The impact of agriculture biotechnology on economic development in South Africa

Nqabisa Nobongoza Ravele

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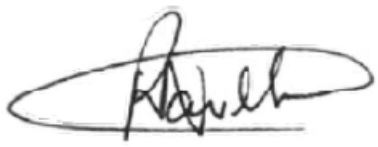
Declaration

I, Nqabisa Ravele, declare that this research article is my own work except as indicated in the references and acknowledgments. It is submitted in partial fulfillment of the requirements for the degree of Master of Business Administration in the Graduate School of Business Administration, University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination in this or any other university.



Nqabisa Nobongoza Ravele

Signed at ……Midrand……

On the 12th day of December 2018

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Abstract

Biotechnology has been in existence for many years and continues to evolve over time. It has been used in many industries, including health, pharmaceuticals, agriculture and others. This research focuses on agriculture biotechnology, with a particular focus on genetically modified (GMO) crops, which have been in existence for more than two decades and have been adopted worldwide; leading countries include the USA, Brazil, Argentina and Canada, amongst others. South Africa is also in the top 10 countries that use GMO crops and is a leader in Africa. According to research, South Africa has three approved GMO crops - maize, cotton and soybeans and has reached an overall 91% adoption rate of the GMO crops. The agriculture industry is one of the key industries in South Africa, which is a developing economy. The sector absorbs a large number of unskilled labourers and it ensures food security. Yet this sector is facing challenges such as climate change, disease and pestilence, which are threatening the growth and sustainability of the industry.

The objective of this paper is to assess the impact that agriculture biotechnology has on the economic development and growth of agribusiness in South Africa. The tools used to collect data included reviewing journals and articles, and holding in-depth interviews with farmers, academics and government officials. The constant comparative analysis method was considered appropriate to analyze the research data.

Research shows that there have been elements of economic development due to the growth of GMO crops, including increased production yields and profitability, yet disadvantages have also been identified with regards to health and the environment. As it is not clear whether some of the challenges mentioned were discovered through research, it is recommended that the government deploy more resources to clarify the current concerns regarding the GMO crops and to address local agricultural challenges. The government should develop strong collaborations with countries with developed economies that have been using GMO crops in order to learn strategies for handling GMO crops. The government should deploy more resources and create public awareness on GMO crops and lastly, more resources should be deployed to monitor GMO crops statistics and such information be made available to the public.

Keywords: agriculture biotechnology, genetically modified crops, agriculture, economy, government.

Introduction

Biotechnology is the combination of biology, science and technology that aims to understand and modify the cellular function in order to obtain applications to apply in health care, agriculture and the environment (Prasad, Kumar, & Prasad, 2014; Serageldin & Persley, 2000). Biotechnology has been in existence for centuries, has evolved over time, and has been influenced by developments in technology. The first generation of biotechnology entailed mainly fermentation technologies in the food industry, followed by the second biotechnology generation which provided a deeper understanding of how microorganisms can be applied in the sector (Semete-Makokotlela, 2016). Like the rest of the world, biotechnology in South Africa has played a significant role in food processing, health and the environment, for example, new vaccines have been developed to enhance the health of many people. With more attention being placed on the green environment, biotechnology has also played a significant role in the production of biofuels which has changed the manner in which waste is managed, i.e. biofuels are sourced from biomass such as crops in order to generate electricity and power, as well as produce liquid fuels such as bioethanol and biodiesel (Andrew & Mduduzi, 2014).

Biotechnology in agriculture entails using DNA molecular-based techniques to modify the genetic composition of agriculturally useful plants and animals (Herdt, 2006; Powell, Koput, & Smith-Doerr, 1996). Developed and developing economies have made substantial investments in agriculture biotechnology to enhance their food supply and boost their economic development. In the US, genetically modified crops have been used for more than a decade now, and more countries are beginning to follow suit.

Problem statement

This paper evaluates the impact that agriculture biotechnology has had on the economic development and growth of agribusiness in South Africa. According to research, agribusiness may become a US$1 trillion industry by 2030 (PriceWaterCoopers, 2016) currently, it is estimated at US$313 billion (Commission, 2016). The African Union, in its efforts to grow and develop agricultural businesses in Africa, formed the Comprehensive Africa Agriculture Development Programme (CAADP) in 2003, which called for a 6% annual increase in agricultural output by all

member countries (Commission, 2016). The efforts to reach the target, recently have been temporarily derailed by the environmental challenges due to climate change. South Africa is no different from the rest of the world - based on the South African Reserve Bank's 2016 quarterly review, poor harvests caused by drought induced a sharp rise in maize and wheat prices, which caused agricultural produce inflation to increase from 5.8% (September 2015) to 27.2% in February 2016 (South African Reserve Bank, 2016). According to Statistics South Africa (2016), the agricultural sector contributed an average of 2% to the South African GDP between 2011 and 2016, and experienced an average growth of 4% between 2011 and 2014 and an average 7% decline between 2015 and 2016, mainly due to drought.

Sub-Saharan Africa is facing a further challenge of an average low crop yield, which is estimated at around 25% compared to East Asia's 90% (David & Rui, 2016). If sub-Saharan Africa were to increase its yield to 50% it would have sufficient food to feed its people and become a net food exporter as well (David & Rui, 2016). In order to stabilize growth and food security for sub-Saharan Africa and the other African countries facing similar challenges, interventions are thus required.

There are many challenges undermining the growth of the agricultural sector, such as vulnerability to climate change that is affecting crops and livestock. With this view, more investments and use of technology are required, especially in countries with developing economies.

To grow and maintain growth, it is critical that the sector adopt new strategies and innovations to overcome the current challenges. A number of technological innovations can be used to boost agribusinesses via biotechnology, e.g. produce plants with improved resistance to disease-causing pests, enhance the ability of plants to grow in inhospitable environments, assist fruits to stay ripe longer, and enhance nutritional value by producing products enriched with Vitamin A (Diehl, 2017; Raimi, Adeleke, & Roopnarain, 2017).

As early as around 2001, South Africa introduced innovative agricultural biotechnology to sustain food supply and economic growth. The question at hand is whether this has had a positive impact on agriculture.

Research objectives

The main objectives of this research are as follows:

- To evaluate the extent of adoption of agriculture biotechnology, with specific emphasis on genetically modified crops in South Africa.
- To assess whether GMO crops have had a positive impact on the growth of the agriculture sector.
- To access the impact on the economic growth of South Africa.

Literature review

Biotechnology in the 21st century

Biotechnology has been in existence since the late 19th century, thanks to the pioneering work of Gregor Mendel, however 'biotechnology' is a new term given the evolution of the science of genetics (Persley, Giddings, & Juma, 1992). Biotechnology is also defined as the processes and systems to manufacture and service industries through the application of biological organisms (Fulekar, 2010). In 1988, the European Federation of Biotechnology defined biotechnology as a science to achieving applications of the capabilities of microorganisms, cultured animal cells or plant cells or part thereof in various industries through the integration of biochemistry, microbiology and engineering (Fulekar, 2010). In the 21st century, commented biotechnology as a science of employing or applying living organism or substance from those organisms to modify or improve or develop micro-organisms for specific desired uses.

Biotechnology is currently used by a number of different industries, but mainly to enhance the environment, health and food supply. In the food industry, biotechnology has played a significant role in food processing, beverage fermentation and diagnostics kits; in health, biotechnology has played a key role in the development of probiotics and vaccines; and in the environmental space, biotechnology has contributed to sustainable living through the introduction of biofuels and genetically modified crops with added nutrition. Biotechnology can be explored to address many of the challenges that South Africa is currently facing, such as food insecurity (Erik Solem & Gaivoronskaia, 2005; Godfray et al., 2010), poor healthcare (Semete-Makokotlela, 2016), and the need for sustainable environmental development through new innovations, e.g. waste recycling (Fulekar, 2010).

Agriculture biotechnology

Biotechnology in agriculture has been used to produce plants with improved pest and drought resistance and fruits which stay ripe longer, as well as enhanced nutritional value by producing products that are enriched with vitamins (Diehl, 2017). This process has resulted in the production of genetically engineered crops.

Biotechnology-derived animals include, but are not limited to (Moreau & Jordan, 2005; Petrick, Brower-Toland, Jackson, & Kier, 2013):

- Genetically engineered or modified animals, in which genetic material has been added, deleted or altered to influence the expression of genes and traits.
- Cloned animals derived by nuclear transfer from embryonic or somatic cells.
- Chimeric animals.
- Interspecies hybrids.
- Animals derived from in vitro cultivation, such as oocyte maturation or manipulation of embryos.

The intervention of biotechnology in agriculture has the potential to help eradicate the current challenges of food security, climate change and drought.

Benefits of genetically modified crops

Economic benefit

Through biotechnology, disease resistant and drought tolerant crops can be developed, which will help crop productivity (Carpenter, 2010; Harrison, 2002; Wieczorek, 2003) while reducing the need for the use of pesticides. Consumers and suppliers also benefit from the increased shelf life of products (Barrows, Sexton, & Zilberman, 2014; Loureiro & Bugbee, 2005).

Health benefits

Biotechnology has the potential to provide people's nutritional needs, which is particularly important in developing countries and can also assist with improving agricultural yields. The volume of micronutrients like vitamin A and the minerals iron and zinc can also be increased through biotechnology techniques (Herdt, 2006). A decline in the use of some pesticides will reduce some chemicals, which may be good for human health. Finally, as the quality of food improves there will be fewer fungal infections and less insect damage and residual pesticides.

Environmental benefits

Some groups of environmentalists are concerned about the pesticides used in agriculture as they threaten the survival of other creatures, i.e. birds, fish and insects. These pesticides reduce the survival and reproduction of these species and

lead to a reduction in their populations (Köhler & Triebskorn, 2013; Lusk et al., 2004). With crops that are pesticide resistant, there will be little or no use of chemical pesticides. In certain instances, there is over-use of soil and water polluting fertilizers in an attempt to manage insects, which could be reduced with the introduction of biotechnology.

Risks of genetically modified crops

Human health

Certain concerns for human health with regards to the introduction of GM crops have been raised, for example, the introduction of new allergies, increased toxins, resistance to antibiotics, and any other unknown reactions (Loureiro & Bugbee, 2005).

Environmental issues

There are concerns about the development of pest-resistance to insecticides, the cross-pollination of crops, and the development of weed resistance (Kajale & Becker, 2015; Loureiro & Bugbee, 2005). Some scientists fear that the new products currently being developed might destroy agricultural diversity, thus changing agricultural patterns beyond recognizable and controllable forms (Brown, 2012; Serageldin, 1999).

Use of agriculture biotechnology in developed countries

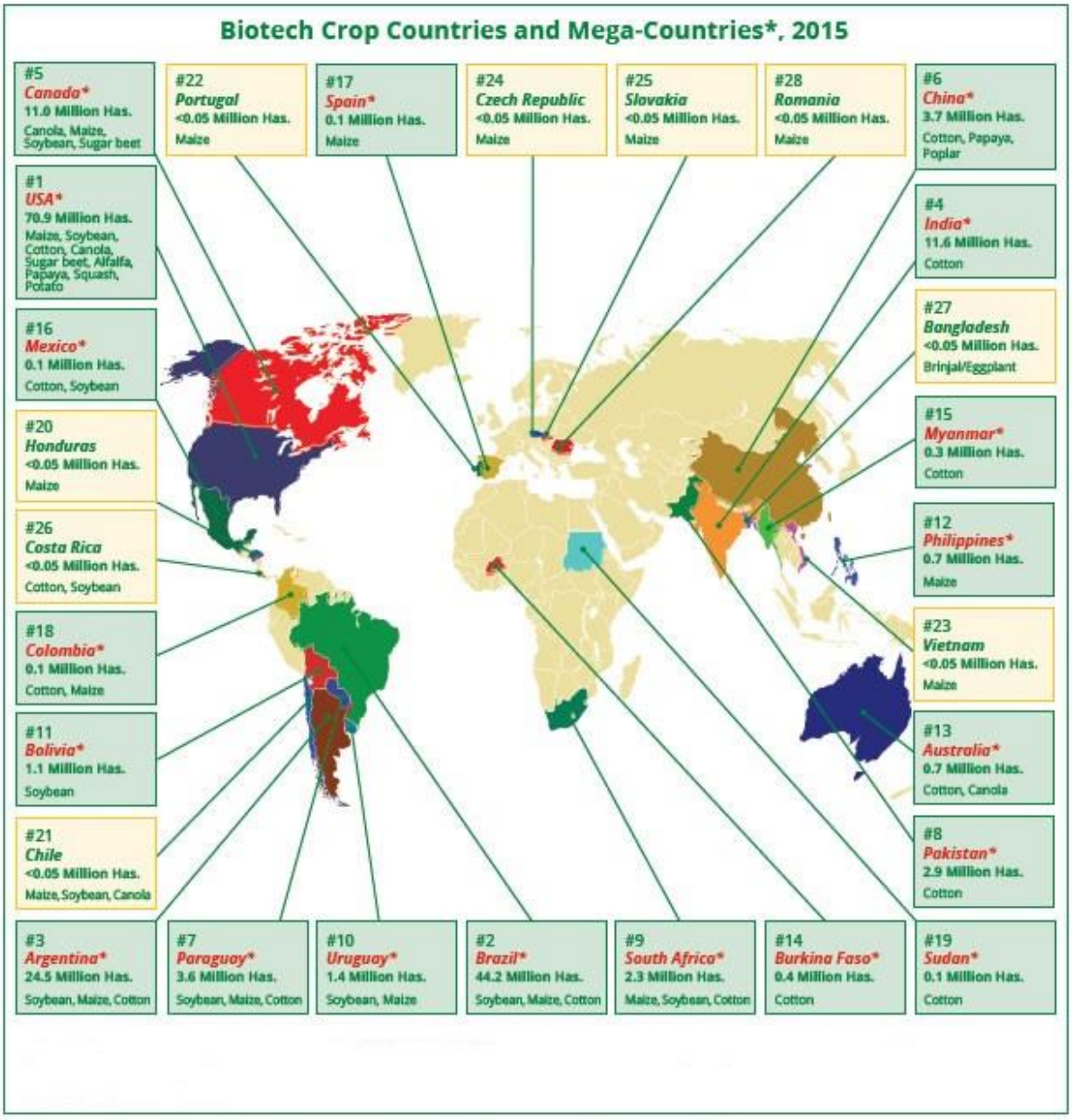
It has to be acknowledged that developed countries comprise of different number of countries, according to the World Economic Situation and Prospects 2018 issued by the United Nations some of the countries that fall under the classification of developed countries are Canada, Japan, France, Germany, United States and many more (Zhenmin et al., 2018). For the purposes of this research more focus has been placed on the United States. According to the literature reviewed, agricultural productivity has been increasing more in developed countries than less developed countries as a result of high investment in research and development, labour, land and capital, and improvements in inputs like fertilizers and machinery (Ramaila, Mahlangu, & du Toit, 2011). In the US, 12 transgenic crops (corn, tomato, soybean, cotton, potato, canola, squash, beets, papaya, rice, flax, and chicory) were already approved for commercial production by 2003 (Borlaug, 2000; Wieczorek, 2003). Genetically engineered varieties of maize, cotton, canola, and soybeans were largely

planted in North America and Asia, yet in Europe and Africa, their use was minimal (Herdt, 2006). Globally, in 1996, about 1 million hectares were planted with transgenic crops, but by 2005 the area had increased to over 90 million hectares (Herdt, 2006). By 2004 the use of biotechnology in agriculture had developed widely - over half of the global soybean crop was planted through means of biotechnology, 30% of cotton, 20% of canola and approximately 20% of maize (Herdt, 2006). In 2005, around 60% of transgenic plants were grown in the US, about 20% in Argentina, 6% in each of Canada, Brazil and China, and the rest of the world made up approximately 2% (Herdt, 2006).

Use of agriculture biotechnology in developing countries

According to research done by the United Nations countries such as China, Brazil, South Africa, India and many more fall under the classification of developing countries (Zhenmin et al., 2018). Brazil relies on agriculture as one of the key contributors to its economy and has been a major player in the export of soybeans, ranking second only to the US. Brazil has approved the use of genetically engineered plants and biotechnology to improve its crop yield and to reduce the production costs of crops (Ho, 2005; Lemaux, 2008). According to research, the use of “biotech crops” has been growing all around the world (James et al., 2015); **Figure 1** below depicts the status of this growth.

Figure 1: Global map of biotech crop countries and mega-countries in 2015



(ISAAA, 2015)

Use of agriculture biotechnology in African countries

According to the International Service for the Acquisition of Agri-Biotech Applications (ISAAA), the African continent has slowly been adopting the use of genetically engineered crops, with the slow implementation being caused by regulations (ISAAA, 2015). These biotech crops can be used to resolve African related challenges of drought, nitrogen use efficiency, salt tolerance, nutritional enhancement, and resistance of tropical pests and diseases (James et al., 2015).

Currently, the biotechnology is mainly used on maize, cotton and soybeans, with maize being one of the main food supplements in Africa. Countries including Burkina Faso, Egypt, Kenya, Uganda, Sudan, Uganda, Malawi, Swaziland, Nigeria and Ghana have adopted the use of genetically modified crops.

Use of agriculture biotechnology in South Africa

The production of GM crops is supported by the South African government. In 1999, the Genetically Modified Organisms (GMO) Act of 1997 was introduced, after which the National Environmental Management Act and the National Environmental Management Biodiversity Act were introduced to support the GMO Act. In South Africa there are about 40 000 commercial farming units, with the agriculture sector contributing approximately 897 000 farmworkers, equating to 4-5% of total employment. South Africa is one of the largest producers of sugar, milk and fresh fruit in the Southern Africa region, whilst of the whole of Africa, it also contributes about 17% of meat, 8% of wheat and 17% of maize production (AgriSA, 2016).

South Africa is a semi-arid country with only approximately 13% of the land able to be ploughed for crops. About 14% of the population in South Africa is vulnerable to food insecurity, while 25% of children below the age of six years suffer from malnutrition (Department of Science and Technology, 2013). Drought, climate change, water scarcity and population growth are worsening food insecurity, thus there is a need for intervention to curb some of these problems. For this reason, the government has initiated some actions and has tapped into biotechnology.

In 1992, trial tests of genetically engineered crops were initiated, which resulted in the issuance of a conditional permit in 1997. South Africa launched a National Biotechnology Strategy in 2001, and by 2002 the country was leading the research into GM technologies of white maize production (Moyo, Bairu, Amoo, & Van Staden, 2011; Pray, Huang, Hu, & Rozelle, 2002). In 2009 the planting of GM crops was commercialized, making South Africa the first African country to do so. According to ISAAA, about 2.3 million hectares of land have been used to plant biotech crops (James et al., 2015).

In the table below is a list of the genetically engineered crops permitted in South Africa:

Table 1: Transgenic varieties approved in South Africa

Transgenic varieties approved in South Africa

Crop	Year approved
Insect-resistant cotton	1997 (reassessed under GMO Act)
Insect-resistant maize	1997
Herbicide-tolerant cotton	2000
Herbicide-tolerant soybeans	2001
Herbicide-tolerant maize	2002 (planted 2004)

(Aerni, 2005)

Cotton: In 1997, insect resistant cotton was first grown in South Africa, while herbicide tolerant and double-stacked herbicide tolerant/insect resistant cotton were later introduced (**Table 1**). By 2012/13, statistics had shown that double-stacked herbicide tolerant /insect resistant cotton accounted for more than 95% of the cotton produced in SA (Department of Science and Technology, 2014).

Maize: In 1997, insect resistant maize was introduced, followed by herbicide tolerant and double-stacked herbicide tolerant/insect resistant maize (**Table 1**). As of 2012/13, statistics showed that approximately 86% of the total maize produced in South Africa was GM maize, with double-stacked herbicide tolerant/insect resistant maize making up 49% and insect resistant maize making up 35% (Department of Science and Technology, 2014).

Soybean: In 2001, herbicide-tolerant soybeans were introduced (**Table 1**). According to 2012/13 statistics, herbicide-tolerant soybeans made up 90% of the soybeans produced (Department of Science and Technology, 2014).

The economic impact of agriculture biotechnology

Since the introduction of GMOs, the need for, and usage of, these crops have been increasing. Globally about 1 million hectares were planted with transgenic crops in 1996; by 2005 the area had increased to over 90 million hectares (Herdt, 2006). Farmers across the world have benefited from positive income gains from the usage of GM crops; the cumulative global farm income from GM crops between 2006 and 2014 was $150.3 billion, with the main contributors being GM herbicide tolerant (HT) soybeans ($46.6b), GM insect resistant maize ($41.4b) and GM insect resistant cotton ($44.8b). In 2014, global direct farm income from GM crops was $17.7 billion, which was equivalent to a 7.2% increase in the global production of the four main crops - soybeans, maize, canola and cotton (Graham & Peter, 2016). From 1996 to

2014, total farm income increased by $150.3 billion. In 2014 the largest profits ($5.3 billion) in farming income came from GM insect resistant (IR) maize, which was equivalent to 3.2% of the global maize crop (Graham & Peter, 2016). From 1996 to 2016, GM resistant maize added an accumulative value of $41.4 billion income to maize farmers (Graham & Peter, 2016).

The cotton, soybean and canola sectors have also made big strides; the global cotton sector made an additional gain of $44.8 billion by 2014 due to higher yields and lower costs. The soybean and canola sectors, meanwhile, made an additional income of $46.6 billion by 2014 (Graham & Peter, 2016).

The new technology of GM crops comes at a cost as well, however. On average, the costs of the GM crops are 23% of the total income for the developing countries and 32% for farmers in developed countries (Graham & Peter, 2016).

In terms of production, farmers have experienced positive yields from their GM crops. Between 1996 and 2014 there was additional production of over 503 million tons of food, of which soybeans had additional production of 158.4 million tons, corn 321.8 million tons, cotton 24.7 million tons, canola 9.2 million tons and sugar beet 0.9 million tons (Graham & Peter, 2016).

Another study performed on the environmental impact of the GMO crops have shown that cumulatively between the period of 1996 to 2014 there has been 581 million kg (-8.2%) reduction in pesticides usage (Brookes & Barfoot, 2016). The study further showed a reduction in fuel usage and tillage changes resulting in significant reduction of greenhouse emissions equivalent to a reduction of nearly 10 million cars from the roads (Brookes & Barfoot, 2016). The reduction in fuel usage is due to reduced usage of tractors for spraying of crops and reduced tillage. The technology has made significant contributions towards the reduction of negative impact from the use of pesticides, in a period of 1996 to 2014 the use of pesticides has reduced by 581million kilograms equivalent to 18.5% reduction (Brookes & Barfoot, 2016). The reduction in tillage has resulted in improved ability to control weeds, enhanced soil quality, reduction in soil erosion, greater water retention, reduced levels of nutrient runoff and more carbon remains in the soil leading to fewer carbon emissions (Blanco-Canqui & Lal, 2008; Brookes & Barfoot, 2016). Emissions that have a negative contribution towards the environment such global warming,

ozone depletion, ecotoxicity of water and acidification and nitrification of soil and water were found to be much lower on the herbicide-tolerant crops when compared to the conventional crop. Further emissions with a negative impact on humans such as summer smog, toxic particulate matter and carcinogenicity were also found to be lower in herbicide-tolerant crops (Bennett, Phipps, Strange, & Grey, 2004; Bonny, 2011).

Developed economies context

The United States of America is the leader in the development and planting of GM crops currently; 70.9 million hectares of the arable land is planted with GM crops (James et al., 2015). Between 1996 and 2014 the US alone made $65.8 billion in farm income from GM crops, totaling 43.7% of global farm income from GM crops (Graham & Peter, 2016). The GM crops brought about some changes in the farming industry in terms of product mix, volumes, costs and use of herbicides, all of which had a positive impact on cost savings, which were estimated at between $6 and $10 per hectare.

Developing economies context

Looking at the developing economies, countries like Brazil, Argentina, China and India have been at the forefront of the use of GM crops and technologies, and have made positive gains. China and India have specialized in GM IR cotton; between 1996 and 2014, India had farm income of $18.3 billion and China $17.5 billion from GM cotton alone. Brazil leads the production of GM HT soybeans and GM IR maize; for the period 1996 to 2014 that country had farm income gains of $13.7 billion from its GM crops alone (Graham & Peter, 2016). The majority of the income for the developing countries has come from GM cotton and soybeans. Brazil has mostly relied on the planting of GM soybeans since 1997, which make up to 93% of the total soybeans in the country (Graham & Peter, 2016). In a study done in Northern China between 1999 and 2001 in the Yellow River cotton-growing region, results have shown that due to the introduction of Bt Cotton, the farmers were able to increase their yield per hectare, reduce illnesses due to pesticides poisoning and reduce pesticides costs, time spent on spraying dangerous pesticides (Pray et al., 2002).

South African context

South Africa was the first African country to adopt the use of GM crops and still remains ahead of the other African countries.

GM HT soybeans were first planted in South Africa around 2001, and by 2014, 618 000 hectares were planted with GM soybeans, constituting 90% of total soybeans produced. Between the period 2004 and 2014, farm income (from maize, cotton and soybeans) was $1.8 billion. Net cost savings of between $1 and $9 were achieved through reduced expenditure on herbicides. In 2014, the cumulative farm income gain since 2001 was $18.1 million (Graham & Peter, 2016). A different study (**Table 2**) done in South Africa in different provinces showed potential benefits from the production of GMO crops, where the GMO crops showed a 10.6% yield benefit (Gouse, Pray, Kirsten, & Schimmelpfennig, 2005).

Table 2: Average Maize yields for Bt and conventional maize

Province	*Conditions*	*Yield with Bt Maize*	*Yield with Conventional Maize*	*% yield Advantage*
Mpumalanga	Irrigation	11 280	10 500	7%
Northern Cape	Irrigation	12 160	10 860	12%
Total	Irrigation	12 081*	10 881*	11.03%
Mpumalanga	Dry land	5 000	4500	11%
North West	Dry land	3 130	2 920	7%
Total	Dry land	3 398*	3 072*	10.60%

(Gouse et al., 2005)

Research questions

Based on the literature reviewed, the following research questions were created:

- Has agriculture biotechnology contributed positively to the economy of South Africa?
- Are the farmers benefitting from agriculture biotechnology?
- What are the challenges facing the farmers with regards to biotechnology?

Research design

Research approach

This chapter introduces the research methodology used to assess the impact of agriculture biotechnology on the economic development of South Africa. This chapter will cover the research design, data collection instruments, and analysis.

The purpose of this paper is to assess the wide use of agriculture biotechnology and its impact on the economic development of South Africa. This paper attempted to ascertain what academics, farmers and government representatives think about the impact that agriculture biotechnology has on the economy. The paper is meant to serve as a recommendation with regards to required agriculture biotechnology improvements.

Research design

The research design used for the research was a qualitative research through interviews. A qualitative research is designed to gather data on the experiences, perspectives and attitudes of a population through the generation of words rather than numbers (Bricki & Green, 2007). The main focus of this qualitative research was to understand, explain, explore, discover and clarify situations, beliefs and experiences of different individuals involved in agriculture biotechnology (Kumar, 2014).

The purpose of the research was to evaluate the impact of agriculture biotechnology on the South African economy and make an analysis without quantifying the results. Interviews were conducted to gather information and obtain the views of different stakeholders in the industry based on their experiences. The interviews resembled everyday conversations, but given the focus on the researcher's need for data, they differed to normal conversations as they were conducted in a vigorous manner so as to ensure the validity and reliability of the data (Bricki & Green, 2007).

Semi-structured interviews were used to collect data from the participants, where open-ended questions were asked to the participants with the main purpose of gathering information on their views and experiences. The key objective of a semi-structured interview is to obtain standard information that can be comparable (Gill, Stewart, Treasure, & Chadwick, 2008; Kumar, 2014), and to gather new information.

The aim of asking open-ended and follow up questions was to gather more information and to enhance the reliability and validity of the data. The interview questions were formulated in a manner that they are easy to be understood by different individuals, certain questions were posed differently to particular groups but with the purpose to obtain information based on their area of specialty.

Twelve interviews were conducted with respondents who represented different stakeholders, i.e. academic, farmers and government representatives. The respondents represented the diversity of the population as they come from different backgrounds (Elo & Kyngäs, 2008), which eliminates any biasedness. Amongst the respondents, there were individuals with a high level of experience and knowledge in the subject matter, individuals with technical experience and know-how. The sample is deemed to be sufficient, as in qualitative research there is not much to be gained from studying bigger samples (Marshall, 1996). Judgemental sampling was adopted as these stakeholders were considered to have the necessary knowledge and information regarding agriculture biotechnology. All the respondents are involved in agriculture biotechnology at different levels and are exposed to different experience which will bring variety to the research namely (Yin, 2017):

- The academics interviewed are highly skilled, have years of experience in the industry and is involved in current research in the agriculture biotechnology industry.
- All the respondents are involved in agriculture biotechnology which brings recent and relevant experience to the research.
- All the government officials interviewed are involved in the agriculture biotechnology area and involved in current research and their entities prioritize biotechnology.

Data collection procedures

Data were collected through person-to-person and over the telephone interviews with stakeholders who played a significant role in the agriculture biotechnology industry. Both the telephone and face-to-face interviews were acceptable tools for collecting data in a qualitative research. Research has shown that telephone interviews have potential disadvantages, such as a loss of data due to, for example, the researcher not being able to read the body language of the respondent (Irvine,

Drew, & Sainsbury, 2013). On the other hand, there are benefits of telephonic interviews such as savings in time and travel costs, and respondents have greater anonymity which may make them open up more (Irvine et al., 2013). Due to the different locations of the respondents, telephonic interviews were deemed suitable. To enhance the reliability of the data all the respondents who were interviewed over the phone were experts in the subject matter, the interviews were scheduled on time, and the interview questions were sent in advance to the respondents.

The interviews were recorded with the approval of the respondents, as a consent letter was sent in advance. Any relevant supporting documents were obtained from the respondents for further analysis. The interview questions are detailed in Appendix A. Both primary (interviews) and secondary (other relevant supporting documents) data were collected and used.

Method of data analysis

Interview questions are likely to yield descriptive and narrative responses, with the researcher's intention being to communicate the research findings in a non-numerical style. The qualitative research methodology for this study took the form of a semi-structured and flexible information collection approach by collecting data through follow-up questions, holding discussions, recording information in a narrative and descriptive format, subjecting the data to largely descriptive analysis and then communicating the research findings in a non-numerical style (Kumar, 2014). The researcher identified the main themes that emerged from the interviews with the research participants and wrote about them, quoting extensively verbatim and also quantifying their frequency of occurrence in order to show their prevalence (Creswell & Creswell, 2017).

The constant comparative analysis method, which compares and contrasts data while searching for consistencies and differences, was used to analyze the data (Boeije, 2002; Kolb, 2012). The purpose of the constant comparative analysis method is to generate theory in a systematic manner (Fram, 2013; Glaser, 1965; Hewitt-Taylor, 2001). Data analysis commenced by editing the interview responses from the participants, and contrasting and comparing their responses to the literature review. Themes were then identified and integrated into the text of the research report.

Reliability and validity

Reliability and validity is a function of the research procedures providing answers to the research objectives and for the research instruments to deliver a greater degree of consistency and stability (Kumar, 2014; Morse, Barrett, Mayan, Olson, & Spiers, 2002).

It is acknowledged that the validity of research conclusions is largely dependent on the research methodology used, i.e. the validity of a study is affected by how informed the research participants are about the topic and the study, and whether they understand the purpose and relevance of the research. The participants in this study were selected as they were qualified farmers with exposure to agricultural biotechnology; science and technology specialists from the government; or agricultural or science and technology academics.

In addition, to enhance the reliability and validity of the data, all the interview questions were sent to the participants well in advance so that they were well prepared. Relevant supporting documents were also obtained from the interviewees. The interviews were recorded once approval was obtained from the interviewees.

The design of the interview questions contributed to the reliability of data (Kothari, 2004), therefore they were worded effectively and without ambiguity so that the participants would interpret them uniformly. Reliability was also delivered by quantifying the number of times a theme occurred.

Finally, the researcher's practical appreciation of the economy also corroborated this study's validity and reliability.

Research participants

Research participants are largely informed by the adopted method of data collection under the research methodology. The socioeconomic-demographic characteristics of the study population play a crucial role in the method of data collection and ultimately influence the research participants over and above the researcher (Kumar, 2014). Due to the complexity of the research topic, valid and reliable conclusions could only be derived from participants who were qualified in the field. The first group of participants, i.e. those in science and technology from the government, addressed the state of agricultural biotechnology in South Africa and how they measure the

impact of its success or failure, as well as the level of resources applied. The second participant group, i.e. the qualified farmers on the ground who have embraced agricultural biotechnology, addressed practical questions with regards to how agricultural biotechnology has affected their yields and operational efficiencies. The last group of participants, i.e. the academics, provided their perspective on the already researched and documented impact of agricultural biotechnology on the country. All the research participants have experiences relating to agriculture biotechnology from different perspective and backgrounds (Groenewald, 2004).

Access to respondents was facilitated through various networks of the researcher and mainly through various referrals such that the respondents came from five different provinces around South Africa. These provinces do participate in agricultural activities in the country for instance

Ethical considerations

All-important ethical issues were taken into consideration when conducting the research (Anteliz, Danaher, & Danaher, 2001), such as confidentiality of information shared during the interviews, ensuring the anonymity of participants, gaining prior consent for the interviews and recording, and disclosing the purpose of the interviews and the research upfront. The vernacular language (Xhosa) was used to interview farmers from Qhoqhweni village so that they could express themselves freely. None of the respondents were compelled to answer all the questions - this was left to their discretion.

Presentation, analysis and discussion of results

Introduction

The objective of this chapter is to analyze the data collected with the intention identifying patterns and themes that describe the impact of agricultural biotechnology; analyze the themes and assess whether they answer the research questions, and discuss the findings as a summative description of interviewee responses and comparison to the literature review. For the purpose of this research, a constant comparative analysis was used.

The constant comparative analysis method is the comparing and contrasting of data to search for consistencies and differences (Boeije, 2002), with the objective of being able to identify conceptual similarities and discover new patterns (Tesch, 2013).

This research study made use of the qualitative approach to gather data and to reach its findings. Face-to-face and telephonic interviews were used to collect data, with the interview questions being sent to the respondents well in advance so that they had sufficient time to prepare. Where the respondents were not comfortable with responding to certain questions, it was left to their discretion whether to respond to the question or not.

Demographics of respondents

Data were generated from 12 face-to-face and telephonic interviews with commercial farmers, subsistence farmers, academics and government officials. The farmers had an average of 12 years' experience in farming, while the other interviewees had an average of 18 years' experience in their respective industries. The subsistence farmers interviewed were from Qhoqhweni village in Mount Fletcher (Eastern Cape). These interviews were conducted in Xhosa and translated into English for the purpose of analyzing the data. It has been observed that human beings feel more comfortable when speaking in their mother tongue and are able to express themselves freely. Further, it has also been observed that different responses can be obtained from the same answer but asked in different languages yet from the same individual and this highlights the importance of mother tongue (Charles, 2007; Guttfreund, 1990).

Table 2: Detailed demographics of the respondents are shown below:

Variable	Category	Frequency	Percentage (%)
Gender	Female	6	50%
	Male	6	50%
	Total	**12**	
Age group	< 35	2	16.67%
	40-50	4	33.33%
	50-60	4	33.33%
	None (age non-disclosure)	2	16.67%
	Total	**12**	
Education level	No matric	6	50%
	Diploma	2	16.67%
	Master's degree	1	8.33%
	PhD level	3	25%
	Total	**12**	
Race	Black people	9	75%
	White people	3	25%
	Total	**12**	
Province	Gauteng	1	8.33%
	Eastern Cape	6	50%
	Western Cape	3	25%
	Free State	1	8.33%
	North West	1	8.33%
	Total	**12**	

*Gender***:** The gender split of the respondents was 50%, i.e. there was an equal representation of both genders.

*Age group***:** The respondents were requested to disclose their age if they wanted to; only two of the respondents did not. Two-thirds (66.66%) of the respondents were between 40 and 60 years, and only 16.67% were less than 35.

Education level: 50% of the respondents had not attained a matric, and all of them were part of local government projects that are led by qualified project extension officers. All the commercial farmers had qualifications in farming. 16.67% of the respondents held a diploma, whilst one-third (33.33%) held postgraduate degrees. All the respondents who were not farmers had a minimum of a Master's degree and held positions that involved biotechnology, agriculture and/or natural resources.

Race: The race categories were classified into two groups, namely black people and white people.

The black race was inclusive of African, Indian and Coloured people as defined by the Broad-Based Black Economic Empowerment Act (Department of Trade and Industry, 2005). 75% of the respondents were black people whilst 25% were white people.

Province: The respondents represented five provinces of the country, with the majority coming from the Eastern Cape, followed by the Western Cape.

Presentation of the results

The results of the study are presented in alignment with the identified themes from the responses to research questions and literature review.

The research questions are as follows:

- Has agriculture biotechnology contributed positively to the economy of South Africa?
- Are the farmers benefitting from agriculture biotechnology?
- What are the challenges facing the farmers with regards to biotechnology?

In studying the interview data the researcher has identified common responses from the respondents and themes, unfortunately, due to limited space, the article cannot report extensively on the interview responses. Below are descriptive summaries of some of the responses from the interviews that support the main themes identified in the article.

The growth of agriculture biotechnology industry in South African

This question was only posed to the academics and government officials as they are in a position to obtain the information as part of their job that enables them to monitor

the state of adoption of biotechnology and the GMO crops. The objective of asking a particular group was to avoid biased answers. Some of the respondents as part of their jobs perform research on the related topics, hence they are in a position to gather information from different database sources. All the respondents indicated that the agriculture biotechnology industry is growing drastically, in the past 20 years new crops have been introduced and the adoption rate of GMO crops is nearing maximum. One respondent further indicated that the productivity of farming has improved due to the technology and that more farmers both small and large are increasing the uptake of the technology, the GMOs in particular.

The extent of adoption of the genetically modified crops in South Africa

Again this question was only posed to the academic and government officials. The researcher wanted to understand from the respondents based on their knowledge and experience of the industry whether there is an increase in the adoption of GMO crops and potential influences for the increase or decrease of the adoption. The potential influences were covered in other questions of the interview. All the respondents indicated that there is growth in the adoption of GMO crops and the adoption rate is increasing. One of the respondents went further to state that the GMO crops have been adopted quite well, currently according to the ISAAA report 90% of maize, 100% cotton and 95-97% of soybeans produced are GMOs in South Africa. He further argued that there should not be a competition between GMO and non-GMO crops as the adoption of either crop should be based on the needs of the farmer i.e. GMOs come with specific traits and thus the farmer should have a choice in terms of which crops to plant based on their needs. Also, the respondents indicated that there are new products in the pipeline that will be introduced in the future over time.

Awareness of other farmers using genetically modified crops

This question was only posed to the farmers, the objective of the researcher was to understand whether farmers are aware of other farmers in their respective surroundings and somewhere else that are making use GMO crops. This question is indirectly linked to the question that was asked academic and government officials with regards the extent of adoption of GMO crops. All the respondents indicated that they are aware of other farmers who are using GMO crops in and around their areas. The subsistence farmers who are mostly part of the government projects indicated

that all the farmers in their individual projects are making use of the GMO crops. One of the respondents further indicated in the local silos where they store maize the slips issued to the farmers do indicate that there is a certain percentage of genetically modified maize in their storages. This then points out the fact that other farmers in the area are also using GMO crops and they make use of the same silos.

Why the use of genetically modified crops

The farmers interviewed were asked whether they use GMO crops and were further asked of their decision and other respondents were asked based on their industry knowledge as to what are the reasons farmers opt to use GMO crops. All the respondents indicated that the yields have increased since the use of GMO crops. All respondents have indicated that the GMO crops have been beneficial to individuals differently. Below are some of the benefits reported:

- The quality of the harvest was reported to have been of quality maize,
- Farmers were reported to have experienced better and increased yields since the use of GMO crops,
- The labour and time that was usually spent on the fields have been reduced significantly as farmers no longer have to remove weed physically nor spray pesticides,
- Some of the respondents reported that crop management has become more simplified,
- It was observed that plants have become more resistant to drought,
- Some of the respondents indicated that GMO crops maize produce tastes better compared to the traditional seeds previously used and that the product is healthy and nutritious,
- Some of the respondents indicated that the GMOs will assist in the reduction of food security as more food is being produced,
- Input or production costs were reported to have been reduced i.e the use of pesticides have been reduced which then results in less usage of the tractors for spraying pesticides thus reducing diesel usage in the tractors and the cost thereof, reduction in spraying pesticides also meant less equipment maintenance required, and
- GMOs have helped to manage or contain price increases in maize.

All the respondents from Qhoqhweni village who are between the ages of 40 and 50 years indicated that the GMO crops have made it possible for them to plough the fields again as there is no intensive labour required anymore especially on removing the weed. Five respondents indicated that if it was not for the GMOs they were not going to plough their fields again as age is against them and they do not have the strength anymore. The commercial farmers applauded the GMOs for a simplified crop management in their farms.

Changes in production yields and quality since the introduction of genetically modified crops

The researcher wanted to find out whether there was any collaboration between the production yields, quality, and GMO crops. All respondents have indicated that since the adoption of the GMO crops, the production yields have increased, one of the respondents further explained that the increase in production is not due to the fact that GMO crops produce more maize. The reason behind the increased yield is due to the fact that the targeted pests by the GMO traits no longer destroy crops thus crops have a survival chance until harvesting, unlike the non-GMO crops. The respondent further explained that GMO crops need to be used when required, for instance, if the characteristic traits contained by the GMOs do not affect the farmer then it adds no value to the farmer to make use of GMO crops as they will add no value.

Profitability of biotechnology i.e. genetically modified crops

All respondents indicated that the GMOs have been profitable to the farmers, some respondents indicated even though the seeds for the GMO crops are more expensive they still outway the benefits received.

The contribution of agriculture biotechnology in the economy of South Africa

The objective of the question was to assess whether there has been any contribution made by agriculture biotechnology to the economy, a contribution can take different folds or can be defined in different ways. For instance, one can consider the job opportunities created, more food supply which then results in food security, the revenues generated by the farmers and many other forms. The question was open to the respondent's interpretation of contribution in order to gather different views in the

research. When asked about the contribution of agriculture biotechnology to the economy, all respondents responded positively. Most of the respondents who are subsistence farmers indicated that they are able to feed their families and animals and where there is excess maize they are also able to sell maize and make some extra money for themselves. The respondents also indicated that they have managed to save a lot of money i.e. they no longer have to buy maize as they grow their own. After the harvest, they keep the mielies in safe containers and consume it throughout the year until the next harvest. One of the respondents also indicated that when she sells her excess mielies she tries to make the maize price affordable so that those who cannot afford in the village are still able to buy maize and feed their families too.

One of the respondents indicated that farming has become sustainable, thus creating jobs for farm workers. The food is safe, healthier and there is food security due to increased production yields. There is more food supply and it is easier now to produce compared to the past. Some of the respondents also alluded to some of the reports which have indicated that the GMOs over the past years have contributed between $1,8 to $2.1 billion towards the economy.

Growth in agriculture directly contributed to the use of genetically modified crops

This question was only posed to the academic and government officials. When asked about the contribution of the GMOs specifically to the agricultural produce, three respondents (out of four) indicated that there is a direct contribution. There has been improved productivity and profitability, 90% of maize, 90-100% of soybeans and 95% of the cotton produced in South Africa are genetically modified. One of the respondents pointed out that the high rate of adoption is an indication there is a benefit to the farmers. One respondent opted not to respond to the question due to lack of sufficient information available to him in order to make an informed response.

Negative effects observed due to genetically modified crops

Contrary to the benefits reported by the respondents from the use of GMO crops, this question was asked to probe further if there were any known negative effects that have been observed due to the use of GMO crops. This question brings balance to the research such that the focus of the research is not focused on one side both

sides positive and adverse are considered. Also, the objective of the question was to probe further from the respondents whether they are aware of the negative issues reported on the GMO crops and what their views were. All the farmers responded to having not observed any negative effects thus far since they have started using the GMOs be it in the environment or anywhere else. The issue of pests resistance has come out from other respondents of which one respondent further indicated that the potential of pests resistance might be caused by non-compliance with the planting requirements of the GMO crops. Yet the respondent confirmed that there is no confirmed answer with regards the issue of pests resistance. Two of the respondents also indicated that the GMOs have brought healthier aspects to the environment, for instance, some of the pesticides farmers use are destroying all pests in the soil. Whilst the GMOs on the other hand only affect the targeted pests.

When enquired about the challenges currently facing farmers with regards agriculture biotechnology, the respondents reported different challenges as listed below:

- Some of the respondents indicated that the seeds for the GMO crops are expensive, thus affordability has been a challenge for some farmers especially small farmers,
- It was reported that the seeds cannot be reused, every year the farmers need to buy seeds. Whilst with the indigenous crops farmers were able to reuse the seeds in the following harvest.
- There is still a lack of knowledge, education, and research around the GMO crops which is causing resistance from other farmers,
- Some of the respondents indicated that there is a lack of end-user/consumer information,
- It was reported that compliance with GMO crops planting instructions and stewardship requirements is a challenge for some farmers.
- There have been instances of development of pests resistance, and
- Lack of development of products that are specific to the South African farmers.

Three of the respondents cited no challenges as they are not aware of them.

Themes identified

The interview data was studied and analyzed using the deductive approach. Three key themes that describe the impact of agricultural biotechnology on the South African economy, from the perspective of farmers, agricultural academics and agricultural government officials, were identified.

The themes reflected the following:

- high degree of adoption of GMO crops, a growing use in South Africa and positive contribution to the growth of the agricultural sector;
- GMOs benefits to farmers, other stakeholders and economy at large; and
- challenges associated with the use of GMOs.

These themes were evident when compiling summative descriptions reflecting the actual responses of the interviewed participants and also when related literature was reviewed.

The summative descriptions that supported the finding of the participant's responses relating to the main themes are presented below under subheading "Analysis and Discussion of results".

Analysis and discussion of results

High degree of adoption of GMO crops, a growing use in South Africa and positive contribution to the growth of the agricultural sector

With regards to adoption, the growing use of GMOs and positive growth in the agricultural sector, the respondents indicated that there is growth in the adoption of GMO crops. According to the 2016 ISAAA report, South Africa has reached an overall 91% adoption of GMO crops, with 90% of maize, 95% of soybeans and 100% of cotton planted in South Africa being genetically modified (ISAAA, 2016). The awareness of other farmers using GMO crops was high among the respondents in and around their areas.

The respondents indicated that agriculture biotechnology is growing, with new crops in the pipeline that will soon be available in the market. This was supported by the 2016 ISAAA report. The results thus support the literature review and also correlate with the increased adoption mentioned above.

Considering the growth of the agriculture biotechnology industry, all the respondents indicated that it is growing drastically; in the past 20 years new crops have been introduced and the adoption rate of GMO crops is nearing maximum. One respondent further indicated that the productivity of farming has improved due to the technology, and more farmers - both small and large - are increasing the uptake of GMOs. Research supports the views of the respondents that the intake of GMOs has increased; South Africa has 2.7 million hectares planted with GMO crops, consisting mainly of maize, soybeans, and cotton (ISAAA, 2016).
This answers one of the research questions regarding whether there are benefits to be gained from the use of GMO crops.

Examples of the participants' responses relating to the high degree of GMOs adoption and wild spread use of GMOs are:
"In the fields, I use GMO crops because they have high yield, in my garden at home I use the traditional white maize because I can reuse it, unlike the GMO crop. If you reuse the GMO crop the harvest becomes less. The GMO crops are very resistant in drought conditions and have less work." [Respondent 6]

“Yes, statistics are supporting and there is room for growth. More efforts and investment in training and research are required to fast track growth. The Agriculture Research Council (ARC) is working on beneficial research on water efficient maize and government plays a role via extension services.” [Respondent 11]

“Adoption is continuing at an impressive pace. However, there are farmers who are reverting to the traditional crops due to economic reasons. The GMO route is expensive, especially the seed as compared to non-GM crops. The farmers who are reverting back to non-GMO crops are benefiting from the cross-pollination of crops from neighboring farmers who adopted GMOs.” [Respondent 7]

Most of the respondents indicated there is a positive contribution from biotechnology to the growth of the agriculture sector in general, even though they do not have the quantitative data to prove it. According to the literature review, by 2014 GMO crops in South Africa had contributed $18.1 million (Graham & Peter, 2016).

Examples of the participants’ responses relating to growth in the agricultural sector as a result of the adoption of GMOs:

“There has been improved productivity and profitability.” [Respondent 12]

“Yes, the yield has grown.” [Respondent 11]

GMOs benefits to farmers, other stakeholders and economy at large

According to the respondents, the government supports farmers who use GMOs via various government institutions, extension officers, and others. Prior research supports these views; according to the literature review the Genetically Modified Organisms Act of 1997 was legislated and various government institutes focus on biotechnology.

All the respondents deemed the availability of information to be an important benefit and indicated that information on GMOs is available to the public and farmers through various public and private institutions, which was supported by the literature review. The respondents also indicated that there is legislation on food labeling on all food items that contain GMOs, however, while regulations on food labeling do exist,

the literature did not cover this topic and the researcher has limited information as to the functionality of this Act.

Examples of the participants' responses relating to government support and availability of GMOs information are:

"Yes, I am part of the government project called Tsoma. We are supplied with seeds, poison, manure, fertilizer. The project is very helpful. We contribute money to the project and get assistance." [Respondent 1]

"Government is supporting GMO programmes. The rural small farmers are being supported extensively by the government as opposed to large commercial farmers, where they are only monitoring." [Responded 7]

"Yes, they are supporting farmers. They host workshops, farmer's days and when the government buys seeds in the province they usually buy GMO crops. In Gauteng, government and farmers have a 5-year agreement where the government will buy farming inputs." [Responded 9]

All the respondents indicated that their yields have increased since they began using GMO crops, which was confirmed by the literature review (Carpenter, 2010; Harrison, 2002; Herdt, 2006). One of the respondents explained further that the increase in yield is due to the fact that the targeted pests no longer destroy the crops, hence farmers are achieving a full harvest, however, the literature did not identify the reason behind the increase in the yield. The respondents also highlighted other reasons for using GMO crops, namely improved quality, a reduction in time and labour spent on the fields, easier crop management and drought resistance. Most of the benefits highlighted by the respondents were also identified in the literature, i.e. a reduction in pesticide use (Loureiro & Bugbee, 2005), a high crop yield (Harrison, 2002; Wieczorek, 2003), and enhanced nutrition (Diehl, 2017). The benefit of saving time and using less labour came more often from the respondents.
All the respondents indicated that the GMOs have been profitable for the farmers, which is as per the literature. Graham and Peter (Graham & Peter, 2016) reported that the net cumulative gain due to the GMOs between 2001 and 2014 was $18.1

million in South Africa, while a global net gain of $150.3 billion was made. According to the literature, the net gain was due to enhanced productivity and efficiency gains, while there was also net cost savings of $1 to $9 due to the reduced usage of herbicides (Graham & Peter, 2016).

All the respondents indicated that access to GMO crops is fairly easy, yet the literature was silent on this topic. Resources that are fairly accessible in the economy promote fair participation by all interested parties.

In terms of the economic contribution of agriculture biotechnology, all the respondents cited that it has made a positive contribution in terms of feeding their families and animals, job creation, food safety, health and food security. The literature supports the views of the respondents, stating that biotechnology in agriculture has been used to produce plants with improved resistance to a disease-causing pest, has enhanced the ability of plants to grow in dry conditions, has assisted fruit to stay ripe longer, and has enhanced nutritional value by producing products enriched with vitamins (Diehl, 2017). The contribution of biotechnology benefits both people in the cities and the rural areas. The subsistence farmers interviewed came from a rural area and highlighted the contribution of being able to supply food to their families, as most people in the rural areas have little income, thus being able to produce their own food lessens the burden on their monetary needs.

The respondents believed that agriculture biotechnology is key for the economy, as a lot of people are dependent on agriculture for food security, labour and imports to other countries. According to research, agriculture contributes an average of 2% to the South African GDP (Statistics South Africa, 2016). Further, according to Statistics SA's third-quarter report for 2017, the agriculture sector recorded the highest growth of 44.2% during the third quarter (Statistics South Africa, 2017).

This theme answers the question of whether agriculture biotechnology has made a positive contribution to the South African economy.

Examples of the participants' responses relating to GMOs profitability and importance to the economy:

“Yes, even though the seeds are expensive you ultimately make profits due to reduced labour and pesticides costs and operational efficiency.” [Responded 5]

“Yes, even though the seed price is high the input costs are reduced; GMOs have high returns. GMOs do not necessarily increase yield, they preserve yield against external factors like drought, diseases and pests. Herbicide-tolerant GMO crops enable farmers to plant without tilling the land which reduces costs.” [Responded 11]

“Yes it profitable, even though the seeds are more expensive they come with much better benefits i.e. drought and insects resistance, better worm management, and the costs afterward are far less.” [Responded 10]

“Yes, farming is sustainable and as a country, we are able to produce our own food i.e. mealies, etc. There is job creation, food security, safe and healthy food.” [Responded 9]

Most of the respondents indicated that agriculture biotechnology has a future in South Africa. In the literature, David and Rui (David & Rui, 2016) stated that if sub-Saharan Africa can increase its crop yield to 50%, the region will have sufficient food and will become a net food exporter. The literature highlighted the introduction of the Act to regulate GMOs, which implies that the government has a long-term strategy with regard to GMO crops. According to research, the natural resources (water, soil, and air) that bring life to human beings are under threat, the earth is losing its fertility, we are experiencing droughts, and the air is polluted (Hobbelink, 1991; Varshney, Bansal, Aggarwal, Datta, & Craufurd, 2011). With all these threats, interventions like biotechnology can be a powerful tool to improve agricultural production (Hobbelink, 1991; Varshney et al., 2011).

Based on the responses and the literature review, there are indeed benefits that are derived from the GMO crops. This theme answers the research questions regarding whether there are benefits to be derived from agriculture biotechnology and whether there are future benefits to be derived from GMOs.

Challenges associated with the use of GMOs

The respondents indicated a number of challenges they have come across, namely: the crops seeds are expensive; seeds cannot be reused; there is non-compliance

with the GMO crop planting instructions; there is a lack of knowledge amongst both farmers and consumers, and pest resistance is developing. The literature supports the respondents' views on pest resistance, as this was highlighted as one of the key risks of GMO crops (Loureiro & Bugbee, 2005). Graham and Peter pointed out a different view from the respondents, however, as they found that GMO crops brought a net cost savings of $1 to $9 due to a reduced usage of herbicides (Graham & Peter, 2016). All the respondents did, however, indicate that they make profits, even with the high costs associated with GMO seeds.

Examples of the participants' responses relating to challenges associated with the use of GMOs:

"The seeds and manure are expensive. You can't replant a seed otherwise the harvest becomes less." [Responded 1]

"Compliance to planting requirements i.e. the 80:20 rule (80% GMO and 20% non-GMO) is difficult to keep track of. The challenges are isolated cases, at times we experience pest resistance." [Responded 7]

"Pest resistance and its management can be a challenge for farmers, development of products that are specific to South African farmers. Misinformation and misunderstanding, lack of local research to develop more technology. Regulations should not be a barrier to technology adoption." [Responded 11]

"Resistance development. Compliance is a challenge for small farmers. Extension services are not adequate in assisting farmers in terms of compliance and support farmers to handle resistance to GMOs intake by users and other stakeholders." [Responded 12]

In addition to the issues listed above, the respondents pointed out a number of other challenges linked to agriculture biotechnology, including a lack of information, a lack of local research and other influences. In the literature review drought was mentioned as one of the reasons why biotechnology is required, i.e. to strengthen agricultural production. The literature consists of opposing groups, however, as one group promotes the use of GMO crops and lists their benefits, whilst the other group

opposes biotechnology and list its concerns about GMO crops. These two different views can confuse the layperson, thus the respondents raised the issue of a lack of information and a dearth of local research to provide clarity on these two different schools of thought.

Research by Biowatch South Africa (Biowatch South Africa, 2016) has identified below some concerns with regards GMO crops:

- GMO crops do not change the performance of the crop, they only grow well with regular irrigation and fertilizer application. One cannot reuse the seed in the next season as it will produce less.
- GMO crops growing in a nearby field might contaminate other crops in the same vicinity, especially in crops like maize as they are wind pollinated.
- After a few years, the targeted pests grow resistance.
- GMOs promote corporate control of the food system as it is the same companies that produce the seeds, fertilizers, pesticides, and herbicides.
- Current GMO crops include the ability of the cells to create toxins and antibiotic resistance. This could cause resistance to antibiotics in the medical sphere.
- Research done on animals indicates serious health impacts such as disturbance in the immune system, increased cancerous tumours, and other medical problems.
- Concerns about soil and water bacteria, but there are no adequate studies yet to confirm this effect.
- Naturally, pests and weeds develop resistance to toxins over time.
- Glyphosate is a herbicide used with the GMOs, but according to research, it is declared to be causing cancer.

Current labeling regulations are causing confusion and many companies are avoiding labeling, thus taking away the consumer's right to choice and knowledge of what they are eating.

The concerns above are similar to those raised in the literature review. Most of the respondents, based on their knowledge and experience, had not experienced most of the issues noted above, except for the development of pest resistance. Most

respondents were aware of some of these concerns but noted that they had not come across conclusive research that confirmed them. This still leaves the issue open-ended, i.e. there is a still a gap that research needs to fill so as to bring clarity to some of the concerns. This theme answers the research question of whether there are challenges with regards to GMO crops.

The contribution of the study

The results of this study have significance for academic research, government leadership, agricultural researchers and the public in general for the purposes of providing more information.

According to the research results, the respondents have indicated that the GMO crops are highly adopted in the agricultural industry and research confirms the same. Currently, South Africa has reached an overall 91% adoption of GMO crops consisting of maize, cotton and soybeans. With regards to the impact on the growth of the agriculture sector and on the economy, the results have shown a positive impact as GMO crops have high yield produce thus enhancing food stability. On the other hand, the concerns raised against the GMO crops still need to be addressed as the respondents did not have much contribute on most of the issues due to lack of available research with conclusive results on the concerns.

Limitations

Like many studies, this study also had limitation and they are listed below:

- The lack of availability of financial information for farmers who are private companies limited access to information.
- The judgemental sampling method used might have imposed limitations on the research, however, this method was used to ensure coverage of different stakeholders in the industry.

Recommendations

The institution of further local research into GMO's

It has come out of the research that there are contrasting views with regards the benefits and challenges of the GMO crops.

The research has confirmed the increased use of GMOs in South Africa, indicating an overall 91% adoption rate (ISAAA, 2016), and economic benefits were also confirmed by both the respondents and the literature. On the other hand, challenges were raised with regards to the use of GMOs, however, there is no certainty on some issues.

The researcher recommends that the government puts more resources into research, so that clarity can be obtained with regard to the risks of GMOs. There is a possibility that the current benefits being experienced are at the expense of the concerns raised, which might surface in the future.

Also, the respondents alluded to the fact that GMO seeds are produced by foreign companies and most of the current research is international, thus it is recommended that more local research is done so that domestic agricultural challenges can be addressed.

Strong collaborations with developed countries that have been using GMO crops

Research has shown that the GMO crops have been in existence for more than two decades and have been adopted worldwide; leading countries include the USA, Brazil, Argentina and Canada, amongst others.

The researcher recommends that further collaboration is undertaken with these developed countries that have been using GMO crops for longer, to ascertain whether they can confirm these challenges and if so, observe how these concerns have been addressed.

Increased public awareness of the GMO crops

Amongst the challenges that have been raised, lack of knowledge was common. It is recommended that the government deploys more resources to inform the public about GMO crops so that consumers can make informed decisions.

Monitoring of GMO crops statistics

The respondents indicated that GMO crops have contributed positively to the growth of the economy and the agricultural sector, however, some respondents alluded to the fact that they do not have statistics to support their argument. The researcher recommends that more resources or information be made available that indicates the direct results of the GMO crops. Currently, with the reported increases in the agricultural sector productivity, especially in maize, there is no information that directly attributes the increase to GMO crops.

Recommendations for future research

- According to research, more countries are adopting the use of GMO crops (ISAAA, 2016), yet negative concerns are being raised about the crops. I propose that government institutes further research to confirm or clarify the validity of concerns raised.
- In order to derive maximum benefits from biotechnology, the responsible government institutions should embark on local researches tailored for our environment to deliver local solutions.
- A cost-benefit analysis of the positives and negatives of GMO crops, both short and long-term, should be done.
- The government should engage in extensive consultations with both the users and farmers of the GMO crops to enable them to make informed decisions.

Conclusion

The results of the interviews and the research conducted concur on most issues, such as the increase in production yields and profit margins, the reduced use of pesticides, the reduction in the labour involved, and the value-add (e.g. food security) caused by GMO crops. The impact of these positive benefits indicates that agriculture biotechnology does have a positive impact on economic development in South Africa in terms of food security, alleviating poverty and healthier food supply. Also, the use of GMO crops has reduced the risk of vulnerability in production yields. In as much as most people are seeing benefits, however, there are still concerns that need to be addressed, which the respondents alluded to.

The research shows a strong need for a robust agricultural sector, with good growth for the sustainability of the economy. South Africa as a developing country is in need of interventions to: eradicate poverty; increase the productivity of natural resources; create self-sufficiency; manage the challenges of climate change; and improve the economy, health and social benefits.

The agriculture sector has a significant role to play in the economy and cannot be left on its own; sustainable interventions are needed to manage imminent emerging challenges.

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Competing interests

The author declares that she has no financial or personal relationship that may be inappropriately influenced her in writing the article.

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