farmers was offered by the Western Cape government at the Elsenburg Agricultural Training Institute.

Table 3. 10 Stakeholders' responsible for communicating climate change information according to the Elim and Genadendal participants.

			Responses				Responses	
Question	Community	Valid	N	Percent of Cases	Community	Valid	N	Percent of Cases
Please indicate which stakeholders do you think are responsible for communicating information regarding climate change?	Elim	The Government (DALRRD)	6	66.66%	Genadendal	The Government (DALRRD)	4	100.0%
		Non-governmental organization (NGO)	4	44.44%		Non-governmental organization (NGO)	1	25.0%
		Community groups	3	33.33%		Community groups	1	25.0%
		You and your family	2	22.22%		Other	1	25.0%
		Other	3	33.33%				

Table 3. 11 Knowledge of stakeholder involvement in the Western Cape of respondents in Elim and Genadendal.

Question	Community	Valid	Frequency (N=9)	Percent
Have you heard of the term climate smart agriculture?	Elim	Yes	1	11.1
		No	8	88.9
	Genadendal	No	4	100.0
Have you heard of the term Smart Agriculture for Climate Resilience (SmartAgri)?	Elim	Yes	1	11.1
		No	8	88.9
	Genadendal	No	4	100.0
Do you know if the Department of Agriculture, Land Reform and Rural Development (DALRRD) has implemented any measures in your community that would help ease the impacts of climate change in the agricultural sector?	Elim	Yes	2	22.2
		No	7	77.8
	Genadendal	Yes	2	50.0
		No	2	50.0

3.3.2.6. Effects of climatic conditions

A network diagram was created in ATLAS.ti v9 (2021) for the codes generated from the interviews shows the effects, the different climatic conditions had on farmers' agricultural activities and livelihoods (Figure 3.8). Participants (N=3) from Elim that took part in the study indicated that they lost livestock as a result of the cold winter conditions, including sheep, pigs, and cattle. The recent temperature changes such as the significant increase in maximum yearly temperatures at a level of 5%, in the Elim area, that were analysed in this study, affected their farming practices, by delaying planting times for crops. A farmer also indicated that an unexpected frost occurrence destroyed his potato harvest for the 2019 season. One farmer also indicated that he had to order more feed as a result of temperature changes, and another indicated that his crops were scorched due to the intense heat conditions in summer.

As a result of the low rainfall conditions during the winter period of 2015-2018, one participant indicated that he had to obtain additional grazing for livestock. Participants indicated that the high rainfall occurrence in 2021, affected their crop farming severely, by either, delaying planting times, not being able to plant this winter season, or planting crops that were drowned by rainfall (Figure 3.8). Livestock farmers indicated that the rainfall of the 2021 season was beneficial for grazing for their livestock. A farmer also indicated that recent changes in the wind, affected his crop farming as he indicated that the wind caused rust disease to grow on his vegetable crops. Rust fungi belong to the order Pucciniales and are plant parasites that can cause serious damage to crops and vegetables (Yamaoka, 2014). The rust spores can be distributed by wind to new plant hosts resulting in the occurrence of rust diseases (Yamaoka, 2014).

Smallholder farmers that took part in the study from Genadendal indicated that temperature and rainfall changes affected their livestock farming, as there was a decreased availability of grazing and water due to dry conditions. Crop farmers also indicated that their crops were burned due to intense heat conditions during the 2021 season. They were also severely affected by the drought period of 2015-2018. Farmers indicated that the decrease in rainfall resulted in their not being able to plant their crops for that period, because fields were waterlogged. Participants also revealed that these effects mentioned had a joint effect on their livelihoods as they generated less income (Figure 3.8). It may also be that participants generated less income, because of other factors such as housing repairs, as farmers indicated that damages occurred to their homes as a result of the heavy rainfall that occurred in the 2021 winter season.

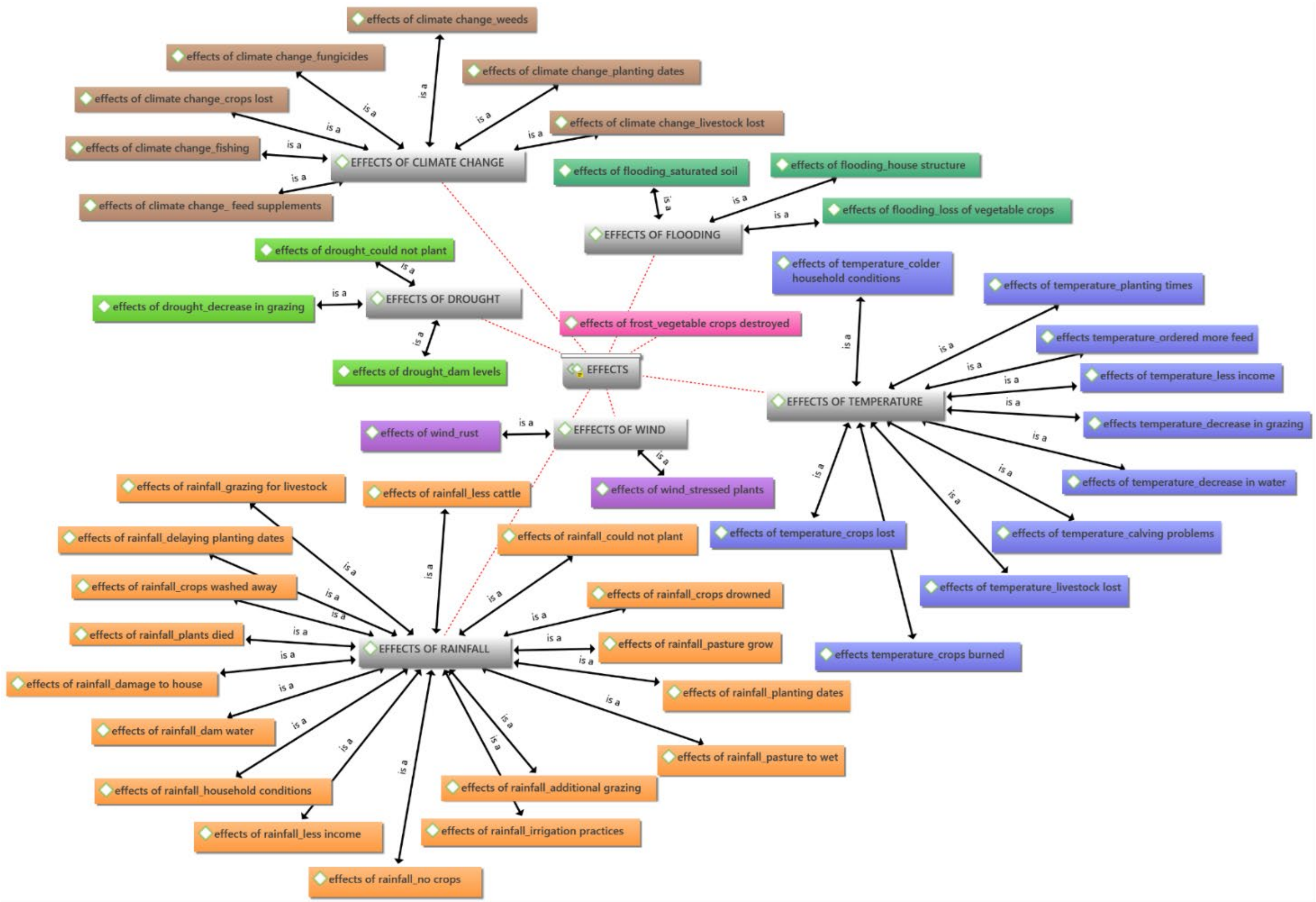


Figure 3. 8 Network of codes generated from the interviews held with the farmers, with regards to the effects, the different climatic conditions-, temperature (blue), rainfall (orange), wind (purple), flooding (dark green), climate change (brown), drought (green) and frost (pink), had on their agricultural activities and their livelihoods, created in ATLAS.ti v9 (2021).

3.4. Discussion

The study revealed that the minimum temperatures in the Genadendal area are increasing at a monthly and yearly rate. Specific months that indicated an increase in minimum temperatures included, January and April - December. The average and total rainfall for April, May, and December were decreasing in the Genadendal area, as revealed in the study. The study also indicated that the maximum temperatures in the Elim area are increasing at a yearly rate. It also revealed that the average and total rainfall for April is decreasing and that the maximum temperature for May in the Elim area is decreasing. Although no smallholder farmers from Suurbraak were interviewed for this study, the climatic data of the area was still analysed and included to provide a better insight with regards to climatic changes and patterns in former Act 9 areas in the Overberg district. The results of the analysed climatic data from Suurbraak indicated that there were no significant long-term changes in the temperatures or precipitation of the area.

It is known that increasing temperatures have detrimental effects on crop and livestock farming (Hatfield *et al*., 2020; Escarcha *et al*., 2018; Rojas-Downing *et al*., 2017; Bisbis *et al*., 2018). Impacts on crop production in Southern Africa as a result of increasing temperatures include, decreases in crop productivity, changes in planting and harvest dates, increased need for irrigation, increase spread of pathogens and diseases (Davis, 2011). Livestock farming in Southern Africa may be directly impacted by increasing temperatures by decreasing livestock productivity, changes in forage, and as well as changes in water quantity and quality (Davis, 2011). Smallholder farmers were similarly affected by the changes in climatic conditions, as some indicated that they lost livestock, had a delay in planting dates, lost crops, and vegetables, and had to obtain additional grazing for their livestock.

When asked if they experienced any long-term changes in the different climatic conditions, smallholder farmers in both Elim and Genadendal focused a lot on the recent 2021 season. This may be as it was the most recent season that farmers experienced and thus, highlighted the extreme weather events such as the flooding that occurred in Elim. In the case of Genadendal, one participant mentioned that the winter was not as cold as previous years. This may be explained by the increase in minimum temperatures for that area that was concluded in this study. Responses from farmers in the Genadendal area with regards to long-term changes in the temperature were contradicting some farmers who indicated that they experience an increase in temperature, and others experiencing a decrease in temperature in the area. This is also somewhat in contradiction to the increase in minimum temperature in the area that was found in the study. This may be explained by the low sample size of participants interviewed in Genadenal. Smallholder farmers in Genadendal perceived a decrease in the rainfall for the area, which may be explained by the proven decrease in rainfall for some months in the area.

The perceptions of smallholder farmers in Elim were consistent with the analysed meteorological data for their area, which entailed an increase in temperature. Both smallholder farmers in Genadendal and Elim perceived that evening temperature in the respective areas, on average, are decreasing. Participants from Elim very much focused on the 2021 rainfall season, as flooding occurred and caused damage to infrastructure and houses in the community. Smallholder farmers in Genadendal and Elim also experienced the recent drought during 2015-2018 in the Western Cape (Baudoin *et al*., 2017; Pienaar and Boonzaaier, 2018).

Information sources on climate change were reported as follows: the television, radio, and other sources such as courses offered by the Western Cape Government at the Elsenburg Agricultural Training Institute. Smallholder farmers also defined climate change as the changes in the temperature and rainfall conditions and temperatures may increase. Participants also indicated that climate change is due to pollution, deforestation, human intervention, greenhouse gasses, and God’s will. Similarly, smallholder farmers in Malawi indicated in a survey conducted in 2013 that climate change is due to deforestation, God’s will, greenhouse gas emissions, and overpopulation (Bezner Kerr, 2017). Farmers in India also indicated that climate change is due to deforestation and pollution among other causes (Raghuvanshi, 2017). Though the rationale for climate change amongst farmers in this study were varied, farmers from both communities agreed that they are eager to learn more about climate change.

Adaptation strategies for summer drought conditions amongst participants in the Genadendal and Elim communities included, installing water tanks, increasing irrigation, switching to drip irrigation, selling livestock and buying supplementary feed for livestock. Participants from Genadendal and Elim adapted to winter flooding by changing planting dates, using fungicides and building tunnel production systems. Other adaptation strategies implemented by farmers to adapt to the changing climatic conditions included supplementing their income by selling other goods, making compost and implementing mulching. Smallholder farmers in the Limpopo Basin reported similar changes to changing climatic conditions. In that study, changing planting dates, supplementing livestock feed, and using irrigation were amongst the adaptation strategies implemented by farmers (Gbetibouo *et al*., 2010). There were, however, participants that did not take remedial action. Crop farmers in southwestern Nigeria also implemented different planting times in response to climate change (Ayanlade *et al*., 2017).

Stakeholder communication is paramount in policy interventions for climate change adaptation (Nigussie *et al*., 2018). It is thus, of great importance to identify and evaluate the stakeholders involved in communicating climate change knowledge to smallholder farmers in the Overberg district. Although it appears that the Western Cape Government has made efforts to introduce the phenomenon of climate change to smallholder farmers through training sessions mentioned by participants, this present study revealed that little has been done to assist smallholder farmers in adapting to climatic changes in their communities. Climate change adaptation initiatives such as CSA and SmartAgri are unfamiliar to smallholder farmers, and more efforts should be made by the government to introduce smallholder farmers to these initiatives, and to support farmers with adapting to the proven changing climatic conditions in their respective communities. Otherwise, these farmers will continue to remain at the margins of the agricultural industry.

Temperature increases may increase disturbances such as wildfires (Davis, 2011). As Mediterranean agro-ecological areas are known for fires, it may be worthwhile to investigate the occurrence of fires and the impact thereof on the agricultural practices of smallholder farmers in the Overberg district for future studies.

Limitations of this study include the small sample size of participants interviewed in the Genadendal and Elim communities respectively and should be kept in mind for future studies of similar nature. Future studies may also include interviewing smallholder farmers in the community of Suurbraak, which is also classified as a former Act 9 rural area, and which falls within the same geographic region (Figure 3.1).

3.5. Conclusions

In conclusion, the study revealed that there is a significant increase at a level of 5% in mean monthly minimum temperatures, from 1990 to 2021, in the Genadendal area, as well as in the mean yearly maximum temperatures at Elim from 2003 to 2021.

Smallholder farmers perceived extreme weather events such as flooding in Elim and the drought of 2015-2018 in both Genadenal and Elim. The study also revealed that most smallholders in the Genadendal and Elim communities are aware of the term climate change, and have a basic understanding of the term, although some farmers struggle to define the term.

Most smallholder farmers are concerned about the impacts of climate change and are interested in learning more about the phenomenon. Farmers are adapting to climate change in the Elim and Genadendal area by implementing measures such as, increasing irrigation, livestock farming, tunnel production, mulching, selling livestock, buying supplementary feed, changing planting dates, and using fungicides. Although the present study has limitations such as the sample size of the participants, the study still presents a better understanding of the climate change knowledge, attitudes, and perceptions of smallholder farmers in former Act 9 areas of the Overberg District. This information may be crucial for the Western Cape Government and other stakeholders concerning policy planning of climate change adaptation responses for smallholder and commercial farming systems in the Overberg District.

Chapter 4 – Conclusions

4.1. Overview

This study aimed to evaluate the perceptions, knowledge, and adaptation strategies concerning climate change, of smallholder farmers in two of the oldest farming communities in the Western Cape: Elim and Genadendal, both situated in the Overberg District. There are many studies focussing on climate change adaptation as discussed in Chapter 1, but few that focus on adaptation of smallholder farmers located in the Cape Floristic Region that experiences Mediterranean-type climatic conditions including anomalous winter rainfall. This study fills that gap, and adds to a small, but growing body of knowledge about smallholder farmers in the winter-rainfall area of South Africa. Other studies that focused on climate change adaptation within the Cape Floristic Region, includes Koelle and Oettle (2009), as mentioned in Chapter 1 and Da Costa (2018).

The body of research is comprised of four chapters. Chapter 1 provided background information with regards to terms and phrases discussed in this study. The problem statement, research questions, and objectives were also stated in Chapter 1. After the introductory chapter, two research chapters followed namely Chapter 2 and Chapter 3. Chapter 2 evaluated smallholder farmers' adaptation strategies globally by means of a systematic review. Chapter 3 included a study that compared climatic data of two regions in the Overberg district to the climate change perceptions and knowledge of the smallholder farmers in those regions. Chapter 4 presents the concluding chapter, which includes the general conclusions made from Chapter 2 and Chapter 3. Chapter 4 also includes recommendations for future studies, limitations of the study, and recommendations for farmers.

4.2. General conclusions

Chapter 2 concluded that most research with regards to smallholder climate change adaptation responses has been conducted in countries in Africa and Asia. The chapter also concluded that research has been focused on the tropical savanna and semi-arid Köppen–Geiger climate climatic regions globally. The main adaptation methods used by smallholder farmers that farmed with crops globally included: planting drought-resistant crops; changing planting dates; implementing soil and water conservation measures; intercropping; irrigation; using improved varieties such as early maturing varieties; crop rotation; implementing terracing; applying fertilizer; crop diversification and using improved seed varieties. Adaptation methods used by livestock smallholder farmers included: supplementing livestock feeds; reducing herd size; migrating livestock to areas with better forage and livestock diversification. Crop and livestock farmers utilised adaptation methods such as water harvesting, implementing agroforestry, and supplementing their income by engaging in non-farm activities.

Chapter 3 concluded that there is a significant increase in the minimum temperatures in the Genadendal area as well as in the yearly maximum temperatures of the Elim area. It was also concluded in Chapter 3 that there are no significant changes in the climatic properties analysed for the 25 years available for the Suurbraak area. The study in Chapter 3 also indicated that the perceptions of smallholder farmers with regards to the climatic conditions were somewhat contradicting the analysed meteorological data of the respective areas. Smallholder farmers in Genadendal and Elim did however emphasise that extreme weather events such as the drought period of 2015-2018 (Genadendal and Elim), and flooding (Elim) were prevalent in their respective areas. The study in Chapter 3 also indicated that smallholder farmers in the areas investigated are aware of climate change and are concerned with the associated impacts of the phenomenon. From the results in Chapter 3, it can also be concluded that the smallholder farmers interviewed in this present study are unaware of climate-resiliency programmes such as SmartAgri and CSA. This represents an opportunity for Provincial government to implement interventions that would improve the knowledge and adaptive capacity of farmers to climate change.

4.3. Limitations

As mentioned in Chapter 3, the sample size was a limitation for the study conducted in that chapter as a result of time constraints associated with the study. The limiting sample size was also due to the study being conducted during the COVID-19 global pandemic and as a result telephonic interviews had to be conducted. Conducting telephonic interviews included constraints, that contributed to the limiting sample size, such as relying on community contacts for referring participants and telecommunication issues such as signal quality. The questions asked during the interview could have also been structured differently, as participants focused more on the present and most recent seasons past and did not voluntarily discuss long-term changes in the climatic conditions of the respective areas.

4.4. Recommendations for future studies

On a global scale, future studies may include focussing on smallholder farmers' climate change adaptation strategies on the continents of North America, South America, Europe, and Australia. As a result of the increasing aridity of these climatic regions, future studies may also include investigating adaptation strategies of smallholder farmers in other Mediterranean climatic regions, globally.

Suurbraak may also be a study site to consider, for analysing smallholder farmers' perceptions and adaptation strategies for future studies, as Suurbraak is also classified as a former Act 9 rural area and because of time constraints, could not be included in this present study. Careful consideration should be given to participant sample size in future studies with regards to the impacts of climate change on smallholder farmers in Mediterranean-type climatic areas as this may give a more appropriate indication of how smallholder farmers in these areas perceive and adapt to climate change.

4.5. Recommendations for smallholder farmers

The results obtained in this study may allow smallholder farmers in the Genadendal and Elim communities to make context-based alterations to their farming practices concerning adapting to climate change. Results obtained in this current study indicated that there is a significant increase in the minimum temperatures in the Genadendal area, as well as a significant increase in the yearly maximum temperatures in the Elim area. Farmers should thus, consider implementing adaptation strategies to cope with the increasing temperatures. Some adaptation strategies implemented by other smallholder farmers that were analysed in Chapter 2, that are yet to be implemented by smallholder farmers interviewed in Chapter 3 but, may be beneficial in adapting to the increasing temperatures include, planting drought-tolerant crops and using improved seed varieties. Examples of drought-tolerant crops in the South African context include some maize varieties (Chukwudi *et al*., 2021) and underutilized crops (NUS) such as sorghum, sweet-potato, and cassava (Mabhaudi *et al*., 2017).

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Addendum A: Table of the descriptive statistics of the monthly temperature and rainfall data of the Boontjieskraal, Agulhas wines and Voorstekop station

Descriptive statistics of the monthly temperature and rainfall data of the Boontjieskraal, Agulhas wines and Voorstekop station.

Station	Variable	Valid N	Mean	Median	Minimum	Maximum	Lower Quartile	Upper Quartile	Range	Quartile Range	Std.Dev
Boontjieskraal	MaxTemp	380	23,60	23,93	15,52	32,37	19,55	27,53	16,85	7,98	4,30
	MinTemp	380	11,32	11,47	4,05	19,34	7,77	14,98	15,29	7,21	3,85
	AverageRain	380	1,10	0,85	0,00	4,79	0,33	1,64	4,79	1,31	0,97
	TotalRain	380	35,70	25,86	0,00	912,00	9,60	48,60	912,00	39,00	53,85
Agulhas wines	MaxTemp	214	21,58	21,48	15,59	27,49	18,94	24,35	11,90	5,41	2,98
	MinTemp	214	12,54	12,37	6,39	18,39	9,89	15,21	12,00	5,32	2,81
	AverageRain	214	1,63	1,32	0,08	8,16	0,69	2,19	8,08	1,50	1,24
	TotalRain	214	49,64	40,15	2,54	253,08	20,83	67,31	250,54	46,48	37,99
Voorstekop	MaxTemp	307	23,29	23,31	14,85	30,95	19,91	26,71	16,10	6,80	3,80
	MinTemp	307	12,35	12,35	4,58	18,31	9,53	15,22	13,73	5,69	3,04
	AverageRain	307	1,31	1,02	0,00	8,45	0,59	1,68	8,45	1,09	1,13
	TotalRain	307	39,52	30,50	0,00	253,50	17,70	50,70	253,50	33,00	34,34

Addendum B: Table of the descriptive statistics of the yearly temperature and rainfall data of the Boontjieskraal, Agulhas wines and Voorstekop station

Descriptive Statistics of the yearly temperature and rainfall data of the Boontjieskraal, Agulhas and Voorstekop wines station.

Station	Variable	Valid N	Mean	Median	Minimum	Maximum	Lower Quartile	Upper Quartile	Range	Quartile Range	Std.Dev
Boontjieskraal	MaxTemp	32	23,59	23,48	22,65	25,54	23,10	23,97	2,89	0,87	0,65
	MinTemp	32	11,32	11,45	9,74	12,77	10,64	11,84	3,03	1,20	0,78
	AverageRain	32	1,10	1,10	0,15	1,56	1,01	1,25	1,41	0,25	0,26
	TotalRain	32	423,95	400,76	55,12	1291,10	366,70	460,25	1235,98	93,55	187,56
Agulhas wines	MaxTemp	18	21,58	21,54	21,02	22,59	21,33	21,77	1,56	0,44	0,42
	MinTemp	18	12,54	12,65	11,97	13,03	12,30	12,75	1,06	0,44	0,29
	AverageRain	18	1,70	1,61	1,32	2,29	1,38	1,98	0,98	0,60	0,32
	TotalRain	18	588,10	572,87	471,69	833,32	504,00	607,80	361,63	103,80	98,26
Voorstekop	MaxTemp	26	23,28	23,32	21,08	24,35	23,06	23,77	3,27	0,71	0,66
	MinTemp	26	12,35	12,32	11,05	13,30	12,18	12,63	2,25	0,45	0,45
	AverageRain	26	1,32	1,32	0,81	2,14	1,07	1,47	1,33	0,40	0,34
	TotalRain	26	466,65	474,83	286,00	743,05	388,12	526,29	457,05	138,17	105,07

Addendum C: Table of the descriptive statistics of the temperature and rainfall data of the Boontjieskraal station per month

Descriptive Statistics of the temperature and rainfall data of the Boontjieskraal station per month.

Month	Variable	Valid N	Mean	Median	Minimum	Maximum	Lower Quartile	Upper Quartile	Range	Quartile Range	Std.Dev
January	MaxTemp	32	28,98	29,17	26,94	32,37	28,24	29,58	5,43	1,34	1,10
	MinTemp	32	16,20	16,23	13,77	19,34	15,46	16,66	5,57	1,20	1,04
	AverageRain	32	0,52	0,25	0,00	2,68	0,16	0,46	2,68	0,30	0,68
	TotalRain	32	16,10	7,72	0,00	83,06	4,95	14,28	83,06	9,33	20,97
February	MaxTemp	32	29,22	29,24	27,77	30,80	28,52	29,86	3,03	1,34	0,92
	MinTemp	32	16,54	16,65	14,28	18,65	15,98	17,18	4,37	1,21	0,94
	AverageRain	32	0,47	0,34	0,04	1,69	0,16	0,62	1,65	0,46	0,43
	TotalRain	32	13,25	9,66	1,10	47,24	4,54	17,60	46,14	13,07	12,00
March	MaxTemp	32	27,52	27,55	25,03	30,09	26,90	28,32	5,06	1,42	1,27
	MinTemp	32	15,06	15,23	12,27	17,04	14,78	15,55	4,77	0,77	1,04
	AverageRain	32	0,53	0,40	0,02	2,74	0,22	0,62	2,72	0,41	0,52
	TotalRain	32	16,35	12,48	0,76	84,90	6,63	19,24	84,14	12,61	16,24
April	MaxTemp	32	24,81	24,57	22,14	28,79	23,92	25,54	6,65	1,63	1,37

	MinTemp	32	12,39	12,50	10,03	15,19	11,85	12,86	5,16	1,01	1,09
	AverageRain	32	1,19	0,99	0,00	4,64	0,56	1,51	4,64	0,95	1,02
	TotalRain	32	35,78	29,65	0,00	139,30	16,60	45,15	139,30	28,55	30,74
May	MaxTemp	32	21,78	21,54	19,75	25,11	20,59	22,66	5,36	2,08	1,38
	MinTemp	32	9,81	9,84	7,20	12,90	8,96	10,64	5,70	1,68	1,49
	AverageRain	32	1,32	1,12	0,00	4,29	0,60	1,85	4,29	1,25	0,99
	TotalRain	32	40,88	34,80	0,00	132,90	18,55	57,15	132,90	38,61	30,60
June	MaxTemp	32	18,74	18,60	16,54	21,17	17,49	20,08	4,63	2,59	1,36
	MinTemp	32	7,35	7,09	4,24	9,62	6,12	8,52	5,38	2,40	1,40
	AverageRain	32	1,85	1,95	0,00	4,18	1,19	2,24	4,18	1,06	0,90
	TotalRain	32	55,07	58,34	0,00	125,30	35,56	67,18	125,30	31,62	27,38
July	MaxTemp	32	17,79	17,71	16,03	20,41	16,89	18,59	4,38	1,71	1,04
	MinTemp	32	6,31	6,51	4,05	8,73	5,67	7,19	4,68	1,52	1,17
	AverageRain	32	1,81	1,80	0,00	3,83	1,13	2,53	3,83	1,40	0,94
	TotalRain	32	55,79	55,88	0,00	118,60	35,15	78,51	118,60	43,36	29,08
August	MaxTemp	32	18,04	17,94	15,52	21,55	17,46	18,72	6,03	1,26	1,18
	MinTemp	32	6,54	6,48	4,17	9,43	5,44	7,54	5,26	2,11	1,43
	AverageRain	32	1,70	1,55	0,00	4,43	1,24	1,94	4,43	0,70	0,99
	TotalRain	32	52,09	47,48	0,00	137,40	38,35	57,70	137,40	19,35	30,40

September	MaxTemp	31	20,18	20,29	17,46	23,31	18,82	21,24	5,85	2,42	1,45
	MinTemp	31	7,83	7,87	5,52	10,35	6,86	8,66	4,83	1,80	1,09
	AverageRain	31	1,00	0,97	0,00	2,65	0,50	1,42	2,65	0,92	0,62
	TotalRain	31	30,13	29,20	0,00	79,60	15,00	42,67	79,60	27,67	18,60
October	MaxTemp	31	23,23	23,10	19,56	25,82	21,96	23,99	6,26	2,03	1,53
	MinTemp	31	10,40	10,53	7,89	12,65	9,45	11,23	4,76	1,78	1,20
	AverageRain	31	1,10	0,79	0,05	3,76	0,37	1,84	3,71	1,47	0,95
	TotalRain	31	34,07	24,64	1,70	116,60	11,40	57,15	114,90	45,75	29,41
November	MaxTemp	31	25,25	25,17	21,31	28,04	24,27	26,16	6,73	1,89	1,46
	MinTemp	31	12,45	12,50	9,29	14,72	11,77	13,15	5,43	1,38	1,16
	AverageRain	31	1,05	0,78	0,12	4,79	0,29	1,29	4,67	1,00	1,10
	TotalRain	31	31,38	23,37	3,50	143,76	8,60	38,61	140,26	30,01	33,05
December	MaxTemp	31	27,69	27,51	25,79	31,40	26,56	28,34	5,61	1,78	1,49
	MinTemp	31	14,95	14,98	12,71	17,87	13,96	15,77	5,16	1,81	1,16
	AverageRain	31	0,68	0,39	0,07	3,77	0,19	0,82	3,70	0,63	0,82
	TotalRain	31	21,05	12,19	2,03	116,90	5,84	25,40	114,87	19,56	25,33

Addendum D: Table of the descriptive statistics of the temperature and rainfall data of the Agulhas wines station per month

Descriptive statistics of the temperature and rainfall data of the Agulhas wines station per month.

Month	Variable	Valid N	Mean	Median	Minimum	Maximum	Lower Quartile	Upper Quartile	Range	Quartile Range	Std.Dev
January	MaxTemp	18	25,28	25,20	21,79	27,49	24,96	25,60	5,70	0,64	1,22
	MinTemp	18	16,26	16,24	13,68	18,20	15,99	16,78	4,52	0,79	0,95
	AverageRain	18	0,79	0,65	0,20	2,97	0,37	0,97	2,77	0,60	0,65
	TotalRain	18	24,47	19,90	6,31	92,00	11,42	28,14	85,69	16,72	20,00
Febuary	MaxTemp	18	25,69	25,70	24,53	26,58	25,28	26,17	2,05	0,89	0,61
	MinTemp	18	16,64	16,60	15,14	18,39	16,16	17,23	3,25	1,07	0,85
	AverageRain	18	0,79	0,67	0,26	2,22	0,51	0,87	1,96	0,36	0,44
	TotalRain	18	22,21	19,16	7,20	62,10	14,20	24,37	54,90	10,17	12,38
March	MaxTemp	18	24,48	24,57	22,80	25,72	23,80	25,40	2,92	1,60	0,85
	MinTemp	18	15,25	15,44	12,94	16,51	14,92	15,79	3,57	0,87	0,89
	AverageRain	18	1,04	0,77	0,25	2,31	0,39	1,73	2,06	1,34	0,71
	TotalRain	18	32,33	23,72	7,80	71,61	12,20	53,76	63,81	41,56	21,92
April	MaxTemp	18	22,53	22,50	21,08	24,51	21,87	23,25	3,43	1,38	0,93

	MinTemp	18	13,18	13,16	12,19	14,12	12,91	13,44	1,93	0,53	0,51
	AverageRain	18	1,54	1,14	0,27	7,35	0,69	1,72	7,08	1,03	1,57
	TotalRain	18	46,15	34,16	8,20	220,40	20,83	51,50	212,20	30,67	47,00
May	MaxTemp	18	20,64	20,60	18,87	22,77	20,03	21,23	3,90	1,20	1,02
	MinTemp	18	11,68	11,66	10,83	13,01	11,24	11,95	2,18	0,71	0,58
	AverageRain	18	1,84	1,38	0,39	5,93	0,78	2,19	5,54	1,41	1,40
	TotalRain	18	56,82	42,66	11,94	183,80	24,13	67,79	171,86	43,66	43,31
June	MaxTemp	18	18,34	18,23	16,70	20,75	17,30	18,95	4,05	1,65	1,15
	MinTemp	18	9,59	9,51	8,33	10,97	9,03	10,07	2,64	1,04	0,73
	AverageRain	18	2,75	2,84	0,75	3,85	2,62	3,16	3,10	0,54	0,80
	TotalRain	18	82,46	85,17	22,60	115,46	75,85	94,67	92,86	18,82	24,12
July	MaxTemp	18	17,71	17,46	15,59	19,92	17,18	18,15	4,33	0,97	1,09
	MinTemp	18	8,99	9,08	8,05	9,75	8,55	9,48	1,70	0,93	0,58
	AverageRain	18	2,70	2,61	0,62	4,41	1,89	3,78	3,79	1,89	1,07
	TotalRain	18	83,59	80,82	19,20	136,60	58,67	117,30	117,40	58,63	33,25
August	MaxTemp	18	17,75	18,02	16,31	18,82	17,35	18,27	2,51	0,92	0,77
	MinTemp	18	8,92	8,94	6,39	10,32	8,49	9,53	3,93	1,04	0,88
	AverageRain	18	2,60	2,38	1,14	8,16	1,37	3,17	7,02	1,80	1,62
	TotalRain	18	80,69	73,66	35,28	253,08	42,62	98,20	217,80	55,58	50,36

September	MaxTemp	17	19,15	19,22	17,58	21,10	18,75	19,61	3,52	0,86	0,80
	MinTemp	17	10,02	10,13	7,97	11,63	9,65	10,39	3,66	0,74	0,87
	AverageRain	17	1,66	1,74	0,69	3,11	0,97	2,07	2,42	1,10	0,77
	TotalRain	17	49,82	52,26	19,40	93,22	29,00	62,23	73,82	33,23	23,25
October	MaxTemp	17	20,68	20,61	18,46	22,62	20,20	21,18	4,16	0,98	0,96
	MinTemp	17	11,76	11,73	10,23	12,80	11,42	12,21	2,57	0,79	0,72
	AverageRain	17	1,75	1,44	0,17	4,48	1,07	2,15	4,31	1,08	1,23
	TotalRain	17	54,26	44,63	5,33	138,83	33,27	66,60	133,50	33,33	38,03
November	MaxTemp	18	22,24	22,24	21,36	24,13	21,68	22,59	2,77	0,91	0,69
	MinTemp	18	13,04	13,08	11,98	14,22	12,38	13,47	2,24	1,09	0,63
	AverageRain	18	1,37	1,26	0,34	3,44	0,77	1,82	3,10	1,05	0,79
	TotalRain	18	40,99	38,18	10,00	103,32	23,11	54,61	93,32	31,50	23,76
December	MaxTemp	18	24,27	24,00	22,71	26,12	23,69	24,93	3,41	1,24	0,97
	MinTemp	18	14,97	15,11	13,20	17,00	14,44	15,72	3,80	1,28	0,99
	AverageRain	18	0,72	0,56	0,08	1,36	0,50	1,10	1,28	0,60	0,43
	TotalRain	18	22,17	17,33	2,54	42,20	15,60	33,97	39,66	18,37	13,17

Addendum E: Table of the descriptive statistics of the temperature and rainfall data of the Voorstekop station per month

Descriptive statistics of the temperature and rainfall data of the Voorstekop station per month.

Month	Variable	Valid N	Mean	Median	Minimum	Maximum	Lower Quartile	Upper Quartile	Range	Quartile Range	Std.Dev
January	MaxTemp	25	27,80	27,75	20,04	30,95	27,36	28,72	10,91	1,36	1,92
	MinTemp	25	16,30	16,23	14,71	17,90	15,81	16,85	3,19	1,04	0,85
	AverageRain	25	1,12	0,80	0,00	5,61	0,45	1,56	5,61	1,11	1,15
	TotalRain	25	34,34	24,89	0,00	173,99	14,10	48,50	173,99	34,40	35,91
February	MaxTemp	26	28,23	28,46	26,39	29,45	27,66	28,97	3,06	1,31	0,85
	MinTemp	26	16,66	16,75	15,08	18,31	16,14	17,20	3,23	1,06	0,77
	AverageRain	26	0,95	0,79	0,05	3,83	0,54	1,08	3,78	0,54	0,77
	TotalRain	26	26,79	22,04	1,52	107,30	15,24	30,20	105,78	14,96	21,77
March	MaxTemp	26	26,83	26,94	22,95	28,89	26,09	27,62	5,94	1,53	1,33
	MinTemp	26	15,33	15,42	13,35	17,02	14,92	15,97	3,67	1,05	0,98
	AverageRain	26	1,47	1,18	0,04	5,16	0,53	1,95	5,12	1,42	1,28
	TotalRain	26	45,16	36,45	1,10	154,80	16,30	60,45	153,70	44,15	39,17
April	MaxTemp	26	24,45	24,47	21,94	28,23	23,44	25,03	6,29	1,59	1,38

	MinTemp	26	13,18	12,99	12,03	14,97	12,74	13,93	2,94	1,19	0,72
	AverageRain	26	1,25	1,14	0,03	3,37	0,73	1,64	3,34	0,91	0,81
	TotalRain	26	37,30	34,26	0,80	101,00	21,90	49,20	100,20	27,30	24,18
May	MaxTemp	26	21,94	21,94	19,89	23,84	21,05	22,66	3,95	1,61	1,10
	MinTemp	26	11,51	11,51	10,25	12,73	11,16	11,86	2,48	0,70	0,60
	AverageRain	26	1,29	0,97	0,00	5,83	0,53	1,76	5,83	1,23	1,22
	TotalRain	26	38,36	29,99	0,10	180,59	16,51	54,50	180,49	37,99	36,53
June	MaxTemp	26	19,10	19,23	16,88	22,19	17,83	19,84	5,31	2,01	1,55
	MinTemp	26	9,46	9,26	8,39	11,15	8,77	10,10	2,76	1,33	0,78
	AverageRain	26	1,36	1,23	0,00	3,73	0,65	1,94	3,73	1,29	0,87
	TotalRain	26	39,92	36,90	0,00	112,01	19,56	57,91	112,01	38,35	25,22
July	MaxTemp	26	18,17	18,28	14,85	20,60	17,59	18,75	5,75	1,16	1,18
	MinTemp	26	8,46	8,27	6,74	10,30	7,96	9,13	3,56	1,17	0,85
	AverageRain	26	1,55	1,37	0,02	4,14	1,05	2,05	4,12	1,00	0,86
	TotalRain	26	47,59	39,80	0,76	128,40	32,40	63,60	127,64	31,20	26,82
August	MaxTemp	26	18,80	18,87	15,52	21,11	17,86	19,89	5,59	2,03	1,33
	MinTemp	26	8,36	8,40	4,58	9,61	7,99	9,28	5,03	1,29	1,13
	AverageRain	26	1,51	1,08	0,05	5,40	0,67	2,17	5,35	1,50	1,37
	TotalRain	26	46,85	33,47	1,52	167,50	20,70	67,30	165,98	46,60	42,43

September	MaxTemp	25	20,57	20,47	16,35	24,34	19,84	21,32	7,99	1,48	1,38
	MinTemp	25	9,45	9,38	7,49	11,32	8,91	10,34	3,83	1,43	0,96
	AverageRain	25	1,15	1,04	0,01	3,38	0,69	1,31	3,37	0,62	0,75
	TotalRain	25	34,21	29,70	0,25	101,35	20,83	39,20	101,10	18,37	22,45
October	MaxTemp	25	22,92	23,08	15,76	25,89	22,38	24,18	10,13	1,80	2,02
	MinTemp	25	11,56	11,46	9,94	13,37	11,05	11,91	3,43	0,86	0,84
	AverageRain	25	1,55	1,02	0,00	4,92	0,56	2,33	4,92	1,77	1,31
	TotalRain	25	47,04	31,60	0,00	152,65	17,50	66,70	152,65	49,20	40,26
November	MaxTemp	25	24,41	24,75	16,99	26,53	24,28	24,99	9,54	0,71	1,92
	MinTemp	25	13,03	13,02	11,05	15,16	12,43	13,40	4,11	0,97	0,91
	AverageRain	25	1,75	1,31	0,00	8,45	0,73	1,71	8,45	0,98	1,81
	TotalRain	25	52,40	39,40	0,00	253,50	21,84	51,20	253,50	29,36	54,34
December	MaxTemp	25	26,55	26,73	18,53	30,64	25,94	27,73	12,11	1,79	2,43
	MinTemp	25	15,15	15,29	11,43	18,02	14,51	15,79	6,60	1,28	1,32
	AverageRain	25	0,81	0,69	0,00	2,64	0,34	1,03	2,64	0,70	0,69
	TotalRain	25	24,78	21,30	0,00	81,70	9,90	31,15	81,70	21,25	21,03

Addendum F: Linear regression analysis for variables predicting the maximum temperature, minimum temperature, average rainfall, and total rainfall for the Boontjieskraal station

Linear regression analysis (unstandardized and standardized regression coefficients) for variables predicting the maximum temperature, minimum temperature, average rainfall, and total rainfall for the Boontjieskraal station.

		Standardized Coefficients		Unstandardized Coefficients			
Model	Source	B	Std. Error	B	Std. Error	t	p
MaxTemp vs. Year (January)	Intercept			54,96	42,85	1,28	0,21
	Year	-0,11	0,18	-0,01	0,02	-0,61	0,55
MinTemp vs. Year (January)	Intercept			-99,38	34,66	-2,87	0,01*
	Year	0,52	0,16	0,06	0,02	3,33	0,00*
AverageRain vs. Year (January)	Intercept			-38,91	25,40	-1,53	0,14
	Year	0,27	0,18	0,02	0,01	1,55	0,13
TotalRain vs. Year (January)	Intercept			-1211,45	787,07	-1,54	0,13
	Year	0,27	0,18	0,61	0,39	1,56	0,13
MaxTemp vs. Year (February)	Intercept			72,66	34,99	2,08	0,05*
	Year	-0,22	0,18	-0,02	0,02	-1,24	0,22
MinTemp vs. Year (February)	Intercept			-48,66	34,87	-1,40	0,17
	Year	0,32	0,17	0,03	0,02	1,87	0,07
AverageRain vs. Year (February)	Intercept			15,81	16,41	0,96	0,34
	Year	-0,17	0,18	-0,01	0,01	-0,93	0,36
TotalRain vs. Year (February)	Intercept			449,84	461,45	0,97	0,34
	Year	-0,17	0,18	-0,22	0,23	-0,95	0,35

MaxTemp vs. Year (March)	Intercept			115,96	46,92	2,47	0,02*
	Year	-0,33	0,17	-0,04	0,02	-1,88	0,07
MinTemp vs. Year (March)	Intercept			-52,08	38,87	-1,34	0,19
	Year	0,30	0,17	0,03	0,02	1,73	0,09
AverageRain vs. Year (March)	Intercept			-4,01	20,47	-0,20	0,85
	Year	0,04	0,18	0,00	0,01	0,22	0,83
TotalRain vs. Year (March)	Intercept			-122,90	633,28	-0,19	0,85
	Year	0,04	0,18	0,07	0,32	0,22	0,83
MaxTemp vs. Year (April)	Intercept			-4,18	53,27	-0,08	0,94
	Year	0,10	0,18	0,01	0,03	0,54	0,59
MinTemp vs. Year (April)	Intercept			-126,21	34,16	-3,69	0,00*
	Year	0,60	0,15	0,07	0,02	4,06	0,00*
AverageRain vs. Year (April)	Intercept			82,79	37,08	2,23	0,03*
	Year	-0,37	0,17	-0,04	0,02	-2,20	0,04*
TotalRain vs. Year (April)	Intercept			2482,33	1113,45	2,23	0,03*
	Year	-0,37	0,17	-1,22	0,56	-2,20	0,04*
MaxTemp vs. Year (May)	Intercept			-37,58	52,56	-0,71	0,48
	Year	0,20	0,18	0,03	0,03	1,13	0,27
MinTemp vs. Year (May)	Intercept			-210,45	42,11	-5,00	0,00*
	Year	0,69	0,13	0,11	0,02	5,23	0,00*
AverageRain vs. Year (May)	Intercept			112,77	32,76	3,44	0,00*
	Year	-0,53	0,16	-0,06	0,02	-3,40	0,00*
TotalRain vs. Year (May)	Intercept			3498,09	1014,01	3,45	0,00*
	Year	-0,53	0,15	-1,72	0,51	-3,41	0,00*
MaxTemp vs. Year (June)	Intercept			-36,20	52,10	-0,69	0,49
	Year	0,19	0,18	0,03	0,03	1,05	0,30
	Intercept			-219,15	36,01	-6,09	0,00*

MinTemp vs. Year (June)	Year	0,75	0,12	0,11	0,02	6,29	0,00*
AverageRain vs. Year (June)	Intercept			18,29	35,01	0,52	0,61
	Year	-0,09	0,18	-0,01	0,02	-0,47	0,64
TotalRain vs. Year (June)	Intercept			627,03	1063,45	0,59	0,56
	Year	-0,10	0,18	-0,29	0,53	-0,54	0,59
MaxTemp vs. Year (July)	Intercept			5,07	40,55	0,13	0,90
	Year	0,06	0,18	0,01	0,02	0,31	0,76
MinTemp vs. Year (July)	Intercept			-149,18	36,00	-4,14	0,00*
	Year	0,62	0,14	0,08	0,02	4,32	0,00*
AverageRain vs. Year (July)	Intercept			5,68	36,56	0,16	0,88
	Year	-0,02	0,18	0,00	0,02	-0,11	0,92
TotalRain vs. Year (July)	Intercept			191,09	1134,72	0,17	0,87
	Year	-0,02	0,18	-0,07	0,57	-0,12	0,91
MaxTemp vs. Year (August)	Intercept			58,07	45,57	1,27	0,21
	Year	-0,16	0,18	-0,02	0,02	-0,88	0,39
MinTemp vs. Year (August)	Intercept			-156,16	47,08	-3,32	0,00*
	Year	0,53	0,15	0,08	0,02	3,46	0,00*
AverageRain vs. Year (August)	Intercept			-32,39	37,99	-0,85	0,40
	Year	0,16	0,18	0,02	0,02	0,90	0,38
TotalRain vs. Year (August)	Intercept			-1006,13	1170,58	-0,86	0,40
	Year	0,16	0,18	0,53	0,58	0,90	0,37
MaxTemp vs. Year (September)	Intercept			57,32	59,05	0,97	0,34
	Year	-0,12	0,18	-0,02	0,03	-0,63	0,53
MinTemp vs. Year (September)	Intercept			-123,01	37,65	-3,27	0,00*
	Year	0,54	0,16	0,07	0,02	3,47	0,00*
AverageRain vs. Year (September)	Intercept			-7,51	25,33	-0,30	0,77
	Year	0,06	0,19	0,00	0,01	0,34	0,74

TotalRain vs. Year (September)	Intercept			-219,14	760,33	-0,29	0,78
	Year	0,06	0,19	0,12	0,38	0,33	0,75
MaxTemp vs. Year (October)	Intercept			22,86	62,52	0,37	0,72
	Year	0,00	0,19	0,00	0,03	0,01	1,00
MinTemp vs. Year (October)	Intercept			-142,06	40,40	-3,52	0,00*
	Year	0,57	0,15	0,08	0,02	3,77	0,00*
AverageRain vs. Year (October)	Intercept			19,22	38,71	0,50	0,62
	Year	-0,09	0,18	-0,01	0,02	-0,47	0,64
TotalRain vs. Year (October)	Intercept			598,94	1199,84	0,50	0,62
	Year	-0,09	0,18	-0,28	0,60	-0,47	0,64
MaxTemp vs. Year (November)	Intercept			58,00	59,35	0,98	0,34
	Year	-0,10	0,18	-0,02	0,03	-0,55	0,59
MinTemp vs. Year (November)	Intercept			-108,79	41,84	-2,60	0,01*
	Year	0,47	0,16	0,06	0,02	2,90	0,01*
AverageRain vs. Year (November)	Intercept			-50,91	44,02	-1,16	0,26
	Year	0,21	0,18	0,03	0,02	1,18	0,25
TotalRain vs. Year (November)	Intercept			-1533,09	1321,77	-1,16	0,26
	Year	0,21	0,18	0,78	0,66	1,18	0,25
MaxTemp vs. Year (December)	Intercept			76,03	60,32	1,26	0,22
	Year	-0,15	0,18	-0,02	0,03	-0,80	0,43
MinTemp vs. Year (December)	Intercept			-81,61	44,06	-1,85	0,07
	Year	0,38	0,17	0,05	0,02	2,19	0,04*
AverageRain vs. Year (December)	Intercept			75,60	30,41	2,49	0,02*
	Year	-0,42	0,17	-0,04	0,02	-2,46	0,02*
TotalRain vs. Year (December)	Intercept			2348,96	942,87	2,49	0,02*
	Year	-0,42	0,17	-1,16	0,47	-2,47	0,02*

Addendum G: Linear regression analysis for variables predicting the maximum temperature, minimum temperature, average rainfall, and total rainfall for the Agulhas wines station

Table S6. Linear regression analysis (unstandardized and standardized regression coefficients) for variables predicting the maximum temperature, minimum temperature, average rainfall, and total rainfall for the Agulhas wines station.

		Standardized Coefficients		Unstandardized Coefficients			
Model	Source	B	Std. Error	B	Std. Error	t	p
MaxTemp vs. Year (January)	Intercept			11,15	114,60	0,10	0,92
	Year	0,03	0,25	0,01	0,06	0,12	0,90
MinTemp vs. Year (January)	Intercept			44,82	89,66	0,50	0,62
	Year	-0,08	0,25	-0,01	0,04	-0,32	0,75
AverageRain vs. Year (January)	Intercept			-94,52	56,03	-1,69	0,11
	Year	0,39	0,23	0,05	0,03	1,70	0,11
TotalRain vs. Year (January)	Intercept			-2925,25	1734,45	-1,69	0,11
	Year	0,39	0,23	1,47	0,86	1,70	0,11
MaxTemp vs. Year (February)	Intercept			-52,42	53,91	-0,97	0,35
	Year	0,34	0,24	0,04	0,03	1,45	0,17
MinTemp vs. Year (February)	Intercept			94,54	78,00	1,21	0,24
	Year	-0,24	0,24	-0,04	0,04	-1,00	0,33
AverageRain vs. Year (February)	Intercept			57,59	39,04	1,48	0,16
	Year	-0,34	0,23	-0,03	0,02	-1,45	0,17
TotalRain vs. Year (February)	Intercept			1611,50	1097,16	1,47	0,16
	Year	-0,34	0,24	-0,79	0,55	-1,45	0,17

MaxTemp vs. Year (March)	Intercept			-16,01	79,24	-0,20	0,84
	Year	0,13	0,25	0,02	0,04	0,51	0,62
MinTemp vs. Year (March)	Intercept			-66,27	81,73	-0,81	0,43
	Year	0,24	0,24	0,04	0,04	1,00	0,33
AverageRain vs. Year (March)	Intercept			-115,05	59,88	-1,92	0,07
	Year	0,44	0,22	0,06	0,03	1,94	0,07
TotalRain vs. Year (March)	Intercept			-3576,13	1858,14	-1,92	0,07
	Year	0,44	0,22	1,79	0,92	1,94	0,07
MaxTemp vs. Year (April)	Intercept			-130,83	78,35	-1,67	0,11
	Year	0,44	0,22	0,08	0,04	1,96	0,07
MinTemp vs. Year (April)	Intercept			7,18	47,71	0,15	0,88
	Year	0,03	0,25	0,00	0,02	0,13	0,90
AverageRain vs. Year (April)	Intercept			290,35	128,93	2,25	0,04*
	Year	-0,49	0,22	-0,14	0,06	-2,24	0,04*
TotalRain vs. Year (April)	Intercept			8700,90	3865,06	2,25	0,04*
	Year	-0,49	0,22	-4,30	1,92	-2,24	0,04*
MaxTemp vs. Year (May)	Intercept			-177,83	82,41	-2,16	0,05*
	Year	0,52	0,21	0,10	0,04	2,41	0,03*
MinTemp vs. Year (May)	Intercept			-9,28	54,37	-0,17	0,87
	Year	0,10	0,25	0,01	0,03	0,39	0,70
AverageRain vs. Year (May)	Intercept			-2,44	131,67	-0,02	0,99
	Year	0,01	0,25	0,00	0,07	0,03	0,97
TotalRain vs. Year (May)	Intercept			-125,01	4081,54	-0,03	0,98
	Year	0,01	0,25	0,09	2,03	0,04	0,97
MaxTemp vs. Year (June)	Intercept			-134,19	101,78	-1,32	0,21
	Year	0,35	0,23	0,08	0,05	1,50	0,15
	Intercept			-16,74	68,79	-0,24	0,81

MinTemp vs. Year (June)	Year	0,10	0,25	0,01	0,03	0,38	0,71
AverageRain vs. Year (June)	Intercept			-137,60	67,03	-2,05	0,06
	Year	0,46	0,22	0,07	0,03	2,09	0,05
TotalRain vs. Year (June)	Intercept			-4171,19	2008,90	-2,08	0,05
	Year	0,47	0,22	2,11	1,00	2,12	0,05
MaxTemp vs. Year (July)	Intercept			-61,65	100,82	-0,61	0,55
	Year	0,19	0,25	0,04	0,05	0,79	0,44
MinTemp vs. Year (July)	Intercept			4,51	54,90	0,08	0,94
	Year	0,02	0,25	0,00	0,03	0,08	0,94
AverageRain vs. Year (July)	Intercept			25,23	100,66	0,25	0,81
	Year	-0,06	0,25	-0,01	0,05	-0,22	0,83
TotalRain vs. Year (July)	Intercept			778,52	3129,14	0,25	0,81
	Year	-0,06	0,25	-0,35	1,55	-0,22	0,83
MaxTemp vs. Year (August)	Intercept			-20,71	71,74	-0,29	0,78
	Year	0,13	0,25	0,02	0,04	0,54	0,60
MinTemp vs. Year (August)	Intercept			-42,85	82,20	-0,52	0,61
	Year	0,16	0,25	0,03	0,04	0,63	0,54
AverageRain vs. Year (August)	Intercept			-135,92	149,06	-0,91	0,38
	Year	0,23	0,24	0,07	0,07	0,93	0,37
TotalRain vs. Year (August)	Intercept			-4205,43	4623,36	-0,91	0,38
	Year	0,23	0,24	2,13	2,30	0,93	0,37
MaxTemp vs. Year (September)	Intercept			-52,70	79,73	-0,66	0,52
	Year	0,23	0,25	0,04	0,04	0,90	0,38
MinTemp vs. Year (September)	Intercept			-21,20	89,28	-0,24	0,82
	Year	0,09	0,26	0,02	0,04	0,35	0,73
AverageRain vs. Year (September)	Intercept			-126,06	72,09	-1,75	0,10
	Year	0,42	0,23	0,06	0,04	1,77	0,10

TotalRain vs. Year (September)	Intercept			-3830,73	2172,25	-1,76	0,10
	Year	0,42	0,23	1,93	1,08	1,79	0,09
MaxTemp vs. Year (October)	Intercept			-99,84	94,24	-1,06	0,31
	Year	0,31	0,25	0,06	0,05	1,28	0,22
MinTemp vs. Year (October)	Intercept			-7,57	73,54	-0,10	0,92
	Year	0,07	0,26	0,01	0,04	0,26	0,80
AverageRain vs. Year (October)	Intercept			147,96	120,56	1,23	0,24
	Year	-0,30	0,25	-0,07	0,06	-1,21	0,24
TotalRain vs. Year (October)	Intercept			4589,35	3732,50	1,23	0,24
	Year	-0,30	0,25	-2,25	1,86	-1,22	0,24
MaxTemp vs. Year (November)	Intercept			85,56	62,73	1,36	0,19
	Year	-0,24	0,24	-0,03	0,03	-1,01	0,33
MinTemp vs. Year (November)	Intercept			47,70	59,02	0,81	0,43
	Year	-0,15	0,25	-0,02	0,03	-0,59	0,57
AverageRain vs. Year (November)	Intercept			-71,92	72,11	-1,00	0,33
	Year	0,25	0,24	0,04	0,04	1,02	0,32
TotalRain vs. Year (November)	Intercept			-2165,76	2168,60	-1,00	0,33
	Year	0,25	0,24	1,10	1,08	1,02	0,32
MaxTemp vs. Year (December)	Intercept			-112,94	85,16	-1,33	0,20
	Year	0,37	0,23	0,07	0,04	1,61	0,13
MinTemp vs. Year (December)	Intercept			-63,89	91,42	-0,70	0,49
	Year	0,21	0,24	0,04	0,05	0,86	0,40
AverageRain vs. Year (December)	Intercept			33,64	39,58	0,85	0,41
	Year	-0,20	0,24	-0,02	0,02	-0,83	0,42
TotalRain vs. Year (December)	Intercept			1046,88	1214,30	0,86	0,40
	Year	-0,21	0,24	-0,51	0,60	-0,84	0,41

Addendum H: Linear regression analysis for variables predicting the maximum temperature, minimum temperature, average rainfall, and total rainfall for the Voorstekop station

Linear regression analysis (unstandardized and standardized regression coefficients) for variables predicting the maximum temperature, minimum temperature, average rainfall, and total rainfall for the Voorstekop station.

		Standardized Coefficients		Unstandardized Coefficients			
Model	Source	B	Std. Error	B	Std. Error	t	p
MaxTemp vs. Year (January)	Intercept			146,74	106,58	1,38	0,18
	Year	-0,23	0,20	-0,06	0,05	-1,12	0,28
MinTemp vs. Year (January)	Intercept			-76,13	44,44	-1,71	0,10
	Year	0,40	0,19	0,05	0,02	2,08	0,05 (0,048)*
AverageRain vs. Year (January)	Intercept			-51,43	64,80	-0,79	0,44
	Year	0,17	0,21	0,03	0,03	0,81	0,43
TotalRain vs. Year (January)	Intercept			-1736,64	2010,55	-0,86	0,40
	Year	0,18	0,21	0,88	1,00	0,88	0,39
MaxTemp vs. Year (February)	Intercept			-44,73	43,22	-1,04	0,31
	Year	0,33	0,19	0,04	0,02	1,69	0,10
MinTemp vs. Year (February)	Intercept			40,14	40,85	0,98	0,34
	Year	-0,12	0,20	-0,01	0,02	-0,57	0,57
AverageRain vs. Year (February)	Intercept			22,58	41,15	0,55	0,59
	Year	-0,11	0,20	-0,01	0,02	-0,53	0,60
TotalRain vs. Year (February)	Intercept			545,32	1162,33	0,47	0,64
	Year	-0,09	0,20	-0,26	0,58	-0,45	0,66
	Intercept			-40,95	69,86	-0,59	0,56

MaxTemp vs. Year (March)	Year	0,19	0,20	0,03	0,03	0,97	0,34
MinTemp vs. Year (March)	Intercept			17,56	52,53	0,33	0,74
	Year	-0,01	0,20	0,00	0,03	-0,04	0,97
AverageRain vs. Year (March)	Intercept			64,20	67,52	0,95	0,35
	Year	-0,19	0,20	-0,03	0,03	-0,93	0,36
TotalRain vs. Year (March)	Intercept			1918,37	2064,42	0,93	0,36
	Year	-0,18	0,20	-0,93	1,03	-0,91	0,37
MaxTemp vs. Year (April)	Intercept			-68,70	71,66	-0,96	0,35
	Year	0,26	0,20	0,05	0,04	1,30	0,21
MinTemp vs. Year (April)	Intercept			19,24	38,57	0,50	0,62
	Year	-0,03	0,20	0,00	0,02	-0,16	0,88
AverageRain vs. Year (April)	Intercept			72,89	41,08	1,77	0,09
	Year	-0,34	0,19	-0,04	0,02	-1,74	0,09
TotalRain vs. Year (April)	Intercept			2022,17	1231,01	1,64	0,11
	Year	-0,31	0,19	-0,99	0,61	-1,61	0,12
MaxTemp vs. Year (May)	Intercept			-25,62	58,28	-0,44	0,66
	Year	0,16	0,20	0,02	0,03	0,82	0,42
MinTemp vs. Year (May)	Intercept			9,14	31,99	0,29	0,78
	Year	0,02	0,20	0,00	0,02	0,07	0,94
AverageRain vs. Year (May)	Intercept			0,13	65,45	0,00	1,00
	Year	0,00	0,20	0,00	0,03	0,02	0,99
TotalRain vs. Year (May)	Intercept			-280,87	1956,87	-0,14	0,89
	Year	0,03	0,20	0,16	0,97	0,16	0,87
MaxTemp vs. Year (June)	Intercept			30,99	83,04	0,37	0,71
	Year	-0,03	0,20	-0,01	0,04	-0,14	0,89
MinTemp vs. Year (June)	Intercept			6,57	42,01	0,16	0,88
	Year	0,01	0,20	0,00	0,02	0,07	0,95

AverageRain vs. Year (June)	Intercept			-43,97	45,75	-0,96	0,35
	Year	0,20	0,20	0,02	0,02	0,99	0,33
TotalRain vs. Year (June)	Intercept			-1484,09	1315,43	-1,13	0,27
	Year	0,23	0,20	0,76	0,65	1,16	0,26
MaxTemp vs. Year (July)	Intercept			-4,82	62,95	-0,08	0,94
	Year	0,07	0,20	0,01	0,03	0,37	0,72
MinTemp vs. Year (July)	Intercept			-2,17	45,67	-0,05	0,96
	Year	0,05	0,20	0,01	0,02	0,23	0,82
AverageRain vs. Year (July)	Intercept			3,55	46,29	0,08	0,94
	Year	-0,01	0,20	0,00	0,02	-0,04	0,97
TotalRain vs. Year (July)	Intercept			11,40	1437,79	0,01	0,99
	Year	0,01	0,20	0,02	0,72	0,03	0,98
MaxTemp vs. Year (August)	Intercept			93,48	69,66	1,34	0,19
	Year	-0,21	0,20	-0,04	0,03	-1,07	0,29
MinTemp vs. Year (August)	Intercept			9,83	60,35	0,16	0,87
	Year	0,00	0,20	0,00	0,03	-0,02	0,98
AverageRain vs. Year (August)	Intercept			-100,11	70,28	-1,42	0,17
	Year	0,28	0,20	0,05	0,03	1,45	0,16
TotalRain vs. Year (August)	Intercept			-3117,73	2180,94	-1,43	0,17
	Year	0,28	0,20	1,58	1,09	1,45	0,16
MaxTemp vs. Year (September)	Intercept			81,33	77,46	1,05	0,30
	Year	-0,16	0,21	-0,03	0,04	-0,78	0,44
MinTemp vs. Year (September)	Intercept			-59,45	52,43	-1,13	0,27
	Year	0,26	0,20	0,03	0,03	1,31	0,20
AverageRain vs. Year (September)	Intercept			-58,67	40,66	-1,44	0,16
	Year	0,29	0,20	0,03	0,02	1,47	0,15
	Intercept			-1850,25	1215,01	-1,52	0,14

TotalRain vs. Year (September)	Year	0,31	0,20	0,94	0,61	1,55	0,13
MaxTemp vs. Year (October)	Intercept			152,96	111,56	1,37	0,18
	Year	-0,24	0,20	-0,06	0,06	-1,17	0,26
MinTemp vs. Year (October)	Intercept			-26,88	47,32	-0,57	0,58
	Year	0,17	0,21	0,02	0,02	0,81	0,42
AverageRain vs. Year (October)	Intercept			-2,93	74,54	-0,04	0,97
	Year	0,01	0,21	0,00	0,04	0,06	0,95
TotalRain vs. Year (October)	Intercept			-252,92	2289,48	-0,11	0,91
	Year	0,03	0,21	0,15	1,14	0,13	0,90
MaxTemp vs. Year (November)	Intercept			141,54	106,72	1,33	0,20
	Year	-0,22	0,20	-0,06	0,05	-1,10	0,28
MinTemp vs. Year (November)	Intercept			-23,54	51,33	-0,46	0,65
	Year	0,15	0,21	0,02	0,03	0,71	0,48
AverageRain vs. Year (November)	Intercept			37,23	102,82	0,36	0,72
	Year	-0,07	0,21	-0,02	0,05	-0,35	0,73
TotalRain vs. Year (November)	Intercept			1112,55	3083,57	0,36	0,72
	Year	-0,07	0,21	-0,53	1,54	-0,34	0,73
MaxTemp vs. Year (December)	Intercept			161,78	135,60	1,19	0,25
	Year	-0,20	0,20	-0,07	0,07	-1,00	0,33
MinTemp vs. Year (December)	Intercept			-32,82	74,40	-0,44	0,66
	Year	0,13	0,21	0,02	0,04	0,64	0,53
AverageRain vs. Year (December)	Intercept			56,71	37,37	1,52	0,14
	Year	-0,30	0,20	-0,03	0,02	-1,50	0,15
TotalRain vs. Year (December)	Intercept			1602,94	1150,31	1,39	0,18
	Year	-0,28	0,20	-0,79	0,57	-1,37	0,18

Addendum I: Interview schedule

Section A: Demographic Information and Agricultural Practices

1. What is your gender?

Male ☐

Female ☐

Other ☐

2. How old are you? ____________________
3. What is the size of your household? ____________________

4. What is your highest level of education?

No formal education ☐

Primary school ☐

Secondary school ☐

Tertiary education ☐ Please specify ____________________

5. How long have you been living in the community?

Less than 1 year ☐ 1 – 5 years ☐

5 – 10 years ☐ 10-15 years ☐

15 – 20 years ☐ Over 20 years ☐

6. How many years have you been engaged in farming?

Less than 1 year ☐ 1 – 5 years ☐

5 – 10 years ☐ 10-15 years ☐

15 – 20 years ☐ Over 20 years ☐

7. With what do you farm? (Mark all that apply)

Livestock ☐

Crops ☐

Fish □

Other □ Please specify ____________________

8. What is the size of the area that you farm on? (i.e., how many hectares (ha) do you farm on?) ____________________

9. What is your monthly household income (ZAR/month)? ____________________

Section B: Climate Perceptions

1. Can you please describe to me if you have you noticed any long-term changes in the temperature over the past _____ years? (e.g., have you experienced an increase, decrease, no change, or variable change in temperature?)

2. If indicated "Yes" for question 1: Did the change in temperature effect your household or farming practices? If so, please specify how.

3. Can you please describe to me if you have you noticed changes regarding heatwaves over the past _____ years? (e.g., have you experienced an increase, decrease, no change or variable change in heatwaves?)

4. Can you please describe to me if you have you noticed any long-term changes in the rainfall over the past _____ years? (e.g., have you experienced an increase, decrease, no change, or variable change in rainfall?)

5. If indicated "yes" for question 5: Did the change in rainfall affect your household or farming practices? If so, please specify how.

6. Can you please describe to me if you have you noticed changes regarding droughts over the past _____ years? (e.g., have you experienced an increase, decrease, no change or variable change in droughts?)

7. Can you please describe to me if you have you noticed changes regarding flooding over the past ______ years? (e.g., have you experienced an increase, decrease, no change or variable change in flooding?)

Section C: Knowledge, Attitudes and Practices towards Climate Change

KNOWLEDGE

1. Have you heard of the term “climate change”?

Yes ☐ No ☐

2. If indicated “yes” for question 1, please indicate from where you have heard of the term “climate change”?

Family member ☐ Friend ☐

Television ☐ Newspaper ☐

Internet ☐ Radio ☐

Extension officer ☐ Other ☐

3. If indicated “other” for question 2, please specify: ____________________

4. In general, how would you define climate change?

5. By your own understanding, would you say that climate change has affected your farming practices, and if yes can you please describe how?

6. Please indicate which stakeholders do you think are responsible for communicating information regarding climate change (can indicate more than one stakeholder):

The Government (Department of Agriculture, Forestry and Fisheries) ☐

Non-governmental organization (NGO) ☐ Community groups ☐

You and your family ☐ Other ☐.

7. If indicated “other” for question 5, please specify: ____________________

ATTITUDES

1. Please indicate on a scale from 1 to 5 (with 5 being the highest) how concerned you are about global climate change:

1□ 2□ 3□ 4□ 5□

2. Please indicate on a scale from 1 to 5 (with 5 being the highest) how concerned you are about climate change effecting your community:

1□ 2□ 3□ 4□ 5□

3. Please indicate on a scale from 1 to 5 (with 5 being the highest) how concerned you are about climate change effecting your livelihood/household:

1□ 2□ 3□ 4□ 5□

4. Please indicate on a scale from 1 to 5 (with 5 being the highest) how interested you would be to learn more about climate change:

1□ 2□ 3□ 4□ 5□

PRACTICES

1. Which of the following farming practices do you engage in on your farm (tick all that apply)?

Irrigation□ Conservation agriculture□

Ridging□ Agro-forestry□

Contour farming □ Composting □

The use of fertilizers□ The use of pesticides□

Mulching□ Cover cropping□

Mixed cropping□ Crop rotation□

Other □____

2. Please give reasons why you do not practice the options you did not select.

Section D: Adaptation Strategies

1. Have you made any changes or shifts in your farming practices in respond to climate change, other then what you have already mentioned in the previous questions? Yes □ No □

2. If indicated "yes" for question 1, please specify which changes were made.

3. Have you heard of the term climate smart agriculture? Yes □ No □

4. If indicated "yes" for question 3, please specify where you heard of the term and please expand on your understanding of the term.
5. Have you heard of the term Smart Agriculture for Climate Resilience (SmartAgri)? Yes □ No □

6. If indicated "yes" for question 9, please specify where you heard of the term and please expand on your understanding of the term.

7. Do you know if the Department of Agriculture, Forestry and Fisheries has implemented any measures in your community that would help ease the impacts of climate change in the agricultural sector? Yes □ No □

If indicated "yes" for question 11, please specify the different measures and are your adopting these measures in your farming practices?

Addendum J: Table of interview coding frame

Table of interview coding frame

Question Code	Identifier
Q1	What is your gender?
1	Male
2	Female
3	Other
Q2	How old are you?
Q3	What is the size of your household (the amount of people living on the property)?
Q4	What is your highest level of education?
1	No formal education
2	Primary school
3	Secondary school
4	Tertiary education
5	Other
Q5	How many years have you been engaged in farming?
1	Less than 5 years
2	5 -10 years
3	11 - 20 years
4	More than 20 years
Q6	With what do you farm?
Q6_LIVESTOCK	

1	Yes
2	No
Q6_CROPS	
1	Yes
2	No
Q6_FISH	
1	Yes
2	No
Q6_OTHER	
1	Yes
2	No
Q7	What is the size of the area that you farm on? (i.e., how many hectares (ha) do you farm on?)
Q9	Would you be comfortable to tell me what your monthly household income (ZAR/month) is?
Q10	How long have you been living in the community?
1	Less than 5 years
2	5 -10 years
3	11 - 20 years
4	More than 20 years
Q20	Have you heard of the term “climate change”?
1	Yes
2	No

Q21	If indicated "yes" for question 20, please indicate from where you have heard of the term "climate change"?
Q21_FAMILY MEMBER	
1	Yes
2	No
Q21_FRIEND	
1	Yes
2	No
Q21_TELEVISION	
1	Yes
2	No
Q21_NEWSPAPER	
1	Yes
2	No
Q21_INTERNET	
1	Yes
2	No
Q21_RADIO	
1	Yes
2	No
Q21_EXTENSION OFFICER	
1	Yes

2	No
Q21_OTHER	
1	Yes
2	No
Q25	Please indicate which stakeholders do you think are responsible for communicating information regarding climate change (can indicate more than one stakeholder):
Q25_The Government (DAFF)	
1	Yes
2	No
Q25_Non-governmental organization (NGO)	
1	Yes
2	No
Q25_Community groups	
1	Yes
2	No
Q25_You and your family	
1	Yes
2	No

Q25_Other	
1	Yes
2	No
Q26	Please indicate on a scale from 1 to 5 (with 5 being the highest) how concerned you are about global climate change:
1	1
2	2
3	3
4	4
5	5
Q27	Please indicate on a scale from 1 to 5 (with 5 being the highest) how concerned you are about climate change effecting your community:
1	1
2	2
3	3
4	4
5	5
Q28	Please indicate on a scale from 1 to 5 (with 5 being the highest) how concerned you are about climate change effecting your livelihood/household:
1	1
2	2

3	3
4	4
5	5
Q29	Please indicate on a scale from 1 to 5 (with 5 being the highest) how interested you would be to learn more about climate change:
1	1
2	2
3	3
4	4
5	5
Q30	Which of the following farming practices do you engage in on your farm (tick all that apply)?
Q30_Irrigation	
1	Yes
2	No
Q30_Conservation agriculture	
1	Yes
2	No
Q30_Ridging	
1	Yes
2	No
Q30_Agro-forestry	
1	Yes
2	No

Q30_Contour farming	
1	Yes
2	No
Q30_Composting	
1	Yes
2	No
Q30_Fertilizers	
1	Yes
2	No
Q30_Pesticides	
1	Yes
2	No
Q30_Mulching	
1	Yes
2	No
Q30_Cover cropping	
1	Yes
2	No
Q30_Mixed cropping	
1	Yes
2	No
Q30_Crop rotation	
1	Yes
2	No

Q30_Other	
1	Yes
2	No
Q32	Have you made any changes or shifts in your farming practices in respond to climate change, other then what you have already mentioned in the previous questions?
1	Yes
2	No
Q34	Have you heard of the term climate smart agriculture?
1	Yes
2	No
Q36	Have you heard of the term Smart Agriculture for Climate Resilience (SmartAgri)?
1	Yes
2	No
Q38	Do you know if the Department of Agriculture, Forestry and Fisheries has implemented any measures in your community that would help ease the impacts of climate change in the agricultural sector?
1	Yes
2	No

Addendum K: Table of summary statistics for the linear regression analyses for variables predicting the maximum temperature, minimum temperature, average rainfall, and total rainfall for the Boontjieskraal station

Summary statistics for the linear regression analyses for variables predicting the maximum temperature, minimum temperature, average rainfall, and total rainfall for the Boontjieskraal station.

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
MaxTemp vs. Month	0,03	0,00	0,00	4,30
MinTemp vs. Month	0,15	0,02	0,02	3,81
AverageRain vs. Month	0,07	0,00	0,00	0,97
TotalRain vs. Month	0,09	0,01	0,01	53,69
MaxTemp vs. Year	0,06	0,00	-0,03	0,66
MinTemp vs. Year	0,83	0,68	0,67	0,45
AverageRain vs. Year	0,25	0,06	0,03	0,26
TotalRain vs. Year	0,32	0,11	0,07	15,01

Addendum L: Table of summary statistics for the linear regression analyses for variables predicting the maximum temperature, minimum temperature, average rainfall, and total rainfall for the Agulhas wines station

Summary statistics for the linear regression analyses for variables predicting the maximum temperature, minimum temperature, average rainfall, and total rainfall for the Agulhas wines station.

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
MaxTemp vs. Month	0,04	0,00	0,00	2,98
MinTemp vs. Month	0,02	0,00	0,00	2,81
AverageRain vs. Month	0,05	0,00	0,00	1,24
TotalRain vs. Month	0,05	0,00	0,00	38,03
MaxTemp vs. Year’]	0,57	0,33	0,28	0,36
MinTemp vs. Year	0,12	0,01	-0,05	0,30
AverageRain vs. Year	0,20	0,04	-0,02	0,33
TotalRain vs. Year	0,05	0,00	-0,06	101,14

Addendum M: Table of summary statistics for the linear regression analyses for variables predicting the maximum temperature, minimum temperature, average rainfall, and total rainfall for the Voorstekop station

Summary statistics for the linear regression analyses for variables predicting the maximum temperature, minimum temperature, average rainfall, and total rainfall for the Voorstekop station.

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
MaxTemp vs. Month	0,04	0,00	0,00	3,81
MinTemp vs. Month	0,01	0,00	0,00	3,05
AverageRain vs. Month	0,00	0,00	0,00	1,13
TotalRain vs. Month	0,02	0,00	0,00	34,39
MaxTemp vs. Year	0,12	0,01	-0,03	0,67
MinTemp vs. Year	0,21	0,04	0,00	0,45
AverageRain vs. Year	0,05	0,00	-0,04	0,34
TotalRain vs. Year	0,02	0,00	-0,04	107,22

Addendum N: Table of summary statistics for the linear regression analyses for years predicting the maximum temperature, minimum temperature, average rainfall, and total rainfall for each month of the Boontjieskraal station

Summary statistics for the linear regression analyses for years predicting the maximum temperature, minimum temperature, average rainfall, and total rainfall for each month of the Boontjieskraal station.

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
MaxTemp vs. Year (January)	0,11	0,01	-0,02	1,12
MinTemp vs. Year (January)	0,52	0,27	0,25	0,90
AverageRain vs. Year (January)	0,27	0,07	0,04	0,66
TotalRain vs. Year (January)	0,27	0,08	0,04	20,50
MaxTemp vs. Year (February)	0,22	0,05	0,02	0,91
MinTemp vs. Year (February)	0,32	0,10	0,07	0,91
AverageRain vs. Year (February)	0,17	0,03	0,00	0,43
TotalRain vs. Year (February)	0,17	0,03	0,00	12,02
MaxTemp vs. Year (March)	0,33	0,11	0,08	1,22
MinTemp vs. Year (March)	0,30	0,09	0,06	1,01
AverageRain vs. Year (March)	0,04	0,00	-0,03	0,53
TotalRain vs. Year (March)	0,04	0,00	-0,03	16,49
MaxTemp vs. Year (April)	0,10	0,01	-0,02	1,39

MinTemp vs. Year (April)	0,60	0,35	0,33	0,89
AverageRain vs. Year (April)	0,37	0,14	0,11	0,97
TotalRain vs. Year (April)	0,37	0,14	0,11	29,00
MaxTemp vs. Year (May)	0,20	0,04	0,01	1,37
MinTemp vs. Year (May)	0,69	0,48	0,46	1,10
AverageRain vs. Year (May)	0,53	0,28	0,25	0,85
TotalRain vs. Year (May)	0,53	0,28	0,26	26,41
MaxTemp vs. Year (June)	0,19	0,04	0,00	1,36
MinTemp vs. Year (June)	0,75	0,57	0,55	0,94
AverageRain vs. Year (June)	0,09	0,01	-0,03	0,91
TotalRain vs. Year (June)	0,10	0,01	-0,02	27,70
MaxTemp vs. Year (July)	0,06	0,00	-0,03	1,06
MinTemp vs. Year (July)	0,62	0,38	0,36	0,94
AverageRain vs. Year (July)	0,02	0,00	-0,03	0,95
TotalRain vs. Year (July)	0,02	0,00	-0,03	29,55
MaxTemp vs. Year (August)	0,16	0,03	-0,01	1,19
MinTemp vs. Year (August)	0,53	0,28	0,26	1,23
AverageRain vs. Year (August)	0,16	0,03	-0,01	0,99
TotalRain vs. Year (August)	0,16	0,03	-0,01	30,49
MaxTemp vs. Year (September)	0,12	0,01	-0,02	1,47
MinTemp vs. Year (September)	0,54	0,29	0,27	0,94
AverageRain vs. Year (September)	0,06	0,00	-0,03	0,63

TotalRain vs. Year (September)	0,06	0,00	-0,03	18,88
MaxTemp vs. Year (October)	0,00	0,00	-0,03	1,55
MinTemp vs. Year (October)	0,57	0,33	0,31	1,00
AverageRain vs. Year (October)	0,09	0,01	-0,03	0,96
TotalRain vs. Year (October)	0,09	0,01	-0,03	29,80
MaxTemp vs. Year (November)	0,10	0,01	-0,02	1,47
MinTemp vs. Year (November)	0,47	0,22	0,20	1,04
AverageRain vs. Year (November)	0,21	0,05	0,01	1,09
TotalRain vs. Year (November)	0,21	0,05	0,01	32,83
MaxTemp vs. Year (December)	0,15	0,02	-0,01	1,50
MinTemp vs. Year (December)	0,38	0,14	0,11	1,09
AverageRain vs. Year (December)	0,42	0,17	0,14	0,76
TotalRain vs. Year (December)	0,42	0,17	0,15	23,42

Addendum O: Table of summary statistics for the linear regression analyses for years predicting the maximum temperature, minimum temperature, average rainfall, and total rainfall for each month of the Agulhas wines station

Summary statistics for the linear regression analyses for years predicting the maximum temperature, minimum temperature, average rainfall, and total rainfall for each month of the Agulhas wines station.

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
MaxTemp vs. Year (January)	0,03	0,00	-0,06	1,25
MinTemp vs. Year (January)	0,08	0,01	-0,06	0,98
AverageRain vs. Year (January)	0,39	0,15	0,10	0,61
TotalRain vs. Year (January)	0,39	0,15	0,10	18,97
MaxTemp vs. Year (February)	0,34	0,12	0,06	0,59
MinTemp vs. Year (February)	0,24	0,06	0,00	0,85
AverageRain vs. Year (February)	0,34	0,12	0,06	0,43
TotalRain vs. Year (February)	0,34	0,12	0,06	12,00
MaxTemp vs. Year (March)	0,13	0,02	-0,05	0,87
MinTemp vs. Year (March)	0,24	0,06	0,00	0,89
AverageRain vs. Year (March)	0,44	0,19	0,14	0,65
TotalRain vs. Year (March)	0,44	0,19	0,14	20,32
MaxTemp vs. Year (April)	0,44	0,19	0,14	0,86
MinTemp vs. Year (April)	0,03	0,00	-0,06	0,52
AverageRain vs. Year (April)	0,49	0,24	0,19	1,41

TotalRain vs. Year (April)	0,49	0,24	0,19	42,27
MaxTemp vs. Year (May)	0,52	0,27	0,22	0,90
MinTemp vs. Year (May)	0,10	0,01	-0,05	0,59
AverageRain vs. Year (May)	0,01	0,00	-0,06	1,44
TotalRain vs. Year (May)	0,01	0,00	-0,06	44,64
MaxTemp vs. Year (June)	0,35	0,12	0,07	1,11
MinTemp vs. Year (June)	0,10	0,01	-0,05	0,75
AverageRain vs. Year (June)	0,46	0,22	0,17	0,73
TotalRain vs. Year (June)	0,47	0,22	0,17	21,97
MaxTemp vs. Year (July)	0,19	0,04	-0,02	1,10
MinTemp vs. Year (July)	0,02	0,00	-0,06	0,60
AverageRain vs. Year (July)	0,06	0,00	-0,06	1,10
TotalRain vs. Year (July)	0,06	0,00	-0,06	34,22
MaxTemp vs. Year (August)	0,13	0,02	-0,04	0,78
MinTemp vs. Year (August)	0,16	0,02	-0,04	0,90
AverageRain vs. Year (August)	0,23	0,05	-0,01	1,63
TotalRain vs. Year (August)	0,23	0,05	-0,01	50,57
MaxTemp vs. Year (September)	0,23	0,05	-0,01	0,80
MinTemp vs. Year (September)	0,09	0,01	-0,06	0,90
AverageRain vs. Year (September)	0,42	0,17	0,12	0,72
TotalRain vs. Year (September)	0,42	0,18	0,12	21,81
MaxTemp vs. Year (October)	0,31	0,10	0,04	0,95
MinTemp vs. Year (October)	0,07	0,00	-0,06	0,74

AverageRain vs. Year (October)	0,30	0,09	0,03	1,21
TotalRain vs. Year (October)	0,30	0,09	0,03	37,47
MaxTemp vs. Year (November)	0,24	0,06	0,00	0,69
MinTemp vs. Year (November)	0,15	0,02	-0,04	0,65
AverageRain vs. Year (November)	0,25	0,06	0,00	0,79
TotalRain vs. Year (November)	0,25	0,06	0,00	23,73
MaxTemp vs. Year (December)	0,37	0,14	0,09	0,93
MinTemp vs. Year (December)	0,21	0,04	-0,02	1,00
AverageRain vs. Year (December)	0,20	0,04	-0,02	0,43
TotalRain vs. Year (December)	0,21	0,04	-0,02	13,29

Addendum P: Table of summary statistics for the linear regression analyses for years predicting the maximum temperature, minimum temperature, average rainfall, and total rainfall for each month of the Voorstekop station

Summary statistics for the linear regression analyses for years predicting the maximum temperature, minimum temperature, average rainfall, and total rainfall for each month of the Voorstekop station.

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
MaxTemp vs. Year (January)	0,23	0,05	0,01	1,91
MinTemp vs. Year (January)	0,40	0,16	0,12	0,80
AverageRain vs. Year (January)	0,17	0,03	-0,01	1,16
TotalRain vs. Year (January)	0,18	0,03	-0,01	36,08
MaxTemp vs. Year (February)	0,33	0,11	0,07	0,82
MinTemp vs. Year (February)	0,12	0,01	-0,03	0,78
AverageRain vs. Year (February)	0,11	0,01	-0,03	0,78
TotalRain vs. Year (February)	0,09	0,01	-0,03	22,13
MaxTemp vs. Year (March)	0,19	0,04	0,00	1,33
MinTemp vs. Year (March)	0,01	0,00	-0,04	1,00
AverageRain vs. Year (March)	0,19	0,03	-0,01	1,29
TotalRain vs. Year (March)	0,18	0,03	-0,01	39,31
MaxTemp vs. Year (April)	0,26	0,07	0,03	1,36
MinTemp vs. Year (April)	0,03	0,00	-0,04	0,73

AverageRain vs. Year (April)	0,34	0,11	0,08	0,78
TotalRain vs. Year (April)	0,31	0,10	0,06	23,44
MaxTemp vs. Year (May)	0,16	0,03	-0,01	1,11
MinTemp vs. Year (May)	0,02	0,00	-0,04	0,61
AverageRain vs. Year (May)	0,00	0,00	-0,04	1,25
TotalRain vs. Year (May)	0,03	0,00	-0,04	37,26
MaxTemp vs. Year (June)	0,03	0,00	-0,04	1,58
MinTemp vs. Year (June)	0,01	0,00	-0,04	0,80
AverageRain vs. Year (June)	0,20	0,04	0,00	0,87
TotalRain vs. Year (June)	0,23	0,05	0,01	25,05
MaxTemp vs. Year (July)	0,07	0,01	-0,04	1,20
MinTemp vs. Year (July)	0,05	0,00	-0,04	0,87
AverageRain vs. Year (July)	0,01	0,00	-0,04	0,88
TotalRain vs. Year (July)	0,01	0,00	-0,04	27,38
MaxTemp vs. Year (August)	0,21	0,05	0,01	1,33
MinTemp vs. Year (August)	0,00	0,00	-0,04	1,15
AverageRain vs. Year (August)	0,28	0,08	0,04	1,34
TotalRain vs. Year (August)	0,28	0,08	0,04	41,53
MaxTemp vs. Year (September)	0,16	0,03	-0,02	1,39
MinTemp vs. Year (September)	0,26	0,07	0,03	0,94
AverageRain vs. Year (September)	0,29	0,09	0,05	0,73
TotalRain vs. Year (September)	0,31	0,09	0,06	21,82
MaxTemp vs. Year (October)	0,24	0,06	0,01	2,00

MinTemp vs. Year (October)	0,17	0,03	-0,01	0,85
AverageRain vs. Year (October)	0,01	0,00	-0,04	1,34
TotalRain vs. Year (October)	0,03	0,00	-0,04	41,11
MaxTemp vs. Year (November)	0,22	0,05	0,01	1,92
MinTemp vs. Year (November)	0,15	0,02	-0,02	0,92
AverageRain vs. Year (November)	0,07	0,01	-0,04	1,85
TotalRain vs. Year (November)	0,07	0,01	-0,04	55,37
MaxTemp vs. Year (December)	0,20	0,04	0,00	2,43
MinTemp vs. Year (December)	0,13	0,02	-0,02	1,34
AverageRain vs. Year (December)	0,30	0,09	0,05	0,67
TotalRain vs. Year (December)	0,28	0,08	0,04	20,65

Addendum Q: Table of analyses of variance for the linear regression analyses for variables predicting the maximum temperature, minimum temperature, average rainfall, and total rainfall of the Boontjieskraal station

Analyses of variance for the linear regression analyses for variables predicting the maximum temperature, minimum temperature, average rainfall, and total rainfall of the Boontjieskraal station.

Model	Effect	Sums of Squares	df	Mean	F	p
MaxTemp vs. Month	Regression	4,72	1,00	4,72	0,26	0,61
	Residual	6997,92	378,00	18,51		
	Total	7002,65				
MinTemp vs. Month	Regression	129,10	1,00	129,10	8,90	0,00*
	Residual	5480,09	378,00	14,50		
	Total	5609,18				
AverageRain vs. Month	Regression	1,54	1,00	1,54	1,65	0,20
	Residual	353,58	378,00	0,94		
	Total	355,13				
TotalRain vs. Month	Regression	9074,29	1,00	9074,29	3,15	0,08
	Residual	1089795,69	378,00	2883,06		
	Total	1098869,98				
MaxTemp vs. Year	Regression	0,04	1,00	0,04	0,10	0,76
	Residual	12,49	29,00	0,43		
	Total	12,53				
MinTemp vs. Year	Regression	12,74	1,00	12,74	61,91	0,00*
	Residual	5,97	29,00	0,21		
	Total	18,71				
	Regression	0,13	1,00	0,13	1,87	0,18

AverageRain vs. Year	Residual	2,01	29,00	0,07		
	Total	2,14				
TotalRain vs. Year	Regresion	769,47	1,00	769,47	3,42	0,07
	Residual	6532,08	29,00	225,24		
	Total	7301,55				

Addendum R: Table of analyses of variance for the linear regression analyses for variables predicting the maximum temperature, minimum temperature, average rainfall, and total rainfall of the Agulhas wines station

Analyses of variance for the linear regression analyses for variables predicting the maximum temperature, minimum temperature, average rainfall, and total rainfall of the Agulhas wines station.

Model	Effect	Sums of Squares	df	Mean	F	p
MaxTemp vs. Month	Regression	3,29	1,00	3,28	0,37	0,54
	Residual	1883,27	212,00	8,88		
	Total	1886,55				
MinTemp vs. Month	Regression	0,51	1,00	0,51	0,06	0,80
	Residual	1675,61	212,00	7,90		
	Total	1676,12				
AverageRain vs. Month	Regression	0,75	1,00	0,75	0,49	0,49
	Residual	325,05	212,00	1,53		
	Total	325,80				
TotalRain vs. Month	Regression	772,04	1,00	772,04	0,53	0,47
	Residual	306643,25	212,00	1446,43		
	Total	307415,29				
MaxTemp vs. Year	Regression	0,98	1,00	0,98	7,71	0,01*
	Residual	2,04	16,00	0,13		
	Total	3,02				
MinTemp vs. Year	Regression	0,02	1,00	0,02	0,22	0,64
	Residual	1,46	16,00	0,09		
	Total	1,48				
	Regression	0,07	1,00	0,07	0,67	0,42

AverageRain vs. Year	Residual	1,71	16,00	0,11		
	Total	1,79				
TotalRain vs. Year	Regresion	452,55	1,00	452,55	0,04	0,84
	Residual	163676,43	16,00	10229,78		
	Total	164128,99				

Addendum S: Table of analyses of variance for the linear regression analyses for variables predicting the maximum temperature, minimum temperature, average rainfall, and total rainfall of the Voorstekop station

Analyses of variance for the linear regression analyses for variables predicting the maximum temperature, minimum temperature, average rainfall, and total rainfall of the Voorstekop station.

Model	Effect	Sums of Squares	df	Mean	F	p
MaxTemp vs. Month	Regression	5,45	1,00	5,45	0,38	0,54
	Residual	4421,62	305,00	14,50		
	Total	4427,07				
MinTemp vs. Month	Regression	0,50	1,00	0,50	0,05	0,82
	Residual	2835,66	305,00	9,30		
	Total	2836,16				
AverageRain vs. Month	Regression	0,00	1,00	0,00	0,00	0,97
	Residual	391,22	305,00	1,28		
	Total	391,22				
TotalRain vs. Month	Regression	88,84	1,00	88,84	0,08	0,78
	Residual	360659,14	305,00	1182,49		
	Total	360747,99				
MaxTemp vs. Year	Regression	0,16	1,00	0,16	0,34	0,56
	Residual	10,90	24,00	0,45		
	Total	11,05				
MinTemp vs. Year	Regression	0,22	1,00	0,22	1,06	0,31
	Residual	4,92	24,00	0,20		
	Total	5,14				
	Regression	0,01	1,00	0,01	0,06	0,80

AverageRain vs. Year	Residual	2,85	24,00	0,12		
	Total	2,86				
TotalRain vs. Year	Regresion	127,65	1,00	127,65	0,01	0,92
	Residual	275890,51	24,00	11495,44		
	Total	276018,17				

Addendum T: Analyses of variance for the linear regression analyses for years predicting the maximum temperature, minimum temperature, average rainfall, and total rainfall for each month of the Boontjieskraal station

Analyses of variance for the linear regression analyses for years predicting the maximum temperature, minimum temperature, average rainfall, and total rainfall for each month of the Boontjieskraal station.

Model	Effect	Sums of Squares	df	Mean	F	p
MaxTemp vs. Year (January)	Regression	0,46	1,00	0,46	0,37	0,55
	Residual	37,36	30,00	1,25		
	Total	37,82				
MinTemp vs. Year (January)	Regression	9,06	1,00	9,06	11,12	0,00*
	Residual	24,45	30,00	0,81		
	Total	33,51				
AverageRain vs. Year (January)	Regression	1,05	1,00	1,05	2,41	0,13
	Residual	13,12	30,00	0,44		
	Total	14,18				
TotalRain vs. Year (January)	Regression	1022,06	1,00	1022,06	2,43	0,13
	Residual	12604,82	30,00	420,16		
	Total	13626,88				
MaxTemp vs. Year (February)	Regression	1,28	1,00	1,28	1,54	0,22
	Residual	24,91	30,00	0,83		
	Total	26,19				
MinTemp vs. Year (February)	Regression	2,88	1,00	2,88	3,50	0,07
	Residual	24,74	30,00	0,82		
	Total	27,63				
	Regression	0,16	1,00	0,16	0,87	0,36

AverageRain vs. Year (February)	Residual	5,48	30,00	0,18		
	Total	5,64				
TotalRain vs. Year (February)	Regresion	129,29	1,00	129,29	0,90	0,35
	Residual	4332,72	30,00	144,42		
	Total	4462,01				
MaxTemp vs. Year (March)	Regression	5,31	1,00	5,31	3,55	0,07
	Residual	44,80	30,00	1,49		
	Total	50,11				
MinTemp vs. Year (March)	Regression	3,06	1,00	3,06	2,98	0,09
	Residual	30,74	30,00	1,02		
	Total	33,80				
AverageRain vs. Year (March)	Regression	0,01	1,00	0,01	0,05	0,83
	Residual	8,52	30,00	0,28		
	Total	8,54				
TotalRain vs. Year (March)	Regression	13,15	1,00	13,15	0,05	0,83
	Residual	8160,23	30,00	272,01		
	Total	8173,38				
MaxTemp vs. Year (April)	Regression	0,57	1,00	0,57	0,30	0,59
	Residual	57,75	30,00	1,92		
	Total	58,32				
MinTemp vs. Year (April)	Regression	13,03	1,00	13,03	16,46	0,00*
	Residual	23,74	30,00	0,79		
	Total	36,77				
AverageRain vs. Year (April)	Regression	4,52	1,00	4,52	4,84	0,04*
	Residual	27,98	30,00	0,93		
	Total	32,49				
TotalRain vs. Year (April)	Regression	4059,82	1,00	4059,82	4,83	0,04*
	Residual	25226,22	30,00	840,87		

	Total	29286,04				
MaxTemp vs. Year (May)	Regression	2,39	1,00	2,39	1,28	0,27
	Residual	56,22	30,00	1,87		
	Total	58,61				
MinTemp vs. Year (May)	Regression	32,90	1,00	32,90	27,36	0,00*
	Residual	36,07	30,00	1,20		
	Total	68,98				
AverageRain vs. Year (May)	Regression	8,42	1,00	8,42	11,58	0,00*
	Residual	21,83	30,00	0,73		
	Total	30,26				
TotalRain vs. Year (May)	Regression	8106,80	1,00	8106,80	11,62	0,00*
	Residual	20921,62	30,00	697,39		
	Total	29028,42				
MaxTemp vs. Year (June)	Regression	2,05	1,00	2,05	1,11	0,30
	Residual	55,22	30,00	1,84		
	Total	57,27				
MinTemp vs. Year (June)	Regression	34,80	1,00	34,80	39,56	0,00*
	Residual	26,39	30,00	0,88		
	Total	61,19				
AverageRain vs. Year (June)	Regression	0,18	1,00	0,18	0,22	0,64
	Residual	24,93	30,00	0,83		
	Total	25,12				
TotalRain vs. Year (June)	Regression	221,88	1,00	221,88	0,29	0,59
	Residual	23011,38	30,00	767,05		
	Total	23233,26				
MaxTemp vs. Year (July)	Regression	0,11	1,00	0,11	0,10	0,76
	Residual	33,46	30,00	1,12		
	Total	33,57				

MinTemp vs. Year (July)	Regression	16,40	1,00	16,40	18,66	0,00*
	Residual	26,36	30,00	0,88		
	Total	42,76				
AverageRain vs. Year (July)	Regression	0,01	1,00	0,01	0,01	0,92
	Residual	27,19	30,00	0,91		
	Total	27,20				
TotalRain vs. Year (July)	Regression	12,42	1,00	12,42	0,01	0,91
	Residual	26199,22	30,00	873,31		
	Total	26211,63				
MaxTemp vs. Year (August)	Regression	1,09	1,00	1,09	0,77	0,39
	Residual	42,26	30,00	1,41		
	Total	43,34				
MinTemp vs. Year (August)	Regression	17,95	1,00	17,95	11,94	0,00*
	Residual	45,10	30,00	1,50		
	Total	63,05				
AverageRain vs. Year (August)	Regression	0,79	1,00	0,79	0,81	0,38
	Residual	29,36	30,00	0,98		
	Total	30,15				
TotalRain vs. Year (August)	Regression	759,53	1,00	759,53	0,82	0,37
	Residual	27881,27	30,00	929,38		
	Total	28640,80				
MaxTemp vs. Year (September)	Regression	0,85	1,00	0,85	0,40	0,53
	Residual	62,37	29,00	2,15		
	Total	63,23				
MinTemp vs. Year (September)	Regression	10,56	1,00	10,56	12,08	0,00*
	Residual	25,36	29,00	0,87		
	Total	35,93				
	Regression	0,04	1,00	0,04	0,11	0,74

AverageRain vs. Year (September)	Residual	11,48	29,00	0,40		
	Total	11,52				
TotalRain vs. Year (September)	Regression	38,33	1,00	38,33	0,11	0,75
	Residual	10342,16	29,00	356,63		
	Total	10380,49				
MaxTemp vs. Year (October)	Regression	0,00	1,00	0,00	0,00	1,00
	Residual	69,92	29,00	2,41		
	Total	69,92				
MinTemp vs. Year (October)	Regression	14,34	1,00	14,34	14,24	0,00*
	Residual	29,20	29,00	1,01		
	Total	43,54				
AverageRain vs. Year (October)	Regression	0,20	1,00	0,20	0,22	0,64
	Residual	26,81	29,00	0,92		
	Total	27,01				
TotalRain vs. Year (October)	Regression	196,85	1,00	196,85	0,22	0,64
	Residual	25754,81	29,00	888,10		
	Total	25951,65				
MaxTemp vs. Year (November)	Regression	0,66	1,00	0,66	0,30	0,59
	Residual	63,01	29,00	2,17		
	Total	63,67				
MinTemp vs. Year (November)	Regression	9,07	1,00	9,07	8,40	0,01*
	Residual	31,32	29,00	1,08		
	Total	40,39				
AverageRain vs. Year (November)	Regression	1,67	1,00	1,67	1,39	0,25
	Residual	34,67	29,00	1,20		
	Total	36,33				
	Regression	1509,94	1,00	1509,94	1,40	0,25
	Residual	31255,34	29,00	1077,77		

TotalRain vs. Year (November)	Total	32765,28				
MaxTemp vs. Year (December)	Regression	1,44	1,00	1,44	0,64	0,43
	Residual	65,09	29,00	2,24		
	Total	66,53				
MinTemp vs. Year (December)	Regression	5,75	1,00	5,75	4,80	0,04*
	Residual	34,74	29,00	1,20		
	Total	40,49				
AverageRain vs. Year (December)	Regression	3,46	1,00	3,46	6,07	0,02*
	Residual	16,55	29,00	0,57		
	Total	20,01				
TotalRain vs. Year (December)	Regression	3343,15	1,00	3343,15	6,10	0,02*
	Residual	15904,20	29,00	548,42		
	Total	19247,34				

* indicates significance at $p<0.05$

Addendum U: Analyses of variance for the linear regression analyses for years predicting the maximum temperature, minimum temperature, average rainfall, and total rainfall for each month of the Agulhas wines station

Analyses of variance for the linear regression analyses for years predicting the maximum temperature, minimum temperature, average rainfall, and total rainfall for each month of the Agulhas wines station.

Model	Effect	Sums of Squares	df	Mean	F	p
MaxTemp vs. Year (January)	Regression	0,02	1,00	0,02	0,02	0,90
	Residual	25,14	16,00	1,57		
	Total	25,16				
MinTemp vs. Year (January)	Regression	0,10	1,00	0,10	0,10	0,75
	Residual	15,39	16,00	0,96		
	Total	15,48				
AverageRain vs. Year (January)	Regression	1,09	1,00	1,09	2,89	0,11
	Residual	6,01	16,00	0,38		
	Total	7,10				
TotalRain vs. Year (January)	Regression	1040,84	1,00	1040,84	2,89	0,11
	Residual	5757,87	16,00	359,87		
	Total	6798,71				
MaxTemp vs. Year (February)	Regression	0,73	1,00	0,73	2,10	0,17
	Residual	5,56	16,00	0,35		
	Total	6,29				
MinTemp vs. Year (February)	Regression	0,73	1,00	0,73	1,00	0,33
	Residual	11,64	16,00	0,73		
	Total	12,37				
	Regression	0,39	1,00	0,39	2,12	0,17

AverageRain vs. Year (February)	Residual	2,92	16,00	0,18		
	Total	3,30				
TotalRain vs. Year (February)	Regresion	302,16	1,00	302,16	2,10	0,17
	Residual	2303,98	16,00	144,00		
	Total	2606,14				
MaxTemp vs. Year (March)	Regression	0,20	1,00	0,20	0,26	0,62
	Residual	12,02	16,00	0,75		
	Total	12,21				
MinTemp vs. Year (March)	Regression	0,79	1,00	0,79	0,99	0,33
	Residual	12,78	16,00	0,80		
	Total	13,58				
AverageRain vs. Year (March)	Regression	1,61	1,00	1,61	3,76	0,07
	Residual	6,86	16,00	0,43		
	Total	8,47				
TotalRain vs. Year (March)	Regression	1557,64	1,00	1557,64	3,77	0,07
	Residual	6608,40	16,00	413,02		
	Total	8166,03				
MaxTemp vs. Year (April)	Regression	2,81	1,00	2,81	3,83	0,07
	Residual	11,75	16,00	0,73		
	Total	14,56				
MinTemp vs. Year (April)	Regression	0,00	1,00	0,00	0,02	0,90
	Residual	4,36	16,00	0,27		
	Total	4,36				
AverageRain vs. Year (April)	Regression	9,98	1,00	9,98	5,02	0,04*
	Residual	31,82	16,00	1,99		
	Total	41,79				
TotalRain vs. Year (April)	Regression	8960,47	1,00	8960,47	5,01	0,04*

	Residual	28592,43	16,00	1787,03		
	Total	37552,90				
MaxTemp vs. Year (May)	Regression	4,71	1,00	4,71	5,80	0,03*
	Residual	13,00	16,00	0,81		
	Total	17,71				
MinTemp vs. Year (May)	Regression	0,05	1,00	0,05	0,15	0,70
	Residual	5,66	16,00	0,35		
	Total	5,71				
AverageRain vs. Year (May)	Regression	0,00	1,00	0,00	0,00	0,97
	Residual	33,18	16,00	2,07		
	Total	33,19				
TotalRain vs. Year (May)	Regression	3,96	1,00	3,96	0,00	0,97
	Residual	31885,13	16,00	1992,82		
	Total	31889,08				
MaxTemp vs. Year (June)	Regression	2,78	1,00	2,78	2,25	0,15
	Residual	19,83	16,00	1,24		
	Total	22,61				
MinTemp vs. Year (June)	Regression	0,08	1,00	0,08	0,15	0,71
	Residual	9,06	16,00	0,57		
	Total	9,14				
AverageRain vs. Year (June)	Regression	2,36	1,00	2,36	4,38	0,05
	Residual	8,60	16,00	0,54		
	Total	10,96				
TotalRain vs. Year (June)	Regression	2164,43	1,00	2164,43	4,48	0,05
	Residual	7724,22	16,00	482,76		
	Total	9888,66				
MaxTemp vs. Year (July)	Regression	0,75	1,00	0,75	0,62	0,44
	Residual	19,45	16,00	1,22		

	Total	20,21				
MinTemp vs. Year (July)	Regression	0,00	1,00	0,00	0,01	0,94
	Residual	5,77	16,00	0,36		
	Total	5,77				
AverageRain vs. Year (July)	Regression	0,06	1,00	0,06	0,05	0,83
	Residual	19,39	16,00	1,21		
	Total	19,45				
TotalRain vs. Year (July)	Regression	57,77	1,00	57,77	0,05	0,83
	Residual	18740,82	16,00	1171,30		
	Total	18798,59				
MaxTemp vs. Year (August)	Regression	0,18	1,00	0,18	0,29	0,60
	Residual	9,85	16,00	0,62		
	Total	10,03				
MinTemp vs. Year (August)	Regression	0,32	1,00	0,32	0,40	0,54
	Residual	12,93	16,00	0,81		
	Total	13,25				
AverageRain vs. Year (August)	Regression	2,30	1,00	2,30	0,86	0,37
	Residual	42,52	16,00	2,66		
	Total	44,82				
TotalRain vs. Year (August)	Regression	2197,62	1,00	2197,62	0,86	0,37
	Residual	40912,32	16,00	2557,02		
	Total	43109,94				
MaxTemp vs. Year (September)	Regression	0,52	1,00	0,52	0,81	0,38
	Residual	9,61	15,00	0,64		
	Total	10,13				
MinTemp vs. Year (September)	Regression	0,10	1,00	0,10	0,12	0,73
	Residual	12,05	15,00	0,80		
	Total	12,15				

AverageRain vs. Year (September)	Regression	1,64	1,00	1,64	3,14	0,10
	Residual	7,86	15,00	0,52		
	Total	9,50				
TotalRain vs. Year (September)	Regression	1517,71	1,00	1517,71	3,19	0,09
	Residual	7133,67	15,00	475,58		
	Total	8651,38				
MaxTemp vs. Year (October)	Regression	1,46	1,00	1,46	1,64	0,22
	Residual	13,43	15,00	0,90		
	Total	14,89				
MinTemp vs. Year (October)	Regression	0,04	1,00	0,04	0,07	0,80
	Residual	8,18	15,00	0,55		
	Total	8,21				
AverageRain vs. Year (October)	Regression	2,15	1,00	2,15	1,47	0,24
	Residual	21,97	15,00	1,46		
	Total	24,13				
TotalRain vs. Year (October)	Regression	2072,89	1,00	2072,89	1,48	0,24
	Residual	21061,70	15,00	1404,11		
	Total	23134,59				
MaxTemp vs. Year (November)	Regression	0,48	1,00	0,48	1,02	0,33
	Residual	7,54	16,00	0,47		
	Total	8,02				
MinTemp vs. Year (November)	Regression	0,14	1,00	0,14	0,35	0,57
	Residual	6,67	16,00	0,42		
	Total	6,82				
AverageRain vs. Year (November)	Regression	0,64	1,00	0,64	1,03	0,32
	Residual	9,96	16,00	0,62		
	Total	10,61				
	Regression	583,12	1,00	583,12	1,04	0,32

TotalRain vs. Year (November)	Residual	9010,10	16,00	563,13		
	Total	9593,23				
MaxTemp vs. Year (December)	Regression	2,25	1,00	2,25	2,60	0,13
	Residual	13,89	16,00	0,87		
	Total	16,15				
MinTemp vs. Year (December)	Regression	0,74	1,00	0,74	0,74	0,40
	Residual	16,01	16,00	1,00		
	Total	16,76				
AverageRain vs. Year (December)	Regression	0,13	1,00	0,13	0,69	0,42
	Residual	3,00	16,00	0,19		
	Total	3,13				
TotalRain vs. Year (December)	Regression	125,74	1,00	125,74	0,71	0,41
	Residual	2825,01	16,00	176,56		
	Total	2950,75				

* indicates significance at $p<0.05$

Addendum V: Analyses of variance for the linear regression analyses for years predicting the maximum temperature, minimum temperature, average rainfall, and total rainfall for each month of the Voorstekop station

Analyses of variance for the linear regression analyses for years predicting the maximum temperature, minimum temperature, average rainfall, and total rainfall for each month of the Voorstekop station.

Model	Effect	Sums of Squares	df	Mean	F	p
MaxTemp vs. Year (January)	Regression	4,56	1,00	4,56	1,25	0,28
	Residual	84,15	23,00	3,66		
	Total	88,70				
MinTemp vs. Year (January)	Regression	2,75	1,00	2,75	4,33	0,05(0,048)*
	Residual	14,63	23,00	0,64		
	Total	17,38				
AverageRain vs. Year (January)	Regression	0,89	1,00	0,89	0,66	0,43
	Residual	31,11	23,00	1,35		
	Total	32,00				
TotalRain vs. Year (January)	Regression	1010,21	1,00	1010,21	0,78	0,39
	Residual	29945,77	23,00	1301,99		
	Total	30955,98				
MaxTemp vs. Year (February)	Regression	1,93	1,00	1,93	2,85	0,10
	Residual	16,25	24,00	0,68		
	Total	18,18				
MinTemp vs. Year (February)	Regression	0,20	1,00	0,20	0,33	0,57
	Residual	14,52	24,00	0,61		
	Total	14,72				
	Regression	0,17	1,00	0,17	0,28	0,60

AverageRain vs. Year (February)	Residual	14,73	24,00	0,61		
	Total	14,90				
TotalRain vs. Year (February)	Regresion	97,48	1,00	97,48	0,20	0,66
	Residual	11754,85	24,00	489,79		
	Total	11852,33				
MaxTemp vs. Year (March)	Regression	1,67	1,00	1,67	0,94	0,34
	Residual	42,46	24,00	1,77		
	Total	44,13				
MinTemp vs. Year (March)	Regression	0,00	1,00	0,00	0,00	0,97
	Residual	24,01	24,00	1,00		
	Total	24,01				
AverageRain vs. Year (March)	Regression	1,43	1,00	1,43	0,86	0,36
	Residual	39,67	24,00	1,65		
	Total	41,09				
TotalRain vs. Year (March)	Regression	1272,12	1,00	1272,12	0,82	0,37
	Residual	37081,35	24,00	1545,06		
	Total	38353,46				
MaxTemp vs. Year (April)	Regression	3,15	1,00	3,15	1,69	0,21
	Residual	44,68	24,00	1,86		
	Total	47,83				
MinTemp vs. Year (April)	Regression	0,01	1,00	0,01	0,02	0,88
	Residual	12,94	24,00	0,54		
	Total	12,96				
AverageRain vs. Year (April)	Regression	1,86	1,00	1,86	3,04	0,09
	Residual	14,69	24,00	0,61		
	Total	16,55				
TotalRain vs. Year (April)	Regression	1428,28	1,00	1428,28	2,60	0,12
	Residual	13185,05	24,00	549,38		

	Total	14613,34				
MaxTemp vs. Year (May)	Regression	0,82	1,00	0,82	0,67	0,42
	Residual	29,55	24,00	1,23		
	Total	30,37				
MinTemp vs. Year (May)	Regression	0,00	1,00	0,00	0,01	0,94
	Residual	8,90	24,00	0,37		
	Total	8,91				
AverageRain vs. Year (May)	Regression	0,00	1,00	0,00	0,00	0,99
	Residual	37,28	24,00	1,55		
	Total	37,28				
TotalRain vs. Year (May)	Regression	36,95	1,00	36,95	0,03	0,87
	Residual	33318,04	24,00	1388,25		
	Total	33354,99				
MaxTemp vs. Year (June)	Regression	0,05	1,00	0,05	0,02	0,89
	Residual	59,99	24,00	2,50		
	Total	60,04				
MinTemp vs. Year (June)	Regression	0,00	1,00	0,00	0,00	0,95
	Residual	15,36	24,00	0,64		
	Total	15,36				
AverageRain vs. Year (June)	Regression	0,75	1,00	0,75	0,98	0,33
	Residual	18,21	24,00	0,76		
	Total	18,96				
TotalRain vs. Year (June)	Regression	842,03	1,00	842,03	1,34	0,26
	Residual	15055,42	24,00	627,31		
	Total	15897,45				
MaxTemp vs. Year (July)	Regression	0,19	1,00	0,19	0,13	0,72
	Residual	34,48	24,00	1,44		
	Total	34,67				

MinTemp vs. Year (July)	Regression	0,04	1,00	0,04	0,05	0,82
	Residual	18,15	24,00	0,76		
	Total	18,19				
AverageRain vs. Year (July)	Regression	0,00	1,00	0,00	0,00	0,97
	Residual	18,64	24,00	0,78		
	Total	18,65				
TotalRain vs. Year (July)	Regression	0,47	1,00	0,47	0,00	0,98
	Residual	17986,61	24,00	749,44		
	Total	17987,08				
MaxTemp vs. Year (August)	Regression	2,02	1,00	2,02	1,15	0,29
	Residual	42,22	24,00	1,76		
	Total	44,24				
MinTemp vs. Year (August)	Regression	0,00	1,00	0,00	0,00	0,98
	Residual	31,68	24,00	1,32		
	Total	31,69				
AverageRain vs. Year (August)	Regression	3,74	1,00	3,74	2,09	0,16
	Residual	42,97	24,00	1,79		
	Total	46,71				
TotalRain vs. Year (August)	Regression	3630,65	1,00	3630,65	2,11	0,16
	Residual	41385,18	24,00	1724,38		
	Total	45015,83				
MaxTemp vs. Year (September)	Regression	1,19	1,00	1,19	0,62	0,44
	Residual	44,49	23,00	1,93		
	Total	45,68				
MinTemp vs. Year (September)	Regression	1,53	1,00	1,53	1,73	0,20
	Residual	20,38	23,00	0,89		
	Total	21,91				
	Regression	1,15	1,00	1,15	2,16	0,15

AverageRain vs. Year (September)	Residual	12,26	23,00	0,53		
	Total	13,41				
TotalRain vs. Year (September)	Regression	1144,96	1,00	1144,96	2,41	0,13
	Residual	10947,04	23,00	475,96		
	Total	12092,00				
MaxTemp vs. Year (October)	Regression	5,45	1,00	5,45	1,36	0,26
	Residual	92,29	23,00	4,01		
	Total	97,75				
MinTemp vs. Year (October)	Regression	0,48	1,00	0,48	0,66	0,42
	Residual	16,60	23,00	0,72		
	Total	17,08				
AverageRain vs. Year (October)	Regression	0,01	1,00	0,01	0,00	0,95
	Residual	41,20	23,00	1,79		
	Total	41,21				
TotalRain vs. Year (October)	Regression	29,01	1,00	29,01	0,02	0,90
	Residual	38869,87	23,00	1689,99		
	Total	38898,88				
MaxTemp vs. Year (November)	Regression	4,42	1,00	4,42	1,20	0,28
	Residual	84,45	23,00	3,67		
	Total	88,88				
MinTemp vs. Year (November)	Regression	0,43	1,00	0,43	0,51	0,48
	Residual	19,54	23,00	0,85		
	Total	19,97				
AverageRain vs. Year (November)	Regression	0,41	1,00	0,41	0,12	0,73
	Residual	78,39	23,00	3,41		
	Total	78,80				
	Regression	362,37	1,00	362,37	0,12	0,73
	Residual	70509,07	23,00	3065,61		

TotalRain vs. Year (November)	Total	70871,44				
MaxTemp vs. Year (December)	Regression	5,90	1,00	5,90	0,99	0,33
	Residual	136,36	23,00	5,93		
	Total	142,26				
MinTemp vs. Year (December)	Regression	0,74	1,00	0,74	0,42	0,53
	Residual	41,05	23,00	1,78		
	Total	41,79				
AverageRain vs. Year (December)	Regression	1,01	1,00	1,01	2,24	0,15
	Residual	10,36	23,00	0,45		
	Total	11,36				
TotalRain vs. Year (December)	Regression	803,01	1,00	803,01	1,88	0,18
	Residual	9812,19	23,00	426,62		
	Total	10615,20				

* indicates significance at $p<0.05$

Addendum W: Table of respondents, in Elim and Genadendal that have heard of the term climate change

Table S16. Respondents, in Elim and Genadendal that have heard of the term climate change.

Question	Community	Valid	Frequency (N=9)	Percent	Valid Percent	Cumulative Percent
Have you heard of the term "climate change"?	Elim	Yes	8	88.9	88.9	88.9
		No	1	11.1	11.1	100.0
	Genadendal	Yes	4	100.0	100.0	100.0