Agricultural adaptation to intensifying El Niño and La Niña periods within North West, South Africa

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ABSTRACT

Climate can be defined as the mean and variability of the relevant atmospheric parameters such as temperature, precipitation and wind over a long period of time. These parameters fluctuate over time, creating different seasonal variations. However, through climate change, these fluctuations are affected, creating extreme climate variabilities. These extreme climate conditions can be further exacerbated through the El Niño and La Niña phenomena, creating more extreme climatic conditions. This adverse change in temperature and precipitation have severe implication for the agricultural sector, as the variation in temperature and precipitation can have a severe impact on the ability to successfully produce agricultural products. This in turn has implications on the economic sector, as well as the health of the surrounding environment as farmers are needed to change their practices, which could be done in unsustainable ways. This study aimed to explore the drivers that could intensify the El Niño and La Niña events within the North West Province and the implications thereof on the environment as well as the agricultural sector. The framework of ecosystem-based disaster risk reduction was incorporated into the analysis to better understand the impacts of the farmers on the environment and to gain perspective about their adaptation measures. Through the use of a mixed methodology and a semi-structured questionnaire, information was gathered by 15 participants regarding these perceptions and measures. Though the participation pool was small, saturation of information from the participants was reached and their answers were also in line with literature. The analysis showed that the farmers that participated in the study did have a rudimentary understanding of climate and the changes thereof, as well that basic reactive adaptation were incorporated into their respective farming practices. However, there was a lack of proactive measures being implemented by the participants, both in adaptation measures and future scenario planning regarding extreme, periodic, climatic variabilities. The main recommendations from this study include further studies in North West and the country on strengthening the ability to

reduce climate impacts, specifically El Niño and La Niña phenomena, on agriculture. Further, the incorporation of the framework of Eco-DRR into the adaptation measures, which will have a positive impact on the equilibrium between the agricultural sector and the health of the environment. Lastly, education on these matters would have a beneficial impact on the ability of the farmers to more easily adapt to a changing climate, as well as being more capable of ensuring environmental sustainability through adaptive agricultural techniques. This education could be possibly provided through future workshops or educational programs.

Key Words: Agriculture; Climate Change; El Niño; La Niña; Adaptation; Disaster Risk Reduction; Eco-DRR; North West

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CHAPTER 1

Introduction and Problem Statement

1. Introduction

El Niño and La Niña events, through the aggravation of climate change, could potentially have dire implications not only for the environment, but also the economic and agricultural sectors of the surrounding communities (Barry, 2000; Ghill, 2002; Smit and Skinner, 2002; UNEP, 2010). These implications ring true for South Africa as well, including the North West Province, as the economic and food security is decreasing (Chilonda and Minde, 2007; READ, 2015). This could hold serious consequences for agricultural communities, since they are vulnerable to changes in the availability of natural resources, which in turn are vulnerable to climate change (READ, 2015). To mitigate these risks, agricultural adaptation, defined as the process to undertake sound farming management practices to adapt to a changing climate, is necessary to reduce the effects of climate change on the livelihood of local communities (Department of Agricultural Research, 2013; READ, 2015).

This study aimed to explore the drivers that could intensify the El Niño and La Niña events within the North West Province and the implications thereof on the environment as well as the agricultural sector. This is done to understand the effect that the El Niño and La Niña events have on the agricultural sector, as well as the cumulative impact that a changing climate has on these events. Perceptions of farmers in the North West Province regarding climatic changes and events as well as impacts on the environment was ascertained to understand their worldviews and the current agricultural adaptation measures being used.

The aim of the study is done in such a way so to introduce alternative adaptation strategies that are beneficial for the agricultural sector as well as the environment through incorporating more environmentally focused frameworks, such as ecosystem-based disaster risk reduction (Eco-DRR) into to the adaptation measures. This is imperative to accomplish, to ensure sustainable agricultural development and environmental sustainability in the light of future El Niño and La Niña events.

Chapter 1 provides insight into what the research entails, why it is important to conduct this study, as well as a short discussion of how the research for this study was conducted. Firstly, the problem statement for this study is described, which included aspects food security, agricultural factors, climate change, El Niño and La Niña as well as the socio-economic impacts of agriculture and the need for adaptation. Secondly, the problem statement, a short description is given of what the key questions are for this study, as well as the main objectives that needs to be met in order for this study to be sufficient. Thirdly, the process and methodology used to complete the study is described. This process included the use of literature review as well as the empirical investigation. Finally, the significance of the study as well as limitations thereof is briefly discussed

1.1. Problem Statement

According to the Alexandratos and Bruinsma (2012) and the Food and Agriculture Organisation of the United Nations, (2017), by the year 2050, the population of the wolrd will increase to around 9.7 billion people and over 11 billion people by the end of the century, as show in Figure 1.1. Specifically, the increase of population in South Africa is projected to increase to a population of 72 million by 2050 which equates to 15 million more people than in 2020.

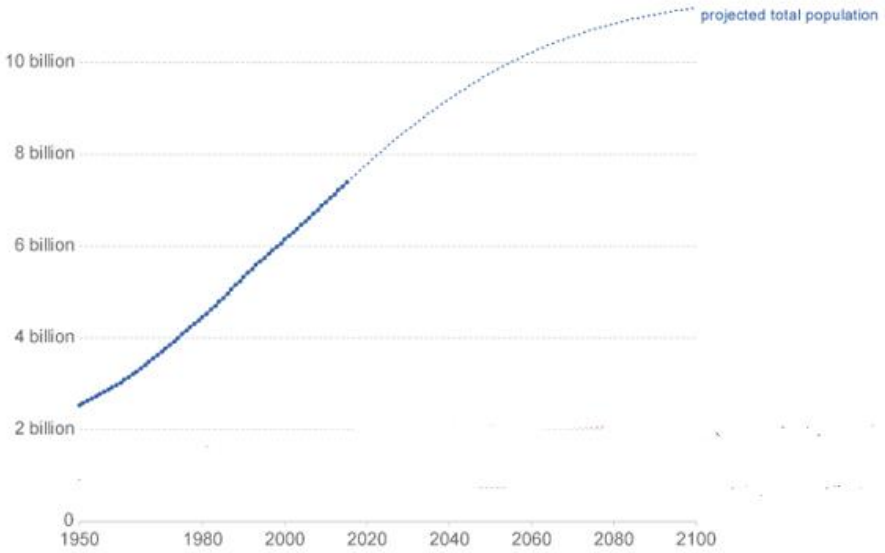

Figure 1.1: The growth of the global population 1950 to 2100 (Rosher, 2019)

1.1.1. Food Security

The 1996 World Food Summit defined food security as “a situation that exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious foods that meets their dietary needs and food preferences for a healthy life.” (Havas, 2011). A larger population could potentially result in a substantial increase in the demand for food, this equates to an increase in the need for food security than which is available in 2020. This could be seen as a significant problem, as the available food resources that were available in 2020, were not enough to sustain the population of the same year. Although there are enough global food resources to feed the population, the distribution of food, the food wastage as well as the access to resources are limited and mismanaged, which results in many people going hungry on a daily basis. Globally, more than 690 million people are affected by hunger and food insecurity. From 2018 to 2019, the number or undernourished people increased by more than 10 million people, whereas from 2014 to 2020, the number of undernourished people grew by nearly 60 million. This equates to around an increase of 10 million people becoming undernourished per year. (Alexandratos and Bruinsma, 2012, FOA, 2019; Rosher, 2019)

1.1.2. Agricultural factors

Pressure of the upward trajectory of population numbers on the food security system could further increase the current challenges that are faced in the agricultural sector as well as increasing pressure on the surrounding natural resources (i.e., the ecosystem). Although the agricultural sector's production capacity has been boosted by the increase in investments as well as advances in the technological aspects thereof, the actual increase in yield size have not increased in proportion with the population growth and will not be able to provide sufficient yields for the projected population growths (FAO, 2017).

Projections towards the year 2050 suggests a lack of natural resources such as water and arable soil to be available for use in the agricultural sector (Alexandratos and Bruinsma, 2012). The rationale behind this statement is due to the unsustainable use, where in some cases the exploitation, of natural resources could lead to the degradation of the environment (Adger *et al.*, 2005). The degradation of the environment is further exacerbated, as the current farming practices are expected to deliver an increase in yield, without a change in the method of farming (Dias, 2015). This strain on the current farming methods could lead to more stringent competition for the natural resources, which will further destabilize the equilibrium of the ecosystem that is being affected by these exploitations (Labuschagne and Sandham, 2018).

Some of the key factors that contribute to this decrease in natural resource availability is the degradation of natural ecosystems and loss of biodiversity, as well as climate change (FOA, 2017). Climate change has the potential to negatively impacts areas and communities that have low food security through affecting the productivity of crop and livestock production, fish stocks and fisheries (Alexandratos and Bruinsma, 2012; FOA, 2017). Due to the decrease in natural resources and the impact of climate change, such as increase in temperature, decrease in precipitation and a change in the seasonal variations, affected communities' resort to intensifying their agricultural

processes, which in turn negatively affects the availability of natural resources and climate change, creating a loop of negative impact on each other (FOA, 2017).

1.1.3. Climate Change

Climate change is described by UNEP as one of the major challenges of our time which adds considerable stress to the environment and subsequently, to societies (UNEP, 2010). Climate change can also be defined as “a long-term shift of the average, micro and macro, weather patterns over a large area” (UNEP, 2010). This shift in weather patterns can include the rapid increase in the normal temperature variations (NOAA, 2008).

According to NOAA (2007) as well as Ahlonsou *et al*., (2000), climate change, as well as the subsequent fluctuation of both precipitation and of maximum and minimum temperatures, cab be described as part of the Earth’s natural climatic variability, which includes the land, ocean and atmosphere, which all interacts with each other (Ghil, 2002; Ahlonsou *et. al,* 2000; NOAA, 2007). Figure 1.2 below indicates data from ice cores describing the natural occurrence of climate change as part of the Earth’s natural climate variability through plotting temperature changes for the past 420 000 years.

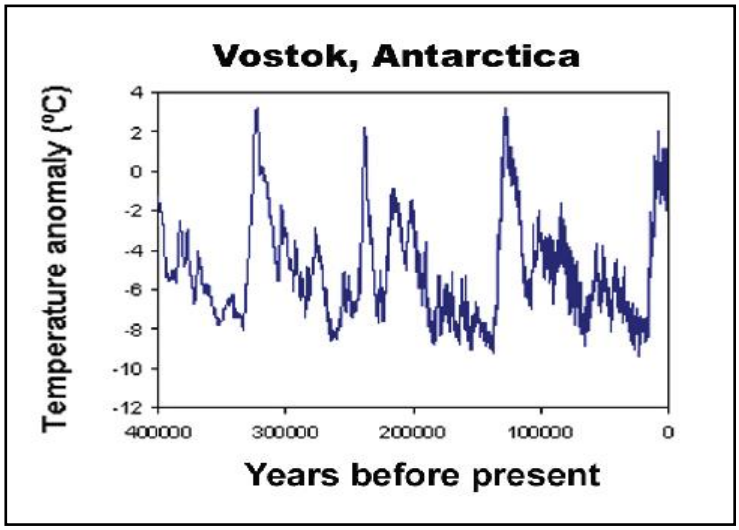

Figure 1.2: Temperature changes in Antarctica determined from the deuterium proxy measured in the Vostok ice core record (NOAA, 2007).

Although climate change can be regarded as a natural atmospheric event, the data accumulated between the 1990s and 2000 have been the warmest period in the entire global instrumental temperature record, which started in the mid-19th century (Ghil, 2002) and is anticipated to continue to increase in intensity. With the abnormal rise in temperature, the natural cycle of climate change has shifted and intensified (UNFCCC, 2007).

This change in the natural climatic cycle will affect the normal climate variability of an area (Ghil, 2002). This change within the natural cycle will disrupt and change the effect of climatic events, such as rainfall and temperature, and can have adverse effects on the entire environment (Barry, 2000; Ghill, 2002; Smit and Skinner, 2002; UNEP, 2010). Studies show that the increase in temperature will continue to increase in intensity and frequency throughout the coming decades and will adversely affect regions such as Africa (Jones and Thornton, 2003; De Wit and Stankiewicz, 2006; Maddison, 2007)

1.1.4. El Niño and La Niña

With the increase in overall temperatures, which can be linked to climate change, the extent of the El Niño and La Niña phenomenon's influence extends. These influences include: droughts, floods, unusual storm activities, heat waves as well as other weather extremes that have serious environmental, social, economic, and health consequences (Lemonick, 2011; WFP, 2016). The global La Niña and the El Niño patterns affect both the precipitation as well as the temperature averages of different areas. This intensifies the current climatic activities of a certain area, for example dry season or wet season (Lemonick, 2011). Both the precipitation as well as the temperature average is affected differently by the El Niño and La Niña activities respectively, but have adverse impacts on the environment.

1.1.5. Socio-Economic impacts

These climatic impacts extend beyond environmental aspects as well as food security, but can have a knock-on impact on national economies by reducing the country's ability to export crops and generate foreign revenue, while food has to be imported. The lengthening of food chains and changes in dietary patterns have further increased the resource-, energy-, and emission-intensity of the global food system (Post, 2002). These trends threaten the sustainability of food systems and undermine the world's capacity to meet its food needs. It is, above all, poorer population groups that will be the most adversely affected by climate change since they suffer most from its impacts, in being mostly directly dependent on the natural environment and ecosystem services for their survival and livelihoods (FAO, 2017) The on-going process of climate change will impact both.

According to the 2014 report of the Intergovernmental Panel on Climate Change (IPCC) as well as Roser (2017) levels of anthropogenic emissions of greenhouse gases (GHGs) are now at their highest Agricultural production and its effect on land use are major sources of these emissions. The impacts of climate change are expected to be most adverse in low- and middle-income countries, where millions of people depend on agriculture and are vulnerable to food insecurity. In 2015 most of the world leaders came together and, with the United Nations Framework Convention on Climate Change (UNFCCC), discussed many world problems at the Paris Agreement, with focus on climate change. It was recognized that "the fundamental priority of safeguarding food security and ending hunger, and the particular vulnerabilities of food production systems to the adverse effects of climate change needs to be a focal point" (UNFCCC, 2015).

1.1.6. Adaptation

To achieve sustainable agricultural activities, climate change adaptation as well as agricultural adaptation must be taken in consideration, because a lack in preparedness and adaptation will lead to a further decline in agricultural production (READ, 2015). Climate change adaptation (CCA) can be described as the adjustment within natural and human systems, through the use of strategies, to the change in the regional climate that can lead to hazard reduction and disaster risk reduction as well as the realisation of benefits associated with climate variability due to climate change (IPCC TAR, 2001; UNDP, 2005; UKCIP, 2003). Whereas agricultural adaptation can be described as the adjustment of local agricultural practices to effectively manage potential climate risks within both crop and livestock sectors (Adger et al, 2003; Batima et al, 2005). Regional coordination, along with CCA and agricultural adaptation is crucial to guarantee sufficient food supply and access for the most vulnerable people (WFP, 2016).

This study, with regards to agricultural adaptation, used ecological disaster risk reduction (Eco-DRR) as a lens through which adaptation was viewed. Eco-DRR is described by the Centre for National Resources and Development (CNRD) and the Ecosystems for Adaptation and Disaster Risk Reduction (PEDRR) (2013) as “the sustainable management, conservation and restoration of ecosystems to reduce disaster risk, with the aim to achieve sustainable and resilient development”. Though incorporating the ideas of Eco-DRR into the framework of this study, the focus included the incorporation of conservation of the natural environment along with agricultural adaptation regarding food security, all whilst including the perspectives of climate change as well as the increasing effects of El Niño and La Niña events.

Therefore, the problem under investigation is the impact of climate change on agricultural activities in the North West Province, with focus on both the intensity and occurrence of future El Niño and La Niña events. Furthermore, the problem under investigation focus on the current perceptions of the impact of climate change on the

subsequent implications for environmental and economic health, as well as what the current agricultural adaptation methods being used by farmers in the North West Province and how it compares to widely accepted and implemented methods found in literature? the aim of the study are to explore what the perceived notions are regarding climate change and the effect it has on the local climate, be it an embracing notion of the impacts of climate change or a notion that climate change does not impact as much, natural resource management as well as the effects of the El Niño and La Niña events within the North West Province, South Africa. This is to determine what the cumulative effects that the change in climate may have on the environment and agricultural activities as well as to understand what adaptation measures are already been taken, as well as what others can be incorporated for the present and future climate. Thus, the aim includes to understand the human aspect of agricultural adaptation towards climate change. The following section will describe the key research questions and objectives needed to complete the study

1.2. Key Research Questions

This study aimed to answer the following research questions:

1. What is the impact of climate change on agricultural activities in the North West Province?
2. What are the effects of climate change on both the intensity and occurrence of future El Niño and La Niña events within the North West Province, from a theoretical standpoint?
3. What are the current perceptions of the impact of climate change on agricultural activities and the subsequent implications for environmental and economic health in the North West Province?
4. What are the current agricultural adaptation methods used by farmers in the North West Province and how does it compare to widely accepted and implemented methods found in literature?

Through answering these above questions, the study will be structured around the research objectives given in the next section.

1.3. Research Objectives

This study aimed to explore the drivers that could intensify the El Niño and La Niña events within the North West Province and the implications thereof on the environment as well as the agricultural sector, all through the lens of Eco-DRR. This was done through accomplishing the following research objectives:

1. Gain a theoretical understanding of the impact of climate change on agricultural activities in the North West Province.
2. Understand the effects of climate change on both the intensity and occurrence of future El Niño and La Niña events within the North West Province, from a theoretical standpoint.
3. Explore current perceptions of the impact of climate change on agricultural activities and the subsequent implications for environmental and economic health in the North West Province.
4. Identify current agricultural adaptation methods used by farmers in the North West Province and compare it to widely accepted and implemented methods found in literature.

The following section describes the central theoretical statement, which is necessary to understand the basis of this study through literature.

1.4. Central Theoretical Statement

Shoemaker *et al.* (2004) states that a central theoretical statement provides supporting literature that will be needed to structure a plausible outcome for the research. El Niño and La Niña events, through the aggravation of climate change, can have serious implications, not only for the climate and the environment, but also for the agricultural

sustainability and livelihoods of the surrounding communities, as stated by Sponber (1999). It is further stated by Sponber (1999), that these climatic events have significant implications on agriculture, forestry, fisheries, transportation, communication, public health as well as other climate related sectors. Southern Africa, including South Africa, is also experiencing the effects of these events, as food and economic security in rural communities is decreasing. This could hold serious consequences for these communities, since they are vulnerable to changes in the availability of natural resources, which in turn are vulnerable to climate change. (WFP, 2016). This is further reinforced by the statement through the ECA (2012) that “a negative impact on agricultural productivity and production from climate change will affect the overall economy at the local level, leading even to macroeconomic vulnerability in some countries that are highly dependent on agriculture”. This is due to the fact that economies in Southern Africa are vulnerable to changes in availability of natural resources, as these communities are highly dependent on natural resources (ECA, 2012). To mitigate these risks from becoming greater, agricultural adaptation is necessary to reduce the risk of climate change (Adger et al, 2003; Batima et al, 2005). To investigate the phenomenon a robust methodology was used.

1.5. Methodology

Research methodology can be defined as a process that solves certain research problems in a particular, systematic fashion and can also be seen as how research will be undertaken (Degu, 2006). Research methodology consists of numerous steps that can be adopted by any study, including the literature review, which forms the theoretical grounding for the empirical study. The following subsections will describe the literature review and the empirical study respectively.

1.5.1. Literature Review

The literature review involves identifying and analysing documents that entails relevant information about the problems at hand and addresses these problems (Rowley and Slack, 2004:31; Boote and Beile, 2005). A literature review can also be defined as a summary of materials that have been published by scholars and researchers, referring to a specific topic and can provide background information for those unfamiliar with the subject (Tetreault, 2014). The reason why a literature review was conducted in this study was to prevent any duplication of studies or work that already had been done, and secondly, the use of a literature review increased the understanding of the problems that were researched (Degu, 2006). An exploratory literature review was used (Schuetzenmeister, 2010). Exploratory literature review focuses on a problem that has not clearly been defined and helps determine the best research design, data collection method and method of analysis through reviewing available literature and finding gaps within the specific field of study for this specific project.

The literature study was used to ascertain information regarding the underlying factors that is needed to be addressed in the study. These factors include the effects and impacts of climate change, the effect that climate change has on El Niño and La Niña events and the implications of climate change on the agricultural activities and on the environment, as well as the impact of the agricultural activities on the environment. The issues identified through the use of the literature study were that there is inadequate support to the producers in the agricultural sector; Rising costs of production inputs as well as barriers to access the market sector; livelihood vulnerability regarding food insecurity; increased hazardous conditions making farming more challenging and unsustainable use of natural resources through agricultural practices and culture.

Databases was used to find literature for the propose of study, which include the effects and impacts of climate change, the effects of El Niño and La Niña events and the implications of climate change on the agricultural activities and on the environment.

These databases included: Academia.edu, NEXUS, EBSCO, ScienceDirect, library books, reports and peer reviewed articles. Additional to the library material, several international documents from organisations such as the FAO, UN, UNDRR (UNISDR) (including the Hyogo Framework of Action, Sendai Framework for Disaster Risk Reduction) were also used. The following describes the empirical investigation, which is fundamental to conduct any research needed to fill in the gaps that are identified through the literature review by means of observation and documentation.

1.5.2. Empirical Investigation

The empirical investigation uses the theoretical foundation that has been built up around climate change, climate change adaptation, Eco-DRR and agricultural adaptation to position the new data obtained within the broader aspects of the study.

1.5.3. Research design

A research design can be regarded as a plan which indicates the systematic flow of the research to be conducted for the study and to show how all the major parts thereof interact (Silverio *et al.*, 2020). Research design also refers to the issues involved in planning and executing a research project (Silverio *et al.*, 2020) and can be grouped into one of three research designs namely: quantitative, qualitative and mixed-method research designs

1.5.4. Mixed Method research

A mixed methodology was used in this study. The mixed methods involve the combining or integration of qualitative and quantitative research and data in a study (De Vos *et al*, 2011). A concurrent procedure was used, which means that quantitative and qualitative data were converged in order to provide a comprehensive analysis of the research problem. The qualitative data that was received from the communities as well as the quantitative data, which included scientific data, were accumulated to

achieve a more comprehensive result. In this design, both forms of data were integrated and an interpretation of this data was made holistically (Creswell, 2003).

1.5.5. Sampling

Sampling is the process whereby a researcher collects a comprehensive sample of the total population/environment in question (Moody, 2002). Due to the fact that this study followed a mixed method design, probability as well as a purposive sampling design were used. Probability sampling refers to any method of sampling that uses a random selection of participants to ensure that the total population of the study area has equal probability of being chosen (De Vos *et. al*, 2011:228).

Probability sampling, such as cluster sampling, was used in this study. This gave a more holistic perspective of the participants as the focus was not to focus on any specific class of people. The purposive sampling method was used to gain more detailed perspectives from farmers or their families, and to increase the transferability of the study. Snowball sampling was also used, as potential participants were discovered when conducting the interviews with participants.

1.5.6. Instrumentation

Both qualitative and quantitative instrumentation were used in this study. An incorporation of semi-structured questions and closed question were used within the survey, so to include the perceptions of the participants as well as to gather analytical, focused data. The target group for the study were farmers in general, ranging from small scale subsistence farmers to large commercial farmers in the North West Province.

1.5.7. Data Collection

Semi-structured surveys were conducted with farmers living in the Province. The surveys that were used for this study was a combination of open-ended questions as well as closed ended, structured questions, as both types of questions provide different types of analytical data for interpretation. The semi-structured questionnaire makes use of a variety of different questions to cover the totality of the research area. These questions are both closed and open-ended question, thus providing a base topic of investigation, but with adequate room for interpretation as well as interaction from the interviewer through the open-ended questions (Silverio *et al.*, 2020). Both in-person interview and electronic interviews where here held where the participant filled in the survey online and submitted the information. Though in-person interviews where the questionnaire was given by the researcher was conducted, online questionnaires reached a wider participation group as well as accommodated those who did not want to have a in-person session.

1.6. Significance of the study

Thematic data analysis was used to discover any themes or patterns that formed within the acquired data (Braun and Clarke, 2006). The use of thematic analysis also revealed the participant's interpretation of the study, in this case of climate change and agricultural adaptation (Braun and Clarke, 2006). This was done after all the information from the interviews were compiled on Google Forms, as this was the program used for the electronic surveys. After the results were compiled, an interpretation of this data was made of the perceptions and ideas of the participants. Furthermore, a comparative assessment was done between the information gathered from the surveys, with the literature available on the subject matter, so to ascertain the level of understanding of the subject matter of the participants and to pin point what is needed to be gained to achieve agricultural adaptation (Creswell *et. al*., 2003). Through ascertaining this level of understanding of adaptation in the agricultural sector

regarding climate change through this study, other research can be aided by this knowledge gained. Furthermore, farmers can be potentially aided if the results of this study are implemented through, for example, workshops or learning programs where information from this study could be incorporated.

1.7. Limitations of the study

The main limitation of the study was the willingness and availability of the farmers to participate in the study. Due to social tension regarding perceived criminal intent on the agricultural sector, numerous potential participants were unwilling to either divulge personal information for fear of misuse, or were unwilling to participate in the study as a whole. Online questionnaires were incorporated into the study to try to give potential participants a feeling of anonymity, thus addressing the limitation as best possible.

1.8. Conclusion

To conclude, Chapter 1 provided the problem statement as well as the process in which the study was conducted. Chapter 1 discussed the importance of food security in a growing population as well as the contributing factors of agriculture and climate change, including El Niño and La Niña. The imperative need to assess the impact of agriculture on the socio-economic as well as the on the environment were discussed and the interlinked impacts of climate, the environment and agriculture was also discussed. Secondly, a short description was given of what the key questions were for this study, as well as the main objectives that needed to be met in order for this study to be sufficient. Thirdly, the process and methodology used to complete the study was described which included the use of literature review as well as the empirical investigation. Finally, the significance of the study as well as limitations thereof was briefly discussed. The following chapter discusses the literature review that was done to gain a theoretical understanding of the research objectives and research questions.

CHAPTER 2

Literature Review

2. Introduction

The previous chapter focused on the problem statement, objectives and the general background of the study. Chapter 2 focused on the literature review for the purpose of establishing a theoretical framework for the study as well as the problem statement. This included a review of the latest developments in research and identifying areas where more research needs to be done regarding agricultural adaptation towards climate change and El Niño and La Niña. Chapter 2 reviews the relevant literature of agricultural adaptation, climate change adaptation and the socio-economic factors affected by a changing climate, as well as the environmental impact of agriculture. Chapter 2 focuses on several aspects, including the importance of agriculture, the dual type agricultural structure of North West, the economic impacts of agriculture, the perspectives on local climate, climate change and El Niño and La Niña, the agricultural impact on the environment as well as the environmental management and adaptation strategies.

2.1. Socio-economic standing of agriculture activities and practitioners

Agriculture is the most comprehensive word used to denote the many ways in which crop plants and domestic animals sustain the global human population by providing food and other products. Agricultural activities include processes such as cultivation, horticulture, arboriculture, and vegeculture, as well as forms of livestock management such as mixed crop-livestock farming, pastoralism, and transhumance Agriculture, both crop and livestock, is mostly affected by environmental factors such as soil

chemistry, temperature as well as water availability. Although there are other natural factors that does impact agriculture, these are seen as the most prominent factors that has an impact on the end result and are subsequently discussed in this chapter. Furthermore, agriculture can be sub-categorised into the different categories regarding the size of the operation, the intensity of the process as well as the subsequent relationship between the agricultural sector, the individual farmer and the social-economic sector of the community. These characterisations of agricultural activities are also applicable for the use of the study as well as the study area, as is discussed in the following section.

2.1.1. Characterisation of agricultural activities

There are primarily two main types of agricultural systems that formed part of this study. These included subsistence farming, communal farming (both of them being small-scale farming methods) and commercial farming (large scale farming), which are discussed in this chapter. Generally speaking, commercial farming can be sub categorised in produce focused production, or wildlife and eco-tourism focused agriculture. The two main components of the agricultural system in North West are a large developed commercial sector as well as a subsistence sector which is mostly located in the rural locations (Labuschagne and Sandham, 2018). Small holder farming, including substance and communal farmers, is the biggest type of agricultural system within the province as it constitutes 70% of the farming population of the North West. This means that biggest percentage of the farming population is also the percentage of farmers with smaller land size and lower production capacity than many commercial farmers. The province, with regards to farming activities, can be divided into three sectors, namely:

- The eastern, wetter parts of the province, where the agricultural activities are mostly crop farming as well as livestock rearing.

- The southern and central regions of the province, where wheat and maize farming are the predominant activities, and
- The semi-arid western parts of the province, which is dominated by livestock and wildlife farming activities (READ, 2015).

The most predominant differences between these farming systems are the amount of product made as well as the total income derived from the products made. The rationale for farming consists fundamentally out of two aspects, which are the monitory income derived from selling produce and goods, as well as using produce grown and acquired from the agricultural activities for own use (Roser, 2017). Further differences between the types of farming include but are not limited to: types of agricultural activities being done; irrigation methods used; point of sale for monitory income; employment of labour; farm size, as well as the relationship of the farming activity to other businesses (Jacobs and Baiphethi, 2009)

2.1.2. Small-scale farming

Small-scale farming generally involves herding livestock and growing crops, which is usually, at least in part, grown for own consumption an individual, family or community, with farming being a staple part of their income and livelihood (Jacobs and Baiphethi, 2009). Machinery is seldom used for small-scale farming and usually involves, by large, manual labor (Kirsten and Van Zyl, 1998). Small-scale farmers use numerous types of crops, which are mostly dependent on the geographical location and the soil type and irrigated by hand (Bruntrup and Heidhues, 2002). Woman also make up the majority of these farmers in North West, as the men are either not active in the families, or they work away from the home in order to send money to the family, usually in urbanized areas (Kirsten and Van Zyl, 1998; (Ali *et al.*, 2020) small-scale farming includes subsistence farming as well as communal farming

Subsistence farming refers to the production of produce, either livestock or crops, for the family's livelihood through mostly own consumption, whereas only a small percentage of small-scale farmers would sell their produce (Bourblanc and Anseeuw, 2019)). This, however, has changed in the last few years as more subsistence farmers have begun to sell produce for a larger income (Baiphethi and Jacobs, 2009;). This is also applicable when referring to communal farming, which can be described as following the same type of farming method, with the biggest difference being the sharing of land with other households (Baiphethi and Jacobs, 2009). Some of the key factors in preventing the shift to commercial agriculture have been a lack of skill and industry knowledge and a lack of properly demarcated land and/or formal tenure (Bourblanc and Anseeuw, 2019) Many small-scale farmers, of which the majority is located in communal areas, struggle to become commercially viable and their location does not allow for effective market access (Khapayi and Celliers, 2016)). Access to finance is very difficult for small-scale farmers to expand, which makes it difficult for small-scale farmers to become key players in providing good towards potential business partners (Ugochukwu Nwafor and van der Westhuizen, 2020)

There are typically three common points of sale for small-scale farmers, including informal markets, small local markets and supermarket chain stores, whereas the latter is less often used (Shemfe, 2019). The business relationship that exists between the chain stores and the small-scale farmers are important, as chain stores tend to attract more clients. As a result of the growth of South African supermarkets and their movement into smaller rural towns, the potential for business between these two are growing (Network, 2013).

Alongside this development, rural poor households, which include smallholder farmers, are increasingly net consumers rather than net producers of foods and they tend to purchase their food from the expanding network of supermarkets in nearby rural towns and cities (Shemfe, 2019). These expanding trends in the sources of local food purchases in communal villages have been observed in Limpopo, Eastern Cape

and KwaZulu-Natal in the post-1994 era (Louw *et al*., 2007), but these trends haven't been studied in North West.

Supermarkets have the ability to reduce their prices so that it can be lower than the local, informal vendors. This is because larger supermarkets buy their produce at larger quantities, thus reducing the overall cost of procurement, which in return still makes it profitable for them to have lower prices (Torero, 2011). The informal local vendors have often been forced out of business due to the fact that these vendors are not able to compete with the larger markets on prices (Bourblanc and Anseeuw, 2019). Though the lower prices are positive for the local consumer, the knock-on consequences that this has on the local farmers are far more negative in the long term (Network, 2013).

Local supermarkets do often, in contrast with the above statement, rely on the local farmers to supply their stores with fresh produce (Torero, 2011). These exchanges usually happen with verbal negotiations regarding the price when farmers deliver the products to the store, following the inspection of a sample of the produce (Ortmann and King, 2006).

South African studies have shown that the number of individuals as well as the households that tend to be active in subsistence farming as their main source of livelihood is declining (Baiphethi and Jacobs, 2009; Daniels et. al., 2013) This could be due to a mismanagement of natural resources, which makes farming less profitable and self-sustainable (Baiphethi and Jacobs, 2009) The complexity arises from the diversity of climate, soils and the range of suitable crops.

In addition, the access to resources needed to successfully participate in agricultural activities is another limiting factor for these individuals to ensure the livelihood of themselves and their communities (Baiphethi and Jacobs, 2009; Daniels et. al., 2013). Poor health services and education further limit productivity of agriculture and access to other livelihood options (Network, 2013). The lack of education with regards to how

soil chemistry and fertilizing affects the productivity of the soil as well as more effective irrigation techniques are some of the biggest restrictions of effective intense agriculture is the limited knowledge (Network, 2013). These are in contrast to the characteristics regarding large-scale farming, as large-scale farmers usually have effective education and knowledge as well superior machinery for their agricultural activities. Both commercial and wildlife farming is discussed in the following sections.

2.1.3. Large-scale farming

Commercial agriculture can be seen as the most influential type of agriculture regarding the contributions to the GDP, which equates to 12 % of SA's GDP (Menong *et al.*, 2013), as well as towards employment which equates to around 30 % of the national employment (Tregurtha, Vink and Kirsten, 2010).

Commercial farming can usually be described as being more intensive in farming than subsistence farming (Bernstein, 2013). Intensive agriculture involves various types of agriculture with higher levels of input and output per unit of agricultural land area. Although there is a larger input of aspects such as capital and labour, there is generally a higher yield from commercial farming that results in a larger output as well (Menong *et al.*, 2013).

This contrasts with more traditional subsistence agriculture, in which the inputs per unit land are lower (Menong *et al.*, 2013) Modern commercial farmers adapted industrial methods of agriculture, which can be referred to as industrial agriculture (Bernstein, 2013; Olayide *et al.*, 2016) This means the use of methods and techniques which are designed to optimize percentage yield per land unit and increase profit (Tregurtha and Vink, 2008).

This means that the commercial farmers provide a larger stimulus for economic growth (Tregurtha and Vink, 2008). These techniques include planting multiple crops per year, improving cultivars, increased use of fertilizers, GM seeds, pesticides, the use of large

machinery, as well as analysis of the weather, logistics and economic impacts (Nouna *et al.*, 2016; Olayide *et al.*, 2016; Wang *et al.*, 2019). Most subsistence farming focuses more on own use or limited market use, whereas commercial farming almost exclusively sells to supermarkets, factories, or exports their goods (van der Merwe *et al.*, 2016)

The tourism trade in south Africa can be seen as one of the most influential drivers regarding wealth creation and economic growth (Taylor *et al.*, 2020) This is supported by the fact that internationally tourism is acknowledged as one of the world's fastest-growing industries (Van der Merwe and Saayman, 2003). Within the continent of Africa, South Africa attracts the most overseas tourists (Ebedes, 2002), which makes tourism one of the largest industries in South Africa (Broughton, 2016). Privately owned game farms equate to almost 80% of all nature conservation that is currently being driven in South Africa (Van der Merwe and Saayman, 2003).

The increase in game farming can result in a reduction in arable land for crop of cattle farming (Taylor *et al.*, 2020). Due to the increase in tourism as well as the increase in revenue brought in by game farming, makes farming with wildlife a lucrative business (Brink et al., 2011; Berem, 2015). Although 82 million hectares of South Africa's land mass can be described as arable, taking in account that South Africa's total land mass is 122 million hectares, only 22% of the total arable land can be described as high-potential arable (Taylor *et al.*, 2020). This increased change from production farming to game farming can be seen as an increasing hazard to food security (Van der Merwe and Saayman, 2003). Although there are characteristic differences between small-scale and large-scale farming, both of them do contribute to the economy, in various degrees. The following section describes the economic impact that the agricultural sector has on the surrounding community.

2.2. Economic considerations related to agricultural practices

The North West Province can be described as one of the key pillar contributors to what is called the South African “food basket”. This is because that almost 44 % of the total landmass within the North West borders can be described as arable land (Bothma, 2002; Ahtiainen *et al.*, 2015).

The Agricultural sector is not only a contributor to food security, but also helps with poverty alleviation (Ahtiainen *et al.*, 2015). The number employed by this sector has however changed dramatically in the last few years. The number of employment increased dramatically from 686 000 to 897 000 jobs between 2014 and 2015 due to the National Development plan introduced in2012, but has steadily declined to 849 000 jobs in 2018, declining further in a steady trajectory (Galal, 2020) This is due to various reasons, including an increased in the use of mechanised processes the decline in profitability due to economic constraints as well as the increased migration of able workers from the rural areas to urban areas (Aliber and Mdoda, 2015).

Though the government has identified employment creation as one of its key priorities, with key sectors such as agriculture expected to play a central role in realizing equitable and inclusive growth as stated in the National Development plan (NDP), it is very doubtful that the agricultural sector will create 1 000 000 jobs before 2030, of which 643 000 to be permanent positions (NDP, 2017).

Figure 2.1 depicts the hypothetical Gross Value added (GVA) contribution of agriculture from 2010 to 2030. This growth could potentially expand from 2.3 % in 2010 to 4.1 % in 2030, with a growth rate of R 3.39 million to R 17.31 million in 2030 (using 2010 Rand values).

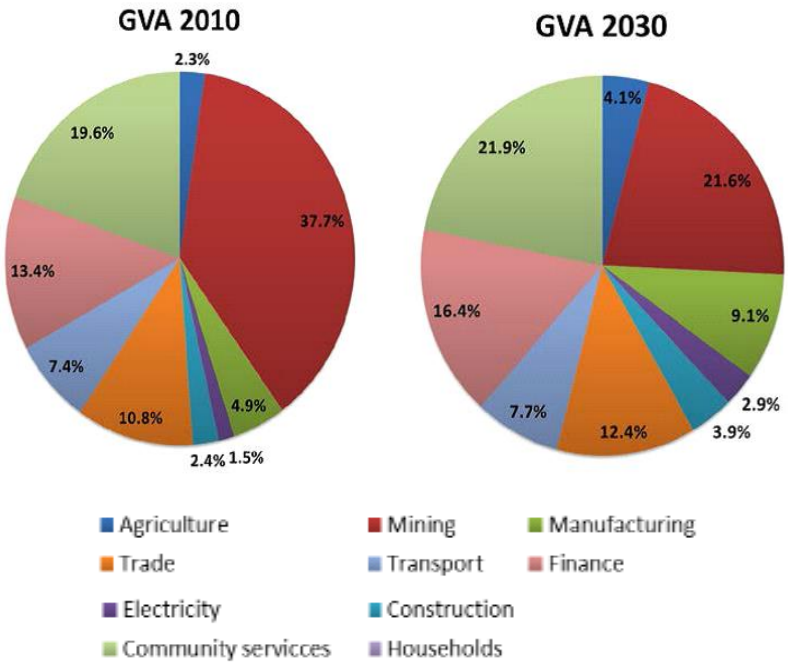

Figure 2.1: Sectoral contribution within North West between 2010 and 2030 (North-West Provincial Development Plan, 2013)

Although the future GVA is positive, the current decline of the profit margin with regards to agriculture as well as prolonged water scarcities, especially due to the drought of 2015/2016, have reduced the number of agricultural households with 20% (Agricultural statistics, 2018). North West had an even larger decrease in the number of agricultural households from 214 049 households in 2011, to 167 780 households in 2016 (Agricultural Statistics, 2018). This rapid decrease in active agricultural households have an impact of the amount of abandoned farming areas. In numerous instances these abandoned farming areas have been allocated to be used for other land use types or a lot of farms in close proximity with each other have been consolidated into a communal farming system so to achieve a higher economic rate of profit for the farmers (Agricultural Statistics, 2018). An important share of public financial resources has been devoted to land reform and agricultural support programs for disadvantaged farming communities. (Chamberlain and Anseeuw, 2018)

Programmes were introduced in 2005 to support the development of market-oriented family farms emerging from the land reform process, mainly through investment grants and provision of microcredit and retail financial services in rural areas (Bourblanc and Anseeuw, 2019). The Land Reform Programme has doubtless reduced social tensions in certain areas and has redressed previous wrongs, but progress has been slow and projects have shown a 90% failure rate, reducing agricultural output in certain areas (Bourblanc and Anseeuw, 2019). The remaining functional farms have generally increased their irrigation, fuel, fertilizer, mechanization and genetically modified seed inputs (Woodhouse, 2010). In many cases, advisory services provided by fertilizer companies and agribusinesses.

Farming practices that are mismanaged or are not done in a sustainable manner, do have a negative impact on the surrounding environment; (Woodhouse, 2010; Chamberlain and Anseeuw, 2018). This can further have a knock-on effect on the people's wellbeing as well as the farmers ability to implement changes into their farming practices (Woodhouse, 2010). The modern dependence on the over use of chemicals in the farming practices, such as fertiliser, herbicide and pesticide produce negative impact on the health of the surrounding environment. These negative impacts include a decrease in soil fertility, water pollution, pollutes aquatic ecologies and exposes the farmers and farm workers to toxins (Chamberlain and Anseeuw, 2018; Dhadli and Brar, 2016).

As a result of the above mentioned, the long-term productivity of a piece of land declines and these areas become more vulnerable to the impact that climate change on the environment. Intensified agriculture often also means increased mechanization, which in turn means fewer jobs on farms. (Abdulhamid, 2018; Woodhouse, 2010). Labor costs have also increased substantially, which although it alleviates some economic constraints, has forced farm owners to reduce the amount of labor worker on their payroll. These factors affect the country's social wellbeing (Agricultural statistics, 2018).

In contrast, government led initiatives to increase irrigated farmland has enabled farmers to successfully grow high value export crops such as deciduous fruit, grapes and citrus (German *et al.*, 2020). The net result has been a decrease in the area under production for staple low value crops such as wheat and maize, and a dramatic increase in the export of high value crops as in terms of value, to the country's agricultural exports. Approximately 90% of South Africa's fruit is exported to the international market, with the remaining proportion being consumed locally and processed (NAMC, 2017). The change from primarily plating crops to incorporating livestock or entirely switching from crops to livestock can also be seen as partly an economic drive, as the profit margin from livestock is larger due to the increase in demand and subsequent price for livestock products.

In 2008, South Africa's shift from low value basic food crops to high value export crops made the country a net importer of food in terms of volume (Bourblanc and Anseeuw, 2019). While this may be regarded as a positive in terms of generating foreign exchange and profits for local farmers, there is also a negative aspect to this with regards to national food security regarding local production. Generally, these high value export crops are produced by commercial farmers (German *et al.*, 2020).

Although the agricultural sector is significantly affected by socio-economic aspects, due to agriculture essentially being a business (Chamberlain and Anseeuw, 2018; Bourblanc and Anseeuw, 2019), agriculture is further affected by natural factors. These include the current climate that the farmer is experiencing, the change in climate, as well as the impact intensifying El Niño and La Niña periods have in relation to a changing climate. These natural factors are discussed in the following section.

2.3. Perspectives on the local climate and climate change

Climate can be defined as the mean and variability of relevant atmospheric parameters such as temperature, precipitation and wind over a long period of time, whereas weather only refers to the current atmospheric parameters of a specific area (IPCC, 2007; Ashraf and Michalopoulos, 2015). To document the climate of a specific spatial location, a record of the particular region must be kept and contain an analysis of the mean conditions, stretching over several seasonal cycles, and including the potential atmospheric extremes such as severe frost, drought, flooding and storms (Walsh *et al.*, 2020). The World Meteorological Organization (WMO), defines a period of 30 years of climatic information as a suitable timeframe to understand the mean parameters of climate for a specific area and to define the specific climate thereof (Walsh *et al.*, 2020). This timeframe is advantages in the sense that it only requires a reasonable amount of recordable data while still providing a good sample of the different types of weather that can occur in a particular area (IPCC, 2007) Furthermore, climate can be defined as a system which includes five primary components. These components are the atmosphere, the hydrosphere, the cryosphere as well as the biosphere (IPCC, 2007).

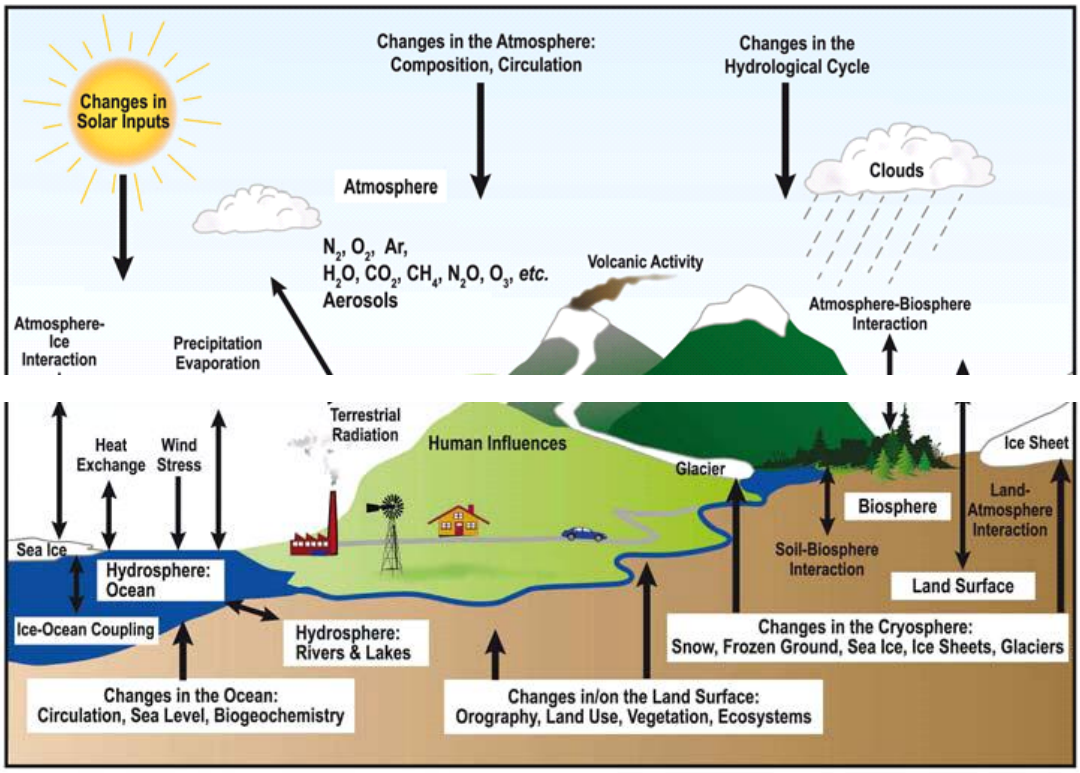

Figure 2.2: Schematic view of the components of the climate system and of their potential changes (IPCC, 2007)

Figure 2.2 depicts the carbon cycle and the different natural and anthropogenic sources of carbon, with focus on CO2.This is important to understand, not only for agricultural purposes, but also regarding climate and the variable periods thereof.

The agricultural sector of South Africa is particularly vulnerable to climate variability through climate change such as the period shift and quality of the rainy season, by temperature, climate variability, extreme weather events and CO_2 concentrations in the atmosphere (Weber *et al.*, 2018).

Given that the agricultural sector is one of the more important contributors to both food security as well as economic growth, the impact that the change in climate could potentially have on the agricultural sector is imperative to understand adverse effect the agricultural sectors. This is because agricultural activities are affected by climate variability, with the two main factors being temperature and water availability. The following are climate related factors that have implications to agriculture.

2.3.1. Climatic description of the geographical study area

Although there are many atmospheric and climatic factors that impact the agricultural sector, the two main aspects that impact agriculture are temperature and water availability. These two factors are briefly discussed in the following sub-sections.

2.3.1.1. Temperature

Temperature is one of the main factors that can affect several processes in the agricultural sector (Mba *et al.*, 2018). It is one of the parameters regarding climate that can be regarded as a certainty to increase with further climate change. Predictions regarding the intermediate future of the annual temperature will be an increase in around 1.5 -2.5 °C along the coast to 3.0 -3.5 °C in the far interior (Weber *et al.*, 2018). Long term predictions for around the end of the current century are between 3.0 -5.0 °C increase along the coast and up to 6.0 °C increase in the interior (Weber *et al.*, 2018) The following table depicts the temperature variations for different crops.

Table 2.1: Minimum, mean and maximum temperature that a crop can function under

Crops	***Minimum Temp***	***Optimal Temp***	***Maximum Temp***
Rice	10	32	36-38
Wheat	4.5	20	.30-32
Maize	8-10	20	40-43
Sorghum	12-13	25	40
Tabaco	12-14	29	35

As table 2.1 indicates, the average optimal temperature for crop growth is between 20 °C and 32 °C, with maximum temperature thresholds beings between 30 °C to 43 °C. This means that if the general atmospheric temperature rises with as much as 6.0 °C (Weber *et al.*, 2018), many of the current crops would not survive in that scenario, or would have to be planted in a less warm area.

2.3.1.2. Rainfall

In agriculture, limitations in the amount of water available for both crops and livestock can be detrimental to the success of the farming activities (Olayide and Alabi, 2018; Weber *et al.*, 2018) Thus, regarding any agricultural production, rainfall, as a basic driving force, is of fundamental importance to both the economic aspects of agriculture as well as for sustainable food security (Horak *et al.*, 2020).

South Africa is regarded as a semi-arid country with almost twenty percent of the population receives less than 200 mm per annum, forty seven percent receives around 400 mm and only nine percent of South Africa's population receives more than 800 mm per annum (Goldblatt, 2010; StatSA, 2018). This is further reiterated by Goldblatt (2010) as close to 85% of the land is dry and depend on natural rainfall. Given the aforementioned, there is strong evidence that shows that water availability is a major challenge. The annual variability of rainfall shows standard deviations to be intensifying into the intermediate future, especially in the east (citation needed). The increase in variable fluctuations regarding the amount of rainfall further increases the threat of food insecurity, as it will have an impact on the agricultural production as well as the water management practices. (Horak *et al.*, 2020)

2.3.2. Perceptions on climate change and its impact on agriculture

The United Nations Framework Convention on Climate Change (UNFCCC) defines climate change as "the change in climate that can be affected through human activities, directly or indirectly, and alters the atmosphere which in addition to natural climate variability is observed over time" (UNEP, 2010).

Climate change can further be defined as a shift in the long-term average weather conditions (UNEP, 2010). This shift in weather patterns can include the rapid increase in the normal temperature variations (UNEP, 2010). Temperature is not the only climate parameter that is affected through the change in climate, as precipitation as

well as cloud formation are parameters that become affected through climate change. Both temperature and rainfall can have a respective or uniformed effect on a geographical location (NOAA, 2008).

Although the change in climate can be regarded as a natural, periodically recurring, atmospheric event, the data accumulated between the 1990s and 2000 can be described as being the warmest period globally since the introduction of instrumental temperature record, which started in the mid-19th century (Ghil *et al.*, 2002) and is anticipated to continue to increase in intensity. With the abnormal rise in temperature, the natural cycle of climate change has shifted and intensified (Alexandratos and Bruinsma, 2012).

This change in the natural climatic cycle will affect the normal climate variability of an area (Ghil et al., 2002; Jury, 2013). This change within the natural cycle will disrupt and change the effect of climatic events, such as rainfall and temperature, and can have adverse effects on the entire environment (Ghil, et al., 2002; UNEP, 2010; Mirza and Nishat, 2019). Temperatures will most likely further intensity throughout the coming decades and will adversely affect regions such as Africa (Few *et al.*, 2004)

Africa is a continent that is already feeling the brunt, socio-economically as well as socio-environmentally, of climate change (Few, et al., 2004; IPCC, 2014). This is because most of the different climatic conditions in Africa are variable of nature with some areas receiving droughts and floods within a short period of time, some as close as a few months apart (Jury, 2013). Due to climate change, the climate of Africa is predicted to become even more variable of nature, with extreme weather events, such as droughts, increasing in intensity and severity (Few *et al*., 2004; Jury, 2013). Southern Africa is at risk to experience economic and ecological setbacks due to climate change (IPCC, 2014; NOAA, 2008).

According to the Rural, Environment and Agricultural Development Department (READ) of the North West Provincial Government (READ, 2015), the Province is at high risk to any sudden changes in the climate. Any changes in the climate can affect the normal vegetation as well as the total biodiversity of the area. This in turn can affect numerous human activities such as forestry, water management, agriculture and healthcare to name a few (READ, 2015). Climate change can also have an adverse effect on climatic events, such as El Niño and La Niña (Few *et al.*, 2004), which in turn can have an accumulative negative effect on the above-mentioned sectors.

The Rockefeller University defines a Community Risk Profile (CRP) as “a resource to inspect the environmental status of the affected area as well as the general health of the people residing within said area”. Climate change has the ability to adversely impact the risk profile of a community through affecting the surrounding environment (UNICEF, 2011). The change in climate can affect a hazard that is already present in the community, resulting in the possibility that the coping capacity of the community could be exceeded if left unmanaged.

According to UNICEF (2011) the effects of climate change does not only impact a single sector, but it impacts multiple sectors of a community. These sectors include both the social sector of the community, including aspects such as healthcare, water management and food security, as well as the environmental and ecological aspect of the surrounding environment, destabilizing the equilibrium of the specific biodiversity within a certain biome.

Climatic impacts such as flooding and droughts, that will impact communities differently depending on their geographical whereabouts, as well as the biodiversity and ecosystem stability, can further become a higher risk of disaster through changing climatic processes such as El Niño and La Niña.

2.3.3. El Niño and La Niña

El Niño has been described by Tsonis and Swanson (2008) and McPhaden (2018) as “a periodic warming of the tropical Pacific”. This phenomenon, which occurs roughly every three to seven years and can lasts up to about 12 to 18 months, is linked to the Southern Oscillation phenomenon, or ENSO. The Southern Oscillation is, as described by McPhaden (2018) “a climatic phenomenon where an interchanging of surface to atmospheric pressure occurs”. This interchanging between the surface and the atmosphere pressures occurs mainly between the Australian-East Asian region and the Eastern tropical Pacific (2014; Lin and Qian, 2019).

Within this atmospheric region of the warmer waters of the Western Pacific, cumulus clouds are followed by high rates of precipitation. When the warmer water travel in an eastward direction, as during an El Niño period, higher rates of precipitation and an increase in temperature can be recorded (Liao, 2019; Lin and Qian, 2019). The increase in temperature is due to the condensation of water vapours, which releases heat energy into both the middle and upper troposphere (see Figure 2.3 below).

With the increase in overall temperatures, which can be linked to climate change, the extent of the El Niño’s influence extends. These influences include: droughts, floods, unusual storm activities, heat waves as well as other weather extremes that have serious environmental, social, economic, and health consequences (Lemonick, 2011; Liao, 2019). El Niño conditions have caused the lowest recorded rainfall between October 2015 and January 2016 across many regions of Southern Africa in at least 35-years (Lemonick, 2011; Liao, 2019).

The La Niña follows the same global climatic patterns as the El Niño, but with opposite tendencies and implications for atmospheric activities (McPhaden, 2018; NOAA, 2007; Tsonis and Swanson, 2008). This is due to the occurrence of stronger trade winds, with which the La Niña period is characterized, as well as a decrease in the Pacific sea surface temperature variability. This period is further characterized by the

occurrence of higher than usual surface to atmospheric pressures in the Eastern Pacific Ocean with lower-than-normal surface pressures within the Western tropical Pacific (McPhaden, 2018). Although the La Niña period is also associated with ENSO, the global climatic effects of the La Niña are opposite to that of the El Niño phenomenon and with a much lower intensity than the El Niño (NOAA, 2007; Tsonis and Swanson, 2008).

The global La Niña and the El Niño patterns affect both the precipitation as well as the temperature averages of different areas (McPhaden, 2018). This intensifies the current climatic activities of a certain area, for example dry season or wet season (Lemonick, 2011; Jury, 2013). Both the precipitation as well as the temperature average is affected differently by the El Niño and La Niña activities respectively.

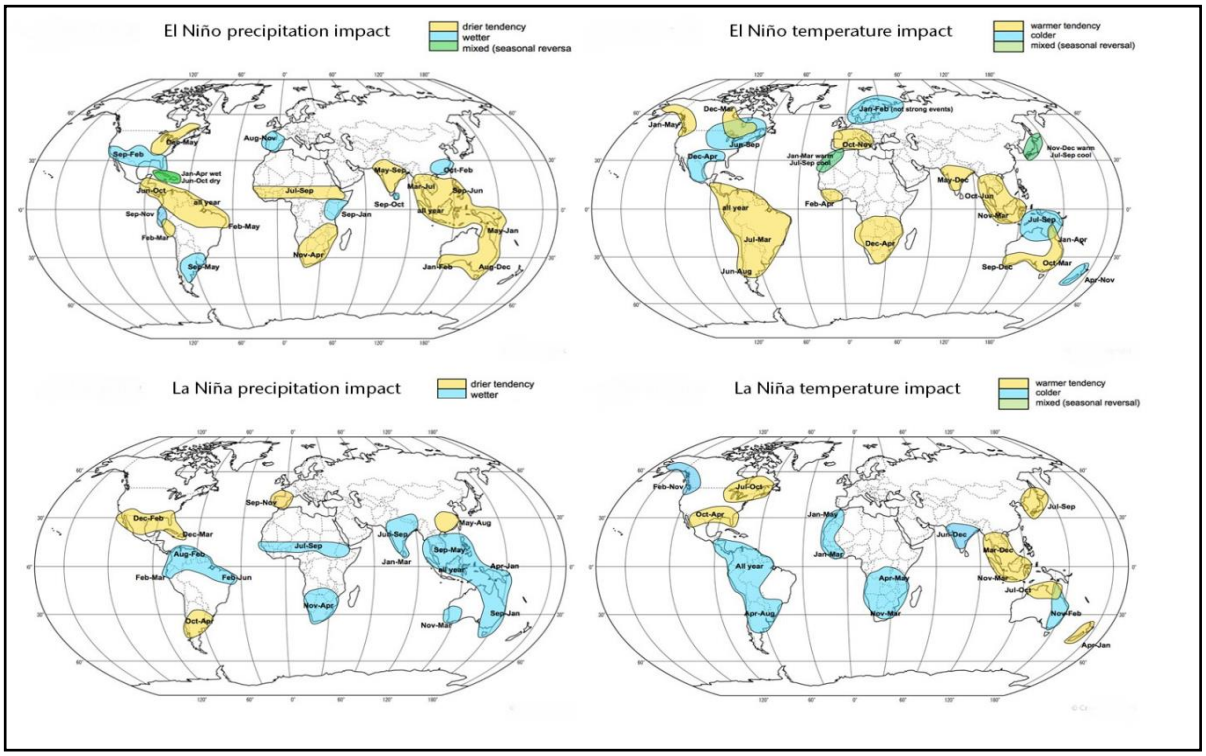

Figure 2.3: Global scope affected by El Niño (top) and La Niña (bottom) regarding precipitation and temperature (Adapted from Met Office, 2016).

As shown by figure 2.3 the increase of climate change as well as the further, subsequent, aggravation of extreme climatic events, such as El Niño and La Niña, will have an adverse effect on the precipitation and temperature on a global scale. This in turn will affect the intensity of droughts, which will exasperate the intensity of drought and floods in regions already stricken by these disasters, such as Southern Africa. Figure 2.4 indicate the change in temporal scales as well as the intensities of the El Niño and La Niña Events.

According to the graph, these phenomena are divided into five consecutive overlapping periods, each stretching over a three-month period which exceeds the normal sea surface temperature barriers. These periods are defined by either above or equal to a +0.5^{o}C anomaly for warm events, i.e., El Nino, and equal to or below the -0.5 ^{o}C anomaly for cold events, i.e., La Nina. These periods are then allocated to more comprehensive categories such as weak, moderate, strong and very strong with their respective parameters between 0.5 – 0.9 (weak), 1.0 – 1.4 (moderate), 1.5 – 1.9 (strong) and anything equal or larger than 2 to be categorized as very strong. According to the graph, the intensity of the El Niño and La Niña events have increased with time, which concurs with the increase in greenhouse gasses, but the temporal distance of each climatic event has also increased and has become more erratic in pattern.

These periodic changes in temperature and precipitation for both El Niño and La Niña will have a knock-on effect on the impact that climate change has on the study area, further exacerbating the change in weather patterns and general climate conditions. These periodic changes, along with the already present effects of climate change, will have an impact on the environmental, both the ecological aspects as well as the sociological aspects, including agriculture. The following section describes the environmental implications which agriculture as on the surrounding environment where it is practiced.

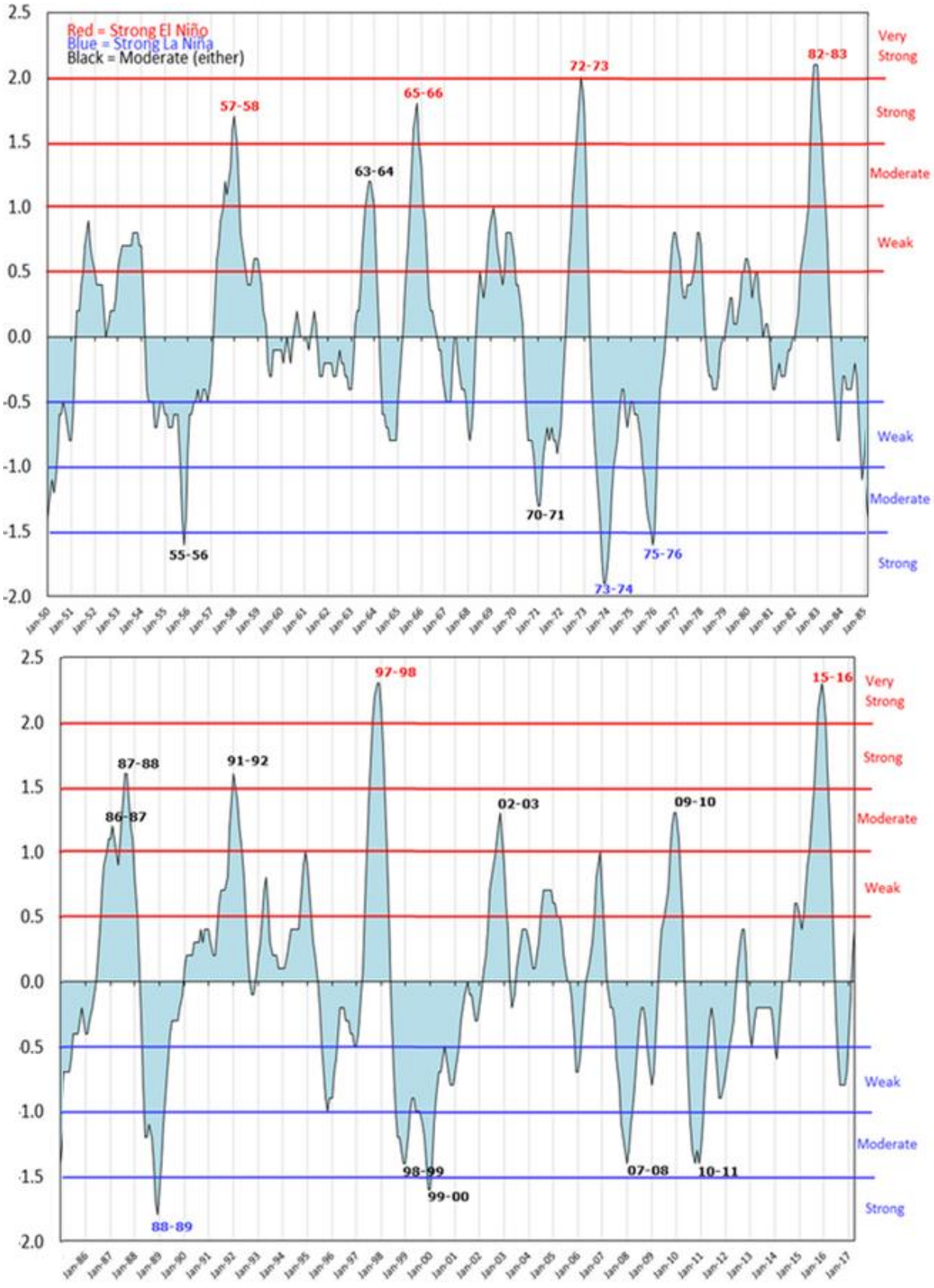

Figure 2.4: Graphical Illustration of the past El Niño and La Niña periods from 1960 to 2017 (GoldenGate, 2017).

2.4. Agricultural impacts on the environment

The National Environmental Management Act 107 of 1998 (NEMA), defines the environment as the following:

1. The surroundings within which humans exist and that are made up of the land, water and atmosphere, as well as micro-organisms, plant and animal life.
2. Furthermore, it is defined as any part or combination of the biotic and abiotic components and the interrelationship among and between them
3. As well as the physical, chemical, aesthetical and cultural properties and conditions of the foregoing that influence human health and well-being. (NEMA, 1998)

Environmental management distinguishes between the “green perspectives as well as the “brown” perspectives of the environment (Kotze, 2016). The green perspectives refer to abiotic (e.g. land; water; soil and atmosphere) as well as the biotic (e.g. humans; animals; plants as well as micro-organisms), thus the green perspectives of environmental management focus on the scientific aspects of the environment (Kotze, 2016). The brown perspectives refer to the social aspects of the environment, such as the community’s ability to change, opportunities, services, as well as the availability of resources. Furthermore, it focusses on the economic aspects as well any constrictions such as education, poverty and availability of opportunity (Kotze, 2016).

In recent decades, biodiversity loss and ecosystem degradation are processes that happen on a global scale, which can potentially undermine numerous environmental systems and the management thereof (UKCIP, 2004, UNFCC, 2007). If climatic conditions or very specific, habitat conditions change beyond the tolerance of the specific species inhabiting the ecosystem, significant losses of biodiversity could result (UKCIP, 2004).

The conservation of ecosystems is not only important for the wellbeing of biodiversity, but also to ensure the essential environmental services for the agricultural sector (UNFCC) as farmers are reliant on a healthy environment to provide them with the needed natural resources (Turpie *et al.,* 2008). The services include the increased availability of clean water, increased soil fertility, grazing for livestock, pollinators for orchards, decreased soil runoff, and protection against natural hazards. These ecosystem services were valued at an estimated R73,000 million per annum in 2008, with a staggering increase to R47 billion in 2017 for South Africa (Turpie et al., 2008; Turpie et al, 2017). Ecosystem degradation through human activities has endangered 40% of terrestrial ecosystems, 57 % of river ecosystems, 65 % of wetland ecosystems and 58% of coastal ecosystems (Nel *et al.*, 2011)

Human activities cause habitat loss and fragmentation, resulting in the loss of species and ultimately in the decline of ecosystem functions (Nel *et al.*, 2011). Poor farm management further reduces species diversity and ecosystem functioning (Nel *et al.*, 2011). The use of pesticides, for example, can have a devastating effect on biodiversity. Many pest predators are also susceptible to pesticides and develop resistance far more slowly than do pests. Thus, spraying for one pest can result in outbreaks of other pests as natural predator populations are devastated. This is called a secondary pest outbreak (Rani *et al.*, 2020). Farmers are being pressured, through needing to produce a higher yield, to use more fertiliser and pesticides (Rother et al., 2008). Many of these chemical products have a negative impact on the community's and environment's health.

Another major threat to ecosystems stemming from human adaptation is changes in the distribution of lands suitable for agriculture. Agricultural development is a well-known driver of habitat loss (Gibbs *et al.*, 2010), and change in productivity due to climate change will prompt agricultural expansion in some areas accompanied by contraction in others. For example, rising temperatures are projected to increase crop suitability at higher latitudes (Labuschagne and Sandham, 2018). The rise in food

demand has also prompted farmers to expand their lands by clearing the natural environment around them to increase their area of yield. This, along with desertification, furthers the loss on natural habitats. Furthermore, the expansion of agricultural land has a knock-on effect on certain variables (i.e., water management, soil degradation and pollution) that affect the environment, which then has a knock-on effect on the actual productivity of the agricultural activities. These examples of factors are discussed in the following sub-sections.

2.4.1. Water management

The main causes regarding agriculture of poor water management are the use of crops that is not suitable for the specific area's precipitation, irrigation systems that are not maintained correctly, as well as farming techniques that isn't considered to be water wise, for example pivot irrigation. Water management is further worsened through a limited awareness of improved activities that could help better the water use. By using water in a way that is not sustainable, it has a trickledown effect on the availability of ground water for agriculture, as well as the surrounding plant life and the freshwater ecosystems in the proximity.

2.4.2. Soil degradation

Soil degradation and erosion refers to the loss of topsoil due to runoff, which is exasperated through the removal of natural plant life. Crop fields of, for example maize, wheat and sorghum, also increases soil degradation (Laflen *et al.*, 2020). Cultivated fields have a lower density than natural plant life, resulting in lower plant base coverage which increases runoff (Laflen *et al.*, 2020). Soil which is transported because of erosion can lead to sedimentation of damns or nearby rivers, which could potentially damage freshwater habitats, as well as the local communities that depend on these habitats.

2.4.3. Pollution

Around 14% of greenhouse emissions globally can be contributed towards agricultural activities (IPCC, 2014). These include activities such as the use of chemical fertilizer, using manure as a natural fertilizer, the management of manure regarding livestock rearing, disposal of agricultural residues through burning as well as mechanical activities such as the use of fossil fuel driven machinery (IPCC, 2014). Furthermore, the increased demand for food security in an ever-growing population will only exacerbate the current greenhouse gas emissions.

For most croplands, but especially with regards to dry croplands, the most important greenhouse gasses are Nitrogen oxide (N_2O) and Carbon dioxide (CO_2) (Six et al., 2004). Management practices are important factors that affect these gas emissions. The CO_2 concentrations within the soil are affected mainly through carbon inputs as well as mechanical actions such as tillage. This affects the soil carbon turnover rate by unearthing the topsoil and thus exposing the organic matter within the topsoil to the surface.

Another factor affecting climate change is Greenhouse gas emissions (GHG). The agriculture sectors contribute substantially to greenhouse gas emissions, representing 23% of GHG globally between 2007 and 2016. Over the past 50 years, greenhouse gas (GHG) emissions, especially the release of CO2, resulting from agriculture, forestry and other land use (AFOLU) have nearly doubled, rising from 2.7 gigatons (Gt) CO2 in 1961 to 5.2 gigatons in 2010. As figure 2.5 states, the average increase of CO2 from 1990 to 2010 is 10.5% and projections suggest a further increase by 2050 (Tubiello et al., 2014).

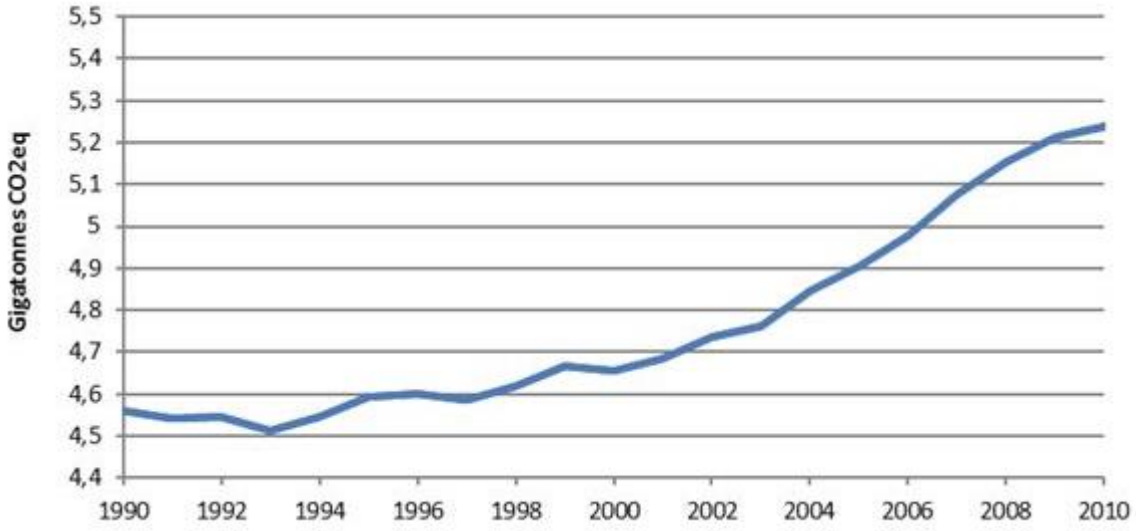

Figure 2.5: Global Agriculture Emissions Trends: 1990-2010 (Faostat, 2015)

This increase in CO2 has an effect on the mean temperature of an area, increasing the temperature which in turn affects other biological factors such as crop growth and crop yield. Although higher temperatures can improve crop growth, studies have documented that crop yields decline significantly when daytime temperatures exceed a certain crop-specific level (FAO, 2017). The 2018 IPCC report has stated that climate change will increase the interannual variability of crop yields in many regions. The report further emphasizes on the necessity of keeping the global temperature from exceeding an increase of 1.5 degrees Celsius, as this is regarded as the cut of line for many ecosystems and crops to continue in equilibrium.

2.5. Environmental management, Disaster Risk Reduction and Eco-DRR

The United Nations Development Program (2004) defines natural hazards as “natural processes or phenomena occurring in the biosphere that may constitute a damaging event”. Therefore, any natural event, which has the ability or potential to impact human lives or activities in a negative way, but has not yet done so, is a natural hazard. A disaster can therefore be described as the impact of a natural hazard, when the

affected community can no longer cope with the impact of said hazard as their coping capacity is less than the combined impact of the hazard and their existential vulnerability.

Vulnerability is defined by Turner Ii *et al.*, 2003 as “the degree to which a system is likely to suffer harm due to exposure to a hazard”. Vulnerability of a system is however, as described by Turner Ii *et al.*, 2003 “not only dependent on the degree of hazard it is exposed to, but also on the system’s capacity to cope with extreme events”. A low capacity to adapt to and cope with natural hazards will therefore lead to a system being more vulnerable and increase the disaster risk of the community.

Disaster risk can be defined as the potential losses of human life or economic damage due to high vulnerability and low coping capacity regarding a present hazard.

The United Nations International Strategy for Disaster Reduction states that in its most simplified form, disaster risk is simply the product of combining hazards with vulnerability and coping capacity. It is easily represented by the notation:

$$Disaster\ risk\ (R) = \frac{Hazard\ x\ Vulnerability\ (V)}{Coping\ capacity\ (C)}$$

Figure 2.6 is a depiction of the interwoven aspects that define the risk of a community regarding its livelihood and coping capacity, the present hazard and the degree of vulnerability for said hazard, as well as pressures that could lead to a change in coping capacity and vulnerability respectively.

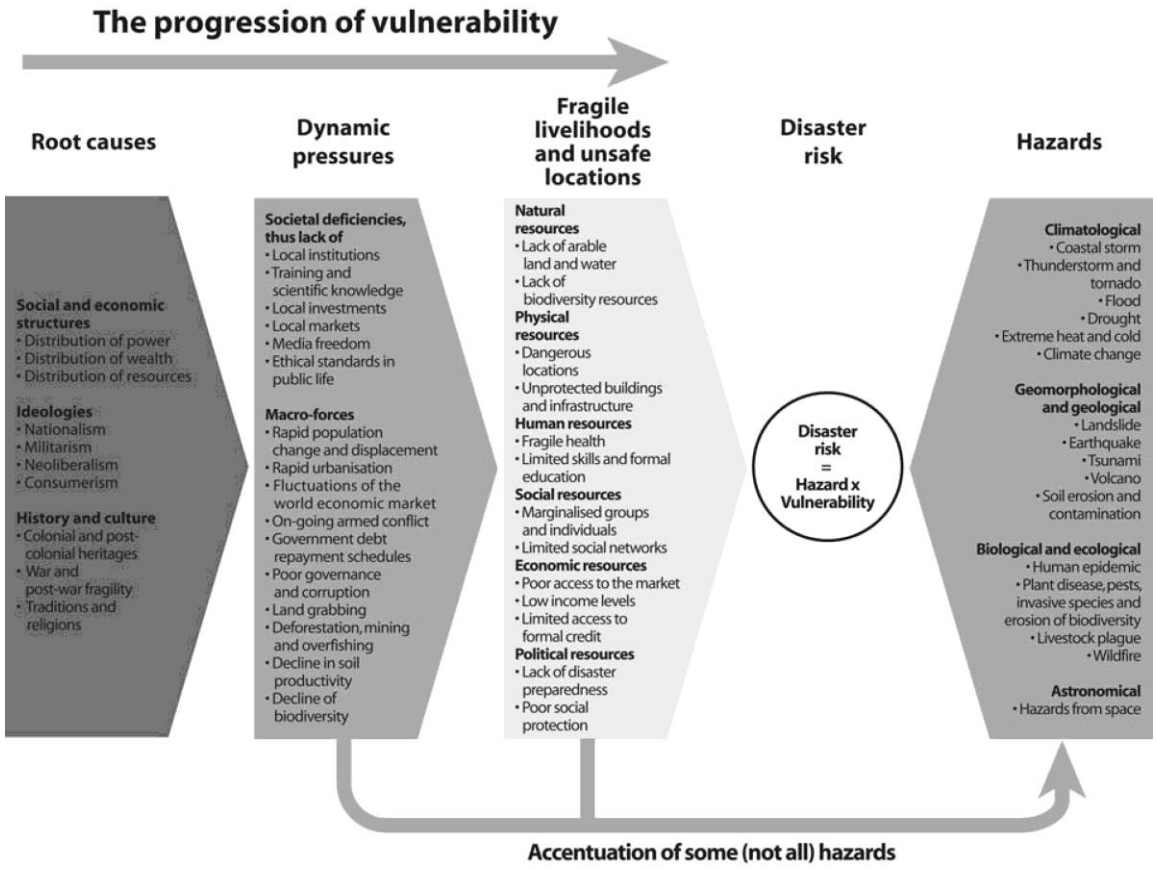

Figure 2.6: Graphical description of the Pressure model defining the progression of vulnerability (Tapsell *et al.*, 2010)

Although natural hazards cannot be prevented, adaptation measures can be incorporated in such a way to reduce their vulnerability as well as increase the resilience of a community to be able to prevent any future hazards from becoming a disaster.

The UNDRR defines resilience as “the ability of a system, community or society exposed to hazards to resist, absorb, accommodate to and recover from effects of a hazard in a timely and efficient manner” whereas the IPCC describes it as “The amount of change a system can undergo without changing state”. According to the UNDP, the above two definitions may be more responsive in nature than preventative, as they describe resilience as “transformative processes of strengthening the capacity of people, communities and countries to anticipate, manage, recover and transform from shocks”.

2.5.1. Resilience thinking

Resilience thinking can be defined as an approach that can be used to understand the dynamics within the socio-ecological system and the drivers behind this system so to ensure sustainable development. The resilience perspective focuses on non-linear dynamics which are in play within the natural world (Folke, 2006). The resilience perspective emerged from ecology in the 1960s and early 1970s through studies of interacting populations such as the predator and prey paradigm as well as their functional places within the ecological stability theory (McNaughton, 1977).

The single equilibrium view, a view that focuses on the present equilibrium of a linear system (Folke, 2006), that dominated main stream ecology led to the interpretation of resilience as return time after disturbance, referred to as engineering resilience (McNaughton, 1977). Engineering resilience is a framework that focuses on the ability of a system to return to equilibrium after a disturbance as well as the speed of which it takes to return to equilibrium. The resistance to change is often addressed in terms of recovery, which is the time it takes to return to the previous state following disturbance (Halford et al., 2004).

The framework perspective and its relation to the concept of resilience can be seen as in contrast with equilibrium cantered strategies, which focuses on the variability of a system and the ability to control it as close as possible to equilibrium (i.e., cattle grazing). These equilibrium focused strategies tend to solve resource problems in the short term, like declining yields, but success in controlling one variable, that often fluctuates, leads to changes in variables that operate at other temporal and spatial scales, like nutrients or food web dynamics (McNaughton, 1977).

This is because complex systems, such as ecosystems, cannot be seen as only being deterministic, predictable and mechanistic in nature, but as process dependent, organic systems that are self-organising and self-regulating to an extent, by embodying the fundamentals of resilience (McNaughton, 1977).

2.5.2. Resilience concept

Resilience does not only refer to the ability to be steadfast in the presence of external factor that can disturb the current balance, but also to anticipate the reactions that the external disturbance will have on the system, to recover from the effects of the disturbance and to adapt and develop as to ensure that the same type of disturbance will not have the same effect in the future (Smit and Wandel, 2006). In this sense, resilience provides adaptive capacity (Smit and Wandel, 2006) that allow for continuous development. It does not simply mean that resilience is always in a positive trajectory, as it can be a slow process to transform an already resilient system from its current state into a new state as the external factors change with time (Smit and Wandel, 2006).

Furthermore, the dynamics of the system after a disturbance are critically dependent on whether the system has the self-organizing capacity to continue without external help (Norberg and Cumming, 2006). In order for the system to be able to increase its capacity threshold, it should consider its external and internal parameters to increase its resilience (Smit and Wandel, 2006

A human society may show great ability to cope with change and adapt if the focus of that study is only done through a social perspective. These adaptations may be at the expense of changes in the capacity of ecosystems to sustain the adaptation (Smit and Wandel, 2006). This in turn can form a breakpoint in the holistic resilience of a social–ecological system (Gunderson and Holling, 2002).

Similarly, focusing on the ecological side only as a basis for decision making for sustainability leads to too narrow and wrong conclusions (Smit and Wandel, 2006). This is also true when focusing on the environmental aspects that agriculture has had on the environment, as focus needs to be on the balance between agricultural development to adapt and the sustainability of the environment. The following section

describes Disaster risk reduction, a framework that can be used to implement change in both environmental sustainability and the agricultural sector.

2.5.3. Disaster Risk Reduction

Disaster Risk Reduction, or DRR, can be defined as a conceptual framework of elements considered with the possibilities to minimize vulnerabilities and disaster risks throughout a society, to prevent or to mitigate the adverse impacts of hazards, within the broad context of sustainable development" Disaster risk reduction can also be defined as a systematic approach to reducing exposure to hazards, lessening vulnerability and increasing the coping capacity of a system and building resilience (van Niekerk, 2011)

DRR can be useful to build resilience, mitigate hazards to lower the potential of hazards becoming disasters and can be seen as an important factor for sustainable development (citation needed). These factors all influence the disaster risk profile of a certain area as well as the community residing in or near it. Another framework that is closely related, but focusses more on the balance between the environment and the community, is Ecosystem based disaster risk reduction, or Eco-DRR, as is discussed in the following section.

2.5.4. Ecosystem-based disaster risk reduction (Eco-DRR)

Eco-DRR, is defined by Estrella and Saalismaa (2013) as "the sustainable management, conservation and restoration of ecosystems to reduce disaster risk, with the aim to achieve sustainable and resilient development". The IPCC Special Report on the Extreme Events made a recommendation that focus should be given towards sustainable land management and ecosystem restoration when conceptualising and implementing DRR plans (IPCC 2012). This is necessary to ensure that any natural resources from the ecosystem as well as the environment itself do not become degraded in any way during response or reconstruction.

In general, CCA and DRR management processes are currently being governed by different policy tracks, which means different stakeholders and institutions are implementing measures separately. The Cancun Adaptation Framework was adopted in 2010, and is aimed at enhancing action on adaptation, through international cooperation, to reduce vulnerability and build resilience in developing countries (UNFCCC, 2016). This framework indicates the need to build resilience of socio-economic and ecological systems, including through economic diversification and sustainable management of natural resources. The Framework furthermore "recognizes the need to strengthen international cooperation and expertise in order to understand and reduce loss and damage associated with the adverse effects of climate change, including impacts related to extreme weather events and slow onset events. Such events include "sea level rise, increasing temperatures, ocean acidification, glacial retreat and related impacts, salinization, land and forest degradation, loss of biodiversity and desertification" (UNFCCC, 2010).

The Hyogo Framework for Action (2005-2015) and also the Sendai Framework for Disaster Risk Reduction (2015-2030) constitutes the global agreements on disaster risk reduction. However, the Sendai Framework integrates a number of references to the need for environment management and the protection of biodiversity as good disaster risk reduction strategies. In particular article 28 (b) states that at a global and regional level stakeholder need to "Foster collaboration across global and regional mechanisms and institutions for the implementation and coherence of instruments and tools relevant to disaster risk reduction, such as for climate change, biodiversity, sustainable development, poverty eradication, environment, agriculture, health, food and nutrition and other". Section 28 (d) explicitly refers to the promotion of transboundary cooperation to enable policy and planning for the implementation of ecosystem-based approaches.

This means that Eco-DRR focuses on reducing the disaster risk of a situation, but shifting more focus on the environmental aspects to ensure social sustainability through environmental management practices. The way in which Eco-DRR reduces risk is through a more indirect method. Rather than only focusing on the task at hand in a responsive manner, Eco-DRR incorporates multi-disciplinary measures that focus not only on the present problem, but also on the future ripple effects that the present solution could make. This includes an incorporation of Climate Change Adaptation, Agricultural Adaptation, Conservation and water management. The implementation of Eco-DRR in the development and resilience building focusses on increasing the resilience of the community and or reducing the risks from hazards by implementing environmental management practices and optimizing ecosystem services (UNEP 2015).

The focal point is on the human-environment interface, meaning that sometimes a balance between environmental sustainability and social development and resilience must be achieved. (IPCC 2012). This means that a trade-off between the environmental, social and economic parameters of a specific situation must be weighed regarding the best course of action to be taken whilst still being economically and technically feasible (ISO 14001:2004).

As stated in the ISO 14001 model (ISO 14001:2004), which coincides with the fundamentals of Eco-DRR that the aspects, or the external factors, be addressed, rather than only focusing on the impacts themselves. This makes for a more futuristic approach, rather than only studying the past impacts. Through proactively defining the current and future situation, formulation of corrective actions for the present as well as mitigation actions for the future scenario can be made, which will increase the resilience of the individual as well as the community. The processes and potential plans that can be used to incorporate adaptation in the agricultural sector is described in the following section

2.5.5. Adaptive measures in the agricultural sector

Adapting to climate change entails taking the right measures to reduce the negative effects of climate change by making the appropriate adjustments and changes. The Intergovernmental Panel on Climate Change (2007) defines adaptation as adjustments in natural or human systems in response to actual or expected climatic stimuli or effects, which moderates harm or exploits beneficial opportunities. It also refers to actions that people, countries, and societies take to adjust to climate change that has occurred. Adaptation has three possible objectives: to reduce exposure to the risk of damage; to develop the capacity to cope with unavoidable damages; and to take advantage of new opportunities. The following table discusses measures or strategies that can be adopted by farmers in adapt to a changing climate.

Table 2.2 describes different strategies that can be incorporated to enhance the capacity for adaptation of the farming practices. These strategies can be described as including the framework processes of Eco-DRR. This refers to bringing a balance between the positive effects it could have on the agricultural sector, as well as limiting negative impacts of agriculture and possibly improving the sustainability of the surrounding environment. Although there are other strategies that can be incorporated, the strategies described in table 2.2 can be used by both small-scale and large-scale farmers in different scales respectively. These strategies do not solely require capital inputs to be successfully incorporated, but also requires innovation, education as well as the ability and capacity to adapt current practices so to ensure successful implementation. The above strategies help to restore the balance between agriculture and the environment, whilst ensuring social adaptation to a changing climate.

Table 2.2: Adaptation strategies for agriculture (adapted from Akinnagbe, 2014)

Adaptation strategies	***Description***	***References***
Planting of drought tolerantvarieties of crops	More resistant crops could help reduce the vulnerability to climate change.	Langill and Ndathi, 1998 Ngigi, 2009
Crop diversification	Crop diversification can be used in irrigated and non-irrigated farming activities and reduces vulnerability to crop loss	Adger *et al.*, 2003 Orindi and Eriksen 2005 Ziervogel *et al.*,2008
Change in cropping pattern and calendar of planting	Actively changing and updating the planting schedule regarding the future climatic activities through use of weather projections	Urama and Ozor 2011
Mixed cropping	Actively growing two or more types of crops in the same proximity or field.	Mendelsohn *et al.*, 2000
Improved irrigation efficiency	Improving efficacy of water use through incorporating new technology or best practices	Nkomo *et al.*, 2005 Osman *et al.*, 2005 Selvarajuet *et al.*, 2006
Adopting soil conservation measures	Activities that positively impact the soil health include for example burying of crop residues to replenish soil fertility and burning crop residues to enhance quick release of nutrients and	Nyong *et al.*, 2007 Lema and Majule, 2009
Agroforestry	The process of land reclamation through the planting of seedlings and samplings.	Adesina *et al.*, 1999 Nyong *et al.*, 2007 Oluwaseun, 2019

Table 2.2 (Continued): Adaptation strategies for agriculture (Akinnagbe, 2014)

Adaptation strategies	***Description***	***References***
Water resource management	improved management of water resources through the introduction of simple techniques for localized irrigation (e.g., drip and sprinkler irrigation), accompanied by infrastructure to harvest and store rainwater	Batima, 2006 Nouna, 2016
No Till farming	Actively not disturbing the soil as to reduce the amount of CO2 being released	Sarauskis, 2020 de Araujo, 2019 Campanha, 2019
Mixed livestock farming	Incorporating both livestock and crop farming to increase carbon sequestration	Oba, 1997
Breeding strategies	identifying and strengthening local breeds that have adapted to local climatic stress and feed sources and improving local genetics through cross-breeding with tolerant breeds	Hoffmann, 2008
Incorporation of agri-ecological technologies	training in agri-ecological technologies and practices for the production and conservation	El Bilali, 2018
Capacity building for livestock keepers	Improving the capacity of producers to understand and deal with climate change and increase awareness of global changes	Herzon, 2007

2.6. Conclusion

For agricultural adaptation to be successful in the long term, both the environmental aspects as well as the socio-economic aspects need to be in balance to ensure sustainable development and disaster risk mitigation. This requires certain key information about the community's and individual's social and economic aspects, which include aspects such as: the availability and use of land for various types of agricultural activities; the local community's economic standing; the mechanization versus labour force regarding local farmers as well as the livelihood drivers regarding economic aspects.

In balance with the socio-economic aspects, key information regarding the environmental aspects is also necessary, such as: The current climactic parameters as well as the key drivers of climate change in a specific temporal and spatial system; the possible occurrence of a natural hazard becoming a disaster scenario; current mitigation measures regarding natural hazards and the understanding of periodic changes regarding climatic phenomena.

Lastly, the agricultural aspects that tie in with both the economic as well as environmental aspects, such as: the current practices used within the agricultural business and the impact thereof of both the social and environmental surroundings as well as the ability to change practices if necessary, to ensure adaptability, are essential to ensure sustainable agricultural adaptation towards a changing climate. This can be done through incorporating and implementing more environmentally sound agricultural processes that includes the framework of Eco-DRR to limit the impact of agriculture on the environment, whilst improving the farmers' ability to adapt to a changing climate, simultaneously focusing on the underlying aspects of food security.

CHAPTER 3

Methodology

3. Introduction

Research methodology can be defined as the process that is incorporated in a certain way as to resolve a research problem in a systematic fashion and can also describe how the research is done (Gounder, 2012). A research methodology consists out of numerous steps that can be adopted by any study, including the literature review, which forms the theoretical grounding for the empirical study.

Chapter 3 provides insight into how the research for this study was conducted. Firstly, the study area is discussed regarding the geographical location; geo-political districts; the demography; the temperature and rainfall; the geology and the agricultural practices of North West. Secondly, the empirical research design that was used is discussed. Following this, the chapter will elaborate on the sampling methods that was used in this study, which includes purposive and snow ball sampling. Following the description of the sampling methods, the tools used to collect the data is described. Specifically, attention will be given to semi-structured interviews as primary data source and document review as secondary data source. After collection of data, the chapter discusses the data analysis techniques used to conglomerate the information into statistical information so to be able to compare the acquired data to the literature. Finally, the limitations and ethical considerations of the study is discussed. The following discusses the study area.

3.1. Study area

The North West Province is located within the upper western parts of South Africa, bordering Limpopo, Gauteng, the Free State and the Northern Cape as well as the Southern parts of Botswana (Statistics, 2014). The North West Province spans across a total area of around 116 320 Km^2, which translates to about 9.5% of the total land area of South Africa and has an altitude which differs between 1000 to 2000 meters above sea level (Statistics, 2014)

3.1.1. Geo-political districts

The North West Province consists of four districts namely: Dr Ruth Segomotsi Mompati; Ngaka Modiri Molema; Bojanala Platinum and Dr Kenneth Kaunda, which in turn consist of twenty-one local municipalities. The Province is predominantly rural, with 65% rural and 35% urbanised, with the main economic activity being agriculture (READ, 2015). The 2014 mid-year population was estimated at around 3.7 million (Statistics, 2014). Nearly 43% live in the eastern Bojanala Platinum District Municipality, and a further 24% live in the Ngaka Modiri-Molema District Municipality (Statistics, 2014)

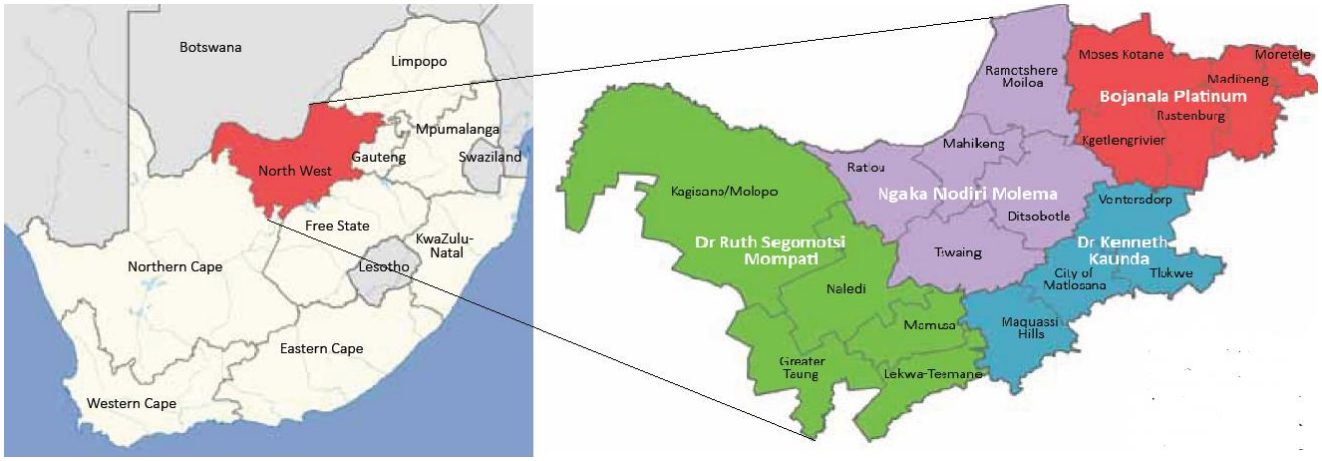

Figure 3.1: Location of the North West Province within South Africa as well as the locations of the four councils and twenty-one municipalities within North West (READ, 2015)

3.1.2. Demography of North West

The average growth of South Africa's population is close to two percent per year (READ, 2015). The total population of South Africa is 52 million in 2016 and is expected to grow towards a population of 82 million by 2035 (Statistics, 2016). The population residing within the borders of the North West Province was approximately 3.51 million people in 2011(READ, 2015; Statistics, 2016) with an increase towards 3.7 million people in 2016 (Statistics, 2016)

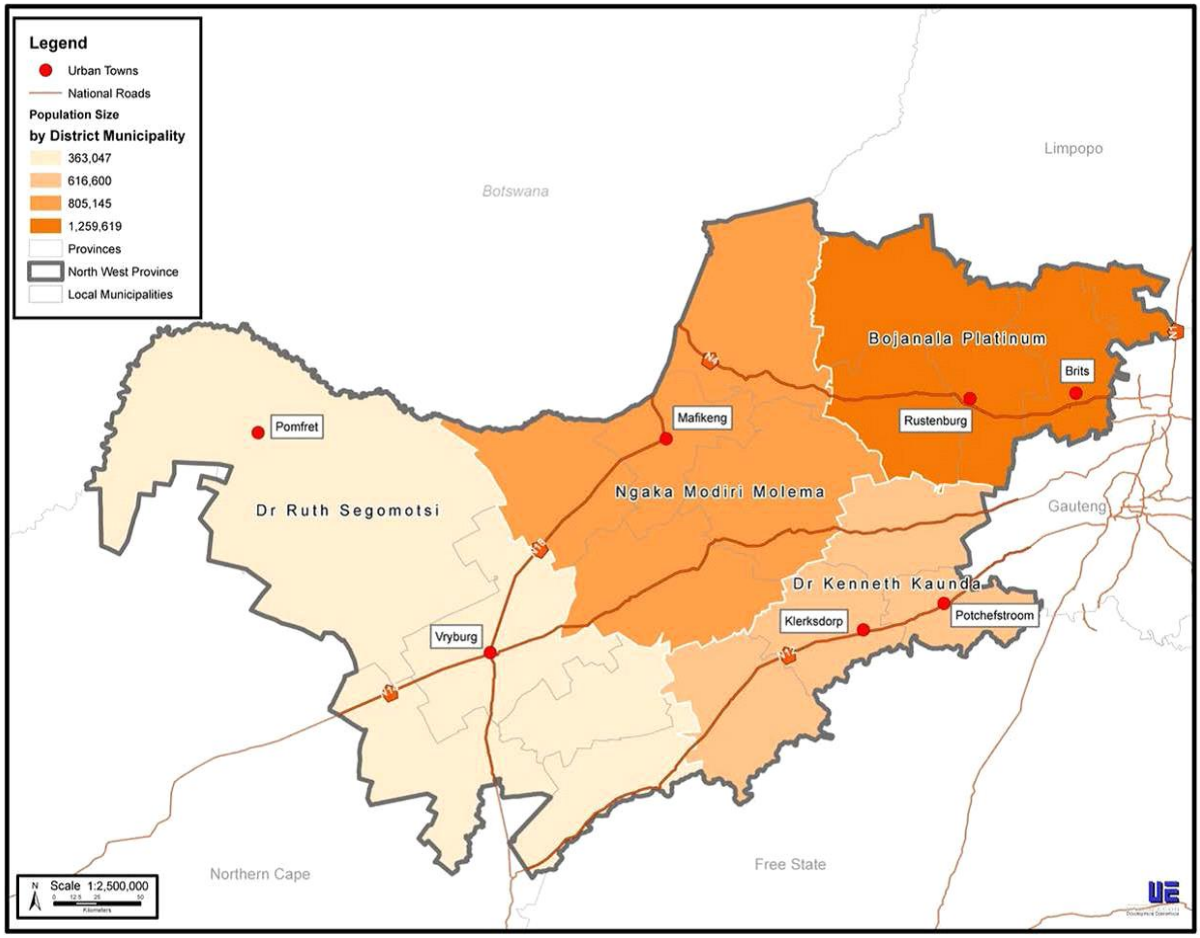

Figure 3.2: Geographical representation of the North West Province (READ, 2015)

3.1.3. Temperature and Rainfall of North West

The average summer temperature of North West is approximately 24.1°C, whereas the winter temperature averages are roughly 12.0°C with the average temperature being 27 °C in 2020 (World Data, 2020). However, due to climate change, these temperatures are likely to increase in the future (Olayide and Alabi, 2018). The North West Province is more than likely to experience a potential increase of overall atmospheric temperatures of as much as 2.5°C by 2035, and 1-3°C between 2040 and 2060 and by 3-6.5°C between 2080 and 2100 (Weber *et al.*, 2018)

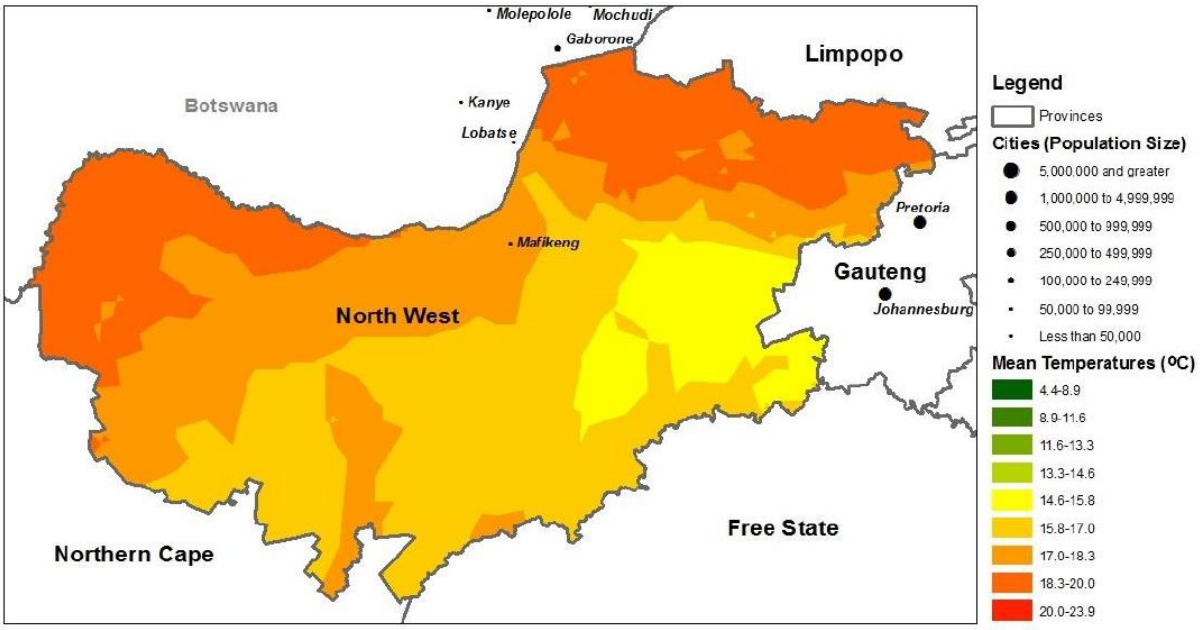

Figure 3.3: North West Mean Annual Temperature in Degrees Celsius (READ, 2015)

The North West Province can be described as a summer rainfall area, which means that the highest rainfall averages coincide with the highest temperature averages (Oladele, 2011; READ, 2015). It has a higher-than-average rainfall per annum than the official South African rainfall average, which is the reason why agricultural activities thrive within the area (Weber *et al.*, 2018). The LTAS project estimates that the average per annum precipitation of the North West Province will decrease in the long-term predictions. Although the rainfall projections in the LTAS project remain within the realm of present-day variability for the North West Province, due to the increase in temperature, an increase in evaporation rates can be expected, which implies a drier future (Adger *et al.*, 2003; Blignaut *et al.*, 2009)

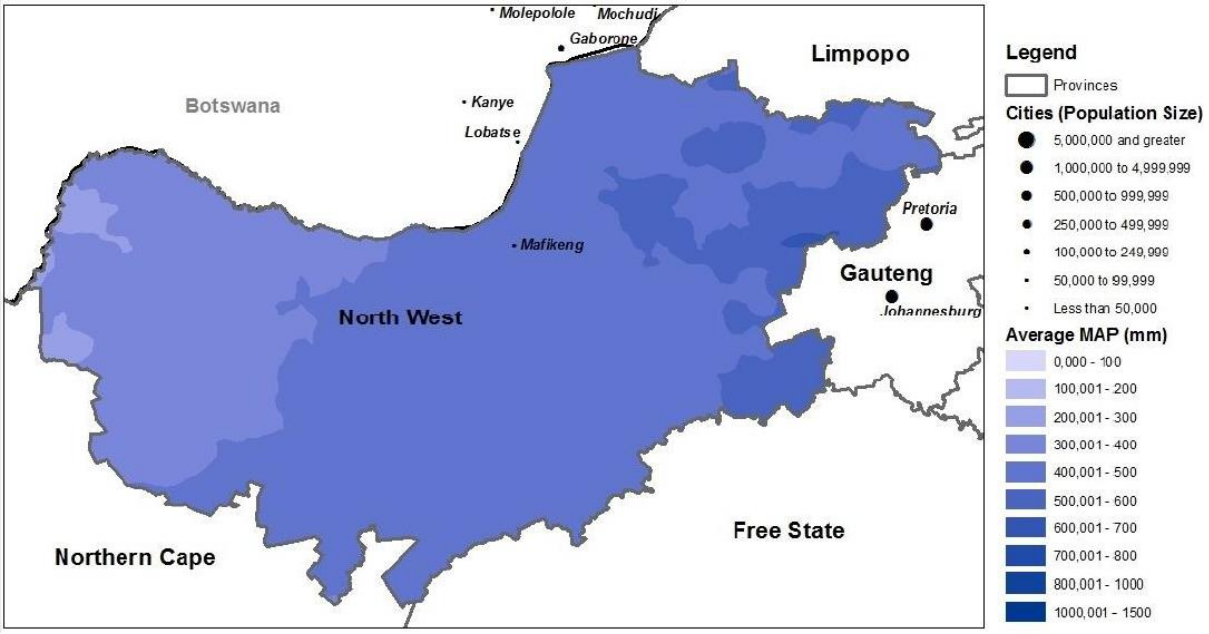

Figure 3.4: North West present Mean Annual Precipitation in millimetres (READ, 2015)

3.1.4. Geology of the North West

The predominant soil formations within the North West Province comprises mostly out of red-yellow apedal soils, particularly within the western parts. Other types of soil formations found in the North West Province are plinthic soils, which are advantages for agricultural activities, as well as glenrosa and mispah soils formations, which are less ideal for agricultural activities such as crop production (Fey *et al.*, 2010)

3.1.5. Agriculture of North West

According to READ (2015), 43.9% of the available land in the North West Province can be categorized as arable. The western parts of the North West Province, which tends to be drier than the rest of the Province, is mostly dominated by livestock farming as well as game farming, whereas the central and southern parts of the Province is dominated by wheat and maize farming. The eastern parts of North West cultivate a variety of crops, due to the fact that this region of the province has a higher precipitation percentage (El Chami and El Moujabber, 2016)

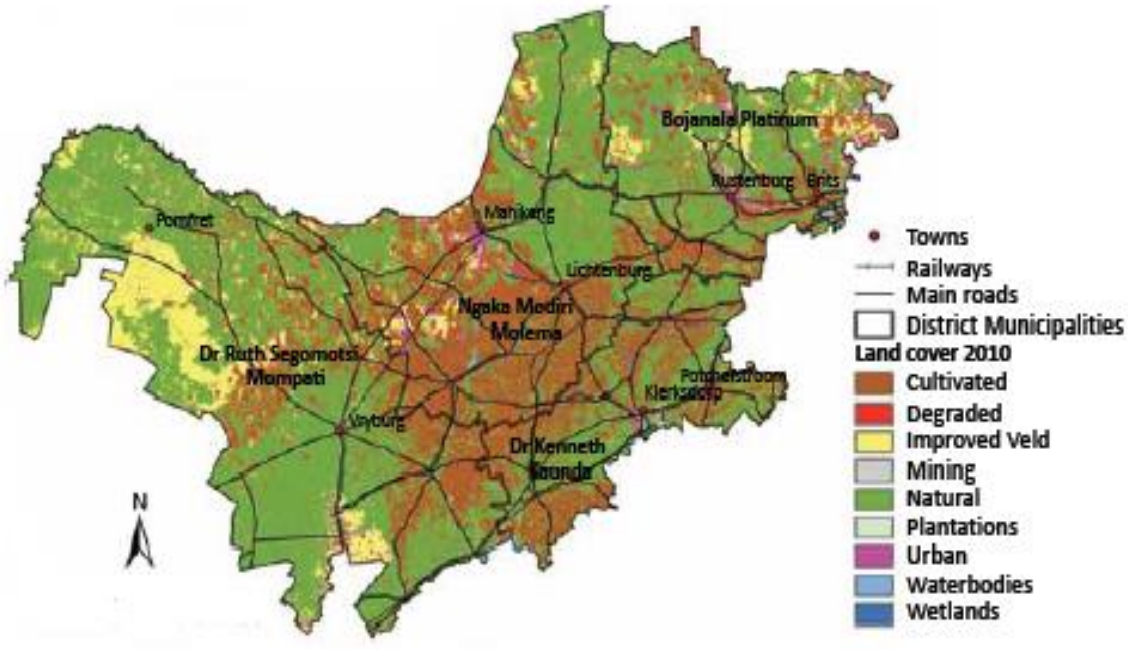

Figure 3.5: North West land cover and land use (READ, 2015)

Even though South Africa can be regarded as one of the largest economies in Africa, food security is still an ever-present problem and cannot be seen as secure (Baiphethi and Jacobs, 2009; Pereira and Drimie, 2016; READ, 2015). 45.6 % of South African citizens have high food security, where 28.3 % of citizens are at risk of becoming food insecure, and 26 % of citizens are in a food insecure scenario. This equates to more than half of the population of South Africa have the potential to be affected by the lack of food resources (Nyirenda *et al.*, 2018). In the North West Province, 1.7 million people are affected by a lack of food security, which equates to 46 % of the population of the North West Province (Baiphethi and Jacobs, 2009). This insecurity could worsen as food production or the importation of food will have to increase dramatically to ensure sustainable food resources, using the same or fewer natural resources (El Chami and El Moujabber, 2016; Ijatuyi *et al.*, 2017).

3.2. Methodology of research

A research methodology consists out of numerous steps that can be adopted by any study, including the literature review, which forms the theoretical grounding for the empirical study (Gounder, 2012). The following describes the literature review and the empirical study respectively.

3.2.1. Literature review

As described in Chapter 1 (Section 1.5.1) a literature review was conducted to ascertain the fundamental grounding for the conduction of this study. This was done in chapter 2, where various literature was reviewed and a summary was compiled. This is imperative to do, so to ground the results gained through this study and compare it with literature for the purpose of triangulation. The following describes the empirical investigation, which is fundamental to conduct any research needed to fill in the gaps that are identified through the literature review by means of observation and documentation.

3.2.2. Empirical Investigation

The empirical investigation uses the theoretical foundation from the literature study in Chapter 2 to position the gathered information in line with the broader aspects of the study, which includes information regarding climate change, climate change adaptation, Eco-DRR and agricultural adaptation. Through this, it was possible to see whether the information gathered in the study aligned with the information from the literature study, and where the gaps are.

3.2.3. Sampling

Sampling is the process whereby a researcher collects a comprehensive sample of the total population/environment in question (Gilbert, 2006) further states that a sample is a selected small representative portion of the population. The main purpose for sampling is to ensure that a sample provides an accurate representation of the totality from which it is selected, and to know as precisely as possible the probability that a sample is reliable in this way (Clemons and McBeth, 2020). There are numerous techniques that can be used to conduct research such as simple random sampling; systematic random sampling, snowball sampling, purposive sampling; stratified sampling; multi-staged sampling and snow ball sampling (Clemons and McBeth, 2020). For this study, purposive and snow ball sampling were used, as these sampling techniques used in unison provides the researcher with participants outside the researcher's knowledge. Purposive sampling was used as the participation scope is known (i.e., farmers), whereas snowball sampling enables a gaining of participants previously not known about.

3.2.4. Purposive Sampling

Purposive sampling refers to a non-probability method that tries to gain representative samples through including specific groups of participants in certain areas or types of areas. According to Gilbert (2006), purposive sampling is performed when the sample population is drawn according to the judgment of the researcher. This is done so the sample is composed of elements that contain the ideal set of characteristics and are most representative of the population that serve the purpose of the study best (Vos *et al.*, 2020). Purposive sampling was used in this study whereby a selection of people was done based on whether they were actively participating in agricultural activities.

3.2.5. Snowball sampling

Snowball sampling is usually used when it is difficult to ascertain all eligible participants or where there is a limited access to the appropriate participants for a study (Vos *et al.*, 2020). Regarding the study, the first participant that was interviewed were asked if the participant knew of any other farmers that would be willing to take part in the study. Consequently, the study, through the use of this sampling technique, was able to gain access to six other participants from one interview that could augment the information being collected. Within this study, the process was applied until saturation of information was attained (Vos *et al.*, 2020).

The projected sample sizes for this project were approximately 30 to 50 participants as a baseline, with a sample size of 100 being the ideal number of participants, which is seen as a suitable sample size regarding the two sampling techniques used in this study (Gilbert, 2006). Regarding the study, only 15 participants were willing to participate. Some of the difficulties include the difficulties of travelling to different areas in North West, as well as that many of the farmers contacted were not willing to participate in a study. Around 70 participants were personally contacted, which equates that 21 % of the contacted farmers became participants for this study. Although this could be seen as a rather small sample size, saturation was achieved at a very early stage, as almost all participants had the same responses to all the questions, coinciding almost entirely with the literature as well. Thus, though a small sample size, the information gathered was relevant as it was in line with the literature. To get information from the sampled population, the main research tool used were semi-structured interviews.

3.2.6. Instrumentation

Research tools, such as questionaries, were used to collect data that is deemed to be relevant to the overall research questions (Poggenpoel, 1998). An incorporation of semi-structured questions and closed question were used within the survey, so to include the perceptions of the participants as well as to gather analytical, focused data. An example of the survey can be found at Annexure A.

3.2.7. Data Collection

Surveys were used as the method of data collection for the study at hand (Poggenpoel, 1998), as surveys are an effective tool to use when focussing on the perceptions of people, as each individual's perception could potentially differ due to external and internal factors (Creswell, 2013). Surveys provide a first-hand data collection as the information comes directly from the target respondents. For the purpose of this study, semi-structured interviews, combined with closed questions were used as the method of primary data collection. The combination of questions was used to acquire quantitative information such as gender; age; experience in farming; type of agricultural activities; irrigation use; employment and percentage of income derived from farming, to be able to align the gained information with that from literature, as well as to gain personal opinions and ideologies pertaining to the objectives of the study.

Semi-structured interviews are guided, concentrated, focused, and open-ended communication sessions that happen outside the normal everyday life of both the interviewer and the interviewee (Poggenpoel, 1998; Creswell, 2014) The study used semi-structured interviews in order to explore the participants' perceptions, as well as to identify any diversity, variety or correspondence between the views of the participants of key concepts that were being investigated. This is done in comparison with the available literature, so to define the validity of the information given by the participants.

Through the use of purposive and snowball sampling, semi-structured interviews were undertaken with 15 farmers living within the Province. The qualitative, semi-structured interview method, using questionnaires, made use of a variety of different questions to cover the totality of the research subject. The questions regarding the climate and environmental aspects were conceptualised to be open-ended questions, thus providing a base topic of investigation, but with adequate room for interpretation as well as interaction from the interviewer (Creswell and Creswell, 2018), whereas the logistical information regarding their agricultural activities were more structured as specific information were required for the study.

The main strength of semi-structured interviews as the data collection tool is that there is freedom of structure regarding the questions, which means that any question can be asked that is relevant to the study (Adams, 2015). Both structured and unstructured surveys were considered, but a semi-structured survey was decided upon. The reason therefore is that both the structured and the unstructured have specific limitations regarding the process of data collection. The structured survey restricts the measure of freedom the researcher has in probing answers that are provided by the respondent, whereas with the unstructured surveys, the conversation is directed by the respondent and not the researcher, therefore diverting the aim of the research (Adams, 2015)

The surveys were carried out individually with participants with the aim of providing more in-depth information about the topic. Whilst participants were conveying their opinions and perceptions, detailed notes were made regarding their shared information. These interviews were carried out with 15 farmers living in the North West Province. The interview questions were aligned with the research questions as well as the theoretical chapters in the study. Although some of the question in the survey were closed questions, the majority of questions were not too rigid in their formulation and questions were asked in such a way that they leave time for follow up questions (Dicicco-Bloom and Dicicco-Bloom, 2016)

Participants were interviewed separately and the recorded names and personal information are not divulged, as anonymity was ensured for the purpose of this study, and none of the participants wanted their personal information to become available. The interviews offered the possibility to modify the line of inquiry as the more open-ended questions made it possible to easily follow up on interesting factoids or perceptions that came up during the interviews and to observe verbal and non-verbal responses so to get a more complete picture of meaning of the answers (Opdenakker, 2006). Conducting semi-structured interviews can be seen as a time and labour-intensive method of data collection. This is due to the time it takes to do the interview regarding the planning, traveling and actual interview session and many participants were of the notion that this action was wasting business time (Opdenaker, 2006). Many potential participants were unwilling to co-operate in an interview, where some of the participants that were willing to participate, were unwilling or unavailable to have a face-to-face interview due to personal reasons and completed the surveys electronically, making it difficult to effectively utilise the more open-ended questions to gather the data that is essential for the research.

After the collection of data was completed, the interpretation of the data collected was conducted as to extrapolate the beliefs and ideas that the farmers have. As not all farmers understand the scientific aspects behind the changing climate, the El Niño and La Niña phenomenon's as well as the concept of Eco-DRR, the study aimed at filling the gaps there is between the knowledge of the farmers and the knowledge of literature so to encapsulate the quality of information from the farmers. This is done through thematic data analysis.

3.2.8. Data Analysis

Thematic data analysis was used to discover any themes or patterns that formed within the acquired data (Dicicco-Bloom and Dicicco-Bloom, 2016). This means that any patterns found within the data can be identified, analysed and reported as well as

interpreted in various aspects with regards to the research topic. This data includes both the quantitative information derived (i.e., the farming practices information and the biographical information of the participants) as well as the qualitative information (i.e., the views and opinions of the participants) Thematic analysis also reveals the participants interpretation of the study, in this case of climate change and agricultural adaptation (Reeping *et al.*). A database of information from the participants was completed after all the results of the surveys were compiled on Google Forms, which was used to automatically arrange the answers of the various questions into comparable graphs.

After the data was collected from all the participants, the information was transcribed into the Google forms format so as to use the graph creation function thereof. The data collected by those participants that completed the survey was electronically automatically populated through Google forms, whereas the surveys that were done in person had to inserted digitally into Google forms, as well as some of the information needed to be translated as it was done in Afrikaans. This process was done through reading and listening to the various interviews to ensure that no nuance was missed.

Through the statistical analysis, information was clustered into similar topics and categorised into clustered groupings that could be compared to one another. After the information was compiled into different categories, a preliminary analysis of the information was done.

This is done by paying attention to factors such as commonalities in the content, uniqueness in content and confusion and contradiction in the content. After these variables were processed, the categories created were reviewed was decided on how useful they are regarding the study.

Details of the findings were made and provided the summary explanations and assessed the significance of the findings. Based on the findings, conclusions were drawn regarding the perception and knowledge of climate change, the El Niño and La

Niña events and environmentally sustainable agricultural actions and adaptation measures which aligns with Eco-DRR, as well as the capacity and willingness of the farmers to adapt to, not only the changing climate, but also to focus more on environmental sustainability and ecological regeneration. the researcher had to draw conclusions concerning the policy integration between disaster risk reduction and food security so as to confirm objectives used in this research project and lastly recommendations were made. Apart from the data gathered from interviews, a policy analysis was conducted from data gathered from document review as well.

Furthermore, a triangulation method was employed to combine and compare all the data acquired from both the qualitative and quantitative methods and literature respectively (Forni and De Grande, 2020; Poggenpoel, 1998)

3.3. Limitations of the study

The main limitation of the study was the willingness and availability of the farmers to participate in the study. There were three main factors that reduced the willingness of farmers to participate in the study

1. For many of the farmers, the time constraint was too much to fit into their schedule. Although the interview, in person or electronically, would only take between 30 minutes to maximum around an hour, for many farmers, even 30 minutes were too long to not use that time for their normal day-to-day activities. The electronic questionnaire could potentially give the participant the ability to answer the questions when he/she had time, but the in-person interview would have to have happened in one session.
2. Many of the perspective participants were not willing to participate in any type of study due to previous bad experiences with past studies done by other researchers. The relevance of this study was discussed, but could not convince many of the potential participants.

3. Due to social tension regarding perceived criminal intent on the agricultural sector, numerous potential participants were unwilling to either divulge personal information for fear of misuse, or were unwilling to participate in the study as a whole. Anonymity was ensured, but was not enough to convince many potential participants.

Another limiting factor was the lack of information the farmers had on record about climate and the changes thereof. Most farmers, understood the idea of a changing climate, yet very few had the inclination to successfully log past climate data as it was not something of note according to them. Those that said they did record the information, were unable to provide said information, as it was not readily available.

3.4. Ethical considerations

Ethical approval for this study was acquired from the Research Ethics Regulatory Committee (RERC) of the North-West University Potchefstroom campus and ethically there was no risk deemed for this study (ethics number NWU-01573-20-A9). All respondents' participation was voluntary, suggesting that individuals were not compelled to participate in the research. A detailed description of the study and the purpose thereof was communicated to respondents before the study commenced and respondents had the option to withdraw from the study at any given stage. Interview questions were accompanied by a cover letter, which specified the personal particulars of the researcher, purpose of the research and the duration of the study. The cover letter also provided the respondent with the methods that were used to ensure anonymity and confidentiality. In cases where the participant provided any information, which could identify him/her, it was not made available to any persons who were not directly involved in the study, so as to guarantee confidentiality.

3.5. Conclusion

Chapter 3 described the process followed to carry out the study. Firstly, the location of the study was described so to become familiar with the study area. Secondly, the research methodology was described in detail of how the study was conducted. It described the systematic flow of the method used, as the literature review was done first to understand the theoretical aspects of the study. Secondly, chapter 3 described the research design followed to acquire the needed field research and data collection, followed by the sampling methods that were employed in the study including purposive and snowball sampling were elaborated on. The rational for using these types of sampling methods was also described. After the discussion of the sampling methods, the tool that was used to collect data for the study, the semi-structured interview, was given. Advantages and disadvantages were given and regarding the use of a semi-structured interview. Chapter 3 described the importance of data analysis and further elaborated how data gathered from interviews was arranged into categories or topics that were relevant to research objectives. After data analysis, the limitations of the study as well as the ethical considerations were discussed to prove that none of the participant' rights were violated. The next chapter discusses the findings from the interviews with links made to the theoretical principals established in chapter 2.

CHAPTER 4

Results and Discussion

4. Introduction

In this chapter, the results of this study are captured and discussed with reference to what the objectives of this study was. This chapter presents and contextualizes the results from the present study. The objectives of this study had several aspects: First was to understand the participant's economic aspects, and how that has changed from when they began farming. Secondly, to record the experiences of the participants regarding the changing climate. Thirdly determine what the participant's knowledge are regarding climate change and the El Niño and La Niña phenomenon, as well as to ascertain any adaptations that they have already made towards the changing climate and the changing economy. Finally, to discuss any measures or systems that could possibly help the participants better adapt to a possible future scenario which is more environmentally sustainable.

The research, as discussed in the methodology, was conducted regarding the geographical location as well as the participation through in-person and electronic interviews using questionnaires. 15 participants, all farmers, formed part of this study. Although the sample size might seem limited regarding the size of the geographical location, the results were overwhelmingly aligned regarding their answers and opinions, which will be discussed in this chapter. The fact that most of the participants, even though the participants come from seven different geographical areas within the Province and farming practices, had roughly the same perceptions regarding the questions on both the economic and ecological factors. The importance of this study is less to a geographical or numerical point, but more towards a holistic, occupational perception of the subject. The perceptions can be extrapolated to potentially say that

a larger participation group would have given roughly the same types of answers, given a few outliers or presented incorrect information (which is discussed in this chapter as well), making the data collected by this study relevant and gives validity to the study.

4.1. Data availability

The data acquisition was done through the use of surveys (in person and electronically), an example of which can be found in Annex A, and was populated using Google forms as the platform as the electronic surveys were completed using the Google forms platform. The collection of this data stretched from 2016 to the end of 2017, where a total of 15 participants were willing to complete the survey (the completed surveys are available upon request).

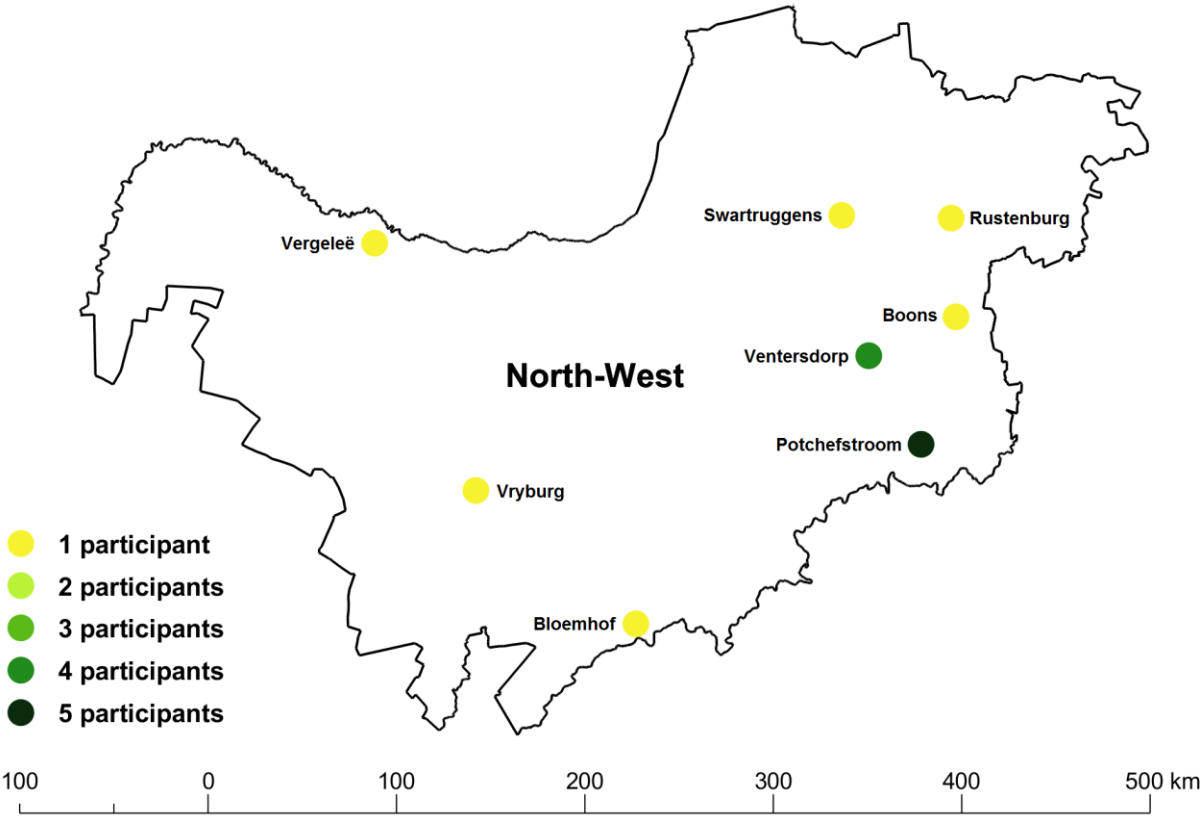

Figure 4.1: Participant distribution map (Bredenkamp, 2020)

4.2. Contextualisation

Most of the participants completed the surveys in a comprehensive and detailed manner, whereas some of the participants where less detailed regarding the open-ended questions and were also less than forthcoming with personal information such as the farm name, telephone number and/or email address. This withholding of personal information was done even though their anonymity was ensured. The most logical reason for this was for fear of their information becoming available and used in some or other manner without their consent.

Furthermore, some of the participants that used the electronic questionnaire gave incomplete information or had gaps in the information that could be seen as faulty. This could be due to an error when an electronic survey was filled in, or the question could have been misunderstood, as a face-to-face or telephonic interview could not have been done with some of the participants due to constraining factors. These factors include that the farmer either did not have time to do a face-to-face interview, or were too mistrusting to allow anyone on their farm that they did not know and opted for an electronic survey. The following describes the biographical data of all the participants in the study.

4.3. Biographical information

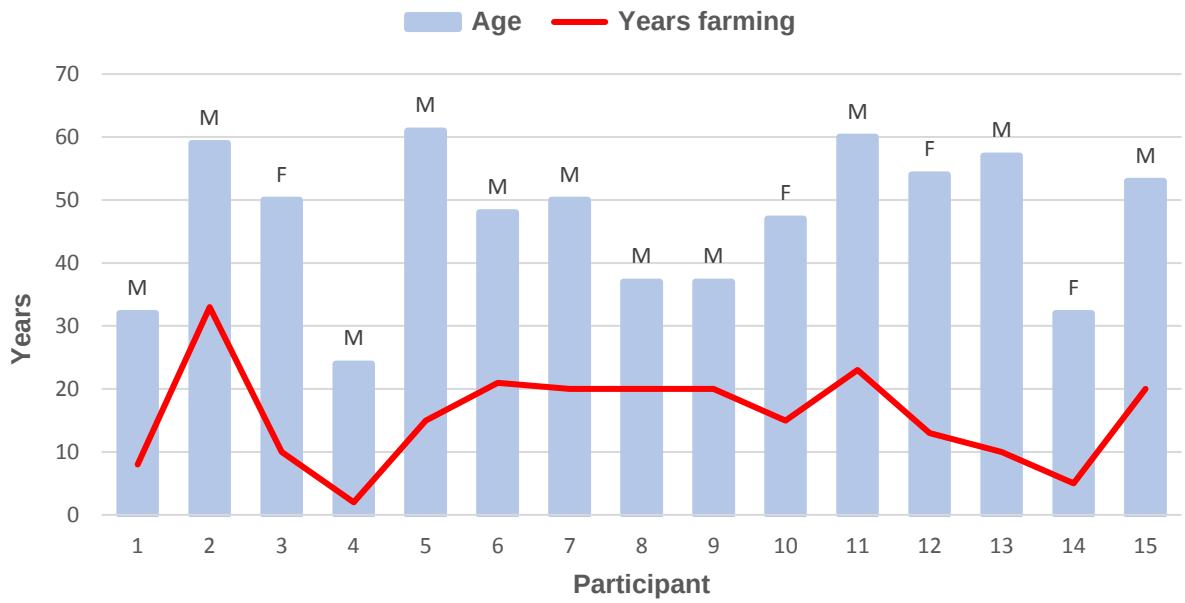

Figure 4.2: Biographical information of the participants, including age, number of years farming and gender (M/F)

Studies have shown that, in South Africa as a whole, almost 70% of all agricultural labour force consists out of women and can be seen as the main producer of food in rural areas (Gladwin et al., 2001; Bob, 2002; Ashby et al, 2011). This is mostly due to men working away from home, many from rural communities going to cities where there are more work opportunities (Ashby et al, 2011). This percentage does not translate towards the number of farmers that head farming households, as the number of men that run agricultural activities are more than double than women, especially regarding commercial farming practices (StatsSA, 2016).

As depicted in Figure 4.2, 11 of the participants are male, whereas only 4 women participated in the study, which roughly correlates with the ratio regarding the number of agricultural households by gender of household head (StatsSA, 2016). The age of the participants is diverse, with the highest general range of age being between 46-56 (9 participants). This data coincides with the age range of farmers that are actively farming in North West (StatsSA, 2016). The number of years of farming mostly

correlated with the age of the participant; the older the participant, the more years of farming experience they had. The following section describes the socio-economic aspects of agricultural activities for the participants

4.4. Socio-economic standing of agricultural activities and practitioners

Farmers are not only affected by the environmental and climatic factors of their surroundings, but is largely impacted by socio-economic factors, as farming is essentially a business, and the main source of income for many farmers, as is discussed in this section. Thus, it is important to consider factors such as the scale of farming and its impact of employment of laborer; the streams of income and the use thereof as well as the point of sale for the produce. The following discusses the characterisation and scale of farming done by the participants.

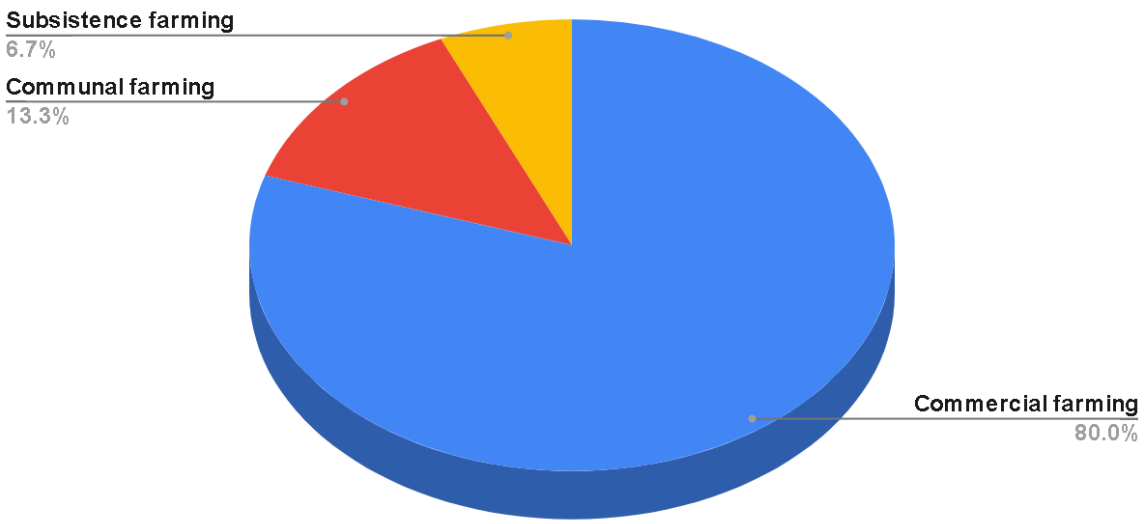

Figure 4.3: Types of farming practices of the participants

Figure 4.3 depicts the scale on which participants were involved in agricultural activities (also see Section 2.1.1) Twelve, i.e., 80% of participants described themselves as being commercial farmers, since they all sold between 90 - 100% of their produce (see Section 4.3.7). One participant was a subsistence farmer (approx. 7%), whereas another two participants (approx. 13%) described their farming method as communal because they shared land with other farmers and families. It is important to understand the scale on which farmers practice agricultural activities, since this has a knock-on effect on the economy, as well as the ecological environment, as discussed in Section 2.1.4.

The scale of farming activities also implies the size at which the agricultural activities takes place and can be indicative of the scale and the type of farming that is done. The following describes the distribution of farming activities done by the participants.

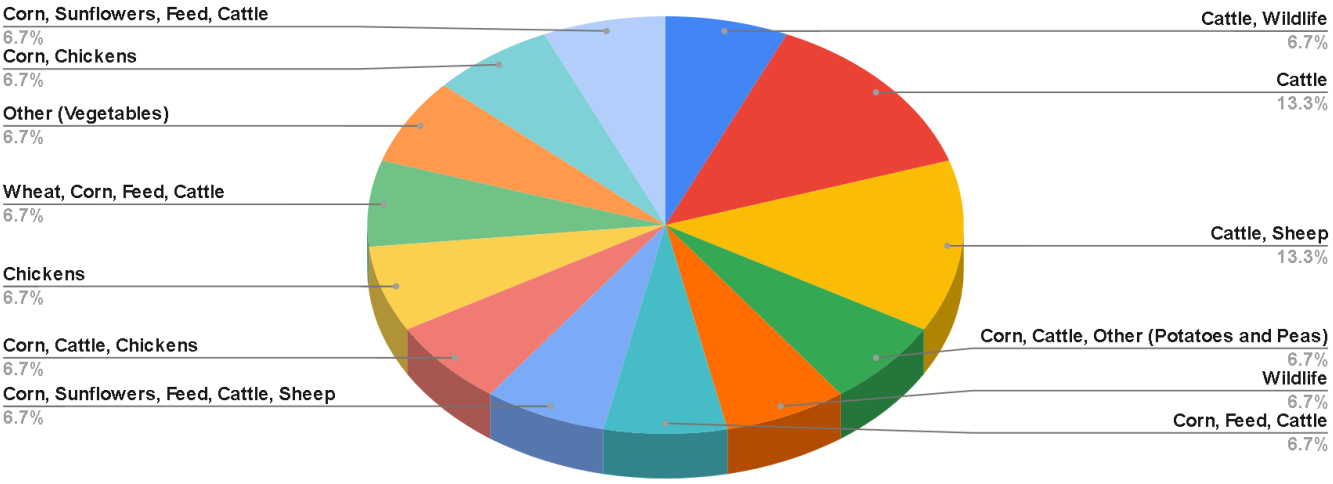

Figure 4.4: Types of farming activities

Figure 4.4 depicts the main agricultural activities of each participant. Two of the participants both farmed with cattle and sheep, another two farmed only with cattle, whereas all the other participants had a unique combination of the agricultural activities being done. This is important to know, as this variety in activities indicate that the farmers already reacted to past changes in their environment.

It is interesting to note that 73% of the participants all raised cattle, some of them changing from crop production to cattle rearing (see Section 2.2). This is due to the economic advantage of rearing cattle over crops, as the price for meat products have risen in the last few years. The price that farmers receive for crops decreased, as well as the fact that more stringent quality tests means a lower profit margin for famers. Only two participants (ei.13%) of the participants grew vegetables and only 7 of the participants (47%) grew cash crops. This further strengthens the reasoning of changing from crops to meat products, as the cash crops are not as profitable as raising animals.

Four of the participants (26%) allocated parts of their arable land towards growing feed. This is done, not to sell, but for own use to feed either cattle or sheep. As one of the participants stated that only using feed for the cattle would be far too expensive, thus the decision was made to start to grow feed for the animals. This is important to note, as the economic pressures can also be a driving force to adapt to changing circumstances.

Another aspect of farming that is by large affected by the types of agricultural activities done, as well as the size of the activities, is the method of irrigation used. The following figure depicts the types of irrigation methods used and the percentage of participants using said methods.

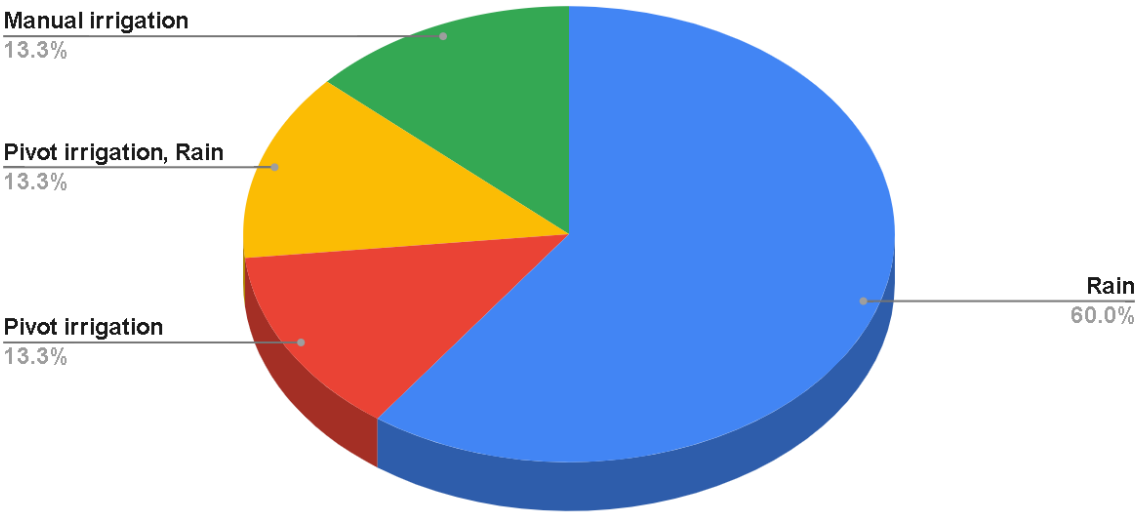

Figure 4.5: Main irrigation methods used by the participants

Figure 4.5 depicts that nine of the participants (60 %) exclusively rely on rainfall as their source of irrigation, whereas manual irrigation, pivot irrigation and the combination of pivot irrigation and rainfall all had two farmers in each category. 73% of the participants rely on rainfall as a method of irrigation. This is a concerning observation as the rainfall patterns and amount of precipitation has changed over the last decade (see Section 2.3.1.2) in a negative trajectory. The future projections predict that rainfall will be even more erratic, with a general reduction in amount of precipitation (see Section 2.3.1.2). If the farmers do not adjust their irrigation methods, or proactively focus and adapt to the future projections, it could bode negatively for them.

Furthermore, it is interesting to note that the commercial farmers rely on rain and pivot irrigation, as their quantity of land to irrigate is too large to effectively use manual irrigation as a method. The subsistence farmers as well as the communal farmers uses both manual irrigation as well as a dependence on rainfall. This can be problematic for the smaller scale farmers as well, as their source of water can dry up if the climate becomes drier and warmer.

Considering the periodic and predictive effects of the El Niño and La Niña periods, it is interesting to note the lack of preparation by many of the participants of constructing catchment areas or water storage systems for the purpose of retaining water during the wetter seasons and having more water available during the drier seasons. This is less feasible for the participants relying on rainfall for crop production, but is a method of ensuring drinking water for those participants whom have livestock (See section 2.2)

As stated above, subsistence and communal farmers generally have smaller pieces of land, which means that they are more likely to produce less than commercial farmers, which have large pieces of arable farm land to produce large quantities of agricultural product. This has a correlation with the point of sale which the different types of farmers use to sell their produce, which is discussed in the following section.

4.5. Economic considerations related to agricultural practices

As figure 4.6 depicts, five of the participants sold to a combination of local farmer's markets and large-scale traders; two participants sold to large scale traders and were active with exports; four only sold to local farmer's markets; two only sold to large-scale traders and two only sold to informal markets. This equates to, out of the 15 participants, 60% of the participants sold to large-scale traders; 60% of the participants sold to local farmers; 13% sold to informal markets and only 13% exported their produce.

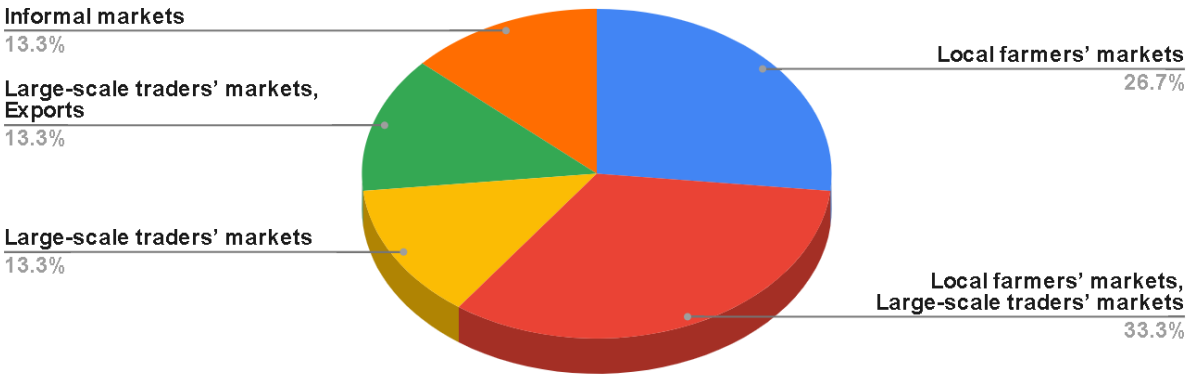

Figure 4.6: Point of sale used by the participants

Referring to Section 2.1.1, it is interesting to note that both the local farmer's markets and the large-scale traders are used as the main point of sale for most of the commercial farmers. The exports are done only through the commercial farmers, whereas the subsistence and the communal farmers sell to both the local farmer's markets and the informal markets. The subsistence farmers as well as the communal farmers do not farm intensive enough to be able to compete with the quantities that the commercial farmers sell at, thus cannot sell at the same prices to make a suitable profit. The inverse is true for most commercial farmers. Even though commercial farmers are not excluded from the informal markets, the quantity at which they produce is better suited for the larger markets so to sell more of their produce before the prime selling time is exceeded and the quality of the product begins to deteriorate. Another aspect of farming to keep in mind is the way in which the total produce is used, either sold, or used by the farmer and family. This is depicted in figure 4.7, which shows the correlation between the percentage of produce sold versus the percentage of produce used by the participants respectively.

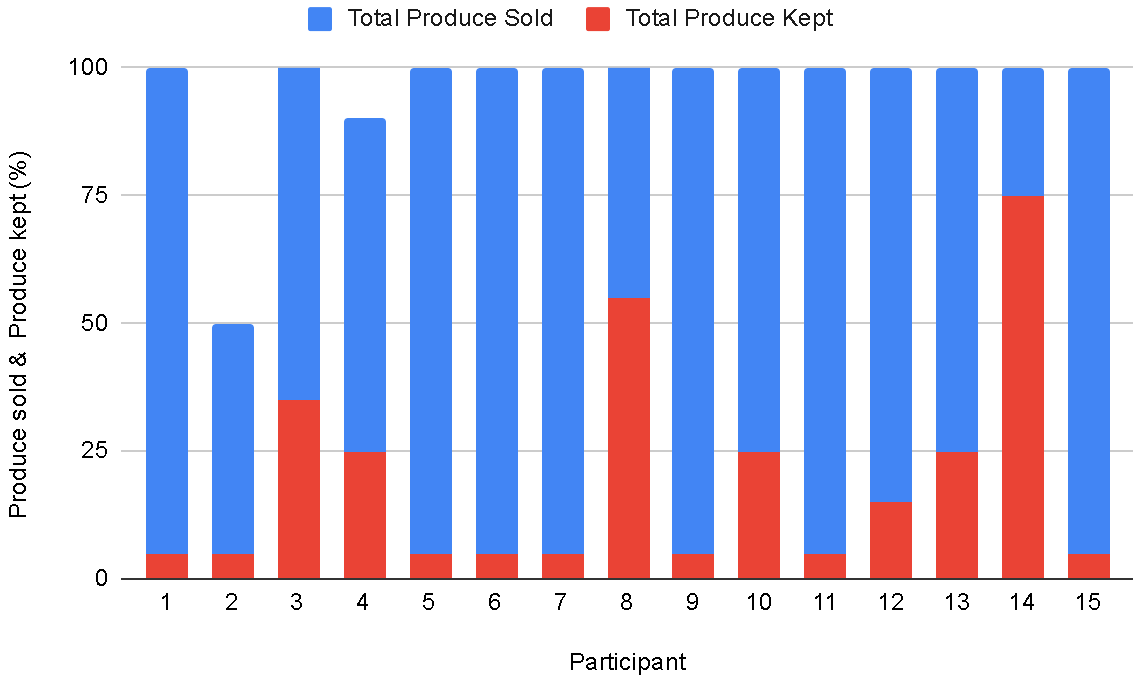

Figure 4.7: Prefered use of produce by the participants

As depicted in figure 4.7, the commercial farmers sold up to 95% plus and kept the minimum for themselves, whereas the subsistance and communal farmers tended to keep a larger amount for themselves than the commercial farmers, but still sold a large amount of their produce for and income (see Section 2.1.1). When the data was analysed, there were discrepancies picked up from three participants. Two of the participants gave percentages that equted to less than 100%, whereas another participant (N14) stated that her percentage produce kept was 75%, which does not compute with the statement that this participant is a commercial farmer and that the percieved percentage of income from agriculture was that of 91 – 100%. These errors could be due to a misunderstanding of the questions, or a error when the survyes were completed, as all three prefered to complete the survey electronically and not in person where guidance could have been given.

The percentage of produce sold for all three types of farming practices are higher than the amount kept. This is beacause a large portion of the participants derived their main income from their agricultural activities, as can be seen in figure 4.8.

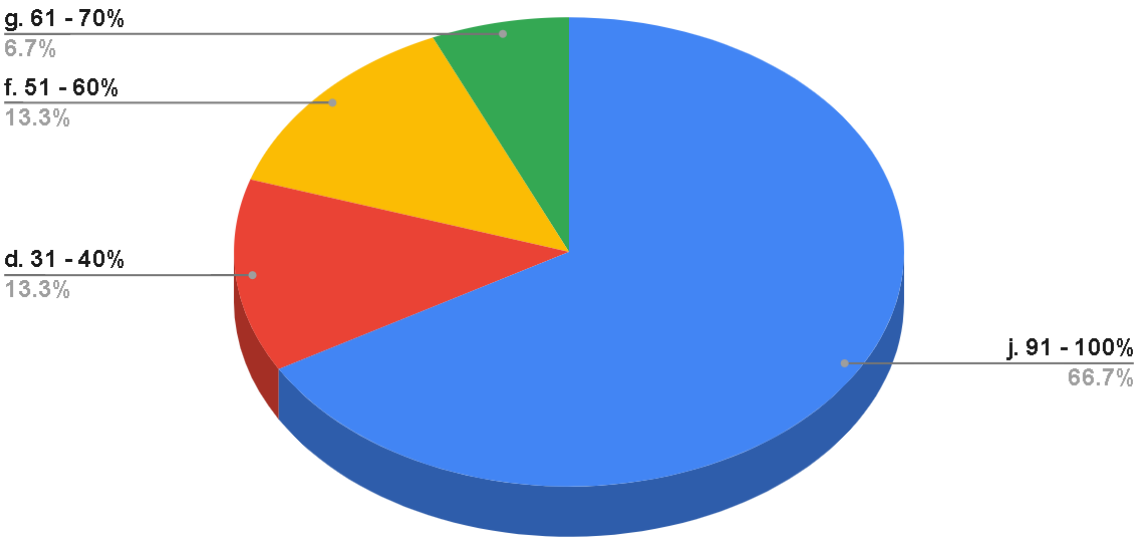

Figure 4.8: Perceived percentage of income derived from agricultural act ivies by the participants

As Figure 4.8 depicts, 10 participants derived their income purely from their agricultural activities; one of the participants derived around half of its from agriculture; 2 of the participants derived around half of their income from agriculture; whereas 2 of the participants derived less than half of their income from their agricultural activities

Interestingly, only 67 percent of the participants claimed that all of their income is agriculturally related, whereas 23 percent of participants stated other sources of income; these include permanent employment at another place to subsidize the farming, selling of other goods and running other ventures such as performing chemical removal of invasive plants.

These figures are important to note, due to many uncontrollable risks associated with profiting from agriculture (economic pressures as well as environmental and climatic factors), almost a quarter of the participants had to resort to other streams of income to subsidize their income from the agricultural sector. Both economic and environmental constraints have impacted the participant's income from their agricultural produce, as well as have affected their ability to employ other workers, both permanent and temporary, as is depicted in figure 4.9, which depicts the number of permanent and temporary employees in service of the participants respectively.

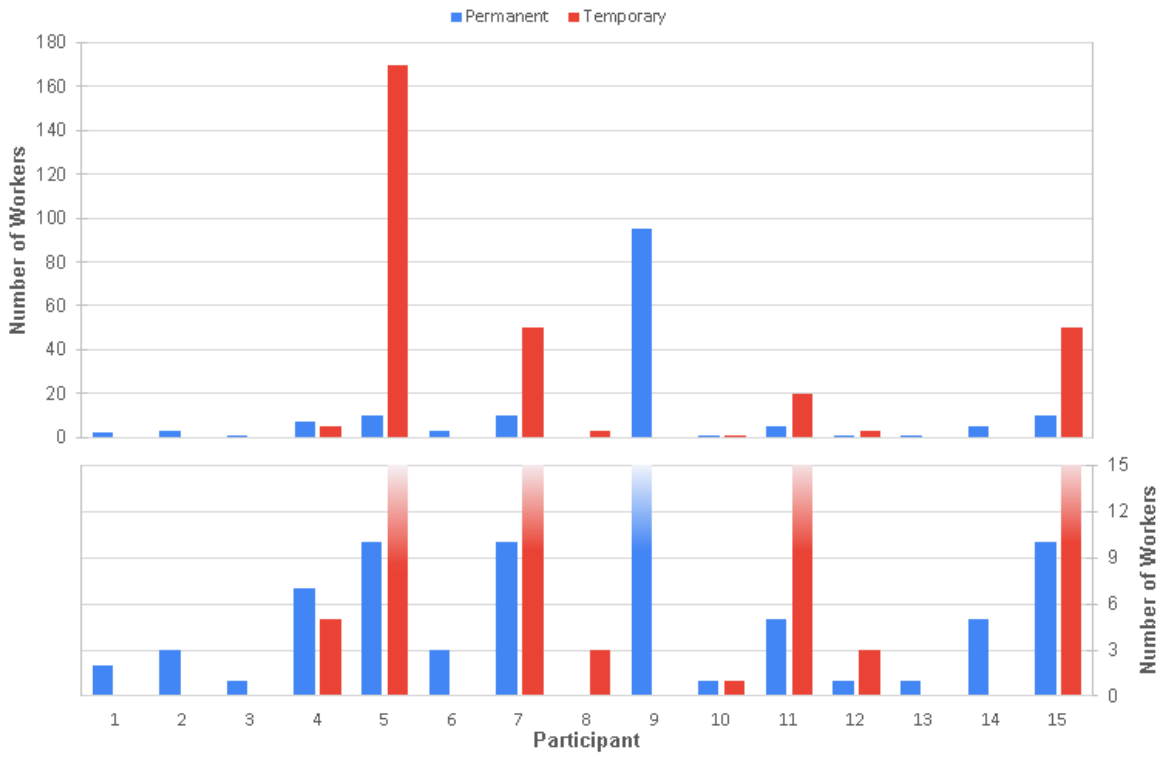

Figure 4.9: Number of workers in employment by the participants

The number of employees a farmer uses are dependent on many variabilities, such as type of agriculture, the size of the farm as well as economic constraints, which could impact the number of workers that can be employed. According to figure 4.9, most of the participants had less than 12 permanent workers employed on their farms, whereas one participant had almost 100 permanent workers. Four of the participants had only one permanent worker respectively and another participant had no permanent worker. Generally, the participants had more temporary workers than permanent workers, with some participants only using permanent workers. The reason given by the participants for this, is because they only need that number of laborers for short intervals, which is cheaper than keeping more workers on a permanent basis.

The number of workers has also by the most part decreased in time since the participants had started farming. The main reason given for this is that it had become too expensive to pay that number of workers, so a smaller number of workers, both permanent and temporary, were kept by the participants. It is interesting to note that one participant (N5) had drastically increased the number of workers, especially

temporary workers, as the participant expanded its farming activities and bought another piece of land.

Although the economic sector plays an enormous part in the agricultural sector and that it is essential for farmers to adapt to the changing economic climate, it is also important to adapt to the changing environmental and climatic factors that affect agriculture. The following section describes the climatic and environmental perceptions and factors.

4.6. Perspectives on the local climate and climate change

It is imperative for farmers to understand their dependence on the local climate, both temperature as well as rainfall, to better plan and adapt their farming activities and methods of agriculture to the changing climate. The following figures, Figure 4.10 and Figure 4.11, depicts the perceived temperature and rainfall respectively that the farmers have regarding their surrounding climate

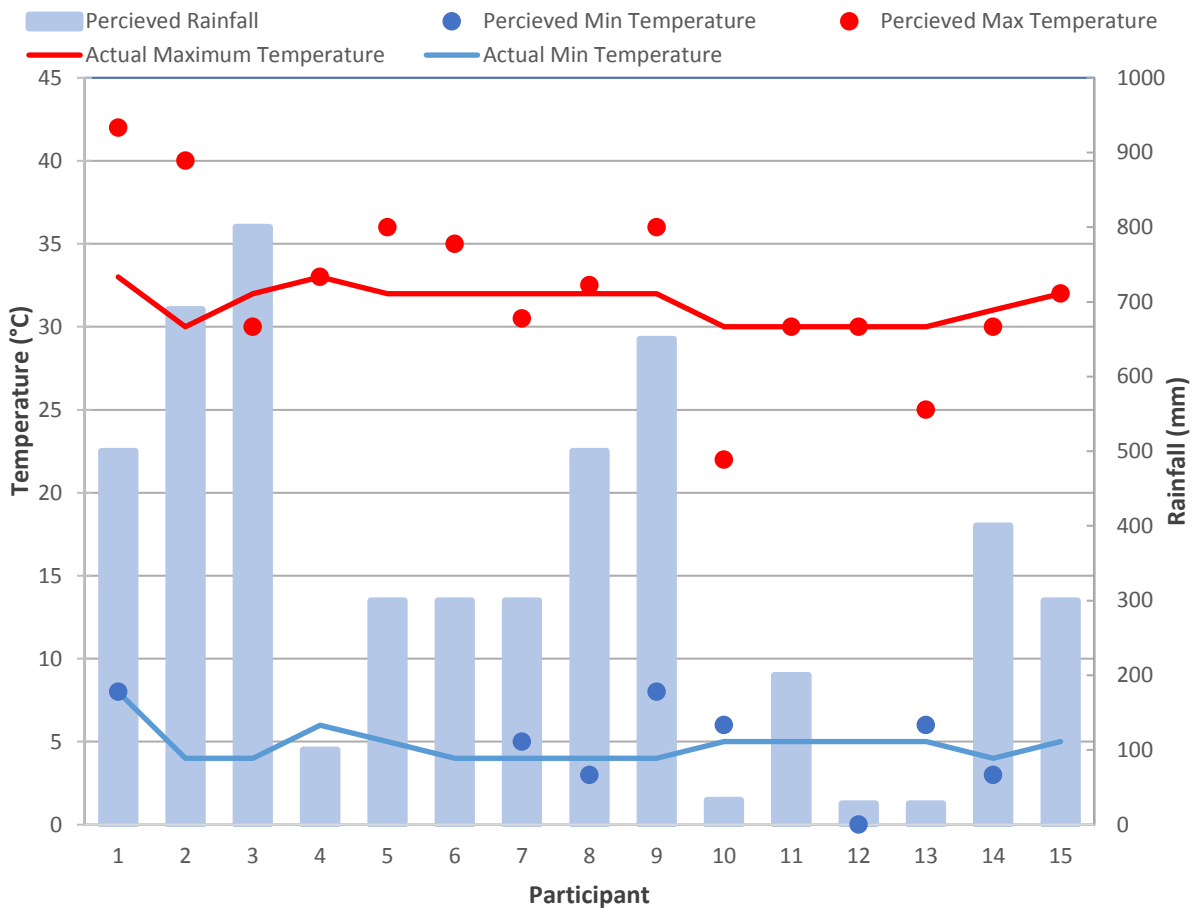

Figure 4.10: Graphical illustration of the perceived average rainfall, maximum and minimum temperatures, as well as actual minimum and maximum temperature for 2016/2017 (Average)

Figure 4.10 depicts the collected data from the participants regarding their perception of rainfall and temperature. The general consensus of the maximum temperature was in the range between 30 °C and 40 °C, with two participants (N1 andN2) stating temperatures above 40 °C. This correlates with the documented temperature extremes. Nine of the participants did not state any minimum temperature in the survey, as they either did not know the answer, or were not as concerned with the minimum than with the maximum temperatures.

Figure 4.11 depicts the perceived rainfall data given by the participants, the recorded data of rainfall in the closest town and surrounding area as well as the farmers that stated that they are solely reliant on rain as their main source of irrigation (red dots)

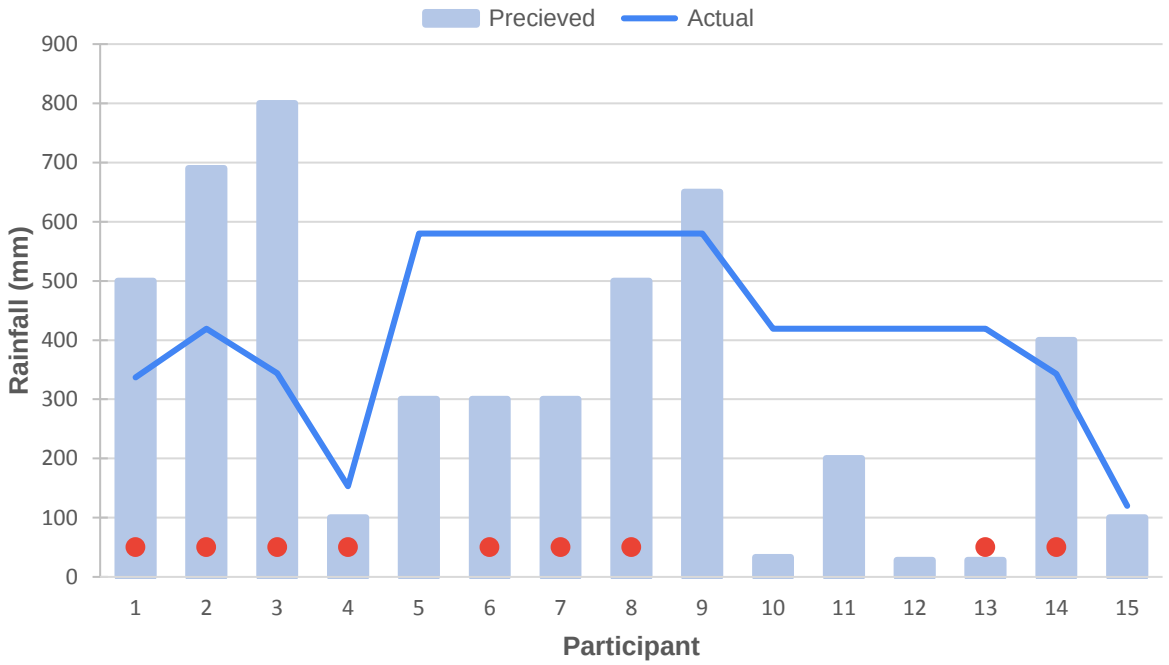

Figure 4.11: Graphical illustration showing the participants relying solely on rainfall (red dots), their perceived value of rainfall versus the actual rainfall

All participants stated what they perceived to be the annual rainfall for their area. However, three of the participants (N10; N12 and N13), all living in the same geographical area (i.e., Ventersdorp) stated a rather low annual rainfall, whereas three of the participants stated quite high rainfall measurements N1; N2 and N3). When compared to recorded data as depicted in figure 4.11, the information given by all the participants, especially the aforementioned participants, do not entirely coincide with the recorded data, however, a trend can be seen coinciding between the perceived rainfall and the actual data.

This could be due to the timeframe in which the surveys were done, as 2016/2017 were extremely dry and warm, and their perceptions could have altered their reasoning thereof. Another possibility is that the information given is accurate and that the amount of rainfall on their farms respectively were different than that which was recorded for the closest cities. The latter is less likely to be the correct reasoning, as none of the participants could present any records of rainfall for any timeframe, which makes the argument that the participants were giving ballpark figures, rather than

giving factual answers. This is further a point of concern as the information of those participants who stated that they rely on rainfall as their main source of irrigation, do not coincide with the recorded data, which makes them possibly more vulnerable to future droughts.

It is interesting to note that, as low temperatures and very high rainfall are as much a risk towards farmers as high temperatures and drought conditions (Creswell and Creswell, 2018), when asked about extreme climatic variations, all the participants referred to drought and high temperatures, as most of the participants stated that 2016 was an extremely hot and dry period, which was during an El Niño period, and some of the farmers could recall extreme hot periods during 2009 and 2010, which was another El Niño period. Only 30% of the participants referred to extreme rainfall seasons and none stated extreme cold conditions. This could indicate a lack of awareness regarding the impact that these climatic extremes have on agriculture, or that the higher temperature and lower rainfall extremes have a larger perception impact on the participants.

Furthermore, none of the participants derived any patterns from these extreme weather conditions, which are indicative of the effects of the El Niño and La Niña phenomenon (see Section 2.3.3). This further enforces the conclusion that the participants do not fully understand the ideas and mechanics of climate change as well as the concepts of El Niño and La Niña, which is discussed in the following section regarding the perceptions on climate change and its impact on agriculture.

4.7. Perceptions on climate change and its impact on agriculture

Most of the participants, when asked what they understand regarding climate change, had a rudimentary understanding of what the concept is. This understanding is that the temperature and rainfall patterns have changed in the last few years, generally becoming warmer and drier. The statements including the above understanding of

climate change is accurate (see Section 2.3.2), though when asked about the more technical aspects such as El Niño and La Niña and their impacts on the general climate (see Section 2.3.3), there was a lack of understanding. Some of the participants had heard about these periods, but did not understand the implications thereof, whereas other participants had never before heard of it. This is interesting to note, as the El Niño and La Niña periods have a large impact on the general climate.

That being said, all of the participants did state that, in their opinions, the climate was changing and that it did have a negative impact on their agricultural activities. An interesting observation that was made regarding the change in climate, was that all the participants said that the seasons timeframe had shifted, and that they needed to adjust their planting period with almost a month earlier so not the be caught by colder conditions during their harvesting period. They also stated that the rainfall season has shifted as well. The above-mentioned observations from the participants implies that they do observe weather patterns and changes in climate, even though they do not fully comprehend the technical aspects. These observations are scientifically grounded, as Walt and Fitchett (2020) described the shift of both the temporal changes as well as the rainfall pattern changes.

When asked whether the change in climate had an effect on their agricultural activities, the consensus regarding this question was that the change in climate had an adverse negative effect on their agricultural activities. Most stated that their production has gone down with some degree, and that if they wanted the same outcome of production, then the input costs would have to increase. The adaption to the timeframe for planting was also mentioned, as well as the types of irrigation needed due to the change in climate. A statement was made that one of the problems are that, due to the lower amount of rain, irrigation such as circle pivots will have to be used, but that in turn drains the underwater and/or dam levels, which is also a problem on its own.

As the climate change, the methodology of farming should change with it (Thomson, 2009). Some of the participants were in the financial position to redesign their farming methods to adapt to the changes (i.e., building of water catchment dams or larger storage silos to keep their crops until the market price improved) or to change from agricultural type entirely (i.e., only farming with chickens, to buying more land and farming with cattle and crops as well). Most of the participant though were not in the financial position to change their entire farming system, but rather did more innovative changes such as adding a small vegetable garden for their own use to reduce the cost of their grocery bill whilst keeping their farming expenses relatively the same, so to produce the same amount of produce to sell. An interesting adaptation that one of the participants made during the drought conditions of 2016, whilst farming predominantly with cattle, he had run out of natural feed as the grass on his farm withered, he cut down a fair number of the Acacia trees on his farm, fed them through a woodchipper, mixed the wood chips with molasses and gave the mixture to his cattle. This saved his cattle from starvation which subsequently kept his farm running until the rain season came again.

Although the participants showed the ability to adapt to a situation, these adaptations were all reactive in nature and not proactively preparing for the future. A proactive method of analysis the potential risks involved and adapting the present method to be able to withstand possible future scenarios are key to sustainability. When referring to a possibly scenario of a change in general temperate and rainfall, both towards the higher or lower parts of the range, the participants were all said that this would have a severely negative impact on their agricultural activities. If, theoretically, the climate changed in the future with 3°C in either direction or if the rainfall changed with 50mm, which is seen as a severe change in climate, especially regarding the increase in temperature (Comoé and Siegrist, 2015; Weber *et al.*, 2018), all participants were under the impression that this type of change in the climate would almost certainly make their current method of farming far more difficult to almost impossible. Most

participants stated that an increase in temperature and decrease in rainfall would make it almost impossible to continue on the same level of farming that they currently are accustomed to, were some stated that a fall in temperature would be as serious of an impact as an increase in temperature, as heavy frost would affect their crops and a drop in temperature would affect their livestock as well. This statement is supported by Mba *et al.* (2018) The following section describes environment sustainability practices in agriculture and the impact of agriculture on the environment.

4.8. Environmentally sustainable practices in agriculture

As stated in Section 2.4, the environment can be adversely affected by mismanaged agricultural practices, which has a knock-on effect on the carrying capacity of the environment. When the environment is degraded, that then has a negative impact on the environment (Walt and Fitchett, 2020). This is the main focus of Eco-DRR as a lens through which environmental sustainability and social development can be seen (Estrella and Saalismaa, 2013).

The participants of the study understood that it was important to look after the surrounding environment, as all the participants stated that the environment had changed, for the worst, since they respectively started farming. Examples that were given included water bodies which dried up since they started to farm and that, due to drier conditions, the plant life and animal life has become less abandon in the natural areas. It was apparent that the subsistence farmers were a bit more concerned regarding the change in the natural environment. The reason for this, could be that they were more dependent on the natural resources than the commercial farmers, being more severely impacted by extreme changes. The following section discusses the adaptative measures used in agriculture to ensure environmental sustainability

4.9. Adaptive measures in the agricultural sector

As stated above, the participants understood to some degree that it is important to look after the environment, and that they, as farmers, need to try and minimise their impact on the environment. Some measures that the participants stated were mentioned were crop rotation, to ensure soil quality and livestock rotation to reduce soil degradation and promote natural grass growing. Other participants mentioned the techniques of which they manage their fields so to reduce soil erosion and runoff. Overall, the participants grasped the idea of agricultural adaptation, but were still lacking the holistic approach of Eco-DRR to make the environment a greater priority, which in the end would definitely increase their agricultural sustainability in the future.

As chemicals used by the agricultural sector has a large impact on the environment the participants needed to describe their use of chemicals and whether they knew about any more environmentally friendly alternatives (i.e., fertilizer, weed controlling chemicals as well as pest controlling chemicals). All the commercial farmers were under the idea that to be able to maximize their profits, they needed to use to most effective chemicals, regardless the impact that it might have on the environment. This made economically sense, but did bring into question their commitment to environmental health. Interestingly, many of the commercial farmers did say that the types of chemicals used at the time of the study is far less damaging to the environment than what was used in previous years. Although this is true, many of the chemicals used in South Africa are banned in other countries due to their toxicity. The subsistence farmers were more environmentally conscious, opting to rather use natural fertilizers or more environmentally friendly alternatives such as manure. This could be because manure is cheaper than other more commercially used chemicals, but most subsistence participants stated that they would rather use the more environmentally friendly alternatives, even if they had the choice to use the other chemicals.

The participants had to state whether they believe that their agricultural activities have a positive or a negative impact on the environment around them. All participants were of the opinion that they have a neutral to somewhat positive impact on the environment, as the notion was that they are not wilfully disrupting the environment. Yet, after a short discussion they did, to some extent, agree that there is more that they can do towards environmental sustainability. The commercial farmers were more reluctant to admit that they had a negative impact, where the small-scale farmers understood that they do impact on the environment, but that they try to lessen the amount of impact they have. Many of the participants stated that, even if they wanted to be more environmentally friendly, their then current farming set up did not lend them to quick adaptations, as this includes a fair amount of time, resources and capital.

The final question was regarding any immediate changes that they would want to make to their farming set up, if they had no limitations, so to adapt to the changing climate and the environment. The answers that the participants gave to this section were interesting to note, as all participants gave different answers, some more outlandish than others. This is due to the fact that, even though all of the participants were in agreement regarding the difficulties of farming in the changing climate, the participants all have different worldviews to life, that they all have different opinions to what is needed to be successful, and what it means to be successful.

Some participants were quite content with what they have, wishing only small changes to their farm style to better safeguard their business and the environment. One participant for example only wanted to move one of his chicken coops further away from the natural body of water, as he observed that when bird flu comes and goes with the natural aviary wildlife, the chickens closer to the natural bodies of water are far more likely to get infected. Other participants, which comprised mostly out of large-scale commercial farmers, were more outspoken financially, stating that if they had more money, that they would be more successful. The latter answer from the participants brought into question their fundamental understanding of Eco-DRR, as

their mismanagement of the environment could have a knock-on effect on the sustainability of their farming business, as one of the participants stated “if I had more money and better equipment, I could increase my fertilizer use, which would increase my yields”, not fully grasping the effects that an increase in chemicals have on the environment, if not managed in a sustainable fashion.

4.10. Conclusion

To summarize the findings from the study: All participants are highly dependent on keeping their farming business successful, as this was their main source of livelihood. But, due to the current socio-economic difficulties as well as the change in climate that they experience, they either had to reduce their workforce, or adapt their way and amount of farming to ensure the continuation of their farming practices. Regarding the change in climate, most had a rudimentary idea of what it means, but was less concerned about the technicalities of environmental science than the result it had on their economic livelihood. Many of the participants could recall having heard of the El Niño and La Niña phenomenon, but almost all of the participants could not explain what it is or how it would affect their farming business. This is evident in the fact that they have made adaptations towards the changing climate, to some degree, but almost solely a reactive sense.

Further, as recording of weather patterns and changes in local weather patterns are important (Danari and Masoud, 2012), it is concerning that most participants did not have any process of recording or foreseeing climate variations. Regarding the participants’ perception of environmental sustainability and the framework of Eco-DRR, most of the farmers did say that it is necessary to look after the environment. However, the minimum strategies have been implemented that are regarded as being environmentally sustainable, bringing into question the understanding of what is needed to bring balance between the agricultural activities and the environmental equilibrium.

CHAPTER 5

Conclusion

5. Introduction

This study aimed to explore the drivers that could intensify the El Niño and La Niña events within the North West Province and the implications thereof on the environment as well as the agricultural sector, A literature review was conducted to ascertain what the current understandings were on the future effects that a changing climate may have on both the environment and agriculture regarding both the change in temperature and precipitation, the increase in variability of El Niño and La Niña events as well as subsequent adaptations that can be implemented. From the literature review, it was found that the general temperature increased whereby the precipitation decreased in the study area, as well that the study area was being affected by the climate variabilities cause by El Niño and La Niña events. From this, a survey was designed to understand the farmers perception and understanding of the changing climate and the impact of El Niño and La Niña events, as well as to understand their incorporation of adaptation measures as well as their impact on the environment. The results were presented and discussed in Chapter 4. For the study to be successful the following objectives needed to be achieved. The objectives and the achievement thereof are discussed in the following section.

5.1. Research objectives

The main aim of this study was to understand past and present adaptation methods used in the agricultural sector and to explore further possible adaptation methods, all through the lens of Eco-DRR, in the North West Province with regards to El Niño and La Niña events. This was done through accomplishing the following research objectives:

5. Gain a theoretical understanding of the impact of climate change on agricultural activities in the North West Province.
6. Understand the effects of climate change on both the intensity and occurrence of future El Niño and La Niña events within the North West Province, from a theoretical standpoint.
7. Explore current perceptions of the impact of climate change on agricultural activities and the subsequent implications for environmental and economic health in the North West Province.

Identify current agricultural adaptation methods used by farmers in the North West Province and compare it to widely accepted and implemented methods found in literature.

5.1.1. Gain a theoretical understanding of the impact of climate change on agricultural activities in the North West Province.

Through the use of Chapter 2, it was apparent that there is a negative impact that climate change has on general agricultural activities, so to for agricultural activities conducted in the North West Province. Although a change in climate can be seen as a periodically recurring event which can be described as natural, the accumulated data from the past decades do show a general increase in temperature and decrease in precipitation. This change in temperature and precipitation can affect not only the environmental aspects of agriculture, but also the anthropogenic aspects of agriculture. These trends are true for North West Province as well, which has an adverse effect on the farmers and their current agricultural methods. This is due to the fact that agriculture is mostly affected by temperature and precipitation, which are two components affected by climate change. As stated in the literature review, certain crops have a temperature threshold of generally around 40 °C, which, if the temperature trajectories continue on the same paths, these thresholds will be exceeded in the near future. This is further exacerbated by a decrease in rainfall, which

also negatively impacts the growth process of plants. These changes in climate wont only impact crops, but animals as well, as livestock won't be able to survive extreme temperatures and a lack of water.

5.1.2. Understand the effects of climate change on both the intensity and occurrence of future El Niño and La Niña events within the North West Province, from a theoretical standpoint.

With the change in climate, subsequently increasing the average temperature, it is apparent, through Chapter 2, that climate change does have an impact on the normal process of the El Niño and La Niña events. The effects of El Niño and La Niña has been increasing over the last few decades to a point where the extreme drought and temperatures that happened in 2015 and 2016 could be contributed to the effects of El Niño, as that timeframe had the lowest rainfall in 35 years and the highest temperatures in 10 years.

The global La Niña and the El Niño patterns affect both the precipitation as well as the temperature averages. This intensifies the current climatic activities of a certain area, for example dry season or wet season. These periodic changes in temperature and precipitation due to El Niño and La Niña will have a knock-on effect on the climate, whereas the change in climate will also have an intensifying effect on the intensity of El Niño and La Niña. These periodic changes, along with the already present effects of climate change, have an impact on the environmental, both the ecological aspects as well as the sociological aspects, including agriculture.

5.1.3. Explore current perceptions of the impact of climate change on agricultural activities and the subsequent implications for environmental and economic health in the North West Province.

As indicated by the results of this study (see Section 4,7), there is a rudimentary understanding of what climate change entails, but the more in-depth mechanisms thereof are not understood. This included the change in climate, El Niño and La Niña events, ecology and the interlinked impacts that each has on the other.

That being said, a practical understanding was observed as the shift in seasonal and temporal variabilities were part of the participant's understanding. This lends to the understanding of early warning in a sense, but most of the practices were only reactive in nature, not proactive. There was a consensus on understanding that the change in climate has had a negative impact on the agricultural sector. There was also an understanding that the effect of climate change could potentially increase in the future, but no proactive adaptive processes were discussed as the perceived roadblock for adaptation was purely a lack of capital. It is vital for effective agricultural practices to adopt a proactive process, so not to need to react to changes, but rather being able to foresee the possible changes and adapt to them. Through identifying possible climatic scenarios, different measures can be considered and narrowed down to the most feasible ones for the specific situation.

5.1.4. Identify current agricultural adaptation methods used by farmers in the North West Province and compare it to widely accepted and implemented methods found in literature.

As discussed in literature, there are numerous adaptive systems that can be implemented to reduce the risk of climate change for agriculture. These do include methods that do require a certain amount of capital to set up, but the implementation of adaptive methods in agriculture are not limited to only a constraint on capital. Although some of the participants were in the position to use their capital to further

their adaptive capabilities, many of the participants lacked the immediate availability to such capital. That being said, those that did not have the capital, did adapt to a certain degree in a manner that they could.

5.2. Recommendations

Although the participants showed the ability to adapt to a situation, these adaptations were all reactive in nature and not proactively preparing for the future. A proactive method of analysis the potential risks involved and adapting the present method to be able to withstand possible future scenarios are key to sustainability. Most participants stated that an increase in temperature and decrease in rainfall would make it almost impossible to continue on the same level of farming that they currently are accustomed to, were some stated that a fall in temperature and increase in excessive amount of precipitation would be just as detrimental to their agricultural activities. There was a lack of awareness of possible future scenarios and what could be done to reduce the risk of these scenarios.

There are three main recommendations from this study. The first recommendation from this study includes further studies to be conducted in North West on a larger scale as well as the whole country on strengthening the ability to reduce climate impacts, specifically El Niño and La Niña phenomena, on agriculture and the environment. This could potentially broaden the understanding of how the agricultural sector perceives climate change, the El Niño and La Niña phenomena, as well as agricultural adaptation measures. Agricultural unions can also be reached for their input on the matter. Secondly, the incorporation of the framework of Eco-DRR into the adaptation measures for agricultural activities. These implementations are discussed in Section 2.5.5, Table 2.2, which will have a positive impact on the equilibrium between the agricultural sector and the health of the environment. Thirdly, education on these matters would have a beneficial impact on the ability of the farmers to more easily adapt to a changing climate, as well as being more capable of ensuring environmental

sustainability through adaptive agricultural techniques. This education could be possibly provided through future workshops or educational programs.

5.3. Future perspectives

Although the objectives for this study were met, there were aspects emerged that could be beneficial for both the academic field as well as the implementation thereof regarding future studies on this field of work.

There are studies done regarding the interlinked impacts that climate change ecology, the El Niño and La Niña events and agriculture has on each other, which is also done through this study, few have been done in North West specifically, more studies on a larger scale can be undertaken in North West with a larger sample group, in order to gather the perspectives of the farmers on the above-mentioned variabilities. There is also the possibility of replicating this study in other provinces.

Regarding the El Niño and La Niña events, these can be used as early warning systems to reduce the risk that they bring, such as droughts and flooding. However, more research should be undertaken into using these events as an early warning system North West Province, as well as incorporating the intensifying impacts that climate change has on the El Niño and La Niña events respectively. Future studies can help strengthen the ability to reduce the impacts of these events, which have the potential to become more intense in the future. Further, incorporation of the framework of Eco-DRR into the adaptation measures will have a positive impact on the equilibrium between the agricultural sector and the health of the environment, as a healthier environment can help buffer the effects of climate change regarding agriculture.

As indicated by the results of this study, many of the farmers were lacking the knowledge about the complex mechanisms of climate change, El Niño and La Niña and environmental sustainability, as well as not having any effective process of

recording or predicting the climate variability. Thus, Education on these matters would have a beneficial impact on the ability of the farmers to more easily adapt to a changing climate, as well as being more capable of ensuring environmental sustainability through adaptive agricultural techniques. This education could be possibly provided through future workshops or educational programs.

5.4. Conclusion

To conclude, the importance of food security in a growing population as well as the contributing factors of agriculture and climate change, including El Niño and La Niña is imperative to understand. It is crucial to assess the impact of agriculture on the socio-economic as well as the on the environmental sectors as they are interlinked with the agricultural sector. For agricultural adaptation to be successful in the long term, both the environmental aspects as well as the socio-economic aspects need to be in balance to ensure sustainable development and disaster risk mitigation.

This requires certain key information about the community's and individual's social and economic aspects, which include aspects such as: the availability and use of land for various types of agricultural activities; the local community's economic standing; the mechanization versus labour force regarding local farmers as well as the livelihood drivers regarding economic aspects. In balance with the socio-economic aspects, key information regarding the environmental aspects is also necessary, such as: The current climactic parameters as well as the key drivers of climate change in a specific temporal and spatial system; the possible occurrence of a natural hazard becoming a disaster scenario; current mitigation measures regarding natural hazards and the understanding of periodic changes regarding climatic phenomena.

Lastly, the agricultural aspects that tie in with both the economic as well as environmental aspects, such as: the current practices used within the agricultural business and the impact thereof of both the social and environmental surroundings as well as the ability to change practices if necessary, to ensure adaptability, are essential to ensure sustainable agricultural adaptation towards a changing climate. This can be done through incorporating and implementing more environmentally sound agricultural processes that includes the framework of Eco-DRR to limit the impact of agriculture on the environment, whilst improving the farmers' ability to adapt to a changing climate, simultaneously focusing on the underlying aspects of food security. Regarding the findings of this study, done through the use of a mixed method design and a questionnaire, there is a rudimentary understanding of climate change and the process to adapt to thee changes, but further changes, of both process a perspective, needs to be implemented, with Eco-DRR in mind, if the need for food security is going to be met in the future whilst ensuring environmental equilibrium.

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ANNEXURE A

Example of questionnaire sent to participants.

SURVEY

Agricultural adaptation in North-West, South Africa

This questionnaire forms part of a study which aims to gather information regarding agricultural activities in North-West, South Africa, and the measures taken to adapt to the changing climate. The completion of this questionnaire is completely voluntary and any personal information will be handled confidentially. Please answer all questions honestly and as completely as possible. Thank you for taking the time to participate in this study.

PARTICULARS OF RESEARCHER	
Name and surname	*Pieter-Wernich (PW) Bredenkamp (079 768 1295)*
Affiliation	*North-West University & African Centre for Disaster Studies*
Capacity	*M.Sc. student under supervision of Prof. Dewald van Niekerk (082 338 5919)*
Title of study	*Agricultural adaptation with intensifying El Niño and La Niña periods in North West, South Africa*

SECTION A: BIOGRAPHICAL DETAIL

A. PARTICULARS OF PARTICIPANT				
A1. Name and surname				
A2. Gender	*Male*		*Female*	
A3. Age				
A4. How long have you been farming?				
A5. Number of family members living on farm				
A6. Location of farm (GPS coordinates if available)				
A7. Approximate size of farm				
A8. Contact number				
A9. E-mail address				

SECTION B: Agricultural information

In this section, please indicate your answer with an "X", unless otherwise specified.

B1. In what capacity do you partake in farming activities?	
a. Farm owner	
b. Farm manager	
c. Farm dweller/worker	
d. Other	
If other, please specify:	

B2. Which of the following farming types do you practise?	
a. Subsistence farming	
b. Communal farming	
c. Commercial farming	
d. Other	
If other, please specify:	

B3. What are the main agricultural activities practised on your farm? Tick all applicable.					
a. Wheat		e. Feed		i. Chickens	
b. Corn		f. Cattle		j. Dairy	
c. Sorghum		g. Sheep		k. Wildlife	
d. Sunflowers		h. Pigs		l. Other	
If other, please specify:					

B4. What is the primary type of irrigation that you use?			
a. Drip irrigation		d. Manual irrigation	
b. Sprinkler irrigation		e. Rain	
c. Pivot irrigation		f. Other	
If other, please specify:			

B5. How many workers are employed in your service? Please write down the number.	
Permanent	
Temporary	

B6. How has the amount of workers which you employ changed over the last 20 years?

B7. What percentage of your produce is kept for your own (family or communal) use?			
a. 0 - 10%		f. 51 - 60%	
b. 11 - 20%		g. 61 - 70%	
c. 21 - 30%		h. 71 - 80%	
d. 31 - 40%		i. 81 - 90%	
e. 41 - 50%		j. 91 - 100%	

B8. What percentage of your produce is sold to obtain an income?			
a. 0 - 10%		f. 51 - 60%	
b. 11 - 20%		g. 61 - 70%	
c. 21 - 30%		h. 71 - 80%	
d. 31 - 40%		i. 81 - 90%	
e. 41 - 50%		j. 91 - 100%	

B9. If you sell your produce, to which of these markets do you sell?			
a. Informal markets		d. Large-scale traders' markets	
b. Local farmers' markets		e. Exports	
c. Small local grocery stores / cafés		f. Other	
If other, please specify:			

B10. What percentage of your income is derived from your farming activities?			
a. 0 - 10%		f. 51 - 60%	
b. 11 - 20%		g. 61 - 70%	
c. 21 - 30%		h. 71 - 80%	
d. 31 - 40%		i. 81 - 90%	
e. 41 - 50%		j. 91 - 100%	

B11. Do you have any other sources of income besides farming?	
a. Yes	
b. No	
If yes, please specify:	

SECTION C: Environmental information

C1. What do you understand with the term "climate change"?

C2. Please provide the average minimum and maximum temperatures on your farm and its surrounding area, as well as your perceptions (and evidence if available) regarding how it has changed since you started farming.		
Season	*Min. temperature (°C)*	*Max. temperature (°C)*
Summer		
Autumn		
Winter		
Spring		
Comments:		

C3. Please provide the average yearly rainfall on your farm and its surrounding area, as well as your perceptions (and evidence if available) regarding how it has changed since you started farming.	
Average yearly rainfall	mm
Comments:	

C4. Have you ever experienced any disasters on your farm? If yes, please elaborate.

C5. Have you observed any *extremely* wet or dry seasons in the past? E.g. 1982-1983, 1997-1998 and 2009-2010. Please provide evidence, if available.

C6. How has any changes in the climate affected your farming activities? E.g. productivity, planting and harvesting times, soil quality and water retention, irrigation use, pest infestations, etc.

C7. Has the type of farming which you practise changed since the establishment of the farm? If yes, please elaborate.

C8. If the climate were to change in the future (e.g. hotter/colder by 3°C, wetter/dryer by 50 mm, change in wet season, etc.) how would it affect your current agricultural practises and/or methods?

C9. How has the natural environment on and around the farm changed since the establishment of the farm, or since you have taken over the farming activities? E.g. erosion, change in volume of water bodies, change in growth/biodiversity of fauna and flora, etc.

C10. Do you have any plans in place to ensure that the impact of your agricultural activities on the environment is minimized (e.g. crop / livestock rotation)? If yes, please elaborate.

C11. Do you make use of chemicals (fertilizers, pesticides, dips, etc.) on your farm? If yes, what type do you use and how often do you use it?

C12. Are you aware of more eco-friendly alternatives to the chemicals that you currently use? If yes, what is your opinion on using these alternatives?

C13. Do you believe that your agricultural activities have an overall positive or negative impact on the natural environment? Please elaborate.

C14. If you could instantly change any of your farming activities to adapt to a changing climate, what would you change?