ADOPTION OF DROUGHT–TOLERANT MAIZE VARIETIES AMONG SMALLHOLDER FARMERS IN LEPELLE-NKUMPI MUNICIPALITY, LIMPOPO PROVINCE, SOUTH AFRICA

BY

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Dedication

This dissertation is dedicated to my father, Majoko Ramokgopa, my mother; Ramaisela Ramokgopa, my late brother, Tshepho Ramokgopa and all of my family.

Declaration

I, Ramokgopa Tshwarelo, hereby declare that, **Adoption of Drought Tolerant Maize Varieties among Smallholder Maize Farmers in Lepelle Nkumpi Municipality**, **Limpopo Province, South Africa**, hereby submitted to the University of Limpopo, for the degree of Master of Science in Agriculture, Agricultural Economics, has not previously been submitted by me for a degree at this or any other University; that this is my own work in design and in execution, and that all material contained therein has been duly acknowledged.

…………………………………. ……………………………………

Surname, Initials (Title) Date

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Abstract

Agriculture is not only the backbone, but also an important sector of the South African economy. It provides food and employment to a majority of people in the country, especially in the rural areas. Smallholder farmers play an important role in livelihood creation and the alleviation of poverty among the population of the Limpopo Province. However, despite their significant contribution, smallholder farmers' production is still low. Climate change has bought increasing frequencies and severity of drought conditions and uncertainties in the length and quality-growing season. Drought threatens the production of maize as a staple food and without measures to counter climate change, food security will be a major problem in South Africa.

This study therefore examined factors determining the adoption of drought tolerant maize among smallholder farmers in the Lepelle-Nkumpi Municipality. Primary data was collected using semi-structured questionnaires to achieve the objectives of the study. Multistage sampling was used for the study because larger clusters were subdivided into smaller and more targeted groupings for surveying. Descriptive Statistics and the Binary Probit Model were used to analyse the data.

The results of the Probit Regression analysis indicated that farm size, hired labour and maize produced per hectare had positive significant influence on the probability of farmers adopting drought tolerant maize varieties. Farm size and maize produced per hectare were statistically significant at 1% and hired labour was statistically significant at 5%. Based on the sample of this study,74% of the households grew non-drought tolerant maize varieties, while 26% of the smallholder farmers grew drought tolerant maize varieties. The results indicate that 24,4% of the farmers were not affected by any constraints in terms of their adoption of drought tolerant maize varieties whilst 76,6% said they are affected by those constraints in Lepelle-Nkumpi Municipality.

Based on the study's findings, it is recommended that extension officers should make it a priority to provide smallholder farmers with timely and accurate information. Extension officers should effectively disseminate information about the adoption of drought tolerant maize through a combination of different pathways.

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List of abbreviations and acronyms

ABET	Adult Basic Education and Training
DAFF	Department of Agriculture, Forestry and Fisheries

DTMV	Drought Tolerant Maize Variety
MSc	Master of Science
NDA	National Development Agency
ARC	Agricultural Research Council

CHAPTER ONE INTRODUCTION

1.1 Background

Agriculture is not only the backbone, but also a very important sector of the South African economy. It provides food and employment to most people in the country, especially in the rural areas (FAO 2011; Fisher 2015). The Limpopo Province is regarded as the garden of South Africa because it produces large quantities of scarce agricultural products. Smallholder farmers constitute a large section of the rural population in the Limpopo Province. In the Lepelle-Nkumpi Municipality, smallholder farmers are predominantly involved in maize production as an effort to alleviate poverty and hunger.

Weather shocks such as droughts and floods undermine crop yields and aggregate production thereby reducing food availability and agricultural incomes (Davies *et al*., 2009; Kassie *et al*., 2009; Kankwamba *et al*., 2018). Farm households' failure to adapt to climate change could aggravate the negative effects and can inhibit further investment and economic growth (Kato *et al*., 2011; Kassie *et al*., 2015). Weather shocks can cascade through low production to food insecurity and local and national economic disruption (Devereux, 2007). The problem is particularly serious among smallholder farmers in Sub-Saharan Africa (SSA), who are repeatedly exposed to weather extremes but with limited adaptation options.

Maize, a field crop that is one of the most cultivated crops in the world, is a staple crop for most countries in SSA. Its yields in developing countries (including SSA) are lower than in developed countries (Chapoto *et al.*, 2015; Kuteya *et al.*, 2017). More importantly, maize production depends on water availability, and most of SSA's agriculture is rain-fed, which make its production an obvious candidate to be affected by weather shocks such as droughts, one of the negative consequences of climate change. Lobell *et al*. (2017) reveal that maize is sensitive to daytime high temperatures above 30°C and with climate change; the projected 2°C in temperatures for most parts of Africa would affect maize production, which would further lower productivity levels in SSA despite increasing the demand.

Investing in agricultural production methods to boost farmers' resilience against weather shocks is a key strategy to reduce negative impacts (Davies *et al*., 2009; Pangapanga *et al*., 2012). In a country like South Africa and most countries in the SSA region, with poor or missing markets for insurance and credit and limited off-farm employment opportunities, adoption of agricultural management strategies that reduce production risks is an important option for smallholder farmers (Kassie *et al*., 2015). Drought tolerant (DT) maize is one potential technology that has the capacity to help smallholders adapt to drought risks. It is estimated that a drought tolerant maize variety can produce up to 30% of their potential yield after 6 weeks of water stress, before and during flowering and grain-formation (Magorokosho *et al*., 2009; Hlalele *et al.*, 2016). It is also estimated that DT maize can give a yield advantage of up to 40% over other maize varieties in severe drought environments (Tesfaye *et al*., 2016)

Generally, maize production is mainly being conducted under rain-fed conditions. According to Bhavnani *et al.* (2008), Shiferaw *et al.* (2014), and Hlalele *et al.* (2016), the declining and low precipitation has led to severe sowing drought in most parts of South Africa, which has severely affected maize production. Even if there is little rain sometimes in year, the uneven temporal distribution often causes drought, and since this season is critical for maize production, drought often results in a marked reduction in crop growth and grain yield (Tadesse, 1998; Shiferaw *et al.*, 2014). Given that maize production in Lepelle-Nkumpi Municipality has a major role in South Africa's food security, taking the effective strategies to mitigate the impacts of drought stress on maize growth is important.

Agricultural production in developing countries is subject to various sources of risk Chapoto *et al.* (2015), with weather variability being a pervasive one (Hill *et al.*, 2017). Such risks discourage farmers' investments in productivity-enhancing technologies. Recent years have witnessed the development of stress tolerant crop varieties designed to help small-scale farmers manage weather stress. Drought Tolerant Maize Varieties (DTMVs) are one such a promising avenue. These maize (*Zea mays*, also known as corn) varieties have an enhanced ability to withstand an abiotic stress like drought. A number of such DTMVs have been developed over the years in a collaborative effort by the International Maize and Wheat Improvement Center (CIMMYT) and National Agricultural Research Organizations (NAROs), particularly in

Africa (Fisher *et al*., 2015). The DTMVs are screened in each of the countries where they undergo extensive on-station and multi-location on-farm testing using participatory variety selection approaches with farmers across the different agro-ecologies. The DTMVs that out-yield popular commercial checks in those agro-ecologies where they are tested are then selected for release and subsequent commercialisation (Setimela *et al*., 2017). By early 2016, over 200 distinct DTMVs had been released in 13 Sub-Saharan countries, with reportedly more than 2 million farmers growing them (CIMMYT, 2017).

Drought has been highlighted as one of the major causes of reduced maize production and food insecurity across the globe and particularly in Sub-Saharan Africa (SSA), where agricultural production is largely rain-fed (Shiferaw, Prasanna, Hellin & Bänziger, 2011). Daryanto, Wang and Jacinthe (2016) estimated that the occurrence of mid-season droughts, particularly at the vegetative and productive phases for maize, reduces yields by 39.3%. Although projected changes in precipitation during the maize growing season in SSA vary with location and region (IPCC, 2007; Cairns *et al*., 2013), overall temperatures are predicted to increase by 2.1–3.6°C by 2050 (Cairns *et al*., 2012). The predicted increase in temperature is likely to have huge implications for maize production and, subsequently, the food security and livelihoods of smallholder farming households (Lobell, Bänziger, Magorokosho & Vivek, 2011). Adapting to such climatic changes is thus critical for ensuring national food security and economic stability. One such adaptation strategy has been the development of drought-tolerant (DT) maize varieties. Thus, since the late 1990s, DT maize varieties have been viewed as part of the solution to sustaining maize production mainly under smallholder farming conditions. Since then, the development of DT maize varieties has remained a major objective of breeding programmes and research institutes across the globe (Masuka *et al*., 2017).

Risk-mitigating technologies such as DTMVs are thus expected to stabilise yields and incomes in the face of shocks, and possibly exhibit a risk reduction dividend. By reducing risks, DTMVs have the potential to catalyse investments in production and achieve higher incomes (Morduch, 1992; Binswanger & Rosenzweig, 1993; Lamaoui *et al*., 2018). A risk reduction technology, therefore, can induce behavioural change, empowering producers to undertake originally risky, but high return investments, which they otherwise would avoid due to risk aversion. Accordingly, Dar *et al*. (2013) show

how farmers with stress-tolerant rice seed increased their investments in rice fields. Via the risk reduction dividend, the adoption of DTMVs is expected to crowd-in additional agricultural investment at both the extensive margin (area planted) and the intensive margin (use of yield or value increasing inputs). Yet, the extent to which DTMV adoption crowds-in additional investments remains an empirical question. These are important empirical questions to better understand and refine the pathways of science-for-impact (Roling, 2009).

1.2 Problem statement

Maize production is under threat from climate change, which calls to produce different maize varieties. Climate change has bought increasing frequencies and severity of drought conditions and uncertainties in the length and quality-growing season(s). Drought threatens the production of maize as people’s staple food and without measures to counter climate change, food security will be a major problem in South Africa (DAFF, 2012). One of the measures to combat climate change in agricultural production is by adopting a drought tolerant maize variety that withstands drought and heat stress and offering protection from new diseases and pests.

South Africa in general, is not suitable for crop production as only a small area of the country is arable due low rainfall and poor soils. Maize yields obtained by smallholder farmers are very low because their crops often subjected to moisture stress and they use very little fertilizers due to lack of resources (most smallholder farmers lack or do not afford irrigation infrastructure; they rely on rainwater for irrigation). Due to limited water resources, maize crop is grown under irrigation. Climate change is predicted to worsen the situation with rainfall that is more variable and above average temperatures (Abate *et al*., 2017). Identifying ways to mitigate and adapt to climate change are important to realising food security and improved livelihoods in South Africa. Low water availability and dry climate are the major challenges faced by smallholder farmers producing maize in the Lepelle-Nkumpi Municipality.

Farmers tend to adopt a portfolio of maize varieties combining both traditional and improved (Lunduka *et al.,* 2012). Two conventional drought tolerant maize hybrids (WE 3127 and WE 3128) were released in September 2014 and, according to Iezzi and Fanciulli (2015), the demonstration plots planted by farmers during 2013/2014 season showed positive results. WEMA (Water Efficient Maize for Africa) hybrids are targeted to smallholder farmers who have limited production resources and have enough of cultivated land.

Drought tolerant maize is one of the innovation smallholder farmers can adopt when trying to increase famers' income, productivity levels and reducing poverty. Therefore, this study will add to the body of knowledge on available maize varieties that farmers grow and some of the factors influencing their adoption. This will assist in knowing how best to address some of the challenges faced by the farmers in the Lepelle-Nkumpi Municipality. This study focuses on adoption and promotion of new varieties of drought tolerant maize. This agricultural adaptation is low-cost and relatively easy for farmers to use, but development of these improved varieties relies on considerable private and public investment. The aim of the study is to analyse factors affecting the adoption of drought-tolerant maize varieties as agricultural innovation by the smallholder farmers.

In the past, agricultural research has largely focused on yield improvement, thus research on drought tolerance has not received adequate attention. This study therefore sought to provide an in-depth understanding and to analyse factors affecting the adoption of drought-tolerant maize varieties among smallholder farmers in Lepelle-Nkumpi Municipality, Limpopo Province, South Africa.

1.3 Motivation of the study

Maize is an important staple food for most people in South Africa. However, its production is affected by many factors. Moisture stress or drought comes on top of the list (Shiferaw, 2011). Frequent drought causes yield loss to smallholder farmers and severe drought causes total crop loss. Failure to produce maize in high quantities and good quality means a disaster to household and food security in South Africa. It is important to create awareness and encourage smallholder farmers to adopt a drought tolerant maize variety that is tolerant to drought since maize is a stable food. In areas where there is little rain and unstable weather conditions, a drought tolerant crop will still retain its enormous potential to increase productivity and nutrition. It is therefore important for smallholder farmers to adopt these maize varieties as stable crops have proven to provide an assured harvest even in poor seasons. This would help smallholder farmers in the Lepelle-Nkumpi Municipality to grow more maize for their households and for commercial purposes.

According to Bosiako (2017), smallholder maize farmers are mostly affected by drought because many of them do not have an irrigation technology and rely on rainfall for their maize produce. With the unpredictability of rainfall patterns, smallholder farmers are no longer able to plan their planting seasons. Over the past several years, there has been an increasing recognition in both international and national agricultural innovation systems of the potential adverse effects of extreme climatic events, such as droughts on agricultural production and livelihood of the farmers (Siopongco, 2013). Drought tolerant maize is one of the innovation smallholder farmers can adopt when trying to increase famers' income, productivity levels and reducing poverty. Therefore, this study will add to the body of knowledge on available maize varieties that farmers grow and some of the factors influencing their adoption. This will assist in knowing how best to address some of the challenges faced by the farmers in the Lepelle-Nkumpi Municipality.

Maize is an important grain crop in South Africa, produced throughout the country under diverse environmental conditions and it has a dominant portion in the diets of rural and urban poor. When successful, these varieties could benefit farmers and consumers by contributing to lower production costs, higher yields, and more food grain (Caliskan *et al.*, 2017). Therefore, it is vital to note that a study on the adoption of a drought tolerant maize variety will not only assist in withstanding the dry conditions but will also assist in enhancing productivity and will boost the food security status of the households in the study area. The study's findings will help in improving the productivity of smallholder maize farmers in the Lepelle-Nkumpi Municipality by providing relevant information on what determines the adoption of a drought tolerant maize among smallholder farmers and productivity.

1.4 Scope of the study

1.4.1 Aim of the study

The aim of the study was to analyse factors affecting the adoption of drought-tolerant maize varieties as agricultural innovation by the smallholder farmers.

1.4.2 Objectives of the study

The objectives of the study were to:

I. Identify and describe the socioeconomic characteristics of smallholder maize farmers in the Lepelle-Nkumpi Municipality.
II. Identify the different drought tolerant maize varieties grown by smallholder maize farmers in the study area.
III. Examine factors determining adoption of drought tolerant maize by smallholder farmers in the Lepelle-Nkumpi Municipality
IV. Identify the constraints to the adoption of drought tolerant maize varieties among productivity smallholder maize farmers in the study area.

1.4.3 Research hypothesis

Socioeconomic characteristics of smallholder maize farmers in the Lepelle-Nkumpi Municipality do not influence the adoption of drought tolerant maize varieties.

1.5 Organisational structure

The research consists of five chapters, with Chapter One encapsulating the introduction, background, problem statement, aim, objectives and the hypothesis of the study. Chapter Two presents the literature review, where previous studies, both locally and internationally, which are related to the study are brought into critical focus. Chapter Three provides the methodology and the analytical tools that were used to carry out the study. Chapter Four presents and interprets the results that were obtained during the data collection process. Chapter Five consists of the summary, conclusion and policy recommendations of the study.

CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

This chapter reviews previous studies on the adoption of drought tolerant maize among smallholder farmers. The definitions of the concepts ‘adoption’ and ‘smallholder farmers’ are also provided in this chapter. The chapter also elucidates the factors that affect the adoption of drought tolerant maize by smallholder maize farmers.

2.2 Review of Previous Studies

2.2.1 Concept of adoption

Technologies play an important role in economic development. Adoption and diffusion of technology are two interrelated concepts describing the decision to use or not use and the spread of a given technology among economic units over a period of time. The adoption of any innovation is not a one step process, as it takes time for adoption to complete (Ogada *et al*., 2014). First time adopters may continue or cease to use the new technology. Adoption refers to the decisions that individuals make each time they consider taking up an innovation or decision of an individual to consider making use of innovation as the best course available (Rogers, 2003; Mills *et al*., 2019). Drought is a huge limiting factor in maize production, mainly in the rain-fed agriculture of Sub-Saharan Africa. In response to this threat, drought-tolerant (DT) maize varieties have been developed with an aim to ensure maize production under mild drought conditions.

2.2.3 Concept of smallholder farmers

The concept of ‘smallholder farmers’ refers to those rural farmers who cultivate on small farm areas with a dense population (McC.Nettin, 1993; Aliber *et al*., 2015). Most sources defined smallholder farmers looking at the farm size, and as those farmers who have less than 2 hectares of land for cultivation. Hazell *et al.* (2013) define smallholder farmers as those farmers who depend on household members for most of their labour with the aim of producing food for household consumption. In this study, a smallholder farmer is defined as a farmer with less than 2 hectares, limited resources and needs external support so that he or she can farm successfully. Kirsten and Van Zyl (1998) and Tefera *et al.* (2017) define smallholder farmers as backward, non-productive and operating in non-commercial subsistence agriculture and are found in the former homelands.

Smallholder farming has the potential of increasing the Gross Domestic Product of South Africa, but this can only happen if the smallholder farmers are able to produce maize in high quantity and good quality in order access or satisfy the markets. Eicher (1994) and Rochester *et al*. (2016) suggest that the governments of African countries should focus on the development of both smallholder and middle farmers.

2.2.4 Maize production in South Africa

Maize (Zea mays L.) is the most important grain crop in South Africa and is produced throughout the country under diverse environments. Successful maize production depends on the correct application of production inputs that will sustain the environment as well as agricultural production (ARC 2002; Khonje *et al.*, 2018). These inputs are, inter alia, adapted cultivars, plant population, soil tillage, fertilisation, weed, insect and disease control, harvesting, marketing and financial resources. In developed countries, maize is consumed mainly as a second-cycle produce, in the form of meat, eggs and dairy products. In developing countries, maize is consumed directly and serves as staple diet for some 200 million people. Most people regard maize as a breakfast cereal. However, in a processed form, it is also found as fuel (ethanol) and starch (ARC, 2016). Approximately 8,0 million tons of maize grain are produced in South Africa annually on approximately 3,1 million ha of land. Maize needs 450 to 600 mm of water per season, which is mainly acquired from the soil moisture reserves.

Maize is the primary staple food in South Africa and most of African countries (FAO/GIEWS, 2011). In South Africa, maize is mostly grown in Gauteng, Mpumalanga, North-West Province and the Free State on a large-scale basis (Chabane, 2002; Wossen *et al.*, 2017). A majority of smallholder farmers are poor, lack resources and credit. This has resulted in the low productivity of most smallholder farmers, which limits them from participating in the markets (Obi *et al*., 2011; Khonje *et al*., 2015).

While the annual national maize production in South Africa fluctuates widely according to rainfall, average production has remained constant over time. This is a concern, as consumption has increased with the growing population and as such, maize production may soon not meet local demand, affecting both local and regional supply (NDA 2009; Huang *et al*., 2017). Like maize, wheat production also fluctuates, and again, its average production has remained constant while consumption has increased dramatically over time. In recent years, wheat imports have increased massively to meet local demands.

2.2.5 Maize varieties in South Africa

Maize varieties cultivated in the SSA region are classified into three major categories: traditional/local, hybrid and Open Pollinated Variety (OPV) (Lunduka *et al*., 2012; Gakidou *et al*., 2017). Generally, smallholder farmers have several fields to grow maize. Using different maize varieties in different fields is regarded as an effective way to mitigate the negative impacts of drought and increase in the maize stability, since different maize varieties vary in resilience to drought. The adoption of more than one variety has been used for a long time because of the frequent occurrence of drought. Over 1,700 varieties have been released between 1950 and 2014 across countries in SSA, of which 68% are hybrids and 32% are OPVs. As of 2014, improved maize occupied 57% of the land area under maize production in SSA (Abate *et al*., 2017). The hybrid maize varieties are high yielding while OPVs are early maturing, compared to local varieties, hence providing farmers with yield advantage (Lunduka *et al*., 2012). However, local varieties are still popular among farm households, despite the proliferation of hybrids and OPVs, because of favourable processing and consumption traits such as taste, storability, poundability, high flour-to-grain ratios and lower requirements for inorganic fertiliser (Smale *et al*., 1995; Denning *et al*., 2009; Katengeza *et al., 2019*). Thus, while hybrids and OPVs have production advantage over local varieties, they do not yet have the consumption attributes that farm households prefer in local maize.

Abate *et al.* (2017) report the adoption rates of 32% hybrids; 23% OPVs and 46% local in SSA. Farmers weigh options as to whether to allocate more land to high yielding varieties with poor post-harvest attributes or put more weight on post-harvest attributes at the expense of high yields. With the apparent recent increase in droughts, farmers not only weigh high yielding against post-harvest characteristics, but also drought tolerance as a hedge against droughts.

2.2.6 Drought tolerant maize variety

Drought tolerant maize seed became an integral component in breeding programmes across SSA countries during the late 1990s because of recurrent droughts (Bänziger *et al*., 2006). The programme received support from the International Maize and Wheat Improvement Centre (CIMMYT) and International Institute of Tropical Agriculture (IITA) with the launch of the Drought Tolerant Maize for Africa (DTMA) project in the mid-2000s. The project supported production and dissemination of DT maize varieties in 13 countries in SSA. Over 200 varieties were released before the project phased out in December 2015. The project was implemented jointly with national agricultural research systems which were responsible for seed delivery with support from public and private seed companies (Tesfaye *et al*., 2016; Toemen, 2016).

In Malawi, as of December 2015, 18 DT maize varieties (15 hybrids and 3 OPVs) were released under the DTMA project. There are also other varieties developed outside the DTMA project that have been certified as drought tolerant by maize breeders (Abate, 2015; Holden & Fisher, 2015).

These improvements have attractive characteristics such as higher yield, shorter maturing period and low susceptibility to diseases. Increased famers' income and sale of the produce is due to the improvement of quality of harvested crops and increased productivity over time. Thus, reducing the level of vulnerability to poverty. It can, therefore, be concluded that the uses of improved maize varieties are keys in the realization of increased agricultural productivity and in raising the standard of living of the farming population (Adenuga *et al.* 2014). Drought tolerant maize is one of the innovation smallholder farmers can adopt when trying to increase famers' income, productivity levels and reducing poverty.

The complex expression of drought tolerance maize variety makes it difficult to analyze using conventional genetic methods. Although major progress to date has been achieved through breeding, this approach not only remains slow and time-consuming.

Also, breeding of varieties that are adapted to arid and semi-arid areas is not straightforward because of contradicted demands between biomass accumulated required for growing maize and stress avoidance due to a reduction of transpiration under water scarcity (Fisher, 2017). These difficulties is the fact that drought occurrence is highly unpredictable over time and space, and diverse strategies are adopted by the genotypes to combat the stress depending on the timing, severity and stage of crop growth.

Studies reveal many agricultural adaptations used by smallholder farmers in SSA. Yet for many farmers these methods are insufficient for protecting livelihoods in drought prone regions of SSA (Shiferaw *et al*. 2018). Investments by governments and other institutions in development of new crop varieties, irrigation infrastructure and storage facilities will likely be necessary (Burke and Lobell 2016). This study focuses on the adoption of new varieties of drought tolerant maize variety. This agricultural adaptation is low-cost and relatively easy for farmers to use. Therefore, this study will add to the body of knowledge on available maize varieties that farmers grow and some of the factors influencing their adoption. This will assist in knowing how best to address some of the challenges faced by the farmers in the Lepelle-Nkumpi Municipality.

Realization of the benefits of drought tolerant maize for smallholder farmers have been repeatedly predicted, although those benefits depends on adoption of the new DT maize varieties by SSA farmers (Tambo and Abdoulaye 2015). Considerable farmer demand for DT varieties, but the literature on adoption of modern crop varieties by smallholders in SSA indicates an uneven record. Occasions of widespread adoption (Alene *et al.* 2019) are mixed with examples of low rates of adoption and lack of sustained use of seemingly advantageous farm technologies (Kijima *et al.* 2017). Furthermore, studies indicate that smallholder farmers in SSA are generally aware of local environmental changes, but many have made no adjustments to reduce impacts of increasing temperature and/or decreasing precipitation (Fosu-Mensah *et al.* 2012; Gbetibouo *et al.* 2016). Research is needed to uncover factors that encourage farmer adaptation.

2.2.7 Agricultural productivity

Agricultural productivity is increasing in most of the developed countries and this is because the developed countries have highly invested in research and development, labour, land, capital and improved use of inputs such as fertilisers, machinery use and others (DAFF., 2011; Manda *et al*., 2016). A study conducted by Barrett (2008) found that a market is equivalent to production technology. This means that production technology affects the ability of the farmer to participate in a market by affecting its productivity. Sandal (2016) further found that in order for a farmer to produce for the markets, production resources are required, and these resources include land, water infrastructures and capital.

Thirtle *et al*. (1993) and Kibirige (2015) studied agricultural productivity and found that agricultural production is fluctuating. In some years, productivity was increasing whilst in others, productivity was decreasing. Studies conducted by Zepeda (2001) and Setimela *et al*. (2017) examined agricultural productivity in developing countries. Different models were used to examine the change in output to identify the relative contribution of different inputs to output growth. The results showed that there is a relatively weak relationship between physical capital and growth, as compared to investment in technology and human capital.

Kamara (2004) and Smale *et al.* (2020) iindicated that the use of high yielding seeds varieties and labour inputs have a positive determinant on agricultural productivity. According to Ndoli *et al*. (2016), farmer organisation can form a basic for improving market access. Furthermore, farmer organisation has the potential to improve the imperfections in the markets. Land is the most significant productive assets that ensure that rural households can have food. According to Mabuza *et al*. (2018), land is a serious challenge to most smallholder farmers in the rural areas. The study investigated the factors influencing the use of alternative land cultivation technologies in Swaziland and concluded that, about 49% of the farmers had total arable land below the threshold of 2 hectares.

In a study conducted Mazvimavi (2012), the results indicated that the adjusted R2 was 0.42. This means the dependent variables were only able to explain 42% of the variation in the study. Furthermore, Kibirige (2015) studied the agricultural efficiency of smallholder farmers in the Eastern Cape Province of South Africa. The results indicated that the adjusted R2 was 0.240. The results indicated that only 24% of the variation was explained by the variable in the study.

2.2.8 Climate change and maize production

Despite its importance, maize productivity in SSA, except for South Arica, has remained quite low and only increased from about 0.9 to 1.5 tons/ha while the yield remains highly variable. The variation in yields is mainly due to dependence on rainfall under uncertain climatic conditions (Ng'ombe *et al.,* 2014). With climate change, the yields of maize have been negatively affected in many regions. Thus, even when compared to the top five maize producing countries in the world, maize yields in SSA have stagnated at less than two tons per hectare and less than 1.5 tons per hectare in Western and Southern Africa. In addition, in SSA, the highest growth in maize area yields and production from the year 1961 to 2010 has been West Africa when South Africa is excluded, and the lowest has been in Southern Africa with yields at a little over 1 ton/ha.

The prime reason put forward for this inconsistency in maize yields between SSA and other regions is less adaptive capacity of smallholder farmers to climatic change-related effects. Ng'ombe *et al*. (2014) state that the success of agriculture in SSA is hindered by the negative effects of climate change while at the same time contending that the less adaptive capacity of smallholder farmers in SSA coupled with their rain-fed farming systems (common in SSA) expose their vulnerability to climatic effects. This observation affirms that there is a large gap in yield between countries in SSA and countries with comparable production conditions. The lower maize yields in SSA are more attributed to drought stress than other reasons such as low soil fertility, weeds, pests, diseases, low input availability, low input use and inappropriate seeds and poor irrigation schemes or lack of efficient irrigation systems. (Mulungu *et al.,* 2019).

According to Nelson *et al.* (2002) and Mulungu *et al.* (2019), the negative effects of climate change on crop production are more noticeable in SSA than in other parts of the world. Thus, severe and prolonged droughts leading to reduced agricultural yields through such avenues as crop failure and loss of livestock, which provide draught power and household income, are still probable. Literature indicates that because of climate change, there is an observed 10% decline in maize yield, 15% decline in rice yield and 34% decline in wheat yield in SSA in the previous years. Yield projections indicate that by the year 2020, yields from rain-fed agriculture in some African countries could be reduced by up to 50%, and that would, to a great extent, affect food security and worsen the malnutrition situation. Mulungu *et al*. (2019) show that in Zambia, under the worst situation, maize yields will decrease by 25% driven mainly by temperature increases offsetting the gains from increased rainfall.

According to Ngoma *et al.* (2019), there will be a decline in water availability in Zambia by 13% by the end of the century in 2100 at a national level because of climate change, which poses a much greater risk to field crops such as maize. Africa's inability to cope with the physical, human and socioeconomic consequences of the extremes of climate makes it the most susceptible to climate change. What also adds weight to the incumbent problem is that the majority of maize agricultural producers in SSA reside in rural areas. However, the rural poor are more vulnerable to these changes in climate and consequently, hunger, poverty and malnutrition levels will mostly likely continue to rise, which means that the severity of climate change will increase keeping other factors constant (Kijima *et al*., 2015). In light of this evidence, there is a need to diversify maize production as dependence on maize production in most SSA countries is a worry for food and nutritional security, especially when alternative supplements for dietary diversity are limited.

2.2.9 Adaptation to drought

Research on maize has a very important role to play when it comes to adaptation to climate change in vulnerable areas. Africa has been projected to be affected the most by climate change due to limited institutional, financial and technological capacity, therefore, adaptation to climate change will be difficult and complicated. It is expected that research and plant breeding will mitigate many of the detrimental effects, but the negative effects of climate change are expected if farmers continue to plant the same varieties in the same way and in the same areas (Jones *et al*., 2018). Some autonomous adaptations that will help offset some negative impacts of climate change include shifting of planting dates, modifying crop rotations or an uptake of pre-existing crop varieties.

The adoption of stress-tolerant varieties is expected to increase productivity and yield stability, and most importantly, to reduce the exposure of farmers to the downside risk. Simtowe *et al*. (2019) provided an ex-ante impact assessment of investments in drought-tolerant maize in Africa, based on the economic surplus method, and predicted positive yield impacts as well as improved yield stability. Ex-post empirical studies confirming these impacts in Sub-Saharan Africa are still scant. One such study was conducted by Wossen et al. (2017), who point to the possibility of DTMV adoption having a yield stabilisation as well as a risk reduction effect.

Although the benefits of DT maize for African farmers have been repeatedly predicted, the realisation of those benefits depends on the adoption of the new DT maize varieties by SSA farmers(Tambo & Abdoulaye, 2013). The study indicates a considerable farmer demand for DT varieties, but the literature on the adoption of modern crop varieties by smallholders in SSA indicates an uneven record. Incidents of widespread adoption are mixed with examples of low rates of adoption and lack of sustained use of seemingly advantageous farm technologies (Alene *et al*., 2013; Kijima *et al.* 2015). Furthermore, studies indicate that smallholder farmers in SSA are generally aware of local environmental changes, but many have made no adjustments to reduce impacts of increasing temperature and/or decreasing precipitation (Fosu-Mensah *et al*., 2012; Shashidahra *et al*., 2016). Research is needed to uncover factors that encourage farmer adaptation.

According to Hellin *et al*. (2012), smallholder farmers have already adopted some strategies to cope with drought but neither the type of adaptation strategies that farmers implemented, nor factors that affected the farmers' decisions to implement the strategies that have been studied. The South African government must prioritise formulating policies and implementing strategies for adaptation to climate change. Furthermore, the decision to adopt adaptation strategies is influenced many factors, such as socio-economic conditions, farm household characteristics and policy incentives.

2.2.10 Drought and crop productivity

Climatic change impacts on crop productivity greatly vary from region to region and climate change also affects crops differently, that is, crops like maize will be highly affected and crops such as millet may be less affected since they are able to resist high temperatures and low water levels. However, smallholder farmers in developing countries are the most vulnerable and disadvantaged people as they entirely depend on rain-fed agriculture.

Cohn *et al.* (2017) showed that in SSA and Latin America, a greater proportion of the variation in maize yields was associated with climate change. Hence, change in climate has the potential to hinder the sustainable development of nations by reducing production in yield, which consequently leads to food insecurity. However, SSA has a huge potential for expanding maize production. About 88 million hectares (88 M ha), excluding protected and forested areas, which has not yet been planted, is suited to maize production. For as long as farmers replace seed every season, advantages in yield can be significant. The adoption of improved open-pollinated varieties and hybrids was at 44% of maize area in Eastern and Southern Africa in 2006–2007 minus South Africa, and it was at 60% in West and Central Africa. This statistic was a suggestion of a significant increase in adopting improved varieties more so in West and Central Africa.

2.2.11 Empirical studies on adoption of drought tolerant maize

Adoption of drought tolerant maize among smallholder farmers in Lepelle-Nkumpi is examined, focusing on how past exposure to dry spells affects adoption of the drought tolerant maize variety. Previous studies across several countries in SSA identify several major factors affecting adoption of DT maize varieties, including unavailability of improved seed, lack of information, lack of resources, high seed prices (Fisher et al., 2015). Other authors report farming experience with DT maize, access to DT seed and awareness of DT maize varieties as key drivers of adoption Holden and Fisher (2015).

Katengeza *et al*. (2019) used four-round panel dataset to examine the adoption of drought tolerant (DT) maize varieties from six districts in Malawi. Results show that past exposure to drought increases the probability of DT maize seed being distributed through Farm Input Subsidy Programme. Farmers who accessed maize seed subsidy coupons and were previously exposed to late season dry spells are more likely to use the seed subsidy coupon to redeem DT maize seed. The likelihood of adoption and adoption intensity (area under DT maize) are positively influenced by previous early season dry spells and access to seed subsidy.

A recent study by Wossen *et al.* (2017) explored the impacts of DTMVs on productivity, welfare and risk exposure in Nigeria. They found that the adoption of DTMVs indeed increased maize yields by 13 per cent and reduced the level of variance by 53 per cent and downside risk exposure by 81 per cent among adopters. As a result, there was a reduction of 13 per cent in poverty incidence and 84 per cent in the probability of food scarcity among adopters. From this study, it is inferred that, interventions against drought stress through genetic improvements and the subsequent adoption of these improved technologies will have a critical role to play in terms of enhancing food security and reducing farmers' exposure to drought risk (Wossen *et al.*, 2017).

In the study conducted by Yin et al. (2015), a linear model was employed to estimate the effects of adaptation strategies against drought and examine the influences of policy support and farm households' characteristics on adopting decisions. Results indicated that using the variety of diversification, drought resistant varieties and dibbling irrigation are three major adaptation strategies against drought. Using variety diversification and drought tolerant maize can respectively increase maize yield by approximately 150 to 220kg/ha under drought. Offering information service, financial and technical support can greatly increase the use of adaptation strategies for farmers to cope with drought.

Simtowe et al. (2019) evaluated the impacts of the adoption of drought-tolerant maize varieties on average maize yield, yield stability, risk exposure and resource use in rain-fed smallholder maize farming. The study used cross-sectional farm household level data, collected from a sample of 840 farm households. The adoption of drought-tolerant maize varieties increased yield by 15% and reduced the probability of crop failure by 30%. Furthermore, the adoption of these varieties increased investments in maize production at the extensive margin through maize area increase and to a more limited extent at the intensive margin through mechanisation. The results show the potential for further uptake and scaling of drought-tolerant maize varieties for increased productivity, reduced risk, and the transformation of the maize sector.

A Multinomial Logit (MNL) Model was used to estimate where the dependent variable is categorical; to describe the relationship between maize type and a set of explanatory variables expected to be influential, based on the literature on the adoption of agricultural technology in low-income settings (Doss, 2006; Feder *et al.*, 1985; Foster & Rosenzweig, 2010). This literature indicates that major determinants of adoption include trait preferences, financial and non-financial returns to adoption, farm size, tenure security, risk aversion, education, credit availability, access to extension services, and market.

A study conducted by Holden et al. (2017) used the Cobb-Douglas Model to assess the impact of smallholder farmers' adoption of DT maize varieties on total maize production. The study found that 93% of the households were growing improved maize varieties and that 30% of the sampled households were growing DT maize varieties. Total maize yield was 436.5 kg/ha for a household that did not grow DT maize varieties and 680.5 kg/ha for households that grew DT maize varieties. The results show that households that grew DT maize varieties had 617 kg/ha more maize than households that did not grow the DT maize varieties. Given that almost all farmers buy their seeds in the market, a change in varieties to DT maize seeds gives an extra farm income to farmers or more than nine months of food at no additional cost.

2.3 Chapter summary

This chapter specifically focused on the previous studies that were conducted on the adoption of drought tolerant maize among smallholder maize farmers. The chapter reviewed studies that were conducted both in South Africa and internationally. The literature review defined smallholder farmers as those farmers with less than 2 hectares, limited resources and who need external support so that they can farm successfully. Literature also found that for a farmer to adopt drought tolerant maize varieties, production resources are required, and these resources include land, water infrastructures and capital. Reasons why smallholder farmers did not grow drought tolerant maize variety include unavailability of seed, inadequate information, lack of resources and high seed price, among other challenges.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Introduction

This chapter describes the study area, method of data collection and explains the analytical tools used to obtain the results of the study. Information on the socio-economic characteristics of smallholder maize farmers, the adoption of drought tolerant maize variety used, and the constraints faced by smallholder maize farmers are highlighted in this chapter.

3.2 Description of the study area

The study was conducted in the Lepelle-Nkumpi Municipality, one of the local municipalities within the Capricorn District. The Lepelle-Nkumpi Municipality is found in the southern part of the Capricorn District, approximately 61km from Polokwane City. The municipality is predominantly rural with a population of approximately 241 414 people, 58 483 households and covers 3,454.78 km², which represents 20.4% of the district's total land area (Lepelle-Nkumpi, 2012). Traditional authorities play an important role in terms of sustaining their traditional culture and the provision of land for development purposes. Most smallholder farmers lack or do not afford irrigation infrastructure and therefore rely on rainwater for irrigation.

Agriculture plays a key role as it comprises of a well-developed commercial agriculture and of smallholder agriculture that has the potential to grow. Most households are unemployed, and some earn lower incomes. Hence, most people are engaged in farming while others migrate to urban areas to seek better paying jobs. The water supply is not enough for irrigation and many smallholder farmers therefore rely on dry-land farming. The development potential in the agricultural sector of the municipality is contained in the expansion of the production of existing products in the region.

3.1 Description of the Study area

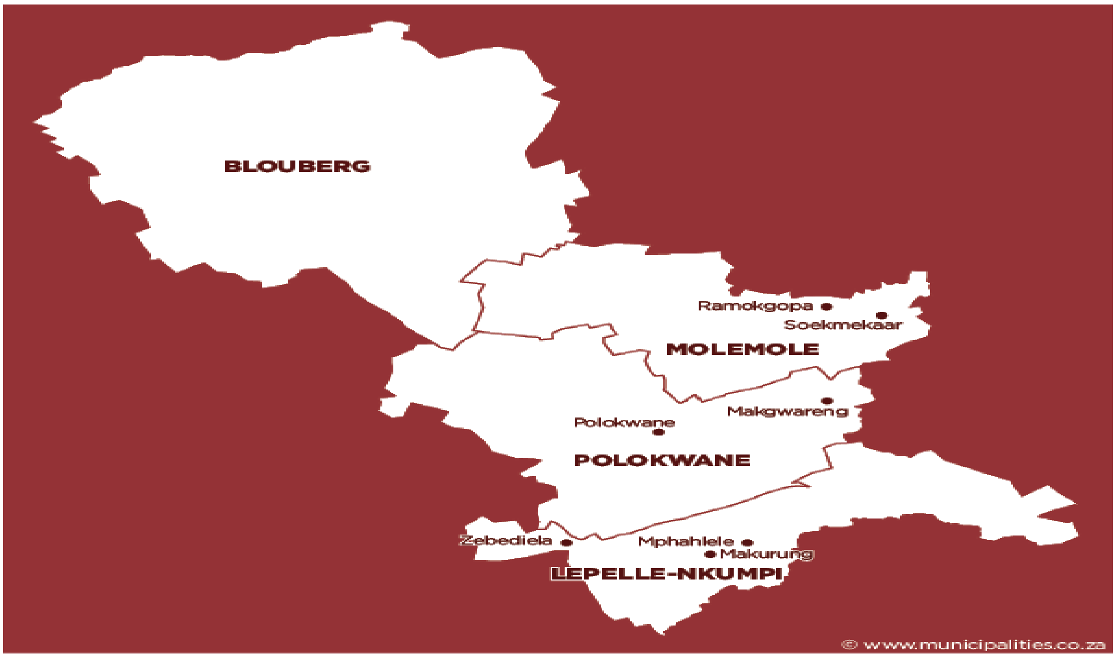

Figure 3.1: Map of Capricorn District

Source: South African Treasury, 2011/2012

3.3 Data collection and sampling technique

Primary data was collected using semi-structured questionnaires to achieve the objectives of the study. Multistage sampling was used for the study because larger clusters were subdivided into smaller, more targeted groupings for surveying. The participants were not forced to participate in the study, instead, they voluntarily agreed to complete the questionnaire. The information provided was used only for the purpose of the research and will be treated with confidentiality. The Lepelle-Nkumpi Municipality is quite expansive. As such, villages from each Traditional Authority was selected. From the selected villages, 120 smallholder farmers were interviewed. Structured questionnaires were used, of which 50 farmers in Ga-Mphahlele, 40-smallholder maize farmers in Magatle and 30 in Mafefe villages were interviewed based on the probability proportion to size. Extension officers from the Capricorn District provided the information about the availability of the farmers.

3.3 Analytical techniques

3.3.1 Descriptive statistics

The study relied on Descriptive Statistics such as mean, tables, graphs and frequencies for the first ,second and fourth objectives, which were set out to identify and describe the socio- economic characteristics of smallholder maize farmers; identify the different drought tolerant maize varieties grown by smallholder maize farmers in the Lepelle-Nkumpi Municipality and to identify the constraints to adoption of drought tolerant maize varieties among productivity smallholder maize farmers in the Lepelle-Nkumpi Municipality

3.3.2 Probit Model

The Probit Model was used to address the third objective, which was to investigate the factors determining the adoption of drought tolerant maize among smallholder farmers in the Lepelle-Nkumpi Municipality. The Probit Model was used to analyse the relationship between the dependent variable (Y) with the relevant independent variables (X's). The Probit model constrains the estimated probabilities to be between 0 and 1 and relaxes the constraint of the effect of independent variables across different predicted value of the dependent variable (Sebopetji & Belete, 2009).

3.3.2.1 Model specification

The Probit Regression Model can be expressed as follows:

$$Y_i = \beta_0 + \beta_1 X_1 + \beta_2 X_2 \dots \dots .. + \beta_n X_n + U_i$$

Where $Y_i =$ Dependent variable

$\beta_0 =$ The intercept of the constant term of the model

$\beta_1 - \beta_n =$ Regression coefficients

$X_1 - X_n$ = Independent or explanatory variables

U_i = Disturbance term

3.3.2 Table describing variables

Table 1: Description of variables used in the Probit Regression analysis

Variables	Description	Unit of measurement
Dependent variable Adoption of drought tolerant maize variety	1 if farmer is adopting drought resistant crop O –otherwise	Binary
Independent variables		
X1= Age	Age of the farmer	Years
X2= Gender	1 if a farmer is male,0 otherwise	Dummy
X3= Household size	Number of individuals in a household	Number
X4= Education	1if the farmer passed matric,0 otherwise	Dummy
X5=Land ownership	Land size owned by the farmer	Hectares
X6= Farmer's income	Total income of the farmer per month	Rand
X7= farming experience	Number of years in farming	Years
X8= Hired Labour	1if a farmer has access water, 0 otherwise	Dummy
X9= Access to credit	1 if a farmer has access to credit,0 otherwise	Dummy
X10= Extension services	1 if a farmer receive training,0 otherwise	Dummy

X11= Tenure status	The distance travelled to local market	Kilometers
X12=Maize produced per ha	Quantity of maize produced per ha	Kilograms
X13 Seed subsidy	1 if a farmer is being subsidised , 0 otherwise	Dummy
X14 fertilizer subsidy	1 if a farmer is being subsidised, 0 otherwise	Dummy

Table 2: Analysis of objectives

Objectives	Data needs	Analytical tool
Identify and describe the socio-economic characteristics of smallholder maize farmers in Lepelle-Nkumpi Municipality	Frequencies, means and percentages	Descriptive Statistics
Identify the different drought tolerant maize varieties grown by smallholder maize farmers in the Lepelle-Nkumpi Municipality.	Frequencies, means and percentages	Descriptive Statistics
Examine factors determining the adoption of drought tolerant maize by smallholder farmers in the Lepelle-Nkumpi Municipality.	Farm size, Household size, Gender of the Farmer, Age of the Farmer, Education, Farm income, Farming experience, Land ownership, Extension services, Hired labour, Access to production inputs.	Probit Regression Model
Identify the constraints to adoption of drought tolerant maize varieties among productivity smallholder maize farmers in the Lepelle-Nkumpi Municipality.	Frequencies, means and percentages	Descriptive Statistics

3.4 Limitations of the study

- Covid-19, poor infrastructure and long distance were the major constraints against reaching other farmers. These constraints were minimised by the help of the extension officer who arranged a meeting with the farmers with whom a survey was conducted after the meeting in order to ease long distances.
- Most of the farmers in the study area were not available in the database of the extension officers from the Department of Agriculture, therefore the sampling process was a challenge. Through the help of the farmers from some of the villages, other farmers were identified.
- It was difficult for the farmers to answer some of the questions asked because most of them were not keeping records of their information.

3.4 Chapter summary

The chapter described the area where data was collected and the analytical procedures that were used as well as the models adopted in the study. The Probit Model was used to address the third objective, which was to investigate the factors determining the adoption of drought tolerant maize among smallholder farmers in the Lepelle-Nkumpi Municipality.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Introduction

The aim of the study was to analyse the factors affecting the adoption of drought tolerant maize varieties as agricultural innovation among smallholder maize farmers in the Lepelle-Nkumpi Municipality. This chapter describes the nature of the data used in the study and summarises the variables which were considered and their measures. The empirical results that were analysed to achieve the objectives of the study are discussed in this chapter. The results are presented in tabular and charts and forms.

4.2 Socioeconomic characteristics of smallholder maize farmers

Table 3: Socioeconomic characteristics of smallholder maize farmers

Variables	Total (120)	Adoption (31) (26%)	Non-adoption (89) (74%)
Age in years	64	63	67
Family labour	95 (79%)	27(22%)	68(57%)
Land ownership	116 (97%)	29(24%)	87 (73%)
Extension services	Yes 90(75%)	23 (19%)	67(56%)
	No 30 (25%)	7 (6%)	23 (19%)
Access to credit	Yes 13 (11%)	13(11%)	0 (0%)
	No 107 (89%)	8 (7%)	107(7%)

Source: From survey data

4.2.1: Age of the household head

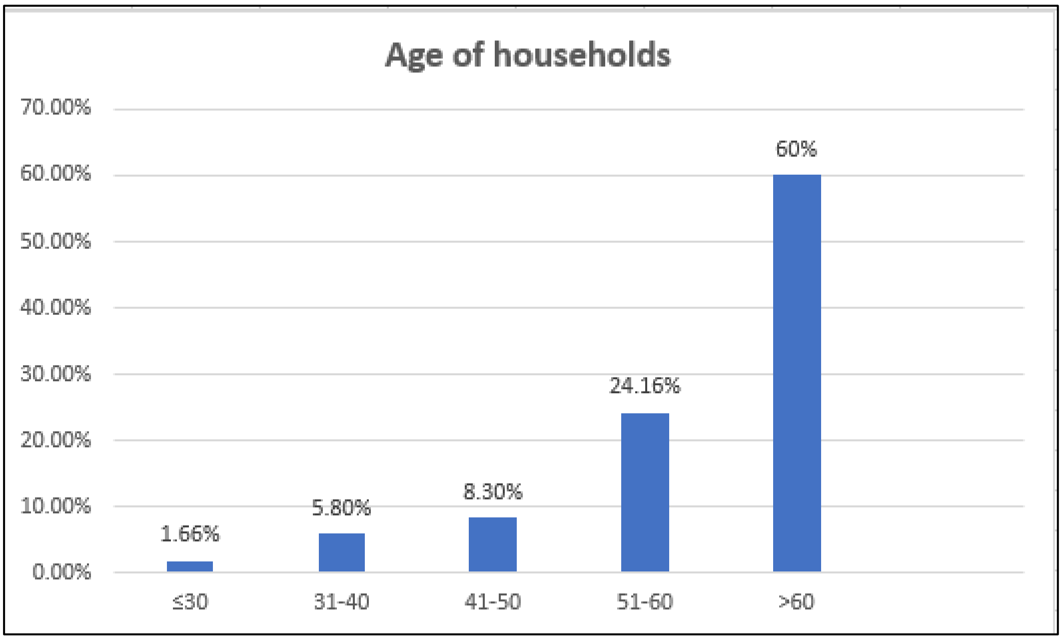

Figure 4.1: Age of household

Source: Survey from data

The age of the farmer was thought to be an important variable because it is believed that age is related to the experience that one has in the adoption of drought maize varieties. As indicated in Table 1, the average age of the smallholder maize farmers was 64 years, with those who adopt drought tolerant maize varieties being 63 years and those who did not adopt drought tolerant maize being 67 years old.

4.2.2 Family labour

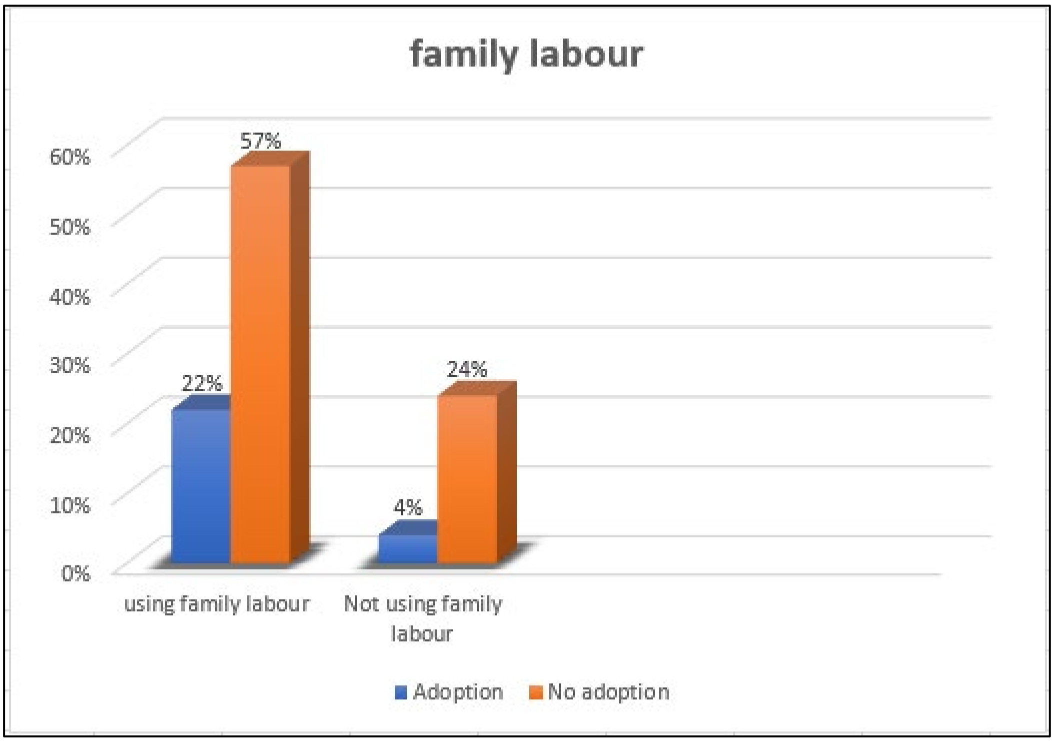

Figure 4.2: Family labour

Source: From survey data

Family labour is mostly used by smallholder farmers because they cannot afford to pay hired labourers since smallholder farmers are associated with low financial capital. As shown in Table 1, 95 (75%) farmers use family labour, 27 (22%) farmers adopted drought maize varieties while 68 (57%) farmers did not adopt maize varieties. The results indicate that most of the farmers who adopt maize varieties use family labourers as opposed to farmers that did not adopt maize varieties.

4.2.3 Land ownership

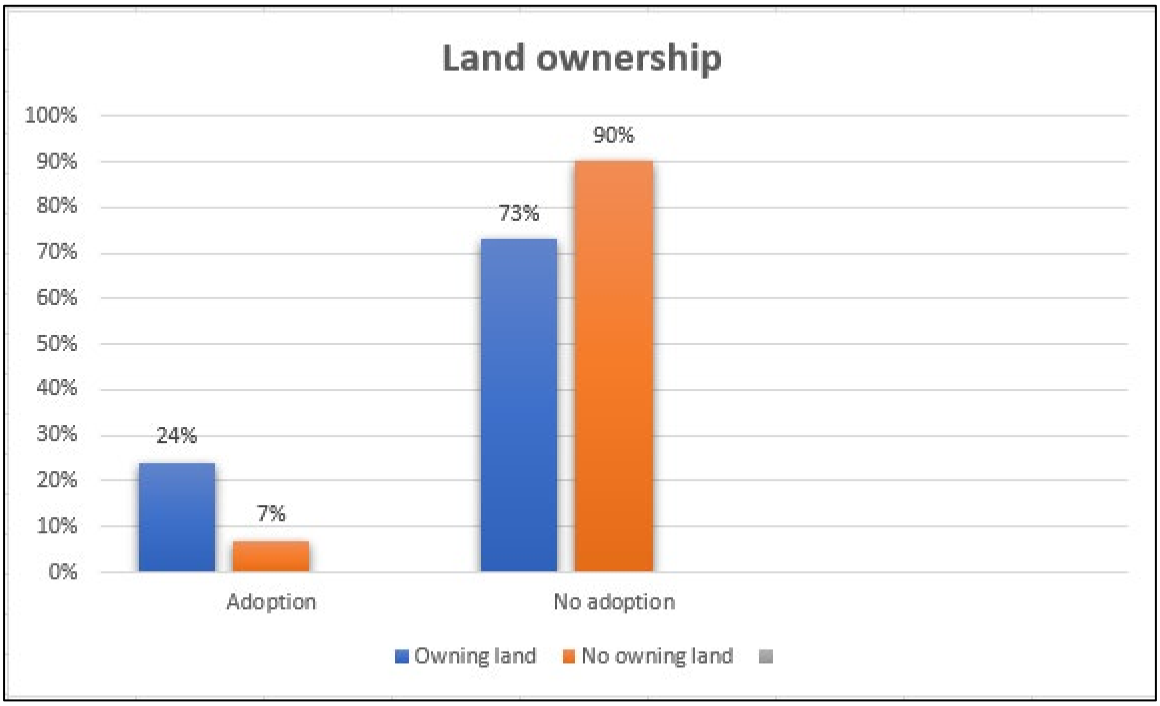

figure 4.3: Land ownership

Source: Survey of data

Land is the main factor that determines the quantity to be produced by the farmer, therefore, the availability of land is the most important determinant of whether the farmer participates in the process of adoption or not. Out of 120 smallholder farmers, 116 (97%) farmers owned the land while 4 (3%) farmers did not own the land. The results also indicate that 29 (24%) farmers who own the land adopt drought tolerant maize varieties whereas 87 (73%) farmers do not adopt the maize varieties.

4.2.4 Extension services

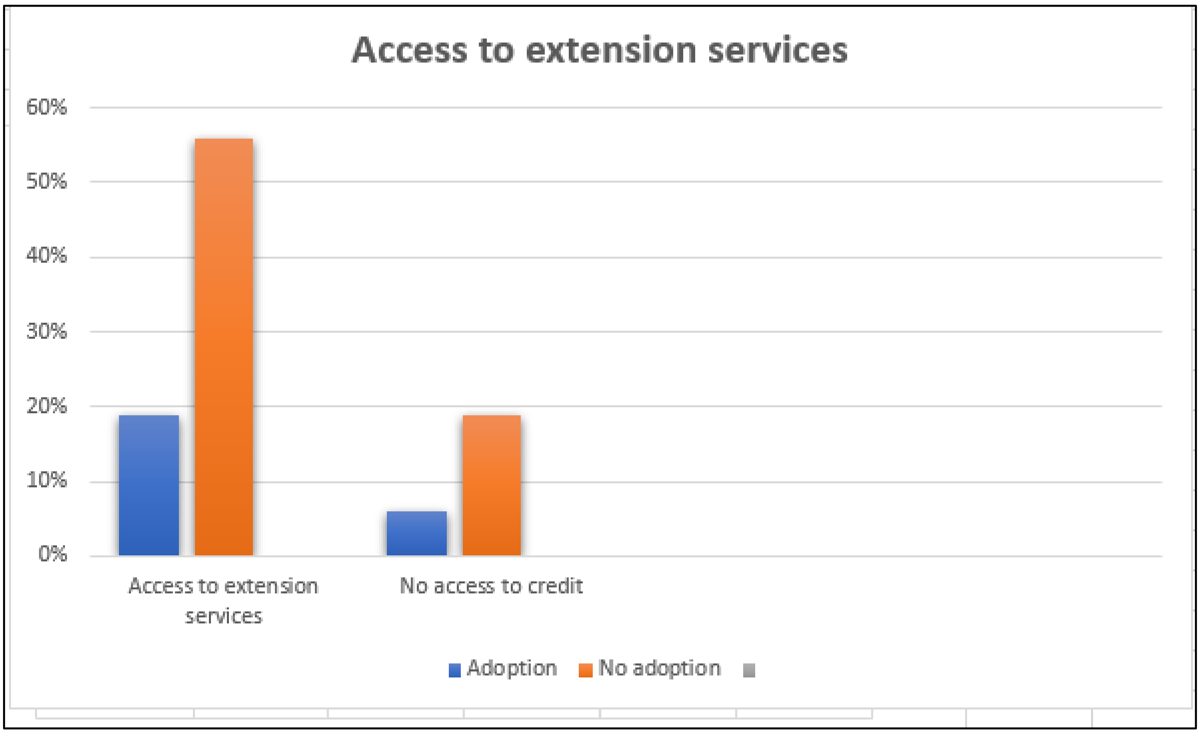

Figure 4.4: Extension services

Source: Survey from data

Extension officers work closely with the farmers in order to help them make better decisions to increase their productivity and to transfer information related to agricultural innovation. On average, 90 (75%) of the sample get extension services, resulting in 23 (19%) adopting maize varieties while 67 (56%) did not adopt maize varieties. These results indicate that farmers who adopt the maize varieties receive more extension services than farmers who do not adopt maize varieties.

4.2.5 Access to credit

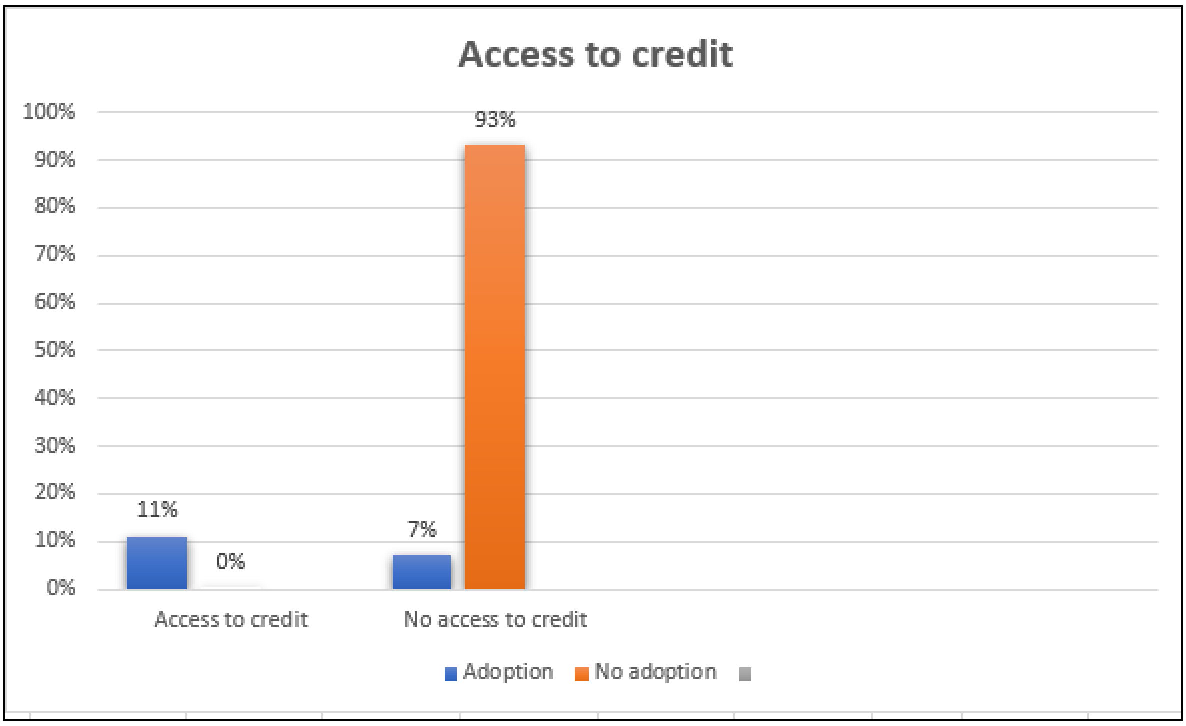

Figure 4.5: Access to credit

Source: Survey of data

Provision of credit has been identified as the most important instrument in improving agricultural productivity through financial investments. Smallholder farmers in South Africa are facing a challenge of accessing credit because creditors target clients with the ownership of relatively high value property of which most smallholder farmers do not have. The results indicate that only 13 (11%) farmers from the sample access credit while 107 (89%) farmers do not access the credit, resulting in 13 (11%) farmers adopting the drought tolerant maize varieties accessing market and 0 (0%) of no-adoption receives credit. These results show that farmers who adopted drought maize varieties received more credits than those who did not adopt maize varieties.

Table 4: Demographic characteristics of smallholder farmers in the study area

Variables	Frequency	Percentages (%)
Age		
≤ 30	2	1.66
31 – 40	7	5.8
41 – 50	10	8.3
51 – 60	29	24.16
> 60	72	60
Gender		
Male	44	37
Female	76	63
Household size		
1 – 5	55	46
6 – 10	43	36
11 – 15	20	17
>15	2	2
Marital status		
Single	18	15
Married	81	68
Widowed	16	13
Divorced	5	4
Access to credit		
Yes	13	11
No	107	89
Access to extension services		
Yes	90	75
No	30	25

Source: From survey data

4.2.6 Gender

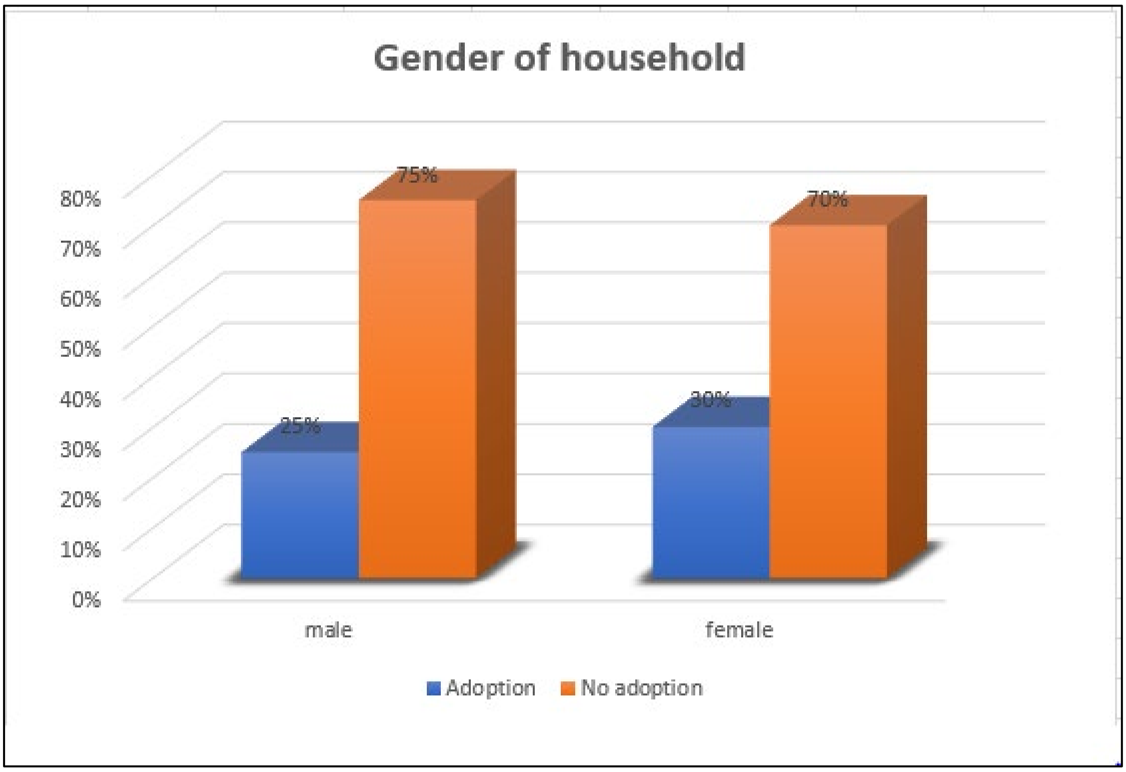

Figure 4.6: gender of household head

Source: From survey data

Figure 4.1 shows the results of the respondents in terms of gender. The results indicated that 25% of the males have access to drought tolerant maize varieties while 70% of the females did not adopt the drought tolerant maize variety. Overall, a large number of female smallholder maize farmers adopted the drought tolerant maize varieties compared to their male counterparts.

4.2.7 Marital status

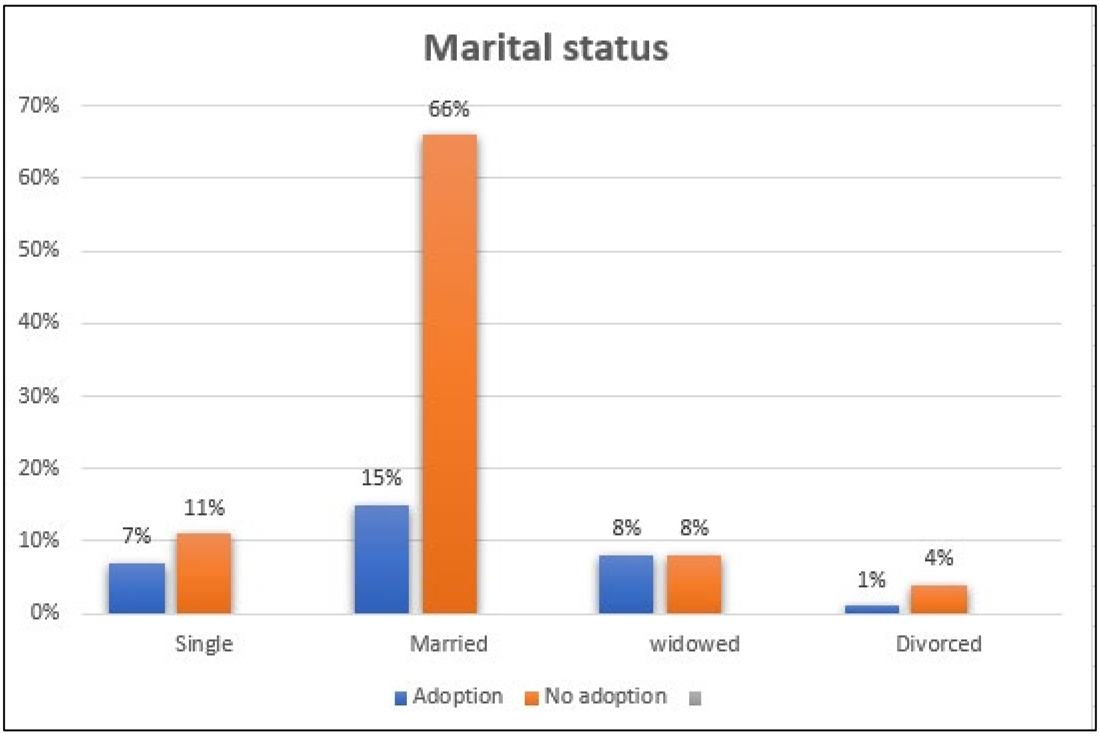

Figure 4.7: Marital status of household head

Source: From survey data

Marital status was thought to be one of the important aspects in the study because of the role played by different family members in a household and also because it directly affects the adoption of drought tolerant maize varieties among smallholder farmers. Marital status was divided into four categories, namely, single, married, widowed and divorced. On average, 15% of smallholder maize farmers are single, 68% are married, 13% are widowed and 4% are divorced. The results from figure 4.2 indicate that the majority of households who are married adopt maize varieties more than their counterparts.

4.3.8 Education level

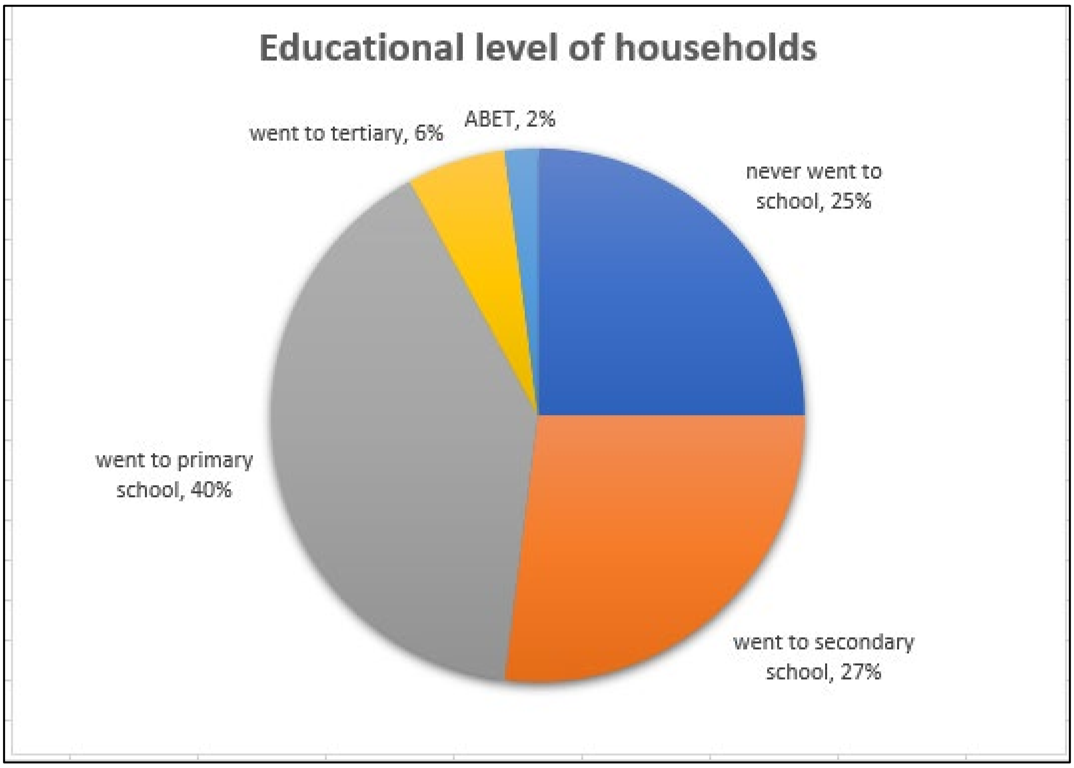

Figure 4.8: Education level of household head

Source: From survey data

Level of education was divided into five categories, which are: smallholder farmers who never went to school, those who went to primary school, those who went to secondary school, those who went to tertiary and those who went to ABET (see Figure 4.3). The results indicate that 25% of the sample never went to school, 40% went to primary school, 27% went to secondary school, 6% went to tertiary and 2% of the sample went to ABET.

4.2.9 Tenure status

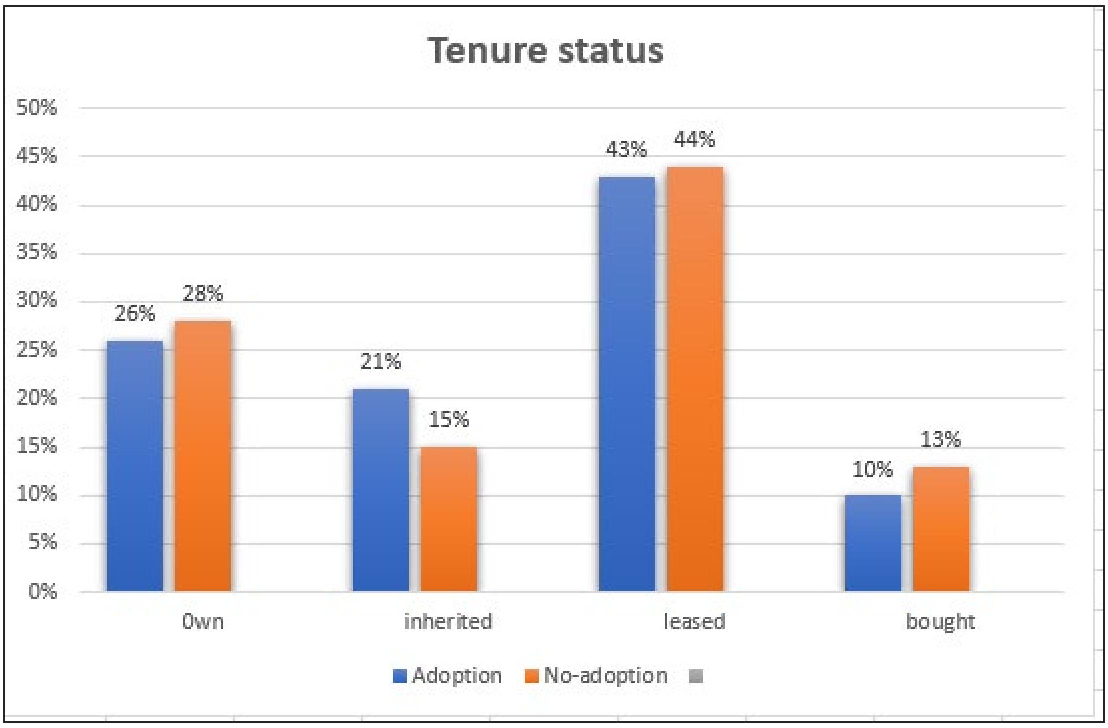

Figure 4.9: Tenure status of household head

Source: From survey data

Land tenure was divided into four categories, namely; owns the land, inherited the land, leased the land and bought the land, as indicated in figure 4.4. On average, 30% of the sample own the land, 18% of the sample used the inherited land, 43% used the leased land and 9% used the land they bought. The results further indicated that 26% of drought tolerant maize variety adopters own the land while 28% of the farmers who do not adopt the drought tolerant maize own their land.

4.2.10 Farming experience

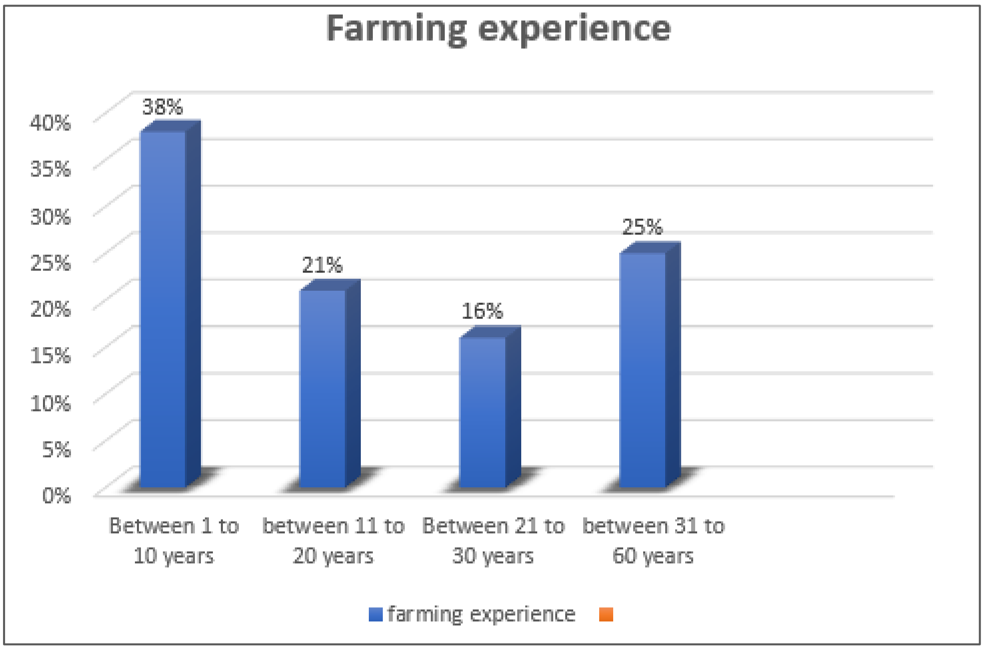

Figure 4.10: Farming experience

Source: From survey data

Figure 4.5 above shows the percentages of farming experience of smallholder maize farmers in the study. Farmers who have maize experience of between 1 to 10 years were found to be the maximum at 38%. Experience between 11 to 20 years was found at 21% and between 21 to 30 years was found at 16%. Farmers with many years of experience were between 31 to 60 years and constituted 25%. The results of this study show that 64% of the farmers in the study area have the experience of more than 10 years and this may lead to improvement in the adoption of drought tolerant maize varieties.

4.3 Types of drought tolerant maize varieties among smallholder farmer

Based on the sample of this study, 74% of the households grew non-DT maize varieties while 26% of the smallholder farmers grew drought tolerant maize varieties. Table 1 shows that of the 26% that grew DT maize varieties, only 15% of smallholder maize farmers grew Open-Pollinated Varieties (OPVs), i.e. ZM 521 (9%) and ZM 401 (6%). Most of the smallholder maize farmers' households who adopted drought tolerant maize varieties grew Pan 53 maize hybrid (16). In general, most farmers grew hybrid maize, which is in consonance with some studies on improved maize seed adoption (Beyene & Kassie, 2015; Chikobvu *et al.*, 2014).

Table 5: Types of drought tolerant maize grown by smallholder farmers in Lepelle-Nkumpi Municipality

Maize varieties	Total (120)	Adoption 31 (26%)	Non-adoption 89(74%)
ZM 521 (OPV)	9	9 (7.5)	
ZM 401 (OPV)	6	6 (5)	
Pan 53 (Hybrid)	16	16 (13.3)	
Total			

Source; Survey from data

4.4 Determinants of adoption of drought tolerant maize varieties among smallholder farmers

Results of the determinants of DTMV adoption and maize yield for both adopters and non-adopters are presented in. maize produced per hectare and fertilizer subsidies were used as dependent variables as shown in the selection equation. The results confirm that indeed the variable (maize produced per hectare) was relevant, as it had a positive and statistically significant effect on the probability of adopting drought tolerant maize varieties. Other significant factors favoring adoption in the selection equation include farm size, maize produced per hectare and I hired labour.

4.5 Probit Regression Model

Table 6: Probit regression on factors determining adoption of drought tolerant maize varieties among smallholder farmers

Variables	Estimated coefficient	dy/dx	z	P>z
Farm size	0.475***	0.126	2.76	0.006
	(0.172)	(0.044)		
Household size	0.040	0.011	0.93	0.352
	(0.043)	(0.011)		
Gender	-0.447	-0.129	-1.56	0.118

	(0.286)	(0.089)		
Age	-0.0136	-0.004	-1.07	0.286
	(.0127)	(0.003)		
Farm experience	-0.009	-0.002	-1.02	0.305
	(0.008)	(0.002)		
Extension service	0.194	0.053	0.70	0.482
	(0.275)	(0.079)		
Hired labour	0.563**	0.149	2.10	0.036
	(0.268)	(0.072)		
Kg of fertilizers	0.004	0.001	1.06	0.289
	(0.004)	(0.001)		
Kg produced per ha	0.001***	0.0003	2.80	0.005
	(0.001)	(0.0001)		
Land ownership	-0.225	-0.055	-0.62	0.538
	(0.365)	(0.082)		
Years in school	-0.002	-0.0004	-0.06	0.952
	(0.029)	(0.0078)		
Log likelihood			-78.069955	
Cases correctly estimated(%)			81.80	
*** Coefficient significant at 1%				
** Coefficient significant at 5%				
* Coefficient significant at 10%				

Source: From Survey Data

According to Gujarati (1992), the sign of a variable indicates how the variables are influencing the dependent variable. If the variable coefficient is positive, it means that a higher value of the variable increases the likelihood of smallholder maize farmers adopting the drought tolerant maize variety. On the other hand, a negative coefficient decreases the likelihood of smallholder maize farmers' adopting drought tolerant maize varieties. The results show that farm size, labour hired and maize produced per hectare in kilograms had positive significant influence on the probability of farmers adopting drought tolerant maize varieties. The gender of the household head had a negative insignificant influence on the adoption of a drought tolerant maize variety. Household size, extension services and fertilizers in kilograms had positive insignificant influence on the adoption of drought tolerant maize variety. Other variables such as farm experience and land ownership do not have any influence on the farmer's adoption of drought tolerant maize varieties.

4.5.1 Farm size

Farm size was statistically significant at 1% and had a positive influence on the probability of farmers to adopt drought tolerant maize varieties. The marginal effect of farm size was 0.126 indicating that a one-unit increase in the hectares of land will probably improve adoption process. The implication of the results suggests that chances of farmers adopting the maize varieties increase with the size of the farm. This is supported by Osmani and Hossain (2015) in the study that was conducted in Durgapur Upazila under Rajshahi District in Bangladesh, where farm size has positive influence on the decision for technology innovation participation of households. A study conducted by Makhura *et al*. (2001) found that larger areas of land provide a greater opportunity of surplus production. The result is in line with Okezie et al. (2012).

4.5.2 Hired labour

Hired labour was statistically significant at 5% and has a positive influence on the probability of adopting drought tolerant maize varieties. The results showed that the probability of farmers adopting the maize variety increases with more hired labour by 0.149. This means that if hired labourers were to increase by 1%, the likelihood of adopting maize varieties would increase by 0.15%. The results also indicated that farmers who hired more labourers were more likely to adopt a drought tolerant maize variety compared to farmers who hired fewer labourers. The implication of this is that more hired labourers increase the productivity of farmers so much so that they can participate in agricultural innovation.

4.5.3 Maize produced per Ha in Kilograms

The results indicated that maize produced per Hectare was statistically significant at 1% and has a positive influence on the probability of adopting drought tolerant maize varieties. The probability of maize produced per hectare in kilograms was 0.0003. The results indicate that if maize produced per hectare increases by 1 kg, the likelihood of adopting drought tolerant maize variety would increase by 0.0003%. Therefore, this means that increasing the productivity of farmers will increase the probability of farmers adopting the drought tolerant maize and participating in agricultural innovation.

4.5.4 Household size

Household size has a positive but insignificant effect on farmers' adoption of drought tolerant maize varieties. This is probably because most farmers prefer to use hired labour instead of family labour for their production, which is the case in the study area. In the study area, a majority of the farmers are old, and their children are married, so farmers have to hire labourers to help them in their production. The result is supported by Sikwela (2013) who found that household size was insignificant. However, the results are in contrast with Hlomendlini (2015), who found that household size was positively associated with agricultural innovation participation, with a statistically significant effect of 5%.

4.5.5 Extension service

Extension service has a positive but statistically insignificant effect on farmers' adoption of drought tolerant maize varieties. This is probably because smallholder maize farmers in the study area do not depend on extension services for them to improve their productivity. The results are in contrast with Osmani and Hossain (2015), who found that extension services correlate significantly and positively with the adoption of drought tolerant maize variety. This means that smallholder farmers' drought tolerant maize adoption increases if they have access to extension services.

4.5.6 Fertilisers in Kilograms

According to Jayne (1998), fertiliser use has increased the land and labour productivity. The variable Kilograms of fertiliser was positive but has a statistically insignificant effect on the farmers' adoption of a drought tolerant maize variety. This means that fertiliser use by smallholder farmers does not determine whether farmers adopt a drought tolerant maize or not.

4.5.7 Gender

The gender of the household head was found to be insignificant and had a negative influence on the probability of adopting drought tolerant maize varieties. The descriptive results show that 27% of the sampled households were male-headed households while 73% were female-headed households. The female-headed households have a greater likelihood to adopt a drought tolerant maize variety. This is supported by the study conducted by Hlomendlini (2015), who found that females are the main participants in the adoption of drought maize variety than males. However, these findings are in contrast with Reyes *et al.* (2012), who found that households that are headed by males are more likely to participate in the adoption of drought tolerant maize variety compared to the female-headed households.

4.5.8 Age

The age of the farmer was found to be insignificant and had a negative influence on the probability of adopting drought tolerant maize varieties. The value of coefficient was -0.004 which shows that the age of the farmer has a negative relationship with drought tolerant maize variety adoption. This means that the older the farmer, the less likely the farmer will adopt the maize variety. This may be because the farmer is too old to compete and produce quality and more products that meet the market grades. Hence, such farmers produce only for home consumption.

4.5.9 Farmers' experience

The experience of the farmer was found to be insignificant and had a negative influence on the probability of adopting drought tolerant maize by farmers. The value of the coefficient was -0.002, which indicates that farmers' experience has a negative relationship with the adoption of drought tolerant maize variety. This means that the more the farmer is experienced, the less likely it is that the farmer will adopt the maize variety. This is in contrast with Sebatta *et al.* (2014), who found that farm experience promotes farmers' decision to adopt drought tolerant maize and participate in agricultural innovation.

4.4.10 Land ownership

Land ownership was found to be insignificant, with the negative coefficient of -0.055. This may be because a majority of the farmers in the study area do not own the land that they use. When farmers do not own the land that they are producing at, they will experience more costs of production because they will have to pay rent to the landowner. This will result in the farmer experiencing more costs of production and will result in the farmer producing less. As such, that these will rarely adopt maize varieties.

4.4.11 Years in school

The results show that years in school was insignificant and had a negative influence on the adoption of drought tolerant maize, with the value of -0.0004. This is because the descriptive results show that 29% of the farmers in the study area never went to school, 44% only went to primary school, 23% went to secondary, 3% went to tertiary and 1% went to ABET. The farmers with less education had a greater likelihood to adopt maize varieties. The results are consistent with Osmani and Hossain's (2015) findings.

4.6 Constraints to adoption of drought tolerant maize varieties among smallholder maize farmers in Lepelle-Nkumpi Municipality

Table 7: Descriptive Statistics of major constraints to adoption of drought tolerant maize variety among smallholder farmers

Constraint	Frequency	Percent
No constraints	29	24.27
unavailability of seed	21	17,57
Inadequate information	18	15,15
Lack of finance	17	13.87
High seed price costs	15	12,81
Farmers transportation cost	9	7,34
Lack resources	4	3.3
Farmers perception of variety trait	2	1.6
Lack of storage facilities	2	1,6

Poor labelling of maize variety	2	1,6
Infrastructure	1	0.8
Total	120	100

Source: From survey data

Smallholder farmers that did not adopt the drought tolerant maize varieties were asked to provide reasons behind their decisions. The table above presents the descriptive results of the constraints faced by smallholder maize farmers in the Lepelle-Nkumpi Municipality. The table indicates the constraints together with the frequency and the percentage of the farmers who face those constraints. The results indicate that 24,4% of the farmers were not affected by any constraints to their adoption of drought tolerant maize varieties whilst 76,6% said they are affected by those constraints. Out of 120 smallholder maize farmers interviewed, 21(17.57%) said they are challenged by the unavailability of improved seed. Fisher *et al*. (2015) also found that major barriers to the adoption of drought tolerant maize variety in eastern and southern Africa include the unavailability of improved seed. These factors require policy intervention in order to bring the seeds closer to the farmers at lower prices. Unavailability of seed is caused by lack of infrastructure and high seed prices in the rural areas (D'Hease & Kirsten, 2003). Smallholder maize farmers in the study area are situated in the dispersed area and are far from agricultural markets to access the seeds, which results in long distances together with poor infrastructure.

Results from this study show that other major barriers to the adoption of drought tolerant maize or reasons why smallholder farmers did not grow drought tolerant maize variety include unavailability of seed, inadequate information, lack of resources, high seed price, farmers' perceptions of variety trait, lack of finances and transportation costs. Storage facilities were found to be among the constraints faced by farmers in the study area. Storage facility helps farmers to store their output so that they can sell to the markets at a reasonable price when there is a demand. The results indicate that 1, 6% of the farmers faced the challenge of storage facility. Access to storage facility increases the farmers' ability to sell their products and have the bargaining power

(Bienabe *et al*., 2004). Another constraint faced by farmers in the study area is lack of Infrastructure.

4.7 Chapter Summary

The chapter presented the socio-economic results from the study. The chapter further presented the different drought tolerant maize varieties grown by smallholder maize farmers and examined factors determining the adoption of drought tolerant maize by smallholder farmers in the Lepelle-Nkumpi Municipality. The constraints faced by smallholder maize farmers were also discussed in this chapter.

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

This chapter gives a summary of the study and also provides the conclusion and policy recommendations of the study. The recommendations can enhance the adoption of drought tolerant maize varieties among smallholder of smallholder maize farmers in the Lepelle-Nkumpi Municipality.

5.2 Summary of findings

The aim of the study was to analyse the factors affecting the adoption of drought tolerant maize varieties among smallholder maize farmers in the Lepelle-Nkumpi Municipality. The objectives of the study were: to identify and describe the socio economic characteristics of smallholder maize farmers in Lepelle-Nkumpi Municipality; to identify the different drought tolerant maize varieties grown by smallholder maize farmers in the Lepelle-Nkumpi Municipality; to examine factors determining the adoption of drought tolerant maize by smallholder farmers in the Lepelle-Nkumpi municipality, and to identify the constraints to the adoption of drought tolerant maize varieties among smallholder maize farmers in the Lepelle-Nkumpi Municipality.

Different analytical techniques were used to address each objective. The three objectives, which were to identify and describe the socio-economic characteristics of smallholder maize farmers in the Lepelle-Nkumpi Municipality; to identify the different drought tolerant maize varieties grown by smallholder maize farmers in the Lepelle-Nkumpi Municipality, and to identify the constraints to the adoption of drought tolerant maize varieties among smallholder maize farmers in the Lepelle-Nkumpi Municipality, were all analysed using Descriptive Statistics. The Binary Probit Model was used to examine factors determining the adoption of drought tolerant maize by smallholder farmers in the Lepelle-Nkumpi Municipality.

The socio-economic results indicated that the average age of the total smallholder maize farmer in the study area was 64 years, with the average age of the farmers adopting drought tolerant maize varieties being 63 years and those who did not adopt the drought tolerant maize varieties being 67 years. The education level of the farmers indicated that, 25% of the sample never went to school, 40% went to primary school, 27% went to secondary school, 6% went to tertiary and 2% of the sample went to ABET. The results also indicated that 25% of males who adopted drought tolerant maize varieties have access to market while 70% of females who did adopt maize varieties did not have access to the market. Overall, many female smallholder maize farmers had adopted drought tolerant maize varieties compared to their male counterparts.

The Probit Regression Model results were found after examining factors determining the adoption of drought tolerant maize by smallholder farmers in Lepelle-Nkumpi Municipality. The results show that farm size, labour hired and maize produced per hectare in kilograms had a positive significant influence on the probability of smallholder maize farmers adopting drought tolerant maize varieties. Farm size and maize produced per hectare were statistically significant at 1% and labourers hired were statistically significant at 5%. Household size, extension services and fertilisers in kilograms had a positive insignificant influence on the adoption of drought tolerant maize varieties. Gender, age, farm experience, land ownership and years in school were found to be statistically insignificant. The results also indicated the constraints to the adoption of drought tolerant maize varieties faced by smallholder maize farmers in the Lepelle-Nkumpi Municipality. The results found that 70.6% of the respondents were affected by those constraints while 29.4% were not affected. Out of 120 smallholder maize farmers interviewed, famers' challenges included unavailability of seed (17,57%), inadequate information (15,15%), lack of finances (13,87%), high seed price (12,81%), transportation costs (7,34%), lack of resources, farmers' perceptions of variety trait (1.6%) and infrastructure (0.8%).

5.3 Conclusion

The study had one hypothesis, which was, 'socioeconomic characteristics do not influence productivity of smallholder maize farmers in the Lepelle-Nkumpi Municipality'.

Research hypothesis: Socio-economic characteristics of smallholder maize farmers in the Lepelle-Nkumpi Municipality do not influence the adoption of drought tolerant maize varieties.

The hypothesis is therefore rejected since the Probit Regression indicated that farm size, labour hired and maize produced per hectare in kilograms had a positive significant influence on the probability of farmers adopting drought tolerant maize varieties. Farm size and maize produced per hectare were statistically significant at 1% and the labourers hired were statistically significant at 5%. Household size, extension services and fertilisers in kilograms had a positive insignificant influence on the adoption of drought tolerant maize varieties. Gender, age, farm experience, land ownership and years in school were found to be statistically insignificant. The results of the study also found that smallholder maize farmers can also be characterised by their age, education, land ownership, household size, marital status and size of the farm. The results also indicated the major constraints to the adoption of drought tolerant maize varieties faced by smallholder maize farmers in the Lepelle-Nkumpi Municipality. The constraints that were identified included the unavailability of seed, inadequate information, lack of resources, high seed price, farmers' perceptions of variety trait, lack of finances, wrong labelling of drought tolerant maize variety and infrastructure.

5.4 Policy Recommendations

- The government should ensure that drought tolerant maize variety seeds are more accessible to smallholder farmers with limited cash or credit. Seed suppliers should consider selling the drought tolerant maize seeds in affordable small packs.
- The government should make sure that smallholder maize farmers are aware of drought tolerant maize varieties, which could be achieved through demonstration plots, field days and electronic promotional materials in order to enhance the adoption of drought tolerant maize.
- The government should subsidise smallholder maize farmers with inputs such as tractor, fertilisers and bring seeds closer at lower prices. Input subsidies can propel the adoption of drought tolerant maize varieties.

- Extension officers should make it a priority to provide smallholder farmers with timely and accurate information. They should effectively disseminate information about the adoption of drought tolerant maize through a combination of different pathways.
- The government should improve land access for smallholder farmers by establishing a proper, consistent and equitable distribution of land to rural household (land reform policy). By so doing, smallholder farmers will have enough land to increase their production.

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University of Limpopo

Faculty of Science and Agriculture

Consent to participate in the study

This questionnaire is meant to be completed by farmers with the help of the enumerators. It is meant to generate information on the adoption of drought tolerant maize varieties among smallholder farmers in the Lepelle-Nkumpi Municipality. The information provided will be used only for the purposes of research and will be treated with confidentiality, without mentioning the participants' names in the analysis. Please tick the correct answers in the box and fill the blank spaces provided.

I agree to complete the questionnaire and do so in a voluntary manner. I understand that the responses will be kept confidential. I understand that I will not directly benefit from participating in the research and all the responses I provide for this study will be treated confidentially. I understand that I am free to contact any person involved in the research to seek further clarification and information. I understand that I am free to withdraw at any stage or refuse to answer any uncomfortable question, even if I agree to participate.

Signature…………………….

Researcher: TSHWARELO CALVIN RAMOKGOPA

Contact No: 072 723 9292

Appendices: Questionnaire

Title: Adoption of drought–tolerant maize varieties among smallholder farmers in Lepelle-Nkumpi Municipality, Limpopo Province, South Africa

Department of Agricultural Economics and Animal Production

Name of Enumerator……………………………………………….

Date of interview …………………………………………………

Name of municipality……………………………………………

Community name……………………………………………….

Name of respondent……………………………………………

SECTION A:

SOCIO-ECONOMIC CHARACTERISTICS

1. What is the size of household? ....

2. Age of the Farmer…………

3. Gender of the farmer

1	2
Male	Female

4. Marital status

1	2	3	4
Single	Married	Widowed	Divorced

5. Number of years at school……….

6. How long have you been farming? …………..

7. What is your farm size in ha? …………

8. Land ownership

1	2
Yes	No

9. If yes, do you have title deeds?

1	2
Yes	No

10. What is your tenure status?

1	2	3	4	5
Own	Inherited	Leased	Bought	Others (specify)

11. What is your main source of income?

1	2	3	4	5
Farming	Grant	Pension	Salary	Other (specify)

SECTION B:

WATER USE INFORMATION

12. Do you have access to water for irrigation?

1	2
Yes	No

26. If yes, what is your main source of water for maize irrigation?

1	2	3	4	5	6
Rain	Boreholes	Dam	Taps	River	Other (specify)

13. How much water do you use to irrigate one hectare of maize in litres? ………

DETAILS OF LABOUR

14. How many family members assist in farming? ………………….

15. Which of the following sources of labour have you used for the past year?

1	2	3	4

Family labour	Friends and relatives	Hired labour	Others (specify)

16. If the labour is hired, what is the method of payments?

1	2	3	4
Credit	Farm income	Own cash	Others (specify)

17. Do you hire tractor for maize production?

1	2
Yes	No

18. If yes, how much does it cost per hectare? R................

19. Do you apply fertiliser for maize production?

1	2
Yes	No

20. If Yes, how many kilograms of fertilisers per hectare?..................

21. How much do you spend on fertiliser? R…………………

22. Do you use any type of pesticides?

1	2
Yes	No

23. How much does it cost per hectare? R……………….

24. Do you apply herbicides for maize production?

1	2
Yes	No

25. If Yes, how many kilograms of herbicides per hectare?

26. How much spend on herbicides?

27. How many kilograms of seeds do you use per hectare?................

EXTENSION INFORMATION

28. Do you have access to extension services?

1	2
Yes	No

29. If yes, for how long have you been getting the services? …………Years.

30. Who provides the extension services?

1	2	3	4
Government departments	Non-government organisation	Development agent	Others (specify)

31. How many times did the extension officer visit last year?

ACCESS TO CREDIT

32. Do you have access to credit?

1	2
Yes	No

33. If Yes, where did you get the money? ……………………………

34. Who provide the credit?...........................

MAIZE PRODUCTION INFORMATION

35. How many years have you been into maize farming?.......................

36. What kind of maize variety to you produce?

1	2	3	4
Local variety	Drought tolerant variety	Gm variety	Others (specify)

37. How have you been responding to drought in maize production?

38. What kinds of adaptation strategies have been used to cope with drought in different seasons?

39. What are the effects of these strategies against drought?

40. Have you received any support from the government when you face serious drought?

41. What kind of assistance?

42. Are you aware of drought tolerant maize varieties?

1	2
Yes	No

43. Where did you hear about drought tolerant maize variety?

1	2	3	4
Agricultural research	Extension officers	government department	Others (specify)

44. Are you producing drought tolerant maize varieties?

1	2
Yes	No

45. If yes, who supplies you with the seeds?............

1	2	3	4	5
Government department	Non-government organization	Development agency	Buy	Others (specify)

46. What are your reasons for adopting drought tolerant maize variety?...............

47. How useful is drought tolerant maize variety?

	Strongly useful	Useful	Neither useful nor not useful	Not useful	Strongly not useful
1 Withstands drought and heat stress					
2. Offers protection from new diseases and pests.					

3. Require less water for irrigation					
4. Yield is high					
5. Can be grown all year round					

48. How many hectares of maize do you produce?.......................

49. How many kilograms of maize do you normally produce per hectare?.............

50. Are you involved in any project that helps with adoption new agricultural innovation?

51. If Yes, what is the name of the project?...

52. How did the project help you to adopt drought tolerant maize variety?

53. Did you gain maize production skills in the last 5 years?

1	2
Yes	No

54. If Yes, give details of those skills…………………………………………………

55. What is the main reason for maize production?

1	2	3	4	5
Home consumption	Job creation	Income generation	Commercial purposes	Other (Specify)

56. What do you think should be done to improve the adoption of drought tolerant maize variety and productivity of farmers?

MARKET INFORMATION

57. Do you have access to the markets?

1	2
Yes	No

58. If yes, where do you sell your produce?

1	2	3	4	5	6	7
Hawkers	Local supermarket	Retailers	Middlemen	Wholesalers	Export	Other (Specify)

59. How accessible are the markets? ………………………………………………….
60.What is the distance from point of production to the nearest market?...............Km

61. Do you have access to market information?

1	2
Yes	No

62. If yes, what is the source of information?

1	2	3	4
Research	Extension officers	Other farmers	Other (specify)

…………………………………………………………………………………………….
THE END!!!!!!!!!!!! Thank you very much for your time.