Effects of climate change on productivity among small-scale maize farmers in the Ngaka Modiri Molema District

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Dissertation accepted in fulfilment of the requirements for the degree Master of Science in Agricultural Economics at the North-West University

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Graduation: July 2023

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DECLARATION

I, Kgomotso Esther Khumalo declare that the work in the submitted dissertation is my work in fulfilment of the requirements for the Master of Science Degree in Agricultural Economics at the North-West University (Mafikeng Campus). This was under the supervision of Dr Khulekani Sithembiso Nxumalo and co-supervised by Ms Thatho Marjorie Moagi. All the sources used in the study have received acknowledgements through citations and references. This work has not previously been submitted to the North-West University or any other institution.

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ABSTRACT

Climate change is a global phenomenon that has various effects on the agricultural industry. The Department of Agriculture, Forestry, and Fisheries identified maize as the most important grain crop in the country, as it accumulates a larger proportion of the gross value of field crops. As such, the study assessed the effects of climate change on yield among small-scale maize farmers in the Ngaka Modiri Molema District Municipality, North-West Province, South Africa. The particular emphasis of the study was on the socio-economic standards of the small-scale maize farmers in the Ngaka Modiri Molema District Municipality, their perceptions and their knowledge regarding climate change. These were analyzed through descriptive analysis, while the assessment of the adaptation strategies was through a multinomial logistic regression model and the assessment of yield concerning climate change was through the use of a multiple linear regression model.

The multiple linear regression model revealed that the volatility which was experienced throughout the area on a yearly valuation resonates with the particular climatic setting; therefore, if temperatures were not favourable in the year of assessment and greater rainfall were to occur then this would influence the overall maize yield in the area of analysis. On the other hand, the multinomial regression model indicated that the farm size, household size, level of education, experienced climate effects, contact with extension officers and the farmer's exposure to Agri-park initiatives implemented by the DAFF particularly influenced the adaption of most strategies in the area. The strategies evaluated in the study include the following: changing production practices, praying, improved irrigation efficiency, and a combination of the aforementioned strategies. The study concludes that climate change has an immense influence on yield production and the choice of adaptation strategies amongst small-scale maize farmers in the Ngaka Modiri Molema District Municipality. The major recommendations of the study is the increase of the influential impact of nigh time temperatures on the yield of maize and the increased participation of small scale maize farmers amongst DAFF exhibition etc. as it increases farmers yield.

Keywords: *climate change, small-scale maize farmers, Ngaka Modiri Molema District, El-Nino, productivity*

ACKNOWLEDGEMENTS

The writing of this dissertation came with great perseverance. Therefore, I would first like to thank God for this achievement, I would never have realized this stage were it not for Him. I appreciate the patience and support that my supervisors gave me (Dr. Khulekani Nxumalo and Ms. Thato Moagi), their immense support, encouragement, and feedback are highly appreciated.

I would also like to thank the National Research Foundation (NRF) for financial support. When I was bound to be defeated towards studying for my Master's Degree through my financial distress the NRF came to my rescue.

I would like to give the greatest acknowledgements to my brother (Sibusiso Khumalo), younger sisters (Neo Khumalo and Lebo Makena), my aunt (Kgomotso Sarah Motsepe), and my father (Manie Khumalo) for the greatest support that they gave me towards this accomplishment. Their encouraging words spurred me on when I doubted myself.

DEDICATION

This study is dedicated to my late mother in heaven (*Priscilla Thulisile "Khonzi" Khumalo)*.

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LIST OF ABBREVIATIONS

SAWS	SOUTH AFRICAN WEATHER SERVICES
AGRI – PARK	AGRICULTURAL PARK
WMO	WORLD METREOLOGICAL ORGANIZATION
GHG	GREENHOUSE GAS
IPCC	INTERGOVENMENTAL PANEL ON CLIMATE CHANGE

CHAPTER ONE

1.1 Introduction

Climate change has become an intriguing study in recent years; the total output related to this field has influenced the mitigation and adoption of adaptation strategies over the years. Thus, the first chapter of the dissertation introduces climate change and its diverse impacts on the agricultural sector. The challenges faced by the sector, particularly in the Ngaka Modiri Molema District Municipality, are of fundamental importance. Therefore, the study adopted research-specific objectives as a means to cover the scope of the study. The chapter fully underlined the minimal challenge areas discussed in the limitations and the particular importance and significance of the study.

1.2 Background of the Study

Change has become a particular driver of every generation; this recognition derives amongst every sector, including the technological, economic, political, educational, and health sectors. All of these changes have affected society; to some extent, society instigates them. However, a change that has influenced a wide spectrum of the human race is climate change (the United States Environmental Protection Agency, 2016). It has influenced the societal health state, transportation, infrastructural buildings and it results from both natural and human-induced activities (Stern & Kaufmann, 2014). Greenhouse gases are a form of natural cause of climate change absorbed from the earth's surface. While this process is necessary to support life on earth, it increases thermal radiation, resulting in increased temperature (the United States Environmental Protection Agency, 2017). Human-induced climate change involves burning fossil fuels, which results in excess amounts of greenhouse gases being trapped in the earth, thereby inducing the potential effect of climate change (VanLoon & Duffy, 2017).

Egan and Mullin (2017) emphasized that climate change is recognized through global warming and that a high correlation is anticipated to exist between the two terms (i.e., global warming and climate change). As defined, global warming is the process of the increased temperatures of the earth through greenhouse gases such as carbon dioxide, methane, and nitrous oxide (MacMillan, 2016). Over the decades, Forabosco *et al*. (2017) recognized that the temperature variable was not singularly fluctuating, but there was variability amongst the overall variables (i.e., precipitation, humidity, and wind). Hence the term 'climate change' was developed; to provide a broader perspective and outline the pre-existing variances of humidity, cloudiness, rain and precipitation. An increase in carbon emissions, together with the concentration of greenhouse gases, results in the instability of the climate. Carbon dioxide emissions are amongst the largest contributing gases towards global warming; however, the contribution is both attributed to human and natural processes (Al-Ghussian, 2019).

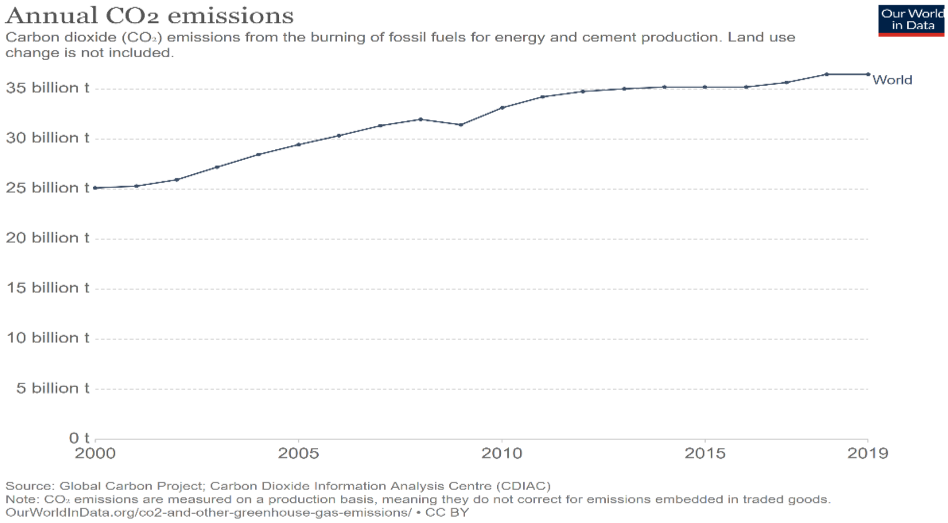

Figure 1.1: Annual carbon dioxide emissions. (Source: Ritchie, Roser and Rosado, 2020)

During the recent two decades, there have been increased carbon dioxide emissions coupled with significant greenhouse gases (methane, nitrous oxide, etc.). The process that brings about increased carbon dioxide emission results in global warming, causing heat waves, droughts, cyclones, blizzards, and rainstorms (World Meteorological Organization, 2021). The increased temperatures have an impact on sectors such as society, the economy, and the environment. Thus, various institutes' research on climate change has been carried out; the focus of the investigations is mainly on the impacts, causes, and resilience strategies and, as indicated; the correlation of climate change with global warming (Nordhaus, 2019). The World Metrological Organization (2019) recorded 2015–2019 as one of the most harmful periods. The 2019 summer resulted in record-breaking wildfires that expanded to the Arctic regions and set new records and widespread fires across the Amazon rainforest (Woodward, 2019). The condensed heat was regarded as the "deadliest meteorological hazard" by being the critical stimulus of rising ocean levels and setting new temperature records across Europe, North America, Asia, and Southern Africa (World Metrological Organization, 2019). In line with the severity of climate change, regions such as the African continent experienced a harsh drought catastrophe between 2015 and 2019 (Wehrli *et al.*, 2019). Countries located within the continent recorded the most considerable drought duration and intensity; thus, the extreme impact of climate change influenced the land cover, agricultural production, and food security (Kogan, 2019).

The prolonged duration of the drought resulted in a significant impact within the region and led to various effects, however, the region's different climatic zones (Xu *et al.*, 2019) solely influenced the variable impacts amongst the regions of Africa. The African continent has been experiencing a difference of climatic zones over the years; however, dry climatic periods have always prevailed especially in recent times. The regions on the African continent have been experiencing a tropical climatic zone, with the exclusion of the Mediterranean region and South Africa (Seneviratne *et al*., 2016). Xu *et al*. (2019) stated that the influence of the climatic zone concurrent to the effect of drought results in the agricultural sector being the most vulnerable to climate change. It poses a significant threat to the sector due to its increased sensitivity and associated costs (Hong *et al*., 2020). An increased impact of climate change on agriculture is projected by the end of the century. The number of hot nights and the length of agriculturally little precipitation may result in variable yield and possibly bring about animal mortality (Jbawi, 2020). Extreme temperatures will propel higher production costs and result in the yield loss of animal commodities such as meat, eggs and milk (Hatfield & Preuger, 2016). Climate change has dramatically influenced the availability of arable land through major attitudinal shifts and the extensions of croplands across different regions (Stiles *et al*., 2017). Thus, crop production has been identified as one of the most affected processes over the years (Parker *et al*., 2019). Climate change has the capability of altering the concentrations that are associated with weeds, diseases, and insect pests, which when combined result in changes in the occurrence and timing of the pollinator's lifecycles, therefore causing detrimental variable effects on the growth and yields of crops (Dubey *et al*., 2019).

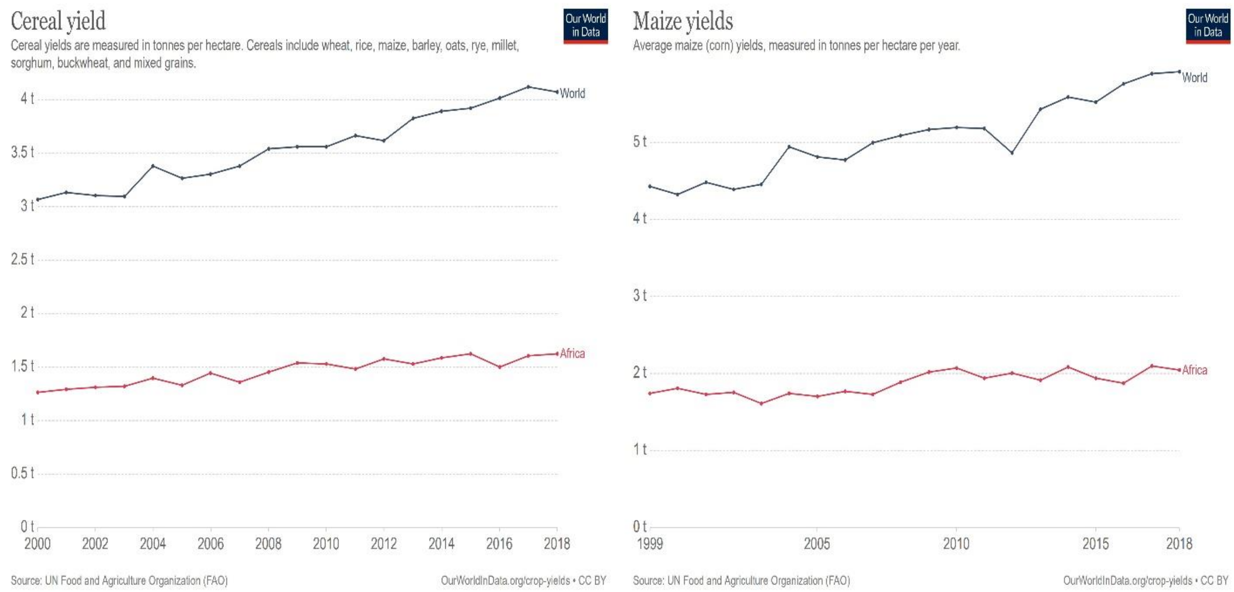

Figure 1.2: Crop output differences between the World and the African Continent (Source: Ritchie & Roser, 2013)

Globally, the level of crop production output has been vastly variable, and the persistence of inconstant growth and yield rates of crops put farmers at a high environmental vulnerability level (Abid *et al*., 2016). Farmer's vulnerability comes from being exposed to the phenomena, their lack of adaptability capacity, and the sensitivity of their agricultural produce (Ubisi *et al*., 2017). Ochieng (2016) indicated the vast impact of climate change on both large-scale and small-scale farmers. However, the differing expertise amongst the large-scale and small-scale farmers results in the adaption strategies being much more convenient for the former. At the same time, it indicates the latter to be the most vulnerable group in the perception of climate change (Salami *et al*., 2019). Zantsi *et al*. (2019) defined small-scale farmers in the South African context as, farmers who participate in the farming sector with a lower sized land and without the use of advanced and expensive technologies.

In most regions, the existence of small-scale and emerging farmers results in employment creation for a more significant part of the community through sustainable food production systems, local agro-processing plants, poverty alleviation, and income generation from agricultural land proceeds within those areas (Jouzi *et al*., 2017). Nevertheless, they face the challenge of climate change. Their vulnerability comes from predominantly being set in the outskirts and from various socio-economic, demographic, and policy trends limiting their ability to adapt to change (Mazibuko, 2013). The inability of the farmers to adapt to changing climatic conditions arises from rain-fed irrigation methods; they nurture marginal areas and are deprived of access to practical and economic support that could help them finance more climate-resilient agriculture (Mereu *et al*., 2018). The study by Annosi *et al*. (2019) highlighted that the lack of investment and advanced technology that is in line with the industrial revolution positions small-scale farmers at high risk, and due to these factors, it varies the contribution of the farmers towards the gross domestic product (GDP). However, they account for a significant portion of food security and poverty alleviation.

The overall performance of farmers is predisposed by the country's development level (Tallentire *et al*., 2019). Developing countries, like South Africa, lack the technological advancements necessary for effectively and efficiently processing raw materials; this results in lower levels of production outputs and returns than what they would have had with the advanced technologies (Shaner, 2019). Under-developed or developing countries cannot change and adapt to modern agricultural processes, this mainly affects small-scale farmers (Makuvaro *et al*., 2018). One example that small-scale farmers lack is the variety of maize seeds. Alternatively, they nurture traditional cultivars conserved through "seed saving and seed exchange networks" (Dwivedi *et al.*, 2019). The improved varieties of maize are noted to be resilient to drought and many other environmental impacts of climate change. The different cultivars of maize in other countries have resulted in ample amounts of maize being produced. In contrast, the Sub-Saharan African countries produce an amount that is far below what they would have had with the modern varieties (Abate *et al*., 2020).

South Africa's Department of Agriculture, Forestry, and Fisheries (2017) identified maize as the most important grain crop in South Africa, accounting for approximately 46.2% of the gross value of field crops. Almost every province has a degree of production output, whether small or large scale. The changing climate can create significant and devastating maize production challenges, leading to economic and financial difficulties for agricultural producers (Herman, 2017). The 2015 and 2016 El Nino resulted in severe impacts within South Africa. The Grain SA (2020) drafted data that indicated the vulnerability which was experienced by the grain sector during this period of 2015/16 and 2019/20.

This data indicated that the crop production sector saw a 50% reduction in output production. Wandaka (2016) highlighted that the temperature increase and the little precipitation greatly impacted maize production and the maize revenue of farmers.

1.3 Problem Statement of the Study

Climate change can, to a large extent, challenge agriculture. The specific Ngaka Modiri Molema District Municipality vulnerability arises due to increased temperature, water shortages and precipitation variability, amongst other factors (Moseki, 2017). As a commonly familiar environmental problem worldwide, it requires urgent actions to be monitored and contained. Since the North West Province is amongst the most significant contributors to maize production in South Africa, it is highly vulnerable to being affected (Samuel & Sylvia, 2019). The changeability in climatic variables can affect maize production within the region, and the manifestation of the phenomena in various sectors of the economy is not given in the quantitative form. The quantitative outcome of climate change within the agricultural sector has not been determined. As a result of the rising climate challenges, small-scale farmers within the Ngaka Modiri Molema District Municipality are exposed to the volatility of climate due to the climate zone in which the area exists. Small–scale farmers will find themselves having to use more inputs for production. Therefore, climate change can potentially affect the economic standing of the farmers through reduced yield. The dispersion of the climate within the study area can affect agricultural production on a more extensive and smaller scale (Oduniyi, 2018).

1.4 Research Questions of the Study

1) What are the socioeconomic characteristics of small-scale maize farmers?
2) What is the knowledge of the small-scale maize farmers about climate change?
3) What are the perceptions of small-scale maize farmers about climate change?
4) What are the adaptation strategies adopted by small-scale farmers in dealing with climate change?
5) What are the effects of climate change on maize yield?

1.5 Research Aim and Hypothesis of the Study

1.5.1 Main Objective of the Study

The study aims to assess the effects of climate change on yield among small-scale maize farmers in the Ngaka Modiri Molema District Municipality, North-West Province, South Africa.

1.5.2 Specific Objectives of the Study

1) Describe the socio-economic characteristics of small-scale maize farmers.
2) Assess the knowledge of small-scale farmers on climate change

3) Assess the perception of small-scale maize farmers on climate change.
4) Describe the adaptation strategies adopted by small-scale farmers in dealing with climate change.
5) Determine the effects of climate change on maize yield.

1.6 Hypotheses of the Study

Objective 4:
H_0: There is no statistically significant relationship between socioeconomic or demographic characteristics and the choice of adaptation strategies utilized by small-scale maize farmers.
H_1: There is a statistically significant relationship between socioeconomic and demographic characteristics and the choices of adaptation strategies utilized by small-scale maize farmers.

Objective 5:

H_0: There is no statistically significant relationship between climate change and yield
H_1: There is a statistically significant relationship between climate change and yield.

1.7 Limitations of the Study

Many studies suggest that the assessment of climate change on the economy should begin with the assumption of future emissions; however, the study used a different approach. It used projections from the recently experienced period of climate change, thus providing evidence towards the assumptions of already investigated studies. In this case, it has provided for future expected projections through marginal analysis. A challenge, in this case, was the availability of periodic data from the specified periods of study. The data collection procedure was from white and yellow maize farmers. Farmers were interviewed on the estimated economic projections from 2016 to 2021 to assess the volatility that climate change imposed on their farms and provide a linkage of the economic flow of the farms with climate change. The Covid-19 pandemic could alter the results of the production output for the 2020 production year, and the specific climate variables that the study focused on are temperature and precipitation changes.

1.8 Rationale of the Study

The burning of fossil fuels results in increased carbon dioxide concentrations in the atmosphere, eventually causing increased risks of climate change daily due to the variability of climate overall (Kellogg, 2019). The study of climate change within the Ngaka Modiri Molema District Municipality arises correspondingly to the agriculturally intensive economic system that drives the study area (Oduniyi *et al*., 2020). The economic background of the smallholder farmers is an entire area in determining the progress and the functioning of the farm in the coming years. A review of the farmer's economic setting through yield provided quantitative data, allowing the development of effective mitigation and adaptive strategy that is in line with climate change (Tlholoe, 2016). Thus, the study analysed climatic conditions and agriculture, specifically maize production within the North West province. While agriculture is a particular driver in the economy of the North West province, it is also precious to individual households. The study looked into the economic impact (yield) that the phenomena displayed on small-scale farmers within a region driven by agricultural production and the long-term effects that it is imposing on yield through a time series analysis. The study reveals the quantitative impact that climate change has and will be posing on small-scale maize farmers, and they will have the opportunity to express their views on this particular matter. The granted economic background and adaptive strategies provided by the study will enhance the knowledge of agricultural farmers participating in maize production. If climate change persists, then the effect that climate change possesses on the maize production output is minimized to maintain and maximize returns. This study will explain the farm revenue losses and support government policy-makers on climate change matters.

CHAPTER TWO: LITERATURE REVIEW OF THE STUDY

2.1 Chapter Introduction

This chapter addresses the broader perspective of the concept of "climate change." The climatic scenario correspondingly affects the yield of agriculture. It thus creates a means to underline the scope of management practices utilized by small-scale maize farmers to withstand the effects of climate change. The conceptual and theoretical frameworks give a general outline of the literature review and research-bound literature about the phenomena.

2.2 Conceptual Framework

This study makes use of a 'concept mapping' framework, which was initially developed by Joseph Novak in 1984 to outline the relationships between variables that are to be used within a particular study. The framework will be able to reveal the relationship between climate change as an independent variable and small-scale farmer(s) yield as a dependent variable.

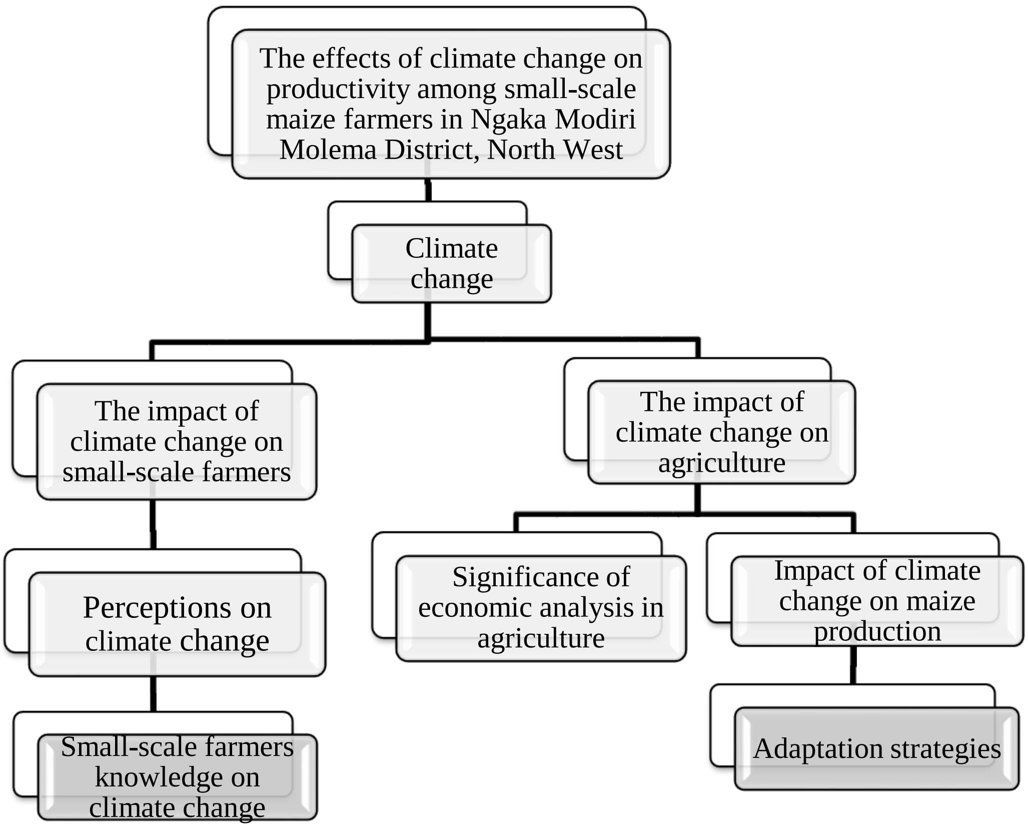

Figure 2.1: Conceptual Framework

2.2.1 Climate Change

Climate change is primarily associated with terms such as "land degradation, rising ocean levels, and widespread wildfires." This is due to its harsh impacts on the environment, which leads to hazardous meteorological impacts at large (Shiru *et al*., 2020). It is a term that defines the changing climate of a particular region, and it outlines its occurrence on various aspects of the human, economic and environmental race (Ruiz *et al*., 2020). The activities bringing about this global phenomenon are numerous such as natural (variations in the solar cycles) or human activities (such as the industrial revolution, and farming activities) (Angelo & Du Plessis, 2017). Israel *et al*. (2020) stated that the agricultural sector contributes about 17% of the greenhouse gas emissions (GHG); this is through the processes of "land clearing and cultivation, wood fuel, and ploughing or pesticides and fertilizer use". With the particular impacts that climate change is imposing on various sectors, the assessment of climate change in recent years is of the utmost importance. Disregarding measures for tracing the occurrence of climate change might result in significant environmental, human and global catastrophes (Probst *et al*., 2019). Thus, climate assessment and monitoring techniques are essential and aid by providing a broad occurrence probability of climate change and the future expected impacts on society, the environment, etc. (Kundzewicz *et al*., 2018).

2.2.1.1 Agricultural Impact of Climate Change

Mendelsohn (2009) concluded that climate change has the potential to have an immense impact on agriculture located within the tropical and subtropical parts of developing countries rather than that located within temperate locations. The evidence proposed by the UCAR Centre of Science Education (2011) showed that the climate of a particular region is mainly dependent on the distance it is from the equator. As such, regions closer to the equator experience higher temperatures than those further from the equator. The study also indicated that crops are amongst the most sensitive organisms due to erratic rainfall patterns. Therefore, an increase in rainfall in dry locations is favourable while inconvenient for rainy locations, as it increases the probable occurrence of waterlogging (Amoateng *et al*., 2018). Expectations are that farms set within the low latitudinal planes could experience a colossal amount of environmental damage, coupled with the continual reoccurrence of hot and dry climatic conditions (Thavhana, 2018). The extent of climate change damage depends on the state of the climate, as the impacts of climate change for areas experiencing relatively mild and wet conditions will be minimal (Hampf *et al*., 2020). In this regard, the Sub-Saharan African region saw a decrease in agricultural production, as climate change influenced the peak of temperatures over the years (Phokele, 2015).

2.2.1.2 Climate Change and Food Supply: An Economic Perspective

The rapid increase in the population and the intensity of climate change challenge the food system in mainly Africa and the Middle East, China, Europe, and Asia (Fitton *et al*., 2019). The Southern African region produced cereal output below the five-year average by 7% (28.7 million tons); this increased the number of people in need of assistance by 13.8 million (WMO, 2017). The Food and Agriculture Organization (2018) suggested using one-third of the land surface for crops or pastures to reach the projected population growth. The worldwide proportion of food supply and demand increases food prices due to the decrease in the supply of food falling short of demand, and vice versa. As a result, the global agricultural product trade intensified, which affected both exporting and importing countries (Lee, 2009). Importing countries are rather concerned about the levels of food security while exporting countries are concerned about the farm income of local farmers.

Agricultural trade is key to balancing the food demand and food production levels. However, the inclusion of climate change creates an imbalance in the competitiveness and comparative advantage amongst countries, thus creating a fairly less or greater profitable advantage to trade with new (or other) trading countries (Santeramo et. al., 2021). Thus, 'economic analysis' in recent times is a fundamental aspect of a farming management tool (Caplinska & Ohotina, 2019); it assists in tracing the use of resources within their enterprises to efficiently produce goods within their limited resources (Altieri, 2018). The term defines as the assessment of economic systems to find the system that is most cost-efficient with a limited amount of resources (Iacovidou *et al*., 2019). Its scope is to find the ideal (profit-maximizing) set of variables by considering the input used at a given period, precisely identifying if the gains of one other entity of the input are more significant than the costs (De Loecker *et al*., 2020). In an empirical assessment by Jain (2007), explained the economic impact of climate change on agriculture in Zambia, the study demonstrated an impact on the net farm revenue due to climate change. The net farm income displays the level of production of the farm; it also determines whether the farm is functioning at a profit or loss (Langemeier, 2016). It is a crucial point in the maintenance of farm operations. The empirical study enabled the development of mitigation and adaptation strategies that were in line with the economic functioning of the enterprises.

2.2.1.3 Food Security

The challenges brought by climate change on the agricultural system have societal implications of reducing the food supply resulting in national food insecurity. Food security is mainly based on four pillars i.e. food availability, food accessibility, food utilisation and food stability; an individual's inability to acquire these would demonstrate them as being "food insecure" (Bilali *et al*., 2020). Climate change alone imposes a negative effect on natural resources such as the water supply; temperature variability, etc., and the resource implication in correlation with agriculture reduces the supply of agricultural production (Šimunić *et al*., 2019). According to the intergovernmental panel on climate change (IPCC) the varying contribution of the agricultural sector across the African region suggests that the sector is a critical contributor to the gross domestic product (IPCC, 2007),. Thus, a decrease in the sector could significantly reduce the food security levels within the region. Masipa (2017) illustrated that the decrease in arable land is highly related to carbon emissions. The vulnerability due to climate change affects the Southern African region, while simultaneously decreasing the food production output which leads to a surge in food prices. Population growth is not proportional to crop production, this greatly challenges food security and the dependency of rural households on arable land results in food insecurity (Masipa, 2017).

2.2.2 Small-scale Farmers' Impact of Climate Change

Conversations around the impacts of climate change on agriculture amongst small-scale farmers vary. Some researchers (Mendelsohn, 2009; Zaehringer, 2018 & Abegunde, 2020) found that small-scale farmers experience negligible impact. At the same time, the research conducted by Ngcoya (2017) identified that the effects of climate change had forced small-scale farmers to find a middle ground for dealing with the phenomena. As indicated by Mendelsohn (2009), small-scale farmers can switch crops or livestock for a more profitable enterprise during climate change. A study conducted by Frank and Buckley (2012) opposed the assertion by indicating that small-scale farmers are vulnerable to the impacts of climate change due to their stricken line of poverty, marginalization and reliance on natural resources. The farming techniques instigated by small-scale and large-scale farmers predominately influence the differences in agricultural crop production (Ntshangase *et al*., 2017). In most cases, small-scale farmers utilize systems such as tillage, which damage the soil structures, resulting in a reduction in crop production. The occurrence of climate catastrophes results in production inefficiency.

2.2.2.1 Adaptation of Small-scale Farmers

The persistent effect that climate change has is amongst the most prominent factors contributing to developing adaptation strategies (Zougmoré *et al*., 2016). As identified, small-scale farmers can switch crops/livestock for a more convenient enterprise when facing climatic catastrophes (Mendelsohn, 2009). Mix cropping, changing planting dates, the use of drought crop(s), crop diversification, improved varieties and furrow irrigation systems are among the adaptation strategies that small-scale farmers implement when faced with climate change (Kom *et al*., 2020). Mix cropping or intercropping is the approach of growing two or more crops within a single growing season. The advantage of this technique during climate change is that it decreases the possibility of crop failure led by environmental stress and increases the probabilities of improved yields of crops due to the complementary nature which they may have on each other (Akinnagbe & Irohibe, 2014). Changing planting dates ensures an adjustment towards the seasonal growing periods to the changing climate (Dharmarathna *et al*., 2014). Using drought-resistant crops is a rationale for the reduced annual rainfall patterns in South Africa, moreso after the 2015–2016 drought catastrophe (Muthelo *et al*., 2019). The diversification of crops is a strategy that ensures that farmers can recover revenue losses from other crops in a situation where one fails (Lakhran *et al*., 2019). Seedling factories are designed to ensure improved varieties of seeds that will be in line with climate change are provided to farmers and extension officers in such cases should ensure that the small-scale farmers receive the readily available varieties suitable for the particular climatic scenarios (Cacho *et al*., 2020).

2.2.2.2 Climate Change Adaptation Barriers

Adaption in agriculture is the most crucial strategy for ensuring that yield is effective and it requires adequate planning to reach the maximum production capacity (England *et al*., 2018). The associated risks and challenges faced in agriculture require solid adaptation strategies; however, inadequate subsidies, insufficient technological use, institutional capacity and a lack of understanding of climate change issues act as barriers to adaptation (Masud *et al*., 2017). The outlined barriers had been investigated by Myeni *et al*. (2019) in the Eastern Free State (South Africa), the study highlighted the barriers faced by smallholder farmer's in-line to the perceptions. Smallholder farmers depend heavily on rain-fed agriculture and the volatility of the precipitation has made them the central area of study (Belay *et al*., 2017).

2.3 Modern Agriculture and Climate Change

Farmers have adapted to a modern agriculture system; it is the ever-improving practice of farming for farmers. The practice uses available natural resources which ensures abundance (Gulyas & Edmondson, 2021). The development of modern agricultural practices was due to the identified need for technological systems that would reduce food insecurity (Takahashi *et al*., 2020). South African small-scale farmers rarely receive exposure to the practice due to their limited exposure to credit facilities and insurance (Wale & Chipfupa, 2021). Modern agricultural practices have an identified negative influence as it is amongst the contributing factors that induce climate change; this occurs through soil depletion and degradation, deforestation, biodiversity loss, coastal water pollution and the acidification of the oceans (Ma & Sexton, 2020). Agriculture contributes to climate change through greenhouse gas emissions (Chang *et al*., 2021). However, techniques such as "crop monitoring" have been identified to reduce the contribution of agriculture towards climate change (Berger *et al*., 2020). Farmers will be able to accurately calculate the required quantity of fertilizers and observe the probable extreme weather patterns expected within the area; in this regard, farmers will have an acute knowledge of when to apply the herbicides/ fertilizers and the plantation dates. However, modern agricultural practices by commercial farmers are not regarded as adaptation strategies as they use the available resources to maximize their production output (Dumont *et al*., 2020).

2.4 Theoretical Framework: Climate Change & Maize Production

The influence of climate change in relation to maize production is undertaken through different methodological approaches. The different approaches typically results from the theory base of the study. As such the theories that have supported various studies on the influence of climate change on maize production are: the production function theory and the Ricardian's Economic Rents theory. The former is used in a mathematical function form to outline the possible quantities of outputs attainable from a specified combination of resources while the latter primarily outlines the overall influence of climate change on land value or farm revenue. This particular section outlines the theoretical aspects bound to the study, and the supporting literature review on the theories will give an overall analysis of the study area.

2.4.1 Theoretical Framework

The theory of Economic Rents by David Ricardo (1817) was the initial theoretical basis of the Ricardian model; however, much of the practical application of the climate-land value analysis is from Mendelsohn (1994). Medelsohn's (1994) approach used an economic perspective to measure the impact of climate change along with the economic and other variables imposed on the land values (or farm revenue) while using cross-sectional data. The assumption made by Ricardo (1817) is that there was an assessment of the farmland value under perfect competition. The Ricardian theory estimates the values of the cross-sectional variation of land values (or net revenues), which can be explained by climate and other confounding factors while measuring the long-run impacts of climate change, taking into account the ability of each farmer to adapt.

Coster and Adeoti (2015) conducted a study involving the Economic Effects of Climate Change on Maize Production and Farmer's Adaptation Strategies in Nigeria using A Ricardian Approach. The study developed the Ricardian Economic Rents theory to estimate the future impacts of climate change on maize production under varying environmental circumstances. Thus, the study area was divided into three agroecological zones: rainforest, guinea, and montane savanna. The study area's division was done to fully represent the influence of the climate, soil and farmer revenue on the output of maize within the region amidst climate change. The study's overall results indicated the high climate change variabilities concerning maize production in the Nigerian region. The increase in rainfall during rainy seasons amongst the three agroecological zones had increased the marginal net revenue. The dry season precipitation increase revealed contradictory results as the marginal revenue saw an upsurge in the rainforest zone, respectively, while negatively affecting the guinea and montane savanna zones. Nevertheless, the study underlined the temperature increase's positive impact on all three agroecological zones in both seasons. Due to the future expectations of the methodological analysis, the study concluded that climate change would negatively affect future maize production in the Nigerian region.

Another study conducted by Wandaka *et al*. (2016) supported the future evidence proposed by Coster and Adeoti (2015). Nonetheless, the general variances between the two studies were in the locality and the method of analysis. Wandaka *et al*. (2016) assessed the future impacts of climate change on maize production in the Kenyan region through the production theory function formula; the results stipulated indicated that climate change has a substantial future impact on maize production. The study used the climate, soil, and household data from 1357 households, during which a cross-sectional regression analysis consisted of a three-stage division of the data. To indicate the influence of the variables relative to the net farmer revenue. The first model consisted of climatic data and the second division accumulated the soil and climate data. The final division consisted of the climate, soil and household data; therefore, the final division was a total accumulation of the overall data used in the study. According to the study, there is an unsystematic relationship between the climate variables and the net farm revenue. The data presented indicated that the increased temperatures in summer and the increased winter precipitation had adverse effects on the net farm revenue, contrary to the high summer precipitation, which had a positive impact.

The results presented by the two prior studies might have resulted from the different methodological approaches. Thus, the study of Nxumalo (2014) used an incisive technique of instigating the Production and Ricardian theories to analyze the economic impact of climate change on maize production in the Jozini municipality, Kwa-Zulu Natal. The assessment of the overall data was done through descriptive statistics, gross margin, multiple regression analysis and the Ricardian model with data collected from 100 smallholder maize farmers from the area (dry-land and irrigated land). The Ricardian model was used to highlight the economic influence that climate change had on the production of maize amongst the categorized areas. Amongst the smallholder farmers, the model results indicated that the climate, household, and soil variables significantly impacted the net farmer revenue, thus significantly influencing the maize production capacity. The production analyses were instigated through the gross margin to measure the profitability of the enterprises under investigation; it had identified that those farmers irrigating their farmland had a more significant gross margin than dry-land farmers. The study identified that education and access to credit significantly influenced the farmer's yield as they had more knowledge and information on profit maximization strategies. Results of the Ricardian model also identified that farmers dependent on rain-fed agriculture were the most affected as the differentiation in climatic variables could immensely influence the maize output. Recommendations from that study were that the farmers use irrigation techniques to reduce the potential effects of climate change.

2.4.2 Literature Review on Climate Change and Maize Production: North West Province Perspective

Maize (*Zea mays* L.) is amongst the leading grain crop in the country that every province has a production contribution. The country's landscape is well suited to allow the production of maize in all the provinces, as it requires a daily mean temperature above 19 °C or an average summer temperature greater than 23 °C. The increased maize yield is in correlation to the climate setting and topographical characteristics of the farmland; hence, this warm weather crop is primarily grown in the Free State, Mpumalanga and the North West Province

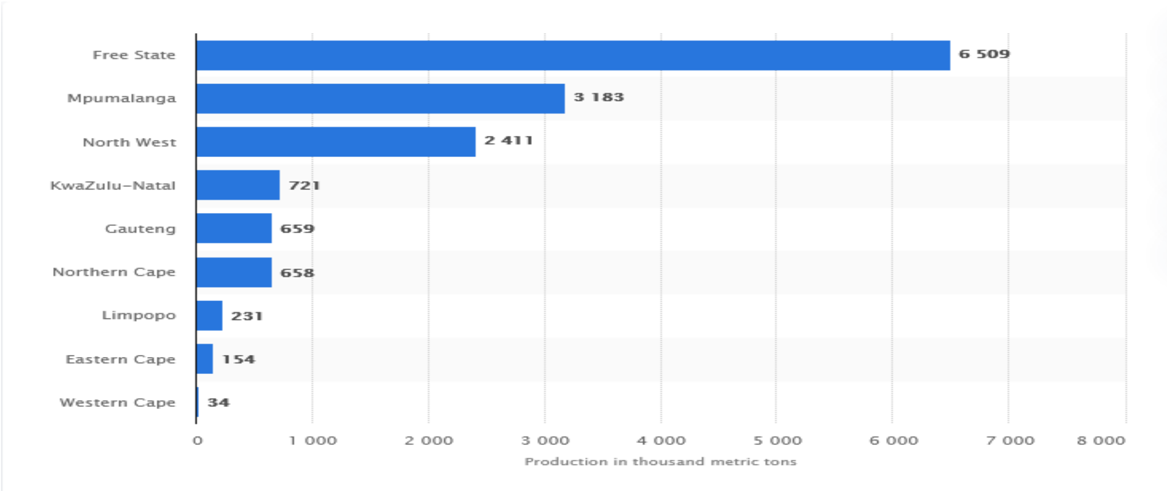

Figure 2.3: Maize production output per province Source: Galal (2022)

The "maize belt" provinces have similar environmental characteristics of flat land surfaces and mean annual rainfall patterns ranging between 500 to 650 mm. An accumulation of arable land is more significant than in most provinces, thus creating a more significant production advantage and capacity to nurture maize production. The North West province is the "food basket" province due to its dominance in white maize and sunflower production. However, Diko and Jun (2020) highlighted that maize production trends are depreciating. Such trends have been influenced by a lack of land, inputs, capital, extension services, and market accessibility. The uncertainties that arise with the variability in the climate and the potential of farm hazards have been the significant attributes that decrease agricultural production in the province (Thomas et. al., 2007). Climate change affects air and water quality in the province; this impact results in a decrease in maize production.

Small-scale farmers primarily produce maize, and the relative correlation between maize production and food security suggests that a decrease in maize production may inversely affect food security (Matimolane, 2018). The occurrence of El Niño events in 2015 and 2016 resulted in extreme drought catastrophes, leading to a 41% food insecurity increase in the North West province (STATS SA, 2016). However, the current state of the La Niña climate events proves to create an advantage for maize production. As such, the climactic event could increase rainfall, reducing incidences of drought catastrophes (Bhatla *et al*., 2020). Thus, significant studies around the province assess the adaptation, mitigation and effect of climate change on the maize sector.

2.5 Gap in Literature

In the North West Province of South Africa, climate change has affected a diverse number of sectors such as the tourism and the health sectors; it has affected the physiology of individuals and of the animals that live within the area (Zantsi *et al*., 2019). The study area has insufficient research on the impacts of climate change and how the phenomena impose on agriculture and small-scale farmers. Studies conducted within the specific area of the North West province have highlighted amongst others, the impact on rural livelihoods and adaptation strategies (Oduniyi, 2019). This presents a gap in research on the specific impacts which climate change imposes on small-scale maize farmers within the locality, which the study seeks to fill.

CHAPTER THREE: RESEARCH METHODOLOGY

3.1 Introduction

Chapter 3 provides a description of the methodological strategies used in carrying out and the analysis of the study. This chapter will firstly provide a full description of the study area, followed by the design of the study and the methods of analysis.

3.2 Description of the Study Area

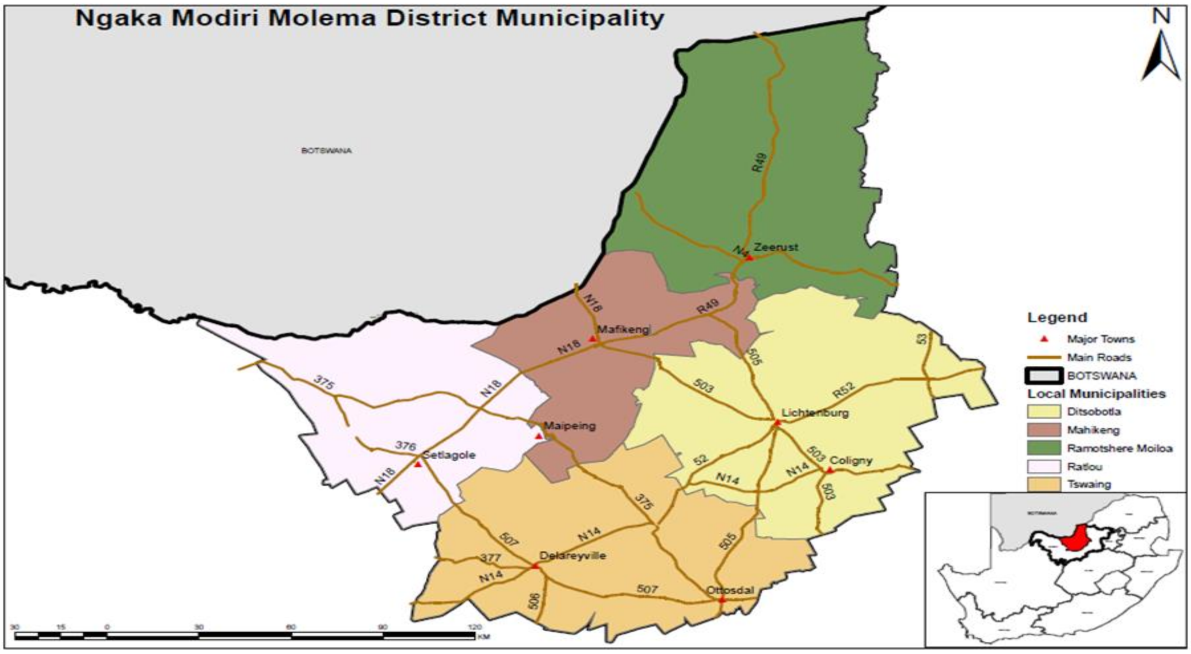

Figure 3.1: Map of the Ngaka Modiri Molema District Municipality (Source: Ngaka Modiri Molema District Municipality (2020))

The focus area of the study is the Ngaka Modiri Molema District Municipality. It is one of the four districts of the North West Province. According to Statistics SA (2016), the population size of the district municipality in 2016 was recorded to be 889 108. The resident's races are categorized as follows: black African, white, and coloured, with that it designates that the languages that are spoken within the area are Setswana, Afrikaans, English, isiXhosa and Sesotho (Asong *et al*., 2019). The district municipality is located 26° 1' 41.383" South 25° 51' 7.834" East; with a latitude of -26.028162 and a longitude of 25.852176. The land covers a total of 28 206 km² the area (2,788,844 hectares), this is comparable to 26% of the total land surface of the North West province (Mindat Organization, 2020). Amongst the hectares belonging to the Ngaka Modiri Molema District Municipality, the Ramotshere Local Municipality accounts for about 27%; this makes the municipality cover the most significant portion of land.

The municipality making up a minor portion of 13% belongs to the Mafikeng Local Municipality, although it contains the highest population within the district municipality. The district's landscape can broadly be described as flat as 68% of the topography is matched as such. Out of that area, 15% is designated as 'mountainous' and 17% as 'rolling.' The Ramostshere Moiloa Local Municipality has a large portion of it classified as mountainous (47%). The Mafikeng, Ditsobotla, Ratlou, and Tswaing Local Municipalities are predominantly flat with a limited amount of mountainous areas in the northern parts of Mafikeng and Ditsobotla municipalities. The district's bulk contains a flat surface area that covers 68% of it (Botlhoko, 2017). On the particular land, the most common activities partaken are mining and farming; however, the agricultural sector, specifically the maize industry, is one of the dominant players in agriculture. Thus, the main economic activity in the district of Ngaka Modiri Molina is agriculture, mainly producing crops and livestock (StatsSA.gov.za, 2017). The advantage of the province comes from the climate setting. The temperature in the district municipality ranges from 17 ° to 31°C (62° to 88°F) in the summer and from 3° to 21°C (37° to 70°F) in the winter (Asong *et al*., 2019).

The yearly rainfall amounts to approximately 360 mm, virtually all of it occurring during the summer, i.e. between October and April. The Ngaka Modiri Molema District Municipality is made up of Ramotsere Moiloa Local Municipality, Tswaing Local Municipality, Ditsobotla Local Municipality, Mahikeng municipality, and Ratlou Municipality (Mindat Organization 2020). The environmental evidence on the soil types in the area indicates that the core territory is of eutrophic soils, dystrophic to mesotrophic soils, mesotrophic to eutrophic soils, and non-calcareous soils. The territory types are linked to the current and possible altitudinal dispersal of the farming sector. The flora of the NMMDM drier western parts are mainly characterized by Kalahari thornveld. The eastern parts mainly covered by Banken veld and Cymbopogon, and turf thornveld and mixed (Makolomakwa & Losaba, 2019), characterize the extreme northern part.

3.3 Research Design

The design of the study is cross-sectional research since the data were collected once. This study also made use of quantitative and qualitative data, this is because it was analysed and provided information on the number of farmers displaying particular characteristics, therefore thoroughly providing evidence on the farmers and enabling sampling to partake on a large population. The particular type of survey undertaken was the descriptive survey; this survey met the research objectives without manipulating the data.

3.4 Population

The population of the study was composed of small-scale maize farmers within the Ngaka Modiri Molema District Municipality. The population size of the small-scale maize farmers was adopted through the study of Oduniyi (2019) which indicated that there were 475 small-scale farmers within the district. Of the given population of small-scale maize farmers, 42.11% reside in the Tswaing Municipality, 31.58% are in Ditsobotla, 21.05% in Mahikeng, 3.16% in Ratlou, and 2.11% in Ramotshere.

3.4.1 Sampling Procedure and Sample Size

The sample size of the population was attained through the use of the Rao-soft calculator which sampled a total number of 213 farmers. The standard settings of the Rao-soft calculator were: confidence interval (Z) (1.96), population proportion (p) (50%), a margin of error (e) (5%) and the population size (N) (475). The farmers were selected randomly to fit the sample size, simple random selection of the farmers reduces biasness and gives farmers an equal chance of being represented in the study.

$$P = Z(^{c}/_{100})^{2} r(100-r) \ldots\ldots (1)$$

$$E = \text{Sqrt}\ [^{(N-n)x}/_{n(N-1)}] \ldots\ldots (2)$$

$$n = \frac{\frac{Z^2 \times p \times (1-p)}{e^2}}{1+(\frac{Z^2 \times p \times (1-p)}{e^2 \times (N)}} \ldots\ldots (3)$$

$$\frac{\frac{1.96^2 \times 0.50 \times (1-0.50)}{0.05^2}}{1+(\frac{1.96^2 \times 0.50 \times (1-0.50)}{0.05^2 \times (475)})}$$

$$\textit{Sample size} = 212{,}40$$

3.5 Data Collection

The given percentage contribution of the farmers' distribution suggests that 90 farmers were from Tswaing Municipality, 67 were from Ditsobotla Municipality, 45 were from Mahikeng Municipality, 7 were from Ratlou Municipality and 5 from Ramotshere Municipality. Information on the farmers from 2016 to 2020 was collected through a face to face, telephonic and research data sources through a structured questionnaire. The use of this particular type of questionnaire was able to convert the information of the farmers into measurable data sets. The study also made use of climate data to account for the variability of rainfall and precipitation from 2016 – 2020 within the study area.

3.6 Data Analysis

How the analysis of the collected data was undertaken through sorting, coding and analysis through the use of the STATA statistical package. Socio-economic data, perception data and knowledge data sets of the small-scale maize farmers were undertaken with descriptive statistics while the analysis of the adaptation strategies made use of the multinomial logistic regression model. The assessment of yield about climate change was through the use of a multiple linear regression model.

3.6.1 Descriptive Statistics

Descriptive statistics are used to describe the relationship between the variables within the sample, and it is composed of summarized data sets in an organized manner. As descriptive statistics summarizes the data sets it results in the assessment of the sample, which is composed of different types of variables. A systematic approach was identified to be the most appropriate descriptive statistical method as it reduces the likelihood of presenting ambiguous data.

3.6.2 Multinomial Logistic Regression Model (MLM)

To capture the adaptation strategies adopted by small-scale maize farmers when dealing with climate change in the Ngaka Modiri Molema District Municipality the customary multinomial logistic regression model was implemented. The MLRM is used to model the outcome of a variable with more than two groups and they are analytically in nominal, ordinal, interval and ration format (Kwak & Clayton-Matthews, 2002). It is used to predict the probabilities of the different possible outcomes of a categorically distributed dependent variable, given a set of independent variables (Starkweather & Moske, 2011). The multinomial logistic regression model also estimates a separate binary logistic regression model for each indicator variable (Bayaga, 2010).

Model specification:

The model is specified as follows:

$$Prob\ (Yi = 1) = \frac{\varepsilon^{\beta}\ j^{Xi}}{\sum_{k=1}^{3} e^{\beta} k^{X_i}} \qquad 3.1$$

The definition of the model following the adaptation strategies and using the assumption:

$$AdpStr_{ij} = \beta_{\theta} + B_j\ X_{ij} + \varepsilon_{ij} \qquad 3.2$$

Where:

* $AdpStr_{ij}$ is the differed adaptation strategies which are adopted by farmers (j=1, 2, 3, 4…)
* B_j is a coefficient of specific strategies
* X_{ij} is a vector of farmers' characteristics that together influence the adaptation strategy selection.
* $\mathcal{E}_{ij}$ is the error term

The multinomial logit model is a function of nine (9) independent variables influencing the adaptation strategy adopted by farmers:

$$\begin{aligned} \mathrm{AdpStr}_{ij} = \beta_0 + \beta_1 GENDHH + \beta_2 AGEHH + \beta_3 EDUHH + \beta_4 \mathrm{HH}S \\ + \beta_5 \mathrm{FMSZ} + \beta_6 HS + \beta_7 \mathrm{EXTSS} + \beta_8 \mathrm{CRDACS} + \beta_9 \mathrm{NCV} + \varepsilon_{ij} \end{aligned} \qquad 3.3$$

The variables measurement and expectation are included in the table below:

Table 3.1: Table of multinomial variables and prior expectations

Variables	Description	Type	Values	Prior Expectations
Dependent Variables				
Adaption strategies	Climate change adaptation strategies	*Y0 = Reference Category	0 – Did not adopt 1 – Diversifying crops 2 – Changing planting dates 3 – Drought Resistance crops 4 – Mixed cropping 5- Other	+
Independent Variables				
Gender	Gender of small-scale maize farmers	Dummy	1 – Male 2 – Female	+/-
Age	Age of small-scale maize farmers	Continuous	Number of years	+/-
Education	Education level of the farmers	Categorical	Categories will be based on the level of education	+/-
Household size	Household size of small-scale farmers	Continuous	Number of people	+/-
Farm size	Size of the farms	Continuous	Hectares	+/-
Extension services	Number or contact with extension services	Dummy	0 – Scarcely 1 – Regularly 2– Occasionally	+/-
Agri-park	Exposure to Agri-park	Dummy	0 – Yes 1 – No	+/-
Noticed climate variability	Types of climate variability observed	Dummy	0 – Precipitation 1 – Temperature	+/-

3.6.3 Multiple Linear Regression Model

The research study made use of multiple linear regression to assess the impact of climate change on the yield of small-scale maize farmers in the Ngaka Modiri Molema District Municipality. The model makes an effort to clarify the relationship between two or more explanatory variables and a response variable by fitting a linear equation to the observed data. Every value of the independent variable *x* is associated with a value of the dependent variable *y* (Bottenberg & Ward, 1963).

Model specification:

$$Y_{it}/CA_{it} = \alpha_{i0} + \alpha_{i1}MaxT_{it} + \alpha_{i2}MinT_{it} + \alpha_{i3}\text{Rainfall}_{it} + \alpha_{i4}\text{Year}_{it} + \varepsilon_{it} \qquad 3.4$$

Where:

* Y = yield (kg/hectare) and CA = cropping area (in hectares) of maize
* *i* = maize
* MaxT = Growing season average daily maximum temperature (°C)
* MinT = Growing season average daily minimum temperature (°C)
* Rainfall = Growing season total daily rainfall (mm)
* t = time (year)
* ε = Error term

Table 3.2: Table of multiple linear regression model variables and prior expectations

Variables	Description	Type	Values	Prior Expectations
Dependent Variables				
Yield	Maize output per hectares	Continuous	Kg/hectare	+
Independent Variables				
Maximum Temp	Average maximum temperature of maize during growing season	Continuous	Degrees Celsius (℃)	+
Minimum Temp	Average minimum temperature of maize during growing season	Continuous	Degrees Celsius (℃)	+
Rainfall	Average rainfall of maize during growing season	Continuous	mm	+
Time	Time periods from 2016 – 2020	Dummy	0 = 2016 1 = 2017 2 = 2018 3 = 2019 4 = 2020	+

3.7 Rigour

When conducting a particular study, a measurement of precision is necessary to account for and to ensure that the set objectives and aims are met. It is also used to ensure that the data which is presented is accurate. This particular study undertook the validity and reliability of the instrument to ensure that the study is reliable and accurate. The validity of a study measures the accuracy of the particular variable that the research undertakes, while the reliability measures the level at which the study can be used for example policy making.

3.7.1 Validity

Construct validity: the study used descriptive, multinomial, and multiple linear regression models. These models have successfully been used in categorizing the socio-economic characteristics, adaptation strategies, and yield outputs in the event of climate change in other countries. Thus it has been a tool in policy construction. This study, therefore, presents validity through the use of previously used methods in the analysis of data. .

Internal validity - The relationship between climate change and its impacts exists, climate change has a factor influencing agriculture largely through environmental change, and this means that the production output for particularly staple foods and seafood is affected. The demand for this particular food becomes increased, therefore the government will be subjected to increasing the prices.

External validity - This particular validity seeks to ensure that the findings of the study are representative and the use of the random sampling technique ensures that every individual has the same chance of being presented within the study. The random sampling technique ensured that the study is not biased.

3.7.2 Reliability

The study ensures to remove the possible following threats: participant error, participant bias, research error and bias.

Participant error - The questionnaires were presented at arranged specific times with the farmers to ensure that they were well prepared for the survey and they would give accurate information.

Participant bias - In order to eliminate participant bias, the study was conducted in an environment where the farmers can easily reveal information about the farms.

Researcher error - Randomized selection of the individual to be represented in the sample was employed in order to reduce the errors that researchers experience.

Researcher bias - To reduce the bias in the study, a verification of the results with more data sources upheld the findings as legitimate. A re-evaluation of the presented data partakes in the absence of data sources to validate the outcomes and review the finding with peers.

3.8 Ethical Considerations

Ethical considerations of the study were validated through the universities committee board in the assurance that the study does not harm the participants, or animals or cause any harm to the environment. Ethical procedures ensure that there is maintained participant integrity. The main considerations the study focuses on are the following: informed consent, anonymity and confidentiality.

3.8.1 Permission and Informed Consent

The study requires data from the small-scale maize farmers in the Ngaka Modiri Molema District however, the availability of the data was through the informed consent and permission of the farmers. Prior to the collection of data, individual farmers were asked to participate in the study. Data were collected only after their approval. The permission and consent of the farmers is a pivotal area in maintaining the ethics of the study, it ensures the collection of valid data and reduces the possibility of invading the personal area of the farmers.

3.8.2 Anonymity

The study assures to maintain the ethical standards of the university by ensuring that the participants are kept anonymous. There would not be any record of their or the companies' details such as identity number, name, cell phone numbers, company name, etc. Small-scale farmers were kept anonymous by conducting a questionnaire that does not reveal their identity.

3.8.3 Confidentiality

Confidentiality ethics are imperative in research to ensure that the data that the farmers display during the interview are not exposed. Information that the participants have provided on the questionnaire is confidential by not sharing it with other sources, the study paper provides a collective set of analysed data and therefore does not expose the individual farmer.

CHAPTER FOUR: RESULTS and DISCUSSIONS

4.1 Chapter Introduction

The following chapter encompasses all the data generated in the study, this chapter reveals the results of socio-economic characteristics of the small-scale maize farmers in the Ngaka Modiri Molema District Municipality, their perceptions and knowledge of climate change, their experiences of climate change effects and the adaptation strategies which they have developed to mitigate the effects of climate change on their farms.

4.2 Socio-economic Characteristics of the Respondents

Socio-economics relates to the social and economics of people in a society (Baker, 2014). The society evaluated in this study is that of the small-scale maize farmers in the Ngaka Modiri Molema District Municipality.

4.2.1 Descriptive Statistics Results on the Gender of the Respondents

The study reveals that maize farming among respondents is dominated by male farmers (70%), and only 30% by women. A study conducted by Oduniyi (2018) revealed that 84.1% of the small-scale and emerging farmers in the North West Province were male while 15.9% were female. The African Continental Free Trade Area has intensified the need for women to participate in the agricultural sector. However, this particular topic has been ongoing for a long time, the agreement between the Sub-Saharan countries in improving the livelihood of the African continent through a uniform approach of advancing every individual (male/female) in the continent provides women with an opportunity to participate in the agricultural industry (Ofori *et al*., 2021).

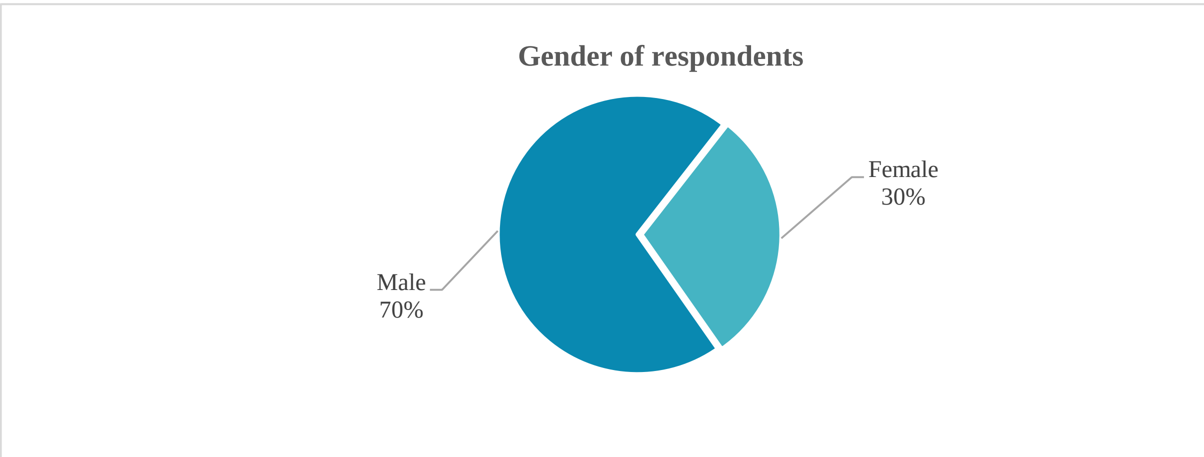

Figure 4.1: Descriptive statistics results on the gender of the respondents

4.2.2 Descriptive Statistics Results on the Age Categories of the Respondents

Figure 4.2 seeks to enlighten on the age distribution of the respondents in the study. The chart shows that a greater percentage (22%) of the respondents were over 60 years. While another substantial percentage (21%) were between the ages categories of 3640 years. The least participation (3, 1%) of respondents were found between 18 – 25 and those between 26 – 30 (6, 3%). Ogujiuba *et al*. (2021) conducted a study on the Socio-Economic Factors Affecting Small Scale Maize Producing Farmers in Kamhlushwa, South Africa. The study found that a large portion (41.6%) of the participants in the study were in the age category of 51 – 60 years while the least participating group (10,9%) were less than 40 years old.

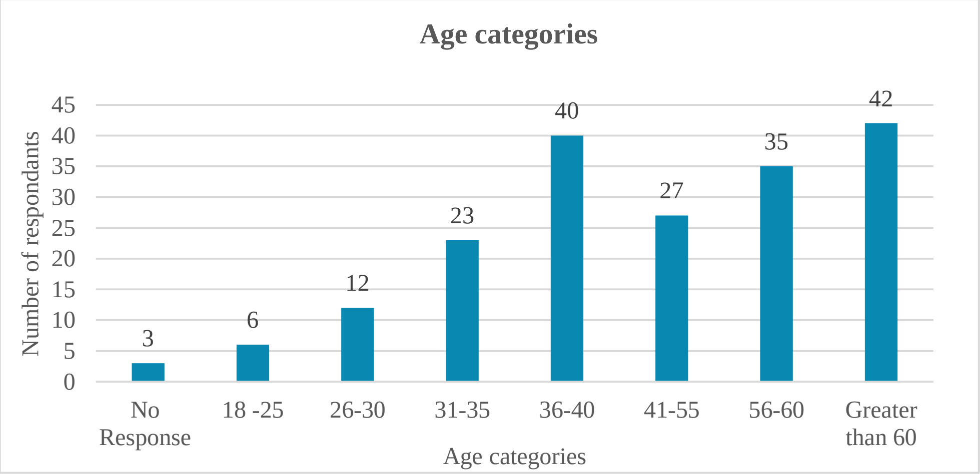

Figure 4.2: Descriptive statistics results on the age categories of the respondents

4.2.3 Descriptive Statistics Results on the Ethnic Categories of the Respondents

Stats SA (2011) reveals that a large proportion of people living in the North West Province are Tshwana-speaking. As such, the study reveals that 137 (73%) of the farmers who participated in the study are Tshwana. While Pedi and Indian ethnic categories are found to have the least participation of (1) 0,005% each.

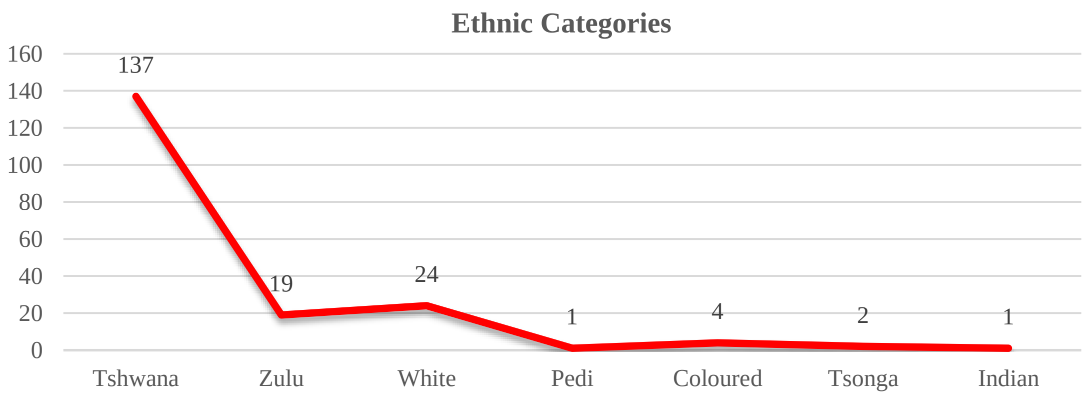

Figure 4.3: Descriptive statistics results on the ethnic categories of the respondents

4.2.4 Descriptive Statistics Results on the Level of Education among the Respondents

The educational background of small-scale maize farmers widely varies within the area. Some 30% of the respondents have a tertiary background while the least 2% of the participants had an educational background of grade 3 – 7. Tlholoe (2015), conducted a study in the Ngaka Modiri Molema District, which involved the participation of livestock farmers. The study found that the majority (30.91%) of the respondents attended primary school while fewer (10%) of the farmers attended tertiary education. Within the study, there exists a high correlation between youth participation and the level of education.

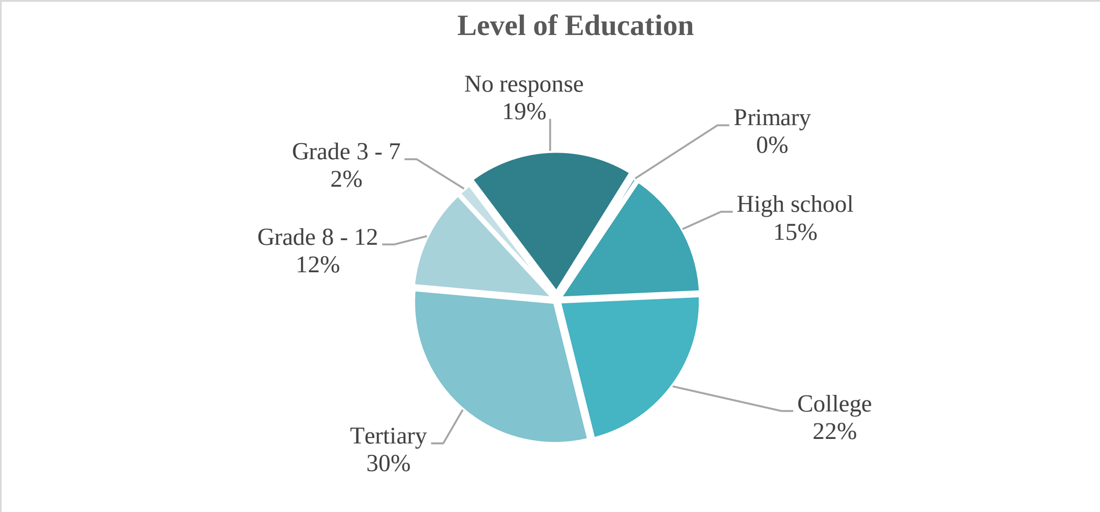

Figure 4.4: Descriptive statistics results on the level of education among the respondents

4.2.5 Descriptive Statistics Results on the Employment Status of the Respondents

The study reveals that a substantial (55%) of the small-scale maize farmers are employed while fewer (40%) are not employed. The larger portion of employed farmers considered farming as a full-time job or rather self-employed while 15% of the employed farmers worked for other formal enterprises to earn a living. Those who considered themselves unemployed considered neither of the aforementioned descriptions. Abafe (2021) recognized that 7% of the farmers are employed, 7% consider farming as a part-time job, and 70% of the farmers considered farming full-time employment, 8% of the farmers were business owners while 8% of the farmers were retired.

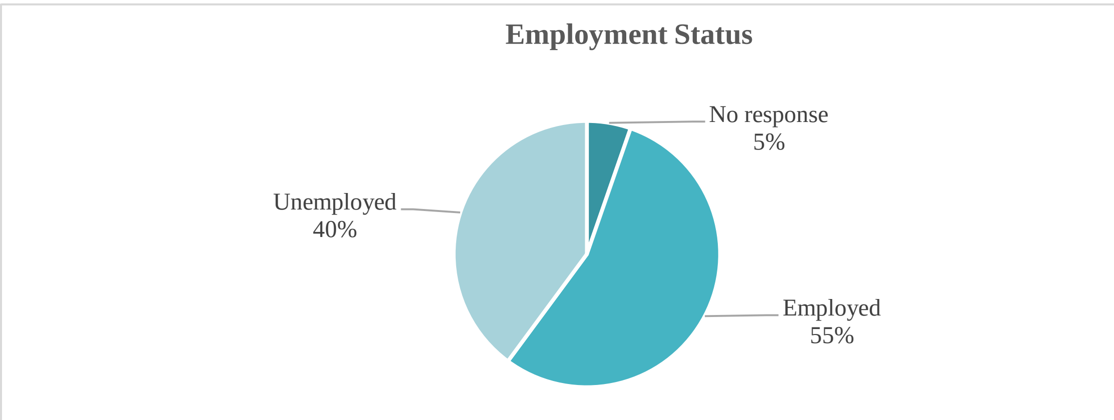

Figure 4.5: Descriptive statistics results on the employment status of the respondents

4.2.6 Descriptive Statistics Results on the Household Size of the Respondents

Agricultural households largely seek to farm for the alleviation of poverty and unemployment (Cervantes-Godoy & Dewbre, 2010). The findings presented by this study indicate that a large proportion (30%) of the households have 2 to 3 people per household. While only 4% of the respondents have 12 to 13 people per household. In a study conducted by Bonokwane and Ololade (2022) they found that in categories of farmers involved in livestock farming and mixed farming, large percentages (67% and 66%, respectively) had 1 – 5 people per household. The lowest percentages (7% & 10% respectively) accounted for household sizes with 10 or more people.

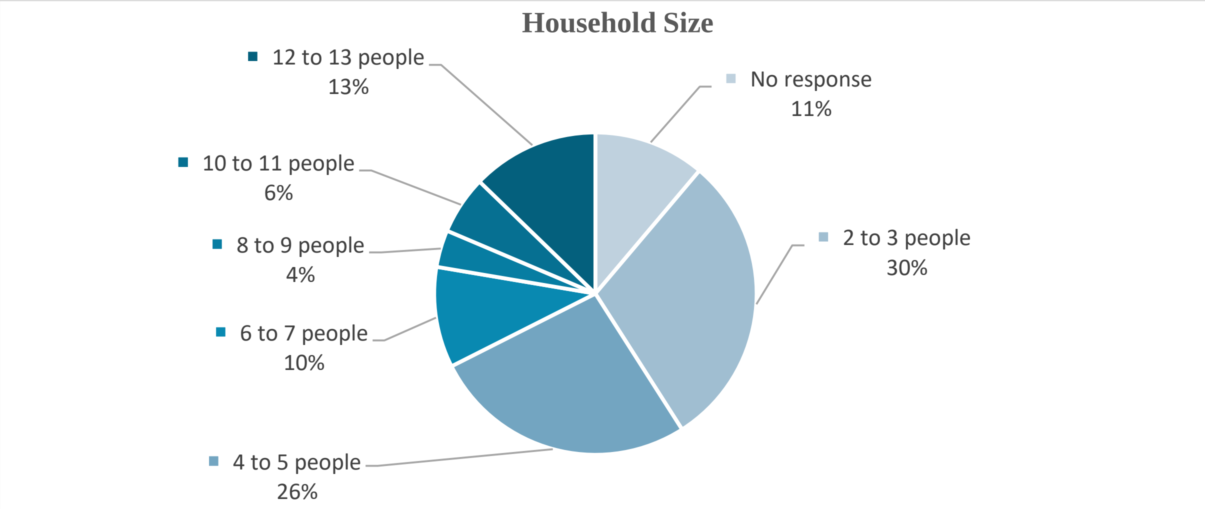

Figure 4.4: Descriptive statistics results on the household size of the respondents

4.2.7 Descriptive Statistics Results on the Farming Experiences of the Respondents

A farmer's experience often links with the farmer's knowledge, skills and adaptive mechanisms (Šūmane *et al*., 2018). As such, the study determined that the largest category of the respondents (26%) had some farming experience of more than 20 years while the least category (7%) had between 1 to 5 years of experience. Oduniyi *et al*. (2021) identified that a statistical significance of Z=2.47 existed between the number of farming years and the market participation of small-scale farmers, the study assessed that the experience gained is highly related to the quality of food required in high-value markets.

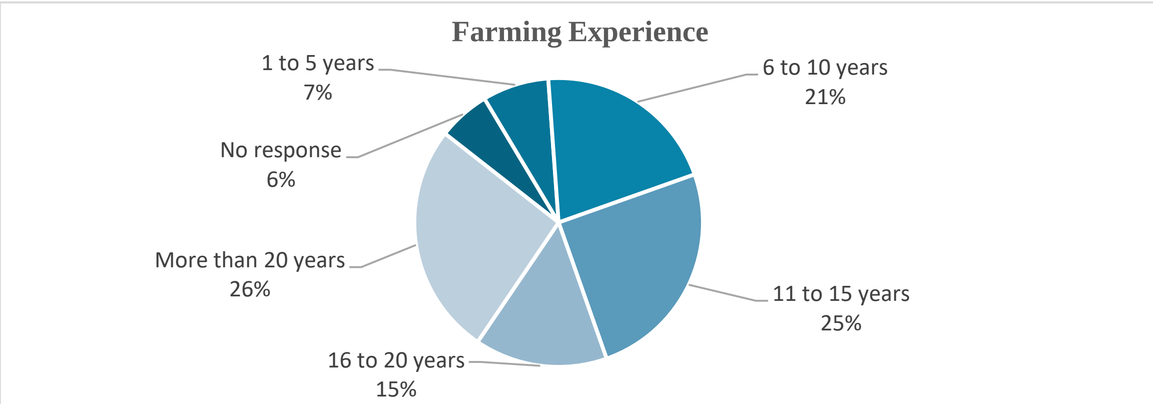

Figure 4.7: Descriptive statistics results on the farming experiences of the respondents

4.2.8 Descriptive Statistical Results on Their Contact with Extension Officers of the Respondents

Agricultural extension officers' participation with small-scale farmers encourages the development and promotion of rural agricultural farming (Baiyegunh *et al*., 2019). In a study by Balarane and Oladele (2012) in the North-West province, 78% of the respondents had contact with the extension officers while 14% indicated no contact with extension officers. As such, amongst the small-scale maize farmers in the Ngaka Modiri Molema District Municipality, 42% of the respondents had frequent contact with extension officers while only 22% rarely had contact with them.

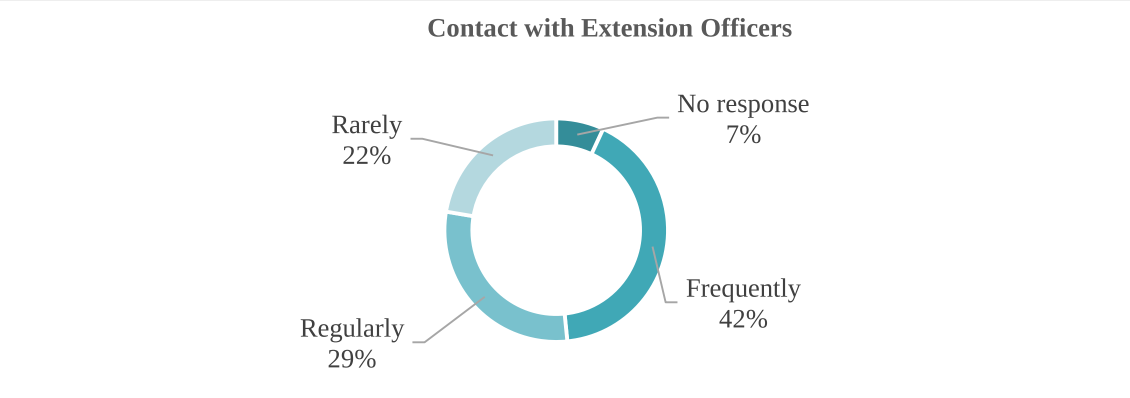

Figure 4.8: Descriptive statistical results on respondents' contact with extension officers

4.2.9 Descriptive Statistical Results on the Agri-park Exposure of the Respondents

The Department of Agriculture, Land Reform and Rural Development has various initiatives to increase farmers' market participation. The fact sheet presented for the Ngaka Modiri Molema District Municipality indicated that maize is the key commodity for the district (DRDLR, 2022). The study indicates that 47% of the participants' acknowledgement of the extension programme presented by the government, but only 41% of the respondents do not.

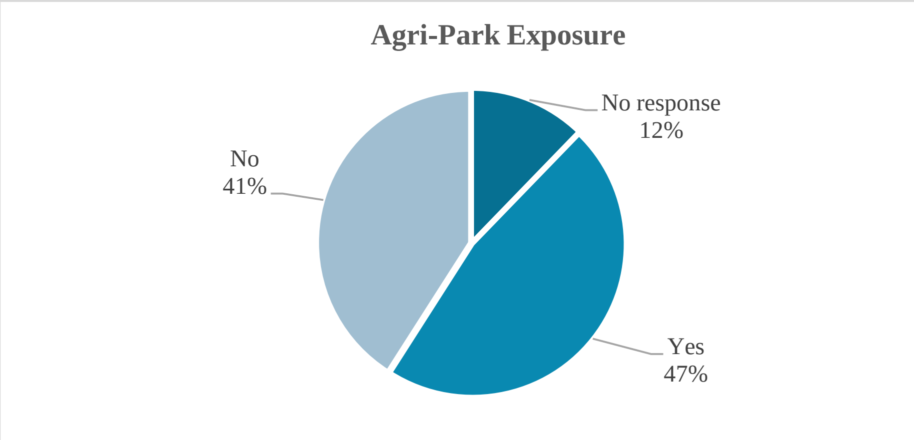

Figure 4.9: Descriptive statistics results on the agri-park exposure of the respondents

4.2.10 Descriptive Statistical Results on the Credit Accessibility of the Respondents

Credit accessibility aggregates towards factors affecting the market participation of small-scale farmers. The study found that 61% of the respondents have access to credit while 30% of the respondents did not have access to credit. A study conducted by Hlongwane *et al*. (2014) within the Greater Giyani Municipality discovered that 40% of the small-scale maize farmers who participated in the study had access to credit, while 60% of the respondents did not have access to credit.

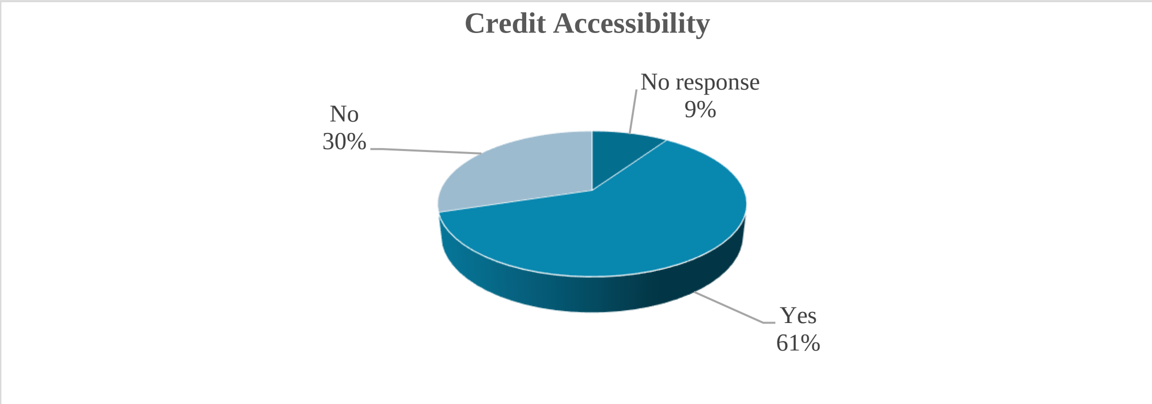

Figure 4.50: Descriptive statistics results on the credit accessibility of the respondents

4.2.10.1 Descriptive Statistics Results on the Credit Range and Satisfaction of the Respondents

The graph represented below (Figure 4.11) indicates the relationship between the credit range and satisfaction. Of the respondents who have access to credit, only 38% proportion of the respondents receive a credit ranging between R10 000 – R15 000, while 22% of the respondents receiving credit have access to credit above R15 000. A majority (67%; 124 participants) of the respondents stated that they have credit satisfaction, while the fewest of the respondents (9%, 17 participants) indicated dissatisfaction with their credit range. The graph also shows that a linear relationship exists between the level of credit and the credit satisfaction

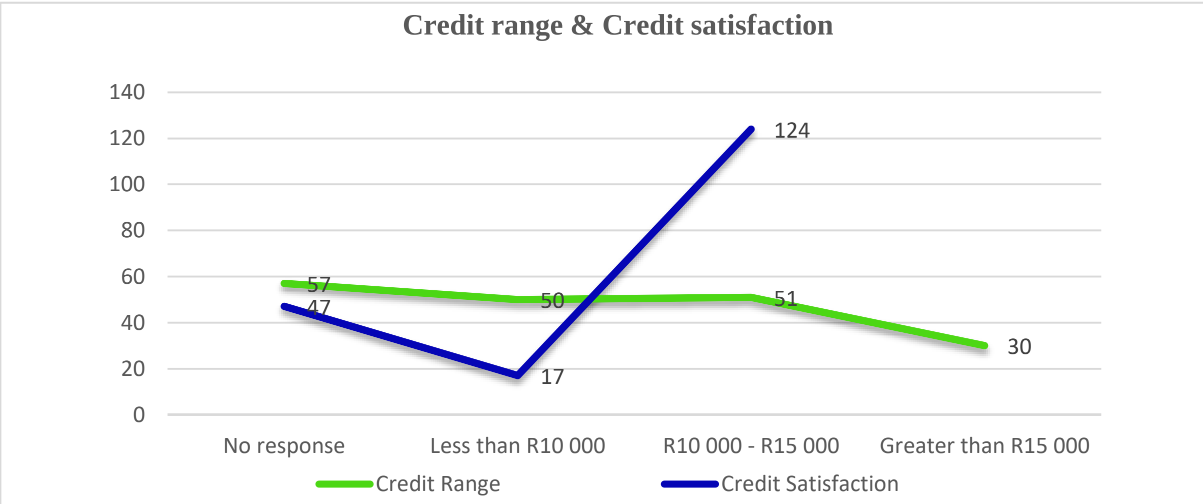

Figure 4.11: Descriptive statistics results on the credit range and satisfaction of the respondents

4.2.10.2 Descriptive Statistics Results on the Credit Repayment and Sources of the Respondents

Figure 4.12 indicates the relationship between the credit repayment strategy and the credit sources utilized by the small-scale maize farmers in the Ngaka Modiri Molema District Municipality. The study did not limit the respondent's loan sources; thereby, including both formal and informal credit sources. The results of the study indicate that 56% of the respondents that have access to credit obtain their loans through a formal institution such as a bank. While fewer (12%) of the respondents receiving credit attained it through family members. Ullah *et al*. (2020) state that the credit sources of individuals are positively related to the socioeconomic scenario farmers may find themselves. Thus, the study indicated that 35% of the respondents received their credit through input providers while only 19% of the remainder received their credit through informal sources such as relatives and family members. The credit repayment bar graph stipulates how farmers are able to repay their received credit on time. A majority (63%) of the farmers indicated that they service their loan repayment obligation on time, while fewer (30%) of the respondents do not.

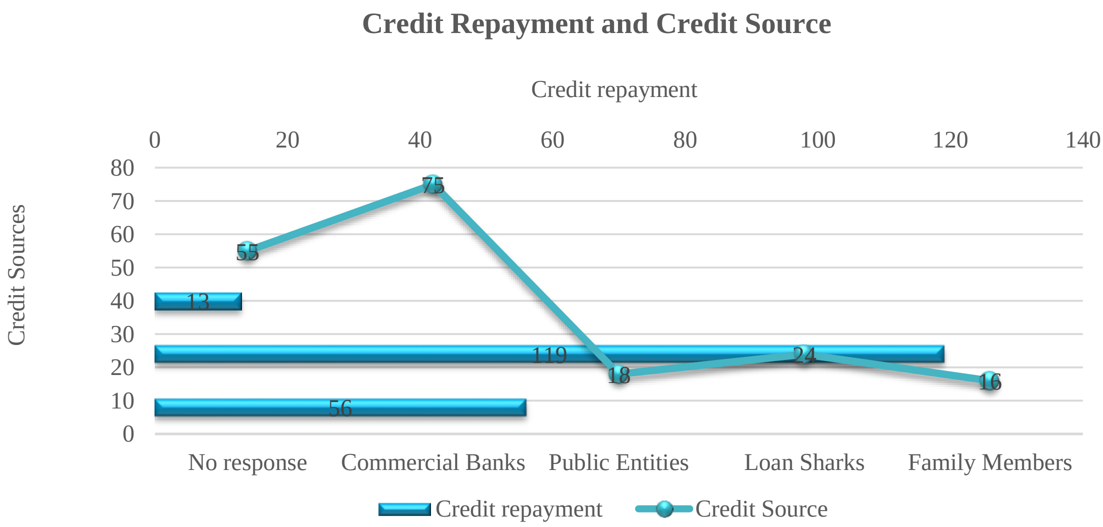

Figure 4.62: Descriptive statistics results on the credit repayment and credit sources

4.2.11 Descriptive Statistical Results on the Credit Inaccessibility of the Respondents

Most of the small-scale maize farmers in the Ngaka Modiri Molema District Municipality stated that credit deniability played a greater proportion of 16% towards the small-scale maize farmer's inaccessibility to credit, while some 14% of the respondent's inaccessibility is influenced by no applications being made to formal banking institutions. A study conducted by Chisasa and Makina (2012) revealed that below 98% of the participants in their study were denied credit due to fundamental factors such as the inability to reveal viability and collateral/assets. While Djoumessi (2018) realised that most of the participant's non-applications were due to distances from banking institutions

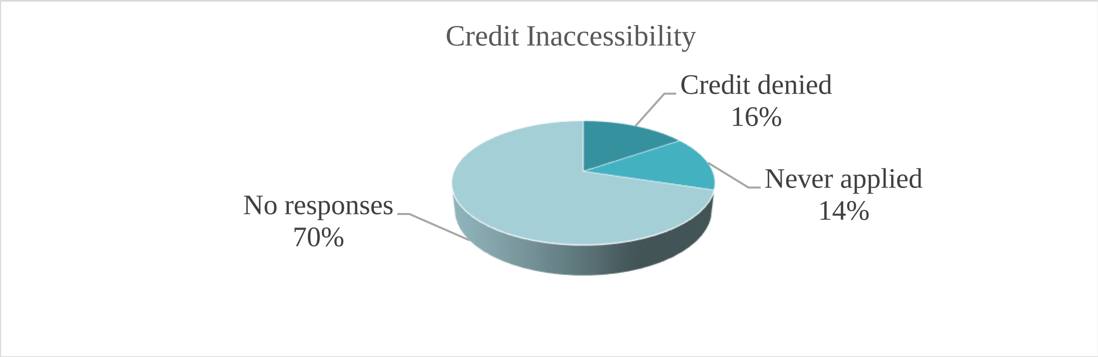

Figure 4.13: Descriptive statistics results on the credit inaccessibility of the respondents

4.2.11.1 Descriptive Statistical Results on the Factors Influencing the Credit Deniability of the Respondents

The results presented in Figure 4.14 below indicate factors that contribute towards credit being denied amongst small-scale farmers. Most of the respondents revealed that the accrued transactional costs (23%) are the largest contributor towards the unsuccessful acquisition of credit amongst the farmers. The lack of access to land (7%) is the least contributing factor as a majority of the farmers in the area are granted access to the land through family relations.

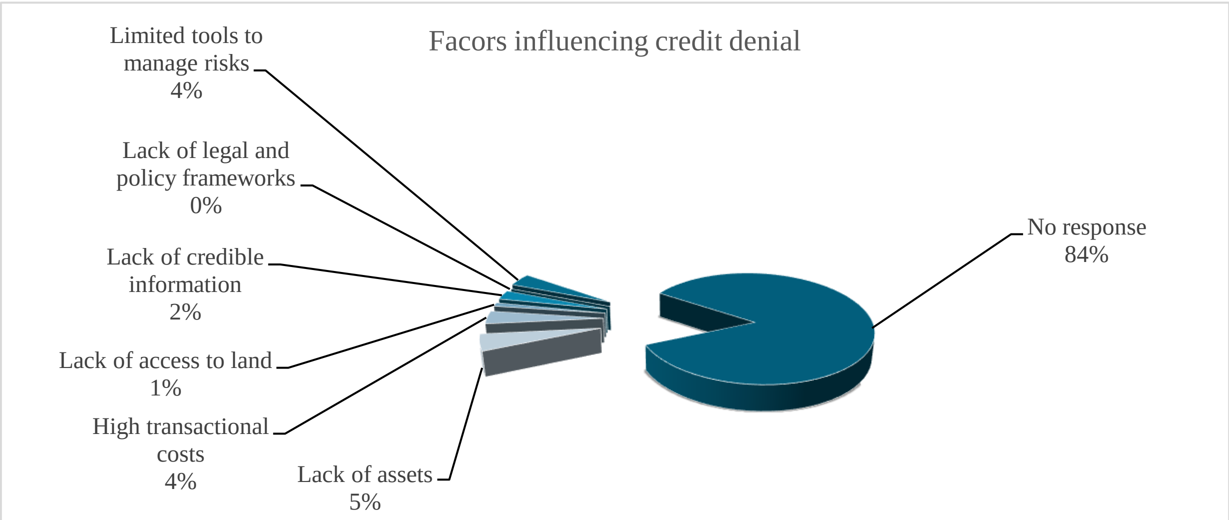

Figure 4.14: Descriptive statistical results on the factors influencing the credit deniability of the respondents

4.2.12 Descriptive Statistics Results on the Land Ownership of the Respondents

Land ownership is widely variable, as such; the study investigated the different forms of land ownership that exist in the area. The farmlands are family owned and therefore passed down from one generation to another. The study found that 77% of the small-scale farmers owned their farming lands. A few 1% of the respondents owned a commonage land. Okeyo (2020) established that 92% of the sorghum small-farming households cultivated from their own farmlands.

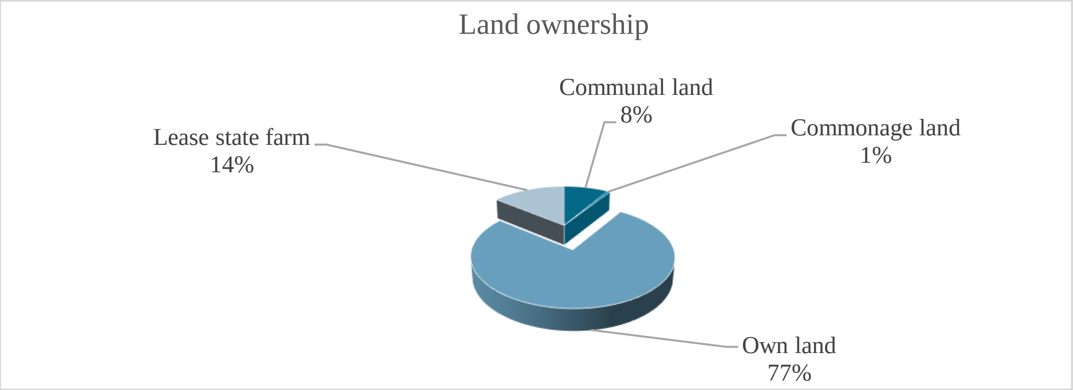

Figure 4.14: Descriptive statistics results on the land ownership of the respondents

4.2.13 Descriptive Statistical Results on the Agricultural Field Activities of the Respondents

Diversification in agriculture attempts to allocate natural resources to produce greater yields (Hufnagel *et al*., 2020). The assessed group in the study indicated that some 53% of the respondents do not apply field diversification methods. While some 41% of the respondents apply diversification strategies on their farmlands.

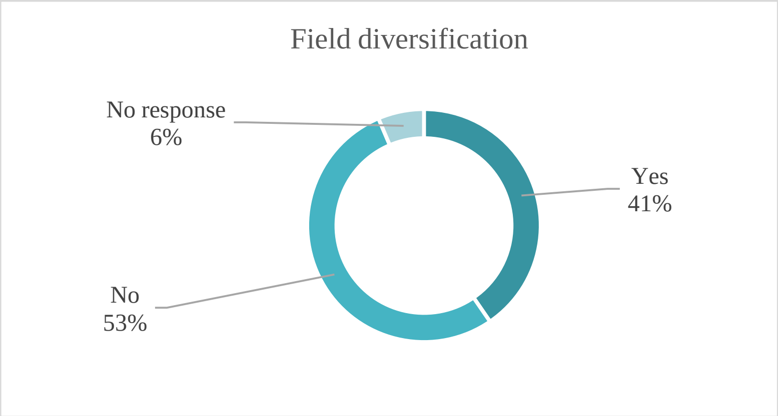

Figure 4.15: Descriptive statistical results on the participation agricultural field activities of the respondents

The study also reveals that about 20% of the participants partake in vegetable diversification to increase profitability on the farm while 1% of the participants diversify their field through growing tobacco. Mwangagi (2021) identified that 89.4% of the farmers in Kenya diversify their methods through bean production while 27% of the participants in the study grew Irish potatoes as a diversification method.

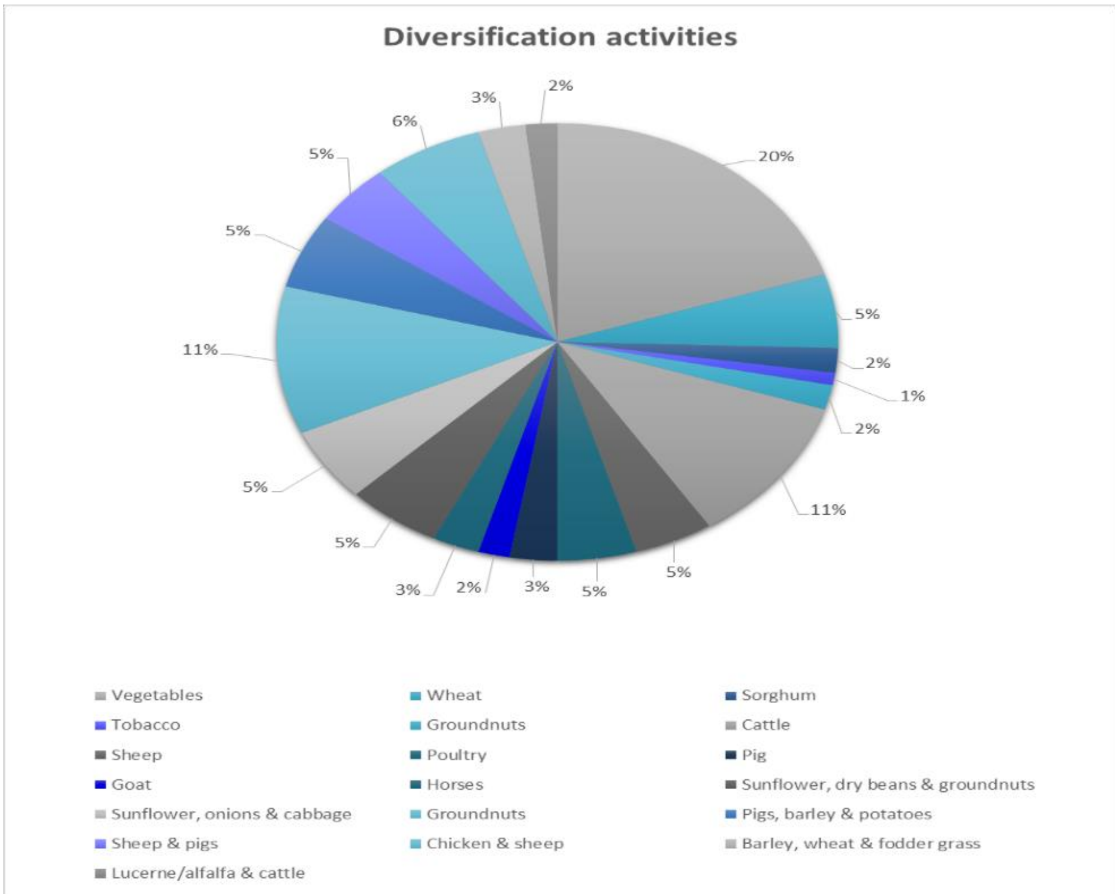

Figure 4.76: Descriptive statistical results on the agricultural field activities of the respondents

4.3 Descriptive Statistics Results on the Perception and Knowledge of Small-scale Maize Farmers

In the following section of the study, we assessed the perception and knowledge of small-scale farmers. The study made use of sampled questions to assess the information that farmers have regarding climate change and how they view the climatic scenario overall. The questionnaire aimed to assess whether farmers had the scope of assessing the perceived climatic scenario.

Table 4.3 below indicates the frequent code of responses (i.e. 1 indicated "strongly agree", 2 indicated "agree", 3 indicated "undecided", 4 indicated "disagree" and 5 indicated "strongly disagree"), this analysis and interpretation of the results was achieved through descriptive statistics. The first question of the perception and knowledge survey seeks to assess the basic understanding of the term "climate change". Some 32% of the farmers in the survey agreed with the statement (frequent response level 2) which was incorrect, as the correct description would be “the climate of a particular area is average”. While the second question of the survey attempted to make the farmers more comfortable in the survey and respond with confidence, therefore 36% of the respondents indicated that they had adequate knowledge of the climatic scenario (frequent response level 1). In support of the respondent’s former questions, a larger group of the farmers (47%) in the following question indicated to have seen volatility in the climate scenarios, most of which indicated “led to a change in the farming practices”.(frequent response level 1). While in the following question a large group (32% and 17%) respectively, perceived climate change to solely be hazardous to small-scale farmers (frequent response level 1) and was brought about by factories only (frequent response level 4). In question 6, most of the farmers (39%) indicated how they perceive climate change and its occurrence. While the following questions (questions 7, 8, 9, 10, 11, 12 and 13) support the knowledge that a majority of small-scale farmers (31%, 36%, 44%, 33%, 24%, 34%, and 43% respectively) have about climate change.

Question Number	**Perception and knowledge statements**	**Frequent responses**	**Response percentage**
1	The climate of a particular area is above average	2	32%
2	I am familiar with the term “climate change” and have fully acquired the necessary information on the term	1	36%
3	Over the years there has been a significant change in climate	1	47%
4	Climate change affects farmers only	1	32%
5	Factories are the only contributors towards climate change	4	17%
6	Climate change has resulted in a change in temperature, rainfall and entrance of seasons.	1	39%
7	Food waste accounts for the total human-made greenhouse gas emission	2	31%
8	Carbon dioxide, methane and water vapour are greenhouse gases	1	36%
9	The greenhouse effect is when the gases in the atmosphere trap heat and block it from escaping our planet	1	44%
10	There are farming practices which are aimed at reducing the emission of greenhouse gases	1	33%
11	China is ranked the top emitter of carbon dioxide in the world.	4	24%
12	Climate change reduces the crops yields	4	34%
13	Climate change has a significant impact on crop quality	1	43%

Table 4. 1: Perception and knowledge of small-scale maize farmers

4.4 Multiple Linear Regression Model

The section provides a graphical cross-sectional data analysis **(**Figure 4.**17)** on historical variable data and historical climate data provided by the South African Weather Services. The analysis of the results was through a multiple linear regression model (Tables 4.1, 4.2, 4.3, 4.4 and Table 4.5). Weather events are divided into El Nino and La Nina climate scenarios. The periods of 2014 – 2016 and 2018 – 2019 represented El Nino climate scenarios while La Nina climatic scenarios particularly occurs for 9 – 12 months post-El-Niño.

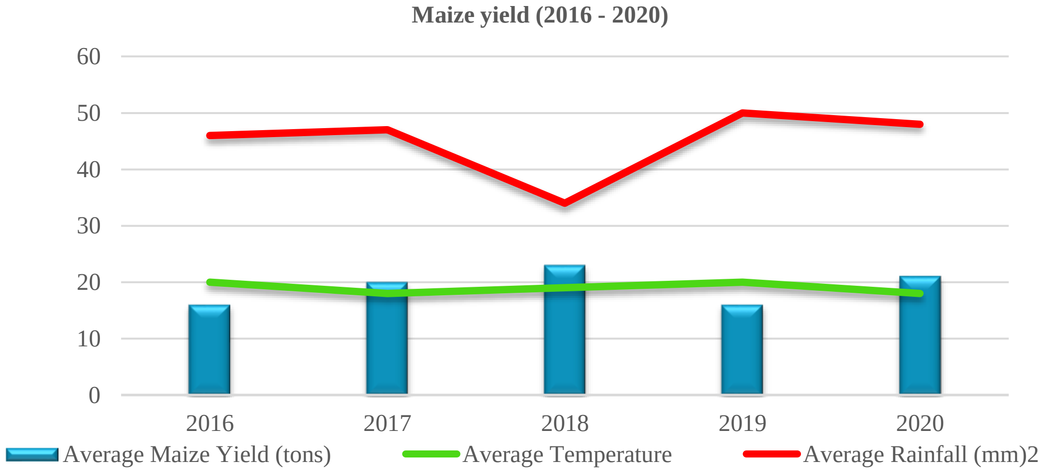

Figure 4. 17:8 Dummy graphical data representation of maize yield, rainfall and temperature **(**Source: Survey data analysis (2022)

The El-Niño climatic scenario is more influential in the beginning phase, i.e. the low rainfall occurrences were usually detected at the beginning of the climatic scenario (e.g. 2018). The results presented in Figure 4.18 below support the evidence found in a study conducted by Andisa *et al*. (2018). The study found that the minimum temperature variations had the most influence on the maize yield within the province, thus, creating greater yield volumes as presented below **(**Figure 4.17)

The output from the statistical software package (STATA) from 2016 – 2020 motivates the rejection of the null hypothesis as there is a statistically significant relationship between the climatic conditions (temperature and rainfall) and the maize yield among small-scale maize farmers in the Ngaka Modiri Molema District Municipality. The South African Weather Services provided data from 4 weather stations in the district. Independent variables from 2016, 2017, 2018, 2019, and 2020 show that a statistically significant relationship exists between climate and maize yield with Prob > F values of 0, 000 individually. The McFaddens Pseudo R-squared values for the years 2016, 2017, 2018, 2019 and 2020 indicated that the model explained 65%; 61%; 74%; 72 and 75% of the maize yield output in the Ngaka Modiri Molema District Municipality within the particular period.

4.4.1 Multiple Linear Regression Results on Effects of Climatic Conditions Affecting Maize Yield Output for the Year (2016)

Table 4.2 indicates the significant variables from the SAWS concerning the collected data. The results indicate that the daily gradual increase in the average minimum temperatures (Lichtenberg) [Coef (.686562*) at 95% CI (.306242 - 1.066882)] about maize yield had a negative relationship, thus, the increase in the average minimum temperatures led to a decrease in the maize yield output. Lisazo et. al. (2018) stipulate that the increase in temperatures results in a decrease in maize crop production. Thus, signifying that temperature as a factor had an impact on maize yield output in 2016. Whilst the monthly daily rainfall data from the Mafikeng station [Coef (1.119778**) at 95% CI (.2119268 - 2.027628)] shows a positive relationship between the rainfall and maize yield. However, the recorded rainfall data from the Ottosdal station [Coef. (-.8901857** at 95% CI (-1.435255 -.3451167)] and the Lichtenburg station [Coef (.6809008**) at 95% CI (-.1253502 - 1.487152)] indicates that the slight increase in the rainfall within the specified areas in 2016, decreased the maize yield output. Amidst drought catastrophes of 2015 – 2016, the areas' differences in coordinate points and evapotranspiration levels may justify the relationship of the areas regarding maize yield output. In an article presented by Botai *et al*. (2016), the average mean temperatures of the Mafikeng region as compared to Ottosdal were greater, thereby justifying that the level of evapotranspiration in the region was relatively greater. Thereby, signifying that the rainfall in the Mafikeng region as compared to the Ottosdal region ensures sufficient production of maize yield.

Table 4. 2: Multiple linear regression results on effects of climatic conditions affecting maize yield output for the year (2016)

Year (2016)			
Variables	Coef.	95% Confidence Interval	
		Lower bound	Upper bound
Average daily minimum temp (Lichtenberg)	.686562*	0.306242	1.066882
Monthly daily rain (mm) (Ottosdal)	-.8901857**	-1.435255	-.3451167
Monthly daily rain (mm) (Lichtenberg)	.6809008**	-.1253502	1.487152
Monthly daily rain (mm) (Mafikeng)	1.119778**	.2119268	2.027628
Number of observations		=	188
F(4, 184)		=	84.81
Prob > F		=	0.0000
R-squared		=	0.6483

Source: Survey data analysis (2022)
Hint: * significant at 10%, ** significant at 5%, *** significant at 1%

4.4.2 Multiple Linear Regression Results on Effects of Climatic Conditions Affecting Maize Yield Output for the Year (2017)

In the preceding year (2017), the effect that the unit increase of the average daily minimum temperatures [Coef. (1.230235***) at 95% CI (.7166661 - 1.743805)] had a positive linear relationship with the average maize yield in the Lichtenberg area. The cold front experienced in the country in the year 2017 may be a potential cause of the positive linear relationship. Thus, the warmer temperatures precisely during June/July had a relatively positive effect on the maize yield in 2017. Whilst a negative relationship exists between the rainfall patterns and the maize yield within the year ([Coef. (.9077935***) at 95% CI (.3013362 - 1.514251)], [Coef. (-.8955715*) at 95% CI (-1.714721 - .0764216)] and [Coef. (.7991982**) at 95% CI (-.0911289 - 1.689525)]). As presented in Figure 4.17, the average rainfall patterns in the district did affect the maize yield amongst small-scale maize farmers in the Ngaka Modiri Molema District Municipality. A recognized imbalance between the average temperature levels and the rainfall patterns inevitably affects the level of evapotranspiration, thereby reducing the average maize yield output (Ali & Mubarak, 2017).

Table 4. 3: Multiple linear regression results on effects of climatic conditions affecting maize yield output for the year (2017)

Year (2017)			
Variables	Coef	95% Confidence Interval	
		Lower bound	Upper bound
Average daily minimum temp (Lichtenberg)	1.230235***	.7166661	1.743805
Monthly daily rain (mm) (Ottosdal)	.9077935***	.3013362	1.514251
Monthly daily rain (mm) (Lichtenberg)	-.8955715*	-1.714721	-.0764216
Monthly daily rain (mm) (Mafikeng)	.7991982**	-.0911289	1.689525
Number of observations		=	188
F (4, 184)		=	72.55
Prob > F		=	0.0000
R-squared		=	0.6120

Source: Survey data analysis (2022)
Hint: * significant at 10%, ** significant at 5%, *** significant at 1%

4.4.3 Multiple Linear Regression Results on Effects of Climatic Conditions Affecting Maize Yield Output for the Year (2018)

The year 2018 indicated to have an equal balance of positive and negative relationships regarding maize yield. The positive relationship between rainfalls was respectively captured throughout the Ottosdal and the Mafikeng stations ([Coef. (1.303747***) at 95% CI (.7069364 - 1.900558)] [Coef. (1.687497***) at 95% CI (.6734427 - 2.701552)], this indicated that the experienced increased rainfall within the particular area had a positive influence on the maize yield output in 2018. Contrary to the average daily minimum temp (Lichtenburg) [Coef (.5146038**) at 95% CI (-.0190877 - 1.048295)] and the monthly daily rain (mm) (Lichtenburg) [Coef (-.6337906**) at 95% CI (-1.292276 - .024695)] which indicated a negative balance against the maize yield. In the Lichtenburg area, the unit increases of the minimum temperatures and the rainfall had a negative influence on the maize yield output in the area.

Table 4. 4: Multiple linear regression results on effects of climatic conditions affecting maize yield output for the year (2018)

Year (2018)			
Variables	Coef	95% Confidence Interval	
		Lower bound	Upper bound
Average daily minimum temp (Lichtenberg)	.5146038**	-.0190877	1.048295
Monthly daily rain (mm) (Ottosdal)	1.303747***	.7069364	1.900558
Monthly daily rain (mm) (Lichtenburg)	-.6337906**	-1.292276	.024695
Monthly daily rain (mm) (Mafikeng)	1.687497***	.6734427	2.701552
Number of observations		=	188
F (4, 184)		=	129.55
Prob > F		=	0.0000
R-squared		=	0.7380

Source: Survey data analysis (2022)
Hint: * significant at 10%, ** significant at 5%, *** significant at 1%

4.4.4 Multiple Linear Regression Results on Effects of Climatic Conditions Affecting Maize Yield Output for the Year (2019)

Table 4.4 below indicates that a negative trade-off was experienced in the year 2019. As such, significant variables indicated the increase in the average daily minimum temp (Lichtenberg) [Coef. (.577273***) at 95% CI (.327469 - .8270764)], the monthly daily rain (mm) (Ottosdal) [Coef. (.5393045***) at 95% CI (.2589052 - .8197038)] and monthly daily rain (mm) (Lichtenberg) [Coef. (.340395*) at 95% CI (.1409355 - .5398544)] had an attributed negative effect on the maize yield in the year. Thus, the increase in the minimum temperatures and the daily rain increase for the year had a decline in the output of maize yield amongst small-scale maize farmers.

Table 4. 5: Multiple linear regression results on effects of climatic conditions affecting maize yield output for the year (2019)

Year (2019)			
Variables	Coef	95% Confidence Interval	
		Lower bound	Upper bound
Average daily minimum temp (Lichtenberg)	.577273***	.3274696	.8270764
Monthly daily rain (mm) (Ottosdal)	.5393045***	.2589052	.8197038
Monthly daily rain (mm) (Lichtenberg)	.340395*	.1409355	.5398544
Monthly daily rain (mm) (Mafikeng)	.0428291	-.2933745	.3790326
Number of observations		=	188
F (4, 184)		=	118.93
Prob > F		=	0.0000
R-squared		=	0.7211

Source: Survey data analysis (2022)
Hint: * significant at 10%, ** significant at 5%, *** significant at 1%

4.4.5 Multiple Linear Regression Results on Effects of Climatic Conditions Affecting Maize Yield Output for the Year (2020)

The table below depicts the multiple linear regression results for the final year of assessment which indicate that the average daily minimum temp (Ottosdal) [Coef. (1.501048***) at 95% CI (.9028328 - 2.099262)], average daily minimum temp (Lichtenberg) [Coef. (-1.31291***) at 95% CI (-2.094472 - -.5313477)], monthly daily rain (mm) (Ottosdal) [Coef. (1.476754*) at 95% CI (.4015969 - 2.551912)], monthly daily rain (mm) (Lichtenberg) [Coeff. (1.62079***) at 95% CI (.8072746 - 2.434307)] and Monthly daily rain (mm) (Mafikeng) [Coeff. (-1.04526*) at 95% CI (-2.05499 - -.03553)].

Table 4. 6: Multiple linear regression results on effects of climatic conditions affecting maize yield output for the year (2020)

Year (2020)			
Variables	Coef.	95% Confidence Interval	
		Lower bound	Upper bound
Average daily minimum temp (Ottosdal)	1.501048***	.9028328	2.099262
Average daily minimum temp (Lichtenberg)	-1.31291***	-2.094472	-.5313477
Monthly daily rain (mm) (Ottosdal)	1.476754*	.4015969	2.551912
Monthly daily rain (mm) (Lichtenberg)	1.620791***	.8072746	2.434307
Monthly daily rain (mm) (Mafikeng)	-1.04526*	-2.05499	-.03553
Number of observations		=	188
F(5, 183)		=	108.75
Prob > F		=	0.0000
R-squared		=	0.7482

Source: Survey data analysis (2022)
Hint: * significant at 10%, ** significant at 5%, *** significant at 1%

4.5 Multinomial Logistic Regression Model (MLM)

The multinomial logistics regression model in this study identifies how the gender, age category, experienced climate effects, other experienced effects, farm size, household size, contact with extension officers, exposure to agri-park and the level of education influence the adaptation strategies utilized by small-scale maize farmers in the Ngaka Modiri Molema District Municipality. The results were analysed through STATA software which presented the Wald chi-squared value [Wald chi^2 (45) = 105.49; Prob > chi^2 = 0,000], this indicates that the model containing the full set of predictors presents significant improvement. This thus interprets that at least one population slope does not equate to zero. Further analysis of the results presented McFadden's pseudo-R-square, the lower bound of the deviance is 0, with higher values reflecting a greater lack of fit. Based on the results of the study we can say that the full model predictors represent 0,000 which is a 0% improvement in fit relative to the null model. The individual adaptive strategies individually present a log-likelihood ratio of -253.53481 which represents a good fit in the model. After the compilation of the results a heteroskedasticity test was done using Breusch-Pagan and depicted a value of [Prob > chi2 = 0.1254.>0.05], which is above 0.05. Thus, it was concluded that there is no heteroskedasticity.

4.5.1 Multinomial Logit Regression Model on Factors Influencing the Choice of Adaptation Strategies (Diversifying Method vs. Did Not Adapt (Base Outcome))

The results as presented in Table 4.7 show factors influencing the choice of adaptation strategies of respondents using the Multinomial Logit Regression Model. The model grouped the various adaptation strategies into (0) did not adapt (reference category), (1) diversifying method, (2) changing planting dates, (3) drought-resistant crops, (4) mixed cropping and (5) other strategies. The individual categories were defined through a Risk Relative Ratio (RRR), concerning the study, this command explains the relative risk of the respondents from adopting a particular climate strategy as compared to no adaptation as a reference category.

The results presented by the model (Table 4.7) indicated that farm size, contact with the extension officer and the level of education had in turn a relative risk ratio of 0.5712111**, 2.728518** and 1.406543**. The results indicate that the relative increase in one unit of farm size [RRR (0.5712111**) at 95% CI (0, 3462085 - 0, 9424438)] reduced the choice in the diversification strategy relative to not adapting. While the relative risk ratio of one unit increase in contact with extension officers [RRR (2.728518**) at 95% CI (1, 027822 - 7, 243294)] and the level of education [RRR (1.406543**) at 95% CI (1.03551 - 1.91051)] had an increase in the choice of adaptation strategy. These results stipulate that farmers made assertive use of the production output from the maize in the field, thereby finding other secondary and tertiary uses of the maize from the production output. While the farmers' contact with extension officers and their level of education had a gradual positive influence on the adaptation of the diversifying methods amongst the small-scale maize farmers. Therefore, the information and training received from the extension officers played a crucial role in the farmers adopting secondary and tertiary use of the maize output. In a study conducted by Makate *et al*. (2016), it is revealed that the technical knowledge provided by the farmers influenced the adoption of the diversification method. This could be attributed to the societal norm and expectation that people with a higher level of education can better articulate information (Sichoongwe *et al*., 2014).

4.5.2 Multinomial Logit Regression Model on Factors influencing the Choice of Adaptation Strategies (Changing Planting Dates vs. Did Not Adapt (Base Outcome))

In the adjusted model where other variables were kept constant, a unit increase in farm size reduces the likelihood of respondents changing planting dates [RR (0.5716101**) at 95% CI (.3028607 - 1.078839)] relative to those who did not adapt. This implies that one unit increase in a farmer's farm size decreases the risk relative ratio of changing planting dates as compared to did not adapt as a reference category. Inversely, household size and contact with extension officers positively influenced the change in planting dates by household size [RR (1.973203**) at 95% CI (1.064647 - 3.657109)] and [RRR (3.853137**) at 95% CI (1.249491 - 11.88217)], respectively. The small-scale maize farmers in the Ngaka Modiri Molema District Municipality maximized the planting dates, therefore, a greater proportion of land did not influence the adaptation strategy. While the household size and their contact with extension officers played a significant role in the adaptation of the strategy, in the period of study, the adaptation of a climate-resistant strategy was the primary concern to larger households as they felt the need to provide sufficient food to their families, hence it had a positive effect in the adoption of the aforementioned strategy while the contact with extension officers played a crucial role in the adoption of the strategy. Extension officers are knowledgeable in the information which is very crucial to small-scale maize farmers.

4.5.3 Multinomial Logit Regression Model on Factors Influencing the Choice of Adaptation Strategies (Drought Resistant Crops vs. Did Not Adapt (Base Outcome)

Farmer's adoption of drought-resistant crops is significantly influenced by the experienced climate effects [RRR (1.626358*) at 95% CI (.9949264 - 2.65853)], the farm size [RRR (.4984694**), 95% CI (.2705596 - .9183623)] and their exposure to agri-park [RRR (.2703474*), 95% CI (.0707676 - 1.032786)]. The results presented indicate that a unit increase in the experienced climate change effects increases the likelihood of farmers adopting the drought-resistant crops strategy relative to those who did not adapt, therefore, small-scale farmers who experienced a greater effect of climate change were likely to adopt the drought-resistant crops for maize farming to ensure the sustainable maize outcomes in the field. Furthermore, the unit increase in the farm size and the exposure to agri-park decreases the relative likelihood of small-scale farmers adopting drought-resistant crops relative to those who did not adopt them in climate change scenarios.

4.5.4 Multinomial Logit Regression Model on Factors Influencing Choice of Adaptation Strategies (Mixed Cropping vs. Non-adapting (Base Outcome))

Table 4.7 below depicts the mixed cropping strategy in the relation to not adapting – the reference category. The significant factors affecting the adoption of mixed cropping in relation to not adopting are (1) the experienced climate change effects [RRR (1.632152**) at 95% CI (1.059588 - 2.514109)], (2) Farm size [RRR (.5138085**) at 95% CI (.3156674 - .8363205)] and (3) contact with extension officers [RRR (4.050242**) at 95% CI (1.542834 - 10.63268)]. The results indicate that the gradual increase in the experienced climate change effects and the contact with extension officers influenced the adoption of mixed cropping strategy compared to those who did not adapt, it is suggested that extension officers provided small-scale maize farmers with the necessary crop mixing strategies which were advantageous to the farmers hence the relative information attained from small-scale maize farmers had an accrued influence on the yield output. Whereof, the unit increase in the farm size has a diminution in the adoption of the mixed cropping as compared to not adapting, therefore farmers made assertive use of the land to ensure that they attain the maximum production outputs.

4.5.5 Multinomial Logit Regression Model on Factors Influencing the Choice of Adoption Strategies (Other Adaptive Strategies vs. Non-adapting (Base Outcome))

The study made an assertive action to collect all known strategies adopted in the area, this included strategies such as the letting the land fallow technique, changing production practices, and praying improved irrigation efficiency. The experienced climate effects [RRR (1.459047**) at 95% CI (.9713274 - 2.191657)], farm size [RRR (.6829588*) at 95% CI (.4434851 - 1.051744)], contact with extension officers [RRR (2.87265**) at 95% (CI 1.147369 - 7.192211)] and the level of education [RRR (1.334131**) at 95% CI (1.013256 - 1.756619] significantly influenced the adaptation of “other strategies” in the area. The aforementioned results indicate that the unit increase in the experienced climate effects, the contact with extension officers and the level of education have a gradual increase in the likelihood of adapting other strategies relative to not adapting. While the unit increase in farm size has a gradual decrease in the likelihood of adapting other strategies as compared to not adopting, therefore an increase in farm size did not influence the aforementioned strategies.

Table 4. 7 Results from the Multinomial Logistics Regression Model

DROUGHT RESISTANT SEEDS		MIXED CROPPING			OTHER ADPTATION STRATEGIES				
95% CONFIDENCE INTERVAL		RRR	95% CONFIDENCE INTERVAL		RRR	95% CONFIDENCE INTERVAL		VIF	
LOWER BOUND	UPPER BOUND		LOWER BOUND	UPPER BOUND		LOWER BOUND	UPPER BOUND	VIF	1/VIF
.2290301	5.229228	.9577466	.253789	3.614336	.8219624	.2347854	2.877617	1.03	0.97
.5973816	1.413319	.8713172	.6036356	1.257702	.9540707	.6753982	1.347725	1.08	0.95
.9949264	2.65853	1.632152**	1.059588	2.514109	1.459047*	.9713274	2.191657	1.42	0.71
.7631616	1.232981	.9756039	.784001	1.214033	.9700789	.7827757	1.2022	1.45	0.69
.2705596	.9183623	.5138085***	.3156674	.8363205	.6829588*	.4434851	1.051744	1.05	0.95
.8109747	2.880249	1.509097	.852779	2.670532	1.552436	.8945775	2.694072	1.04	0.96
.7365854	6.760171	4.050242***	1.542834	10.63268	2.87265**	1.147369	7.192211	1.04	0.96
.0707676	1.032786	.5147884	.1699888	1.558968	.5944523	.2111712	1.673399	1.04	0.96
.8519198	1.69134	1.158097	.8657828	1.549105	1.334131**	1.013256	1.756619	1.03	0.97
								1.13	

(Continued)

Table 4.8: Results from the Multinomial Logistics Regression Model (continued)

VARIABLES	DIVERSIFYING STRATEGY			CHANGING PLANTING DATES			
	RRR	95% CONFIDENCE INTERVAL		RRR	95% CONFIDENCE INTERVAL		RRR
		LOWER BOUND	UPPER BOUND		LOWER BOUND	UPPER BOUND	
GENDER	.4816119	0,11901	1.948873	.2504717	.0370668	1.692516	1.094372
AGE CATEGORY	1.01747	0,6972623	1,484729	.9292644	.5826747	1.482014	.9188529
EXPERIENCED CLIMATE CHANGE EFFECTS	1.358469	0,8748384	2,10946	1.062916	.6154317	1.835771	1.626358*
OTHER EXPERIENCED EFFECTS	1.032205	0,8242608	1,29261	1.031346	.7885571	1.348887	.970033
FARM SIZE	.5712111**	0,3462085	0,9424438	.5716101*	.3028607	1.078839	.4984694**
HOUSEHOOLD SIZE	1.475701	0,8276377	2,631214	1.973203**	1.064647	3.657109	1.528335
CONTACT WITH EXTENSION OFFICERS	2.728518**	1,027822	7,243294	3.853137**	1.249491	11.88217	2.231467
EXPOSURE TO AGRIPARK	.4976104	0,1622393	1,52624	.7031658	.1811521	2.729431	.2703474*
LEVEL OF EDUCATION	1.406543**	1.03551	1.91051	1.115808	.7862722	1.583455	1.200369
Mean VIF							
Number of observations	=		**188**				
Wald chi2 (45)	=		**105.49**				
Prob > chi2	=		**0.0000**				
Log likelihood	=		**-253.53481**				

Source: Survey data analysis (2022)
Hint: * significant at 10%, ** significant at 5%, * significant at 1%**

CHAPTER FIVE: SUMMARY, RECOMMENDATIONS AND CONCLUSIONS

5.1 Chapter Introduction

The effect of climate change is harshly experienced globally and may be a result of various factors as presented in the literature. The final chapter of the study encompasses the overall summary of the dissertation as it provides recommendations and conclusions regarding the overall effect that climate change inevitably has on small-scale maize farmers in the Ngaka Modiri Molema District Municipality.

5.2 Summary

The North West Province was among the drought-stricken provinces in the country together with the Free State Province between the years 2016 - 2018. With the particular interest in the maize production capacity of the province, it created an area of interest in the study as research on the particular subject matter was limited to a few of the provinces. The study addressed various objectives which were concerning climate change i.e. (i) the socio-economic characteristics of small-scale maize farmers of the Ngaka Modiri Molema District Municipality, (ii) their perceptions and (iii) knowledge of climate change, (iv) the adaptation strategies adopted by small-scale farmers in dealing with climate change and (v) To analyse the effects of climate change on maize yield. The first three objectives of the study were assessed under a descriptive analysis, as such, the study interpreted the results through a count method and represented them in graphical figures.

A summary representation of the first objective of the study was undertaken, the results of the study indicated that a large group of the small-scale maize farmers in the Ngaka Modiri Molema District Municipality were predominately male (70%), while fewer of the respondents were female (30%). It also assessed that a greater proportion of the farmers who participated in the study were between the age category of 36-40 years (21%), while a fewer percentage of the farmers were between the age category of 18-25 (3%). The summarized economic culture of the respondents indicates there exists a linear relationship between the credit range and credit satisfaction, as such, small-scale maize farmers in the Ngaka Modiri Molema District Municipality have a greater credit satisfaction with the increase in credit range, Figure 4.12 indicates that a majority of those with credit can meet their repayment obligation on time (63%), while a fewer of the respondents do not (30%).

In order to determine the knowledge and the perceptions that the small-scale maize farmers had in regard to climate change, the study made use of funnel questions, also giving the respondents a choice in their response. As such, the results presented in Table 4.1 indicated the results of the method. The study thus concluded that the younger respondents were well-informed about the effects of climate change amongst small-scale maize farmers, thus having greater perception and knowledge.

The study hypothesized that climate change had an overall effect on the yield amongst small-scale maize farmers in the Ngaka Modiri Molema District Municipality with the contingent assessment to analyse the various factors which influenced the mitigation of adaptation strategies in the area. A yearly assessment of the overall estimated production outputs provided for by the farmers was regressed against the historical recorded climatic variable data provided by the SAWS through a Multiple Linear Regression Model. The primary assessment of climate change was particularly rainfall and temperature which showed that climate change influenced the volatility of maize production. This model reveals that the volatility which was experienced throughout the area on a yearly assessment resonates with the particular climatic setting; therefore, if temperatures were not favourable in the year of assessment and greater rainfall were to occur then this would influence the overall maize yield in the area of analysis.

In an attempt to assess the influence of adaptation strategies amongst small-scale maize farmers, the study implemented the Multinomial Regression Model, which indicated that the farm size, household size, level of education, the experienced climate effects, contact with extension officers and the farmers' exposure to Agri-park initiatives implemented by the DAFF, particularly influenced the adaption of most strategies in the area. Small-scale maize farmers who did not adapt were placed in a referential category in the analysis. The model identified that the use of adaptation strategies by the small-scale maize farmers in the Ngaka Modiri Molema District Municipality was predominately influenced by the farm size, contact with extension officers, and level of education, household size and the experienced climate change effects, with the particular assessment of farm size and their contact with extension officers playing a greater role. As a result, we rejected the null hypothesis of the study as there exists a statistically significant relationship between socioeconomic, demographic characteristics and the choice of adaptation strategies utilized by small-scale maize farmers in the Ngaka Modiri Molema District Municipality. Amongst the strategies evaluated in the study included the fallowing practice: changing production practices, praying, improving irrigation efficiency and a combination of the aforementioned strategies.

5.3 Conclusions

It is concluded that climate change has an identified effect on the small-scale maize farmers in the Ngaka Modiri Mole District Municipality. The particular adaptation strategies are influenced by factors such as gender, age, farm size, household size, contact with extension officers, exposure to Agri-park, level of education and the farmers' experienced climate change effects. These factors have influenced the maize yield yield (2016-2020). While it has been identified that a significant relationship exists between rainfall and temperature and maize yield. Therefore, the study rejects the null hypothesis of the study and accepts the alternative hypothesis.

5.4 Recommendations

The following are the recommendations from this study: 1) as the study has represented a linear relationship between the adaptation of climate resilient strategies and the contact with extension officers, DAFF should suggest strategies to capture the small-scale farmer’s production capacity. The study experienced challenges in the precise historical data provided by the small-scale maize farmers. The uniform approach of small-scale maize farmers and extension officers could increase the yield output in the province.

2) The study creates a channel for the investigation of the effect of nighttime temperature on the influence of climate change, as they are seen to be significant in the multiple linear regression models.

3) There should be an increase in the participation of small-scale maize farmers amongst DAFF exhibitions/ expos as it positively influences farmers' yield.

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