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Diffusion and Adoption of Genetically Modified Crops: Evidence from Zimbabwe, Malawi and South Africa

THESIS

By

Edworks Edward Mhandu

N0233716

Supervisors: Dr Francis Neshamba and Dr Michael Ehret

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ABSTRACT

This thesis seeks to explore opportunities for diffusion and adoption of genetically modified (GM) crops in three Southern African countries. In the African context, genetic modification of crops is a new agricultural technology that promises to enhance farm productivity and farmers' incomes. However, the promises are overshadowed by concerns about the impact of genetically modified organisms to the health of human beings, animals and the environment. Anchored on pragmatism research philosophy and using mixed methods research, evidence is gathered in Zimbabwe, Malawi and South Africa from participants representing stakeholders that include policy makers, farmers, technology developers, ginners, non-governmental organisations, media, scientists and consumers.

The study confirmed that in South Africa, insect-resistant GM cotton helps smallholder farmers to achieve high yields. The study established that, in Zimbabwe political will is the dominant factor which determines the diffusion and adoption of GM crops. The government of Zimbabwe's stance on GM crops is resolutely based on the precautionary approach and research on the GM crops is allowed. In contrast, Malawi allows scientists to evaluate GM crops in preparation for commercialisation of insect-resistant GM cotton. However, government officials in Malawi fear that neighbouring countries who have not commercialised GM crops may not allow Malawian agricultural products to pass through their lands. If the fear of movement of goods is not resolved, it has implications for the diffusion and adoption of GM crops in Malawi. This may slow the adoption or outright rejection. The solution to this issue may be through bilateral country-to-country engagements with reference to the Cartagena Protocol on Biosafety (CPB). The CPB is an international agreement which provides for movement of living modified organisms through member States.

CHAPTER 1
INTRODUCTION

Background and research context

During the past two decades that span from 1996 to 2018, research on genetically modified (GM) crops has demonstrated that GM technology is a means of achieving higher productivity and incomes for smallholder farmers in South Africa and other developing countries such as India (Gouse, 2012; Qaim, 2016; Brookes and Barfoot, 2016a). However, from the period when the GM crops were introduced to farmers, their rate of adoption vary between countries. For example, in South Africa, farmers adopted GM crops in 1997 (Gouse, 2012) and by 2015, the adoption rates had increased to 86 percent for white maize and 92 percent for yellow maize, 100 percent for cotton and 95 percent for soyabeans (James, 2015). The reason for higher adoption of yellow maize may be attributed to its use for stock feed by large-scale commercial farmers, unlike white maize which is used as a staple food and is produced by both small-scale and large-scale farmers. A question that arises is, assuming that GM crops raise productivity on the farms; why is it that more than twenty years after the initial adoption of GM crops in South Africa, its neighbours that include Zimbabwe and Malawi have been slow to diffuse and adopt the technology?

It is against this backdrop that this study seeks to identify factors that drive or constrain diffusion and adoption of GM crops in Zimbabwe, Malawi and South Africa. In addition, the study aims to provide some understanding of how new ideas, technologies and knowledge on GM crops is transferred to smallholder farmers. In this regard, the study also investigates what role policy makers, farmers and other stakeholders play in the adoption of GM crops and in protecting the environment.

Some proponents of GMOs claim that the adoption of GM crops is the solution to the eradication of global hunger and boosting of food security (Roberts, 2014; Bennet, 2015). Taleb *et al.* (2014) posit that the argument about boosting world food with GM crops is deceitful because food crops are being diverted to non-food uses such as biofuels. Other critics argue that the benefits of genetically modified organisms (GMOs) are often exaggerated, and no scientist can provide absolute guarantees that GMOs are safe (Robinson, Antoniou and Fagan, 2015). It is also argued that foreign genes inserted into the genomes of plants can cause unintended harmful effects to humans, animals and the environment (Price, 2004).

Meanwhile, as the debate continues on the pros and cons of GM crops, the United Nations (2015) projected the global population will increase from 7.3 billion in 2015 to 9.7 billion by 2050. The increase in population means that globally, farmers will need to mobilise resources that will enable them to adopt innovations and methods of farming that produce sufficient food and fibre crops to feed and clothe an additional 2.4 billion people. However, the farmers will be operating in a difficult environment with a host of external challenges that are out of their control, including climate change, droughts and diminishing land resources due to other competing demands such as roads, housing, new cities and other infrastructure projects. In addition to the challenges above, farmers in Southern Africa also face challenges that include new crop pests and diseases, for example, the Fall Armyworm which arrived in South Africa in 2017 and has been difficult to control (The Conversation, 2017).

In Southern Africa, as is the case with the rest of the world, the debate around GMOs is far from being settled because of the polarisation between the proponents and opponents of the technology. Therefore, it is crucial that biotech regulators, policy makers and other stakeholders involved in making decisions about adopting GM crops, make use of evidence-based research that informs decisions (Wambugu, 2014). It is against this background that this research seeks to establish the factors that influence diffusion and adoption of GM crops in Zimbabwe, Malawi and South Africa. The next section defines the problem statement.

Problem statement and rationale

The researcher is a senior executive at an international seed company that is based in Harare, Zimbabwe. The researcher has been involved in the crop seeds business for over twenty-eight years, ten of which have been at the level of Managing Director. A strategic issue that confronts the researcher is to establish why outstanding agricultural innovations such as GM crops have not diffused as fast as expected in Africa, particularly in Zimbabwe and Malawi. This is against the backdrop of perennial low harvests of crops in the two countries.

In 2016, thirty-nine countries in the world required external food assistance and among them, twenty-eight were from Africa (FAO, 2017). Zimbabwe and Malawi were among the African countries that required external food assistance during that period. The FAO (2017) estimates that in 2016, in Zimbabwe, three million people out of a population of 16.1 million (World Bank, 2017a) were hunger stricken and malnourished. The situation was worse in Malawi with an estimated 6.5 million people in need of food assistance against a population of 18.1 million. The researcher notes that previous research found that farmers who adopted GM crops in South Africa achieve high crop yields and the country has surplus food (Brookes and Barfoot, 2018; Gouse, 2009, 2012; Bennett, Morse and Ismael, 2006). One aspect of the theory of diffusion of innovations is that an innovation which is perceived to have a greater relative advantage over the one that it replaces diffuses faster (Rogers, 2003). In this regard, the key objective of this study is to establish the factors that drive or constrain diffusion and adoption of GM crops in Zimbabwe, Malawi and South Africa.

This study is about diffusion and adoption of GM crops. The reasons for including cotton in this study are numerous and chief among them is because cotton was the first GM crop to be commercialised in South Africa in 1997 (Gouse, 2012). In addition, cotton is grown in Zimbabwe, Malawi and South Africa, the three countries under study. Cotton provides cash income that supports hundreds of thousands of families in Southern Africa (Juma and Gordon, 2015). Therefore, improvement in farm productivity and crop yields will have a positive impact on national incomes and living standards of many people.

A drought-resistant crop, cotton, is grown in semi-arid regions by smallholder farmers in Zimbabwe, Malawi and South Africa (Bennett *et al*., 2003). Cotton is mainly grown for its fibre. The by-products of cotton include oil which is consumed by humans and the cake which is used to feed livestock. In comparison with maize which is a staple food in Southern Africa, cotton does not directly contribute to food security and nutrition but contributes to poverty alleviation through the much-needed household income (Juma and Gordon, 2015). Cotton is among the top four leading GM crops worldwide and the proportion of cultivation for each crop is soyabean 79 percent; cotton 70 percent; maize 32 percent; and rapeseed 24 percent (The Organization Committee of the International Workshop on the Global Status of Transgenic Crops, 2015). In Zimbabwe and Malawi, the productivity of non-GM cotton grown by smallholder farmers is perennially low. The Agricultural Marketing Authority of Zimbabwe (AMA) (2015) points out that in Zimbabwe, smallholder farmers that grew non-GM cotton on 200,000 hectares of land during the farming season 2015, achieved yields below 710 kilogrammes per hectare against potential yield of 4,000 kilogrammes per hectare. The yields are based on aggregate national crop delivered against the area planted. In comparison, the yield of non-GM cotton achieved by Malawian smallholder farmers in Malawi in 2011 was 250 kilogrammes per hectare against potential yield of 2,500 kilogrammes per hectare (Kenamu and Phiri, 2014).

The yield of cotton is mainly affected by the bollworm, a caterpillar which feeds on cotton bolls during vegetative stages of the cotton plants (Schnurr, 2012). However, there is insect-resistant GM cotton which has an inbuilt insecticide which protects the plant against bollworms (Lone *et al*., 2016). In this regard, it is important to establish how insect-resistant GM cotton adoption affects farm productivity and income.

The critics of GMOs raise concerns about risks to the health of humans and animals that eat GM products. Such concerns are supported by the findings of the studies carried out by Ewen and Pusztai (1999) and Seralini *et al.* (2014) which established that animals that were fed with products of GM crops showed evidence of harm. The studies by Ewen and Pusztai (1999) and Seralini *et al.* (2014) are analysed in Chapter 3, Literature Review. In addition, there are general concerns that the production of GM crops can introduce new traits in the environment, thus causing unintended consequences. For example, the genes of GM crops can be transferred through cross-pollination with their wild relatives or conventional non-GM plants (Murnaghan, 2017).

The GM crops that are available for evaluation in Zimbabwe and Malawi are developed by private companies. The same private companies developed GM crops that are on the market in South Africa and the respective governments, using biosafety regulations, regulate their adoption and commercialisation. The biosafety regulations can either be driving or restraining forces for the adoption of GM crops.

The priorities of the State are manifold, they include, food security and the economic well-being and protection of its people against externalities. Even though there are claims that GM crops have the potential to improve yields which may positively impact National Income, Governments must protect their citizens against new products and technologies that may be harmful to health and the environment. Therefore, GM crops are subject to biosafety regulations before release for commercial production and stakeholders which include policy makers, farmers, technology developers and seed companies, consumers, industry, non-governmental organisations (NGOs), the media and scientists have varying interests about diffusion and adoption of these crops. In light of the concerns that are raised about the safety of GMOs, it is also important for this research to establish what role policy makers, farmers, and other stakeholders play in influencing the adoption of GM crops and in protecting the environment.

Research aims, objectives and questions

The following research objectives and related research questions arise both from the identified gaps in existing research and expectations of benefits from this research for practical implementation.

The primary objective of this research is to: identify and critically evaluate the factors that drive or constrain diffusion and adoption of GM crops in Zimbabwe, Malawi and South Africa. A secondary objective emerges from this primary objective which is to: establish how new ideas, technologies and knowledge on GMOs are transferred to smallholder farmers. Finally, a supplementary objective of the research is to: examine how different players or stakeholders, that include early and late adopters of GM crops, can ensure higher productivity from GM crops and protect the environment from potential risks. Therefore, the strategic research questions faced by practitioners and stakeholders who are involved in GM crops are indicated below:

1. What factors drive or constrain the diffusion and adoption of GM crops in Zimbabwe, Malawi and South Africa?
2. How are new ideas, technologies and knowledge on GM crops transferred to smallholder farmers in Zimbabwe, Malawi and South Africa?
3. What role do policy makers, smallholder farmers and other stakeholders play in influencing the adoption of GM crops and protecting the environment in Zimbabwe, Malawi and South Africa?

Contribution of the research

This research contributes to the study of GM crops by identifying the factors that drive or constrain diffusion and adoption of GM crops in Zimbabwe, Malawi and South Africa. It seeks to establish how new ideas, technologies and knowledge on GM crops are transferred to smallholder farmers in Zimbabwe, Malawi and South Africa. In addition, the study contributes to knowledge by establishing the role that policy makers, smallholder farmers and other stakeholders play in influencing the adoption of GM crops and protecting the environment in Zimbabwe, Malawi and South Africa.

Myths and ambiguity embroil the subject of GMOs and the researcher explores the farming communities of Zimbabwe, Malawi and South Africa to understand what motivates farmers to prefer GM crops to conventional crops. The research draws on empirical evidence of data collected from smallholder farmers, policy makers, experts and other stakeholders that are involved in GM crops. Data are also collected during visits at Chitala Research Station, Salima in Malawi and Toleza Farms, Balaka in Malawi where confined field trials (CFTs) and open field trials (OFTs) are conducted as well as during conferences and workshops on biotechnology. Furthermore, as the research contributes to the researcher's professional practice on GM crops, the researcher plans, upon completion of the degree of Doctor of Business Administration (DBA), to disseminate knowledge gained from the research by conducting consultancy projects as well as offering lectures at agricultural institutions and publishing papers at conferences.

Previous Documents

The DBA is a culmination of six documents. The current document, the thesis (Document Five), has a symbiotic relationship with the four previous documents, but it is a stand-alone document. The final document, Document Six, is a reflective statement in which the researcher uses records kept in a journal during the research period to reflect on the DBA journey. The previous four documents are outlined below:

Firstly, Document One introduced the research area on the diffusion and adoption of GM crops in Zimbabwe, Malawi and South Africa. The research questions were defined and mapped and the main question was to identify the economic benefits of GM crops to smallholder farmers. Secondly, in Document Two, a detailed initial literature review on diffusion and adoption of GM crops in Zimbabwe, Malawi and South Africa was presented. The theoretical underpinning of the study was drawn from Rodgers (2003) as well as Scandizzo and Savastono (2010).

Thirdly, an interpretive qualitative research on the diffusion and adoption of GM crops in Zimbabwe, Malawi and South Africa was done in Document Three. The main research objective was to establish the economic benefits and costs to smallholder farmers who would adopt GM cotton in Zimbabwe, Malawi and South Africa. Finally, in order to test the results of the qualitative research of Document Three, a survey-based quantitative research was done in Document Four.

Thesis structure

This thesis is divided into six chapters. In this introductory chapter, the researcher sets the context and background by evaluating what the motivations for this research are. The problem statement, aims and research questions articulating a clear purpose of the research are presented. This Chapter concludes by highlighting and discussing key research objectives and contributions of the research to theory and practice.

Chapter 2 examines the political and economic context of the study. A broad overview of the global status of GM crops is presented to provide an international context. The diffusion and adoption of the technology are examined, with a brief tour of the USA, Europe, India and China. Finally, the status of GM crops in Zimbabwe, Malawi and South Africa is evaluated in detail since the research focuses on these three countries.

Chapter 3 critically reviews related literature and provides an understanding of what is currently known and unknown about GM crops. It includes examining the theories related to the topic of diffusion and adoption of innovations. The findings from previous research on the impacts of GM and non-GM crops on farm productivity and income in Malawi and South Africa since Malawi is conducting research on GM crops and South Africa adopted GM crops. In addition, literature on the effects of GM crops on the health of humans and the environment is evaluated. The literature review helps the researcher to develop a conceptual framework that guides the primary research and enables the researcher to analyse and evaluate the findings that emerge from the primary research to draw conclusions.

Chapter 4 explains the research methodology, which covers the research process and how data collection was conducted and analysed. It explains where data were collected, what methods were used to collect data and how the researcher targeted participants. Justifications for the research questions, the key challenges that the research design responds to and the tools used in the research methods are explained. In Chapter 5, the results of the research are presented and analysed followed by a discussion of the findings. Finally, the conclusions of the research and suggestions for further research are presented in Chapter 6.

CHAPTER 2

POLITICAL AND ECONOMIC CONTEXT

Introduction

In this chapter, the political and economic contexts of the environment of this study, as well as the status of GM crops in the countries under study, are examined. This study on diffusion and adoption of GM crops is conducted in three countries that are located in Southern Africa, which are Zimbabwe, Malawi and South Africa. The map of Southern Africa shown in Figure 2.1 provides a guide to the location of the countries under study which are shaded in the colour green. Zimbabwe is situated north of South Africa and Malawi is located northeast of Zimbabwe. The two countries that are surrounded by South Africa are Lesotho (Ls) and Swaziland (Sz).

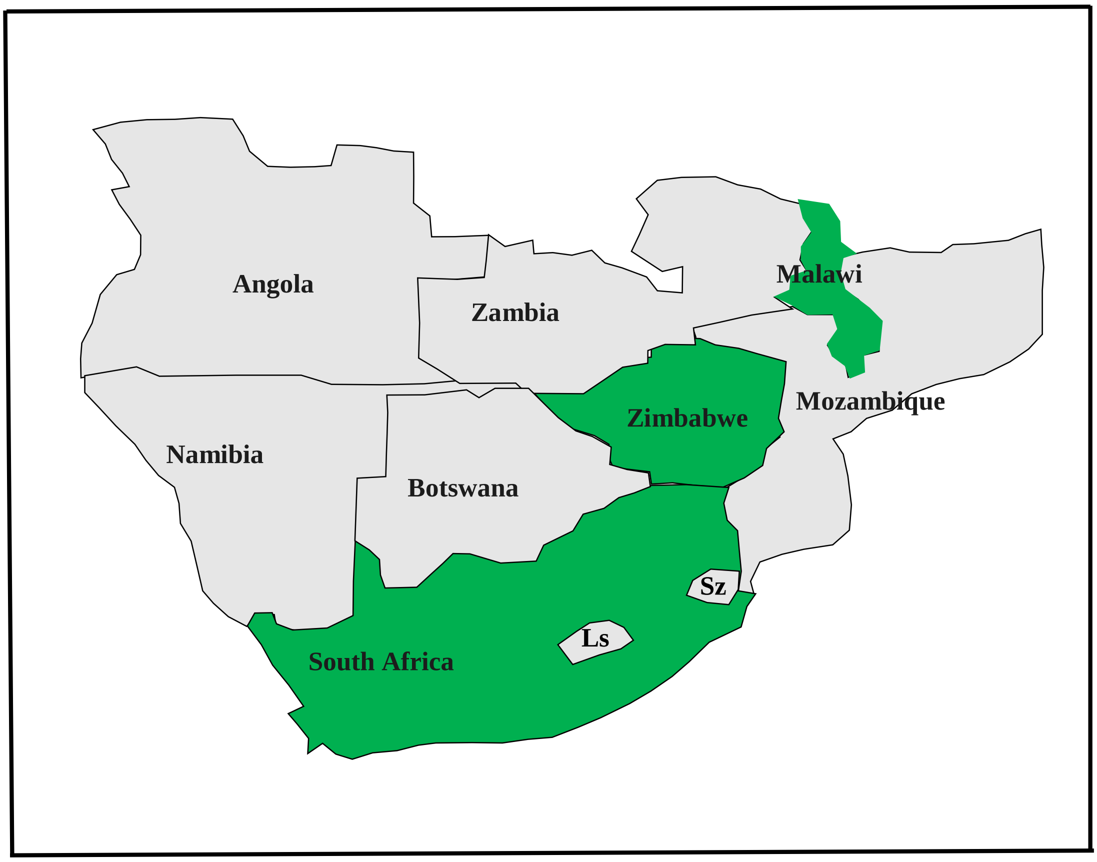

Figure 2.1 Map of Southern Africa

In 2015, the populations of Zimbabwe, Malawi and South Africa were 15.6 million, 17.2 million and 54.4 million respectively (United Nations, 2015). The economies of Zimbabwe and Malawi are dependent on agriculture for their Gross Domestic Product (GDP) and in 2015 this was $13.9 billion and $6.6 billion respectively (World Bank, 2017a). However, according to the World Bank, South Africa with a GDP of $312.8 billion has a larger and more diversified economy than the other two countries in this study.

The three countries under study, that is, Zimbabwe, Malawi and South Africa share similar environmental conditions but show different political and economic approaches on GM crops. The three countries are also at different stages on the diffusion and adoption of GM crops. For example, in 2002 research trials of GM crops were undertaken in Zimbabwe (Mushita *et al.*, 2007). However, the GM cotton was destroyed by government officials because it had been planted without prior government approval (Mushita *et al.*, 2007). A moratorium on GM crops has been in place in Zimbabwe since then (Chideme, 2015).

There is a new political dispensation in Zimbabwe which came about in November 2017. The new government is calling on technology developers and researchers to commence research trials on GM crops. The stance of the new government will result in the Zimbabwe farming community catching up with its neighbours such as South Africa and Malawi on technological development. The previous government's stance was that the technology is relatively new and not yet well understood (Chideme, 2015). In Malawi, research trials of GM crops started in 2012 and by 2018 the research had progressed to pre-commercialisation stage. South Africa adopted GM crops in 1997 (Gouse, 2012). The application of GM crops is also at various stages globally.

Global status of GM crops

Knowledge and information on the global status of GM crops benefit this study. In 2016, twenty-six countries – spanning across five continents including Americas, Europe, Africa, Asia and Australia – produced GM crops on 185.5 million hectares spread over five continents of the world (ISAAA, 2016), thus making GM crops global farming products. The development of GM crops started in the 1970s and commercialisation happened in the United States of America (USA) in 1996 (Halford, 2012). During the first ten years, the diffusion and adoption of GM crops in the USA increased (Fernandez-Cornejo and Caswell, 2014). For example, herbicide-tolerant soyabeans accounted for 87 percent of total soyabean acreage. In 2015, the adoption rate of three main GM crops in the USA was 94 percent soyabeans, 92 percent maize and 94 percent cotton (James, 2015). This adoption rate is attributed to a rise in crop yields by 22%, farmers' profits by 68% (Lucht, 2015) and an increase of farm income benefit of $35 per hectare (Brookes and Barfoot, 2016). However, in Europe and Africa, the technology has not been received with the same enthusiasm due to health and environmental concerns (Twardowski and Malyska, 2015).

The diffusion and adoption of GM crops is higher in countries where farmers freely choose which technology to use between GM crops and non-GM crops (Lucht, 2015). Within the two major economic blocs of the USA and Europe, GM crops are viewed differently in the way they are brought to the market. In the USA, regarding registration for commercialisation, GM crops are mainly considered the same as conventional crops. However, in some European countries, GM crops are viewed as intrinsically different from their conventional equivalent (Davison and Ammann, 2017). Hence, in the USA, the process of approval of an application for GM trials takes twenty-four hours. In contrast, in some European countries it takes up to ninety days (Gomez-Galera *et al*., 2012). In South Africa (see Appendix 3) and Malawi, the process of registration of GM crops takes ninety days. In Zimbabwe, it is indefinite.

Some African countries (see Table 2.1) are showing interest in evaluating GM crops on the backdrop that South Africa – that adopted GM crops in 1997 – is self-sufficient in food and crop production. Table 2. 1 shows twelve African countries that are conducting CFTs of GM crops (James, 2015; ISAAA, 2016, 2017). These are Burkina Faso, Cameroon, Egypt, Ghana, Kenya, Malawi, Mozambique, Nigeria, South Africa, Sudan, Swaziland and Uganda. The purpose of conducting CFTs is to evaluate the efficacy of the GM crops in controlled environments. Of the twelve countries, three have already adopted GM crops, that is, South Africa, Burkina Faso and Sudan. The other nine are still to commercialise GM crops. The situation in Egypt has been start-stop. Egypt suspended production of GM crops in 2010 because there was no biosafety regulatory framework in place, yet a draft of the regulations had been completed as early as in 2004 (Sarant, 2012).

Table 2.1 African countries conducting confined field trials as at 28 February 2017

	Country	Crop
1	Burkina Faso	Cowpeas, cotton and rice
2	Cameroon	Cotton
3	Egypt	Wheat
4	Ghana	Cotton, rice and cowpeas
5	Kenya	Maize
6	Malawi	Banana, cotton and cowpeas
7	Mozambique	Maize
8	Nigeria	Cassava, cotton cowpeas, sorghum and rice
9	South Africa	Maize
10	Sudan	Cotton
11	Swaziland	Cotton
12	Uganda	Maize, banana and cassava

Source: Adapted from James (2015, p.189-190; ISAAA, 2016, 2017)

In 2014, there were only three countries in Africa – South Africa, Burkina Faso and Sudan – that cultivated GM crops commercially (James, 2014). In 2016, the countries that grow GM crops in Africa had been reduced to two. Burkina Faso suspended planting GM cotton in 2016 because the fibre produced by the GM cotton was shorter in comparison with that of conventional cotton and did not meet the required standards (Dowd-Uribe and Schnurr, 2016; Maiga, 2016; Bavier, 2017). According to Dowd-Uribe and Schnurr (2016), Monsanto inserted an insect resistant gene into a local variety of Burkinabe cotton using a backcrossing procedure. To achieve the quality standard, the procedure requires a minimum five backcrosses, but only three backcrosses were done (Dowd-Uribe and Schnurr, 2016). As a result, the GM cotton that was commerciased in Burkina Faso did not meet the quality standards in terms of fibre length.

The technology failure in Burkina Faso reaffirms Correa's (2009) argument that a key issue in technology transfer is its suitability to recipients and markets. Cotton plant breeders serve mainly two distinct markets that have different needs: the farmers and textile processors (Roupakias and Mavromatis, 2010). Farmers demand cotton varieties that are better than the ones they replace in terms of yields and resistance to pests and diseases. The textile processors demand cotton lint that meets quality measured by parameters that include fibre length, uniformity, strength, elongation, fineness and colour (Roupakias and Mavromatis, 2010). It is clear that in Burkina Faso, the technology developers failed to meet the needs of a key stakeholder, the textile processors, hence the suspension of cultivation of GM cotton.

The issues relating to the failure of the technology in Burkina Faso are important for this study because they point to strategies relating to management of technology transfer. Vyakarnam (2013) posits that technology developers should pay attention to issues regarding the translational journey as technology moves from the laboratory to commercialisation. In this regard, the technology developer could have avoided the debacle of suspension of planting of GM cotton in Burkina Faso had they ensured that the technology was ready in terms of quality for the market requirement.

Other developing countries that have adopted GM crops and are of interest to this study include India and China. India adopted insect-resistant GM cotton in 2002 (Qaim, Subramanian, and Sadashivappa, 2009) and by 2008, over 80% of the area planted to cotton was GM cotton (James, 2015). In 2015, 12.2 million hectares of cotton were planted in India and of that, 11.6 million hectares were GM cotton, an adoption rate of 95% (James, 2015). There are similarities in land holdings of farmers that produce cotton in India, Zimbabwe and Malawi. In these countries, the crop is mainly grown by smallholder farmers with land holdings of less than six hectares and cotton fields are between one hectare and two hectares (Kathage and Qaim, 2012).

Even though proponents of GM crops herald India's 11.6 million hectares of GM cotton as an endorsement of GM technology, India has not commercialised staple food crops (Mukherji, 2016). For example, insect resistant GM eggplant that was developed in India by Monsanto in collaboration with Maharashtra Hybrid Seeds Company Limited was not released in India (Medakker and Vijayaraghavan, 2007). The GM eggplant was commercialised in Bangladesh (James, 2015). The eggplant is an important food security vegetable in India and some Asian countries (Kolady and Lesser, 2012). Several studies investigating farm-level impacts of GM cotton were carried out in India, and notable is the study by Kathage and Qaim (2012) on the economic impacts of *Bacillus thuringiensis* (*Bt)* cotton. They found that *Bt cotton* achieved 50% profit gain over the conventional varieties. The high adoption of GM cotton in India has caused challenges of access to non-GM cotton by farmers who want to produce organic cotton as Forster *et al*. (2011) note. Seed companies in India were no longer producing non-GM cotton because of reduced demand.

Another notable country, China commercialised three GM crops: cotton, poplar and papaya (James, 2015). James (2015) notes that about 3.7 million hectares were allocated to planting GM cotton in China, an adoption rate of 96 percent against a total of 3.8 million hectares. According to James (2015, p.11) "strong government support and political will" are key factors that create an enabling environment to advance developments in GM crops. To this end, the government of China has committed financial resources to invest in research on GM crops (Roberts and Bjerga, 2015). Furthermore, the Chinese President, Xi Jinping pronounced that the country prefers home grown solutions and does not encourage foreign companies to dominate the GMO market (Roberts and Bjerga, 2015). However, the industry, for example, Monsanto, is involved in Public-Private Partnerships (PPP) with government agencies in five Indian states (Monsanto, 2018). The purpose of the PPP is to work on programmes in agriculture that aim at introducing new technologies to increase productivity at the farm and improve the lives of farmers.

The next section now turns to the status of GM crops by way of a comparison of the three African countries that are the focus of this study. Discussed first is Zimbabwe.

The status of GM crops in Zimbabwe

Even though Zimbabwe has not adopted GM crops, the country is included in this study because a debate is taking place among stakeholders who include Members of Parliament, scientists, policy makers and farmers, on whether or not GM crops should be adopted (Tsiko, 2018). In 2006, Zimbabwe established the National Biotechnology Authority (NBAZ) with a mandate to oversee the National Biotechnology Authority Act of 2006. However, policy makers are calling for more evidence on the safety and usefulness of GM crops. On 26 May 2005, Zimbabwe ratified the Cartagena Protocol on Biosafety (CPB) to the Convention on Biological Diversity (CBD). The CPB is an international agreement among mainly, members of the United Nations (UN) and on 1 October 2016, it had 170 parties (CBD, 2017). According to the CBD (2017, p. 1), the primary objective of the CPB is to "ensure the safe handling, transportation and use of living modified organisms (LMOs) resulting from modern biotechnology that may have adverse effects on biological diversity, also taking into account risks to human health".

Zimbabwe shares a border with South Africa, and there is no guarantee that Zimbabwean visitors to South Africa do not import seeds of GM crops undetected by the authorities. Furthermore, Zimbabwe's eastern neighbour, Mozambique, started to conduct confined field trials of GM maize in the cropping season beginning 1 September 2016 (ISAAA, 2017). The border between the two countries is porous. Villagers along the border of the two countries live side by side, oblivious of immigration formalities. In this regard, if Mozambique commercialises GM maize, there are high chances that the Zimbabweans in the eastern districts will grow the crop without government approval.

Evidence from South Africa on the effects of GM cotton show 22 percent increase in effective yield in comparison with non-GM cotton (Qaim, 2010). Furthermore, Qaim (2010) found that farmers that adopted GM cotton achieved an increase in profit per hectare of US$91. This study will also seek to establish whether South African smallholder farmers that grow GM cotton achieve higher incomes in comparison with their Zimbabwean and Malawian counterparts that grow non-GM cotton.

The status of GM crops in Malawi

In 2012, the academia at the Bunda College of Agriculture, an affiliate of the University of Lilongwe in Malawi, started to conduct CFTs of insect-resistant GM cotton in collaboration with Monsanto under the supervision of Environmental Affairs Department (EAD). Monsanto provided the GM seeds, and the role of the scientists at Bunda was to evaluate the efficacy of the GM cotton against non-GM cotton. The role of the academia at Bunda College involved monitoring and evaluation of the crop during the growing and harvest stages. The overarching objective of the collaboration was to ensure that GM crops are made available to smallholder farmers in Malawi. The successful CFTs led to the approval by EAD of the release of the GM cotton on 12 April 2016.

After the approval of the insect-resistant GM cotton by EAD, the next step involves scientists at the Department of Agriculture Research Services (DARS) who conduct open field trials (OFTs). The purpose of OFTs is for the government scientists of the Ministry of Agriculture to assess the efficacy of the varieties at various research centres in the cotton growing ecological zones country-wide. The OFTs started in the cropping season beginning in September 2016. The crop varietal release regulations of the Ministry of Agriculture provide that new crop seed varieties must undergo OFTs for a minimum of two cropping seasons before an application can be lodged for commercial release.

In May 2017, results of the first OFT were released by DARS (Appendix 8). The results from various research sites reveal that GM cotton had yield advantage ranging from 44 percent to 88 percent (Malawi, 2017). These results are significantly higher than those in Finger *et al*.'s (2011) findings that show that in South Africa, the farmers that adopted GM cotton achieved a yield advantage of 20 percent. The second stage of the OFTs was planted in November 2017 and they are due for review at the next harvest in May 2018. It is during that time that commercialisation of the GM cotton will be considered.

The status of GM crops in South Africa

In 1997 South Africa passed the *Genetically Modified Organisms Act*, and commercial production of GM crops started the same year with insect resistant cotton (Gouse, 2012). The commercialsation of maize and soyabeans followed in 2001 (Morris and Thomson, 2014). Therefore, there are three GM crops produced in South Africa, that is, maize, soyabeans and cotton (Gouse *et al*., 2016). The adoption of GM crops was rapid and by 2013, the area planted under GM maize had reached 2.9 million hectares, harvesting 14.4 million tonnes (James, 2014). In 2015, the adoption rates had increased to 86 percent for white maize and 92 percent for yellow maize, 100 percent for cotton and 95 percent for soyabeans (James, 2015). The GM cotton seeds available in South Africa are dual-stacked genes that combine insect-resistant and herbicide-tolerant traits (James, 2014). James (2014) points out that the single herbicide-tolerant trait is only used as a mandatory refuge crop to manage insect mutations against the GM crops.

In South Africa, the adoption of GM cotton led to an increase in crop yield of 24% (Brookes and Barfoot, 2016a). However, there has been a marked decline of production of the cotton crop from over 180,000 hectares planted in 1988 to 37,340 hectares planted in 2017 (Cotton South Africa, 2013; 2018). The decline in production is attributed to unfavourable low lint prices during the selling season that causes the farmers to switch to other crops at the time of planting (Cotton South Africa, 2013). Dowd-Uribe and Schnurr (2016) argue that the declining production of cotton in South Africa is an indication of the failure of the technology. However, Dowd-Uribe and Schnurr (2016) do not recognise that the farmers that stopped growing GM cotton did not switch to non-GM cotton, but switched to other higher income crops such as soyabeans and maize, which are higher yielding GM crops too.

Smallholder farmers are the backbone of agriculture in Zimbabwe and Malawi. In South Africa, smallholder farmers comprise the largest number of cotton growers. The next section discusses the conditions of smallholder farmers in the three countries under study in relation to the adoption of GM cotton.

Smallholder farmers

The study is conducted on smallholder farmers who grow cotton in Zimbabwe, Malawi and South Africa. In contrast to large-scale commercial farmers – found in South Africa with fully mechanised farming operations – smallholder farmers are generally resource-poor subsistence farmers and land holding is less than two hectares (Hendrickson *et al.,* 2014). Noticeably, in Zimbabwe and Malawi virtually all the cotton crop is grown by smallholder farmers estimated at around 200,000 and 100,000 respectively. In South Africa, there are 300 large-scale farmers against 3,000 smallholder farmers that grow cotton.

In Zimbabwe, Malawi and South Africa, smallholder farmers sell raw cotton to ginning companies who determine the floor price based on the Cotlook 'A' Index ('A' Index) published by Cotton Outlook (2017) (Baffes, Tschirley and Gergely, 2009; AMA, 2015). The International Cotton Advisory Committee (ICAC) (2017) also relies on the 'A' Index in its international publications that include the monthly press release on the global status of cotton. ICAC is a body that represents governments whose countries grow cotton. The fact that the prices are determined externally by demand and supply fundamentals on the international market means crop yield is the only variable that the farmers can control internally to increase their incomes.

It was explained on pages 3-4 of this study that smallholder farmers in Zimbabwe and Malawi are achieving significantly low yields of cotton against potential. Essentially, smallholder farmers are the majority in the three countries in this study. However, in comparison with large scale commercial farmers, smallholder farmers are the least productive. Therefore, technology and knowledge transfer can potentially give an opportunity to smallholder farmers in poorer countries such as Zimbabwe and Malawi to access the high technologies which would not be ordinarily possible (Qaim, 2016; Ugochukwu and Phillips, 2018).

Extant literature suggests that GM technologies have the potential to increase crop yields for smallholder farmers and it is essential to test the technologies to establish their suitability in local environments (Paarlberg, 2010; Qaim, 2016). This study supports Gouse (2012) and Qaim (2016) that Southern African economies are heavily dependent on agriculture and for their economies to grow, it is important to focus on diffusion and adoption of emerging agricultural technologies that enhance productivity in the small farming sector which commands the majority in Southern Africa. Therefore, this study seeks to establish the reasons for the slow uptake of GM crops in Zimbabwe and Malawi in spite of evidence being presented in many studies (Qaim, 2016) that GM crops have delivered economic and social benefits. The next chapter presents an in-depth discussion of the literature on GMOs.

CHAPTER 3

LITERATURE REVIEW

Introduction

This chapter aims to discuss the key theories on GM crops and review the literature associated with GM crops. A critical literature review is provided on factors that drive or constrain the diffusion and adoption of GM crops in Zimbabwe, Malawi and South Africa. Furthermore, a review of the literature related to technology and knowledge transfer as well as the impact of GM crops on farm productivity, farm income and the environment in the three countries under study is provided. Literature relating to the stakeholder theory and how stakeholders influence the adoption of GM crops including protection of the environment is also reviewed. Emerging from the literature review, the strategic research questions faced by practitioners and stakeholders who are involved in GM crops are indicated below:

1. What factors drive or constrain the diffusion and adoption of GM crops in Zimbabwe, Malawi and South Africa?
2. How are new ideas, technologies and knowledge on GM crops transferred to smallholder farmers in Zimbabwe, Malawi and South Africa?
3. What role do policy makers, smallholder farmers and other stakeholders play in influencing the adoption of GM crops and protecting the environment in Zimbabwe, Malawi and South Africa?

This chapter explores what is known about diffusion of innovations in GM crops and the impact of technology and knowledge transfer of GM crops to smallholder farmers. Most research ideas, technologies and innovations on GM crops have largely been imported from abroad, especially the USA. The researcher explores how the ‘imposition’ of ideas and innovations have influenced crop production in Zimbabwe, Malawi and South Africa. This critical evaluation of the literature guides the development of a conceptual framework which the researcher justifies towards the end of the chapter. The researcher notes that many academic studies were done on the impacts of GM crops, including cotton, on the welfare of smallholder farmers in South Africa. However, these studies did not cover the diffusion and adoption of GM crops in Zimbabwe and Malawi which is the subject of this study. The next section provides an insight into the nature of what GMOs are.

What is genetic modification of crops?

The main focus of this study is on the business issues of GM crops. However, it would be helpful, at the first instance, to gain insights on what GM crops are and to evaluate the reasons why GM crops are produced. Some definitions of GM crops are also presented and detailed definitions of other terms are presented in Appendix 2.

Scientists and academics of GM crops have divergent views about the terms to use to describe GMOs. According to Wagner-Weick and Walchli (2002), supported by Qaim (2016), genetic modification is a misleading term, but genetic engineering would be more appropriate. This, Qaim (2016) argues, is because people have been altering the genetic makeup of crops from time immemorial. However, it is noted that Qaim (2016) recognises the widespread use of the term 'genetically modified' because the title of his recent book is "*Genetically Modified Crops and Agricultural Development*". Other writers, including James (2015), prefer to use the term 'biotech crops' instead of 'GM crops'. This study uses the term 'genetically modified' because that is the term used in legal documents of Zimbabwe, Malawi and South Africa (*Genetically Modified Organisms Act, 1997 of South Africa).*

This study adopts Milavec *et al.*'s (2014, p.6488) definition of GM crops, that is, "organisms in which the genetic material has been altered through the application of gene technology in a way that does not occur naturally through mating and natural recombination". This definition points to two things that must have happened for an organism to be called a GM crop. Firstly, it must have had its deoxyribonucleic acid (DNA) altered and secondly, the alteration must have happened unnaturally between unrelated species (World Health Organisation (WHO), 2014). However, a new technique of genetic modification of organisms by which scientists modify organisms without the introduction of new genes using clustered regularly interspaced short palindromic repeats (CRISPR) tools recently emerged (Khatodia *et al*., 2016). Scientists and technology developers claim that the gene editing technique using CRISPR system holds the promise to speed up diffusion and adoption of GM crops in countries that shun GM crops which contain foreign genes (Bunge, 2017).

This study is focusing on insect resistant and herbicide tolerant (HT) – first-generation – GM crops which were developed to fight crop diseases and increase crop yields (Qaim, 2016). The next generation GM crops that are at various trial stages have traits that address various farmer needs that include abiotic tolerance, ammonium nitrate efficiency and nutritional value of the GM product (Gong and Wang, 2013; Liang *et al*., 2014). If successfully commercialised, it is expected that farmers and consumers will derive more benefits from these crops. The advances in GMO technology do not replace traditional plant breeding as this study accepts Qaim's (2016) argument that the plant breeding methods of conventional and genetic engineering are complementary because the conventional breeder still needs to do the selection and adaptation process of cultivars for suitability in the ecological areas of production. The selected variety is then introgressed with the desired GM trait after conventional breeding.

The process of genetic modification

Currently, two methods are commonly used in the transformation of crops. The one is Agrobacterium-mediated transformation and the other is transformation by particle bombardment, also known as the gene gun (Mahmood-ur-Rahman *et al.*, 2014). The two methods are performed by scientists in controlled laboratories at various institutions that include universities, public research institutes and private research institutions. The first stage of genetic modification involves the selection of the desired trait (Halford, 2012). For example, Ismael, Bennett and Morse (2001) argue that the cotton bollworm causes significant losses in yields in cotton farms all over the world where cotton is grown. Therefore, cotton farmers derive immense value from a cotton crop that contains an inbuilt insecticide against the bollworm caterpillar (Kranthi and Kranthi, 2010). To address the farmers' needs, technology developers identified and isolated a gene of a bacteria that has toxic protein which kills a target group of caterpillars. The transformation of a plant is done using one of the two methods: Agrobacterium or the gene gun (Mahmood-ur-Rahman *et al.,* 2014). Upon successful insertion of the gene into the genome of the cotton plant, the genes are multiplied using the tissue culture method in the laboratory (Halford, 2012). An unintended consequence can be suffered whereby GM plants can contaminate their wild relatives through cross-pollination (Andersson and de Vicente, 2010; Breckling *et al.,* 2011; Murnaghan, 2017). Therefore, the stakeholders involved in the production of GM crops should consider the environmental risks and take mitigation measures to minimise the risks of contamination.

The long process of genetic modification, coupled with a considerable capital outlay needed, are barriers to entry for the GM crop industry. For example, it takes about ten years to develop and market a GM product and capital costs can accumulate to about US$100 million by the time the product is launched in the market (Halford, 2012). In contrast, McDougall (2011) finds capital costs to be higher at US$136 million for the discovery and development of a new trait of GM crop through to its registration and product market launch. As a result, only a few multinational companies (BASF, Bayer Cropscience, Cargill, Dow AgroSciences, DuPont Pioneer, Monsanto and Syngenta) can afford to undertake the research and development of GM crops (Wambugu, 2014; Parisi, Tillie and Rodriguez-Cerezo, 2016). However, Kranthi and Kranthi (2010) suggest that the discovery of new genes by public funded institutions in the developing world can lower the price of GM seeds for smallholder farmers. The next section discusses what is known about the factors that influence diffusion and adoption of GM crops.

Theories of diffusion of innovations

In this section, theories by leading authors on the diffusion of innovations are reviewed. The theory of diffusion of innovations is important to this study because, in Southern Africa, GM crops are at various stages of adoption. This study draws on Rogers (2003) study which leads the debate on diffusion and adoption of innovations and has been used in many studies on GM crops (Wagner-Weick and Walchli, 2002; Aizstrauta, Ginters and Eroles, 2015). The study also reviews Qaim's (2010) articles which lead studies on the economic benefits of GM crops to farmers in developing countries. In addition, the study examines Gouse's (2012) work on the impact of GM crops in South Africa.

Diffusion is "the process by which an innovation is communicated through certain channels over time among members of a social system" (Rogers, 2003, p. 11). Scandizzo and Savastano's (2010, p. 145) provide a definition that complements Rogers' which is, "the endogenous process by which individual adoption decisions influence each other and coalesce, thus causing the endogenous determination of the spread of the new technology". This study adopts Rogers' (2003) definition because it embodies four elements that are relevant to the study, that is, an *innovation, communication channels, time* and the *social system*. The four elements are evaluated in turn starting with the innovation:

The Innovation

In line with Rogers (2003), for the purposes of this study, GM crops are the innovation, idea and practice that is perceived by the farmers, who are the adopters, as new. It is not the newness of the idea or product that matters but how the potential adopters perceive it. Even though some farmers in South Africa have planted GM crops since 1997 (Gouse, 2009), they remain an elusive new idea, yet to be explored by farmers in Zimbabwe and Malawi. Rogers (2003) argues that five factors, *relative economic or social advantage, compatibility, complexity, trialability* and *observability* determine the diffusion and adoption of innovations. The five factors are critically analysed in turn.

Relative economic or social advantage

Relative advantage is the degree to which an innovation is perceived as better than the idea it supersedes (Rogers, 2003). To persuade farmers to adopt an innovation – GM crops – the change agents need to prove that GM crops perform better than the existing technologies, which in this case are conventional non-GM crops. Farmers will invest in new technology if this will help reduce uncertainty regarding perceived benefits (Scanndizzo and Savastono, 2010).

The findings by Gouse's (2012) study of South African smallholder farmers that produced GM maize and isogenic non-GM maize revealed that GM crops have a relative economic advantage against non-GM crops. Figure 3.1 shows the yield comparison of insect-resistant GM maize (Bt Maize) and herbicide tolerant GM maize (HT Maize) against conventional non-GM maize varieties.

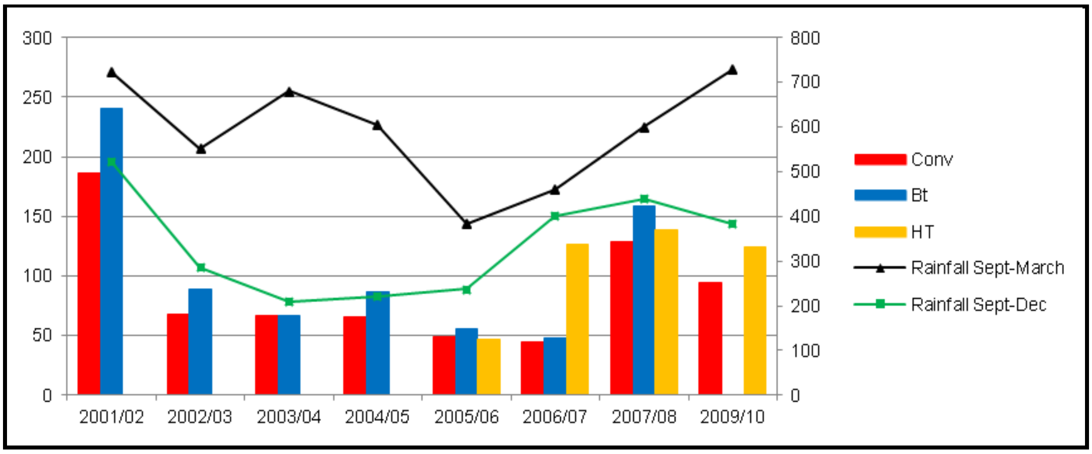

Figure 3.1 Yield comparison for conventional, Bt, and HT maize for the eight seasons 2001/02 - 2007/08 and 2009/10.

Source: Gouse (2012)

The results shown in Figure 3.1 reveal that during the periods under Gouse's (2012) study, in South Africa, GM maize consistently produced higher yields than the conventional varieties except for the 2003/04 season in which the output for GM maize and conventional non-GM maize was similar. Gouse (2012) attributed the similarity in yield to drought conditions that prevailed during the cropping season. The yield performance of both GM maize and non-GM maize was relative to the rainfall pattern; the more the rainfall received during the year, the higher the yield. The variation of yield according to weather partterns is a recurring phenomenon in smallholder farming communities who rely on rain-fed agriculture without supplementary irrigation facilities. Gouse (2012) proved that farmers who adopted GM maize achieved higher yields in comparison with farmers that grew non-GM crops. However, Gouse's study does not extend to establish whether the farmers also achieved higher incomes.

If given the wide selection of competing crops, farmers make decisions on what crop to grow based on profitability per unit of land used for cropping (Mannion and Morse, 2012). In other words, it would appear that in the farmers' view, the choice of which technology to use is determined by relative advantage of the technology against alternative technology measured in economic terms. Dharmasiri (2012) argues that farm productivity is measured as the ratio of farm output against farm inputs. When using Dharmasiri's (2012) formula to establish the effectiveness of the adoption GM crops on farm productivity, the income achieved by the farmer is divided by the cost of production of a GM crop. The income that a cotton farmer receives is a function of the quantity of harvest achieved and the price paid for cotton per kilogramme.

The impact of GM cotton on farm productivity is analysed using Qaim's (2010) study of Indian farmers. However, Qaim (2010) used the term 'enterprise budget' in Table 3.1 which may be misleading because the data is not farmers' planned activities but actual results of Qaim's study. Table 3.1 is an extract from Qaim (2010, p. 553) and the researcher calculated the percentage increase or decrease using the data provided in GM cotton and non-GM cotton columns, and inserted the column that shows the changes.

Table 3.1 Crop enterprise budgets for Bt and conventional cotton in India: 2006

	GM cotton	Non-GM cotton	% increase/ (decrease)
Number of insecticide sprays	3.3	3.8	(13%)
Insecticide use (kg/ha)	3.0	3.8	(21%)
Yield of raw cotton (kg/ha)	2,080	1,458	43%
Production cost (US$/ha)			
Seed	41.3	24.7	67%
Insecticides	60.4	58.6	3%
Fertilizer	100.5	75.5	33%
Labour	236.9	209.4	13%
Other costs	58.1	34.5	68%
Total cost	497.2	402.7	23%
Revenue (US$/ha)	864.0	617.9	40%
Profit (US$/ha)	366.7	215.2	70%

Source: Qaim (2010)

Table 3.1 shows that in 2006, farmers that grew GM cotton in India sprayed their crop 3.3 times against 3.8 sprayed on non-GM cotton and yield of GM cotton of 2,080 kilograms was 43 percent higher than non-GM cotton of 1,458 kilograms. The seed price of GM cotton was 67 percent higher than non-GM cotton, and notably, the cost of insecticides was 3 percent higher for GM cotton. One weakness of Qaim's (2010) study is that the fertiliser applied to the two different crops was not equal. The higher yield achieved by GM cotton farmers might have been partly caused by higher application of fertiliser which was 33 percent higher than the non-GM cotton. Furthermore, labour cost for GM cotton was 13 percent higher than that for non-GM cotton. Other costs were 68 percent higher for GM cotton and the total cost was 23 percent higher for GM cotton. The farmers that grew GM cotton achieved revenue per hectare that was 40 percent higher than that achieved by their counterparts who grew non-GM cotton. The difference in profit achieved was US$151.50 or 70 percent higher for GM cotton against non-GM cotton. These profits should be sufficient to influence Indian farmers to adopt GM cotton. As a result, the adoption of GM cotton in India is 95 percent (James, 2015).

Effects of insect resistant GM cotton on boll retention

As mentioned earlier, the first-generation GM crops were developed to improve crop yields through control of diseases and pests (Qaim, 2016). Cotton yield is determined by the plant population per unit area of land, the quantity of retention of bolls on a plant and the weight of bolls (Chaudhry and Guitchounts, 2003). Therefore, to achieve higher yields the farmers focus on preservation of plant population and cotton bolls on the plants. The bollworm is a major pest that affects yields of cotton in Africa (Schnurr, 2012). The *Bt* cotton is a variety of cotton that has an insect-resistant gene inserted which enables the crop to protect itself from leaf and boll-feeding worms, reducing the need for applications of insecticides (Monsanto, 2015). However, the insects can mutate and build resistance against the *Bt* cotton (Adenle, 2014). In 2015, farmers in India and Pakistan suffered yield losses caused by the pink bollworm which developed resistance against the first generation *Bt* gene (ICAC, 2016). The biotechnology industry responded by putting in place crop management preventative measures. The preventative measures involve planting a non-GM crop in the same field with GM crop so that insects can feed on non-GM crops to mitigate resistance when the resistant insects mate with non-resistant insects (Sanahuja *et al*., 2011).

A comparison of chemical use: non-GM cotton and Bt cotton

To achieve boll retention, the farmers that grow non-GM crop need to spray chemicals that protect their crop from bollworms (Juma, 2016). It was established that in the event of a heavy rain downpour immediately after spraying a crop, the insecticide becomes ineffective (Sanahuja *et al*., 2011). In this regard, the inbuilt insect-resistant GM cotton has a comparative advantage because the crop is always protected during the vegetative stage. The realisation that insect-resistant GM cotton reduced the number of sprays motivated farmers in South Africa to adopt the technology (Bennett, Morse and Ismael, 2006). Furthermore, Bennett, Morse and Ismael (2006) found out that a single spray per hectare would take 4.6 hours, 7.2 knapsacks, 118.1 litres of water and the farmer would walk 9 kilometres. Men would be spraying and women – sometimes children – fetching water from long distances (Bennett, Morse and Ismael, 2006). They note that the smallholder farmers were resource-poor and did not have adequate protective clothing for use in spraying toxic chemicals. That led to high incidents of chemical poisoning, which in some cases resulted in loss of life.

A review of studies done on similar phenomena in other developing countries reveals that in China, farmers who use insect-resistant GM cotton reduced the number of pesticide sprays from thirty to three times per season (Pray *et al.*, 2001). Brookes and Barfoot (2016b) established that in China, between 1996 and 2014, the use of insecticides was reduced by 123.6 million kilograms as a result of adoption of insect resistant GM cotton. In India, the reduction in chemical resulted in less toxic chemicals stored in homes, leading to reduced risk of exposure of children to the harmful chemicals (Kouser and Qaim, 2011). Furthermore, they found that less toxic chemicals were released into water bodies. Some farmers may not be able to comprehend the instructions on chemical dosage provided in leaflets or on container labels hence accidents may occur. In some cases, the wrong dosage may be applied to the crop leading to poor performance of the chemical.

Compatibility

The second attribute relates to the degree to which an innovation is consistent with existing values, cultural beliefs, past experiences, and the needs of the adopters (Wagner-Weick and Walchli, 2002; Rogers, 2003). A new way of farming that is incompatible with the values and norms of a social system will not be adopted as rapidly as an innovation that is compatible. One factor that constrains the diffusion and adoption of GM crops are the perceived risks to humans, animals and the environment (Pellegrini, 2013).

Risks of GM crops to humans and animals

A classic definition of risk is provided by Knight (1921) who differentiates risk from uncertainty. Knight (1921) characterises risk as measurable and uncertainty as immeasurable. The perceived harm associated with GM crops is immeasurable and the safety of GM crops cannot be 100% guaranteed (Chadwick, 2017). Haimes' (2009) definition of risk includes the probability of the occurrence of an adverse effect. To manage risks associated with GMOs, countries have enacted biosafety laws and regulations that require that GM crops undergo safety evaluation before they are released commercially (Carstens *et al.*, 2012; Pellegrini, 2013; Kamle and Li, 2016).

The inherent presence of uncertainty – as perceived by adopters – about costs, benefits and health issues of GM crops, is a risk that constrains the diffusion and adoption of GM crops (Nadolnyak and Sheldon, 2002). In Ethiopia, Akay *et al*. (2012) found strong risk aversion among poor rural farmers that did not have access to information about new agricultural technologies, leading to the low adoption of new technologies. Comparatively, Barham *et al.* (2014) suggest that ambiguity aversion is higher with farmers that have knowledge about new technology and there is higher adoption rate of new technologies. In the diffusion and adoption of technologies, trialability and observability are used to enhance communication about the new product with the adopters. Barham *et al.* (2014) argue that the agents that promote new technology should endeavour to eliminate ambiguity and make outcomes more predictable. The researcher notes that in Africa, technology developers use CFTs to showcase the performance of GM crops. At the CFTs, the stakeholders, scientists and researchers exchange knowledge about GM crops that include the potential health risks to humans and animals that are associated with GM crops.

The two studies by Ewen and Pusztai (1999) and Seralini *et al.* (2012) (retracted by *Food and Chemical Toxicology* and republished by *Environmental Sciences Europe* in 2014) reveal the health risks to animals that consumed GM products. Ewen and Pusztai (1999) fed rats with a GM potato for ten days and the rats developed a proliferation of the gastric mucosa. The researchers observed that the stomachs of the rats fed with the GM potato had been damaged. Similarly, Seralini *et al.* (2012) found that rats developed tumours after eating herbicide-tolerant GM maize over ninety days. Both reports caused concern about the potential effects of eating GM products to people's health (Adenle, Morris and Parayil, 2013). In addition, a study by Guyton *et al*. (2015)

which assessed the carcinogenicity of the herbicide *Glyphosate* suggests that *Glyphosate* is probably carcinogenic to humans.

Concern about GM crops has been raised because the *Bacillus thuringiensis (Bt)* crops are known for their toxic effects on specific insects which die after eating their foliage (Lone *et al*., 2016). However, Sanahuja *et al*. (2011) point out that the *Bt* toxin is effective during the early stages of the larvae and older larvae are more tolerant of the toxin. Furthermore, Christou and Twyman (2004) explain the biological differences between the stomachs of human beings and the guts of the small insects that are killed at their early stages by the *Bt* toxin. The guts of human beings are acidic as opposed to the alkaline guts of the insects targeted by the *Bt* crop (Christou and Twyman, 2004; Thomson, 2015).

Meanwhile, in 2012, Walsh *et al.* (2012) carried out a study to establish the effects of feeding pigs with insect-resistant maize. The study was done over a period of 110 days and they fed the pigs with a Monsanto insect-resistant *Bt* Maize variety and its non-GM equivalent. Walsh *et al.* (2012) concluded that the pigs suffered no adverse health effects, including allergies, after eating *Bt* maize during the trial period. Their finding supports Key, Ma and Drake's (2008), who claim that regarding health effects, transgenic crops are not different from conventional crops and all crops have potential risks of allergies.

The causes of various food allergies are traced to proteins found in mammalian milk, fish, soyabeans, peanuts and rice (Wang and Sampson, 2011). However, food allergens are not new because they have always been present in most food products well before GM crops were released (Halford, 2012). GM crops are safer because the R&D that is conducted on them is more stringent in comparison to non-GM crops (Key, Ma and Drake, 2008). The evaluation of transgenic crops against allergies is done using *bioinformatics*, a unique management information system for molecular biology that has many practical applications (Luscombe, Greenbaum and Gerstein, 2001). This software is also used to screen transgenic crops against potential allergenicity (Ladics *et al*., 2011).

Potential risks to the environment

Among the major concerns of the risk of GM crops to the environment is their inability to be taken back once they have been introduced into the environment (Halford, 2012; Taleb *et al*., 2014). Halford (2012) further illustrates this by pointing out that maize and cotton have wild relatives that they can cross-pollinate. Halford's argumement resonates with irreversible risk to the environment which Douglas and Wildavsky (1983) identified ahead of the introduction of GM crops. GM crops have the potential to "sexually hybridise with non-GM plants through the transfer of pollen", for example, maize pollen can travel several hundred meters (Key, Ma and Drake, 2008). This can cause unintended consequences because, in a communal environment where farmers are densely populated, a single farmer's crop can contaminate other farmers' crops. However, it may be argued that the neighbours of smallholder farmers who grow GM crops may benefit from receiving free traits, provided the trait is desirable to the receiving farmers and the farmers use farm-saved seed. There is an inherent risk that GM crops can transfer genes to their wild relatives that impact biodiversity (Andersson and de Vicente, 2010; Taleb *et al*., 2014; Murnaghan, 2017). In this regard, the measures that mitigate the risk need to be established including the application of the precautionary principle (Taleb *et al*., 2014).

Herbicide tolerance (HT) and *Bt* insect resistance are the traits that are commonly available and widely adopted for GM cotton (Smith, 2011). The traits are usually offered as a dual-stacked package, meaning that the genes are combined in the seed and farmers have the option to spray *Glyphosate* herbicide on the emerged crop for the control of weeds and the plants are insect resistant too. The International Food Information Council Foundation (IFIC) claims that *Glyphosate* is sixteen times less toxic than older herbicides, making it more environmentally friendly (IFIC, 2018). The IFIC (2018) further claims that carbon emission is lower at farms that use GM crops because less toxic chemicals are sprayed for the control of pests. In the Ecological

Society of America report of 2005, Snow *et al.* (2005) argue that the ecological benefits of herbicide-tolerant crops include preservation of topsoil and erosion due to minimum tillage (Snow *et al.*, 2005). However, Deb *et al.* (2013) argue that farmers who grow HT crops invariably apply higher amounts of herbicides with the effect of "altering the plant and wildlife biodiversity". Also, Deb *et al.* (2013, p. 313) claim that there is a potential risk of HT crops cross-pollinating with non-HT crops, thereby causing the crossed crop to behave like "super weeds". The issues on risks of GM crops are summarised by Taleb *et al*. (2014) who argue that the risk posed by GM crops is systemic, irreversible ruin and should be classified under the precautionary principle. As such, Taleb *et al*. (2014) urgue for suspension of production of GM crops because the discovery of the harm caused by GM crops may happen after considerable damage.

Complexity

Complexity relates to what degree the innovation is relatively difficult to understand or use by potential adopters (Rogers, 2003). Of the five characteristics of an innovation, complexity is the one that negatively impacts the adoption of an innovation. The more difficult to grasp an innovation is, the slower it is to diffuse (Rogers, 2003; Sahin, 2006). Dibra (2015) argues that innovations that require adopters to develop new skills do not diffuse quickly. On the face of it, GM cotton would seem not difficult for farmers to understand because the physical appearance of GM cotton planting seed and conventional non-GM cotton is the same. Furthermore, farming methods of GM cotton and non-GM cotton are the same.

However, once planted, GM crops are irreversible and the farmers can be concerned about this. Furthermore, farmers are exposed to high prices of GM seeds which are exacerbated by the world market of GM crops dominated by a few multinational corporations (Arcieri, 2016). An illustrative case is a withdrawal by Monsanto of an application to register its new GM technology 'Bollgard II RRF®' in India reportedly because the company is at loggerheads with the government over seed prices (Mukherji, 2016; Mulvany, 2016).

A discussion that has dominated the debate about the adoption of GM crops in Africa is the concern about losing sales of agricultural commodities to European countries. However, none of the three countries under study export any grain or stock feed to Europe. In relation to other agricultural commodities, Malawi exports raw sugar and tobacco. Likewise, Zimbabwe exports tobacco, raw sugar and cotton lint mainly to China and other Asian countries; whereas South Africa exports ostrich meat to Europe. Exports of agricultural products by African countries to Europe are important because they are a source of foreign currency earnings and impact positively on balance of payments. The Zimbabwean Minister of Agriculture was forthright about Government stance on GM crops when he was quoted in The Herald newspaper telling seed companies not to introduce GM crops in Zimbabwe because Germany had expressed interest in importing Zimbabwean horticultural crops (Chikwati, 2017).

A number writers including Paarlberg (2008) and Atkinson, Roderick and Tripathi (2015), note that government policy makers in Africa fear the risk of losing export markets to Europe if their countries adopt GM crops. According to Aghaee *et al*. (2015), Namibia banned imports of GM maize from South Africa in 2000 after buyers from the European Union (EU) withdrew from buying beef on suspicion that the cattle had been fed GM based stock feed. However, Masip *et al.* (2013) point out that 80 percent of stock feed in the EU is imported from GM producing countries in South America and the USA. In a related study, Twardowski and Malyska (2015) state that the EU imports 30 million tonnes of GM soyabean and maize annually for stock feeds. Therefore, this points to policy inconsistency about how the EU views imports of agricultural products from Africa. In 2016, four countries cultivated insect-resistant GM maize in Europe led by Spain with 129,081 hectares, Portugal with 7,069 hectares, Slovakia with 138 hectares and Czechia with 75 hectares (ISAAA, 2016). Most European countries do not support the production of GM crops.

South Africa exports agricultural products to its neighbouring countries which have not yet adopted GM crops. In 2015, South Africa exported 66,355 tonnes of poultry products to Lesotho, Mozambique, Namibia, Zimbabwe, Botswana, Swaziland and

Zambia (South African Poultry Association, 2015). Soyabean meal and maize meal are the main raw material ingredients for chicken feed. This study notes that 95 percent of soyabeans and 92 percent of yellow maize grown in South Africa are genetically modified (James, 2015). Therefore, over 90 percent of the chicken exported by South Africa is fed with GM products. Hence, there is 90 percent chance that people in Zimbabwe and other Southern African countries that buy imported chicken from South Africa eat chicken fed with GMO products.

Trialability and observability

According to Rogers (2003), supported by Dibra (2015), innovations which can be tested and verified by potential adopters are adopted sooner. Before a GM crop is registered and released for commercial production, it is a biosafety regulatory requirement that the technology developer conducts confined field trials (CFTs) under the supervision of government regulatory officers. This requirement is entrenched in the biosafety laws of Zimbabwe, Malawi and South Africa. In Malawi, the CFTs are conducted in terms of the guidelines provided by the Environmental Affairs Department (EAD) of the Republic of Malawi (2009).

However, in conducting the CFTs, the strategic goal of technology developers is to evaluate the performance of the new GM crops against the conventional equivalent varieties as the first step towards commercialisation of GM crops in the target market (Waithaka *et al*., 2015). At the CFTs, crops under evaluation are planted side by side, GM crops and non-GM crops of the same varieties, that is, the transgenic and the isogenic lines. In the diffusion of GM crops, trialability and observability also give stakeholders an opportunity to assess the risks associated with GM crops.

Thus far, Rogers' (2003) five characteristics of an innovation, that is, relative economic or social advantage, compatibility, complexity, trialability and observability which determine the diffusion and adoption of innovation have been evaluated. The next section examines technology and knowledge transfer issues of technology developers in their quest to protect their investments in research and development in the marketplace.

Technology and knowledge transfer

In the diffusion theory, Rogers (2003) argues that the less difficult it is to understand an innovation, the faster the innovation diffuses. In this study, technology and knowledge transfer deal with the issues that are related to how multinational corporations (MNCs) such as Monsanto, take GM crops from the laboratory to smallholder farmers. One of the factors that constrain the development of GM crops in Southern Africa is the financial resources that are required in order to carry out research and development (R&D) which exceed US$100 million (Halford, 2012; McDougall, 2011). The technology developers also bear costs in respect of compliance for regulatory approval of new GM crops which range between $7 million and $15 million (Kalaitzandonakes, Alston and Bradford, 2007). In addition, the time lag between product development and commercialisation which ranges between eight and ten years is too long (Halford, 2012; Phadke and Vyakarnam, 2017). According to Kumar *et al.* (2015), it would not be possible to transfer technologies from the developed countries such as the USA to developing countries such as Zimbabwe, Malawi and South Africa without some formal agreements that include national laws and regulations. Such laws include patents and intellectual property rights (IPR).

Patents

Patents are defined by Van Norman and Eisenkot (2017, p. 89) as “the instruments by which inventors retain for a limited period of time the exclusive rights to exclude others from using the invention”. This definition is supported by Chien (2016, p. 1083) who argues that IPR offer “the right to exclude, including the right to pursue legal actions against others for copying and misappropriating one’s work”. A technology developer, Monsanto, uses patents as barriers to entry into the market for GM crops (Moran, 2014) as well as defensive strategies of protecting its existing GMO traits (Li and Yu, 2007).

The defensive strategies used by Monsanto in the USA include suing farmers and other companies for infringement of its patents as in the case of Bowman v. Monsanto (Gambini, 2013) and Monsanto v. DuPont and DuPont Pioneer (Dow Jones Institutional News, 2012). In the USA, to register patents, the technology developer is required to disclose details of the invention in return for the IPR guaranteed by patent law (Moran, 2014). Patents may also be inputs in the innovation process as they disclose information about the technology (Corbel and Le Bas, 2010). In this regard, Moran (2014) argues that the publishing of technical details is one of the advantages of patents in that they enable knowledge transfer as the other scientists and researchers learn how the innovation is made.

The technology developers of GM crops also use licencing as a form of technology transfer arrangement. For example, Monsanto offers its GM seeds under licence for propagation by seed companies and traits to other companies in return for royalty payments or licence fees (Monsanto, 2018).

In Malawi, in relation to knowledge transfer, the technology developer and seed company invite groups of farmers and other stakeholders to CFTs and OFTs on what has been dubbed, ‘seeing is believing tours’. The field visits are used to transfer technology and knowledge from the GM technology developers to farmers who are the adopters and other stakeholders who include regulators and disseminators. At such visits, the farmers interact with scientists from the technology developers as well as government researchers. According to Valente and Davis (1999), opinion leaders accelerate or deaccelerate the diffusion of innovations. It would be helpful to establish whether the technology developers and seed company make use of opinion leaders and how the selection of opinion leaders is carried out. According to Rogers (2003), the second element in the diffusion of innovations is communication channels and this is evaluated next.

Communication Channels

This section evaluates the second element in the diffusion of innovations, communication channels. Communication plays an important role in the diffusion and adoption of GM crops (Ezezika *et al.,* 2012). Technology developers use some communication channels that include CFTs, one-on-one discussions at workshops, the media and social media on the Internet (ISAAA, 2013). The technology developers and seed companies use CFTs to communicate the potential relative advantage of GM crops to key stakeholders. The CFTs as channels of communication improve the understanding of GM crops by relevant stakeholders as farmers interact with scientists and physically see the plants under evaluation. In most cases, the farmers can make a comparison of the performance of the GM crops against non-GM crops in a real-world environment.

Time

The third element in Rogers' (2003) diffusion of innovations is *time* which measures the rate of adoption of an innovation in communities. However, in the innovation decision-process, various authors identify political will and biosafety regulations as factors that affect the diffusion and adoption of GM crops in Southern Africa (James, 2015). Several studies on adoption of GM crops in Africa identify biosafety regulations and political will as critical factors that determine the rate at which GM crops are diffused in Africa (Alhassa and Adekunle, 2014; Wambugu, 2014; Mabaya *et al.*, 2015; James, 2015). These factors are evaluated in turn:

Biosafety regulations

The diffusion of GM crops is slow because Governments, in most countries, regulate GM crops to ensure the safety of humans, animals and the environment (Jaffe, 2004). In Zimbabwe, Malawi and South Africa, biosafety regulations are mainly guided by the Cartagena Protocol on Biosafety (CPB) of the Convention on Biological Diversity (CBD) (2017) which was finalised by member countries and adopted in Montreal, Canada in 2000. The CPB is considered important because its objective is to ensure protection and safety in the movement of GMOs between member countries. The CPB encompasses membership of more than 140 countries (Kinderlerer, 2008) and Zimbabwe, Malawi and South Africa are signatories to the agreement.

One feature of the CPB is the precautionary principle derived from Principle 15 of the Rio Declaration on Environment and Development (United Nations, 1992) which provides that, where there is sufficient doubt about possible risks of new technologies, it is better to stick to existing practices than change them. Taleb *et al*. (2014) argue that GM crops should be under the precautionary principle mainly because of their irreversibility when they crossbreed with wild relatives. Proponents of GM crops that include Paarlberg (2008) have accused some African governments of abusing the precautionary principle and of being overly protective, leading to failure to embrace new technology. However, the study notes that the CPB came into being in 2000 and innovations which include gene editing had not been discovered. This means that there is need to encorporate these into the CPB.

Political will

It is essential to analyse the impact of government policies on GM crops because many studies have revealed that singularly, government policy, as driven by its political will, is a key variable that determines the success or failure of commercialisation and adoption of GM crops in Africa (Wambugu, 2014; Mabaya *et al.*, 2015; James, 2015). The political will of policy makers in governments, argues Wambugu (2014), is the foundation to achieving acceptance of the technology and the taking up of GM crops in Africa. In support, Alhassan and Adekunle (2014) establish that in African countries where GM crops were adopted, the pronouncements by Heads of State in favour of GM crops translated into favourable biosafety laws that allowed the CFTs and commercialisation of GM crops. This was the case in Burkina Faso where the President supported the adoption of GM cotton (Traore, Hema, and Traore, 2014). For Aerni (2005), the political decisions on the adoption of GM crops are shaped by factual knowledge, stakeholder interests and prevailing public perception.

Government commitment and political will in the adoption of GM crops is re-enforced by Okeno *et al*. (2013, p. 126) who note that, "A government commitment to GMOs is evidenced by the establishment of clear and transparent regulatory frameworks, support for GM crops, public awareness strategy and increased capacity in the approval process". In their study, biosafety regulations, training and stakeholder awareness are recognised as the critical elements in the adoption of GM crops. The biosafety regulations can either be driving or restraining forces for the adoption of GM crops. In Egypt, for example, forty tonnes of GM seed maize that had been imported from Monsanto of the USA in 2012, was confiscated by the Ministry of Agriculture because there was no approval for the planting of GM maize from the Egyptian Ministry of the Environment (Sarant, 2012). The "biosafety policy framework is a political process by design", therefore, the key essential element to succeed in the adoption of GM crops is political will (Wambugu, 2014).

The studies cited above define political will in terms of the policy makers and the politicians' readiness to embrace the GM crops. However, the other side of the coin could be the political will of the technology developers and seed companies. Notwithstanding the fact that technology developers and seed companies are commercial enterprises driven by the profit motive, the political will of these technology developers and seed companies may be defined in relation to technology transfer – the willingless of technology companies to move into new territories and markets that have not yet taken up the technology and embrace the cultural aspects of the locals. Dowd-Uribe (2014) presents the example that in 2003, Monsanto entered a partnership with the government of Burkina Faso to build a research facility and introgressed insect resistant traits into two local cotton varieties. Schnurr (2013) presents a further example that in Uganda, the farmers prefer Bt cotton, but, policy makers prefer that the insect resistant genes be inserted into local varieties that are known to the farmers and have been adapted to the local ecological environment. However, the technology developers have not shown interest in the suggested public-private partnership (Schnurr, 2013). Meanwhile, Walters (2006, p.29) points out that policy makers in Zambia, a Southern African country, did not support the adoption of

GM crops because they did not want “the seed industry to be in the hands of a few large firms”. The diffusion of GM crops happens within a social system and the researcher now turns to the discussion of the social system of GM crops.

The Social System

The definition of a Social System is given by Rogers (2003, p. 23) as “a set of interrelated units that are engaged in joint problem solving to accomplish a common goal.” This study supports Rogers’ (2003) definition and takes note that the members involved in the diffusion and adoption of GM crops in Zimbabwe, Malawi and South Africa within Social Systems comprise diffusers, adopters, regulators and disseminators of information. Furthermore, the study notes that Aerni and Bernauer (2006) argue that stakeholders’ interests and power impact diffusion and adoption of GM crops. Therefore, it is important to identify and analyse the diffusers, adopters, regulators and disseminators of information about GM crops who make up the Social System of GM crops in Zimbabwe, Malawi and South Africa.

According to Aerni (2005) and Ezezika *et al*. (2012) members of a Social System involved in GM crops in Southern Africa include policy makers, farmers, technology developers and seed companies, consumers, ginners, Non-governmental organisations (NGOs), the media and scientists. In Aerni’s (2005) study of stakeholder attitudes towards the risks and benefits of GM crops conducted in South Africa, five stakeholder groups that included the academia, NGOs, government, business, and other stakeholders were identified. An analysis of Aerni’s ‘other stakeholders’ shows that it includes a group named ‘producer organisations’. It is not clear who the producer organisations are and what they produce. Also, in Aerni’s study, there is a discussion of farmers, but they are not listed as a separate category of stakeholders. Aerni (2005) also mentions that the media were participants in the study and again, they are not listed separately. In comparison, Ezezika *et al*.’s (2012) study provides a more detailed list of stakeholders that include, farmers, seed companies, regulatory institutions, NGOs, research institutions and the media. The diffusers, adopters, regulators and disseminators are analysed in turn.

Diffusers

In this study, the diffusers of GM crops are technology developers, seed companies, the academia, scientists and researchers.

Technology developers and seed companies

Technology developers are involved in research and development of GM crops. The GM crops that are available in the world are distributed by a few MNCs that include BASF, Bayer CropScience, Cargill, Dow AgroSciences, DuPont Pioneer, Monsanto and Syngenta (Parisi, Tillie and Rodriguez-Cerezo, 2016).

The time lag between R&D of GM crops and the launch of the product on the market is more than ten years against accumulated costs that may exceed US$100 million (Halford, 2012). This delay is in line with Phadke and Vyakarnam's (2017) estimate of eight years in the commercialisation of GM crops. In the commercialisation process of GM crops – to get the product to reach the market – the technology developers safeguard their intellectual property rights (IPR) by the use of patents and endeavour to recoup accumulated R&D costs while at the same time achieving sustainable profit margins. In this regard, the technology developers enter into technology transfer and IPR agreements with the seed companies that market and distribute planting seeds of GM crops. For example, in South Africa, GM seed varieties that have Monsanto insect-resistant and herbicide-tolerant traits are sold by seed companies under licence. At agreed intervals, the seed companies make payments to Monsanto in respect of royalties against gross sales of the seed. Therefore, in the diffusion of GM crops, technology developers and seed companies play prominent roles.

The academia, scientists and researchers

New innovations are created by the academia, scientists and researchers. In Southern Africa, policy makers are showing support for institutions of higher learning in their involvement in bringing new technologies to the market. The support for institutions of higher learning was shown by Zimbabwean President Emmerson Mnangagwa in

January 2018 during his address at a meeting of Vice Chancellors of state universities; he said:

> We look upon institutions of higher learning to lead in research to produce a qualitative and technological edge thereby supporting our agricultural sector and agro-based industries through production of new seed varieties, adoption of water harvesting technologies for irrigation development and adoption of new farming methods (The Herald, 2018).

In the diffusion and adoption of GM crops, academics, scientists and researchers (scientists) produce useful research papers that elucidate the matters relating to advantages and disadvantages of GMOs and thereby helping with the dissemination of information. In relation to the dissemination of information on new technologies, communities tend to trust academics more than technology company representatives (Rogers, 2003). However, in the African context, Eicher, Maredia and Sithole-Niang (2006) urge technology developers to speed up education and development of African scientists to equip them with the skills to make homegrown biotechnology products. Furthermore, Cooke and Downie (2010) urge the USA to be cautious in its approach to advocating GM crops in Africa. Rather, they recommend provision of resources to African universities to educate scientists, thus creating home-grown solutions of GM crops in Africa.

The researcher supports Cooke and Downie's (2010) argument because African policy makers are more likely to prefer innovations by African scientists to the imposition of foreign ideas. However, the researcher notes that it costs around $100 million to produce a GM crop (Halford, 2012), thus making it very difficult for poor African nations, including South Africa – Africa's second largest economy (World Bank, 2017b) – to come up with their own GM crops. Therefore, the solution may be found in technology transfer collaborations among government agencies, institutions of higher learning and technology developers. Models may be styled in line with PPPs, for instance, Monsanto is collaborating with government agencies in India (Monsanto, 2018).

Adopters

In the context of this study, the adopters of the GM technology are the farmers, ginners and consumers. The roles of the farmers, ginners and consumers are analysed in turn:

Smallholder farmers and their opinion leaders

Agriculture is the mainstay of Zimbabwe's and Malawi's economies (World Bank, 2017b). In turn, farmers are the lifeblood of all agriculture and if the farmers reject the innovations, nothing happens (Rogers, 2003). This study accepts the significance of farmers in the decision-making process of adoption of GM crops. Regarding power and interest, farmers are considered key stakeholders and adopters of the technology. Furthermore, voices of farmers should be heard (Cohen and Paarlberg, 2004) in the development and review of national biotechnology regulations; the farmer's voice should be heard because the farmers are the front-line users of the technology. Farmers are mainly motivated by economic benefits when they select a cash crop to grow (Mannion and Morse, 2012). For Mannion and Morse (2012), if farmers are given a wide selection of competing crops, they make decisions on which crop to grow based on profitability per unit of land put under cropping.

In the smallholder farming communities, opinion leaders play a key role in the spread of new ideas and the success of adoption of agricultural technologies (Valente and Davis, 1999; Rogers, 2003; Feder and Savastano, 2006). In the context of smallholder farming communities in Zimbabwe, Malawi and South Africa, it is important to establish who opinion leaders are and their characteristics. Rogers (2003) posits that in comparison with their peers, opinion leaders are more cosmopolite, have higher socioeconomic status and are more innovative. Complementary to Rogers' (2003) assertion, Goldenberg *et al*. (2009) point out that opinion leaders are endowed with three traits: they are convincing, are experts and have a large network of social ties.

Ginners

The ginners are the primary buyers of raw cotton from farmers. They process raw cotton using special machinery called gins – hence the name ginner – separating the fibre from the seed. The initial process results in two products: lint and ginned cotton seed. In Zimbabwe and Malawi, cotton is mainly grown under contract farming between the farmers and ginners. Therefore, in this study, the ginners are adopters of GM crops.

Regarding the agreements between farmers and ginners, at the harvest, the farmers should sell their cotton to the contracted ginners. However, in Zimbabwe and Malawi, challenges arise when farmers avoid meeting their contractual obligations and side market their crop to a secondary market. A similar scenario was witnessed on South Africa when a scheme that involved smallholder farmers and a ginner collapsed (Schnurr, 2012). In this study, ginners are considered key players because of their role in bringing the technological innovation to the market through the purchase of planting seed from seed companies for onward disbursement to smallholder farmers under grower contracts.

Consumers

In relation to the adoption of GM crops, consumers have high power and high interest. The adoption of GM crops is mainly determined by issues to do with the safety of the consumers who eat the products of GM crops. Even though De Groote (2012) classifies cotton as an industrial crop rather than a food crop, this study notes that cotton may also be regarded as a food crop because the oil extracted from its seed is used for human consumption. In addition, the cotton cake is used for animal feed. The GM crops available in Southern Africa do not provide relative social or economic benefits to end consumers but are developed to provide benefits to farmers, technology developers and seed companies (Wagner-Weick and Walchli, 2002). The African farmers are also consumers of agricultural crops (Wambugu, 2014). In this regard, the issues that relate to consumers resonate with the farmers. However, in this research, farmers are classified separately because roles in the production of GM crops are unique in contrast to other consumers.

Regulators

Regulators are responsible for ensuring the safety of citizens against potential hazards. The three countries under study, Zimbabwe, Malawi and South Africa, are constitutional democracies. The elected politicians ultimately supervise the government officials. Wambugu (2014) points out that in Africa, the frequent changes of political offices that happen every 4-5 years may positively or negatively impact diffusion and adoption of GM crops. In some cases, the changes may usher in politicians who speed up GM crop registration processes that lead to the adoption of GM crops and in others, politicians who do not support GMOs. This study critically examines the role that policy makers play in the diffusion and adoption of GM crops.

For this study, the category of regulators are the policy makers who include politicians, regulatory officers/ institutions and all senior government officials that are involved in the regulation of GM crops. In Southern Africa, government policy and regulations determine whether a country is likely to take up GM crops (Mabaya *et al*., 2015). In this regard, policy makers play a prominent role in the diffusion and adoption of GM crops.

Disseminators

In this study, the disseminators of information about GM crops are the media and NGOs and they are analysed in turn:

The media

In the diffusion and adoption of GM crops, change agents use the media as a communication channel to disseminate information on GM crops (Marques, Critchley and Walshe, 2015). In Southern Africa, the media has shown interest in GM crops and several articles have been written on the subject. For example, Tsiko (2016) has written widely about the adoption of GM cotton in Zimbabwe. However, some reports by the media on GMOs have shaped government policies on GM crops (Mabaya *et al.,* 2015). For example, Willingham (2012) argues that the Minister of Health for Kenya in 2012 issued an order prohibiting imports of GM crops after media reports of the study by

Seralini *et al.* (2012). Seralini *et al*.'s (2012) study reveals that rats fed from a Monsanto GM herbicide-resistant maize developed tumours and kidney diseases.

However, GMWatch (2016) claims that, notwithstanding the concerted efforts of the GM company sponsored experts to discredit the Seralini *et al.*'s (2012) study, Professor Giles-Eric Seralini had won a defamation case against journalist Jean-Claude Jaillette and the magazine *Marianne* which published a malicious story on the 2012 study. The retraction of Seralini *et al.*'s (2012) study did not eliminate the controversial issues about the effects of GM crops on the health of humans and animals because two years later, the same study was republished by another peer-reviewed journal (Seralini *et al.*, 2014; GMWatch, 2016). The researcher supports Krimsky's (2015) argument that the retraction of Seralini *et al.*'s (2012) study by the journal *Food and Chemical Toxicology* may have been caused by a conflict of interests because it happened after the journal had hired a former employee of Monsanto as an assistant editor.

Non-governmental organisations

This study recognises that there are two classes of NGOs who are involved in the diffusion and adoption of GM crops, that is, proponents and opponents. However, in this study, the two classes of the NGOs are disseminators of information about GMOs. Paarlberg (2014) argues that the stance taken by African governments to shun GM crops is mainly influenced by NGOs from European countries. One such NGO is Greenpeace International which has been the leading NGO crusading against adoption of GM crops, urging farmers to use conventional seeds (Greenpeace International, 2017). In Southern Africa, there are two NGOs that are based in South Africa which are the most prominent in the fight against GMOs. These are, The African Centre for Biodiversity (ACB) (2018) and Biowatch (2018). The missions of the two NGOs are to stop the spread of GM crops in Southern Africa and beyond. Their activities include lobbying regulators to decline applications for registration of GM crops. In September 2016, ACB celebrated their successful lobby against commercial release of insect resistant GM potatoes in South Africa (ACB, 2018).

In the diffusion and adoption of GM crops, NGOs are more likely to get the ears of the public as opposed to company representatives who are perceived to advance their companies' profit agendas (Tait, 2001; Gutteling *et al*., 2006). However, the NGOs pursue their own agendas in terms of communication objectives and they use strong language, adjectives and rhetoric which are not used by scientists and the academia. The interest of NGOs in the diffusion and adoption of GM crops is evidently high (The Alliance for Food Sovereignty in Africa, 2018). However, in terms of power, it is relatively low because NGOs do not administer statutes and they have no legal authority. Adenle (2011) argues that Zambia was influenced by the international NGO Greenpeace to reject the GM maize grain aid from the USA.

Public trust and goodwill for technology companies may be negatively affected by reports revealing that the USA government works hand in glove with its multinational corporations to promote GM crops and punishes countries that are vocal in opposing the GM crops (Schnurr, 2013). Also, a decade earlier, American interests in technology transfer in Africa were revealed when the BBC News (2003) reported that President Bush had accused Europe of blocking the diffusion and adoption of GM crops in Africa because of "unfounded, unscientific fears".

The members of the Social System involved in the diffusion and adoption of GM crops in Zimbabwe, Malawi and South Africa that comprise diffusers, adopters, regulators and disseminators have been identified and analysed in relation to the roles that they play. A question has arisen to establish what role policy makers, farmers and other stakeholders play in influencing the adoption of GM crops and in protecting the environment in Zimbabwe, Malawi and South Africa.

Religion, culture and ethics

The researcher notes that religion, culture and ethics are some of the factors that impact the diffusion and adoption of GM crops (Arthur, 2011; Ezezika *et al.*, 2012). However, these factors are not the focus of this study. Suffice to note is the claim that the insertion of genes taken from animals or other living organisms into the genomes of food crops is said to be unacceptable to some religious sectors (Arthur, 2011). Furthermore, some studies reveal that the 'creation of new things' is abhorred as unethical by people who point out that scientists are playing God (Arthur, 2011).

Some ethical issues may arise when a farmer grows a GM crop adjacent to a farmer field that has been grown to non-GM crop and the GM crop contaminates the non-GM farmer's crop (Bruce, 2003; Bennett, 2013). In the context of Zimbabwe, Malawi and South Africa, this situation is most likely to occur in smallholder farms where the isolation distance between fields is a few metres apart. In this regard, disputes may arise which lead to costly litigation. The focus now turns to key theories that emerged from the literature review.

Key theories that emerged in literature review

The literature review has discussed key theories on GM crops and reviewed the literature associated with GM crops. GM crops are an innovation which involves novel scientific technologies. Hence, it is necessary to gain insights on how GM crops are created and to establish the science involved (discussed on pages 22-24). The overarching objective of this study is to critically evaluate the factors that drive or constrain diffusion and adoption of GM crops in Zimbabwe, Malawi and South Africa. In this study, Rogers' (2003) four main elements in the diffusion of innovations which are, the innovation, communication channels, the social system and time are used as the themes to present a summary of key theories that emerged in the literature and research questions.

Table 3.2 Summary of key theories that emerged in the literature review and research questions

Elements	Factors evaluated	Author	Research findings/theoretical conclusions	Gaps in the literature addressed/ Link with own research questions
The Innovation	**Relative advantage or social advantage**	Scandizzo and Savastano (2010)	The adoption rate of GM crops will depend on how profitable they are perceived as compared to the conventional varieties they replace.	RQ1. What factors drive or constrain the diffusion and adoption of GM crops in Zimbabwe, Malawi and South Africa?
		Qaim (2010; 2016); Gouse (2012); Mannion and Morse (2012); Brookes and Barfoot (2016a)	GM crops achieve higher yields in comparison to their non-GM crops equivalents.	
		Bennett, Morse and Ismael (2006); Kouser and Qaim (2011); Sanahuja *et al.* (2011)	Farmers that use insect-resistant GM cotton spray the crop fewer times against bollworms than farmers who use non-GM cotton. As a result, the farmers save on labour used to spray the crop and the time saved is allocated to other farming activities. In the meantime, the GM crop has an inbuilt insecticide which protects the plant from insects.	
		Qaim (2009); Bennet *et al*. (2003)	Adoption of GM crops leads to health benefits due to reduced exposure to toxic chemicals.	
	Compatibility	Rogers (2003)	Compatibility of innovation relates to how consistent it is to the community's existing ways of doing things.	
		Chadwick (2017)	The safety of GM crops cannot be 100% guaranteed.	

		Christou and Twyman (2004); Thomson (2015)	Bt toxins kill targeted insects but do not kill humans and other mammals because the guts of the targeted insects are alkaline and the human stomachs and other mammals are acidic.	RQ2. How are new ideas, technologies and knowledge transferred to smallholder farmers in Zimbabwe, Malawi and South Africa?
		Andersson and de Vicente (2010); Murnaghan (2017)	GM crops can transfer genes to their wild relatives through cross-pollination.	
	Complexity	Sahin (2006); Dibra (2015)	The more difficult an innovation is to deal with, the less attractive it is to diffuse.	
	Trialability	Rogers (2003); Dibra (2015)	Innovations which can be tested and verified by potential adopters are adopted sooner.	
	Observability	Waithaka *et al.* (2015)	Technology developers conduct confined field trials to evaluate the performance of the GM crop against non-GM equivalent variety. This is the first step in technology transfer journey from the laboratory to the farmers.	
	Technology and knowledge transfer	Van Norman and Eisenkot (2017)	Technology developers use patents to defend their markets. Patents are instruments by which inventors retain for a limited period of time exclusive rights to exclude others from using the invention.	
		Vyakarnam (2013)	Key success factors of the innovation process include the translational journey.	

Communication Channels	**Confined field trials**	Waithaka *et al*. (2015)	Technology developers and seed companies conduct confined field trials to: • evaluate the performance of the new GM crops against the conventional equivalent varieties • showcase the efficacy of the new technology as the first step towards commercialisation of GM crops in the target market.	
Time	**Political will**	Alhassa and Adekunle (2014); Wambugu (2014); Mabaya *et al*. (2015)	In Africa, government policy and political will of policy makers determine the rate at which GM crops are diffused.	RQ3. What role do policy makers, farmers and other stakeholders play in influencing the adoption of GM crops and in protecting the environment?
		Paarlberg (2008); Atkinson, Roderick and Tripathi (2015)	In Africa, policy makers fear the risk of losing export markets to Europe if their countries adopt GM crops.	
	Biosafety regulations	Okeno *et al*. (2013)	Biosafety regulations can be barriers to diffusion and adoption of GM crops if there are no clear and transparent regulatory frameworks.	
The Social System	**Stakeholder analysis**	Aerni and Bernauer (2006)	Stakeholders’ interests and power impacts diffusion and adoption of GM crops.	

Conceptual framework

The topic of this study is, 'Diffusion and Adoption of Genetically Modified Crops: Evidence from Zimbabwe, Malawi and South Africa'. One argument that motivates this study is that, food shortages, hunger and malnutrition recur in Zimbabwe and Malawi albeit claims that farmers in South Africa that adopted a new innovation – GM crops – achieve higher crop yields and the country has surplus food (Gouse, 2009, 2012). Consequently, the overarching objective of this study is to establish factors that drive or constrain diffusion and adoption of GM crops in Zimbabwe, Malawi and South Africa.

This study is guided by a conceptual framework (CF) shown in Figure 3.2 which is developed using theories and concepts that emerged from literature. The CF is anchored on Rogers' (2003) four main elements in the diffusion of innovations, which are: the innovation, communication channels, the social system and time. It is presented in five boxes, of which the outer boxes represent the four main elements. The fifth box at the centre symbolises the diffusion and adoption of GM crops. Arrows are used to link the boxes in the manner described below.

The relationships of elements

The elements in the CF diagram are presented in boxes and their relationships are indicated by arrows (Fisher, 2010; Punch, 2014). In this study, two way arrows are used to show that outer boxes are all linked because the diffusion of an innovation is a seamless process that does not start or end at a specific point (Rogers, 2003). The two way arrows indicate that the four elements are interrelated. The one ended arrows show the relationship of the elements of diffusion of innovations and the factors –within the elements– that drive or constrain the adoption of GM crops in Zimbabwe, Malawi and South Africa.

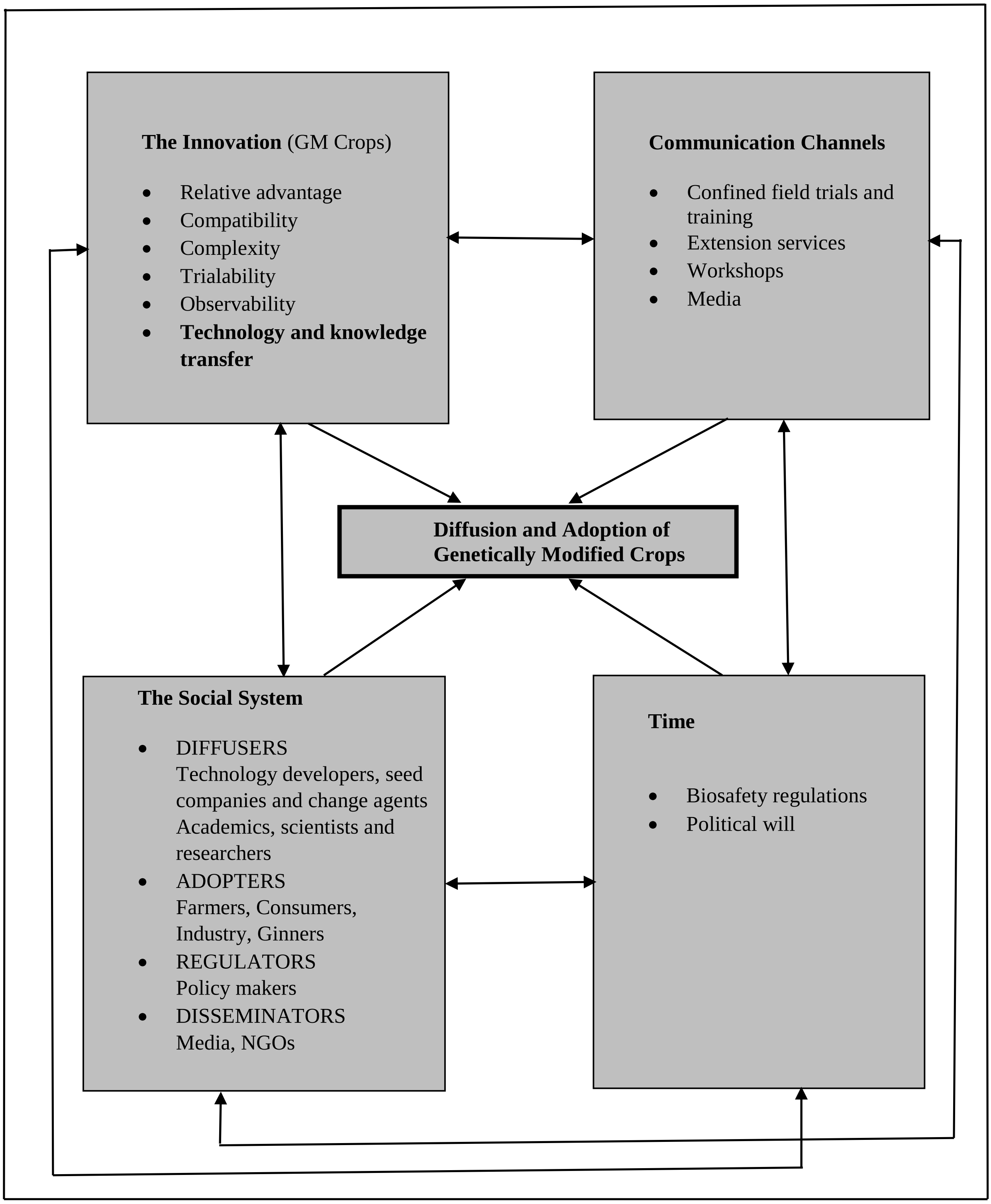

Figure 3.2 Elements of diffusion of innovations and the factors that drive or constrain the adoption of GM crops in Zimbabwe, Malawi and South Africa.

Contribution to theory

This study contributes to theory by adding to the understanding of Rogers' (2003) four main elements in the diffusion of innovations in the following areas:

- Technology and knowledge transfer added as key factors of Innovation,
- Identified diffusers, adopters, regulators and disseminators within the Social System,
- Included CTFs, extension services, workshops and media as essential factors of the Communication Channels element, and
- Identified biosafety regulations and political will as important factors in the fourth element, Time.

The contributions to theory are discussed in turn:

First Element: The Innovation

This study contributes to Rogers' (2003) elements as it identified why technology and knowledge transfer are important factors in the diffusion and adoption of GM crops in Zimbabwe, Malawi and South Africa. It emerged in the literature reviewed that in the diffusion and adoption of GM crops, technology and knowledge transfer have become an integral part of business strategy of technology developers in their quest to take new innovations to the market (Kalaitzandonakes *et al.,* 2018). In addition, the researcher supports Vyakarnam (2013) who argues that, managing the translation journey is a key success of technology transfer and the promoters of the technology must respond to the needs of customers. Furthermore, the previous studies suggest that, in the process of technology and knowledge transfer, technology developers use patents and IPR as defensive strategies for their GMO traits against infringement and unauthorised use.

The CF incorporates Rogers' (2003) five characteristics of an innovation as he posits that, in the adopters' point of view, the speed at which an innovation is diffused and adopted is determined by five factors, which are: relative advantage, compatibility, complexity, trialability and observability. However, of the five factors, complexity is the only one that is negatively correlated with the rate of adoption (Sahin, 2006).

Therefore, in order to ensure that an innovation is diffused quickly, the change agent should ensure that complexit1y is turned into simplicity.

Second Element: Communication Channels

This study contributes to Rogers (2003) model as it identified important communication channels that are used by technology developers and seed companies in Zimbabwe, Malawi and South Africa in their quest to take GM crops to the market. The communication channels include CFTs and training, extension services and workshops. Communication Channels relate to communication and marketing strategies that technology developers and seed companies use to disseminate information about GM crops to farmers, policy makers and other stakeholders.

In the diffusion of GM crops, the communication channels that are used by technology developers to disseminate information include, one-on-one communication with farmers, including the opinion leaders, stakeholder visits to CFTs, government extension services, workshops and the media. Technology developers and seed companies work closely with government extension services because the government extension services have, in the past, successfully implemented several change initiatives with farmers (Anderson and Feder, 2004; Njuguna and Wambugu, 2014). The technology developers also offer training to the government extension workers as well as the farmers on the use of the new products. The diffusion and adoption of GM crops involve engagement of various stakeholders (Aerni, 2005; Ezezika *et al*. 2012). The activities shown in the four outer boxes overlap as pointed out by Rogers (2003); communication happens at any stage, so do training and stakeholder engagement by change agents.

Third Element: Time

In the CF, the third box is in relation to the time dimension which measures the rate at which an innovation is diffused into the market (Rogers, 2003). The study contributes to Rogers' (2003) model by including political will and biosafety regulations because several studies identify political will and biosafety regulations as key factors which determine the rate of adoption of GM crops in Africa (Alhassa and Adekunle, 2014; Wambugu, 2014; Mabaya *et al*., 2015; James, 2015).

Fourth Element: The Social System

In the diffusion and adoption of GM crops in Zimbabwe, Malawi and South Africa, there are stakeholders who determine whether the GM crops are adopted or rejected depending on the perceived usefulness of the technology. The CF draws from Rogers' (2003) theory of the Social System and adds to Rogers' theory by identifying the members that influence diffusion and adoption of GM crops in Zimbabwe, Malawi and South Africa that comprise diffusers, adopters, regulators and disseminators. In order to establish a theoretical perspective of the roles of the members of the Social System who are involved in the diffusion and adoption of GM crops in Zimbabwe, Malawi and South Africa, an analysis of the members is done on pages 41- 48.

Development of research questions

The topic of this study is '*Diffusion and Adoption of Genetically Modified Crops: Evidence from Zimbabwe, Malawi and South Africa'.* The overarching objective is to establish factors that drive or constrain diffusion and adoption of genetically modified (GM) crops in Zimbabwe, Malawi and South Africa. Secondary objectives which are closely related to the diffusion question are to provide some understanding of how new ideas, technologies and knowledge is transferred to smallholder farmers in Zimbabwe, Malawi and South Africa; and to establish the roles which policy makers, farmers and other stakeholders play in diffusion and adoption of GM crops and in protecting the environment in Zimbabwe, Malawi and South Africa.

In order to operationalise the CF, three research questions were developed, underpinned by the theories emerging from the literature review:

1. What factors drive or constrain the diffusion and adoption of GM crops in Zimbabwe, Malawi and South Africa?
2. How are new ideas, technologies and knowledge on GM crops transferred to smallholder farmers in Zimbabwe, Malawi and South Africa?
3. What role do policy makers, smallholder farmers and other stakeholders play in influencing the adoption of GM crops and protecting the environment in Zimbabwe, Malawi and South Africa?

In the CF, Figure 3.2, the first research question is located in Box 1 (The Innovation) and it emerges from the theories and concepts that relate to Rogers' (2003) characteristics of an innovation and two factors which emerged from other previous research on GM crops, that is, technology and knowledge transfer. The second research question is located in Box 2 of the CF (Communication Channels). Finally, the third research question, of which its theories are located in Box 4 of the CF, is about the roles that policy makers and smallholder farmers who are involved in the adoption of GM crops play.

The following chapter constitutes the research design and methods to apply the conceptual framework and answers the three research questions. The research philosophy and research approach are explained and justifications for their choice given.

CHAPTER 4

RESEARCH METHODOLOGY

Introduction

This chapter aims to explain the research process, the rationale for the research design and data analysis of this study. It includes data collection procedures and ethical aspects of the study. A discussion of why pragmatism as a research philosophy and mixed methods research strategy is used in the study as opposed to other philosophies and strategies is articulated. At the end of the chapter, ethical considerations are discussed together with the limitations of the research methods used.

The primary objective of this study is to establish factors that drive or constrain diffusion and adoption of GM crops in Zimbabwe, Malawi and South Africa. Secondary objectives which are closely related to the diffusion question are to provide some understanding of how new ideas, technologies and knowledge is transferred to smallholder farmers in Zimbabwe, Malawi and South Africa; and to establish the roles which policy makers, farmers and other stakeholders play in diffusion and adoption of GM crops and in protecting the environment in Zimbabwe, Malawi and South Africa.

In this regard, the study attempts to answer the following three research questions:

1. What factors drive or constrain the diffusion and adoption of GM crops in Zimbabwe, Malawi and South Africa?
2. How are new ideas, technologies and knowledge on GM crops transferred to smallholder farmers in Zimbabwe, Malawi and South Africa?
3. What role do policy makers, smallholder farmers and other stakeholders play in influencing the adoption of GM crops and protecting the environment in Zimbabwe, Malawi and South Africa?

The next section discusses Pragmatism, which is the philosophical stance that inspires this study.

Pragmatism

The researcher has chosen pragmatism philosophy in undertaking this study. Pragmatism is a philosophy which resonates with the researcher's values and is in line with the study's research objectives and questions. Fisher (2010) asserts that – consciously or unconsciously – at the beginning of the research process, a researcher chooses the philosophical stance that underpins the values of the researcher. An examination of the three research questions reveals that different research approaches are needed to address them satisfactorily. In this regard, the researcher adopted pragmatism because it is a philosophy that is guided by research questions (Wilson, 2014) and it gives the researcher flexibility to use data collection methods that best address the research questions. More so, the research question should determine the choice of a research strategy to use in a study (Tashakkori, Teddlie and Johnson, 2015). Pragmatism philosophy is an overarching paradigm that accommodates both the qualitative and quantitative research methods by considering practical consequences of a research approach (Morgan, 2014; Van Griensven, Moore and Hall, 2014). Furthermore, a fundamental aspect of the pragmatism paradigm is its focus on the practicality of the research method chosen (Krivokapic-Skoko and O'Neill, 2011).

The researcher takes into account that, pragmatism is a middle of the road philosophy similar to critical realism that brings two opposing philosophies together, that is, positivism and interpretivism (Agerfalk, 2010). Whereas positivism takes the objective view to conducting research and the research process is detached from participants – offering minimum interaction between the researcher and the participants – there is a claim that the research is free from personal bias (Wilson, 2014). However, in this study, the perceptions of stakeholders who are involved in diffusion and adoption of GM crops play a key role. The diffusion theory is interested in the innovation behaviour of social systems, where relative advantage, compatibility, complexity, trialability and observability are essential elements (Rogers, 2003). Therefore, applying an interpretive qualitative approach offers advantages of gaining insights about the factors that promote or inhibit the diffusion and adoption of GM crops through personal observation and conversations with informants.

Mixed methods research

This study is using mixed methods research (MMR) to address research question 1, 'What factors drive or constrain the diffusion and adoption of GM crops in Zimbabwe, Malawi and South Africa?' The researcher supports Punch's (2014) contention that more insights about the research area can be gained by drawing from the strengths of MMR and combining both quantitative and qualitative methods in one study. The view of this study is that the quantitative research is the appropriate method which is used to establish the profit margins achieved by smallholder farmers who grow GM and non-GM crops in Zimbabwe, Malawi and South Africa. The profit margins are used to measure relative advantage and trade-offs of GM crops against non-GM crops in smallholder farming communities of the three Southern African countries. This is followed by an interpretive qualitative research to gather data on the views and opinions of participants about the factors that drive or constrain the diffusion and adoption of GM crops.

The MMR is used to deal with research question 1 only because the interpretive qualitative research adequately addresses research questions 2 and 3. Relative advantage is one of the factors that drive or constrain the diffusion and adoption of GM crops. On their own, the quantitative results of the survey will not explain what drives or constrains the diffusion of GM crops. Therefore, to establish what motivates as well as what influences the diffusion and adoption of GM crops, it is necessary to conduct an interpretive qualitative research that includes in-depth interviews with participants. Data for the interpretive qualitative research is gathered from in-depth interviews with experts, focus groups and informants selected from stakeholder groups that include policy makers, smallholder farmers and consumers, technology developers, ginners, NGOs, media and scientists.

The advantages of using quantitative research in a study on GM crops are revealed in several studies that include Qaim (2010; 2013) and Bennett, Morse and Ismael (2006) who used quantitative methods in their data collection and analysis to establish the economic benefits of GM crops on farmers' welfare. For example, Qaim (2010) used quantitative methods in his study whose main objective was to establish the financial benefits, household income, nutrition, and health of farmers that use GM crops in India. In the study, Qaim (2010) measured the quantities harvested quantitatively, gross revenue received and costs of production for cotton farmers. In contrast, Adenle (2014) used interpretivist qualitative research methods in a study that assessed the perceptions of stakeholders on GMOs in Ghana and Nigeria. Adnele sought to establish the opinions of the stakeholders in their own words and gathered data during in-depth interviews with the participants.

Meanwhile, Bennet, Morse and Ismael (2006, p.662) used MMR that included quantitative research methods and qualitative research methods in a study that sought to establish "the economic impact of GM cotton on South African smallholders: yield, profit and health effects". However, Bennet, Morse and Ismael's (2006) study was more skewed on quantitative research and the qualitative research only related to a group discussion with farmers about issues relating to the health of the farmers. It is useful to compare Bennet, Morse and Ismael's (2006) earlier findings with the findings of this study because their study was done ten years earlier with similar objectives in the Makhathini Flats farming area of smallholder farmers in KwaZulu Natal, South Africa, where this study is also conducted.

Quantitative research

The data for the quantitative research segment of this study is from two sources which are, primary and secondary. Primary data is collected from smallholder farmers located in cotton growing areas of Zimbabwe, Malawi and South Africa shown in Table 4.1. The secondary data is taken from results of GM cotton trials conducted by researchers of Ministry of Agriculture in Malawi during September 2016 to May 2017 (see Appendix 8). One of the advantages of using the secondary data from the results of the trials by the government researchers is that the data were collected by experts, therefore, they are relatively accurate. Furthermore, there are no expenses to be incurred by the researcher.

Sampling approach

The participants of the survey are 169 smallholder farmers drawn from farming communities in Zimbabwe, Malawi and South Africa shown in Table 4.1. The smallholder farmers were selected mainly at gatherings of farmers during field days. The field days are sponsored by input suppliers who include seed companies, chemical companies and government extension services. These are occasions which are used to train farmers on new farming methods and new technologies are introduced. The researcher focused the survey in the areas where cotton is mainly grown. In Zimbabwe, cotton is mainly grown in Gokwe district followed by Sanyati and Chinhoyi districts. Gokwe, at 40%, dominates the production of cotton in Zimbabwe, followed by Sanyati at 20% and Chinhoyi at 15% (AMA, 2014). In Malawi, the Lower Shire Valley dominates cotton production followed by Salima and Balaka districts. In South Africa, cotton smallholder farmers that produce cotton are mainly located in Makhathini Flats, KwaZulu Natal.

Table 4.1 Number participants of survey

Country and location	**Number of smallholder farmers**
Zimbabwe: Gokwe (42), Sanyati (15) and Chinhoyi (15)	72
Malawi: Lower Shire Valley (25), Salima (15) and Balaka (15)	55
South Africa: Makhathini Flats, KwaZulu Natal	42
Total	**169**

The population of the smallholder cotton farmers is given by AMA (2014) which states that about 220,000 smallholder farmers grew cotton in Zimbabwe and during the same period, between 120,000 and 150,000 smallholder farmers grew the crop in Malawi

(Kenamu and Phiri, 2014). In South Africa, Cotton South Africa (2013) estimated that 3,000 smallholder farmers grew cotton in 2014.

The questionnaire

The purpose of the questionnaire is to collect data from smallholder farmers that grow GM cotton and non-GM cotton in South Africa, Zimbabwe and Malawi. Using farmers' records, the questions focus on yields and incomes achieved per unit of land. Data on the costs of production is also collected to establish the profits or losses. In line with Rowley (2014), the aim is to develop a questionnaire that sufficiently collects the data that answers the research questions and achieve the required response rate. The subject of GMOs is scientific and difficult to understand for the laymen. Therefore, the researcher should be present during the completion of the questionnaire by the participants to answer any queries that might arise. This also improves the response rate. It is recognised that many factors which might include the rainfall patterns, soil type and agronomy practices among others, might affect the crop yields achieved by farmers in the three countries under study. Nevertheless, for this study, it is assumed that all other factors remain constant.

There have been challenges relating to farm records. In the three countries under study, particularly South Africa, most smallholder farmers do not keep accounting records, but they retain invoices and receipts of purchases for farm inputs. The researcher uses the vouchers presented by the farmers to record the data. However, in Zimbabwe and Malawi, the costs of all inputs are not difficult to establish because the farmers receive the inputs on credit from ginners. The ginners give the farmers contract forms which indicate the inputs supplied. Similarly, in South Africa, it is not difficult to establish the input costs because the farmers in Makhathini Flats buy their inputs from one supplier.

Pilot survey

A pilot survey was carried out on five smallholder farmers in Zimbabwe to establish the effectiveness of the questionnaire and whether the farmers' responses answered the questions accurately. This led to changing some questions to suit the literacy level of the farmers. To ensure trustworthiness of the quantitative research, the actual survey does not include the farmers that participated in the pilot survey.

Analytical approach

The analytical approach of the quantitative research includes financial ratios and the net profit margin is applied to evaluate the profitability of GM and non-GM cotton in order to establish the relative economic advantage in the diffusion of GM cotton. Financial ratio analysis is widely used to evaluate financial performances of small, medium and large scale enterprises (Horrigan, 1965). The smallholder farmers are, by nature, subsistence farmers who rely on farming for family income. The smallholder farmers do not prepare financial statements. Therefore, the absence of financial records that include balance sheets and profit and loss accounts of smallholder farmers' operations makes it difficult to apply full-fledged financial ratios. However, it is possible to prepare useful and reliable profitability ratios, particularly the profit margin which is the ratio of net profit against sales (Delen, Kuzey and Uyar, 2013).

Quantitative data analysis

The questionnaire is designed in a format that replicates a farmer's profit and loss account (Appendix 7). On completion of the survey, data from completed questionnaires is captured on Statistical Package for Social Sciences (SPSS). A consolidated report which summarises farmers' income statements is generated from the SPSS and exported to a Microsoft Excel spreadsheet. The researcher has found the spreadsheets easy to use.

Qualitative research

The key question addressed by this qualitative research is, 'what factors drive or constrain the diffusion and adoption of GM crops in Zimbabwe, Malawi and South Africa?' The study is employing three primary methods in the qualitative research which are: in-depth interviews, focus group interviews and participant observation.

Choosing participants for the qualitative research

Drawn from Rogers' (2003) theory of the Social System, this study classifies members that are involved in the diffusion and adoption of GM crops in Zimbabwe, Malawi and South Africa as diffusers, adopters, regulators and disseminators. The categories of the members emerge from previous studies that suggest that eight stakeholder groups are involved in the diffusion and adoption of GM crops in Zimbabwe, Malawi and South Africa and they include policy makers, farmers and consumers, technology developers and seed companies, industry, NGOs, media and scientists (Aerni, 2005; Ezezika *et al*., 2012). In line with the literature reviewed, the participants in the study are drawn from the eight stakeholder groups. The area of GMOs is a specialist study which involves scientists, agricultural experts and academics.

The qualitative research includes fifty-three participants from the three countries shown in Table 4.2. In order to access key informants who would provide useful information for the study, the researcher uses the snowball sampling and purposeful sampling strategies to select the participants (Noy, 2008). Of the twelve participants drawn from policy makers, Zimbabwe has the largest number with eight participants. This is largely due to accessibility of the participants because the researcher is based in Zimbabwe. With eighteen participants, farmers comprise the largest group of participants. The farmers are all from cotton growing areas of the three countries. In Zimbabwe, the researcher attended one farmer field day gathering where farmers met to share experiences with service and product developers. The researcher made a several efforts to secure interviews with participants from NGOs in the three countries but secured one interview in Zimbabwe.

Table 4.2 Number of participants of qualitative research

Category of participants	Role played	Zimbabwe	Malawi	S. Africa	Total
Policy makers	Regulators	8	3	1	12
Farmers	Adopters	10	2	6	18
Ginners	Adopters	3	1		4
GMO technology and seed companies	Diffusers	2	1	1	4
Non-governmental organisations	Disseminators	1			1
Media	Disseminators	2		3	5
Academia/ scientists/ experts	Diffusers	4	2	3	9
Total participants		**30**	**9**	**14**	**53**

In line with Silverman (2013), in this study, the researcher does not ask the research question directly to the participants because it might affect their responses if they are made aware of the researcher's interests. Thus, during the in-depth interviews, the researcher uses several questions that are formulated to answer research questions.

In-depth interviews

Face-to-face in-depth interviews are conducted with participants drawn from stakeholder groups. In preparation for the interviews, interview guide questions that are aligned with research questions are prepared ahead of the in-depth interviews. Research question one, that is, 'What factors drive or constrain the diffusion and adoption of GM crops in Zimbabwe, Malawi and South Africa?' elicits the perspectives and opinions of the participants about the factors that drive or constrain the diffusion and adoption of GM crops. The second research question: 'How are new ideas, technologies and knowledge on GM crops transferred to smallholder farmers in Zimbabwe, Malawi and South Africa?' seeks to establish the methods that technology developers use to market the new innovations to farmers. Finally, research question three: 'What role do policy makers, smallholder farmers and other stakeholders play in influencing the adoption of GM crops and in protecting the environment in Zimbabwe, Malawi and South Africa?' aims to establish the role of key stakeholders that are involved in the adoption of GM crops and how they determine the success of adoption of the innovation. The interview guides are prepared for each stakeholder group ahead of the interviews and this helps the flow of the interviews.

When conducting in-depth interviews, the researcher follows Denscombe's (2010) suggestion that before closing the interview, participants should be allowed to point out any issues that they consider important but were not asked. A voice recorder is used to capture the interviews and transcriptions are typed by the researcher into Microsoft Word using a laptop. The process requires the researcher to listen to the recordings repeatedly during the process of transcribing. After completing the transcribing, in some cases, the researcher seeks further clarification from the participants to ensure rigor of the transcripts.

In all situations, the researcher places the recorder in full view of the respondent and asks the respondent for permission before recording the discussion. A few challenges are experienced when conducting interviews with some government officers that refuse to be audio-recorded. In such cases, the recorder is switched off and notes are taken manually. The researcher ensures that important aspects of the interview are written down and repeatedly goes through the summary of the conversation checking with the respondent that the issues are captured.

The creation of new things through genetic modification by insertion of alien genes into the genome of other organisms, thus creating GM crops makes the subject of GMOs controversial. In this regard, one of the challenges faced by the researcher during in-depth interviews is that, some participants are eager to know whether the researcher is for or against GMOs. The researcher does not evade the question and advises the participant that on completion of the interview, an answer to the question will be provided. The delay in answering the question is a tactic supported by Goodell, Stage and Cooke (2016). Cooke (2016) points out that if a researcher presents own perspective during an interview, it may result in undesirable consequences because participants can change answers to fit what they think the interviewer wants to hear, resulting in biased responses. In such situations, at the end of the interview, the researcher gives participants an honest account of previous findings by leading researchers on GM crops that emerged from the literature reviewed, presenting both points of view of proponents and critics of GMOs.

The researcher conducts in-depth interviews with participants at venues chosen by the participants, in their environment and the researcher has an opportunity to connect with the participants. The advantages of conducting in-depth interviews are that the researcher does not only collect data first-hand as the participants speak but watch the body language of the participants. The researcher can interpret meaning in ways that may not be possible with a self-administered quantitative questionnaire. Furthermore, the researcher asks the participants follow-up questions that had not been anticipated at the time the questions of the interview guides were formulated. Some follow up questions are also asked after the researcher has transcribed the interviews to clarify issues that are not clear.

Focus groups

In this study, in-depth interviews are the main data collection tool for the qualitative research. However, focus groups are also used to collect data because, as pointed out by Wilson (2014), a wider range of information can be generated from them as opposed to one-on-one in-depth interview. Participants may be more candid and engaged in a group interview than they would be in a single in-depth interview (Wilson, 2014). However, for focus group discussions to achieve their objective, participants need to be homogeneous because in heterogeneous groups, participants at lower levels may not be free to express themselves in the presence of experts or higher educated people (Acocella, 2012).

An enquiry into Genetic Modification, a specialist scientific area, requires the researcher to share information with experts. For example, Bennet (2015) selected four experts to participate in a focus group to find out whether there are risks to the health of people that consume GM foods as well as establish the economic benefits of GM crops. It became clear that the focus group was aware that GM crops grown in the United States are safe for human consumption as they undergo tests which are much more stringent than those applied to their conventional counterparts before they are released to the market. In the focus group discussion, doubt was raised, however, about the potential benefits to farmers in developing countries in a situation where farmers had no choice to buy alternative seed. From Bennet's (2015) findings, it was apparent to the researcher that the researcher's study can benefit from discussions with various experts at focus group situation.

For these reasons, three focus group interviews were conducted with selected stakeholders where the researcher was the moderator in all sessions. The first one took place in Pretoria, South Africa, on 2 September 2015; the second one at Great Zimbabwe, in Masvingo, Zimbabwe, on 26 September 2015 and the third at Cresta Lodge in Harare, on 14 November 2016. The focus group discussion held in South Africa was attended by four journalists, one academic and one scientist and lasted fifty minutes. The topic of the discussion was based on research question one (RQ1) that sought to establish the factors that drive or constrain the diffusion and adoption of GM crops. The objective of the group discussion was to understand how to improve communication between scientists and journalists about scientists sharing information for publication about GM crops.

The focus group meeting held at Great Zimbabwe involved three members of the Parliament of Zimbabwe and the Chief Executive of the National Biotechnology Authority (NBAZ) who is also the registrar of biotechnologies in Zimbabwe. The Members of Parliament were familiar with GM crops, having visited confined field trials of GM cotton in Malawi in 2014. The meeting lasted forty minutes and the topics discussed focused on the three research questions. The objective of the discussion was to establish an understanding of the perceptions of the Members of Parliament on the adoption of GM crops in Zimbabwe and their role as policy makers about GM crops.

Qualitative data analysis

This research is conducted on the backdrop of a controversial and politically charged debate about the adoption of GM crops (Chadwick, 2017). On calling for a rational debate on GM crops, Whitty *et al*. (2013) argue that an emotional and polarised debate is not helpful to policy makers in their decision-making processes. This study draws from Thorne (2000, p.68) and aims to "discover the truths that exist in the world" of GM crops to establish the factors that drive or constrain the diffusion and adoption of

GM crops in Zimbabwe, Malawi and South Africa. In addition, the researcher is inspired by Denscombe (2010) who points out that a researcher should suspend personal beliefs and judgements about the subject of research during the research.

Based on the pragmatism research philosophy and focusing on research methods that best answer the research question, the qualitative research involves in-depth interviews, focus group discussions and observations of field trials of GM crops. To begin data analysis, the researcher prepares manually typed interview transcripts and notes of observations using word processing (Microsoft Word). The completed transcripts are printed and placed in a file. This is a time-consuming exercise because, in line with Hsieh and Shannon (2005, p. 1279) and Noble and Smith (2014, p. 3), the researcher reads the transcripts repeatedly "immersing within the data to gain detailed insights" into the phenomena on stakeholders' perceptions about GMOs. To maintain the quality of the research, contributions of all participants are considered and the researcher uses quotations from the interview transcripts to capture accurate responses from participants. The researcher uses narrative analysis to gain insights into participants' lived experiences of GM crops using direct quotations from the participants.

To summarise, the overarching philosophy of this research is pragmatism which selects the research strategy based on the research question. In this regard, data analysis of the qualitative research is informed by interpretivist epistemology. This approach uses verbatim quotations from interviews during the presentation of findings and compares it against literature to establish differences or similarities to what is known already. However, the researcher is aware of the inherent risk that may be caused by quotes whereby the participants may recognise their contributions or be recognised through failing to anonymise participants (Tsai *et al*., 2016). The mitigating measures that the researcher has put in place to avoid this issue include the strict use of codes for participants and avoidance of details of locations and the source of information. The actual names of participants will not be revealed when verbatim quotations are used. The ethical considerations of the research are discussed in the next section.

Ethical considerations

It is important to consider the principles of ethical conduct relating to this study on the diffusion and adoption of GM crops in Zimbabwe, Malawi and South Africa because it is conducted in three countries cutting across diverse cultural settings. When researching different cultures, it is important to respect and adapt to different cultures because what may be acceptable in one culture may not be acceptable in another (Wilson, 2014). For example, while it is the general norm to shake hands when greeting, it is not acceptable for a male stranger to shake the hands of a woman in some communities in Zimbabwe and Malawi. In this regard, during field-work, the researcher, being a middle-aged male, needs to be alert to such norms.

In the words of Denzin and Lincoln (2011), ethics relates to the moral standing of a human being in the world. However, Saunders *et al.'s* (2007, p.178) definition that states, "Research ethics therefore, relate to questions about how we formulate and clarify our research topic, design our research and gain access, collect data, process and store data, analyse data and write up our research findings in a moral and responsible way" resonates with the goals of this study. In this regard, three ethical principles espoused by Gray (2009) and Fisher (2010) as well as supported by Singh (2012) guide this study, that is, to:

- ensure informed consent of participants
- respect the privacy of participants
- avoid the use of deception.

The ethical principles are considered in turn.

Consent of participants

During field-work, a letter addressed to participants introducing the study and consent form (Appendix 4) is handed to the participants. The participants are asked to read the letter and sign the consent form before participating in the study. The contents of the letter include an explanation that the researcher is a doctoral student at Nottingham Trent University. The participants are informed that the purpose of the study is to identify the factors that drive or constrain the diffusion and adoption of genetically modified crops in Zimbabwe, Malawi and South Africa. They are also advised that they can withdraw from the study at any time even after the interview or completion of the questionnaire. The researcher does not offer gifts or rewards to the participants and ensures that participants participate in their free will.

There have been a few cases where participants refused to be interviewed or to complete the questionnaire. This is more notable in Zimbabwe, particularly with the officials from the Ministry of Agriculture. One participant declared, “I would have participated in your study if I was not employed at this Ministry.” However, in some cases, it has been noted that it is because of busy schedules that government officials took long to respond. For example, it took several visits to the Ministry of Health in Harare to secure an interview with a senior government official. The same happened in Malawi; regardless of prior appointment, the researcher was made to wait more than two hours in the reception area before being granted an interview with a senior government official.

Privacy of participants

The participants in the study are guaranteed their anonymity and that data gathered will remain confidential. In the qualitative research findings, codes are used instead of actual names of participants. Even though in some cases participants have expressed a willingness that their real names be used in the study, the real names are not used to maintain consistency.

Data management: avoiding deception

During the field work of the qualitative research, in-depth interviews are recorded using a digital voice recorder. Consent for recording is requested from participants before recording begins and the participants sign a form as evidence of their consent. Before signing the form, the participant is informed of the purpose of the study and that signing the form signifies consent to be recorded. The voice recorder is placed prominently for the participant to see and be aware that recording is happening. Transcripts of the recordings are prepared using a word processor after which the transcripts are printed, put into a file and secured in a locked cabinet. Completed survey questionnaires are processed using Microsoft Excel spreadsheet and the processed questionnaires are put into a file and secured in a locked cabinet.

Affiliation and conflicts of interest

The researcher is Executive Director, Business Development for Africa at Quton Seed Company (Quton). Quton is a subsidiary of Maharashtra Hybrid Seeds Company Limited (Mahyco) based in Mumbai, India. Domiciled in Harare, Zimbabwe, Quton's business is mainly production and distribution of certified cotton planting seeds and other crop seeds. Quton has operations in Zimbabwe, Malawi, Tanzania and Zambia and exports its products to Uganda, Mozambique and Swaziland. In India, Mahyco is involved in the research and development of GM crops including cotton. This study is on diffusion and adoption of GM crops. Therefore, there would be a possible conflict of interests because the researcher is a senior executive of a subsidiary company whose parent develops GM crops. However, Mahyco, the parent company, acquired Quton after the researcher had already commenced and completed three years of his Doctoral research at Nottingham Trent University. There is no undue influence by the employer on the research findings and academic work. The next chapter presents the findings of the research.

CHAPTER 5

RESEARCH RESULTS AND ANALYSIS

Introduction

This chapter presents the results of the research and analyses data collected from 222 participants of which fifty-three were involved in the qualitative research and 169 participated in the quantitative survey. The response rate of both quantitative and qualitative research was 100% outturn. This high response rate was achieved because the researcher personally took questionnaires to the participants (smallholder farmers) and waited while they completed them. In situations where the smallholder farmers needed clarification, the researcher explained.

From the outset, the primary objective of this study is to establish factors that drive or constrain diffusion and adoption of genetically modified (GM) crops in Zimbabwe, Malawi and South Africa. The study seeks to answer the following three research questions through data collected from stakeholders that are involved in the adoption of GM crops that include policy makers, farmers, consumers, technology developers, ginners, NGOs, media and scientists; and data collected during observation of field trials of GM crops in Malawi:

1. What factors drive or constrain the diffusion and adoption of GM crops in Zimbabwe, Malawi and South Africa?
2. How are new ideas, technologies and knowledge on GM crops transferred to smallholder farmers in Zimbabwe, Malawi and South Africa?
3. What role do policy makers, smallholder farmers and other stakeholders play in influencing the adoption of GM crops and protecting the environment?

This study is anchored on pragmatism research philosophy and is conducted using the mixed method research strategy. The presentation of the findings is guided by research questions and is divided into two parts, a quantitative segment and an interpretive qualitative segment. The presentation starts with the quantitative part followed by the qualitative part. Research question one, which addresses the main research objective is answered using the mixed method research. This has been done so that the theories that emerged from the literature that relate to relative advantage of GM crops are tested quantitatively. The reason why an interpretive qualitative research segment is applied on RQ1 is to gain insights into the perceptions of research participants with regard to the factors that drive or constrain the diffusion and adoption of GM crops in Zimbabwe, Malawi and South Africa. Verbatim quotations of participants from in-depth interviews and focus groups are interpreted in the context of questions asked by the researcher. The researcher notes that the other two research questions are adequately answered using the interpretive qualitative research.

Part I: Potential benefits of GM crops

In order to establish the factors that drive or constrain diffusion and adoption of genetically modified (GM) crops in Zimbabwe, Malawi and South Africa, as a first step, the research sought to establish the potential relative advantage of GM crops in terms of farm profitability. Cotton varieties that are currently used by farmers in the three countries under study were evaluated. The plant breeders at the Cotton Research Institute in Zimbabwe and Makoka Research Station in Malawi confirmed that the cotton varieties grown in Zimbabwe and Malawi have a potential yield of more than 4,000 kilogrammes (kg) per hectare under excellent management. However, the researcher notes that the yield potential given is at controlled research station environment where resources are available in human, financial and land. Such optimum yields will not be achievable by resource poor farmers that lack financial resources and better lands.

Depending on the variety, cotton breeders recommend a population of 30,000 to 33,000 plants per hectare. Some variables determine the yield that farmers can achieve. Table 5.1 illustrates how potential yield can be estimated using data gathered from plant breeders at a research station in Zimbabwe. The variables that determine yield include the number of plants established per hectare, boll retention and the weight of the bolls.

Table 5.1 Yield potential of raw cotton

Plant population/ha	Number of bolls/ plant	Weight of each boll (gr)	Yield per hectare (kg)
30,000	5	5	750
30,000	10	5	1,500
30,000	20	5	3,000
30,000	30	5	4,500

In Table 5.1, the plants established have been held constant at 30,000 and the bolls retained per plant are varying from 5 to 30. The boll weight has been held constant at 5 grams to illustrate the yield that can be achieved. Any variation of the three variables affects the potential yield and farm productivity.

Even though plant breeders claim that the cotton varieties that are grown in Southern Africa can potentially yield more than 4,000 kilograms (kg) per hectare (ha), the smallholder farmers that participated in this study did not achieve those yields. In Zimbabwe, smallholder farmers that have not adopted GM cotton achieved a yield of 819 kg per ha and their counterparts in Malawi who have not adopted GM cotton achieved 772 kg per ha in comparison to adopters in South Africa that achieved 1,012 kg per ha (see Table 5.3). There are a number of reasons why smallholder farmers fail to achieve potential yields; these include failure to apply fertilizers, crop protection chemicals, rainfall patterns and poor farm husbandry.

Results of GM cotton open field trials in Malawi for 2016-17

On 24 May 2017, government scientists at Makoka Research Station in Malawi organised a field visit of the OFT of GM cotton being evaluated at Toleza Farms in Balaka. The researcher attended the field visit along with other guests who included policy makers from the Ministry of Agriculture, farmers, ginners and representatives of technology developers. Before the visitors were taken to the demonstration plots, the organisers briefed them about the purpose of the visit. It was explained that DARS had invited key stakeholders to see the OFT to familiarise them with the GM cotton in preparation for commercial release. The organisers explained that nine OFTs of GM cotton had been established in different ecological zones of cotton growing areas throughout the country. The reason why the OFTs were grown in nine different sites was to evaluate the performance of the GM cotton in those areas so that farmers are advised of expected performance at the time of commercialisation.

Figure 5.1 shows a photograph of GM cotton trials taken by the researcher on 23 May 2017 at Toleza Farms. The GM cotton had split bolls and was ready to be harvested. However, the conventional non-GM cotton was still at vegetative stage and had noticeably less number of bolls compared to the GM cotton. The researcher asked a government plant breeder why the cotton was showing different maturity stages, yet they claim that the varieties were the same except that one had GM insect resistant trait and the other did not have. In response, the breeder explained that GM cotton matured faster because it had not lost many fruits. Therefore, the plant did not need to continue growing. The breeder further explained that the non-GM crop which had lost a lot of bolls to bollworms continued to grow in search of more fruits.

The researcher counted the bolls retained on the GM cotton on one plot. Five plants were counted at random and they had between fifty and sixty bolls per plant. There were thirty bolls per plant on non-GM cotton. The researcher found out that at the one plot, GM cotton out yielded non-GM cotton by a minimum 67 percent even though the non-GM cotton had been sprayed ten times against bollworms and the GM cotton had not been sprayed against bollworms.

Figure 5.1 Open field trials of GM cotton in Malawi: May 2017

Source: Photograph by the researcher

The DARS released the results of OFTs for the 2016-17 season which are presented in Table 5.2. The table shows that the yields achieved by GM cotton are higher than the yields achieved by non-GM cotton at all trial sites.

Table 5.2 Summary of four sites for GM cotton trials in Malawi for 2016-17 season

Research Centre	Ngabu	Kasinthula	Baka	Lupembe	Mean
GM Cotton kgs	4803	2552	4887	3109	3838
Non-GM Cotton kgs	2561	1772	3088	2041	2365
Difference kgs	2242	780	1799	1068	1472
Difference %	88%	44%	58%	52%	62%
GM Cotton GOT %	32%	32%	33%	34%	33%
Non-GM GOT %	34%	36%	36%	35%	35%

The results in Table 5.2 are for cotton trials conducted by breeders from the Department of Agriculture in Malawi and the crop husbandry was done under the supervision of specialist agriculturalists. In that regard, optimum yields are expected at the research centres under heterogeneous conditions. The mean yield of the four research stations of 3,838 kgs per hectare is 62 percent above the yield achieved by non-GM cotton varieties. This is much higher than 20 percent yield increase that Finger (2011) found in South Africa. However, the ginning outturn (GOT) of GM cotton at 33 percent is two percentage points lower than the non-GM cotton and seven percentage points lower than the minimum 40 percent that a ginner that participated in the research stated. However, the non-GM cotton at the research centres achieved 35 percent GOT which may indicate that the ginner overstated expectation. The GOT is important to the ginners because it is the ratio of lint produced against remaining cotton seed and waste after processing.

Analysis of GM and non-GM cotton: yield, cost of production and profitability

This study was conducted in Zimbabwe, Malawi and South Africa and the researcher notes that Zimbabwe and Malawi have not yet commercialised GM crops. South Africa began commercial cultivation of GM crops in 1997. The data from the South African smallholders that adopted GM crops is used to compare with the data from Zimbabwean and Malawian smallholder farmers that use conventional non-GM cotton.

Following is an analysis of findings of the survey conducted on 169 farmers of which seventy-two were participants from Zimbabwe, fifty-five from Malawi and forty-two from South Africa. The purpose of the survey was to answer research question 1: What factors drive or constrain the diffusion and adoption of GM crops in Zimbabwe, Malawi and South Africa? In this regard, a questionnaire was developed which sought to gather data on farm records that could be used to establish the incomes achieved by smallholder farmers in the three countries under study.

The results of the survey of smallholder farmers that participated in the quantitative research are shown in Table 5.3.

Table 5.3 Cotton production and the incomes of smallholder farmers by country (1 hectare): Farming season 1 September 2013 - 31 August 2014.

	Zimbabwe (Non-GMO)	Malawi (Non-GMO)	South Africa (GMO)
Seeding rate (kg/ha)	15	15	6
Yield (kg/ha)	819	772	1,012
Raw cotton price (US cents/kg)	56	51	56
Number of sprays	9	5	2
Gross income (US$)	459	394	567
Variable production costs (US$)	359	251	306
Seed	27	20	40
Labour	117	115	71
Fertilizer	90	-	98
Insecticides	35	13	2
Other costs	90	103	95
Net income (US$/ha)	100	143	261
Net profit margin	22%	36%	46%

Everything being equal, the results of Table 5.3 show that GM crops grown by smallholders in South Africa have a relative advantage over non-GM crops grown by smallholders in Zimbabwe and Malawi. The results show that South African farmers who grow GM cotton achieved a net profit margin of 46% which is twenty four and ten percentage points higher than their counterparts who grow non-GM cotton in Zimbabwe and Malawi respectively. On the face of it, the results indicate that GM cotton has a relative economic advantage over non-GM cotton.

It was established that the seeding rate of non-GM cotton in Zimbabwe and Malawi is 15 kg per hectare compared to 6 kg per hectare which smallholder farmers who plant GM cotton use in South Africa. According to a manager of a seed company in South Africa they recommend seeding rate of 12 kg per hectare. However, the smallholder farmers in South Africa use 6 kg per hectare. The difference is mainly caused by the germination percentages which is 90 percent in South Africa, whereas in Zimbabwe and Malawi the minimum germination standard for certified cotton seed is 70 percent. Therefore, Zimbabwean and Malawian farmers use 2.5 times more seed to plant one hectare of cotton than their South African counterparts. This means it costs 2.5 times more to distribute seed in Zimbabwe and Malawi as compared to South Africa.

When asked why 6 kg is used to plant a hectare, a leading South African smallholder farmer from Makhathini Flats in KwaZulu Natal explained that GM cotton planting seed is expensive and farmers plant one seed per planting station to manage costs of production. In Zimbabwe and Malawi, farmers plant at least five seeds per station and remove extra plants after germination. It was notable that in Zimbabwe and Malawi, government extension officers encourage farmers to plant three to five seeds per station because they claim that cotton is a weak crop that requires assistance to push soil during germination. This claim was disputed by senior plant breeders from a seed company who insisted that one seed per plant station was required if the vigour of the seed was established during seed conditioning at the plant.

The study established that in Zimbabwe, nine insecticide sprays were applied as compared to five insecticide sprays in Malawi and two insecticide sprays in South Africa. Likewise, in Zimbabwe, the cost of insecticides at \$35 per hectare, was significantly higher in comparison to the cost of insecticides incurred by South African farmers at \$2 per hectare. To the South African smallholder farmers, the cost of GM seed was \$40 per hectare as compared to \$27 and \$20 to the Zimbabwean and Malawian smallholder farmers respectively. If the cost of seed and insecticide is combined – on the basis that GM cotton is an insecticide on its own – the Zimbabwean farmers paid \$20 per hectare more than the South African farmers. Furthermore, there is an unestablished opportunity cost with regard to distance travelled by Zimbabwean and Malawian farmers during application of insecticides.

The distance covered by a farmer doing manual spray is 10 kilometres per hectare. During the cropping season under review, the distance walked per hectare by smallholder farmers in Zimbabwe was 90 kilometres, in Malawi 50 kilometres and South Africa 20 kilometres. The relative advantage of using GM cotton is that a South

African smallholder farmer walks 70 kilometres less than a Zimbabwean smallholder farmer and 30 kilometres less than a Malawian smallholder farmer. However, the 20 kilometres that the South African smallholder farmer walks may still be unacceptably high. The study confirms previous findings that farmers who use insect-resistant GM cotton spray fewer times against bollworms than farmers that use non-GM cotton (Bennet, Morse and Ismael, 2006; Kouser and Qaim, 2011; Sanahuja *et al.*, 2011). These findings also show that the smallholder farmers that make use of insect resistant GM cotton can use the labour hours saved from spraying the cotton crop elsewhere in their farming activities.

This study has compared and contrasted the profitability of GM crops produced by smallholder farmers in South Africa against the profitability of non-GM crops produced by smallholder farmers in Zimbabwe and Malawi. In this regard, an analysis of the data in Table 5.3 revealed that South African farmers who used GM cotton achieved higher incomes and profit margins in comparison to Zimbabwean and Malawian farmers who used non-GM crops.

Part II: Diffusion and adoption of GM crops

In this segment, the results and findings of interpretive qualitative research relating to the three research questions are presented. The topic of this study is, 'Diffusion and Adoption of Genetically Modified Crops: Evidence from Zimbabwe, Malawi and South Africa'. The quantitative research in Part I shows that smallholder farmers that use GM crops achieve higher net profit margins in comparison to their counterparts that use conventional varieties. The theory of diffusion of innovations suggests that an innovation which has greater perceived relative advantage diffuses faster (Rogers, 2003). However, the diffusion and adoption of GM crops in Zimbabwe and Malawi has been slow. The results and findings of RQ1, 'what factors drive or constrain diffusion and adoption of GM crops in Zimbabwe, Malawi and South Africa?' are presented:

The factors that emerged in the literature and conceptual framework of this study that drive or constrain the diffusion and adoption of GM crops in Zimbabwe, Malawi and South Africa are: 1) relative advantage, 2) compatibility, 3) complexity, 4) trialability, 5) observability, 6) communication, 7) technology and knowledge transfer, 8) biosafety regulations and 9) political will.

These factors are now analysed in turn.

Relative advantage

The findings on the first factor, 'Relative advantage' from smallholder farmers that adopted GM cotton in South Africa, showed that 100% of the participants in the research were motivated to adopt GM cotton by the expectation of higher productivity, yields and incomes, decrease in use of pesticides, reduced labour costs for spraying chemicals and convenience. This is in line with Scandizzo and Savastano (2010) who argue that the adoption rate of GM crops will depend on how profitable they are perceived as compared to conventional varieties they replace.

The study established that all the smallholder farmers that participated in the study confirmed that the bollworm was the major pest that affected yields. In order to assure profitable harvests, the cotton farmers must protect the crop against fruit devouring pest. The findings were consistent with Schnurr's (2012) comments that the bollworm is the most devastating pest that affects the yield of cotton in the three countries under study–Zimbabwe, Malawi and South Africa.

Economic benefits

All the farmers that participated in the research are motivated to grow GM cotton against non-GM cotton in anticipation to achieve higher returns per unit of land. This study found that in Zimbabwe, Malawi and South Africa, smallholder farmers grow cotton in semi-arid regions where other crops such as maize and soyabeans do not thrive. As a result, the crop yield that is achieved by the farmers is low because of the harsh environment and growing conditions. Cotton, because of its resilience in harsh conditions, is the preferred crop. Furthermore, cotton is a cash crop and it adds to the much needed household income. These findings are supported by Bennett *et al*. (2003) whose study established that cotton was grown by farmers in the dry lands of Makhathini Flats in KwaZulu Natal, South Africa, mainly because it performs better in dry weather conditions in comparison with maize and beans.

In line with Baffes, Tschirley and Gergely (2009), the study established that the smallholder farmers in Zimbabwe, Malawi and South Africa are price takers and do not determine the price of raw cotton which the ginners pay. The price is determined by the international price of cotton lint measure by the A Index (ICAC, 2017). In this regard, in order to improve returns per hectare, the smallholder farmers need to improve crop yields at the minimum cost. Under optimum conditions, the yield potential of cotton varieties grown in Southern Africa is over 4,000 kg per hectare. The study found out that owing to several reasons that include climatic conditions, availability of inputs and farming skills, yields achieved by the smallholder farmers were far below potential.

When asked in what ways GM cotton improves the crop yield, an executive of a technology developer and seed company explained:

> When introducing GM cotton to farmers, we do not claim that *Bt* genes increase yield. Instead, we tell farmers that the insect resistant traits protect the crop against bollworm attack. Farmers need to know that to a large extent, agronomic practices determine the yield potential. We encourage farmers to practice good crop husbandry that includes the application of recommended fertilisers and weeding. Finally, farmers are advised to conduct regular scouting for pests and if they find that the infestation is above the economic threshold, they should spray the crop with pesticides (Participant ZW30).

The explanation by Participant ZW30 that technology developers do not claim that *Bt* genes increase yield is fundamental and it is in line with Qaim's (2016) argument that first-generation GM crops were developed to improve crop yields through control of diseases and pest. It is fundamental in that it underlines and contradicts the widely held claim that GM crops increase yields. Genetics, as Participant ZW30 further explained, are crop characteristics that are the result of plant breeding efforts which should not be confused with the genetic modification process. This also confirms Glover's (2010)

argument that GM crops are not the only solution to farm productivity and increasing crop yield, but should be used complementary to good crop husbandry.
When asked, what would be the benefits of GMOs from a national point of view, a policy maker in Malawi said: “To be honest, we want to increase yields and reduce production costs, but what we have seen in the trials is nothing to write home about” (Participant MW07).

The study found that in September 2015, the regulators in South Africa declined to release insect resistant GM potatoes for commercial cultivation. A government official was asked why the government had declined to release the GM potatoes. He explained that the decision had been made after considering the economic and social benefits of the GM potatoes to smallholder farmers. The government had not found sufficient potential benefits to the smallholder farmers that warranted the release. The decision by the South African government not to allow commercial release of the GM potatoes on the basis of failure to prove economic and social benefits showed that in the diffusion of GM crops, economic and social advantage are important factors that drive diffusion and adoption. One important factor that influences adoption of GM crops is the high cost of GM seeds.

Concern for the cost of GM seeds

In the adoption of GM crops, the cost of GM seed is a troublesome perceived risk for the farmers. In Malawi, 100 percent of farmers that participated in the study pointed out that they were concerned that the GM cotton seed will be too expensive and the underprivileged farmers would not afford to buy the seed. The farmers demanded that cost-benefit analysis be undertaken before commercialisation of the GM cotton to ensure that there is a business case in which smallholder farmers get incremental benefit by the adoption of GM cotton. A leader of a farmers’ union said:

> We are pleased with the performance of GM cotton regarding control of bollworms and yield potential. The only issue that is of concern to many people is that of the price of seed. We asked officials from the seed company for an indicative price of the seed, but we did not get a straight answer. They either ignored the question or when they answered they talked about shared benefits to the farmers without giving specific amounts (Participant MW08).

In South Africa, the study found that farmers plant 50 percent of the recommended seeding rate because they save on the cost of seed. However, the seeding rate did not affect the crop establishment because the farmers made sure that they planted the seed when the soils had sufficient moisture to ensure maximum germination. In that way, they still achieved plant population of over 22,000 plants per hectare.

The researcher sought to establish the pricing structure of GM cotton from the technology developer and seed companies. The responses from both the technology developer and the seed company were similar and consistent with the points raised by Participant MW08 of Malawi. The companies explained that the price of seed is determined after approval of commercialisation and it is based on sharing profits among the technology developer, the seed company and the farmers. To the farmers and government policy makers, the pricing policy is not transparent. The farmers and policy makers suspect that the seed companies are hiding "something". The failure of the seed companies to provide accurate information of seed prices ahead of commercialisation of GM cotton in Malawi is causing distrust among the stakeholders. This might negatively impact the adoption of GM cotton in Malawi.

The decrease in the use of pesticides

In the case of non-GM cotton, farmers control the bollworm by spraying toxic chemicals depending on infestation levels. In some instances, farmers need to spray up to ten times during the growing stages of the crop. These sprays cost a lot of money. In Zimbabwe, in February 2016 at the peak of bollworm infestation, one litre of pyrethroid sufficient to spray one hectare, cost \$3.50. Therefore, ten sprays using pyrethroids would cost \$35. In 2016, at a research farm of a seed company in Kadoma, Zimbabwe, non-GM cotton on a demonstration plot were sprayed twenty-one times with toxic insecticide chemicals of which fifteen were against bollworms and five were against sucking pests.

Smallholder farmers in South Africa demonstrated that the use of GM cotton reduced the number of sprays by 50 percent in most cases. Participant SA08 who is an expert in cotton farming in northern KwaZulu Natal explained:

> In our area, we have a subtropical climate and normal annual rainfall is about 450 millimetres. The pest pressure is much higher than in other parts of the country. In our area, if a farmer grows conventional cotton, he will spray 7 to 8 times and if he grows GM cotton, he sprays at most four times. When the climatic condition is not favourable for spraying for example when the weather is very hot or very wet – even during social reasons like Christmas – which happens mostly over the peak flowering and boll forming stages, GM cotton’s in-built insecticide protects the crop. Should a farmer fail to make an essential spray during that period, the cotton has inbuilt protection which will help maintain a good yield. If the farmer has grown conventional cotton, one slip up on an important spray can result in loss of up to 50% of expected yield (Participant SA08).

As explained by Participant SA08, there are various reasons why farmers may fail to get into the fields to spray the cotton crop against boll devouring pests during boll formation stage. The lands may be inaccessible due to immediate heavy rains, a bereavement within the family or an important holiday such as Christmas or New Year’s Day. The pests do not attend funerals, neither do they go on holidays. However, if the cotton crop is GM that has an inbuilt insect defence system, then the yields will not be affected.

In line with Sanahuja *et al.* (2011), the study found out that technology developers and seed companies introduced refugia to mitigate against the development of resistance to the *Bacillus thuringiensis (Bt)* gene by the bollworms. GM cotton seed packs included five percent non-GM cotton that is planted at the same time with the GM crop. The bollworms feed on the bolls of non-GM cotton and they mate with other bollworms that may have survived the *Bt* toxins. As a result, the onset of development of resistance by bollworms against the *Bt* toxins is slowed down.

However, 50 percent and 30 percent of policy makers interviewed in Zimbabwe and Malawi respectively highlighted that they were concerned that regardless of these measures, the pests eventually build resistance against the *Bt* gene, thus rendering the insect resistant gene useless as Participant ZW03 put it, "I do not agree with the argument that refugia will delay the onset of insect resistance to the *Bt* gene. To me, it is just a marketing gimmick. The bollworms will eventually build resistance just like mosquitos did against DDT." However, of the six farmers that were interviewed in South Africa, all of them stated that they would not want to go back to planting "the old" varieties, meaning non-GM cotton in preference of GM insect resistant cotton.

The study sought to establish the views the participants in Malawi hold about GM cotton with regards to CFTs that were conducted over a three-year period. A participant was asked his views about the performance of GM cotton in comparison with conventional varieties. The participant said: "The people in the cotton sector welcome GM cotton because most of our farmers do not have protective clothing and sprayers. There is also a challenge in accessing chemicals for pest control." (Participant MW09).

Convenience

All South African farmers who participated in the study grew GM cotton and had experience in growing non-GM cotton. They all emphasised that they will not switch to non-GM cotton because GM cotton provided unparalleled convenience. The farmers highlighted the reduced number of sprays, less exposure to harmful pesticides and the reduced number of labour hours required to attend the crop. The study found that 90 percent of the farmers that participated in the study were above fifty years old. A farmer in Gokwe put it thus, "We are ageing and our children do not want to be involved in cotton farming because it is not easy". A technology developer added, "We want to bring innovations to farmers that will make it convenient for them to grow cotton and insect-resistant GM cotton does that because it has inbuilt insecticide".

Compatibility

A policy maker in Malawi pointed out that there is concern that GM genes in the cotton might affect lint quality as what happened in Burkina Faso where the quality of cotton deteriorated over time. He explained that the government wanted assurance from the technology developers and seed companies that the GM cotton which was intended to be commercialised in Malawi was not going to repeat the Burkina Faso scenario. This shows that policy makers in Malawi are aware of the failure of GM cotton in Burkina Faso which is also in the studies by authors that include Dowd-Uribe and Schnurr (2016), Maiga (2016) and Bavier (2017). However, the implications for diffusion and adoption of GM cotton in Malawi are that technology developers should explain why in Burkina Faso the fibre length of GM cotton was shorter in comparison to its isogenic non-GM variety. In addition, the technology company should explain how they are ensuring that this does not happen in Malawi.

Risk of GM crops to humans and animals

In line with Taleb *et al.* (2014), the study found that policy makers in Zimbabwe take a precautionary principle approach towards GM crops because of the unknown long term effects of GMOs on the health of humans, animals and the environment. The study found that 50% of the policy makers interviewed in Zimbabwe pointed out that GM crops could potentially cause harm to human health and they all referred to Seralini *et al*.'s (2012) study in which rats had tumours after eating a GM maize meal. Five participants pointed out that twenty years is a short period to satisfactorily evaluate the effects of GMOs on human beings and animals.

The researcher asked a scientist who is also an academic to explain the effects of the *Bacillus thuringiensis* (Bt) toxins on humans and she explained that the oil that is extracted from cotton seeds which humans consume do not carry dangerous levels of Bt toxins. She further explained that the human stomachs are acidic and any Bt protein that may be present in the oil is neutralised during digestion. The scientist further explained that the people of Southern Africa have been consuming GM products since 1998 when South Africa commercialised GM crops and there hasn't been a single report about a person whose health was adversely affected by a GM product. These findings are in line with Christou and Twyman (2004) who argue the same. However, the study notes that Taleb *et al*. (2014) throw caution to the wind as they argue that the discovery of harm caused by GM crops may happen years later after considerable damage has been caused.

The study also found that there is wide disagreement amongst the scientists about the safety issues regarding GMOs. At a GMO workshop held in Harare on 25-26 July 2016, the question of disagreement amongst scientists was raised. Showing signs of frustration, an academic exclaimed, "If there is a scientist who doesn't believe in science, I say renounce your doctorate!" However, another academic cautioned that "Scientists tend to present only the bright side of GMOs as if there is no negative side. The debate should include both sides of the GMOs, the positives and the negatives". At the workshop, the researcher asked an academic whether he eats GM products and the academic was quick to answer 'yes'. He explained that to his knowledge, no GM crop is released into the market that has not passed the necessary safety evaluation. He further explained that the GM crops in South Africa had undergone at least two evaluation processes. The first one was done in the USA – the country of origin of the trait – and the second was done in South Africa before approval of the trait.

Effects of GM cotton to the environment

The study discovered that policy makers responsible for environmental management in Zimbabwe and Malawi are concerned that GM cotton may cross-pollinate with wild relatives. This is consistent with Murnaghan (2017) who argues that the genes of GM crops can be transferred through cross-pollination with their wild relatives or conventional non-GM plants. When asked, "what is the risk of cotton cross-pollinating with wild relatives?" a plant breeder explained that the pollen from the cotton plant is comparatively heavier than pollen of most other plants such that wind does not blow cotton pollen beyond five metres. He further explained that the fertilisation process of cotton happens within the flower where the stamen which contains the pollen and stigma that receives the pollen to fertilise the seeds are located millimetres apart.

In contrast, the tassels of the maize plant that contain pollen are about a metre apart from the cob which has silks that carry pollen to the kernels. The pollen of the maize plant is relatively lighter and can be blown by wind several hundreds of metres away. Thus, cross-pollination of maize with its wild relatives is at higher risk. Cotton has lower chances of cross-pollination with pollen to plants further away. This study established that farmers and other stakeholders can control cross-pollination by isolating GM crops and other crops during planting.

Risk of unauthorised GM seed planted in Zimbabwe and Malawi

There are Zimbabwean and Malawian nationals who are migrant workers in South Africa and they return to their home countries on vacation. The migrants usually take various essential goods from South Africa that include food, clothing and other essential commodities. There may be an opportunity that the migrants may buy a packet of seed from a shop in South Africa to bring home. For example, James (2015) notes that if the seed purchased in South Africa is cotton, the chance that it is GM will be 100 percent, white maize 86 percent, yellow maize 92 percent and soya beans 95 percent.

In this regard, there is the likelihood of unknown production of unauthorised GM crops in Zimbabwe and Malawi. In Malawi, the policy makers that participated in the study could not confirm whether there are unauthorised GM crops under cultivation. However, the policy makers pointed out that if any GM crops are in production, the volume is insignificant. In Zimbabwe, an expert pointed out that the prevalence of unauthorised GM crops might be quite serious. However, in mitigation, he said:

> The good thing about Zimbabwe is that GM maize varieties in South Africa are not well adapted to the ecological zones of Zimbabwe. The GM maize seed is very expensive in South Africa as compared to the conventional hybrids of Zimbabwe. In addition, there is no shortage of quality hybrid maize seed in Zimbabwe. Therefore, there is no incentive for the visitors to bring the GM seed from South Africa to Zimbabwe (Participant ZW17).

The National Biotechnology Authority of Zimbabwe (NBAZ) has biotechnology officers stationed at all the border posts of Zimbabwe that includes the Beitbridge border post which connects Zimbabwe and South Africa. The NBAZ biotechnology officers' mandate is to ensure that no unauthorised biotechnology products, including GM products, enter Zimbabwe. The biotechnology officers have test kits that can detect the level of GMO contamination in food products including crop seeds.

Control of national seed bank by multinational companies

The study established that Zimbabwean authorities are concerned about seed companies being controlled by external multinational companies. The government of Zimbabwe wants the germplasm and national seed bank to remain in the control of national institutions such as the Department of Research and Specialist Services (DR&SS) or locally owned companies. A senior policy maker in Zimbabwe said, "Seed is very strategic, it cannot be left in the hands of foreign companies", (Participant ZW24). This finding draws a similarity to Roberts and Bjerga's (2015) report that the Chinese President, Xi Jinping, pronounced China's policy which he described as supporting home-grown solutions against foreign companies on the GMO market.

The researcher noted that international seed companies had established bases in Zimbabwe through the acquisition of shares of local seed companies. However, Zimbabwe has the Indigenisation and Economic Empowerment Act [Chapter 14:33] (IEEA) that stipulates that foreign companies are not allowed to control local companies unless the Minister grants permission. Section 3 (1) (a) of the IEEA provides that indigenous Zimbabweans shall own at least fifty-one per centum of the shares of every public company and any other business. In this regard, international seed companies cannot own more than 49 percent of local seed companies without government approval. With such legal protection, fear of international seed companies taking over the national germplasm and seed bank is nebulous.

It was, therefore, necessary to establish what form of guarantees a multinational corporation (MNC) could offer to assure the government that the MNC will not take over the national germplasm and seed bank of Zimbabwe. A participant said:

> There is no need for the multinationals to provide guarantees in any form because what they will bring to the country is complementary to what is already available. The introduction of new hybrids did not decimate the national germplasm. In any event, farmers are not fools; they will not adopt any new thing that is not good for them. Farmers in this country adopted hybrid seed maize ahead of all African countries, the popular SR52? Other maize hybrids have come and gone. That is progress (Participant ZW21).

When asked how issues about the adoption of GM crops may be handled in a polarised environment, a policy maker said, "My advice is, do not take important but controversial issues to politicians a few months before an election. Politicians do not want to be involved in controversial decisions which may be used against them by their opponents during campaigns" (Participant ZW21). A senior policy maker explained that the reason why GM crops are not allowed in Zimbabwe is political. However, technical reasons are used to support the political stance. He further said, "We safeguard our country against big foreign companies that can use terminator genes to force our people to continue buying their seeds" (Participant ZW24).

Complexity

The study established that the complex nature of GMOs is a factor that inhibits the diffusion and adoption of GM crops in Zimbabwe, Malawi and South Africa. In line with Halford (2012), this study found that government environmental regulators in Zimbabwe and Malawi are concerned about the irreversibility of GM genes once released into the environment. A policy maker in Zimbabwe expressed concern that it may not be possible to get farmers to revert to conventional varieties should the world decides against the cultivation of GM crops at some point in the future.

The regulators pointed out that pollen from a GM crop can escape and contaminate the plants in the same family of crops, consequently affecting the genetic biodiversity. In this regard, it is important to firstly, familiarise the farmers with the wild relatives of cotton. Secondly, the farmers need to be trained on how to protect the environment to ensure that GM crops are not planted in the proximity of their wild relatives or to destroy nearby wild relative plants. An environmental officer in Malawi stated that she is concerned that the insect resistant GM plants can kill other insects which are not the intended bollworms, thus negatively impacting the biodiversity of the environment.

The study found that 80 percent of the policy makers interviewed in Zimbabwe were concerned about losing export markets if the countries adopt GM crops. When asked to explain the government policy regarding GM crops, a policy maker in Zimbabwe said, "We will not allow our germplasm and seed bank to be contaminated by GMOs. Our varieties are in high demand in other countries because they are known to be clean and not GMOs" (Participant ZW 023). This was confirmed by Quton Seed Company of Zimbabwe that sold 1,100 tonnes of certified non-GM cotton planting seeds to Malawi in 2013. However, some of the export markets in Africa that Zimbabwe is targeting are conducting CFTs and OFTs of GM crops. James (2015) reported that Malawi is conducting OFT of GM cotton. Therefore, in the long term, Zimbabwe's exports to Malawi may not be guaranteed if Malawi commercialises GM crops as is expected.

Malawi is a land-locked country and movement to and from the sea of its imports and exports is through other countries which have not yet commercialised GM crops. In this regard, a government official said that the government fear that when GM crops are commercialised in Malawi, neighbouring countries who have not commercialised GM crops might not allow passage of Malawian agricultural products through their land. If the fear of movement of goods is not resolved, it has implications for the adoption of GM crops in Malawi. This may slow the adoption or outright rejection. The solution to this issue may be through bilateral country-to-country engagements with reference to the CPB. The CPB provides for the movement of LMOs through member States and the government of Malawi may need to engage neighbouring countries in this regard. However, the study notes that products processed from GM crops such as cotton lint and cotton cake for animal feed have minimal risk of contaminating the environment because they do not propagate. Malawi exports agricultural products to European and Asian countries that include cotton lint, tobacco and sugar.

However, a senior government official in Malawi stated that when GM cotton is commercialised, he would want farmers who prefer non-GM cotton to be able to access it so that they serve a niche market in Europe that needs non-GM cotton. Following up on the conversation, the researcher asked the policy maker to what extent the European Union (EU) and NGOs affect the development and adoption of GMOs and the policy maker said, “The EU, at the moment, has had no say in the development and adoption of GMOs in Malawi. The NGOs, on the other hand, have expressed their concerns over the adoption of GMOs citing loss of markets as one factor”.

In April 2015, during a workshop on GM crops that was held in Nairobi, Kenya, the researcher asked an official representing the EU to explain the policy of the EU on imports of agricultural products from African countries that would have adopted GM crops. The EU official said: “This question about exports from Africa and GM crops keeps coming up. The issue of exports is a matter of the relationship between two countries. It is a bilateral trade issue between trading partners and it has nothing to do with the EU”. However, the study found that South Africa exports ostrich meat to the EU without hitches and poultry products to Southern African countries that include Zimbabwe. This was confirmed by the South African Poultry Association (2015).

Trialability and observability

In Malawi, the study found that, Monsanto in collaboration with Bunda College of Agriculture, began conducting confined field trials (CFTs) of insect-resistant GM cotton in 2012. The CFTs were successful because they achieved their main objective after the Environmental Affairs Department (EAD) deregulated the insect resistant trait of the Monsanto GM cotton variety on 12 April 2016. These findings are consistent with Waithaka *et al*. (2015) who point out that the strategic goal of conducting CFTs is to evaluate the performance of the new GM crop against the conventional equivalent variety as the first step towards commercialisation of GM crop in the target market.

The study found the technology developers were satisfied that the CFTs had achieved that objective and are now working on the next stage which is open field trials (OFTs).

Communication

Consistent with Ezezika *et al*. (2012), the study established that communication is an important factor in the diffusion and adoption of GM crops in Zimbabwe, Malawi and South Africa. When asked how prepared Malawi was for the adoption of GM cotton given that the Environmental Affairs Department (EAD) had deregulated the insect resistant trait on 12 April 2016, a senior policy maker pointed out that GMOs are a mythical subject. She stressed that it was important that the technology developer and the seed company should do more to explain to stakeholders in the Ministry of Agriculture the pros and cons of GM crops.

The technology developer and seed company that is involved in the OFTs have been inviting various stakeholders to see the trials. During the visit of the OFTs, the researcher asked a smallholder farmer who has fifteen years cotton growing experience what he thought about GM cotton in comparison to non-GM cotton and the farmer said; "It is clear that production is much higher with GM cotton because the plant is an insecticide on its own". A participant from a seed company explained that the OFTs are a means of communication about the benefits of GM cotton to farmers. He said, "We do not need to talk much because the crop speaks for itself, let the farmers see the difference." Indeed, there is a remarkable difference between the GM cotton and non-GM cotton at the nine open field trials in Malawi.

In Malawi, the study found that technology developers need to engage ginners who are the stakeholders that contract farmers in cotton production. It became apparent that some ginners had doubts about the benefits of GM cotton when a ginner pointed out that farmers in that country were not sufficiently mature to handle the advanced technology:

> Our farmers have failed to maintain our local varieties well. They need education in cotton growing. I do not see how a person would be given a Rolls Royce to drive in the bush when he is failing to ride a bicycle. The hybrids and GMOs are high-tech products which will be put to waste if they are given to our farmers at this stage (Participant MW06)

When asked to explain the difference in crop farming between GM cotton and non-GM cotton, an expert explained that there is no difference in the basic farming practice. He explained that farmers would find it easier to produce the GM cotton, more so if the crop has staked genes – insect resistant and herbicide tolerance. In that case, the farmers can spray the crop with glyphosate herbicide, a chemical that kills most weeds and green plants indiscriminately, but the chemical does not kill GM herbicide tolerant cotton.

The subject of GMOs is loaded with technical terms. The researcher asked a senior manager of a technology developer who is an expert in the diffusion of GM cotton how he handles communication with stakeholders on issues regarding GM crops, he said:

> In communicating with the public about GM issues, I acknowledge that GMOs issues are not scientific issues, they are emotional issues. When you respond to emotional issues with scientific facts, it doesn't work. Objections from the scientific community can be effectively addressed using research data, but if it is from non-scientific people, I find it much better to agree with them first. After that I ask them to visit the open field trials where the crop speaks for itself. At the field trials, I speak less. You do not answer every question scientifically (Participant ZW 022).

Focus group discussion on communication

In the diffusion of GM crops, the dissemination of correct, accurate and timely information on GMOs is important to ensure that the public is not misinformed. Scientists that participated in the study lamented the poor quality of stories which journalists write about GMOs and GM crops. A focus group discussion was conducted in Pretoria, South Africa, with one academic, one scientist and four journalists. The purpose of the focus group was to answer RQ2: 'How are new ideas, technologies and knowledge on GM crops transferred to smallholder farmers in Zimbabwe, Malawi and South Africa?' The journalists comprised a science journalist, an editor, a journalist with a daily newspaper and a television journalist at the South African Broadcasting Corporation (SABC). The researcher was the moderator.

The discussion revealed that scientists and academics do not share knowledge with the media effectively. It was established that it would help scientists who put their stories in the media if they understood the needs of journalists in the newsrooms. Furthermore, the use of technical terms was identified as a barrier to communication. A journalist said, "Whenever we engage scientists, they intimidate us with their big words." When the television journalist was asked how he interacts with scientists on GMO issues, he said:

> What I am looking for is '*breaking news'* not the uninteresting stories. You rise to the top of journalism by publishing *'breaking news'*. The GMO stories seldom make headlines news because they are not extraordinary neither are they exciting. When I call a scientist, he should provide me with extraordinary news which the editor will want to broadcast in a slot of 90 seconds on SABC News prime time. The other problem that I have with scientists is that they do not respond immediately, it's always 'talk to me tomorrow' kind of stuff. There is no tomorrow on the news because after a few hours the news will be stale, therefore, useless for me (Participant SA09).

Other three journalists corroborated the points articulated by the television journalist from SABC at the focus group. The four journalists concurred that it helps a scientist to establish a working relationship with a journalist who will release their stories. They also suggested that scientists should participate in the social media like Twitter and Facebook because the journalists surf the social media when they look for contacts for specific stories. A scientist asked the journalists, "You focus on breaking news. Why don't you wait until the right information is available?" The journalists pointed out that there is competition for space in the news. Therefore, the story that appeals to be newsworthy is what gets published.

The focus group established that in order for scientists and technology developers to get new ideas, technologies and knowledge transferred to smallholder farmers through journalists, they needed to use language that is free of jargon and difficult scientific terms. It was also noted that networking and establishing relationships among the technology developers, scientists and journalists is a critical factor in communication.

Technology and knowledge transfer

RQ2: How are new ideas, technologies and knowledge on GM crops transferred to smallholder farmers in Zimbabwe, Malawi and South Africa?

In order to answer RQ2, in-depth interviews were conducted with nine participants who comprised four members of management of technology developers and seed companies, three smallholder farmers and two regulators. In line with Van Norman and Eisenkot (2017) the study established that technology developers are motivated to bring technologies to countries which have legislation that protects intellectual property rights (IPR). The study found that such IPRs are available in Zimbabwe, Malawi and South Africa and any person who has developed a seed crop – GM crops and non-GM crops – including seed companies may register the crop varieties with the registrar of Plant Breeders Rights (PBR).

The legal provisions on PBR in the three countries are mainly identical. In Zimbabwe there is the Plant Breeders Rights Act of 2001 of Zimbabwe (Zimbabwe, 2017) which is identical to the Plant Breeders' Rights Act of South Africa (South Africa, 2017). The piece of legislation was enacted to safeguard the PBR and to ensure that the entities that hold PBR licences can exclusively market their crop seeds that are products of their R&D for periods up to twenty years before the seed varieties are open to public use. The legislators are of the view that at the expiry of the PBR, the developer will have recouped his investment in R&D and made reasonable profits. In many ways, this provides the incentives for investment in R&D and encourages innovation and creativity.

In line with Monsanto's technology transfer strategy, the study found that Monsanto enters into licence agreements with seed companies and charges technology fees against GM crop seeds sales which carry Monsanto traits (Monsanto, 2018). The study found that in Zimbabwe, Malawi and South Africa, the process of technology and knowledge transfer of GM crops involves diffusers, adopters and regulators as illustrated in Figure 5.2.

In Figure 5.2 at the bottom of the diagram, from the left, the first arrow shows the process of technology transfer from the technology developers who engage in research and development of GMO traits to the seed companies who are engaged in seed production. The second arrow shows the next movement in the technology transfer process from the seed companies to the farmers who grow the crops. The last arrow shows the final stage of the technology transfer as the produce is sold to the consumers.

As shown in Figure 5.2, in Zimbabwe, Malawi and South Africa, there are three principal categories of players in the process of GM crops technology transfer who are: the diffusers being the technology developers, the seed companies; the adopters being the smallholder farmers and the market (consumer and end users); and the regulators.

The role of the technology developers is to provide the GM crop traits in the form of insect resistant or herbicide tolerant as may be demanded by the seed companies. The seed companies provide the GM crop seeds to smallholder farmers. The demand for seed by smallholder farmers is driven by market demand arising from the need of the product by the consumers of grain or end users of fibre as the case may be. The process of GM crops technology transfer involves a number of stages and complex activities which are explained below:

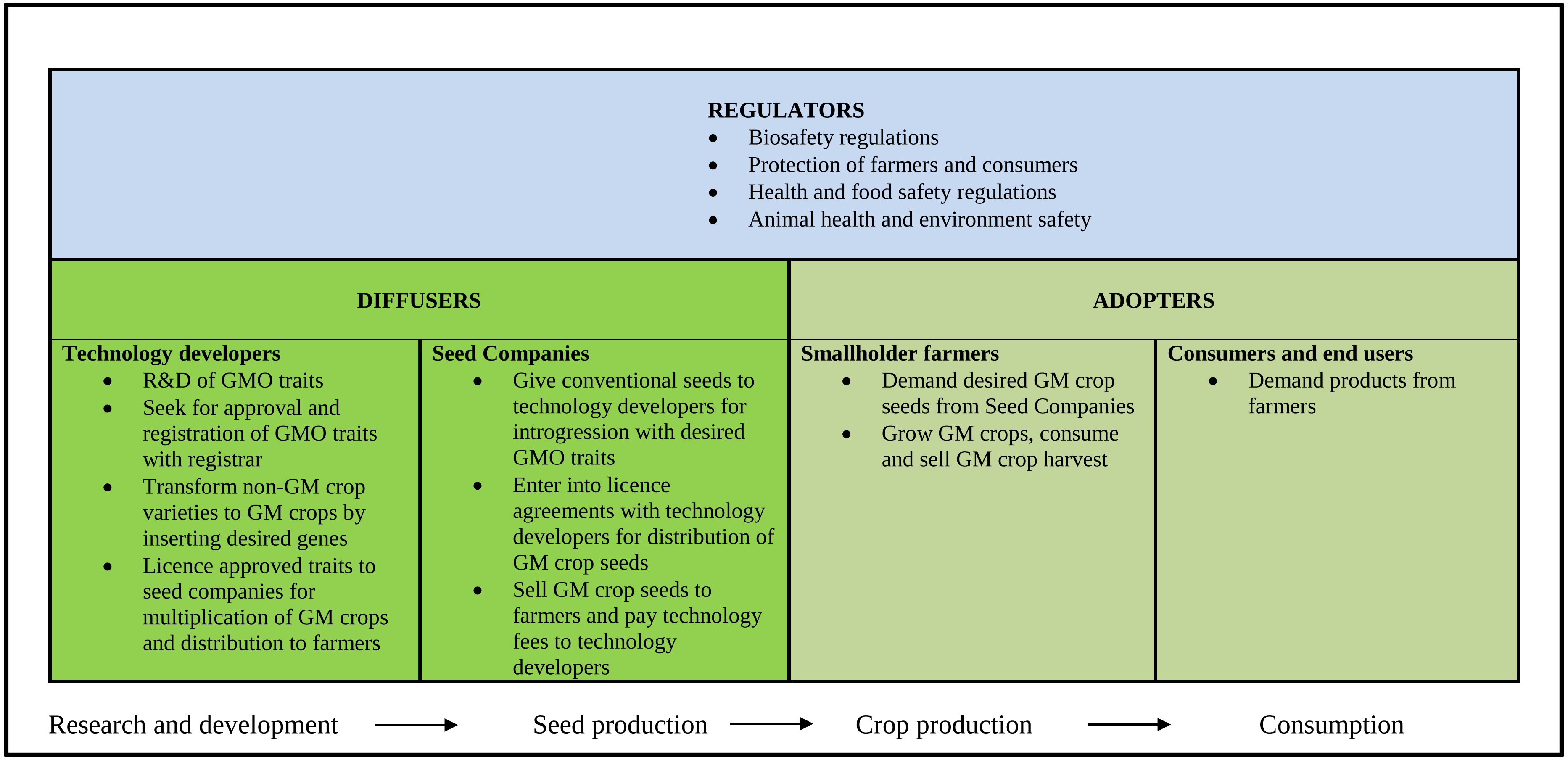

Figure 5.2 Process of technology and knowledge transfer of GM crops from technology developers to smallholder farmers in Zimbabwe, Malawi and South Africa.

Firstly, the technology developer must seek approval of the desired trait from the regulators, for example, insect resistant or herbicide tolerant, commonly known as ‘Bt’ and ‘Round-up Ready’ respectively. The activities involved in the approval process of GM crops in South Africa are shown in Appendix 3. When the trait is deregulated, that is, approved for release by the regulator, the technology developer enters into technology transfer agreements with seed companies which include, research, testing and commercialisation agreements. The agreements provide contractual obligations between the technology developer and seed companies regarding stewardship of the technology and collaboration on research and commercialisation activities.

The seed company, having identified a crop variety for a particular market – usually through conventional breeding methods – gives the seeds to the technology developer to convert the non-GM crop by inserting the chosen trait. After the successful transformation process, the technology developer gives back the new GM crop seeds to the seed company for testing efficacy and equivalence. The efficacy test is to check whether the trait is effective. The equivalence test is essential to ensure that the new GM crop is performing as per original variety (non-converted). The equivalence test is the process which would ensure that the so called ‘Burkina Faso debacle’ discussed on page 14 is avoided.

In line with Roupakins and Mavromatis (2010), the study established that, indeed, the seed companies attend to two distinct markets when they are involved in selling cotton planting seeds. First, there are the smallholder farmers who have a particular need and the ginners with their own need. On the one hand, the smallholder farmers demand seeds that will achieve higher returns per unit of land. On the other hand, the ginners demand cotton whose fibre meets certain quality standards. Cotton is an industrial crop whose value is exploited through an industrial process of separating the lint from the seed. Ginners perform that process in their factories. In Southern Africa, the ginners’ business focuses on selling lint to exports markets. In Malawi, a ginner was asked his views on adoption of GM cotton given that he had seen the product on show at the OFT, he said:

> We are told that the GM cotton varieties on trial here are hybrids from India. I am very mindful of the debacle in Burkina Faso where GM cotton has performed very badly regarding quality. As ginners, we will only be satisfied that this new cotton is good if the minimum ginning outturn is 40% and the lint meets the quality parameters required by our export markets regarding fibre length and fibre strength (Ginner Malawi).

The ginners in Malawi are aware of the failure of GM cotton in Burkina Faso. The technology company and the seed company should ensure that the cotton that is marketed in Malawi meets the demands of the two markets. If the two collaborators fail to address the market needs, then the technology will fail like what happened in the much cited Burkina Faso situation. These findings are in line with Correa's (2009) argument that a key issue in technology transfer is the suitability of the innovation to recipients and markets. The findings support Vyakarnam's (2013) emphasis that in the diffusion of innovations, the key aspects of the translational journey relate to the needs of customers. The needs of customers can be established by engaging the customers. The products should then be configured to meet customer needs. Accordingly, in the diffusion of GM crops, it is essential that the seed company should conduct quality tests on the lint of GM cotton ahead of commercialisation to ensure the minimum quality standards required by the industry.

Of the agreements which the technology developers and seed companies enter, one agreement that has many challenges and issues that require close attention is the one to do with commercialisation and the related stewardships. The stewardships include issues to do with how seed companies and farmers comply with refugia requirements. The refugia is the proportion of non-GM crop which is required to be planted along side with the GM crop to minimise and postpone the development of resistance to the trait by target pests. According to a senior official of a seed company, most smallholder farmers are not keen to plant refugia. Given that the smallholder farmers avoid to plant the refugia, one solution would have been that seed companies mix the proportion of non-GM seeds with the GM seeds during packaging. However, the challenge is that the technology developers do not allow the mixing of non-GM and GM seeds because that affects the purity of the GM seeds. In this regard, the seed companies may need to engage the farmers and train them on the benefits of the refugia and use of opinion leaders may be helpful.

In their collaborative efforts on taking new technologies to smallholder farmers, the technology developer and seed company involved in the diffusion of GM crops in Malawi recognise the role of opinion leaders in line with Rogers (2003). The seed company uses opinion leaders who are called 'lead farmers' or 'champion farmers' in training smallholder farmers. When asked, 'how does the company take GM crops and new knowledge to smallholder farmers?' a participant who works at a seed company and is responsible for product development in Africa including Zimbabwe and Malawi said:

> The process of familiarising farmers with new technology is done through the conduct of advanced breeding trials with farmers and allowing farmers to participate in breeding. When the crop has matured, we invite farmers of the surrounding community to a field day which is done at the trial site. The guests are asked to choose technologies which they think are best for their areas and we encourage them to give reasons for their choices. The field day is an interactive session where information is shared. The farmer who hosts trial plot is usually the influential or lead farmer in the cotton area and is well respected and followed by other farmers. During trials or demonstrations, sites resemble field schools around which other local farmers gather to get information. This way we get important input from farmers on their preferred traits while also getting to know farmer preferred technologies (Official of a Seed Company).

The researcher notes that the seed company's choice of the 'lead farmer who is influential in the cotton area and is well respected and followed by other farmers' is in line with Rogers' (2003) and Goldenberg *et al.'s* (2009) characteristics of an opinion leader. The characteristics are: more cosmopolite, higher socioeconomic status, more innovative, convincing, experts and a large network of social ties. By making use of opinion leaders, the seed company stands a good chance in successfully transferring their technologies and new knowledge to farmers. In this regard, the new technologies are expected to diffuse faster.

A manager of a seed company emphasised the role of extension workers. However, the participant lamented that extension workers lack resources in the form of motor cycles and computers. He highlighted that extension workers cover all farming regions and they are trusted by smallholder farmers.

Capacity building of local institutions of higher learning

The research and development of GM crops is dominated by the overseas multinational corporations. As a result, there is a monopoly in the supply of GMO traits which the country under research may want introgressed into local varieties. In this regard, the views of the participants were sought to establish how local institutions could develop the capability to research and develop GM crops. An expert said, "The financial resources required to set up laboratories for transforming GM crops are phenomenal. It will cost hundreds of millions of dollars. It is better to spend the money improving our fertiliser delivery system, improving our roads and other infrastructure." The expert further said that Public Private Partnerships (PPP) might be used to accelerate the capacity building of local institutions. A model of the PPPs may be taken from Monsanto's Indian experience (Monsanto, 2018).

Role of policy makers and smallholder farmers in adoption of GM crops and protection of the environment

This section answers RQ3: 'What role do policy makers, smallholder farmers and other stakeholders play in influencing the adoption of GM crops and protecting the environment in Zimbabwe, Malawi and South Africa?' The process of transferring GM crops from laboratory to the market through various stages that include diffusers who are seed companies and the adopters who are smallholder farmers was discussed in the section on technology and knowledge transfer on pages 101-107.

Governments have a constitutional obligation to protect and safeguard citizens of the country and civil servants carry out that mandate on behalf of the government. In this study, policy makers are civil servants and employees of government bodies who have interest in the adoption of GM crops. In the literature review, the policy makers who are the regulators were identified to play a prominent role in the diffusion and adoption of GM crops. In addition, biosafety regulations and political will emerged as key factors that drive or constrain the adoption of GM crops in Zimbabwe, Malawi and South Africa.

Biosafety regulations and political will

The three countries under study, that is, Zimbabwe, Malawi and South Africa have biosafety regulations that are anchored by the Cartagena Protocol on Biosafety. The South African biosafety environment is mature in comparison with that of Zimbabwe and Malawi. Its maturity arises from two decades of experience gained by regulators in the Department of Agriculture, Forestry and Fisheries in managing GM crops. In Zimbabwe, the NBAZ is responsible for the administration of the GMO Act. In Malawi, GM crop registration is controlled by application of the Biosafety Act, 2002; Biosafety (Management of Genetically Modified Organisms) regulations, 2007; and the National Biotechnology and Biosafety Policy, 2008.

The study found that the legal frameworks of regulating GM crops are similar for Zimbabwe, Malawi and South Africa. The similarity of the biosafety regulations is mainly because the three countries are signatories of the Cartagena Protocol on Biosafety (CPB).

The researcher posed the question to a senior official of the NBAZ: What role does the NBAZ play to ensure that the environment is protected against GMOs? The official of NBAZ responded as follows:

> The NBAZ has officers stationed at all border posts who are mandated to test all grains and food items that enter the country to ensure that they are free from GMOs. In case of food or feed, the maximum allowable GMO content in Zimbabwe is one percent. However, the regulations are still to be gazetted. If it is above the threshold, then it must be labelled. In the event of food shortages, the country can import GM grain, but it must be transported and milled under the supervision of NBAZ staff. In the case of GM crop trials, we have procedures to handle them. When an applicant submits an application to conduct confined field trials of GM crops, the NBAZ undertakes an environmental risk assessment before a decision to approve the trials of GM crops. The results of the risk assessment lead to risk management measures if need be, and the decisions are communicated to the applicant (NBAZ official).

In 2016, the NBAZ organised stakeholder meetings to discuss GMO labelling on food products. When asked why it had considered it necessary to initiate GMO labelling on food products in Zimbabwe, the NBAZ responded:

> There are some reasons why we initiated GMO labelling of food products and these include: a) To allow informed consumer choice. b) The NBAZ was approached by manufacturers that wanted to label locally produced products to show that the products had not been produced using GM techniques. The objective was to capture customers that do not want GMO products thereby increasing competitive advantage. Subsection 5 (1) (i) of the Statutory Instrument 265 of 2002 (Food and Food Standards (Food Labelling) Regulations) states that *where food or any of its ingredients has been genetically modified, it shall be declared in writing near the produce or ingredient name.* However, the procedures for labelling were not specified; i.e. how does one label in a manner that does not mislead consumers. Therefore NBAZ, as a regulator of all biotechnologies including GMOs sought to complement an already existing statute (NBAZ official).

In contrast, the study found that the governments of Malawi and South Africa have not directed food producers to put labels on products that show levels of GMOs. In Malawi, a policy maker said that at its borders, Malawi does not have biotech officers stationed there. However, she said that agricultural officers are stationed at the borders who control and monitor the movement of goods. Like Zimbabwe, Malawi mills GM grain when it enters the country to ensure that there is no spread of unauthorised GM crops.

The study also established that in Malawi, the government is committed to the provision of a clear and transparent regulatory framework for GM crops and smooth approval processes. This is in line with Okeno *et al*.'s (2013) theory of political will of a government that is committed to the adoption of agricultural innovations. When asked how long it takes to get approval to conduct confined field trials for GM crops in Malawi, a policy maker said it takes not more than ninety days. However, the participant also said that if the regulators had had their way, they would not include public participation at the trial sites because "it is cumbersome and it leads to confusion" (Participant MW03).

When asked what was the government policy on the adoption of GM crops in Zimbabwe? A policy maker said:

> As I said, from my platform, at the moment we have no justification for jumping onto GMOs. My view is that we need to get a greater understanding of GMO aspects through researching. Adoption of GMOs in crop production is premature. When you look at the claims on GMOs, currently they claim pest resistance on cotton. There are claims on tolerance to stress. But when you look at it, the genetic material that we currently have in conventional breeding has an output or yield potential which is very high. Yet we are probably sitting on 20% yields of the potential (Participant ZW03).

In Zimbabwe, the study found that after the new political dispensation of 15 November 2017, the government officials are talking freely about the need to conduct field trials of GM crops. On 4 May 2018, five senior government officials who comprised, three directors from the Ministry of Agriculture, the Chief Executive Officer of NBAZ and the Production Manager at Agricultural Marketing Authority of Zimbabwe (AMA), travelled to Malawi to see OFTs of GM cotton. The researcher accompanied the team on the visit to see the trials at Chitala Research Station in Salima, Malawi. An important observation by the researcher (see photograph in Figure 5.3) was that the Malawi government officials explained to their Zimbabwean counterparts what motivated Malawi to conduct trials of GM cotton. It was a government-to-government discussion and the Zimbabwean officials were very attentive.

Figure 5.3 Malawian and Zimbabwean officials discussing GM cotton: May 2018
Source: Photograph by the researcher

The Malawian official explained that cotton had been grown in Malawi for many years. However, production of cotton has been declining in the last four years. He attributed the fall in production mainly to the bollworm. Therefore, the government had allowed the trials of insect resistant GM cotton in order to evaluate the effectiveness of the technology against bollworms as well as evaluate the productivity of the new genetics. At the end of the presentation, the Zimbabwe officials resolved that it was important to conduct the trials of GM cotton in Zimbabwe to evaluate it in the Zimbabwean ecological zones. The next section deals with the revised conceptual framework (CF)

Revised conceptual framework

In this chapter, the concepts and theories which emerged from the literature review in Chapter 3 were critically analysed and compared with the findings of this study. Now, it is necessary to revise the initial CF in line with the findings of this study. The study's contribution to theory is shown in the revised CF in Figure 5.4. This study found that in the diffusion and adoption of GM crops in Zimbabwe, Malawi and South Africa some factors and stakeholders are more dominant than others depending on the country under study. In Figure 5.4, the factors and stakeholders that are more dominant are shown in bold and the docile or dormant ones are shown in italics. The changes are explained below:

Of the factors that determine the diffusion and adoption of an innovation in Zimbabwe, Malawi and South Africa, relative advantage and technology and knowledge transfer were found to be more dominant. This is followed by compatibility, complexity, trialability and observability, in that order. In the communication channels which technology developers and seed companies use to disseminate information about GM crops, four items emerged dominant. These are: research field trials which include CFTs and OFTs, field days and demonstration plots, extension services and training and, finally, the media. The technology developers also use workshops and seminars where they disseminate information about GM crops to farmers and other stakeholders. However, these communication channels are not commonly used.

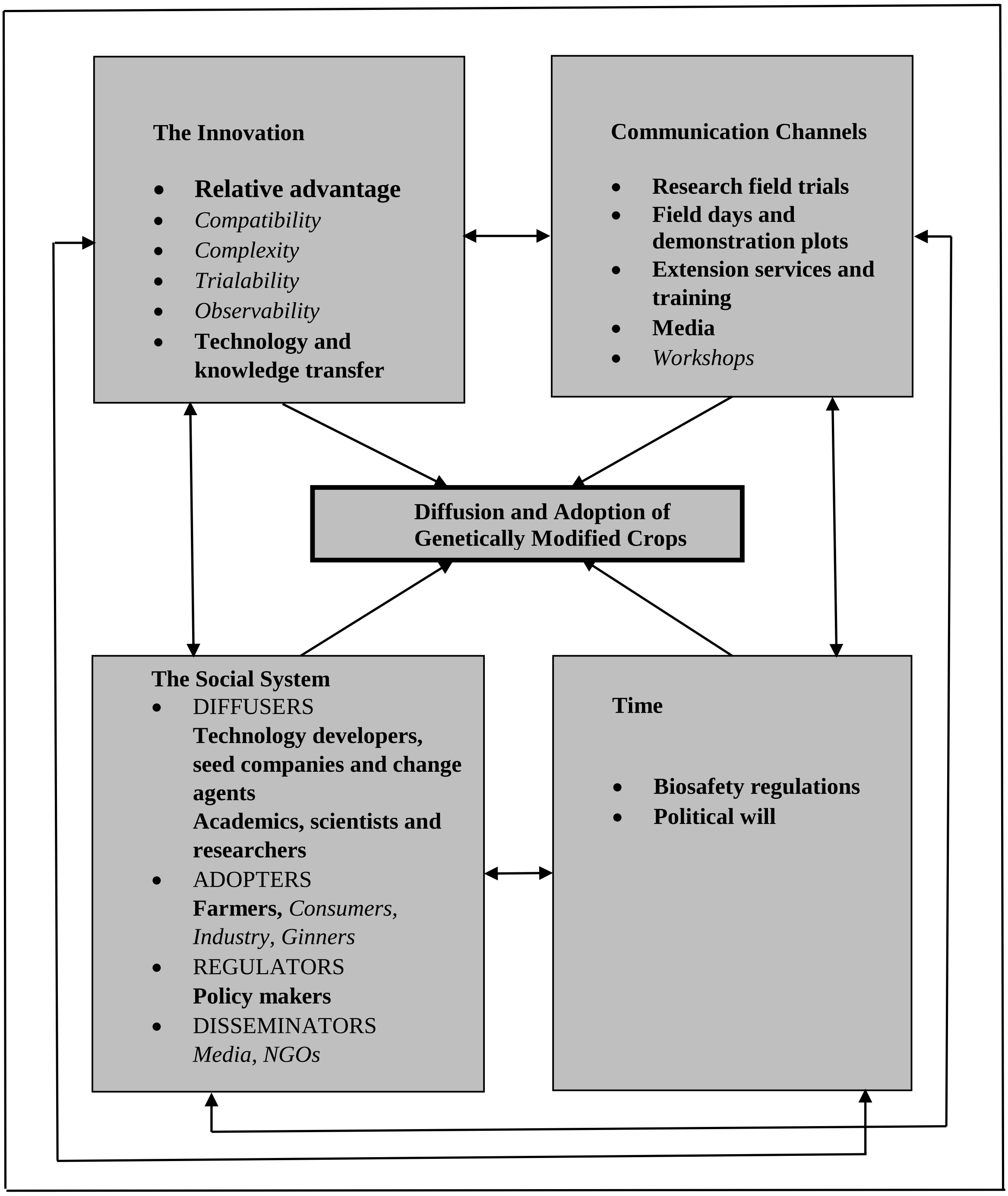

Figure 5.4 Elements of diffusion of innovations and the factors that drive or constrain the adoption of GM crops in Zimbabwe, Malawi and South Africa.

The biosafety regulations and political will are crucial factors that determine the diffusion and adoption of GM crops in Zimbabwe and Malawi. However, the two factors are not dominant in South Africa because the country commercialised GM crops in 1997 and has biosafety frameworks that support the GM crops. The study found that three stakeholder groups are more dominant and crucial in diffusion and adoption of GM crops, these are policy makers, farmers and technology developers and seed companies. Other stakeholders who play a less dominant role include consumers, ginners, NGOs, Media and institutions of higher learning. The next Chapter concludes this study.

CHAPTER 6
CONCLUSIONS

Introduction

This chapter brings the curtain down on the study by reflecting on the findings in relation to the initial objectives of the study, the research questions and the theories the researcher used in the study. The researcher explains how the three research questions of this study were answered and highlights of the findings are discussed. There are discussions relating to implications, conclusions for practice and limitations. Finally, the researcher makes recommendations for further research.

Based on the pragmatism paradigm and applying mixed methods research, the study set out to establish factors that drive or constrain diffusion and adoption of genetically modified (GM) crops in Zimbabwe, Malawi and South Africa. In addition, the study aimed to provide some understanding of how new ideas, technologies and knowledge is transferred to smallholder farmers. The study also investigated what role policy makers, farmers and other stakeholders play in the adoption of GM crops and in protecting the environment. The study noted that GM crops are treated differently in the three countries under study. In Zimbabwe, the policy makers take a precautionary approach and in Malawi, since 2012 the government has allowed researchers to carry out trials of GM cotton. In South Africa, GM crops were commercialised in 1997 and continue to cultivate three GM crops, cotton, maize and soyabeans.

In cognisance of the controversial nature of GMOs in agriculture, the pragmatic philosophical stance stirred the researcher focusing on the practical aspects of diffusion and adoption of GM crops – mainly what works and which solutions resonate with the smallholder farmers' needs. The study has primarily drawn on Rogers' (2003) theories of diffusion of innovations which led to the development of a conceptual framework that underpins the study.

The study is conducted against the backdrop of promises of a bounty against warnings of bondage that are intertwined in the complex topic on GM crops. The debate on the usefulness and potential risks of GM crops is enveloped in controversy. On the one hand, proponents of GM crops claim that farmers who take up GM crops achieve higher yields and more income than farmers who use non-GM crops. On the other hand, critics argue that there could be health and environmental risks arising from the current use of GM crops yet to be discovered. The critics further argue that the adoption of GM crops will lead to farmers being tied to buying expensive seed from companies without recourse to farm-saved seed. Genetic modification of crops is a relatively new innovation in agriculture which involves the manipulation of genes of an organism by means which do not occur naturally in order to introduce desired traits in the plant, for example, insect resistance or herbicide tolerance.

Global population is increasing and it is projected that another two billion people will be added by 2050 to the current 7 billion (UN, 2015). However, the land available for farming will not increase, if anything, it will decrease because of other uses that include cities, housing and roads. Furthermore, in crop production, farmers face challenges that include climate change, drought, crop diseases and pests. Consequently, there is a need for farmers worldwide to harness resources and embrace agricultural technologies to produce adequate food and fibre to feed and clothe the growing population. This is on the backdrop of persistent food shortages and malnutrition in Southern Africa.

It was established that GM crops are an innovation that is developed using novel biotechnologies and one among many other agricultural technologies that are at the disposal of farmers to enhance agricultural productivity. Other technologies available include fertilisers, chemicals, plant and machinery and good crop husbandry. However, the study established that farmers that use GM crops achieve higher yields in comparison to those that use conventional varieties. The insect resistant GM cotton provides inbuilt insecticide that protects the crop from pests such as bollworms. As a result, farmers achieve higher yields because the cotton crop retains bolls throughout the growing period. The more the bolls that are retained by a cotton plant, the higher the yield and the higher the yield, the more income the farmer receives.

The results of the first year open field trials of GM cotton in Malawi showed that GM cotton achieved significant yields against non-GM cotton ranging from 44 percent to 88 percent. The researcher noted that plant breeders who are specialist agriculturalists conducted the trials and resource-poor farmers who grow cotton in semi-arid regions, under harsh climatic conditions may not achieve such high yields. However, evidence has been provided that smallholder farmers who use GM insect-resistant cotton achieve significant economic and social benefits.

Factors that influence diffusion and adoption of GM crops

The factors that emerged in the literature and conceptual framework of this study that drive or constrain the diffusion and adoption of GM crops in Zimbabwe, Malawi and South Africa are: 1) relative advantage, 2) compatibility, 3) complexity, 4) trialability, 5) observability, 6) technology transfer and intellectual property rights, 7) communication, 8) biosafety regulations, 9) political will and 10) knowledge transfer and this is line with Rogers (2003) and Wagner Weick and Walchli (2002).

Relative advantage

This study has illuminated relative advantage as the significant factor that drives the adoption of GM crops. Relative advantage, measured in economic terms or by social factors as perceived by the adopters, determines how fast innovation is diffused (Rogers, 2003). In the adoption of GM crops, in the farmers' point of view, the farmers are attracted by returns per unit of land put under cropping and the yield potential of the GM crops in comparison with the conventional varieties that they replace. In terms of economic benefits, this study showed that the smallholder farmers that grow GM cotton in South Africa achieved a net profit margin of 45% per hectare against 22% and 36% achieved by their counterparts that grow non-GM cotton in Zimbabwean and Malawian farmers respectively.

The study demonstrated that there are social benefits which accrue to farmers who use insect-resistant GM cotton that include reduced time working in the fields spraying insecticides on the crop and less exposure to toxic chemicals. Also, the environmental benefits derived from the use of insect resistant GM crops which include less toxic chemicals released into water bodies which are the source of drinking water for people and animals. Notably, all the smallholder farmers who were interviewed in South Africa stated that they would never go back to using non-GM cotton because GM cotton provided them with unparalleled convenience. The social benefits are an incentive for farmers to adopt GM cotton. However, there are downsides to the relative advantage of GM cotton.

The GM crop seeds cost comparatively higher than the conventional varieties. This is mainly because there are technology fees that are paid to the technology developers. Farmers that plant GM cotton in South Africa have reduced seeding rates to minimise the cost. The high cost of seed may be a barrier to adoption of GM crops because poor farmers may not afford them. The situation is exacerbated by the monopolistic nature of GM traits which are developed by few multinational corporations.

Compatibility and complexity

Innovations that are compatible with norms and values of a social system have a faster rate of diffusion and adoption; and inversely, innovations that are difficult to understand do not diffuse faster (Rogers, 2003). The technology failure of GM cotton in Burkina Faso is dogging the diffusion and adoption of GM crops in Africa. When GM cotton was introduced in Burkina Faso, the technology company inserted an insect-resistant gene into a local variety using a donor plant (Dowd-Uribe and Schnurr, 2016). The transformation procedure required that a minimum five backcrosses be conducted to ensure that the transgenic plant became as close as possible to its original variety. In Malawi, stakeholders who include policy makers and ginners have expressed concern about quality risks of GM cotton and they refer to the Burkina Faso situation. If the concerns of the policy makers are not attended to the consequences are that the policy makers may not approve commercialisation of the technology unless there is proof that quality standards are met. The other concerns of GMOs are with regards to risks to humans, animals and the environment.

The study noted that of the eight policy makers interviewed in Zimbabwe, four highlighted their concern about the risk of GM crops on humans and animals. They referred to the study by Seralini *et al*. (2012) whereby rats developed tumours after being fed with GM maize meal over ninety days. In line with Chadwick (2017), the experts who were interviewed in the study could not guarantee 100% safety of the GM crops. However, a South African policy maker said that he was confident that GM crops that were released in South Africa are safe because they have undergone stringent safety evaluation before approval and release.

The scientific theories emerging in the literature indicate that the insect resistant gene inserted in GM crops is not harmful to human beings, domestic and wild animals because their stomachs are acidic (Christou and Twyman, 2004). The stomachs of the target insects which are killed by the insect resistant gene are alkaline (Lone et al., 2016). These theories resonate with what a Zimbabwean scientist who is also an academic said about the low risks of insect resistant GM crops. The scientist explained that the physiology of human stomachs allows neutralisation of the Bt toxins. She also said that in Southern Africa, human beings had consumed GM products since 1998, but no adverse effects have been reported. However, the study notes that Taleb *et al*. (2014) point out that the risks of GM crops are systemic with widespread impacts on the human health and the ecosystem. They also point out that the health impacts of GM crops may manifest years later when irreversible the damage is done. Consequently, Taleb *et al*. (2014) implore policy makers to deal with GM crops on the basis of the precautionary principle, a principle that defers decisions until all risks are measured.

The study also found that there is a significant risk of GM crop genes escaping into the environment and crossing with wild relatives or conventional crops without the knowledge of farmers. The communal farming in Zimbabwe, Malawi and South Africa is congested and the demarcation of lands of smallholder farmers does not give room for isolation distance. In that case contamination of neighbours' crops is highly likely which can lead to disputes.

The study found out government officials in Malawi fear that neighbouring countries who have not commercialised GM crops may not allow Malawian agricultural products to pass through their lands. If the fear of movement of goods is not resolved, it has implications for the adoption of GM crops in Malawi. This may slow the adoption or outright rejection. The solution to this issue may be through bilateral country-to-country engagements with reference to the Cartagena Protocol on Biosafety (CPB). The CPB is an international agreement which provides for movement of living modified organisms through member States.

Trialability and observability

The literature reviewed revealed that innovations that can be experimented with on a limited basis diffuse faster (Rogers, 2003). The process of registration and commercialisation of GM crops in Zimbabwe, Malawi and South Africa require that the technology developers must first of all conduct CFTs under the supervision of government regulatory officers. One of the technology developers' and seed companies' strategic goal of conducting the CFTs is to evaluate the performance of new GM crops against their conventional equivalent varieties as the first step towards commercialisation of GM crop in the target market (Waithaka *et al.*, 2015). At the CFTs crops under evaluation are planted side by side, GM crops and non-GM crops of the same varieties; that is the transgenic and the isogenic lines.

The technology developers and seed companies use the CFTs as a communication channel with stakeholders. The companies invite stakeholders to see the performance of the GM crops at the CFTs. Farmers are given an opportunity to interact with researchers and share knowledge. It is at the CFT tours that knowledge is transferred to farmers. The government regulators approve or decline approval of the GM trait after a number of years of CFTs – usually three years. If the GM trait is approved, the next stage is open field trials (OFT) which are conducted in several ecological sites ahead of commercial release.

The OFTs are the last stage of evaluation which is done by government researchers of the Ministry of Agriculture in collaboration with the technology developer and seed company promoting the GM crop. As is the case with CFTs, during the OFTs, the technology developer and seed company use the same strategies of stakeholder awareness, albeit on a larger scale. More farmers are given an opportunity to observe the performance of GM crops in farm level situation. The study established that trialability and observability are essential factors that drive the adoption of GM crops because the farmers are able to evaluate for themselves the efficacy of the new crop in comparison with the varieties that they currently use.

How technologies and knowledge are transferred to smallholder farmers

This study established that South African smallholder farmers who grow GM cotton achieve higher profit margins in comparison to smallholder farmers who use non-GM cotton in Zimbabwe and Malawi. Qaim (2016) argued that Southern African smallholder farmers should take up new innovations that make them more productive on the farms and improve their standards of living. GM crops are a novel innovation whose research and development take several years and cost hundreds of millions of dollars (Halford, 2012). In this regard, technology and knowledge transfer play key roles in making smallholder farmers access the technology.

The process to transfer technology and knowledge of GM crops to smallholder farmers involves collaboration of technology developers and seed companies. This collaboration is achieved through various agreements that include research and commercialisation licences. Consumers of grain and end users of farm products trigger the demand for agricultural products and farmers respond by demanding seeds from seed companies. The seed companies demand transformation of their non-GM seeds using traits of GMOs developed by technology developers.

It is essential that the technology developers and seed companies conduct the efficacy and equivalency tests before the GM crops are released to the farmers for cultivation. The efficacy test will ensure that the trait is effective. For example, the trait of the insect resistant GM cotton should kill the bollworms. The researchers will conduct an efficacy test to see that the bollworms die after eating the cotton bolls. The equivalency test will ensure that the GM crop performs true to type and equivalent to the original non-GM crop. The two tests are important to ensure that the smallholder farmers are provided with seeds that meet market needs.

The study notes that the two tests, efficacy and equivalency, are critical components of how MNCs such as Monsanto manage the translational journey of taking new technologies from the laboratory to the market. In the literature reviewed, it was noted that when Monsanto commercialised GM cotton in Burkina Faso, quality issues where not adequately addressed and the fibre length of GM cotton was shorter than that of the non-GM cotton which it had replaced (Dowd-Uribe and Schnurr, 2016). The lint which had shorter fibre was not accepted by the market. As a result, in 2015 farmers in Burkina Faso discontinued planting GM cotton.

The failure of the technology in Burkina Faso has far reaching implications for diffusion and adoption of GM crops in Africa because potential adopters raise concerns about the quality of GM crops and make reference to the Burkina Faso technology failure. In Zimbabwe and Malawi, policy makers who participated in the study raised concerns about the failure of GM cotton in Burkina Faso. What this means for diffusion and adoption of GM cotton in Zimbabwe and Malawi is that, policy makers will not approve the technology unless they are satisfied that there will not be a repeat of poor lint quality.

The roles of policy makers and other stakeholders in protecting the environment

The Governments have a role in protecting their citizens against potential harm and GM crops are regulated by Governments to ensure the safety of humans, animals and the environment (Jaffe, 2004). In Zimbabwe, Malawi and South Africa there are biosafety frameworks that are used to regulate the GM crops. These frameworks are discussed below:

In Zimbabwe, the National Biotechnology Authority deploys biotech officers at all ports of entry whose role is to regulate all materials that enter Zimbabwe to ensure that they are free of GMOs. The biotech officers are provided with rapid tests kits that can detect GM proteins in grain, seeds and food. Any materials that are found to contain GMO levels beyond the acceptable threshold of one per cent GMO content are not allowed to enter Zimbabwe. However, the borders of Zimbabwe are porous and manning the official ports of entry does not guarantee that illegal entry of GMO materials cannot happen.

However, other stakeholders that are involved in the protection of the environment against potential hazards of GM crops include environmentalist non-governmental organisations (NGOs). In Zimbabwe, Malawi and South Africa there are two NGOs that play a prominent role in lobbying governments and other stakeholders against the spread of GM crops.

Political will is about the preparedness and support of policy makers in government to adopt GM crops. In the countries under study – as it is common practice worldwide – the use of GM crops is regulated by the State using biosafety regulations. GM crops are regulated to safeguard people, animals and the environment against potential risks that may arise as a result of their use. The researcher noted from literature and empirical evidence that political will is a critical factor in the adoption of GM crops because different governments have different positions on the potential risks. For example, the registration process of GM crops in the USA takes about two days whereas in Europe it may take thirty days. In Malawi, it took two years for CFTs to be allowed and in Zimbabwe the application period for CFT is indefinite. In South Africa, the government supports the development of GM crops. However, in 2015 the Department of Agriculture, Forestry and Fisheries turned down an application for commercialisation of GM potatoes on the basis that it could not be justified regarding socio-economic requirements of smallholder farmers.

Limitations

The methodological limitations of this study include the use of purposeful snowball sampling. The researcher noted that, given the controversial nature of the GMO debate, the participants could point to their colleagues that share the same beliefs, acceptance or non-acceptance of GM crops. In this regard, the researcher took into account that such referrals could cancel out as the antis would direct the researcher to antis and vice versa. Notwithstanding the guidance of the supervisors, limitations arise that only one person conducted this study from its conceptualisation at the formative stage, to its design and data collection, data analysis and interpretation.

The study is a mammoth task handled singlehandedly in an environment that spans the geography of three countries that have different political dispensations and also different economic development levels. For example, in Zimbabwe, GM crops are not allowed for commercial production and the former Minister of Agriculture issued statements warning seed companies not to introduce GMOs. The political environment in Zimbabwe is very difficult and unpredictable. In many cases, it took more than one visit to secure an appointment for interviews with Zimbabwean policy makers. It called for patience and perseverance to follow-up appointments for interviews with the policy-makers. The quantitative data was collected between April- July 2015 for one cropping season beginning 1 September 2013 and ending 31 August 2014. Agriculture is affected by seasonal rain conditions. Hence, the results of the quantitative research may have significant variation if the study is repeated in another period.

The smallholder farmers in the three countries under study are resource poor. They lack financial resources to pay for inputs such as fertilisers, chemicals and labour. The smallholder farmers do not have tractors and machinery that could improve productivity on the farms. They also lack education and training in agronomy and farm management. Hence, the diffusion and adoption technologies are investigated in a difficult setting.

Further research and consultancy

After completion of the DBA, the researcher will be involved in consultancy in the area of Agricultural Knowledge and Technology Transfer in Zimbabwe and other African countries. In this regard, the researcher has identified opportunities in farmer education, knowledge transfer, political will, stakeholder awareness and engagement. The researcher will also seek to establish how the adoption and commercialisation of crops that have been modified using the new CRISPR system of genome editing can be accelerated.

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APPENDICES

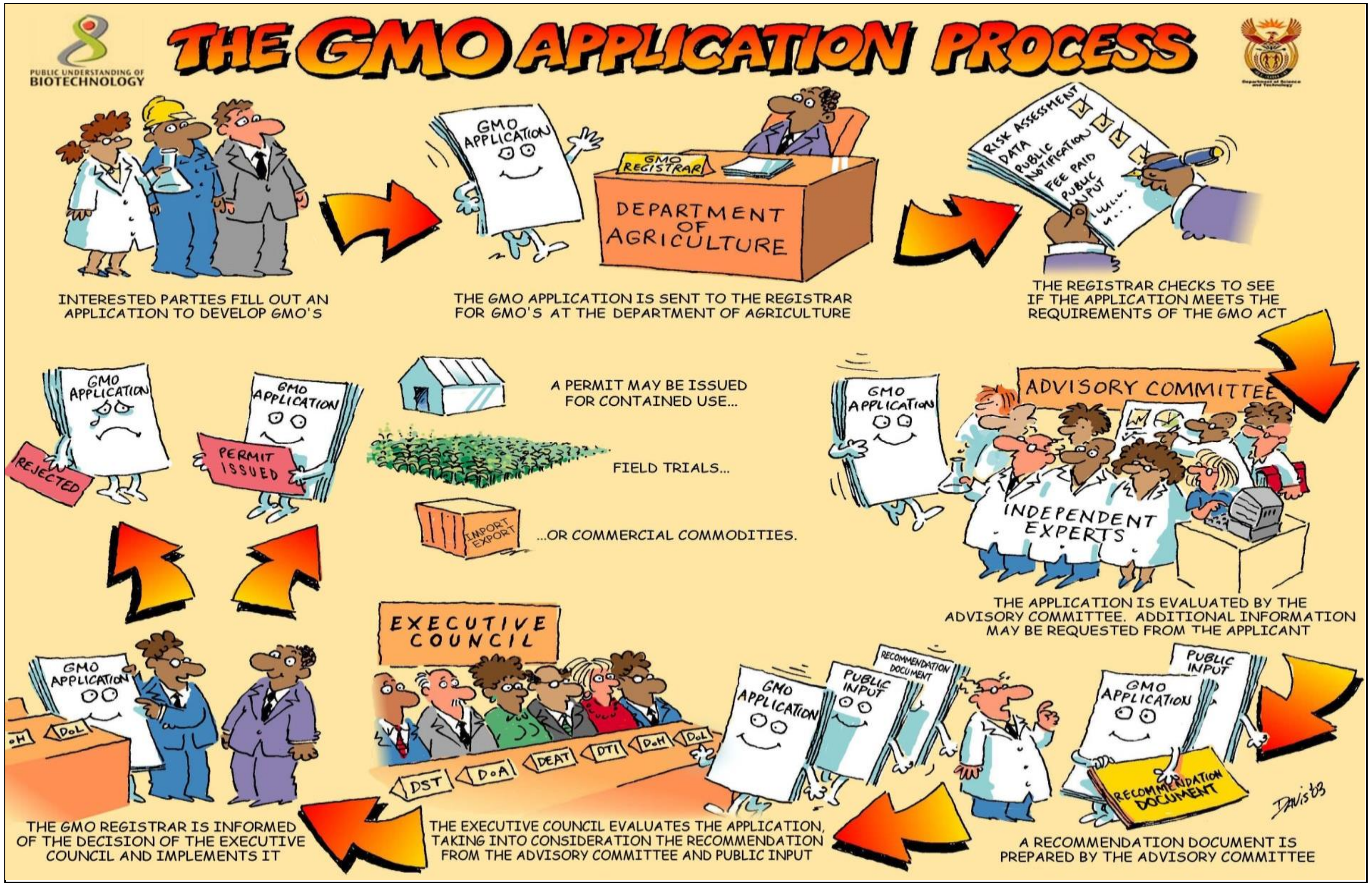
Appendix 1: List of Acronyms and Special Terms

AATF	African Agricultural Technology Foundation
ACB	The African Centre for Biodiversity
AMA	Agricultural Marketing Authority of Zimbabwe
Bollgard II®	GMO insect resistant genes registered trademark of Monsanto
Bollgard II RRF®	GMO staked genes insect resistant and herbicide tolerant registered trademark of Monsanto
Bt	*Bacillus thuringiensis*
CBD	Convention of Biologgical Diversity
CFT	Confined field trial
CPB	Cartagena Protocol on Biosafety
CRISPR	Clustered regularly interspaced short palindromic repeats
DAFF	Department of Agriculture, Forestry and Fisheries of the Government of the Republic of South Africa
DDT	Dichlorodiphenyltrichloroethane - an insecticide used to control mosquitoes
DNA	Deoxyribonucleic acid
DR&SS	Department of Research & Specialist Services in the Ministry of Agriculture, Zimbabwe
EAD	Environmental Affairs Department of Malawi
EU	European Union
FOEI	Friends of the Earth International
GBP	Gross domestic product
Ginner	Cotton ginning company
GM	Genetically modified
GMO	Genetically modified organism
Ha	Hectares
Ht	Herbicide tolerant
ICAC	International Cotton Advisory Committee
IEEA	Indigenisation and Economic Empowerment Act [Chapter 14:33]
IFIC	International Food Information Council
IFPRI	International Food Policy Research Institute
IRIN	Originally “Integrated Regional Information Networks”
ISAAA	International Service for the Acquisition of Agri-biotech Applications
Kg	Kilogramme
LMO	Living modified organism
MMR	Mixed methods research
MNC	Multinational corporation
Mt	Metric tonne
NBAZ	National Biotechnology Authority of Zimbabwe
NGO	Non-Governmental Organisation
OFAB	Open Forum on Agricultural Biotechnology in Africa
OFT	Open field trials
PBS	Programme for Biosafety Systems
SABC	South African Broadcasting Corporation
SADC	Southern Africa Development Community
SPSS	Statistical Package for Social Sciences
WHO	World Health Organisation of the United Nations

Appendix 2: Definition of terms

Term	**Definition**	**Source**
Bacillus thuringiensis	A common soil bacterium that produces a protein toxic to insects	Halford (2012)
Biotechnology	Any technological application that uses biological systems, living organisms, or derivatives thereof, to make or modify products or processes for specific use.	Food and Agriculture Organisation of the United (2013).
Confined field trial	This is a field trial of GM plants not approved for general release, in which measures for reproductive isolation and material confinement are enforced in order to confine the experimental plant materials and genes to the trial site. These trials/experiments provide researchers with important information on environmental interactions and agronomic performance of the crop in a safe and controlled manner.	Republic of Malawi (2009).
Genetically modified organism	An organism that has been transformed by the insertion of one or more transgenes.	Food and Agriculture Organisation of the United (2013).
Germplasm	A collection of breeding materials, usually crop seeds used by plant breeders.	Smale and Day-Rubenstein (2002).
Pest	Any species, strain or biotype of plant, animal or pathogenic agent injurious to plants and plant products, materials or environments and includes vectors of parasites or pathogens of human and animal disease and animals causing public health nuisance.	Food and Agriculture Organisation of the United (2014).
Pesticides	Pesticide means any substance, or a mixture of substances of chemical or biological ingredients intended for repelling, destroying or controlling any pest, or regulating plant growth.	Food and Agriculture Organisation of the United (2014)
Refugia	A strategy in which a portion of a field containing GM crop is planted with the non-GM crop to encourage the breeding of non-resistant pests, which after mating with resistant pests mitigates resistance of the GM trait.	Sanahuja *et al*. (2011)

Appendix 3: The GMO Application Process in South Africa



Source: Department of Agriculture, Forestry and Fisheries, Republic of South Africa (2014)

Appendix 4: Letter to participants introducing the research

Edworks E. Mhandu
2 Innerleithan Road
Mandara
Harare, Zimbabwe
Mobile: +263 772240858

15th March 2016

Dear Sir

Re: Participation in a research on GMO Crops

Thank you for finding time to participate in my research on GMO crops.

I am a candidate of the doctor of business administration (DBA) degree with the Nottingham Trent University, United Kingdom (UK). The title of my thesis is **'Diffusion and Adoption of Genetically Modified Crops: Evidence from Zimbabwe, Malawi and South Africa'**. Genetically modified organism (GMO) crops are not commercialised in Zimbabwe, but trials are taking place in Malawi towards commercialisation. The GMO crops were adopted in South Africa in 1997. There are no known previous doctoral researches done in Zimbabwe and Malawi on the opportunities and challenges of diffusion and adoption of GMO crops. However, many studies were done in South Africa, particularly of farmers in the Makhathini Flats in KwaZulu Natal province.

The research will contribute to the understanding of the subject of GMO crops mainly to benefit policy makers in Zimbabwe and Malawi, farmers, technology companies (including seed companies) and the general public. I am doing this research towards the fulfilment of the requirements for a Doctoral degree at Nottingham Trent University, UK.

I look forward to your participation.

Yours Faithfully

Edworks Mhandu

Appendix 5: Informed Consent Form and Participant's Statement

I confirm that I have been fully informed about the purpose of the research and I am fully aware of that what is required to participate. I have read the accompanying letter and I agree to participate voluntarily. I am also aware that I can withdraw from participating in this research at any time even after having given an interview without giving reasons of my withdrawal.

Tick appropriate box

I permit the interview to be audio-recorded on the understanding that the recording will be destroyed at the end of the project	
I do not wish to be recorded. However, I permit that the researcher to take notes.	

I agree to take part in this research and I append my signature below:

Signature	
Full Names (Print)	
Date	

Researcher Conducting Interview

Edworks Mhandu
Doctorate Student
Nottingham Business School
Nottingham Trent University
Mobile: +263772240858 Email; edwardmh@qutonafrica.com

Appendix 6: Interview Guide

Diffusion and Adoption of Genetically Modified Crops: Evidence from Zimbabwe, Malawi and South Africa

1. What is the role of your institution in the commercialisation of GM crops?
2. In your opinion what are the key factors that influence adoption of GM crops?
3. What are the decision-making processes of adoption of GM crops?
4. What would be the benefits of GMOs from a national point of view?
5. By adopting GM cotton, what benefits accrue to the farmers and the country?
6. How does the government protect citizens from undesirable elements of GMOs
7. Are there any risks or problems associated with GM crops? If any, what are they and how have these risks been addressed?
8. What are the environmental concerns of adoption of GM crops?
9. Are GM crops safe for human consumption?
10. Have you ever eaten GM crops or products?
11. Are GM crops safe for consumption by domestic and wild animals?
12. How are new ideas and new technologies transferred to smallholder farmers?
13. How is knowledge transferred to smallholder farmers?
14. Is there anything that I may have left out in the discussion that you may want to add?

Appendix 7: Questionnaire - Farmer's Income Statement

Section B

Using farm records, please complete in the appropriate box, the actual achieved for the cropping season 2013/2014.

Activities/Inputs		
1	Farming activity: indicate small scale or large scale	
2	Crop planted: indicate GMO or non-GMO	
3	Total hectares planted	
4	Total harvest (kilogrammes)	
5	Total sales (Income $)	
6	Yield of raw cotton (kg/hectare)	
7	The price received by the farmer on sales of raw cotton ($/kg).	
8	How many times did the farmer spray the field/(s) using insecticide?	
9	Type of pests/ e.g bollworm, sucking pests, others, please specify	
10	Quantity of insecticide used (litres/hectare)	
Production cost (US$/ha)		
11	Land preparation	
12	Seed	
13	Insecticides	
14	Fertilizer (indicate type, chemical or organic)	
15	Labour	
16	Other cost (specify)	
17	Other cost (specify)	
18	Other cost (specify)	
19	Total production cost	
20	Net income	

Appendix 8: Abridged Progress Report GM Cotton Open Field Trials 2016-17 Season

MINISTRY OF AGRICULTURE, MALAWI

Introduction

Malawi's socio-economic development depends on agriculture which provides food, income and employment to about 85% of the workforce. In an effort to diversify from tobacco as the main income generator for smallholder farmers, the country is prioritizing cotton due to declining tobacco markets and value following the ban on tobacco smoking by the World Health Organization. Cotton has great potential as a cash crop because it is used in many industries such as textile, animal feed and cooking oil production. Cotton is widely grown in Malawi by many smallholder farmers especially in drier and hot areas where other crops such as maize, beans do not grow very well. However, cotton production is mainly constrained by insect pest damages, especially bollworms (*Lepidoptera insects (Heliothis armigera and Diparopsis castania (*African and Red bollworms).

The desired effect from *Gossypium hirsutum* with the inserted Bt- genes is tolerance to attacks from the *Lepidopteran* bollworm complex. When larvae of the primary *lepidopteran* pests feed on Bollgard II cotton plants, the Cry1Ac and Cry2Ab2 proteins produced in Bollgard II cotton tissues cause paralysis of the insect mid-gut, and the insect typically stops feeding and eventually dies.

Main Objective

To evaluate Bollgard II cotton hybrids for yield and yield components in major cotton agro-ecological zones of Malawi.

Specific objectives

1. To assess the impact of Bt-cotton (Bollgard II) on bollworm population and other cotton pests.
2. To evaluate the agronomical performance of the Bt cotton (Bollgard II) for yield and yield components.
3. To assess the economic benefits of Bt-cotton (Bollgard II)

Materials and methods

Four BG II cotton hybrids (MRC 7017 BG II, MRC 7031 BG II, MRC 7361 BG II and MRC 7377 BG II) were evaluated together with the non- traited conventional hybrids (C 570, C 569, C 571 and C 567) and recommended varieties: Makoka 2000, IRM 81 and RASAM 17 as controls in a Split plot design with four replicates. In total, there were nine (9) treatments in the trial. Makoka 2000 was the local control in Shire valley; IRM 81was the local control in medium to high altitude areas and RASAM 17 was the local control in the lakeshore areas. The trials were conducted in nine sites in the major cotton growing areas throughout the country.

Foliar fertilizers were also applied. Experimental plots were scouted for insect pests. Spraying for boll worms was restricted to sprayed conditions only while in unsprayed condition, spraying for boll worms was not done. All other cultural practices were followed during trial implementation.

Table 1: ***Performance of Bollgard II cotton hybrids at Ngabu Station 2016/ 17 season***

Genotype	Seed cotton yield ($Kgha^{-1}$)		Ginning out turn (%)		Boll size (g)		Lint/seed (mg)		Seed size (mg)		Mean plant height (cm)		Final plant stand	
	S1	**S2**	**S1**	**S2**	**S1**	**S2**	**S1**	**S2**	**S1**	**S2**	**S1**	**S2**	**S1**	**S2**
MRC 7017 BGII	4924	4440	29.42	29.96	6.6	6.6	49	52	116	116	136	125	50	51
MRC 7031 BGII	4788	4381	33.45	31.89	5.8	5.7	59	52	118	116	143	139	48	51
MRC 7361 BGII	4765	3998	32.08	32.87	6.1	6.2	52	54	111	110	136	130	44	51
MRC 7377 BGII	4735	4433	33.19	32.83	5.2	5.6	51	53	103	100	136	143	47	52
BG II mean	**4803**	**4313**	**32.04**	**31.89**	**5.9**	**6.0**	**53**	**53**	**112**	**111**	**138**	**134**	**47**	**51**
Makoka 2000	2561	1838	33.66	33.95	4.8	4.6	58	58	115	113	184	171	49	52

Table 2: ***Performance of Bollgard II cotton hybrids at Kasinthula Station 2016 / 17 season***

Genotype	Seed cotton yield ($Kgha^{-1}$)		Ginning out turn (%)		Boll size (g)		Lint/seed (mg)		Seed size (mg)		Mean plant height (cm)	
	S1	**S2**	**S1**	**S2**	**S1**	**S2**	**S1**	**S2**	**S1**	**S2**	**S1**	**S2**
MRC 7017 BGII	2585	2040	29.17	30.75	6.3	5.3	45	46	109	103	88	78
MRC 7031 BGII	2327	2044	34.10	33.97	5.3	4.9	56	53	108	104	107	86
MRC 7361 BGII	2671	2350	32.95	33.52	5.9	5.4	53	51	108	101	102	95
MRC 7377 BGII	2626	2613	32.98	33.89	4.8	4.6	44	45	98	97	106	92
BG II mean	**2552**	**2260**	**32.30**	**33.03**	**5.6**	**5.1**	**50**	**49**	**106**	**101**	**101**	**88**
Makoka 2000	1772	1761	36.24	37.50	4.8	4.6	57	62	100	100	97	109

Table 3: ***Performance of Bollgard II cotton hybrids at Baka Station 2016 / 17 season***

Genotype	Seed cotton yield (Kgha^{-1})		Ginning out turn (%)		Boll size (g)		Lint/seed (mg)		Seed size (mg)		Mean plant height (cm)		Final plant stand	
	S1	**S2**	**S1**	**S2**	**S1**	**S2**	**S1**	**S2**	**S1**	**S2**	**S1**	**S2**	**S1**	**S2**
MRC 7017 BGII	4662	4632	34.47	30.90	6.5	5.7	54	45	101	101	145	145	39	40
MRC 7031 BGII	4914	4033	34.12	36.17	5.8	5.0	52	55	100	96	157	147	35	38
MRC 7361 BGII	4818	4423	32.31	34.82	5.6	5.6	50	56	104	104	136	143	41	41
MRC 7377 BGII	5152	4228	32.72	35.02	5.4	5.3	49	48	101	100	149	154	40	38
BG II mean	**4887**	**4329**	**33.41**	**34.23**	**5.8**	**5.4**	**51**	**51**	**102**	**100**	**147**	**147**	**39**	**39**
RASAM 17	3088	2998	35.66	34.41	5.9	5.6	54	57	108	108	156	180	45	45

Table 4: ***Performance of Bollgard II cotton hybrids at Lupembe Station 2016 / 17 season***

Genotype	Seed cotton yield (Kgha^{-1})		Ginning out turn (%)		Boll size (g)		Lint/seed (mg)		Seed size (mg)		Mean plant height (cm)		Final plant stand	
	S1	**S2**	**S1**	**S2**	**S1**	**S2**	**S1**	**S2**	**S1**	**S2**	**S1**	**S2**	**S1**	**S2**
MRC 7017 BGII	3002	2667	31.33	31.16	5.9	6.0	51	38	113	84	92	107	44	34
MRC 7031 BGII	3364	2566	36.11	34.17	5.6	5.6	59	55	104	105	120	122	34	37
MRC 7361 BGII	3107	2471	34.25	30.80	5.7	5.9	57	56	110	103	112	96	40	40
MRC 7377 BGII	2962	2679	35.36	34.99	5.5	5.4	54	51	100	98	97	107	42	41
BG II mean	**3109**	**2596**	**34.26**	**32.78**	**5.7**	**5.7**	**55**	**50**	**107**	**98**	**105**	**108**	**40**	**38**
RASAM 17	2041	1817	34.70	34.59	5.3	5.4	62	54	116	103	116	129	44	42

Table 5: ***Performance of Bollgard II cotton hybrids at Chitala Station 2016 / 17 season***

Genotype	**Seed cotton yield ($Kgha^{-1}$)**		**Ginning out turn (%)**		**Boll size (g)**		**Lint/seed (mg)**		**Seed size (mg)**		**Mean plant height (cm)**		**Final plant stand**	
	S1	**S2**	**S1**	**S2**	**S1**	**S2**	**S1**	**S2**	**S1**	**S2**	**S1**	**S2**	**S1**	**S2**
MRC 7017 BGII	1867	1679	33.26	33.62	5.8	5.5	54	52	109	103	119	124	50	52
MRC 7031 BGII	1905	1298	35.99	36.55	5.3	5.2	59	60	108	104	136	126	52	50
MRC 7361 BGII	2136	1585	34.48	35.06	4.9	5.2	57	55	108	101	121	126	52	51
MRC 7377 BGII	1991	1764	36.57	36.70	4.8	4.8	52	51	90	88	131	133	50	50
BG II mean	**1975**	**1582**	**35.08**	**35.48**	**5.2**	**5.2**	**56**	**55**	**104**	**99**	**127**	**127**	**51**	**51**
Hybrid mean	**825**	**512**	**33.93**	**33.46**	**4.8**	**3.3**	**56**	**52**	**108**	**103**	**135**	**133**	**52**	**51**
RASAM 17	412	341	35.58	35.22	3.4	2.4	55	56	100	100	136	145	52	51