ANALYSIS OF THE ADOPTION OF MAIZE BIOTECHNOLOGY BY DEVELOPING MAIZE FARMERS OF GAUTENG PROVINCE SOUTH AFRICA

By

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DECLARATION

I, Malose Charles Matlou, declare that the dissertation entitled, ”Analysis of the adoption of maize biotechnology by developing maize farmers of Gauteng Province, South Africa”, is my own work in design and execution and that all the sources used or quoted in the study have been indicated and acknowledged by means of complete references.

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SIGNATURE Date

(Mr Malose Charles Matlou)

DEDICATION

I dedicate this study to my mother, Alice Mathobela. She has always encouraged me to study in order to encourage my siblings.

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ABSTRACT

Science and technology can help feed the ever-growing human population. Green Revolution, still under critique, helped to certain extent, to reduce poverty in Asia. Biotechnology is not a solution to all problems but could be used in conjunction with other new technologies, to feed Africa. The adoption of biotechnology by farmers throughout the world, and by African farmers in particular, could help Africans to farm successfully without asking for food aid from other continents. The study analysed the adoption of maize biotechnology by developing maize farmers of Gauteng Province, South Africa. Primary data was collected through a survey (using a structured questionnaire) from 121 maize farmers from 2011 to 2014 maize production seasons. Data was analysed using SPSS computer software for descriptive statistics, rate of adoption and logit function to determine factors influencing adoption of *Bt* maize by farmers. The results of the descriptive analysis showed that 54% of the farmers adopted *Bt* maize during the 2011 to 2014 maize production seasons in the Gauteng Province. Results of the Logit model analysis indicated that farm size, gender, age, education level, off-farm employment, extension visits and farm neighbour had positive significant impact on the adoption of *Bt* maize by farmers. Visits by sales representatives of companies selling maize seeds, affiliation to farmer organisations and farmers speaking about *Bt* maize during meetings had negative significant impact on adoption of *Bt* maize by farmers. Developing farmers need regular visits of extension officers and their knowledge in order to achieve a high rate of *Bt* maize adoption. Well planted demonstration plots should be encouraged for farmers to adopt *Bt* maize as farmers believe in seeing to copy. Representatives from seed suppliers need to improve their sales approach in order to encourage adoption of *Bt* maize. Female developing farmers should be encouraged to get involved in maize farming by example making exclusive financing model for women farmers. Government can create legislations to commit financial institutions to provide women farmers with low interests or zero interest on farm loans to women farmers. Rigorous training should be encouraged so that farmers could successfully adopt *Bt* maize.

Key words: Adoption of biotechnology, logit, model, developing farmers, extension services, Bt-maize, Gauteng Province, South Africa

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LIST OF ABBREVIATIONS AND ACRONYMS

AFASA	:	Association of African Farmers of South Africa
AU	:	African Union
Bt	:	*Bacillus Thuringiensis*
CAADP	:	Comprehensive Africa Agriculture Development Programme
CEC	:	Crop Estimate Committee
DAFF	:	Department of Agriculture, Forestry and Fisheries
DNA	:	Deoxyribonucleic Acid
DOH	:	Department of Health
DST	:	Department of Science and Technology
DTI	:	Department of Trade and Industry
FCDA	:	Foodstuffs, Cosmetics and Disinfectants Act
GM	:	Genetically Modified
GMO	:	Genetically Modified Organisms
Grain SA	:	Grain South Africa
Ha	:	Hectares
IRM	:	Integrated Resistance Management
ISAAA	:	International Services for the Acquisition of Agri-biotech Applications
LRAD	:	Land Redistribution and Agricultural Development
MAFISA	:	Micro- Agricultural Financial Institutions of South Africa
MDG	:	Millennium Development Goal
MSV	:	Maize Streak Virus
NBS	:	National Biotechnology Strategy
NEA	:	National Environmental Act
NEMA	:	National Environment Management Act
NEPAD	:	New Partnership for Africa's Development
NRC	:	National Research Council
OPV	:	Open Pollinated Varieties
OSAA	:	Office of the Special Advisor on Africa
PLAS	:	Proactive Land Acquisition Strategy
PTO	:	Permission to occupy
SAGENE	:	South Africa Genetic for Experimentation

SPSS	:	Statistical Package for Social Sciences
TIA	:	Technology Innovation Agency

CHAPTER ONE

1. INTRODUCTION

1.0 BACKGROUND OF THE STUDY

The end results of the Green Revolution were the doubling of grain production from 1965 to 1990 (Uphoff, 2002). The author also maintains that had human beings not been innovative enough since the Green Revolution, the human race would have been facing food deficit. A combination of hybrid seeds, water, good soil, good nutrient management strategy and Integrated Pest Management systems could achieve an increase in the production of food by more than 200 per cent even with adverse environmental conditions (Uphoff, 2002).

The Green Revolution managed to increase the yield two folds; but challenges for African farmers are still massive. A repeat of the Green Revolution, even though criticised by Uphoff (2002) as unsustainable, in modern times, could see developing African farmers still lagging behind. The fact that African farmers are not innovative (as seen with the adoption of biotechnology in agriculture), that consequently means that they will be the last to benefit from any forms of innovation if any in our lifetime (National Research Council, NRC, 2009).

In South Africa, the term developing farmers is used to refer to farmers or part of communities that were previously disadvantaged (black people). Black farmers are farmers of African, Coloureds and Indian origins, who are South African by birth (MAFISA Credit Policy, 2009). They are referred to as subsistence farmers, developing farmers, emerging farmers, small-scale farmers and growing farmers. This could be due to the fact that the past is still haunting South Africans, both blacks and whites with regard to segregation, as these farmers are categorised along racial lines. In some areas, these farmers have more hectares of land and produce better than their white neighbours, but they are still not regarded as commercial farmers, and classified by names that will immediately tell which racial category of farmers the name refers to. These farmers are scattered throughout South Africa, especially in homelands created by apartheid government. They are members of rural communities of South Africa where 70% of poor people reside, as a result of several years of racial segregation spanning from 1913 to 1932 when the Land Segregation Laws were passed (Sangina *et al*. 2009: 334). The long-term damage of apartheid is still felt today by the country as these farmers experience limitations in terms of quantity, quality and accessibility of key inputs (Sangina *et al*. 2009).

Gauteng Province in South Africa is also home to this category of farmers and a greater part of their agricultural activity is maize production. *Zea mays* (maize), production in South Africa is used to supplement a large part of maize meal consumption by South Africans and foreigners who have immigrated into the country. The study examines the adoption of technology by developing maize farmers in terms of exploiting all efforts to feed the ever-growing population in the Province. Although technology is not the only determining factor in terms of the success of farmers, for farmers' access to improve inputs, methods and knowledge can make a substantial contribution to better agricultural production (National Research Council, 2009). However, the same innovation is said to have not benefited millions across the world. Uphoff (2002) warns that human beings should not be complacent with technology as it cannot meet all future agricultural needs.

1.1 PROBLEM STATEMENT

Since the dawn of democracy in South Africa, the government has been involved in many agricultural programmes in trying to reduce the inequalities that remain elusive in the country.. Agriculture has also attracted considerable policies and academic interests as more and more programmes fail to yield the desired results (Obi, 2011). African Agricultural Development Programme, Agricultural Broad-Based Black Economic

Empowerment, Comprehensive Agricultural Support Programme, Small holder Farmer Evaluation etc. are some of the examples of the programmes that government introduced to help improve black farmers in South Africa. Developing farmer programmes also form part of these initiatives and there are some farmers who have being trying to keep level with the speed by which government is trying to bridge this inequality gap. Factors such as the adoption and the use of maize biotechnology by developing farmers continue to play a major role in gauging the level of their success.

Adoption and usage of maize biotechnology can be influenced by the characteristics of the particular maize biotechnology, the farming environment such as the agro-climatic conditions of the area, the prevailing cropping systems, the degree of commercialisations of agriculture in the particular area and the level of education that farmers in the particular area have (Mabaya *et al*. 2015).

The use of hybrid and maize biotechnology seeds by many developing farmers has been and continues to be a challenge to governments and other pro-development institutions in their decision-making. The South African government, together with local Non-Governmental Organisations such as AfricaBio, have been trying to introduce *Bt* maize through training programmes throughout the country, including Gauteng Province. Seed companies such as Pannar Seed and Monsanto have also gone out to try to introduce *Bt* maize seed to developing farmers (through the introduction of *Bt* maize on small packs such as 2, 5 and 10kg bags at affordable prices before the 2011 season). It was expected that developing farmers would adopt the technology to improve yields and *Bt* maize production. The focus of this study is, therefore, to analyse the adoption of *Bt* maize technology among developing maize farmers from 2011 to 2014 maize production season. The study will assist institutions with relevant information regarding the distance developing maize farmers have travelled in terms of adopting the use of *Bt* maize.

1.2 AIM AND OBJECTIVES OF THE STUDY

The main objective of the study was to analyse the adoption of *Bt* maize by developing maize farmers of Gauteng province, South Africa.

The specific objectives of the study were to:

- Describe the demographic and socio-economic characteristics that impact on the adoption or non-adoption of *Bt* maize by developing maize farmers in Gauteng Province;
- Identify developing maize farmers in Gauteng who have adopted and those who have not adopted *Bt* maize;
- Asses the rate of adoption of *Bt* maize among developing maize farmers in the study area;
- Identify and ascertain factors that the influence developing maize farmers to adopt maize; and
- Identify the constraints that limit developing maize farmers from adopting Bt maize.

1.3 RESEARCH QUESTIONS

From the above objectives, the following research questions were formulated:

- What are the demographic and socio-economic characteristics that impact on the adoption of *Bt* maize by developing maize farmers in Gauteng?
- How many developing farmers participating in the study have adopted *Bt* maize?
- What is the rate of adoption of *Bt* maize by developing farmers?
- What are factors that influence the adoption of *Bt* maize by developing farmers? and
- What are the constraints that limit the adoption of *Bt* maize by developing farmers in Gauteng?

1.4 HYPOTHESIS

It is hypothesised that the demographic and socio-economics characteristics of farmers have statistically significant impact on the adoption of *Bt* maize by developing farmers.

1.5 SIGNIFICANCE OF THE STUDY

Governments and the private sector are involved in several programmes to uplift the farming production of developing or small-scale farmers in South Africa. These efforts which include the introduction and promotion of new technology, funding of agricultural programmes and the buying of implements, are important tools to ensure that black South African farmers can benefit from agriculture. The adoption of new technology depends on the farmers, whether they see a future in the use of biotechnology is their choice.

The findings from this study will provide government and all pro-agricultural development institutions and individuals a clear understanding of developing farmers with regard to the adoption of technology. Findings will also assist in terms of providing these institutions with one part of a solution when drafting developmental policies and strategies of approaching developing farmers.

The findings of this study will be shared with government officials, farmer associations and the private sector. The recommendations advanced in this study could provide evidence that will assist in improving yields, maximise profits and create more employment within the community. According to Altman *et al.* (2009), employment of community members can reduce poverty and ensure food security.

1.6 ETHICAL CONSIDERATIONS

This study is based on human elements and all the guidelines on Research and Higher Degrees Committee in the College of Agriculture and Environmental Sciences of UNISA have been strictly followed. No modification of living beings whatsoever has been involved in this study. However, ethical approval was requested and obtained from the Ethics Committee which is a branch of the College Research and Higher Degrees Committee before conducting the study in all areas specified. Consent forms were issued to participants to sign before collecting data from them through interviews. Assurance of confidentiality was guaranteed to all interviewees (farmers, government officials, multinational company officials and those considered fit for interview).

1.7 OUTLINE OF THE STUDY

Chapter One provides a background on the impact of the Green Revolution on agriculture in general, especially in developing countries and the impact of the adoption of biotechnology by developing countries by small-scale farmers. It also examines how ethical considerations were dealt with during the study and the significance of the study.

Chapter Two is a review of past research on Green Revolution and Biotechnology and factors that influence the adoption of biotechnology by developing farmers.

Chapter Three focuses on the research methodology used in conducting the study, the area and population of the study, the research design, sampling methods and methods of data collection as well as analysis.

Chapter Four presents the results obtained from data analysis including that of the Logit Model.

Chapter Five is a summary of the findings and conclusions drawn. It also provides recommendations based on the findings, possibilities for future research is also indicated in this Chapter.

CHAPTER TWO

2. LITERATURE REVIEW

2.1 INTRODUCTION

This chapter presents both local and international literature related to the adoption of biotechnology or genetically modified crops by developing farmers. It also provides reasons why some farmers have not adopted biotechnology in their farming activities. It further highlights in a very minimal way, challenges faced by developing African farmers since the introduction of the Green Revolution the farming sector. The chapter also presents the impact of biotechnology since its introduction among developing farmers in Africa and South Africa's involvement in efforts to reduce the gap of farming technology created by apartheid directed exclusively to developing or black farmers in the country.

2.2 Green Revolution in Africa

The Green Revolution was most active from the late 1960s. It was an initiative to breed new varieties that will help improve the yields of stable crops such as maize, rice and wheat. The Green Revolution was more beneficial to other continents than Africa in terms of offering new varieties of crops to farmers that allowed them to improve their agricultural yields. Hobbelink (1989) concurs that the Green Revolution emphasised on high yielding varieties, but failed to concentrate on farmers and their sophisticated farming systems. Its major advance was to increase farm production in Asia and other South American countries such as Mexico. The Green Revolution increased the availability of cereals per capita by a third, when the population in Asia increased by 60% between 1970 and 1995 (Hobbelink, 1989). The Green Revolution managed to lower the food prices for everyone, including both urban and rural poor, this as the poor spend a large proportion of their income on food (Hobbelink, 1989). The Green Revolution also greatly increased employment in the rural non-farm economy and agricultural wages generally rose (The

Economist 2014). The Economist (2014) further noted that in 1975, six out of ten Asians lived in poverty and by 1993; only two out of ten East Asians and four out of ten South Asians lived in poverty.

As mentioned earlier that the Green Revolution has benefited many countries and their farmers, despite this, African farmers are still lagging behind compared to their Asian counterparts. Conway (1990: 11) criticised the shortcomings of the Green Revolution by saying that it suffered "...from problems of equity and failures in achieving stability and sustainability of production". He argued that technologies used were not accessible or unsuitable to "resource-poor environments, farmers with small or marginal holdings". In most cases, the solution could be the introduction of new technology or the adjustment of such to Africa where the technology has not being introduced. As Hobbelink (1989) argued, the emphasis of whatever technological systems to be introduced, it should be able to address the specific needs of farmers on a regional basis as farming cannot be painted with one brush. Conway and Barbier (1990) pointed out the importance of a different approach which should be "equally revolutionary" and should be "conceptual and operational in style". Smil (2000) argues that the introduction of new technology should not be intensified, but instead, the existing one should be used effectively. It should be intensified with regard to developing farmers, in particular, developing farmers in South Africa. Most of them have never experienced the use of technology before due to policies that denied them access to mainstream agriculture or simply put non-exposure to modern agricultural activities before 1994.

The Green Revolution did not give Africa the possibility to help itself as it did in Asia due to the inequalities between the developed and the developing world (Conway, 2003). Conway (2003) further questions the role played by institutions that were the source of research and knowledge, like universities, to manage the technology and the knowledge in order to advance economies and help poverty-stricken people. The Green Revolution experienced real failures in the environmental and social domains. Some of the crops created had short stems, and required shallow root systems; they needed more water and fertilizers than traditional varieties, increased pesticides usage that had some negative impact on the environment (Hobbelink, 1989). Some shortcomings were seen on the degradation of the soil as farmers had to work the land more to incorporate high fertilizer usage needed in order to make these new crops to yield more. It also had some social short comings for both what it did and what it did not do. The seeds of the new varieties needed more fertilisers, irrigation and some special implements were expensive, affordable mainly by richer farmers (Hobbelink, 1989). As the value of inputs became higher, the value of land became more and more valuable and out of the reach of the poor.

Why Africa missed out on Green Revolution? The Green Revolution focused on wheat and rice, crops that are mostly grown on irrigated land. Crops such as sorghum, millet, cowpeas and cassava (staple food in Africa) receive little support and research from western scientists (ISAAA, 2000). The Green Revolution was a one size fits all type of technology and African farmers operate on a wide diversity of ecosystem such as depleted soils, harsh rains and very dry seasons in some regions, salty soils, sandy soils, various crop and animal diseases, various insect pests and very poor road infrastructure to the markets. Africa's political instability and governance, which to some extent still exists until today, could have also contributed to the failure of the Green Revolution in Africa.

The shortfalls of Green Revolution let to several programmes including Comprehensive Africa Agriculture Development Programme (CAADP) by African Union (AU). In 2003 AU made the first declaration on CAADP as an integral part of the New Partnership for Africa's Development (NEPAD) (Kimenyi, *et al.*, 2012). Kimenyi, *et al.* (2012) further clarify CAADP as a pan-African framework that provides a set of principles and broadly defined strategies to help countries to critically review their own situations and identify investments with optimal impact and returns. CAADP is design to be flexible as each country generates its own compact and investment plan to achieve its own stated goals. Office of the special Advisor on Africa (OSAA) indicates that CAADP is continental in scope but exists through integrated national and regional efforts to promote agricultural sector growth and economic development (OSAA. 2015). CAADP is a work in progress, as the ‘Sustaining CAADP Momentum’ exercise undertaken in 2012 to look back into the ten years of CAADP implementation concluded that the CAADP vision was just as valid as it was in 2003 (NEPAD. 2015).

2.3 Biotechnology or Genetically Modified Crops in Africa

There are three practical processes resulting from basic advances in cellular and molecular biotechnology as follows: genetically modified technology; tissue culture; and marker aided selection. The latter two are not controversial, but simply makes traditional methods more efficient and more powerful compared to genetic engineering (ISAAA, 2000).

With conventional breeding, there is little or no guarantee of obtaining any particular gene combination from the millions of crosses generated in one particular breeding attempt (ISAAA, 2008). Genes that are not desirables can be transferred along with those or the ones that are or needed as genes of both parents mixed during the attempt process under conventional breeding. These create a huge challenge for breeders as it takes time and money to come out with the preferred offspring (ISAAA, 2008).

Genetically modified crops are those that have had changes introduced in their DNA by genetic engineering techniques for breeding purposes (Mannion & Morse, 2013). The author further maintains that genetic modification is based on recombinant DNA technology, which enables the direct transfer of genes from one organism to another. In genetic engineering, genes are moved between organisms, including those that do not cross in nature (Conway, 2003). In contrast with conventional breeding, genetic engineering allows direct transfer of one desirable gene between either related or unrelated organisms (Mannion & Morse 2013). The author further maintains that *Bacillus thuringiencis* (*Bt*), is an example of genetic technology that is a common spore forming bacterium that can be found on but not limited to soil and dead insects. *Bt* (the main focus of this study) produces endotoxin protein, Cry1Ac, which has a narrow spectrum of activity against lepidopteran pests (Ruttan, 1998). Federici *et al.* (2009) described the insecticidal proteins, Cry1Ac, that it is continuously produced directly by plants after it has been introduced inside the plant system and that *Bt* endotoxins are stomach poisons selective to lepidopteran pests. According to Sharma and Naim (2010), Ledopteran pests are the most damaging pests on maize and sorghum in Africa, India and Asia.

Tissue culture permits the growth of a whole plant from a single cell or a clump of cells in an artificial medium. Plants derived from tissue culture are usually stronger and reach maturity earlier than ordinary plants (Wambugu, 2001). The author explains further that being raised under sterile conditions, tissue cultured plants can also be free of pests and most diseases. These advantages lead to higher and better quality yields from mature plants. Since tissue culture can greatly speed up the multiplication of planting materials, it is a powerful tool of disseminating improved varieties to farmers, especially in crop species with a low multiplication ratio such as cassava, sweet potato or banana (Wambugu, 2001).

Marker-aided selections are sequences of DNA that correlate with the presence of certain traits in a plant, animal or micro-organism (Conway, 2003). The author further maintains that segments of the plant genome that are closely linked to the desired genes are identified using the marker-aided selections so that the presence or absence or the trait (that is the success of the cross), can be identified at the seedling or the seed stage. The marker-aided selection makes it possible to achieve new varieties in four to six generations instead of ten (Conway, 2003).

Gows (2003) testified that *Bt* genes, Cry1Ac were tested in South Africa and were found to be controlling local lepidopteran pests. Kirsten (2005) maintains that the South African biosafety committee approved maize containing Cry1Ac in 1998 and commercialised it in the same year in yellow maize hybrid.

The GM technology has attracted a huge controversy within the scientific community because moving genes across the species is seen as unnatural and people around the world are suspicious of GM crops and are hostile to their use, especially in food (ISAAA 2015). But in South Africa, biotechnology is being used on maize, a staple food in the country. According to Kirsten (2000), South Africa is the only country in the world with a staple food that is genetically modified. Since 1997, after the first approval of the first insect resistant GM maize in South Africa, there has been a progressive and steady increase in the adoption and usage of GM maize (Kirsten, 2000). The main concern of the hostility of this technology is its safety in food. According to Soberón (2015), *Bt* toxins are stomach poison selective for specific insects and not for vertebrae. Soberón (2015) further maintains that under the highly acidic conditions that exists in the stomach of vertebrae, the endotoxin crystals of *Bt* technology is solubilised and get degraded within minutes by gastric juices in the stomach.

Ruttan (1994) argues that the new farming method of using biotechnology have not yet raised yields beyond the levels achieved using older methods, and it is not even promising to do so in the near future. Babatunde and Mabaya (2013) posits that Biotechnology or genetically modified crops bear a great potential to increase productivity and reduce poverty by improving food security in Africa. Ruttan (1998) maintains that despite its shortfalls, biotechnology can bring some solutions in the midst of very environmental conditions (like salty soils) by bringing salinization points and desertification processes closer. Despite the arguments advanced by the two authors, adoption of Biotechnology in Africa has been slow or non-existent as shown in Table 2.1.

Table 2.1: Genetically modified crops in Africa

Country	Cotton ha	Soy ha	Maize ha	Total ha
Burkina Faso	300 000	0	0	300 000
Egypt	0	0	1000	1000
South Africa	15 000	382 000	1 870 000	2 300 000
Sudan	200 000	0	0	2 801 000

Source: ISAAA 2013

There are many countries that are on various stages of creating an enabling environment for the adoption of biotechnology; however, indicators show that the road is still far. There is still the fear of the unknown with little or no scientific merit. The controversy regarding the benefit of transgenic crops is still ragging in many countries around the world. Countries are still concerned about the potential negative impacts of these crops on the environment, non-target organisms, food safety and the unintended spread of the transgenic traits into conventionally bred-crop. Richerson (2012) emphasized the fear that for some people, one thing that remains unclear is the safety of the non-plant matter injected into the seed for human ingestion.

How can Africa gain access to genetic engineering technology? Techniques to transfer this technology belong to universities and private institutions, hence they are patented (Conway, 2003). For Africa to access the technology, governments need to invest more on research and make sure they own the research in order to help Africa to access modern development. Often, as Conway (2003) argues, the underlying inventions are made at universities funded by private companies but because of the large investments needed to turn an invention into a product, commercial companies now hold rights to most of the genes and technologies.

Will agricultural biotechnology manage to overcome the shortcomings of the Green Revolution? Biotechnology does not differ much with the Green Revolution, both emphasize crop development rather than farmer development. Biotechnology concentrates on changing the genetic make-up of a crop to adopt certain agricultural conditions, that is, the symptoms, rather than concentrating on the course of the conditions and coming up with solutions. Biotechnology, just like the Green Revolution, could fail in addressing the farming systems experienced by African farmers.

Conway and Barbier (1990) describes agricultural resources as internal and external. External are those resources that a farmer has minimal or no impact on, examples include the rainfall pattern, natural fixed nitrogen, existing nutrients and biological pest control. Biotechnology and its adoption can help reduce these external resources such as improved crops to resist drought and the already existing insect resistant crops which could result in the decline in the use of chemical pesticides (Morse, 2008). Some commercial farmers in South Africa have adopted the use of biotechnology seeds and have noticed some benefits (NRC, 2009). Conway and Barbier (1990) further describes internal resources as those that the farmer can have a say on, such as water for irrigation, chemicals and seeds. Knowledge can be categorised under internal resources as well. Transferring the biotechnology knowledge to the farmers or simply put, accessibility of biotechnology knowledge, is also discussed in this study.

The benefits of agricultural biotechnology introduced in developing countries thus far have been predominantly of economic benefits for farmers. (Gouse *et al*. 2002). The benefit of GM crops is the potential to address chronic nutrition problems in developing countries. Increasing productivity and income among small farmers in Africa is critical to addressing hunger, but the magnitude of the nutrition crisis is such that introduction of genetic engineering cannot be the only effort. Nutritionally enhanced food through biotechnology could also help reduce the number of children growing up malnourished due for example, to lack of Vitamin A (Wambugu, 2001). The long-term impact of GM crops on the environment and health of both human beings and animals (very controversial), is still under discussion in many forums around the world.

Will Africa miss out on biotechnology? Biotechnology in Africa should be based on people's needs rather than supply or profit as was the case with the Green Revolution. African production yields improve with the increase in land production whereas, in Asia, yields are able to go up on the same land that was used the previous year, due to the introduction and adoption of technology (NRC, 2009). The greatest challenge should be to improve crops such as maize, sorghum, millet, cowpeas and cassava in order to improve their yields, considering the fact that these crops are the mainstay of subsistence farming in Africa. The best way of raising yields in Africa is through seed-based technologies, which are relatively easier to disseminate, they are easier to acquire and use, even if it means saved seed which could be reused over decades with relevant local technology. Where conventional selection and breeding to develop improved seeds hits the barrier, biotechnology offers the best way forward at this day and era. African research institutions and universities need to be improved and financed by governments in order for states to own the research outcome for the betterment of African people, rather than patented research outcomes that will be dictated by their financiers at the expense of farmers and the world's poorest of the poor.

2.4 Biotechnology in South Africa

South African scientists recognised the advent of biotechnology since the sixties and in 1978, the South African Genetic for Experimentation (SAGENE) was formed (van der

Walt, 2002). Van der Walt (2002) maintains that the formation of SAGENE was to oversee the future benefits of biotechnology to government and the industry in South Africa.

As one of the early adopters of agricultural biotechnology, South Africa remains ahead of many African countries. According to a study conducted by Kenya's NRC (2009), it was found that transgenic or technology maize seed is fast growing in South Africa compared to other sub-Saharan African countries. Technology is fast gaining momentum with regard to development of agriculture as science continues to explore the capacity of biological and mechanical technology to harness its benefit for the needs of mankind. NRC's report (2009, 25) states that "beyond the fields traditionally associated with agriculture, advances in physics, chemistry, electrical engineering, material science, remote sensing and computer science are increasingly recognised as sources of novel ideas with implications for agriculture". According to the Annual Biotechnology Report of South Africa (2006), South Africa is way advanced in agricultural technology in terms of plant breeding and biotechnology. The further report highlights the fact that South Africa has been involved in Biotechnology research for the past thirty years and that biotechnology production continues to increase and sitting at 72% for maize, soybeans at 85% and 100% for cotton. However, all genetic events in South Africa are from multinational companies, not a single South African GM crop has entered the market after 37 years of biotechnology communication and 25 years of testing and adoption. (Van der Walt, 2002).

According to Kirsten (2000), the current *Bt* maize was developed with commercial farming in mind but insect tolerant cotton is already having significant positive impact in rural farmers in resource poor regions of South Africa. Maize is found in almost every back yard of rural and some urban communities in South Africa. In most cases, maize stalk borer get along without being controlled. According to Kirsten *et al.* (2000), this is due to the following reasons: the damage is not visible; developing farmers have no skill to scout effectively; and the costs of controlling the insects are high. Depending on the intensity of infestations and the maize production skill, two or more spraying may be required on maize farms per production season. In South Africa, *Bt* maize has shown some significant reduction in pesticides spraying and some farmers have opted for the use of *Bt* maize (Kirsten *et al*. 2000).

According to Van der Walt (2002), the early adoption of *Bt* maize was slow in South Africa. During the 2002/2003 production season, 20% of maize was *Bt* and 2.4% was white. Van der Walt (2002) maintains that the reasons for the slow adoption of this technology were as follows: hybrid seeds used were not good for African conditions; farmers thought it would be wise to plant on large portions of land in order to mitigate the yield that could be lost due to attacks by insects; and that farmers were scared of the response of the market towards their product. Van der Walt (2002) further maintains that the demand of *Bt* maize increased from 2003/2004 production season as the market accepted the harvest and, combined with the increased stalk borer infestation of that year, the adoption rate increased. A finding by Gouse *et al.* (2003) in his study of six sites, found that developing farmers liked the quality of *Bt* maize than its conventional counterpart.

However, critics of biotechnology in South Africa claim that adoption and usage of biotechnology benefits multinational seed corporations and not farmers. Information Manual on Biotechnology – DAFF (2009) maintain that although GMO seeds might appear expensive at the purchasing stage which would ultimately benefit multinationals, the increase in yields and the reduction in spraying costs, outweigh the increase in the cost of seeds. Farmers may, as with conventional seeds, keep GM technology grains as seeds after harvest. GM technology soybean farmers keep their harvests as seeds and reuse them for two seasons in a row and then buy new seeds in the third year. Hybrid maize, which in most cases is usually made of GM technology seeds, lose vigour that delivers optimum yields after a single planting season, hence farmers do not replant them and opt to buy new seeds (DAFF, 2009). Cotton farmers may also keep harvested seeds on either conventional or *Bt* technology, but unless they have the ability to separate the fibre from the seed coat, it is extremely difficult to establish a new crop from saved seeds (DAFF, 2009). An analysis of the adoption of *Bt* maize by developing farmers is done in this study.

GM crops approved for commercial cultivation purposes in South Africa are as follows: insect resistant cotton; herbicide tolerant cotton; the combined herbicide and insect tolerant cotton; herbicide tolerant soybean; insect resistant white maize; insect resistant yellow maize; and the combined insect and herbicide white and yellow maize.

Table 2.2: Hectares of GM crops planted in South Africa versus non-GM counterparts

Crop	**2013 Status Planting**	
	GM Crop	Non GM Crop
Cotton 8300 ha	Insect resistant cotton 0% Herbicide tolerant cotton 5% Stacked insect resistant and herbicide tolerant cotton 95%	Conventional cotton 0%
Maize GM maize is 2.363 million ha (86.6%) of national production of 2.73 million ha	Herbicide tolerant Maize 18.2% Insect resistant maize 28.4% Stacked insect resistant and herbicide tolerant maize 53.4%	Conventional maize is 13.4% of national production or 0.367 million ha
Soya beans National production of 520 000 ha	Herbicides tolerant soya bean of 478 000 or 92% of total planted	Conventional soya bean 8%

Source: Biotech-Facts and Trends 2014, South Africa – ISAAA

Monsanto is the dominant *Bt* gene company in South Africa and sells its *Bt* maize through its own hybrid seeds. Pioneer Hi-Bred, Pannar seed and some small maize seed companies such as Link Seed, Karoo Seed and Agricol are also distributing *Bt* technology under the licence of Monsanto (ISAAA, 2014). Initially, all these companies used to sell their seeds mostly to commercial farmers. It is only Pannar seed which had some special distribution programmes that catered for developing farmers. *Bt* technology was not part of the special distribution programme by Pannar seed as it was used on varieties used solely by developing farmers such as the open pollinated varieties (OPV). Monsanto introduced *Bt* seed in small packs in 2002/03 production season and other companies such as Pioneer Hi-Bred followed in 2012/13 production season. In a study conducted in nine areas of South Africa, Gouse *et al.* (2003) found that *Bt* maize has a large yield advantage over non-*Bt* maize, hence its adoption by farmers. A study by Gouse *et al*. (2003) further found that farmers adopting *Bt* maize, especially commercial farmers, are already convinced of the value of planting hybrid seeds. For developing farmers to adopt *Bt* maize seeds, they need to be convinced of the benefits of hybrid maize.

Gouse *et al*. (2003) further noted that the areas under *Bt* maize cultivation, could be expanded only if maize seed companies had some special programmes for distribution of *Bt* maize and charging a lower fee. The introduction of *Bt* technology on OPV could also see more and more farmers adopting the use of *Bt* technology, weather the adoption would be price related or knowledge related remains to be tested and verified. The other challenge for seed companies is the signing of the technology agreement when purchasing *Bt* maize, which is the case with commercial farmers as well. Pioneer Hi-Bred RSA's Biotechnology and product Guide (2013) maintain that when one buys *Bt* maize seed, one agrees to:

- Use the seed containing the subject technology for planting a commercial crop only in a single season;
- Not to supply any of this seed to any other person or entity for planting, and not to save any crop produced from this seed for replanting or supply saved seed to anyone for replanting;

- Not to use this seed or its progeny or provide it to anyone for crop breeding, seed production or research (other than to make agronomic comparisons and conduct yield testing);
- Implement an Insect Resistance Management (IRM) programme specified in the appropriate Product Guide(s) accompanying products, if applicable, and to cooperate with Insect Resistance Management programmes and research;
- That you are affirming your contractual obligation to follow IRM requirements
- IRM requirements set forth in Product Use Guide and referred to in this Agreement supersede the IRM requirements set forth in any previously executed agreements or Product Use Guide; and
- That Pioneer Hi-Bred RSA (Pty) Ltd is entitled to recover its full amount of legal costs and fees and any costs incurred in enforcing this agreement on the attorney and client scale.

These and many clauses within the agreement become an impossible task to enforce on developing farmers as these farmers are not properly organised. Every member of a community could plant a small portion within the yard and be regarded as a farmer. Considering the fact that there are several thousands of such farmers in South Africa, if government could ensure the enforcement of the law on the technology agreement, companies may end up not selling *Bt* maize to developing farmers at all.

Developing farmers in South Africa, like their counter parts in many other African countries, face challenges of dryland agriculture and poor soil fertility. An African farmer will normally grow several crops in one hectare, the reasons behind this practice emanates from the survival strategy they apply to minimise risks of droughts. Synthetic fertilizer is expensive from an African farmer’s point of view, while the soil is very dry and with shallow topsoil. Crop production per unit of land cultivated is the lowest in the agricultural world. Diseases such as the MSV and ACMV are common within the South

African farming environment and need a trained eye to scout, identify and control. However, African scientists have developed some msv resistant varieties, but the resistance continues to break down due to the development of more virulent strains (Gouse *et al*. 2009). Strigga spp. is another type of disease found to be a problem in maize production, particularly among developing farmers as they plant late and have no money and knowledge to control this parasite.

The agricultural sector is quickly changing, while at the same time, there is a growing need for rural development in terms of poverty alleviation. The success of the latter depends on innovation, knowledge and related information, skills, technologies and attitudes. In this instance, the supply of extension information services is a key in unleashing the success of developing farmers.

2.5 Biotechnology policies and GM product approval processes in South Africa

The Cartagena Protocol on Biosafety is the only international treaty specifically regulating GMO and all parties have to take legal, administrative and other measures to implement the protocol (van der Walt, 2002). The protocol recognises that agricultural biotechnology has a great potential for human well-being if developed and utilised with correct safety measures for both the environment and human beings. South Africa has ratified the protocol and there are three key legislative instruments in South Africa that are directly related to the issue of monitoring GMOs as amended. The first one is the Genetically Modified Organisms Act no. 15, 1997, which aims at ensuring that any GMO related activity in South Africa is conducted so as to limit potential risks to the environment, to human and animal health and takes socio-economic considerations into account (DAFF, 2009). The second is the National Environmental Management Act no. 107, 1998 which provides established general principles for decision-making with regard to the activities that affect the environment and promotes cooperative governance (DEA, 2008). Lastly, the National Environmental Management Biodiversity Act no. 10, 2004 which reports on the environmental impacts of GMOs released into the environment in South Africa (DEA, 2008).

The South African government developed National Biotechnology Strategy in 2001 to strengthen scientific and technological capacities in the field of biotechnology. Through this strategy, government recognises that biotechnology could play an important role in alleviating poverty, but it is aware of the potential risks involved in the application of biotechnology and, is, therefore, sensitive towards concerns raised in this regard. The South African government, therefore, embraces biotechnology with the proviso that the application of biotechnology is managed properly.

The National Biotechnology Strategy was found to have several gaps as it focused solely on market ready products and not a value chain for biotechnology-based product. The gaps within the National Biotechnology Strategy led to the formation of the Bio-Economy Strategy. The implementation of the Bio-Economy Strategy is in process and its role involves strengthening agricultural biosciences innovation to ensure food security through agriculture, science and technology health.

AfricaBio Policy Brief (2010) highlights important structures developed across the country to make biotechnology and innovation a footprint. The Biotechnology Innovation Centre consisting of CapeBiotech, BioPAD, LIFELab and PlanBio were formed. These structures were later incorporated into the new established Technology Innovation Agency (TIA). The aim of TIA was to improve coordination and promote any innovation, including biotechnology (AfricaBio Policy Brief, 2010).

The purpose of the GMO Act was the formation of an Executive Council that could make recommendations to the Minister of Agriculture on an application submitted to the

Registrar for permit to develop, produce, use or apply genetically modified organisms in South Africa (AfricaBio Policy Brief, 2010).

The process of the approval starts with the GMO Registrar receiving an application and once satisfied with compliance with the provision of the GMO Act, the application is forwarded to the Advisory Committee for risk assessment pertaining to food, feed and environmental impact. Based on the findings of the committee, the application is recommended to the Executive Council for a decision.

The general public is also informed and consulted on intended activities relating to GMO through notification in major newspapers. Comments from the public are therefore considered in the process of evaluating any relevant application. If the Executive is satisfied that certain activities with a GMO may be conducted, the Registrar is authorised by the council to issue the necessary permit (DAFF, 2009).

2.6 GM products in South Africa

2.6.1 Insect resistant crops

In the last few years, several crops have been genetically modified to produce their own Bt proteins, thus making them resistant to specific groups of insects (Federeci, 2010). Insect-resistant maize is the focus of this study and its adoption by Gauteng developing farmers between 2011 to 2014 production season is explored.

Planting *Bt* maize requires some special management in order to present *Bt* gene resistance. One of the components of the insect resistant management strategy is the creation of the refuge areas. A refuge is a block of strip of maize seed without *Bt*, which must be planted on the side of the maize with *Bt* technology (Pioneer – Biotechnology Guide, 2014). Potentially resistant insects emerging from the fields with *Bt* technology may mate with susceptible stock borers from the refuge resulting in offspring that are susceptible to the *Bt* technology. (Pioneer– Biotechnology Guide, 2013). Accordingly, the method dilutes the resistant gene, thereby making the Bt technology to avoid ever experiencing any resistance. Research is still underway in all maize growing areas of South Africa as resistance has already developed, especially with the *Chilo partellus* in the Free State and North West provinces of South Africa.

Planting a refuge is a requirement for growing the *Bt* products and it is a primary component or insect resistance management tool. There are two acceptable refuge options in South Africa as follows:

- 'Option A: 95% *Bt* technology with an accompanying 5% refuge. No chemicals should be applied to control *Busseola Fusca* (maize stalk borer), *Chilo partellus* (Sorghum stemborer and *Sesamia calamistis* (Pink Stalkborer) and *Helicoverpa Armigera* when opting for option A (Pioneer – Biotechnology Guide, 2014); and
- Option B: 80% Bt technology with an accompanying 20% refuge. With this option, chemical control is permitted after scouting on targeted insects, *Busseola Fusca* (maize stalk borer), *Chilo partellus* (Sorghum stemborer and *Sesamia calamistis* (Pink Stalkborer) and *Helicoverpa Armigera*' (Pioneer – Biotechnology Guide, 2014).

2.6.2 Herbicides resistant technology

The first herbicide tolerant maize was introduced in South Africa in 2003 and, currently, 284 000 ha of land is used for this technology (ISAAA, 2015). Gouse *et al.* (2009) maintain that developing farmers increased their yield gains between 3 and 8% using the herbicide compared to conventional maize. The products with herbicide tolerant approved for commercial purposes in South Africa include maize, soybeans and cotton. Not much is said about herbicide tolerant crops as they do not form part of this study.

2.6.3 Stacked gene technology

The stacked gene, the first double gene maize, was first introduced in South Africa in 2004 and 904 000 ha of land was used under stacked gene in the 2013 maize production season (Isaaa, 2013).

2.7. Factors that determine the adoption of *Bt* maize in South Africa

South African recognised the advent of biotechnology since the sixties and the started making formations like the South African Genetic for Experimentation (SAGENE) to be ready for adoptions (van der Walt, 2002). The policies and GM product approval processes in South Africa are made easy by legislation which make adoption easy.

A study by Gouse *et al*. (2003) found that farmers adopting *Bt* maize, especially commercial farmers, are convinced of the value of planting hybrid seeds. And developing farmers as neighbours of commercial farmers could adopt *Bt* maize seeds as well when copying from their neighbours.

2.8. Challenges facing adoption of *Bt* maize in South Africa

Bt maize is seen as not suitable for South African conditions as highlighted by van der Walt (2002). The author further indicates that developing farmers were initially not sure about the feeling of the market with regard to *Bt* maize, but are gradually changing this perception. Quality of maize is also a mitigating factor for the adoption of *Bt* maize as found by Gouse *et al* (2003).

There is still a lot of perception by developing farmers about *Bt* maize as being expensive and only benefits multinational companies (DAFF, 2009). Gouse *et al*. (2003) indicated that owners of this technology need to consider some special prices for developing farmers to afford it and improve adoption.

OPV’s which are still the main maize crop under production in many South African communities need to be coated with *Bt* maize to improve adoption.

Signing of the technology agreement when purchasing *Bt* maize should be done away with to increase developing farmers and communities planting maize to adopt Bt maize.

The supply of extension information services is a key in unleashing the success of adoption of *Bt* maize. Many extension officers are thought to not have relevant information regarding *Bt* maize to pass it to the farmers as expected.

Genetic events in South Africa are from multinational companies, not a single South African GM crop has entered the market after 37 years of biotechnology communication and 25 years of testing and adoption (Van der Walt, 2002).

2.9 Maize production in South Africa

Maize remains the main field crop and stable food in South Africa. According to the Crop Estimates Committee (2016), maize accounts for about 35% of the total South African estimated field crops for 2016. The CEC (2016) further indicates that yellow maize accounts for 52% and is normally used for animal feed while white maize, which is normally used for human consumption, accounts for about 48% of the total maize crop estimated for the 2016/2017 maize production season.

According to Gouse *et al.* (2009), 95% of maize in Africa is produced by developing farmers on less than 10 hectares of land. Grain SA (2011/12) Production Season Report indicates that 90% of maize in South Africa is produced under commercial farming while Gouws *et al*. (2006) maintains that 50% of Southern African maize comes from South Africa. The CEC report (2016) shows that the bulk of the maize is grown in the Free State (which contributes about 40%), Mpumalanga (which contributes about 24%) and North West (which contributes about 14% of maize produced in the country). Gauteng province (where the study was conducted), contributes only 4.5% of the total maize production in the country (CEC Report, 2016). Maize is produced mainly in the following areas of Gauteng: Sedibeng municipality in the Vanberbijlpark Agricltural Hub; City of Tshwane in

Bronkhorspruit; City of Ekurhuleni in Nigel Town; and West Rand in the Randfontein Municipality.

Maize production in South Africa is hampered by a number of factors, including stalk borers. According to Kirsten (2000), the most important maize stalk borers are the *Busseola fusca* and *Chillo partellus* in South Africa.

Table 2.3: List of GM related crops and varieties in South Africa

	Total varieties	GM hybrids (%Total)	Other varieties
White maize	312	103 (33%)	132 Conventional
			24 OPVs
			9 High Lysine OPV
			44 High protein hybrids
Yellow maize	298	153(51%)	131 Conventional
			7 High Lysine OPV
			7 High protein hybrids
Soybean	148	115(77%)	33 Conventional
Cotton	15	15(100%)	

Source: Global Status of Commercialised Biotech/GM Crops 2015 – ISAAA

2.8 Conceptual framework of the study

Like many other African farmers, South African farmers were denied access to modern agriculture before 1994 due to the policies of apartheid. As indicated earlier in this chapter, poor maize yields by African farmers could also be due to research which is profit oriented rather than farmer development. The questionable role played by African institutions of higher learning, (Conway, 2003) that were supposed to be the source of research and knowledge for the benefit of African farmers could also be the reason why farmers' yields are low.

According to Van der Walt (2002), the introduction of biotechnology in South Africa was slow in the early 2000. Due to the quality of Bt maize (Gouse *et al*. 2006), reduction in pesticides usage (Kirsten *et al*. 2000) and the acceptance of the genetically modified products by the market (Van der Walt, 2002), the adoption rate gained momentum as in 2013, 2 300 000 ha of land were planted with genetically modified crops in South Africa (ISAAA, 2013). South African government on other hand introduced policies to strengthen capacities in the field of biotechnology. The National Biotechnology Strategy was introduced in 2001, which led to other policies such as Biotechnology Innovation Center, The Bio- Economy Strategy and GMO Act to help with the process of approval of introduction of genetically modified products.

NRC report in Kenya (2009) noted the growing Bt maize in South Africa compared to other sub-Saharan African countries. The annual Biotechnology Report of South Africa (2009) indicates that South Africa is way advanced in agricultural technology including biotechnology and according to Kirsten *et al*. (2000) this introduction has seen significant positive impact in resource poor regions and then improvements of their livelihood and that of their country's GDP. The assumption is that had South Africa not adopted the use of agricultural biotechnology, the benefits would not be achieved.

The following items were used to conceptualise the study before and after the introduction of Bt maize in South Africa.

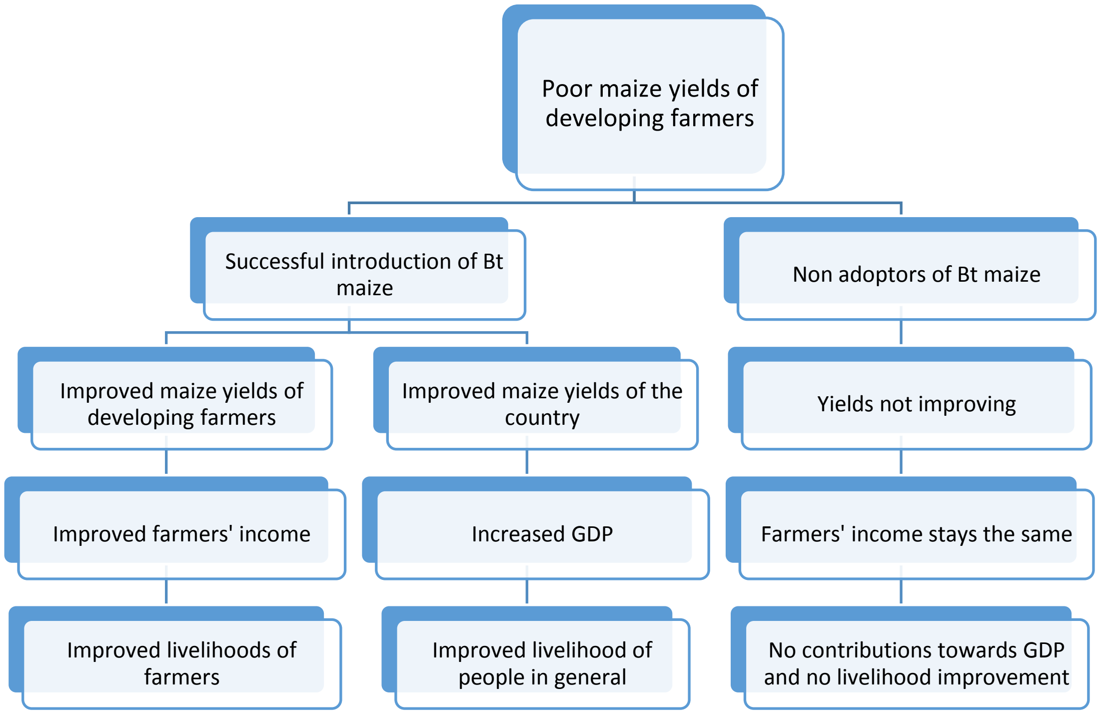


Fig 2.1 Conceptual framework of the study

2.9 Summary of chapter

The literature study revealed that biotechnology is fast growing in developed countries, but its adoption in Africa in slow due to lack of knowledge and political decision-making. Like the Green Revolution, biotechnology may end up not benefiting Africa as it is not people-centred, but profit-driven. African crops such as sorghum, millet and cassava are not given the necessary research attention they deserve as they do not promise the profit return which multinational companies anticipate in research and investment. South Africa is the only country that adopted biotechnology more than a decade before three more countries in Africa started to show some interest. The literature also revealed that South Africa has benefited through the adoption of biotechnology even though critics of biotechnology think otherwise. The following biotechnology crops are on the market in South Africa: White maize; yellow maize; soybean; and cotton. There are several laws in South Africa to monitor and assist in the advancement of biotechnology.

The literature further revealed that African governments ignore funding of institutions of higher learning to develop African products and to assist with African problems; instead, governments leave the role of funding to private companies that end up patenting the outcome of research for their own profits.

It will need a combination of efforts from all sectors of the African society for biotechnology to be beneficial to Africans. More research about bottlenecks in the adoption of biotechnology in Africa are due, in order to help wakeup this so-called ‘sleeping giant’ (Africa), to benefit from the technology.

CHAPTER THREE

3. RESEARCH METHODOLOGY

3.1 INTRODUCTION

This chapter presents the research methods used in conducting the study. The following aspects are discussed in this chapter: the study area; research design; population of the study; sampling method; data collection method; and methods used in analysing the data. The specification and estimation of the Logit Regression Model is also discussed in this chapter.

3.2 STUDY AREA

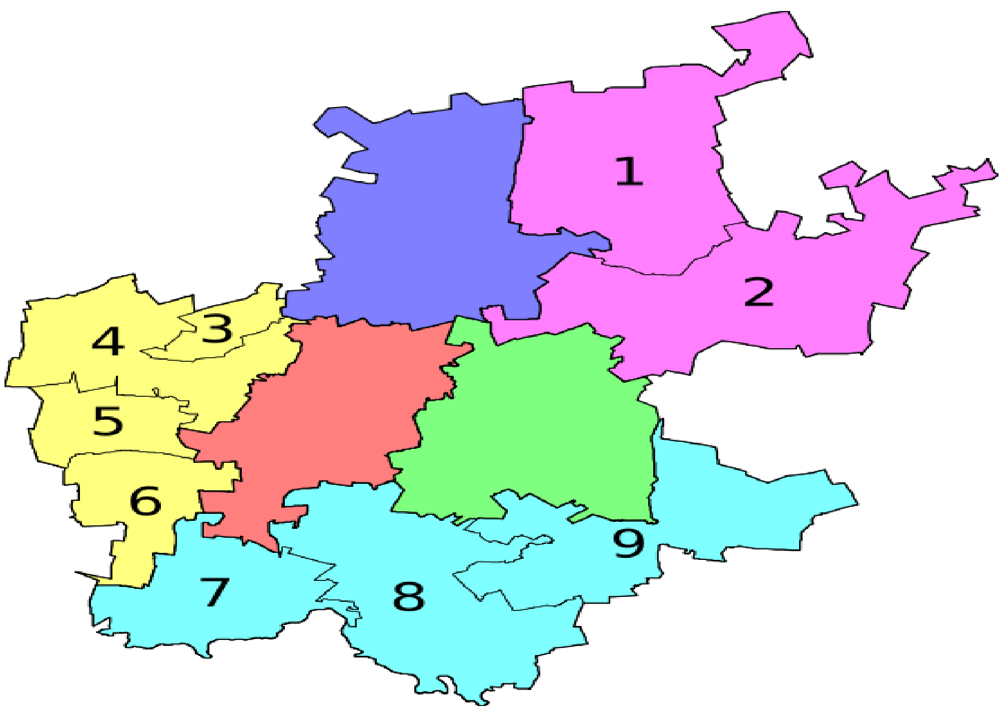
The study was conducted in Gauteng Province, South Africa. According to the Gauteng Municipal Demarcation Board (2009), Gauteng Province was formed as part of the old Transvaal Province of South Africa's first all-race elections held on 27 April 1994. The Province is situated in the Highveld, considered the smallest province in South Africa, accounting for only 1.5% of the land area and hosts the city of Johannesburg (Gauteng Municipal Demarcation Board, 2009).

The study focused solely on developing maize farmers (black maize farmers) in Gauteng Province. This category of farmers constitutes 4% of maize farmers in South Africa (Agricultural Statistics, 2007). The land size used by farmers selected for the study ranges from 0.5 hectares and above.

The study was conducted in maize production municipalities of Gauteng Province as follows: City of Tshwane area 1 on the map, Ekurhuleni area 2 on the map, Sedibeng area 7-9 on the map and West Rand area 3-6 on the map.

Source: Gauteng Municipal Demarcation Board

Figure 3.1: Study area



Source:

Gauteng Municipal Demarcation Board

Figure 3.2: Study area

3.3 RESEARCH DESIGN

The research design used in the study was mainly quantitative. Quantitative research analysis is the numerical representation and manipulation of variables for the purpose of explaining what the particular variables represent (Van der Merwe, 2009). A questionnaire was used to collect data from respondents in different maize farming localities in Gauteng Province. During data collection, farmers were visited and interviewed face-to-face for less than 20 minutes.

3.3.1 Sampling procedure

A list of farmers was compiled from four regional extension offices of the regional department of agriculture in Gauteng Province and all farmers, despite their gender, age, farm size and area of farming, were visited. The population consisted of 200 developing farmers. Out of this number, 121 farmers were selected randomly to constitute the sample size of the study. A large sample size of 121 out of 200 farmers was important in order to obtain reliable results.

3.3.2 Data Collection

Municipalities were approached and authorisation letters obtained from the four municipalities before the commencement of visits. The purpose and procedure of the survey were explained during the visits. Local farmers associations were also informed prior to the visit about the intention of the survey in the area. They were further informed about how they will benefit from the outcome of the survey. The consent form that accompanied the questionnaire was also explained to farmers. The form served as agreement between the surveyors and the farmers. It also indicated the confidentiality of the information provided. Face-to-face interviews were conducted with farmers (main decision-makers within the household). Where the farmer did not understand English, a local language was used to convey the message across to such farmer. It took less than an hour for the questionnaire to be completed. Data was collected only once but the interviewer asked the respondents on the activities between 2011 to 2014 maize production seasons using a questionnaire. Personal observation by the surveyor was carried out in order to verify some of the responses given by farmers. There were no instances where farmers were not interested in the study, thus there were no instances of withdrawals from participants. All information collected was captured and form part of this study.

Table 3.1: Definitions of variables and expected indicators

Variables in the study are as used in Table 3.1	
Yi (Dependent variable)	Farmer adoption decision which will be measured by the value 1, if adopting *Bt* maize and 0, otherwise
Independent variables	
Farm size (X_1)	Farm size measured by ha
Size of household (X_2)	Size of the household measured by numbers
Gender (X_3)	Gender of the farmer: 1 male and 0 female
Age (X_4)	Age of the farmer measured in years
Marital status (X_5)	Marital status of farmer: 1 single, 2 married, 3 divorced, 4 widowed, 5 separated, 6 co-habiting
Education (X_6)	Level of education of farmer: 1 pre-primary, 2 primary, 3 secondary, 4 matric, 5 tertiary
Agricultural education (X_7)	Education related to agriculture: 1 yes and 0 no
Staying on the farm (X_8)	The farmer staying on the farm: 1 yes and 0 no
Have other sources of income (X_9)	The farmer has other sources of income:1 yes and 0 no
Farmers associations (X_{10})	Farmers' affiliation to associations; 1 yes and 0 no
Farming techniques (X_{11})	Type of techniques used: ripping 1, zero tillage 2, Plough 3, Conventional 4, Mulching 5, Combinations 6, Others 7
Maize experience (X_{12})	Years of maize farming experience, measured in years
Bt maize experience (X_{13})	Years of *Bt* maize farming experience, measured in years
Grouped for *Bt* maize (X_{14})	Farmers organised to farm *Bt* maize: 1 yes and 0 no
Farm management (X_{15})	Farm management: 1 individual farmer, 2 family, 3 farmers groups, 4 cooperative, 5 private company
Farm ownership (X_{16})	The ownership of the farm will include the following: 1 Individual farmer, 2 family members, 3 farmer group, 4 Cooperative, 5 Private companies, 6 Trust, 7 Others
Land acquired (X_{17})	How the farmer acquired the land: 1 privately purchased, 2 communal, 3 PTO, 4 renting, 5 own finance, 6 bond, 7 LRAD, 8 PLAS, 9 restitution, 10 inheritance, 11 others
Bt maize Information (X_{18})	Information that farmers received about *Bt* maize: 1 yes and 0 no
Bt maize training (X_{19})	Farmers participate in *Bt* maize training: 1 yes and 0 no
Source of information (X_{20})	Source of information used by farmers: 1 Extension, 2 magazines, 3 Radio, 4 Local newspaper, 5 others

Extension (X_{21})	Contact with extension agent, measured by the frequency of contact or participation at farmers days
Farm neighbour-user (X_{22})	Contact with a neighbour who is also a farmer measured by the frequency of contact talking about maize technology
Input suppliers (X_{23})	Contact with input suppliers measured by frequency of contact, visits or participation at farmers' days
Planting *Bt* incentive(X_{24})	Any incentive that farmers receive for planting *Bt* maize from extensions, neighbours, private companies, relatives measured by 1 yes and 0 no
Bt maize information (X_{25})	The impact of *Bt* maize information on the farmers behaviour towards biotechnology: 1 yes and 0 no
Social position (X_{26})	The impact of social position of the farming community of the farmers towards adoption of *Bt* maize: 1 bad, 2 good and 3 fair
Type of maize (X_{27})	The type of maize farmers and hectares planted after being informed about *Bt* maize between 2011 and 2014 maize production season: 1 *Bt* maize, 2 hybrid maize, 3 OPV, 4 saved seed and 5 none
Knowing *Bt* maize (X_{28})	Knowing *Bt* maize information and the informer during the 2011 to 2014 maize production season: 1 formal extension, 2 other farmers, 3 private companies, 4 relatives, 5 other, 6 none.
Reaction to *Bt* maize (X_{29})	The farmer's reaction after knowing *Bt* maize during the maize production season of 2011 to 2014: 1 planted it and 0 did not plant it
Ha with *Bt* maize (X_{30})	Ha planted with *Bt* maize between 2011 and 2014 maize season measured with by number of ha planted
Satisfaction with *Bt* (X_{31})	The farmers' level of satisfaction with *Bt* maize between the 2011 and 2014 maize production season: very high, average and very low

3.3.3 Data analysis

In analysing the data, the variables that were the most representative of the study were selected, Table 3.1. Existing data comprising of numeric data was used and analysed using descriptive statistics including frequencies and percentages. The data was analysed with the aid of MS Excel and SPSS computer programme.

3.4 POPULATION

The population of the study consisted of developing maize farmers of the four farming regions of Gauteng Province. Some maize farmers in Gauteng Province are beneficiaries of the Government Land Programme and have more than 500 hectares of land while others farm on municipal, Transnet and mine vacant land and plant on less than one hectare of land.

3.4.1 The Logit Regression Model

The univariate logit model was used to analyse factors influencing farmers' adoption of *Bt* maize in their production. The model is based on cumulative logistic probability functions and was applied because of its advantage to predict the probability. This model refers to the probability that the value of a random variable falls within a specified range (Weiers, 2011). Weiers (2011) further highlights the cumulative probabilities model as frequently referring to the probability that a random variable is less than or equal to a specified value as below:

$$P= \frac{e^{li}}{1+e^{li}} \qquad (1)$$

Conceptually, the behavioural model was used to examine factors influencing the adoption of Bt maize technology given by:

$$Y_i = g\ (I_i) \qquad (2)$$

$$I_i = b_o + \bullet\ b_j\ X_{ji} \qquad (3)$$

here Y_i is the observed response for the i^{th} observation (i.e. binary variable, Y_i = 1 for an adopter, Y_i=0 for non-adopter).

Ii is an underlying stimulus index for the i^{th} observation, g is the functional relationship between the field observation (Y_i) and the stimulus index (I_i) which determine the probability of the technology adoption.

I = 1,2,.....,m are observations on variables for the adoption model; m is the sample size; X_{ji} is the j^{th} explanatory variables for the i^{th} observation and j = 1,2,3,...,n; bj is an unknown parameter, j = 0,1,2,.....,n, where n is the total number of explanatory variables.

The logit model assumes that the underlying stimulus index (Ii) is a random variable which predicts the probability of the adoption of technology:

$$P_i = \frac{e^{li}}{1+e^{li}}$$

Therefore, for the i^{th} observation (an individual farmer):

$$I_i = \ln \; Pi/^{1-P_i} = b_o + \sum b_j X_{ji} \qquad (4)$$

The relative effect of each explanatory variable (X_{ji}) on the probability of the adoption of technology is measured by differentiating with respect to X_{ji} i.e

$\frac{\delta Pi}{\delta Xji}$, using the quotient rule

$$\frac{dPi}{dXji} = \left(\frac{eli}{1+eli}\right)\left(\frac{Ii}{Xji}\right) \qquad (5)$$

The definitions and expected effects of the variables used in the study are presented in Table 3.2 here below.

Table 3.2 Variables of the logic regression

No.	Independent variables and their measurements
X_1	Farm size in ha

X_2	Gender: Male=1, Female 0
X_3	Age in years
X_4	Level of education
X_5	Engaged in off-farm employment: Yes=1 No=0
X_6	Regular farm visits of Bt maize suppliers: Yes=1 No=0
X_7	Frequency of extension visits: continuous variable
X_8	Farmer to farmer Bt talk: Yes=1 No=0
X_9	Neighbouring farmer's Bt talk: Yes=1 No=0
X_{10}	Affiliation with farmer organizations: Yes=1 No=0

Yi (Dependent variable): Farmer adoption decision which will be measured by the value 1, if adopting *Bt* maize and 0, otherwise

3.8 SUMMARY OF CHAPTER

The area of the study such as the Province, district municipality concerned as well as socio-economic status of the area were presented in this chapter. The map of Gauteng Province shows the district municipalities where the study was conducted. The map shows the demarcation of the study areas (City of Tshwane, City of Ekurhuleni, Sedibeng and West Rand).

A description of the research design was done in the chapter. A quantitative research approach was used to collect data from200 developing farmers from the 4 district municipalities. Face-to-face interviews were conducted with 121 farmers. Municipalities were contacted and issued authorisation letters to give a green light for the survey to take place. Respondents were visited in their farms after setting an appointment with them through their mobile phones. Data was analysed using descriptive statistics and Logit

Regression Model which was used to analyse factors influencing the adoption of *Bt* maize by farmers.

CHAPTER FOUR

4. RESULTS AND DISCUSSIONS

4.1 INTRODUCTION

This chapter presents the results and discussion on the analysis of data obtained. A presentation of results and discussion of both descriptive statistics and inferential analysis (Logit Regression Model) used to determine factors that influences the adoption of biotechnology by developing farmers of Gauteng Province, South Africa is also done in this chapter. The results are presented in the form of graphs and tables.

4.2 DEMOGRAPHIC AND HOUSEHOLD CHARACTERISTICS OF FARMERS

The following demographic characteristics of respondents who participated in this study are presented in Table 4.1: (i) Size of the farm; (ii) Size of the household; (iii) Gender of the head of the household; (iv) Age of the head of the household; (v) Marital status of the head of the household; (vi) Level of education of the head of the household; (vii) Farming status; (viii) Income status; and (ix) membership of farmer organisations.

Table 4.1 Demographic and household characteristics of farmers

Range	Frequency n=121	Percentage	Adoption Freq*	Adoption %
Size of the farm				
50 Ha and less	42	34.7	2	3.7
51 to 100ha	5	4.1	1	1.8
101 to **200**ha	**19**	**15.7**	**11**	**20.3**
201ha and above	**55**	**45.3**	**40**	**73.9**

Total	**121**		**54**	
Household size				
10 members and less	113	93.3	50	92.5
11 and above	**8**	**6.5**	**4**	**7.3**
Total	**121**		**54**	
Gender of head of household				
Female	24	19.8	10	**18.26**
Male	97	80.2	43	79.6
Total	**121**		**54**	
AGE				
40 years and younger	19	15.7	10	18.5
41 to 60 years old	61	50.41	27	50
61 years and above	41	33.88	15	27.7
Total	**54**		**121**	
Marital status				
Single	20	16.5	7	12.9
Married	82	67.7	39	72.2
Divorced	2	1.6	1	1.8
Widowed	14	11.5	6	11.1
Co-habiting	3	2.5	1	1.8
Total	**121**		**54**	
Level of education				
Pre-school	14	11.6	1	1.8
Primary	32	26.4	10	18.5
Secondary	26	21.5	12	22.2
National Senior Certificate	28	23.1	15	27.7
Tertiary	21	17.4	14	25.9
Total	**121**		**54**	
Agricultural education				
Not related to agriculture	109	90.1	46	85.1
Related to agriculture	12	9.9	7	12.9
Total	**121**		**54**	
Full time farming				
Part time farming	20	16.5	4	7.4
Full time farming	101	83.4	49	90.7
Total	**121**		**54**	
Off farm employment				
Do not have off farm employment	91	75.2	43	79.6
Have off farm employment	30	24.8	11	20.3
Total	**121**		**54**	
Farmer organisation				
Not a member of any farmer organisation	61	50.4	36	66.66
Member of a particular farmer organisation	60	49.6	17	31.4
Total	**121**		**54**	
Name of farmer organisation				
AFASA	41	33.9	27	50
Nafu	3	2.5	3	5.55

Nerpo	4	3.3	1	1.8
AgriSA	1	0.8	1	1.8
Not affiliated to any organisation	60	49.6	16	29.6
Other organisations other than the above	12	9.9	6	11.11
Total	**121**		**54**	

Source: Data from the study. *Farmers who adopted *Bt* maize out of the total number interviewed in the particular category of the variable

(i) Size of the farm

The results revealed that 34.7% of the 121 farmers interviewed have a farm size of 50 hectares or less. Out of this number, 3.7% have been involved in the cultivation of *Bt* maize between 2011 and 2014 maize production seasons. About 15.7% of farmers planted more than 101 ha but below 200 ha; 20.3% adopted *Bt* maize between 2011 and 2014 maize production seasons. Farmers with 200 ha and more represent 45.5% of the 121 farmers interviewed and 33% have adopted *Bt* maize. From the results obtained, it is very likely that farmers who cultivate more hectares of land will tend to adopt or plant *Bt* maize more than those who cultivate on a few hectares of land.

(ii) Size of the households

There were 121 farmers who were interviewed in the course of the study. Some of these farmers work with relatives and family members. The results obtained indicate that 93.3% of farmers have less than 10 family members per household. Out of the 93.3% of farmers with 10 or less family members in the household, 92.5% of these farmers adopted *Bt* maize between 2011 and 2014 production seasons. Farmers with 11 or more family members constituted 6.5% of the total 121 farmers interviewed during the study and 7.3% adopted *Bt* maize during the 2011 to 2014 maize production seasons in Gauteng Province, South Africa.

(iii) Gender of head of the house hold

Gender parity is an issue of concern among developing farmers involved in maize farming in Gauteng Province. Out of the 121 farmers interviewed, 80.2% were males and 19.8% females. It was revealed that 79.6% of males adopted and cultivated *Bt* maize between 2011 and 2014. The high number of male farmers correlates with the findings of Tshilowa (2015) who found that 56% of developing farmers in the Greater Tzaneen Municipality, Limpopo Province were males. Out of the 121 farmers interviewed, a total of 19.8% were female and out of which 18.5% adopted *Bt* maize between 2011 and 2014. Out of the 121 farmers interviewed, 35% males and 8.3% females adopted *Bt* maize in Gauteng Province between 2011 and 2014 maize production seasons. This is contrary to the popular notion that in Africa female farmers are the most dominant sex in farming in Africa (Ishmael, 2002).

(iv) Age of head of the household

With respect to age it was indicated that, 15.7% were below 40 years. 8.26% of farmers within this age group adopted *Bt* maize between 2011 and 2014 maize production seasons. Farmers aged between 41 and 60 years represented 50.4% of the total number of farmers interviewed. 50% of farmers in this age bracket adopted *Bt* maize between 2011 and 2014 maize production seasons. Farmers aged 61 years and above represented 33.88% while 27.7% in this age bracket adopted *Bt* maize between 2011 and 2014 maize production seasons. It was found that Gauteng Province had high number of developing maize farmers aged above 40 who constitute 84.28% and when added, 77.7% of these farmers adopted *Bt* maize between 2011 and 2014 maize production seasons. There is 18.26% of farmers who have adopted *Bt* maize and are below 40. It is very likely that farmers aged 40 years and above will adopt *Bt* maize.

(v) Marital status of farmers

Single farmers constituted 16.5% of the farmers interviewed, while 12.9% of farmers within this age bracket adopted *Bt* maize between 2011 and 2014 maize production seasons. Married farmers represented 67.7% of the 121 farmers interviewed, while 72.2% of farmers within this category adopted *Bt* maize between 2011 and 2014 maize production seasons. Widowed farmers constituted 11.5%, while 11.1% of the widows adopted *Bt* maize. The farmers who are co-habiting constituted 3 or 2.5% and 1.8% of farmers were divorced. Not more than two farmers within this category adopted *Bt* maize between 2011 and 2014 maize production seasons. From the findings, it is likely that farmers who are in a marriage relationship will adopt *Bt* maize.

(vi) Level of education

There was a variation in the level of education of farmers. Eleven percent of the farmers attended school up to pre-school level or had no formal education, 1 farmer (0.8% of farmers) within this category adopted *Bt* maize between 2011 and 2014 maize production seasons. Farmers who attended schools up to primary level represented 26% of the farmers, while 18.5% of this group of farmers adopted *Bt* maize between 2011 and 2014 maize production seasons. Farmers who had secondary school education represented 21.5%. Out of this number, 12 farmers or 22% adopted *Bt* maize between 2011 and 2014 maize production seasons. In this study, 23.1% had the National Senior Certificate. Twelve percent of these farmers adopted *Bt* maize during the 2011 to 2014 maize production season. Farmers with tertiary education represented 17.4%, and out of this number, 25.9% of such farmers adopted *Bt* maize between 2011 and 2014 maize production seasons. Farmers with agricultural-related education represented 9.9% and out of this number, 12.9% of such farmers adopted *Bt* maize during the 2011 to 2014 production season. It was indicated that the higher the level of education of the farmer, the higher the adoption as indicated in Table 3.1 (farmers with secondary and tertiary levels of education are most likely to adopt *Bt* maize, than those with primary and pre-primary levels of education). It was further observed that farmers with tertiary knowledge on agriculture were most likely to adopt *Bt* maize than those with no knowledge on agriculture.

(vii) Farming status of farmers

Approximately 83.4% of the farmers were involved in farming on fulltime basis; 90.7% of this number adopted *Bt* maize between 2011 and 2014 maize production seasons. It was found that 16.5% of farmers practise farming on part time basis; 7.4% of such farmers adopted *Bt* maize between 2011 and 2014 maize production seasons. Full time farmers are likely to adopt *Bt* maize as found in this study.

(viii) Off-farm employment

It was found that, 75.2% of the farmers had no other form of income; 79.6% of such farmers adopted *Bt* maize between 2011 and 2014 maize production seasons. Approximately, 24.8% of farmers had other forms of income; while 20.3% of such farmers adopted *Bt* maize between 2011 and 2014 maize production seasons. It was found that farmers with no other form of income are likely to adopt *Bt* maize.

(ix) Organisational membership

50.4% of farmers are not part of any farmer organisation and **out of this number 66.66% adopted Bt between 2011 and 2014 maize production season**, while 49.6% of farmers belong to a farmer organisation 31.4% of farmers adopted *Bt* maize between 2011 and 2014 production seasons. It was found that farmers who did not belong to any farmer organisation are most likely to adopt *Bt* maize 66.66% than those who belong to farmer organizations (31.4%).

(x) Name of farmer organization

It was further revealed that AFASA is the dominant farmer organisation with 33.9% of farmers compared to other farmer organisations. **50%** of AFASA affiliated farmers adopted *Bt* maize during the 2011 to 2014 maize production season. 6.6% of farmers belong **to other farmer organisations like Nafu, Nerpo and AgriSA and only** 3.3% from the total farmers under organizations adopted *Bt* maize between 2011 and 2014 maize production seasons. It is unlikely that farmer organisation contributes towards the adoption of *Bt* maize. It was found that it is unlikely that affiliation to a farmer organisation will influence farmers to adopt *Bt* maize.

4.3 History of maize farming

The following aspects of the farming history of participants in the study are presented in Figures 4.1 and 4.2: (i) Years of maize farming; (ii) Technology used in farming maize; (iii) History of maize farming per farmer between 2011 and 2014; (iv) History of *Bt* maize farming per farmer between 2011 and 2014; (v) Organised to farm *Bt* maize; (vi) Management of the farm; (vii) Ownership of the farm; and (viii) How the land was acquired.

(i) Years of maize farming

It was revealed in Table 4.2 that during the 2011 to 2014 maize production season, out of the 121 farmers interviewed, 64.4% had been involved in farming for less than 10 years, while 70.3% of such farmers adopted *Bt* maize during this period. Farmers with 10 to 20 years of experience represented 23.1%. Out of this number, 18.5% adopted *Bt* maize during the 2011 and 2014 maize production seasons. Approximately 12.2% of farmers had more than 20 years of experience in maize farming and out of this number, 9.2% adopted *Bt* maize during the 2011 and 2014 maize production seasons. It is unlikely that the number of years involved in maize farming will convince farmers to adopt *Bt* maize.

(ii) Technology used to prepare the land

The combination-cultivation method is used by 47.9% of farmers, where in one year, farmers rip the soil, and the following year, they plough the land as indicated on Table 4.2. Only 5.7% of farmers use ripping of the land as the only method of farming. The traditional method of ploughing is practised by 21.7% of the farmers in this study. Conventional tillage is practised by 17.4% of farmers while ploughing of the land is practised by 21.5% of the farmers. Only 2.5% of the farmers practised zero tillage. The combination method is used by 47.95 of farmers.

(iii) Maize planted between 2011 and 2014

Figure 4.1 shows that in 2011, 76% of the 121 farmers interviewed planted maize while 24% did not plant maize in the same year, 2011 maize production season. The number of farmers who planted maize in 2012 increased from 76% in 2011 to 81.1% in 2012. The percentage increased in 2013 (from 81.1% to 87.6%), an increase of 6%. But in 2014, the number of farmers planting maize decreased from 87.6% to 81.8%

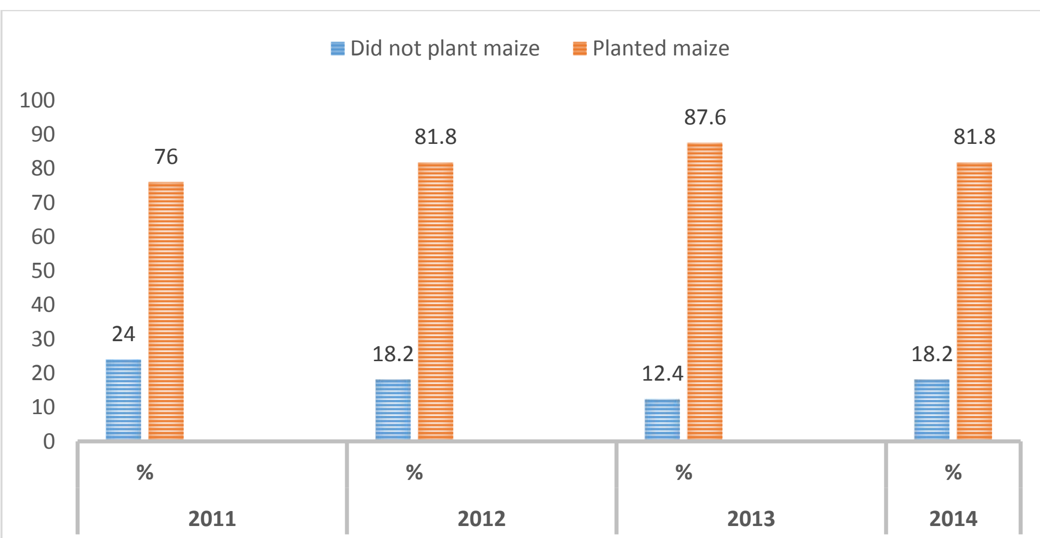


Figure 4.1: History of maize planting (n=121). Source: Data from the study

(iv) *Bt* maize planted during the 2011 and 2014 planting seasons

Of the 76% of farmers involved in maize cultivation in 2011, only 28.1% planted *Bt* maize while 71.9% did not plant *Bt* maize as shown in Figure 4.2. In 2012, the number of *Bt* maize farmers increased from 28.1% to 32.2%. The number of farmers cultivating *Bt* maize increased from 28.1% to 35.5% in 2013. In 2014, out of 81.1% of farmers involved in the cultivation of maize, 33.1% planted *Bt* maize, signifying a 2.4% drop, while the number of farmers not cultivating *Bt* maize increased from 64.5% to 66.9%. The reason for this trend could be market preference or benefits for planting *Bt* maize not being realised as expected.

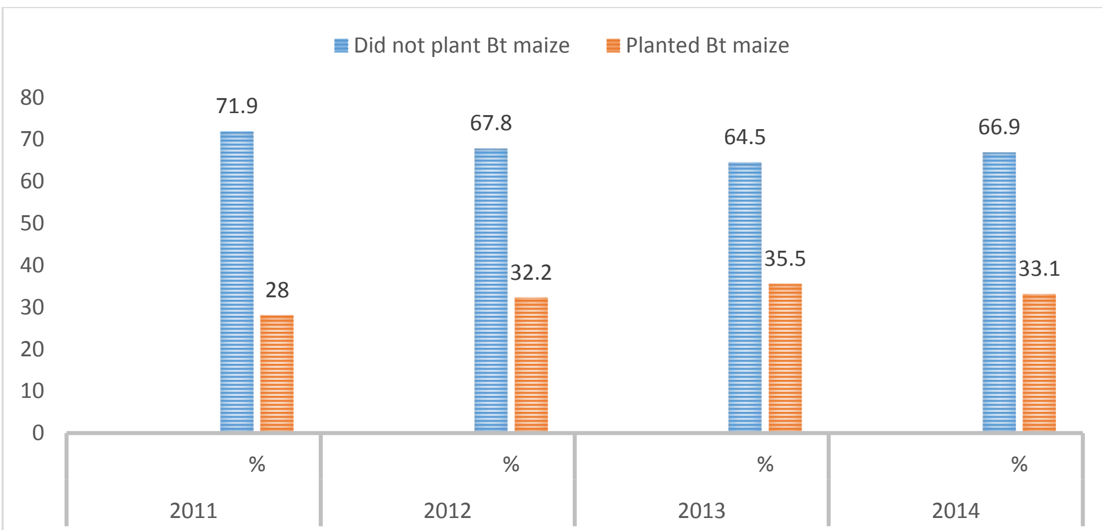


Figure 4.2: History of the cultivation of *Bt* maize (n=121). Source: Data from the study

(v) Organised in groups to cultivate *Bt* maize

The researcher discovered that farmers were not organised into groups to cultivate *Bt* maize during the 2011 and 2014 production season in Gauteng Province.

(vi) Management of the farm

The management structure of the farm showed that 70.2% of the farmers managed their own farms as shown in Table 4.2. Out of this number, 62.9% of such farmers adopted *Bt* maize between 2011 and 2014 production seasons. Approximately 7.4% of farms were managed by families. Out of this number, 9.2% of such farmers adopted *Bt* maize between 2011 and 2014 maize production seasons. Only 0.8% (one farm) of the farmers was managed by a group of farmers, and this group adopted *Bt* maize between 2011 and 2014 production seasons. The South African government developed a strategy to promote cooperative farming over a period of ten years (from 2012 to 2022) (DTI Strategy, 2012). Farmers who practised cooperative farm management constituted 13.2%. Out of this number, 20.3% of such cooperatives adopted *Bt* maize between 2011 and 2014 maize production seasons. It was further revealed 5.8% of farms were managed by private companies did not adopt the cultivation of *Bt* maize between 2011 and 2014 maize production seasons. It could be concluded that farmers who manage their own farms are highly likely to adopt *Bt* maize.

(vii) Farm ownership

The study showed that, 48.8% of the farmers own the farm. Table 4.2 indicates that 55.5% of such farmers adopted *Bt* maize between 2011 and 2014 maize production seasons. Families owned 10.7% of farms, while 12.9% of such farms adopted *Bt* maize during the 2011 to 2014 maize production seasons. 24.8% of farms are owned by groups, while 20.3% of such groups adopted *Bt* maize between 2011 and 2014 maize production seasons. It was discovered that 9.1% of private companies own farms in the study area, 5.5% of such companies adopted *Bt* maize between 2011 and 2014 maize production seasons. Trust ownership of the farms constituted 1.7% of ownership and 3.3% of farms are owned by transnet, mines and municipalities. It could therefore be concluded that farmers who own personal farms are very likely to adopt *Bt* maize as found in this study.

(viii) Acquisition of land

Table 4.2 shows that 3% of farmers acquired land through private purchase; out of this number, 3.7% of such farmers adopted *Bt* maize during the 2011 to 2014 maize production seasons. 9.9% of farmers were granted permission to occupy (PTO) land. Out of this number, 7.4% of such farmers adopted *Bt* maize during the 2011 to 2014 maize production seasons. The bond constitutes 2.47% of the total number of farmers interviewed. Land acquired through LRAD, PLAS and Restitution (which are government land programmes), represent 26.4%, 24% and 1.7% respectively or a total of 52% of the 121 farmers interviewed and 22.2%, 46.29% and 0% adopted Bt maize between 2011 and 2014 maize production season respectively. 16.5% of farmers cultivate land owned by others which include Transnet, mines and municipalities. Out of this number, 7.4% adopted *Bt* maize during the 2011 to 2012 maize production seasons. It is, therefore, concluded that farmers who acquired land through government programmes are very likely to adopt *Bt* maize.

Table 4.2: Farming history (n=121)

Years of maize farming	Freq.	%	Adopt Freq.	Adoption %
10 years of less	78	64.4	38	70.3
11 to 20 years	28	23.1	10	18.5
21 years and above	15	12.2	5	9.2
Technology used				
Ripping	7	5.7		
Zero tillage	3	2.5		
Plough	26	21.5		
Conventional	21	17.4		
Combinations of methods	58	47.9		
Others	6	5		
Groups organised to plant *But*				
Not organised in groups to plant *Bt* maize	121	100		
Management of the farm				
The farmer personally manages the farm	85	70.2	34	62.9
Farm managed by family members	9	7.4	5	9.2
Farm managed by farmers group	1	0.8	1	1.8
Farm managed by cooperatives	16	13.2	11	20.3
Farm managed by private companies	7	5.8	0	0
Farm managed by others	3	2.5	2	3.7
Ownership of the farm				
Individual farmer	59	48.8	30	55.55
Family members	13	10.7	7	12.9
Farmer group	30	24.8	11	20.3
Cooperatives	2	1.7	0	0
Private companies	11	9.1	3	5.55
Trust	2	1.7	1	1.8
Others	4	3.3	0	0
Acquisition of the land				
Private purchase	4	3	2	3.7
Communal land	3	2	1	1.8
Permission to occupy	12	9.9	4	7.4
Renting	5	4.1	1	1.8
Own finance	10	8.3	2	3.7
Bond	4	3	2	3.7
LRAD	32	26.4	12	22.22
PLAS	29	24	25	46.29
Restitution	2	1.7	0	0
Other methods	20	16.5	4	7.4

Source: Data from the study (2016)

4.4 Access to information on *Bt* maize

The following items are presented in the study about access to information on maize technology **referred in Table 4.3**: (i) training on maize technology; (ii) source of information on *Bt* maize; (iii) training on *Bt* maize; (iv) the role of government extension services in terms of information on *Bt* maize; (v) the role of farmer-to-farmer knowledge transfer; (vi) the role of maize seed suppliers in terms of information on *Bt* maize; (vii) the role of farmer's neighbour in terms of information transfer; (viii) the role of visits by extension officers and seed suppliers in influencing the adoption of *Bt* maize; (viii) the impact of *Bt* maize information on the decision of farmers; and (ix) the social position of the community on which the farmer operates.

(i) Information on *Bt* maize

Results showed that, 58.7% did not receive any information about *Bt* maize. Out of this number, 31.4% adopted *Bt* maize in the 2011 to 2014 maize production season seasons. 41.3% of farmers received information about *Bt* maize during the 2011 to 2014 production seasons. Out of this number, 68.5% of such farmers who received information about *Bt* maize, adopted *Bt* maize during the 2011 to 2014 maize production seasons. It is very likely that farmers adopt *Bt* maize because they source some information about *Bt* maize.

(ii) Training on *Bt* maize

In terms of training, only 39.7% of farmers received training on *Bt* maize, 64.8% of this number adopted *Bt* maize during the 2011 to 2014 production seasons. Farmers who did not receive training on *Bt* maize constituted 60.3% and 35.1% of this number adopted *Bt* maize in the 2011 to 2014 maize production seasons. It is very likely that farmers adopt *Bt* maize because they received some training on *Bt* maize.

(iii) Source of information on *Bt* maize

About 68.9% of farmers maintained that the general source of information is through extension services. Out of 68.9% of farmers who regard extension service as one of their source of information, 79.6% adopted *Bt* maize between 2011 and 2014 maize production seasons. Approximately 14.9% of farmers received general information through reading magazines and 9.2% adopted *Bt* maize between 2011 and 2014 maize production season. Table 4.3 shows that

9.9% received information through the radio, 5.8% through the television, while 0.8% received information from local newspapers. It is very likely that government extension system is the main conveyor belt of information on maize and *Bt* maize farming in Gauteng Province.

(iv) The role of extension officers

Formal extension service was accessed by 34.7% of the farmers and out of this number, 64.8% adopted *Bt* maize during the 2011 to 2014 maize production seasons. According to this finding, it is clear that extension service plays a very important role in the adoption of *Bt* maize in Gauteng Province. Out of the 65.3% of farmers who did not receive any farming information from government extension services, 35.1% of them adopted *Bt* maize during the 2011 to 2014 maize production seasons.

It was revealed that 66.9% of farmers knew their government extension officers. Out of this number, 83.3% adopted *Bt* maize between 2011 and 2014 maize production seasons. The study showed that 33.1% of farmers do not know their extension officers. Out of this number, 16.6% adopted *Bt* maize between 2011 and 2014 maize production seasons. Approximately 23.1% of farmers were visited by extension officers once a month and out of this number, 35.1% adopted *Bt* maize during the 2011 to 2014 maize production seasons. It was further found that extension officers visited 24.8% of farmers more than once a month during the 2011 to 2014 maize production seasons. Out of this number, 25.9% adopted *Bt* maize. Out of the 12.4% of farmers visited once a year by extension officers, 14.8% adopted *Bt* maize during the 2011 to 2014 maize production seasons. It was also revealed that 38.8% of farmers were not visited by government extension officers during the 2011 to 2014 production seasons. However, 9.9% of farmers not visited 22.2% adopted *Bt* maize. It is very likely that farmers who know their extension officer and get regular visits from such will adopt *Bt* maize.

(v) Farmer-to-farmer information sharing

Approximately 40.5% of farmers communicated by sharing information from farmer-to-farmer and out of this number, 83.33% adopted *Bt* maize during the 2011 to 2014 maize production seasons. It was found that 59.9% of farmers did not talk to other farmers about *Bt* maize. Out of this number, 16.6% of farmers adopted *Bt* maize in the 2011 to 2014 maize production seasons.

During the 2011 to 2014 production seasons, 24% of the farmers always talk about *Bt* maize with other farmers and 48.1% farmers adopted *Bt* maize. The study showed 13.2% of farmers often talk to other farmers about *Bt* maize and out of this number, 25.9% adopted *Bt* maize during the 2011 to 2014 maize production seasons. 8.3% of farmers almost always talk about *Bt* maize with other farmers and 9.2% of such farmers adopted *Bt* maize during the 2011 to 2014 maize production season. Farmers who always talk with other farmers about *Bt* maize are very likely to adopt *Bt* maize.

(vi) The role of seed suppliers

The study showed that 45.5% of farmers did not know their seed suppliers. Out of this number, 9.25% adopted *Bt* maize during the 2011 to 2014 maize production seasons. 54.54% of farmers know their seed suppliers out of this number, 90.7% adopted *Bt* maize during the 2011 to 2014 maize production seasons. Maize suppliers visited 20.7% of farmers once a month during the 2011 to 2014 production seasons and out of this number, 40.7% adopted *Bt* maize. 9.1% of farmers were visited by seed suppliers more than once a month, and out of this number, 14.8% adopted *Bt* maize. 19.8% of farmers were visited once a year and 33.3% of such farmers adopted *Bt* maize during the 2011 to 2014 production seasons. 49.6% of the 121 farmers interviewed were never visited by seed suppliers during the 2011 to 2014 maize production seasons. However, only 9.2% adopted *Bt* maize. It is concluded that seed suppliers are highly likely to influence farmers to adopt *Bt* maize.

(vii) The role of neighbours

Approximately 39.7% of farmers maintained that their neighbours are not farmers and out of this number, 11.11% adopted *Bt* maize during the 2011 to 2014 maize production seasons. Farmers that indicated that their neighbours are also maize farmers, constituted 60.3% and out of this number, 88.88% adopted *Bt* maize during the 2011 to 2014 maize production seasons. Farmers who practised neighbour perusal or over the fence talking about *Bt* maize constituted 19.8%. Out of this number, 40.7% adopted *Bt* maize during the 2011 to 2014 maize production seasons. The study showed that 13.2% of farmers often talk about *Bt* maize and out of this number, 25.9% adopted *Bt* maize during the 2011 to 2014 maize production seasons. Approximately 59.5% of farmers do not talk about *Bt* maize and out of this number, 16.6% adopted *Bt* maize during the 2011 to 2014 maize production seasons. Table 4.3 indicate that 40.5% of the farmer talk about Bt maize with other farmers and out of this number 83.33% adopted But maize between 2011 and 2014 maize production season. Therefore, maize farmers whose neighbours are also maize farmers are highly likely to adopt *Bt* maize.

(viii) Incentives for planting *Bt* maize

It was revealed that there were no incentives whatsoever to persuade farmers to plant *Bt* maize from formal extension personnel, neighbours, *Bt* maize seed suppliers, relatives, any other person and any other source during the 2011 to 2014 maize production seasons. It is highly unlikely that incentives could persuade farmers to adopt *Bt* maize.

(ix) The impact of *Bt* information on a farmer's behaviour

Fifty seven percent of farmers maintained that *Bt* information had no impact on their behaviour towards *Bt* maize while 43% demonstrated that *Bt* maize information had an impact on their behaviour towards *Bt* maize. It is highly likely that *Bt* maize information will have an impact on farmers adopting *Bt* maize. Of the 121 farmers interviewed, 54 farmers adopted *Bt* maize during the 2011 to 2014 maize production seasons.

(x) The social position of farmers

The study showed that 64.5% of the farmers cultivate on community land and have good social positions. Out of this number, 23.9% adopted *Bt* maize during the 2011 to 2014 maize production season. Nineteen percent of farmers have a fair social position and all adopted *Bt* maize. Approximately 33.3% have a bad social position and out of this number, 0.8% adopted *Bt* maize during the 2011 to 2014 maize production seasons. A good social position could highly likely have an influence on the farmer's adoption of *Bt* maize.

Table 4.3: Access to technological information (n=121)

Any *Bt* information obtained by farmer	**Freq.**	**%age**	**Adopt Freq.**	**%**
Never received any information about *But*	71	58.7	17	31.4
Received information about *But*	50	41.3	37	68.5
Any *Bt* training received by farmers				
Never trained about planting *Bt* maize	73	60.3	19	35.1
Received training about planting *Bt* maize	48	39.7	35	64.8
Source of general information				

Government extension services	83	68.9	43	79.6
Magazines	18	14.9	5	9.2
Radio	12	9.9	0	0
Television	7	5.8	4	7.4
Local newspapers	1	0.8	1	1.8
Any extension service received on *Bt*				
Do not receive extension service on *Bt*	79	65.3	18	35.1
Receive extension service on *But*	42	34.7	35	64.8
Know your Extension Officer				
Do not know Government Extension Officer	40	33.1	9	16.6
Know government extension officer	81	66.9	45	83.33
Talk to other farmers about *But*				
Do not talk to other farmers about *But*	72	59.5	9	16.6
Talk to other farmers about *But*	49	40.5	45	83.33
Know your maize seed supplier				
Do not know maize seed supplier	55	45.5	5	9.25
Know maize seed supplier	66	54.5	49	90.7
Is the neighbour a maize farmer?				
Neighbour is not a farmer	48	39.7	6	11.11
Neighbour is a farmer	73	60.3	48	88.88
Any other source of extension				
No other source of extension	121	100		
Frequency of visit of extension officer				
Extension officer visits once a month	28	23.1	19	35.1
Extension officer visits more than once a month	30	24.8	14	25.9
Extension officer visits once a year	15	12.4	8	14.8
Extension officer does not visit	47	38.8	12	22.22
Others	1	0.8	0	0
Frequency of farmer-to-farmer *Bt* talk				
Always talk to other farmers about *Bt* maize	29	24	26	48.1
Often talk with other farmers about *Bt* maize	16	13.2	14	25.9
Almost always talk with other farmers about *Bt* maize	10	8.3	5	9.2
Do not talk about *Bt* maize with other farmers	66	54.5	9	16.6
Frequency of visits of maize supplier				
Maize supplier visits the farm once a month	25	20.7	22	40.7
Maize supplier visits the farm more than once a month	11	9.1	8	14.8
Maize supplier visits the farm once a year	24	19.8	18	33.33
Maize supplier does not visit	60	49.6	5	9.2
Others	1	0.6	1	1.8
Frequency of visits by neighbours to talk about BT				
Always talk with neighbour about *Bt* maize	24	19.8	22	40.7
Often talk with neighbour about *Bt* maize	16	13.2	14	25.9
Regularly talk with neighbour about *Bt* maize	2	1.7	2	3.7
Almost always talk with neighbour about *Bt* maize	7	5.8	4	7.4
Do not talk with neighbour about *Bt* maize	72	59.5	11	20.3
Impact of information				
Bt information has no impact towards *Bt* maize	69	57	7	12.9
Bt information has impact towards *Bt* maize	52	43	47	87
Social position of farmers				
Bad	4	3.3	1	1.8
Good	78	64.5	29	53.7
Fair	39	32.2	24	44.4

Source: Data from the study

4.5 Farmers' perspective on *Bt* maize (n=121)

The following perspective of maize technology items are presented in this study: (i) The type of maize planted after the farmer was informed about *Bt* maize; and (ii) number of hectares under *Bt* maize cultivation.

(i) Type of maize planted after the farmer was informed about *Bt* maize

Out of the seventy three percent of farmers who planted maize in 2011, 28% planted *Bt* maize, 11.5% planted hybrid maize, 21% planted OPV, 14% planted saved seeds while 19% planted other crops.

In 2012, 81.85% of farmers planted maize, 32.2% planted *Bt* maize, 9.1% planted hybrid seeds, 18.2% planted OPV, 11% planted saved seeds while 19% planted other crops.

In 2013, 87.6% planted maize, 35.5% planted *Bt* maize, 9.9% planted hybrid maize, 19.9% planted OPV, 19.8% planted home saved seeds while 14.8% planted other crops.

In 2014, 81.2% planted maize, 33.1% planted *Bt* maize, 9.15 planted hybrid maize, 19.7% planted OPVs, 10.7% planted saved seeds while 15.7% planted other crops.

(ii) Hectares under *Bt* maize cultivation

It was found that in 2011, 53.7% of land under *Bt* maize cultivation was done on less than 50 hectares, 20.3% of land under *Bt* maize cultivation was done on more than 50 hectares, 25.8% of land under *Bt* maize cultivation was done on more than 100 hectares. In 2012, 50% of land under *Bt* maize cultivation was done on less than 50 hectares, in 2013, 48% of land under *Bt* maize cultivation was done on less than 50 hectares and in 2014, only 40.7% of land under *Bt* maize cultivation in Gauteng Province was below 50 hectares. The number of hectares above 100 hectares under *Bt* maize cultivation improved from 25.8% in 2011 to 31.3% in 2012, 38.7% in 2013 and 40.1% in 2014. Farmers who owned 50 hectares or below are highly likely to adopt *Bt* maize cultivation.

Table 4.4: Perspective on *Bt* maize (n=121)

Type of maize planted	**2011**		**2012**		**2013**		**2014**	
	Freq.	%	Freq.	%	Freq.	%	Freq.	%
Bt Maize	34	28	39	32.2	43	35.5	39	33.1
Hybrid maize	14	11.5	11	9.1	12	9.9	11	9.1
OPV	26	21.4	22	18.2	24	19.8	23	19
Saved seeds	18	14.8	14	11.5	14	11.5	13	10.7
Other crops	23	19	24	19.8	18	14.8	19	15.7
Nothing planted	7	5.8	11	9.1	10	8.3	16	13.2
Reaction to *Bt* maize								
Not planted it	87	71.9	82	67.8	78	64.5	81	66.9
Planted it	34	28	39	32.2	43	35.5	39	33.1
***Bt* maize ha arrangement**								
50 hectares and less	29	53.7	27	50	26	48	22	40.7
51 t0 100 hectares	11	20.3	10	18.5	7	12.9	10	18.5
101 to 150 hectares	4	7.4	5	9.2	7	12.9	6	11
151 to 200 hectares	5	9.2	7	12.9	6	11	8	14.8
201 hectares and above	5	9.2	5	9.2	8	14.8	8	14.8

Source: data from the study

4.6 Perspective on *Bt* maize adopters (n=54).

The following perspective on maize technology items are presented in Table 4.5: (i) farmers' reaction after learning about *Bt* maize; (ii) the reason for planting *Bt* maize; (iii) difference noticed by farmers after planting Bt maize for the first time; (iv) reverting to non-*Bt* maize after planting *Bt* maize; (v) yield obtained; (vi) satisfaction with yield; and (vii) machinery purchased after harvesting *Bt* maize.

(i) Farmers' reaction after learning about *Bt* maize (n=54)

Developing farmers in Gauteng Province are satisfied with *Bt* maize as shown by the findings of this study. Table 4.5 indicates that in 2011, 55.56% of the 54 farmers who planted *Bt* maize are very satisfied with *Bt* maize. The percentage increased over the years. In 2012, 59.3% of the 54 farmers planting *Bt* maize were highly satisfied with *Bt* maize, in 2013, 63% of the 54 farmers were very satisfied with *Bt* maize and in 2014, 64.8% of the 54 farmers who planted *Bt* maize were highly satisfied with *Bt* maize. From 2011 to 2014, the level of satisfaction with *Bt* maize by developing maize farmers in Gauteng Province who have adopted *Bt* maize were very high (60.6%). It is highly likely that farmers will continue adopting *Bt* maize as long as they are satisfied with *Bt* maize.

Table 4. 5: Perspective of adopters on *Bt* maize (n=54)

	2011		2012		2013		2014	
	Freq.	**%**	**Freq.**	**%**	**Freq.**	**%**	**Freq.**	**%**
Farmer's level of satisfaction with *Bt* maize								
Very high	30	55.56	32	59.3	34	63	35	64.8
Average	15	27.7	17	31.5	16	39.6	17	31.5
Very low	9	16.7	5	5	4	7.4	2	3.7
Reasons for planting *Bt* maize								
Less spraying	10	18.5	12	22.2	14	25.9	15	27.8
High yields	31	57.4	29	53.7	27	50	28	51.9
Less work in terms of weed control	2	3.7	3	5.6	2	3.7	2	3.7
Less expenses incurred	6	11.1	5	9.3	6	11.1	5	9.3
Combined reasons	5	9.3	5	9.3	4	7.4	4	7.4
Differences noticed on *Bt*								
No	15	27.7	12	22.2	11	20.3	11	20.3
Yes	39	72.2	42	77.8	43	79.6	43	79.6
Revert back to non-*Bt* maize								
NO	53	98.1	50	92.6	51	94.1	50	92.6
YES	1	1.9	4	7.4	3	5.5	4	7.4
Yield obtained with *Bt* maize								
High	19	35.1	22	40.7	33	61	32	59.3
Average	15	15	17	31.5	12	22.2	8	14.8
Low	2	3.7	1	1.9	0	0	2	3.7

No difference	18	33.3	13	24.1	9	16.7	12	22.2
***Bt* yield satisfaction after harvesting**								
High	29	53.7	34	63	36	66.6	35	64.8
Average	13	24	13	24.1	12	22.2	11	20.3
Low	0	0	0	0	0	0	0	0
No difference	12	22.2	7	13	6	11.1	0	11.1
Machinery bought after harvesting *Bt* maize								
Tractors	4	7.4	0	0	3	5.6	0	0
Trucks	0	0	1	1.9	2	3.7	2	3.7
Harvester	0	0	0	0	3	5.6	1	1.9
Boom sprayers	2	3.7	0	0	0	0	1	1.9
Planters	0	0	0	0	2	3.7	2	3.7
Ploughs	0	0	1	1.9	0	0	1	1.9
Disc	1	1.9	0	0	0	0	1	1.9
Purchased other things on the farm	10	18.5	13	24.1	11	20.4	11	20.4
None	37	68.8	39	72	33	61.1	35	64.6

Source: Data from the study

(ii) Reasons for planting *Bt* maize

The results in Table 4.5 show several reasons why farmers planted *Bt* maize between 2011 and 2014 maize production seasons. Less spraying to control stalk borers is one of the reasons for adopting *Bt* maize. There are 18.5% of farmers who indicated less spraying as their reason for adopting *Bt* maize in 2011; 22.2% of farmers mentioned less spraying as the reason for planting *Bt* maize in 2012 while 25.9% and 27.8% of farmers mentioned less spraying as the reason for planting *Bt* maize in 2013 and 2014. On average, 23.6% cited stalk borer control as one of the reasons why developing maize farmers in Gauteng Province adopted or planted *Bt* maize. It is highly likely that developing farmers adopt *Bt* maize to control stalk borers.

High yield was the main reason why farmers opted for *Bt* maize between 2011 and 2014 maize production seasons. Table 4.5 shows that in 2011, 57.4% of the 54 farmers who planted *Bt* maize did so because of high yields. In 2012, 53.7% of the 54 farmers who planted *Bt* maize did so because of high yields, in 2013 and 2014, 50% and 51.9% respectively adopted *Bt* maize because of high yields.

On average, only 4% of farmers planted *Bt* maize to control weeds. Between 2011 and 2014, 10.2% of farmers planted *Bt* maize and maintained that even though *Bt* maize seeds are, in the long run, the benefits outweigh the price.

It is, therefore, concluded that it is highly likely that high yield is the main reason for the adoption of Bt maize by developing farmers.

(iii) Differences noticed by farmers after planting *Bt* maize

Farmers noticed some differences on their crops when planting *Bt* maize. In 2011, 72.2% of the farmers who planted *Bt* maize, indicated they noticed differences when planting *Bt* maize. In 2012, 77.8% of farmers noticed the difference when planting *Bt* maize. In 2013 and 2014, the percentage of farmers who noticed differences when planting *Bt* maize increased from 77.8% to 79.6% of the farmers who planted *Bt* maize for both years. It is highly likely that farmers adopted *Bt* maize because they could notice some differences.

(iv) Farmers reverting to non-*Bt* maize after planting *Bt* maize

It was revealed that in 2011, 98.1% of the farmers who adopted Bt maize, did not revert to non-*Bt* maize. In 2012, 92.6% of the 54 farmers who planted *Bt* maize did not revert to non-*Bt* maize. In 2013, 94.1% of the 54 farmers who adopted Bt maize did not revert to non-*Bt* maize and in 2014, 92.6% of the 54 farmers who adopted *Bt* maize did not revert to non-*Bt* maize. Farmers who reverted to non-*Bt* maize maintained that they did so producing under certain market contracts that do not need genetically modified traces in their products. Farmers maintained that they were paid slightly more than the normal maize price at the time of the contract. It is, therefore, concluded that it is highly unlikely for farmers to revert to non-*Bt* maize after planting *Bt* maize.

(v) Yields obtained after harvesting *Bt* maize

It was observed that the main reason why developing maize farmers in Gauteng adopted *Bt* maize was because of high yields. The researcher was unable to determine the actual yields obtained by farmers during the 2011 to 2014 maize production seasons. However, the researcher was able to capture what farmers indicated in terms of high, average, low or no difference in yields. In 2011 maize production season, 35.1% of the 54 farmers cultivating Bt maize indicated that they obtained high yields and 24% of the 54 farmers who planted *Bt* maize in 2012, mentioned that they obtained average yields. The farmers who maintained that they did not notice any difference between *Bt* maize yields and what they were planting previously constituted 33.3%. In 2012, 40.7% of the 54 farmers who planted *Bt* maize maintained they obtained high yields on *Bt* maize, 17 or 31.5% of the 54 farmers who planted *Bt* maize indicated the yield was average in 2012 and 24.1% of the 54 farmers who planted *Bt* maize in the 2012 maize production season maintained there was no difference in yield with the previous maize crop. In 2013, 61% of the 54 farmers who planted *Bt* maize indicated that the yield was high, 22.2% maintained that the yield was average and 9 or 16.7% of the 54 farmers who planted *Bt* maize in 2013 indicated that there was no difference in yields. In 2014, 59.3% of the 54 farmers who planted *Bt* maize indicated that the yield was high, 14.8% indicated the yield was average and 22% maintained that there was no difference with the previous crop.

(vi) Satisfaction with yields

In 2011, 53.7% of the 54 farmers who planted *Bt* maize indicated that they were highly satisfied with *Bt* maize yields and 24% indicated their satisfaction with *Bt* maize was averaged. 22% of the 54 farmers who planted *Bt* maize indicated no difference observed with their yields. For the 2012 production season, 63% of the 54 farmers indicated they were highly satisfied with *Bt* yields while 24.1% indicated their level of satisfaction was average. 13% of the 54 farmers who planted *Bt* maize in 2012 indicated there was no difference observed with yields obtained from planting *Bt* maize. For the 2013 production season, 66.6% of the 54 farmers who planted *Bt* maize indicated that they were highly satisfied with *Bt* yields while 22.2% indicated they were fairly satisfied with *Bt* maize. There are 11% of farmers who maintained there was no difference in terms of satisfaction with Bt maize. In 2014 maize production season, 64.8% of the 54 farmers who planted *Bt* maize indicated they were highly satisfied with *Bt* maize. 20.3% of the 54 famers who adopted *Bt* maize indicated they were fairly satisfied with the level of *Bt* maize. It is highly likely that farmers are satisfied with *Bt* maize as indicated in Table 4.5. It is highly likely that farmers will adopt *Bt* maize provided *Bt* maize yields keep them satisfied.

(vii) Machinery obtained or purchased after harvesting *Bt* maize

With the yields obtained from 2011 to 2014 maize production seasons, machinery was purchased in order to improve farming. In 2011, 7.4% of the 54 farmers who planted *Bt* maize managed to buy tractors, while 3.7% purchased boom sprayers, 18.5% paid for other necessities on the farm such as electricity and to maintain debts. In 2011, 68.5% of the 54 farmers who planted *Bt* maize purchased nothing. In 2012, 24.1% of the 54 farmers who planted *Bt* maize paid for other things on the farm, including electricity and to service other debts while 72% paid nothing or cannot recall what they did with the money after harvesting *Bt* maize. In 2013, 5.6% of farmers who planted *Bt* maize purchased tractors while 3.7% of the 54 farmers who planted *Bt* maize purchased trucks. 3 or of the 54 farmers who planted *Bt* maize in the 2013 maize production season purchased combined harvesters. Only 3.7% of farmers purchased planters in 2013 maize production season after harvesting and 20.4% of the 54 farmers who planted *Bt* maize in 2013 paid for other things on the farm and 61% of farmers paid or purchased nothing out of the yields obtained. In 2014, farmers purchased several things, 3.7% purchased 1 harvester, boom sprayers, ploughs, discs and 2 trucks while 11 or 20.4% paid for other items on the farms. After harvesting, 64.6% paid nothing or purchased no implements on the farm in 2014 maize production season. It is highly likely that farmers who adopted *Bt* maize managed to buy several implements such as tractors, planters and boom sprayers. The 20.4% of farmers who used their income to maintain the running of the farm by paying debts and other farming essentials are considered of great importance in the study.

4.7 Results of Logit Model Analysis

The Logit estimates for the effects of socio-economic factors on the probability of developing farmers adopting *Bt* maize are presented in Table 4.6. The convergence information of the iterations indicates that an optimal solution was found. The Chi-square tests/Pearson Goodness-of-fit Test was 268.400 and significant ($p<0.000$). The results of the analysis of the Logit model had 10 coefficients which were statistically significant at 5% level. The statistically significant coefficient estimates of the respective variables of the Logit model are discussed below.

4.7.1 Farm size

The co-efficient associated with farm size is positive (0.006) and statistically significant ($p<0.01$) as shown in Table 4.6 during the 2011 maize production season. The trend continued, 0.005 – $p<0.000$, 0.006 –$p<0.002$, 0.004-$p<0.024$ for 2012, 2013 and 2014 respectively, indicating that the higher the number of hectares cultivated by a farmer, the higher the adoption. Farmers who cultivate large portions of land are commercially oriented, more experienced and tend to need more innovative ways for higher returns on their investment than farmers who cultivate on small portions of land. In a study conducted in a German district, Consmüller *et al*. (2009) found that the higher the farm size, the more the *Bt* crop benefits. The findings by Consmüller *et al.* (2009) correlate with the study conducted in the Philippine by Mutuc *et al*. (2012) who found that farmers with lower propensity to adopt *Bt* crops are usually those with small farm sizes compared to farmers with larger farm sizes within the same farming community. This attests to the findings of this study, that farmers with small farm size in Gauteng province have low propensity to adapt to *Bt* maize than those with large farm sizes.

4.7.2 Gender

The results in Table 4.6 indicate that the estimated co-efficient associated with gender is positive (5.450) and statistically significant ($p<0.05$) for 2011 and positive (1.476) and statistically significant ($p<0.05$) for 2012 maize production season. This is an indication that male farmers in Gauteng Province adopted *Bt* maize more than their female counterparts. This is contrary to the results obtained in this study. In a study entitled, ”Less drudgery for her, more maize for him? Evidence from small-maize farmers in South Africa (2016)”, Gouse *et al*. (2009) maintain that female farmers adopt *Bt* maize because of less work during production while their male counterparts focus on yields in order to adopt. Farmers who adopted *Bt* maize in this study are semi-commercial farmers, hence yield was the determining factor.

4.7.3 Age of farmer

Table 4.6 shows that the co-efficient associated with age of farmer is positive (0.123) and statistically significant ($p<0.05$) only in the 2011 maize production season. This is an indication that increases in the age of farmers translates in an increase in the adoption of *Bt* maize technology, all other factors held constant.

4.7.4 Level of education

The coefficient associated with level of education of the farmer is positive (1.445) and statistically significant ($p<0.01$), an indication that farmers’ level of education contribute towards innovative means of farming and survival as indicated in Table 4.6.In a study conducted in the Philippines, Sergio (2012) found that high number of farmers adopting

Bt maize have secondary and post-secondary education compared to non-adopters and these findings by Sergio (2012) correlates with the results obtained in this study.

4.7.5 Engaging in off farm employment

Some of the farmers interviewed in this study have other forms of income. The estimated co-efficient associated with off-farm employment in Table 4.6 indicates positive (8.889) and statistically significant ($p<0.01$) results for the 2011 maize production season. The estimated co-efficient associated with this parameter is also positive (8.443) and statistically significant ($p<005$) for the 2014 maize production season. Farmers with extra employment tend to adopt more than those without extra means of income. This could be due to the fact that *Bt* maize is considered slightly more expensive and beneficial only to multinational companies (Dias, 2012), and that farmers need to have an extra income to fund this expensive technology. However, information Manual on Biotechnology (2014) maintains that although GMO seeds might appear expensive at the purchasing stage, increase in yields and the reduction in spraying costs outweigh the increase in seed costs. In a study conducted in the Philippines, Miladis (2014) found that growing *Bt* maize has significant positive impact on return on investment.

4.7.6 Regular farm visits of *Bt* maize suppliers

The Logit coefficient estimate associated with regular farm visits of *Bt* maize suppliers contributing to adoption is negative (-2.164) and statistically significant ($p<0.10$). This is an indication that maize supplier did not have a significant effect to the adoption of biotechnology by farmers during the 2011 maize production season with other factors held constant.

4.7.7 Frequency of extension visits

The results of the analysis in Table 4.6 show that the estimate associated with frequency of visits by government extension officers is positive (2.380) and statistically significant ($p<0.01$) from 2011 to 2014. This is an indication that to some extent, developing farmers still rely on extension officers for information, including adoption of new and innovative techniques. This could be due to the dedication of extension officers to their work and or knowledgeable to convey the message successfully to farmers. No data was collected with regard to the qualification of extension officers in order to draw conclusions about the extent of the influence of the knowledge of extension officers on *Bt* maize technology and the extent of the success in transferring the knowledge to farmers when they pay visits to farmers.

4.7.8 Farmer-to-farmer talk about *Bt* maize technology

The estimates associated with farmers talking with other farmers about *Bt* maize is negative for the 2011 maize production season (-5.298) and statistically significant ($p<0.01$). This is an indication that developing farmers at some point, talk to one another about anything associated with their farming activities wherever they meet (during farmers-days or meetings). During such meetings, farmer-to-farmer *Bt* talk did not contribute towards *Bt* maize technology planting in 2011 to 2014 maize production seasons among farmers in the study area. This could be due to the fact that farmers are not innovative enough to become early adopters and may also hold some doubts for just hearing about the effect of a technology without seeing it physically. The other reason could be that the source of *Bt* information during the meeting is not a reliable farmer to convince other farmers about new innovation. The source of the information could also contribute towards influencing farmers, either positively or negatively (in this study), the influence was likely negative.

4.7.9 Neighbour being a Bt maize farmer

The results of the analysis associated with the farmer's neighbour being a *Bt* maize farmer is positive (1.454) and statistically significant ($p<0.05$). This is an indication that if a farmer's neighbour is a *Bt* maize farmer, it could influence the adoption of *Bt* maize. The reason for this variable contributing towards adoption could be attributed to the notion that 'seeing is believing'. The farmer could see the performance of a neighbour's *Bt* maize farm over the fence and decide to adopt.

4.7.10 Affiliation with farmer organisations

The co-efficient associated with affiliation with farmer organisations is negative (-11.610) and statistically significant ($p<0.01$). This is an indication that farmer organisation did not significantly influence farmers' adoption of *Bt* maize in the study area. Farmers who are affiliated to a certain farmer organisations may adopt based on the position of the mother organisation on the technology under consideration. No data was collected on the extent of knowledge of farmer organisation on *Bt* maize in order to draw conclusions about its contribution towards *Bt* maize adoption.

Table 4.6: Result of Logit Model Analysis for 2011 to 2014 maize production seasons for the effects of socio-economic factors on the probability of developing farmers adopting *Bt* maize

	2011				2012				2013				2014			
Parameter	Estimate	Std. Error	Z	Sig.	Estimate	Std. Error	Z	Sig.	Estimate	Std. Error	Z	Sig.	Estimate	Std. Error	Z	Sig.
Farm Size	.006	.001	4.079	.000	.005	.001	4.564	.000	.006	.002	3.027	.002	.004	.002	2.258	.024
Gender	5.450	1.591	3.425	.001	1.476	.672	2.198	.028	-1.396	2.362	-.591	.555	.705	1.627	.433	.665
Age	.123	.046	2.697	.007	-.035	.029	-1.225	.220	-.042	.055	-.766	.444	-.090	.069	-1.307	.191
Level of education	.472	.366	1.292	.196	.568	.363	1.562	.118	1.445	.596	2.422	.015	-.208	.904	-.230	.818
Engaged in off farm employment	8.889	2.152	4.131	.000	7.343	1.764	4.162	.000	8.768	2.338	3.750	.000	8.443	2.838	2.975	.003
Regular farm visits of *Bt* maize suppliers	-2.164	.942	-2.298	.022	-1.184	1.675	-.707	.480	2.402	1.684	1.426	.154	-2.176	2.970	-.733	.464
Frequency of extension visits	2.380	.559	4.256	.000	2.131	.493	4.320	.000	2.569	1.024	2.509	.012	1.326	.710	1.867	.062
Farmer-to-farmer *Bt* talk	-5.298	1.196	-4.431	.000	-.967	.243	-3.985	.000	-3.313	1.176	-2.816	.005	-3.702	1.938	-1.910	.056
Neighbouring farmers *Bt* talk	1.454	.425	3.422	.001	-2.559	.726	-3.523	.000	1.467	1.012	1.450	.147	.144	1.216	.119	.906
Affiliation with farmer organisations	-11.610	3.003	-3.866	.000	-10.252	2.290	-4.477	.000	-7.404	2.112	-3.506	.000	-6.481	1.989	-3.259	.001
Intercept	-19.576	4.946	-3.958	.000	-6.926	2.838	-2.440	.015	-18.132	6.163	-2.942	.003	-.643	6.550	-.098	.922

LOGIT model: LOG (p/(1-p)) = Intercept + BX, Convergence information: optimal solution found. Chi-Square Tests: Sig .000, n=121.

4.8 Rate of adoption

The rate of adoption per area is measured where the rate of adoption is defined as the proportion of area devoted to GM maize technology out of the total number of hectares under cultivation as indicated below.

$$\text{Rate of adoption} = \frac{\text{Number of hectares under cultivation with technology seed}}{\text{Total number of hectares under cultivation}}$$

The rate of adoption is measured where the total number of hectares under maize cultivation is compared to the total number of hectares under *Bt* maize during the 2011 to 2014 maize production seasons in Gauteng Province as shown in Table 4.7. A total of 35162.1 hectares were under maize cultivation and 21797 were under *Bt* maize cultivation representing an adoption rate of 61.9%. The adoption rate between these 4 years shows an overall increase among the 121 farmers interviewed in this study (Figure 4.3).

Table 4.7: Total number of hectares under maize and *Bt* maize cultivation

	2011	2012	2013	2014	TOTAL
Bt hectares	4681	5261	6188	5667	21797
Total hectares	8149.4	8989.4	9026.4	8996.9	35162.1
%	57.4	58.52	68.5	62.9	61.9

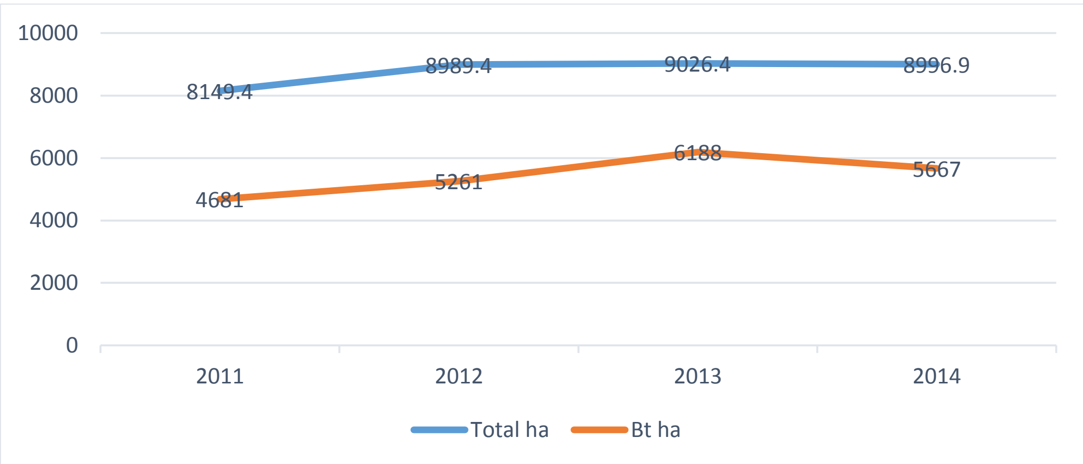


Figure 4.3: Total number of hectares planted with maize and *Bt* maize in 2011 to 2014 in Gauteng province

The rate of adoption of *Bt* maize according to selected variables are measured in this study using the above-mentioned formula. The variable selected include: (i) Age of the farmer; (ii) Gender; (iii) Level of education; (iv) Full time farmer; (v) Off farm employment; (vi) Organisational affiliation; (vii) History of maize farming; (viii) Farm size; (ix) How land was acquired; (x) Farm management; (xi) Information on *Bt* maize received; (xii) Visits by extension officers; (xiii) Visits by maize suppliers; and (xiv) Neighbour is a *Bt* farmer.

(i) Age of the farmer

Farmers were divided according to their age brackets. Farmers aged 40 years and below cultivated a total of 11540.9 hectares of land during the 2011 to 2014 maize production seasons, and 59% of the total number of hectares, were under *Bt* maize cultivation. Farmers aged between 41 and 60 years cultivated a total of 13555.7 hectares during the 2011 to 2014 maize production seasons, an increase of 2000 hectares. Out of this number, 70% of the total number of hectares was under *Bt* maize cultivation. The rate of adoption increased by 10.3% for this age bracket, according to the findings, farmers adopt *Bt* maize as they grow older. Farmers above 60 years tend to adopt less than the other

(ii) Gender

Out of the 121 farmers interviewed, 80.2% were males and 19.8% females. Female farmers cultivated a total of 3965.4 hectares during the 2011 to 2014 maize production seasons. Out of this number, 67% were under *Bt* maize cultivation. Male farmers cultivated 31197 hectares of land during the same period and out of this number, 61% of the land was under *Bt* maize cultivation. The study revealed that the rate of adoption by female farmers was more than their male counterparts (67% and 61% respectively). According to a study conducted in Kwazulu-Natal by Gouse *et al*. (2016), women farmers value labour saving, taste, quality and other traditional activities involved in the house more than just yield which is mostly favoured by male farmers.

(iii) Level of education

The level of education of farmers is generally low. More than 30% of the total number of farmers interviewed has either primary or pre-primary education. Farmers with pre-primary level of education cultivated a total of 1100 hectares between 2011 and 2014 maize production seasons and out of this number, 13% were under *Bt* maize cultivation during the same period. Farmers with primary education cultivated a total of 7739.4 hectares and 3146 of the 40.65 hectares were under *Bt* maize. Farmers with secondary education cultivated a total of 10117.2 hectares and out of this number, 41.6% were under *Bt* maize between 2011 and 2014 maize production seasons in Gauteng province as shown in Table 4.7. Some farmers attended school up to Grade 12 representing 23.1% of the total number of farmers interviewed. This category of farmers cultivated a total of 16208 hectares and out of this number, 57% of the land was under *Bt* maize. 11.5% of the total number of farmers had tertiary qualifications and cultivated 5546 hectares of land. Out of this number, 91% of the land was under *Bt* maize. The rate of adoption increased with the level of education (from 13% hectares under *Bt* maize cultivation by farmers with low levels of education to 91% hectares under *Bt* maize cultivation by farmers with tertiary education).

(iv) Full time farmers

Out of the 121 farmers interviewed, 83.4% were fulltime farmers and cultivated a total of 33866.2 hectares of land between 2011 to 2014 maize production seasons. Out of this number, 62.8% of the land was under *Bt* maize cultivation. 16.5% of the farmers were part-time farmers and cultivated only 39.4% of land under *Bt* maize between 2011 and 2014 maize production seasons. The rate of adoption by full time farmers was high (62.8%) compared to farmers part-time farmers (39.4%) cultivating *Bt* maize.

(v) Off farm employment

75.2% of the 121 farmers interviewed had no other source of income during the 2011 to 2014 maize production seasons. These farmers cultivated a total of 30910.2 hectares and 62% of these hectares were under *Bt* maize cultivation. Farmers with other form of income planted a total of 4252.4 hectares and 60% of hectares in this category were under *Bt* maize cultivation. According to the findings in Table 4.7, the rate of adoption for both categories fluctuates with years of production.

(vi) Farming history

The total number of hectares for famers who have been farming for 10 years or less and adopted *Bt* maize was higher for the 2011 to 2014 maize production seasons. Table 4.7 shows that a total of 25712.4 hectares were under cultivation and 65.9% were under *Bt* maize cultivation. This is an indication of young and upcoming farmers in Gauteng province using new technology. Farmers who have been cultivating maize for 11 years and less than 20 years showed a higher rate of adoption than the other 2 categories of farming history. A total of 4546 hectares of land were under maize cultivation during the 2011 to 2014 production seasons and 79.5% adopted *Bt* maize. Farmers involved in maize farming maize for more than 20 years cultivated more hectares than those with 11 years but less than 20 years of farming, and their adoption rate was low. Less experienced farmers showed more adoption rate than those who had been on the field for more years in Gauteng Province between 2011 and 2014 maize production seasons.

(vii) Farm size

The rate of adoption by farmers with 50 hectares and less was low. 21.6% out of the 388.6 hectares were under cultivation during the 2011 to 2014 maize production seasons as shown in Table 4.8. An increase in the total number of hectares cultivated signifies an increase in the adoption rate.

(viii) Municipality

Tshwane farmers cultivated a total of 7882 hectares between 2011 to 2014 maize production seasons and 51.2% of this land was under *Bt* maize. Ekurhuleni farmers cultivated 9612.3 hectares and 74% of the land was under *Bt* maize during the 2011 to 2014 maize production seasons. 4033 hectares were cultivated in the West Rand District Municipality and 12% cultivated *Bt* maize during the 2011 to 2014 maize production seasons. Sedibeng farmers cultivated more hectares than all regions in Gauteng (a total of 13635 hectares and 74% of this number were under *Bt* maize). The rate of adoption by farmers in all these 4 maize regions of Gauteng Province shows that Sedibeng is the highest in terms of number of hectares under *Bt* maize cultivation. The rate of adoption in Ekhurhuleni is second with the total number of hectares cultivated and an adoption rate of 74%.

(ix) Affiliation with farmer organisations

A total of 18557.6 hectares were cultivated by farmers affiliated to farmers' organisations, and 76.5% hectares were under *Bt* maize cultivation during the 2011 to 2014 maize production seasons. Farmers who are not affiliated to any farmer organisation cultivated a total of 16605 hectares and 45.7% hectares were under *Bt* maize cultivation. The rate of adoption by farmers affiliated to farmers' organisations was higher than those not affiliated to any farmers' organization during the 2011 to the 2014 maize production season in Gauteng Province.

(x) Farm management

Famers who manage the farm themselves cultivated a total of 15803 hectares and 73% of these hectares were under *Bt* maize cultivation during the 2011 to 2014 maize production seasons. Farmers managed by family members experienced 78% adoption rate out of the 1714 hectares cultivated. Farms under cooperatives experienced 48.5% adoption rate. The rate of adoption by farmers who managed their own farms was higher than those managed groups or cooperatives.

(xi) Farm ownership

A total of 15024 hectares were cultivated during the 2011 to 2014 maize production seasons by farmers who personally owned the farms. Out of this number, 73% of the hectares were under *Bt* maize cultivation. Family members, who owned farms, cultivated a total of 1941 hectares and 71% of the hectares were under *Bt* maize cultivation. The rate of adoption where the farms were owned by family members was higher (76%) than those owned otherwise. The government has been promoting cooperative farming, as depicted within the DTI Strategy (2012), the rate of adoption by cooperative was fairly higher (60%), but lower than the other category of ownership.

(xii) How the land was acquired

Farms acquired by private funds cultivated a total 1720 hectares and 87.7% of the land was under *Bt* maize cultivation between 2011 to 2014 maize production seasons as shown in Table 4.8. Farms rented by farmers occupied a total of 3674 hectares and

7.8% of the land was under *Bt* maize cultivation. The rate of adoption for farms acquired through the government programme (PLAS) was higher representing 92% of the number of hectares under *Bt* maize cultivation out of the total of 12178 hectares cultivated during the 2011 to 2014 maize production seasons.

(xiii) Information on *Bt* maize received

The rate of adoption by farmers who received information on *Bt* maize during the 2011 to 2014 maize production season was high (73.7%) out of the 21068 hectares cultivated. Only 44% of farmers who did not receive any information on *Bt* cultivated *Bt* maize between 2011 and 2014 maize production seasons.

(xiv) Visits by extension officers

A total of 24812 hectares were cultivated by farmers who indicated that an extension officer paid them a visit during the 2011 to 2014 maize production seasons and out of this number, 71.6% cultivated *Bt* maize. Table 4.8 indicates that the rate of adoption was lower where farmers indicated that they were never visited by an extension officer.

(xv) Know *Bt* maize supplier

The rate of adoption by farmers who knew the *Bt* maize supplier was higher (72.9%) out of a total of 29587 hectares planted during the 2011 to 2014 maize production seasons. The influence by maize suppliers played a major role in terms of the number of *Bt* maize hectares cultivated during the 2011 to 2014 maize production seasons.

(xvi) Neighbour is a *Bt* maize farmer

A total of 27748.4 hectares were cultivated by farmers who indicated that their neighbours were *Bt* maize farmers and the rate of adoption was high (71.5% of hectares were under *Bt* maize cultivation during the 2011 to 2014 maize production seasons). Perusal or over-the-fence watching played an important role in terms of farmers' adoption of *Bt* maize as indicated in Table 4.8.

Table 4.8: The rate of adoption according to the variables

Age of the farmer	Adoption Ha	2011	2012	2013	2014	Total
40 years or younger	Ha of adoption	1881	1996	1885	1131	6893
Total	Ha planted	3204	3447.3	2863.3	2026.3	11540.9
%	Adopted %	58.7	57.9	65.8	55.8	59.7
41 to 60 years	Ha of adoption	1785	2175	2686	2856	9502

Total	Ha planted	2990.3	3122.3	3512.3	3930.8	13555.7
%	Adopted %	59.7	69.6	76.4	72.6	70
60 years & older	Ha of adoption	1015	1120	1617	1680	5432
Total	Ha adopted	1954.8	2419.8	2650.8	3039.8	10065.2
%	Adopted %	51.9	46	61	55	53.9
Gender	**Adoption Ha**	**2011**	**2012**	**2013**	**2014**	**Total**
Female	Ha of adoption	416	684	729	839	2668
Total	Ha planted	978.1	1046.1	883.1	1058.1	3965.4
%	Adopted %	42.5	65	82.5	79	67
Male	Ha of adoption	4265	4577	5459	4829	19130
Total	Ha planted	7171.3	7943.3	8143.8	7938.8	31197.2
%	Adopted %	59.4	57.	67	60.8	61
Level of education	**Adoption Ha**	**2011**	**2012**	**2013**	**2014**	**Total**
Pre-school	Ha of adoption	15	24	39	68	146
Total	Ha planted	254.8	215.8	281.8	347.8	1100.2
%	Adopted %	5.8	11	13.8	19.5	13
Primary school	Ha of adoption	526	622	1146	852	3146
Total	Ha planted	1576	1832.8	2128.8	2201.8	7739.4
%	Adopted %	33	33.9	53.8	38.6	40.6
Secondary school	Ha of adoption	692	911	1205	1405	4213
Total	Ha planted	2563.3	2597.3	2322.3	2634.3	10117.2
%	Adopted %	26.9	35	51.8	53	41.6
Grade 12	Ha of adoption	2411	2375	2622	1842	9250
Total	Ha planted	3754.5	4343.5	4297	3813	16208
%	Adopted %	64	54.6	61	48	57
Tertiary	Ha of adoption	1037	1329	1176	1500	5042
Total	Ha planted	1111	1380	1230	1825	5546
%	Adopted %	93	96	95.6	82	90.9
Fulltime farming	**Adoption ha**	**2011**	**2012**	**2013**	**2014**	**Total**
Yes	Ha of adoption	4567	5166	6040	5513	21286
Total	Ha planted	7860.3	8707.3	8680.8	8617.8	33866.2
%	Adopted %	58	59	69.5	63.9	62.8
No	Ha of adoption	114	95	148	154	511
Total	Ha planted	289.1	282.1	346.1	379.1	1296.4
%	Adopted %	39.4	33.6	42.7	40.6	39.4
Off farm employment	**Adoption ha**	**2011**	**2012**	**2013**	**2014**	**Total**
Yes	Ha of adoption	406	719	565	871	2561
Total	Ha planted	820.1	1045.1	1141.6	1245.6	4252.4
%	Adoption %	49.5	68.7	49.4	69.9	60
No	Ha of adoption	4275	4542	5623	4796	19236
Total	Ha planted	7329.3	7944.3	7885.3	7751.3	30910.2
%	Adoption %	58	57	71	61	62
Farming history	**Adoption ha**	**2011**	**2012**	**2013**	**2014**	**Total**
10 years and below	Ha of adoption	3593	4192	4775	4409	16969
Total	Ha planted	6087.1	6666.1	6787.6	6171.6	25712.4
%	Adoption %	59	62.8	70	71	65.9
11 to 20 years	Ha of adoption	754	903	868	1092	3617
Total	Ha planted	1035.5	1083.5	930.5	1496.5	4546
%	Adoption %	72.8	83	93	72.9	79.5
Above 20 years	Ha of adoption	334	215	594	234	1377
Total	Ha planted	1008.8	1239.8	1308.8	1328.8	4886.2
%	Adoption %	33	17	45	17.6	28
Farm size	**Adoption ha**	**2011**	**2012**	**2013**	**2014**	**TOTAL**
50 and less	Ha of adoption	21	21	21	21	84
Total hectare	Ha planted	80.4	90.4	108.9	108.9	388.6
%	Adoption %	26	23	19	19	21.6

50 to 100	Ha of adoption	0	0	1	2	3
Total hectare	Ha planted	85	87	108	106	386
%	Adoption %	0	0	0.9	1.8	0.7
100 to 200 hectare	Ha of adoption	339	570	517	673	2099
Total hectare	Ha planted	817	941	1088	1234	4080
%	Adoption %	41	60.5	47.5	54.5	51
200 and above	Ha of adoption	4321	4670	5648	4971	19610
Total hectare	Ha planted	7167	7871	7722	7548	30308
%	Adoption %	60	59	73	65.8	64.7
Municipality	**Adoption ha**	**2011**	**2012**	**2013**	**2014**	**Total**
Tshwane	Ha of adoption	846	918	1180	1119	4063
Total	Ha planted	1470	1980	2102	2330	7882
%	Adoption %	57.5	46	56	48	51.5
Ekurhuleni	Ha of adoption	1613	1988	2200	1328	7129
Total	Ha planted	2719	3069.1	2327.1	1497.1	9612.3
%	Adoption %	59	64.7	94.5	88.7	74
West Rand	Ha of adoption	100	100	50	250	500
Total	Ha planted	1008.1	855.3	1009.8	1159.8	4033
%	Adoption %	9.9	11.6	4.9	21.5	12
Sedibeng	Ha of adoption	2122	2255	2758	2970	10105
Total	Ha planted	2952	3085	3588	4010	13635
%	Adoption %	71.8	73	76.8	74	74
Organisational affiliation	**Adoption ha**	**2011**	**2012**	**2013**	**2014**	**Total**
Yes	Ha of adoption	3233	3582	3641	3747	14203
Total	Ha planted	4449.9	4720.9	4682.4	4704.4	18557.6
%	Adoption %	72.6	75.8	77.7	79.6	76.5
No	Ha of adoption	1448	1679	2547	1920	7594
Total	Ha planted	3699.5	4268.5	4344.5	4292.5	16605
%	Adoption %	39	39	58.6	44.7	45.7
Farm management	**Adoption ha**	**2011**	**2012**	**2013**	**2014**	**Total**
The farmer	Ha of adoption	2347	2611	3144	3488	11590
Total	Ha planted	3081.1	3735.4	4045.9	4940.9	15803.3
%	Adoption %	76	69.8	77.7	70.5	73
Family members	Ha of adoption	106	244	482	512	1344
Total	Ha planted	139	477	534	564	1714
%	Adoption %	76	51	90	90	78
Farmer group	Ha of adoption	0	0	44	40	84
Total	Ha planted	0	0	44	40	84
%	Adoption %	0	0	100	100	100
Cooperatives	Ha of adoption	2218	2396	2408	1507	8529
Total	Ha planted	4929	4777	4403	3452	17561
%	Adoption %	44.9	50	54.6	43.6	48.5
Others	Ha of adoption	10	10	110	120	250
Total	Ha planted	130	130	240	240	740
%	Adoption %	7.6	7.6	45.8	50	33.7
Farm ownership	**Adoption ha**	**2011**	**2012**	**2013**	**2014**	**Total**
Farmer 1	Ha of adoption	2274	2460	3009	3293	11036
Total	Ha planted	2900	3540	3942	4642	15024
%	Adoption %	78	69	76	70.9	73
Family members 2	Ha of adoption	119	305	402	567	1393
Total	Ha planted	299	532	467	643	1941
%	Adoption %	39.7	57	86	88	71.7
Coops 4	Ha of adoption	2218	2296	2352	1447	8313
Total	Ha planted	4032.3	3870.3	3430.8	2475.8	13809.2
%	Adoption %	55	59	68.5	58	60
Others 7	Ha of adoption	70	150	260	260	740
Total	Ha planted	800	800	800	800	3200

%	Adoption %	8.75	18.75	32.5	32.5	23.
HLAQ	**Adoption ha**	**2011**	**2012**	**2013**	**2014**	**Total**
Privately purchased 1	Ha of adoption	380	380	370	380	1510
Total	Ha planted	380	380	380	580	1720
%	Adoption %	100	100	97.3	65.5	87.7
Communal	Ha of adoption	0	0	110	110	220
Total	Ha planted	33	33	162	162	390
%	Adoption %	0	0	67.9	67.9	56.4
PTO3	Ha of adoption	419	374	130	614	1537
Total	Ha planted	1213	968	1045	1175	4401
%	Adoption %	34.5	38.6	12	52	34.9
Renting 4	Ha of adoption	55	120	30	85	290
Total	Ha planted	911	976	886	901	3674
%	Adoption %	6	12	3	9	7.8
Own finance 5	Ha of adoption	0	20	35	51	106
Total	Ha planted	9	25	40	166	240
%	Adoption %	0	80	87.5	30.7	44.
Bond 6	Ha of adoption	108	120	141	140	509
Total	Ha planted	123.5	135.5	155.5	155.5	570
%	Adoption %	87	88.5	90.6	90	89
Lrad 7	Ha of adoption	1494	1620	1608	557	5279
Total	Ha planted	2747	2865	2327	1421	9360
%	Adoption %	54	56	69	39	56
PLAS	Ha of adoption	2117	2527	3042	3518	11204
Total	Ha planted	2516	2849	3187	3626	12178
%	Adoption %	84	88.6	95	97	92
Restitution	Ha of adoption	0	0	0	0	0
Total	Ha planted	0	42	33	70	145
%	Adoption %	0	0	0	0	0
Other	Ha of adoption	108	100	722	322	1252
Total	Ha planted	226.9	715.9	788.4	738.4	2469.6
%	Adoption %	47.5	13.9	91.5	43.6	50.6
Know *Bt* maize supplier	**Adoption ha**	**2011**	**2012**	**2013**	**2014**	**Total**
Yes	Ha of adoption	4661	5236	6143	5541	21581
Total	Ha planted	6818	7636	7632	7501	29587
%	Adoption %	68	68.5	80	73.8	72.9
No	Ha of adoption	20	25	45	126	216
Total	Ha planted	1331.4	1353.4	1394.9	1495.9	5575.6
%	Adoption %	1.5	1.8	3.2	8.4	3.8
Neighbour *Bt* farmer	**Adoption ha**	**2011**	**2012**	**2013**	**2014**	**Total**
Yes	Ha of adoption	4316	4991	5310	5235	19852
Total	Ha planted	6650.1	6993.1	7131.1	6974.1	27748.4
%	Adoption %	64.9	71.3	74.4	75	71.5
No	Ha of adoption	365	270	878	432	1945
Total	Ha planted	1499.3	1996.3	1895.8	2022.8	7414.2
%	Adoption %	24.	13.5	46.3	21	26
Extension visits	**Adoption ha**	**2011**	**2012**	**2013**	**2014**	**Total**
Once a month	Ha of adoption	1297	1589	1820	2000	6706
Total	Ha planted	1638	1835	2112	2399	7984
%	Adoption %	79	86.5	86	83	83.9
More per month	Ha of adoption	645	900	1132	1297	3974
Total	Ha planted	1108	1545	1624	1887	6164
%	Adoption %	58	58	69.7	68.7	64.4
Once a year	Ha of adoption	663	783	1054	647	3147
Total	Ha planted	1016	1136	1457	1020	4629
%	Adoption %	65	68.9	72	63	67.9
Does not visit	Ha of adoption	2076	1989	2182	1723	7970

Total	Ha planted	4387.4	4473.4	3833.9	3690.9	16385.6
%	Adoption %	47.31	44	56.9	46.6	48.6
***Bt* Information received**	**Adoption ha**	**2011**	**2012**	**2013**	**2014**	**Total**
Yes 1	Ha of adoption	3228	3672	4544	4101	15545
Total	Ha planted	4504.5	5244.5	5575.5	5743.5	21068
%	Adoption %	71.6	70	81	71	73.7
No 0	Ha of adoption	1453	1589	1644	1566	6252
Total	Ha planted	3644.9	3744.9	3451.4	3253.4	14094.6
%	Adoption %	39.8	42	47.6	48	44

CHAPTER FIVE

5. SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 SUMMARY

This study on the analysis of the adoption of maize biotechnology by developing farmers of Gauteng Province, South Africa, revealed that developing maize farmers adopt and plant biotechnology maize seeds based on several farming aspects. The role of government extension services, in collaboration with biotechnology maize seed suppliers, plays a vital role in influencing the decision by developing farmers to adopt.

The aim of the study was to analyse the adoption of maize biotechnology by developing farmers of Gauteng Province, South Africa.

As noted in Chapter One, the specific objectives of the study were to:

- Analyse demographic and socio-characteristics that impact on the adoption or non-adoption of maize biotechnology by developing maize farmers in Gauteng Province;
- Identify developing maize farmers who adopted and those who did not adopt maize biotechnology;
- Assess the level or rate or intensity of adoption of maize biotechnology among developing maize farmers in Gauteng;
- Identify and analyse factors that influence the adoption of maize biotechnology by developing maize farmers in Gauteng; and
- Identify and analyse general constrains that limit the adoption of maize biotechnology by developing farmers in Gauteng.

Questionnaires were used to collect data from 121 farmers. The data collected was captured and statistically analysed using descriptive statistics and the Logit Model as it has the advantage of predicting probability (Wiers, 2011).

5.2 CONCLUSION

South African government has been involved in many agricultural programmes in trying to reduce the inequalities that remain elusive in the country. Agriculture has also attracted considerable policies and academic interests as more and more programmes fail to yield the desired results (Obi, 2011). Developing farmer programmes also form part of these initiatives and there are some farmers who have being trying to keep level with the speed by which government is trying to bridge this inequality gap.

The use of hybrid and maize biotechnology seeds by many developing farmers has been and continues to be a challenge to governments and other pro-development institutions in their decision-making. The South African government, together with local Non-Governmental Organisations such as AfricaBio, have been trying to introduce *Bt* maize through training programmes throughout the country, including Gauteng Province.

This study was therefore conducted to analyse the adoption of *Bt* maize technology among developing maize farmers from 2011 to 2014 maize production season.

The results showed that 54% of the farmers adopted *Bt* maize during the 2011 to 2014 maize production seasons in Gauteng. Results also indicate that that farm size, gender, age, level of education, off-farm employment, extension visits and a neighbour who is also planting *Bt* maize had positive significant impact on the farmer's adoption of *Bt* maize. The visits by sales representatives of companies selling maize seeds, affiliation with farmer organisations and farmers speaking about *Bt* maize during meetings, had negative significant impact on farmers adoption of *Bt* maize. Developing farmers need regular visits by extension officers and knowledge in order to adopt *Bt* maize.

5.3 RECOMMENDATIONS

Based on the research findings, the following recommendations were made:

(i) regular visits by extension officers; (ii) planting of demonstration plots; (iii) the role of seed suppliers;(iv) women farmers; and (v) Farming skill.

5.3.1 Regular visits by extension officers

Formal extension service was accessed by 34.7% of farmers and 28.9% of these farmers adopted *Bt* maize during the 2011 to 2014 maize production seasons. The Logit Model analysis in Table 4.6 shows that the parameters estimate associated with frequency of visits by government extension officers is positive and statistically significant, an indication that farmers need extension officers for farming advice. It is, therefore, recommended that extension officers be capacitated and nurtured to get down to the level of farmers at the very bottom of the human ladder in order to improve the adoption of *Bt* maize by developing farmers.

5.3.2 Demonstration plots

According to this study, instances where a farmer has a neighbour who is also a *Bt* farmer, the adoption rate is better than those whose neighbours are not *Bt* farmers. Table **4.3** indicates that 39.66% of farmers whose neighbours were *Bt* maize farmers adopted *Bt* maize during the 2011 to 2014 maize production seasons. The Logit analysis results associated with the farmer's neighbour being a *Bt* farmer is positive and statistically significant.

Therefore, it is recommended that well planted demonstration plots be encouraged for farmers to adopt *Bt* maize. The old adage of 'seeing is believing' still has contributing impact on farmer's reaction towards new technology.

Bt maize seed suppliers need to make *Bt* maize seed freely available for planting of demonstrations plots through government extension officers. Farmer organization need to negotiate with maize seed companies on behalf of their farmers for this initiative to succeed. Farmers should also make their farms available for demonstration plots and for farmers days to take place on their farms. The extension officers should as well took some initiatives to approach the seed companies to make Bt maize seed available for this proposal.

5.3.3 The role of seed suppliers

The Logit coefficient associated with regular farm visits by *Bt* maize suppliers is negative and statistically significant, an indication that maize suppliers did not have significant positive impact in influencing farmers' adoption of *Bt* maize during the 2011 to 2104 maize production seasons. *Bt* maize seed is supplied by the private sector in South Africa and there are several multinational seed companies operating in this industry.

Representatives from seed suppliers need to improve their sales approach in order to encourage adoption. Such representatives need to be approachable and make it easy for farmers to ask questions and or clarifications where necessary. The seed companies can also form private – public partnership with government extension office to facilitate exchange of agricultural knowledge while at the same time conveying knowledge to the farmers.

5.3.4. Women farmers

According to Table 4.1 of this study, 79.6% of male farmers cultivated *Bt* maize between 2011 and 2014 maize production seasons compared to only **18.5%** females who adopted *Bt* maize. The study further found that the rate of adoption by female farmers were high. However, the rate of adoption by female farmers stood at 67% compared to their male farmers with 61%. The total number of female farmers was low (24 of the 121 farmers interviewed).

It is recommended that more female developing farmers be encouraged to get involved in maize farming by example making exclusive financing for women farmers. Government can create legislations to force financial companies to give women farmers a low interests or no interests at all when allocating loans to women farmers. South African Breweries is currently running an interests-free-loan program of financing women maize farmers to plant conventional maize. If more companies can adopt nearly the same program as part of their social responsibility, this could see more women farmers taking part. This could lead to the adoption of new technologies, including *Bt* maize and an improvement of the livelihood of people in general and positive contribution to the country's GDP.

5.3.5 Farming skill

The coefficient associated with education is positive and statistically significant, an indication that the level of education contributes towards adoption as shown in Table 4.6. According to this study, 30% of farmers interviewed had no education above primary school and only 13%

cultivated *Bt* maize. Farmers with tertiary qualifications were 11.5% of the total number of farmers interviewed and 91% cultivated *Bt* maize.

It is recommended farmers undergo thorough training programmes across all farming sectors, particularly farmers with low levels of education. The low level of education which does not contribute positively towards adoption of *Bt* maize, could also contribute towards overall low yield throughout all farming activities. Institutions of higher learning should come up with programmes to capacitate farmers with basic farming skills.

5.4 FUTURE RESEARCH

The role which extension officers play in transferring knowledge to farmers is very important as their attitude towards uneducated farmers can either make or break poor farmers. However, the level of understanding of *Bt* maize by extension officers was not assessed. Further studies need to be conducted in order for government to capacitate and allocate 'the right extension officer, with the relevant knowledge to the rightful farmers.' Also, government needs to come to the 'party' with regard to making available resources for extension officers to cover rightful areas. Data was not collected in terms of profit gained by *Bt* maize farmers versus non-*Bt* maize farmers. It is imperative for more studies in this regard in order for farmers to assess the value of one Rand invested in adopting biotechnology.

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APPENDIX 1

ANALYSIS OF THE ADOPTION OF MAIZE BIOTECHNOLOGY BY DEVELOPING MAIZE FARMERS OF GAUTENG PROVINCE, SOUTH AFRICA

This questionnaire is part of a research project conducted by the University of South Africa with no commercial interest involved. We would appreciate you taking time to answer our questions. We would also like to assure you from the outset that any information you give us is just for the purpose of this research project and will be seen only by us and as such, will be treated with utmost confidentiality.

DATE OF VISIT: …………………………………………………………………………….

NAME OF THE FARMER: ……………………………………………………………………

HOW MANY YEARS HAVE YOU BEEN FARMING? …………………

HOW LARGE IS YOUR FARM IN HA? ………………..

TYPE OF FARMING PRACTISED ON THE FARM ………………………………

……………………………………………………………………………………………..

DISTRICT MUNICIPALITY (please tick the appropriate box):

1. Randfontein	2. Emfuleni	3. Midvaal	4. Kungwini

METROPOLITAN MUNICIPALITY: (please tick the appropriate box)

1.City of Tshwane	2.City of Ekurhuleni	3.West Rand	4.Sedibeng

LOCAL MUNICIPALITY: ……………………………………………………………………………….

WARD: ……………………………………………………………………………………………….

FARM NUMBER: …………………………………………………………………..

A. FARMER'S DEMOGRAPHICS

Please fill in the household characteristics information with the interviewee.

A.1 FARM HOUSEHOLD CHARACTERISTICS

1	2	3	4	5	6	7
Size of household ………	Gender of head of household Male…….1 Female….0	Age of head of household (years) ………	What is marital status of the household head? Single………..1 Married………2 Divorced……..3 Widowed……..4 Seperated ..…...5 Co-habiting ………6	Education level Pre-school…….1 Primary .. ..2 Secondary…….3 Matric…............4 Tertiary. ……...5 Is the qualification related to agriculture? Y ....1 N.................2 How many years of schooling? …………….	Is the principal farmer operating the farm on a fulltime or pertime basis? Fulltime Farming…….1 Partime farming….2	Does the principal farmer have off farm employment? Yes …1 No …..2

A.2 FARMING HISTORY

Are you a member of any farmer organizations in South Africa …………

If yes, please give the name(s) of that/those organization …………………………………………………………

How many years of maize planting experience does the farmer have ....

Which of the following technologies are you using?

- **Ripping (After harvesting to harvest intermediate rains)**
- **Zero tillage (Herbicides used before the rains to kill grasses and weeds)**
- **Plough (Land is ploughed before the rains)**
- **Conventional (Preparations is done before the rains with hand hoe or tractor, plough is deep and soil turned up and down)**
- **Mulching**
- **Others**

A3. Did the farmer planted maize? (tick with √)

Year	2011 1.Planted 2.Not planted	2012 1.Planted 2. Not planted	2013 1.Planted 2. Not planted	2014 1.Planted 2. Not planted
Reasons if not				

A4. Did the farmer planted maize with technology (tick with √)

Year	2011 1.Planted 2. Not planted	2012 1.Planted 2. Not planted	2013 1.Planted 2. Not planted	2014 1.Planted 2. Not planted
Reasons if not (below)				

Did not know it 1

Liked it but it was expensive 2
Liked it but have no implements to plant it 3
Liked it but have other reasons 4
Did not liked it because it was expensive 5
Did not liked because it need special implements.........6
Did not liked it because it tastes bad ………………….7
Did not liked it and have other reasons 8

A5. Do you know farmers who are organized in group in order to farm this maize?
Yes ….1
No ….2

A. 6 Who manages the farm? (tick with √)

1. The farmer personally	2. Family members	3.Farmers' group	4.Co operative	5.Private company	6.Trust	1. Other (specify) ………………………………

A7. Who owns the farm? (tick with √)

1.Individual Farmer	2.Family members	3.Farmers' group	4.Co operative	5.Private company	6.Trust	7. Other (specify) ……………………………….

A8. How the farmer acquired the land.

1. Private (purchased)	2. Communal	3. Permission to occupy (P.T.O)	4. Renting	5. Other (specify) …………………………………..

1.Own finance	2. Bond	3. LRAD	4. PLAS	5. Restitution	6. Inheritance	7. Other (specify)……………
Ha	**ha**	**Ha**	**Ha**	**ha**	**Ha**	**Ha**

B. ACCESS TO TECHNICAL INFORMATION ON MAIZE TECHNOLOGY

B.1 Is there any information that you get on maize technology?

Yes ………………….….1
No……………………..2

B2. Did you ever participated in training or a workshop or demonstration about this maize technology?
Yes….1
No….2

B3. Which source of information transfer do you use?

1. Extension	2. Magazines	3. Radio	4. Local newspapers	Other (specify) ………………	None

B4. Is there any extension service that you receive on maize technology?

Yes ………………….……1
No………………………2

B.5 From which source do you receive extension service on maize technology and how frequent in one production season? (circle your answer)

1.Formal extension	2 Farmer to farmer	3.Private company	4.Neighbor	5.Other (specify)
Do you know the name of your extension? Y ………....1 N…………2 Frequent visits Once a month……1 More/ month…. …2 Once a year………3 Doesn't visit …….4	Do you talk with other farmers about maize technology Y ……….1 N………..2 Frequent talking about technology Always ………...1 Often….………..2 Regularly ……...3 Almost always 4	Do you know the name of your seed supplier? Y ……….1 N…………2 Frequent visits Once a month…..1 More/ month ……2 Once a year……...3 Doesn't visit …...4	Is your neighbor a maize farmer Y……..1 N……..2 Frequent talk about maize technology Always ………...1 Often…………..2 Regularly ……...3 Almost always ...4	

B.6 Do you receive any incentive for using maize technology from the below mentioned?

1.Formal extension	2.Farmers neighbor	3.Private company	4.Relatives in the village	5.Other (specify)	6. None
Yes ……1 No ……2	Yes ……1 No ……2	Yes ……1 No ……2	Yes ……1 No ……2	Yes ……1 No ……2	Yes ……1 No ……2

If, Yes, please specify the incentive ……………………………………………………………………

B.7 Does the information you get have any impact on your behavior towards maize technology?

Yes …………….1
No………………2

If yes how ………………………………………………………………………………………..

B.8 How is the social position (reputation) in the community of farmers who are practicing this maize technology?
Bad ……1
Good ……2
Fair…….3

B.9 What are the general constrains facing you on this farm?

……………………………………………………………………………………………………

……………………………………………………………………………………………………

………
.

C. FARMERS' PERSPECITVE OF MAIZE TECHNOLOGY

C1. What type of maize technology is/was the farmer planting?

2011	2012	2013	2014
1. Biotech Ha ------------- 2. Hybrid Ha------------- 3. OPV Ha-------------- 4. Others Ha----------------	1. Biotech Ha ---------------- 2. Hybrid Ha ---------------- 3. OPV Ha ---------------- 4. Others Ha----------------	1. Biotech Ha --------------- 2. Hybrid Ha --------------- 3. OPV Ha --------------- 4. Others Ha ---------------	1. Biotech Ha ------------- 2. Hybrid Ha -------------- 3. OPV Ha ------------- 4. Others Ha-------------

C2. When did the farmer first knew about the availability of maize technology and who was the informer

Year	2011	2012	2013	2014
	1. Formal extension 2.Other farmers 3. Private company 4. Relatives 5. Other (specify) ………………..	1. Formal extension 2.Other farmers 3. Private company 4. Relatives 5. Other (specify) ………………….	1. Formal extension 2.Other farmers 3. Private company 4. Relatives 5. Other (specify) ………………….	1.Formal extension 2.Other farmers 3.Private company 4. Relatives 5. Other(specify) ………………..
Answer				

C.3. What was the farmer's reaction towards maize technology after knowing the technology?

Year	2011	2012	2013	2014
	1.Planted it 2. Not planted it	1.Planted it 2. Not planted it	1.Planted it 2. Not planted it	1.Planted it 2. Not planted it
Ha planted				

C.4 What was the main reason for the farmer to start planting technology?

2011	2012	2013	2014

C5. What is the farmer's level of satisfaction with maize technology?.(tick with √)

Year	2011 1.Very high 2. Average 3.Very low	2012 1.Very high 2. Average 3.Very low	2013 1.Very high 2. Average 3.Very low	2014 1.Very high 2. Average 3.Very low
Why				

Less spraying ….1, High yield….2 Less work on weed control…3, Less expenses incurred…4 No reason ….5

C6. What was the reason for the farmer to NOT start planting the technology?

Year	2011	2012	2013	2014
Reasons				

Expensive …1, Have no knowledge…2, I just hate it…3 Not accessible....4 Does not give high yield ....5 Other reasons ….5

C7. Did the farmer notice any difference when planting technology maize?

Year	2011 1.Yes …. 2. No …	2012 1.Yes…. 2. No….	2013 1.Yes….. 2.No….	2014 1.Yes…. 2.No…..

C8. Did the farmer revert back to the other maize products after planting technology and why?

Year	2011 1.Yes 2.No	2012 1.Yes 2.No	2013 1.Yes 2.No	2014 1.Yes 2.No
Reason & on how many Ha				

C9. Yield obtained when started planting the biotechnology

2011 **1. High** **2. Average** **3. Low** **4. No difference**	**2012** **1. High** **2. Average** **3. Low** **4. No difference**	**2013** **1. High** **2. Average** **3. Low** **4. No difference**	**2014** **1. High** **2. Average** **3. Low** **4. No difference**

C10. Farmer's level of satisfaction with biotechnology

2011	2012	2013	2014
1. High 2 Average 3 Low 4 No differenc	1. High 2. Average 3. Low 4. No differenc	1. High 2. Average 3. Low 4. No differenc	1. High 2. Average 3. Low 4. No differenc

C11. MACHINERY OWNERSHIP FOR PRODUCING MAIZE TECHNOLOGY – Yes=1 and No=2

Machinery	2011	2012	2013	2014	Total
Tractors					
Trucks					
Harvester					
Boom sprayers					
Planters					
Ploughs					
Disc					
Tiller					
1. Others **(a)................** **(b)...............** **(c)..............**					