AN ANALYSIS OF PUBLIC PERCEPTION TOWARDS CONSUMING GENETICALLY MODIFIED CROPS AND THE ACCEPTANCE OF MODERN AGRICULTURAL BIOTECHNOLOGY: A SOUTH AFRICAN CASE STUDY

by

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ABSTRACT

South Africa is one of the biggest producers of genetically modified crops in the world. However, recent studies in South Africa show a low public willingness to consume genetically modified crops and accept modern agricultural biotechnology. The study analysed public perception towards consuming genetically modified crops and the acceptance of modern agricultural biotechnology in South Africa. 220 participants (N = 220) were sampled from the city of Kempton Park and the Chi-square formula was used to determine how well the sample represented the population under study. Data was collected using a 7-point Likert scale questionnaire designed following the guidelines for developing a theory of planned behaviour questionnaire in Ajzen (1991, 2001). Data analyses were carried out using the Statistical Package for Social Sciences (SPSS). The Cronbach's alpha and Exploratory Factor Analysis were both used to determine the internal consistency and validity of the questionnaire. Correlations, independent sample t-tests, ANOVA, linear regression, and path analysis were also conducted. Findings of the study confirmed that there is low public willingness to consume genetically modified crops and to accept modern agricultural biotechnology in South Africa.

KEY TERMS

- Environmental impact assessments
- Genetically modified crops
- Genetic engineering
- Modern agricultural biotechnology
- Modern biotechnology
- Public awareness
- Public perception
- Transgenic crops

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This work is dedicated to Patricia and Tilden.

Lastly, the voice of the LORD is upon the waters; The God of Glory thunders,
The LORD is over my waters - Psalm 29:3

DECLARATION

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I declare that the above dissertation is my own work and that all the sources that I have used or quoted have been indicated and acknowledged by means of complete references.

04/01/2019

LIST OF TABLES, DIAGRAMS AND EQUATION

DIAGRAMS	**DESCRIPTION**	**PAGE**

LIST OF ABBREVIATIONS

AUML	African Union Model Law
ANOVA	Analysis of variances
CBP	Cartagena Biosafety Protocol
CPA	Consumer Protection Act
DEAT	Department of Environmental Affairs and Tourism
EIA	Environmental impact assessments
EU	European Union
FAO	Food and Agriculture Organisation
FCDA	Foodstuffs, Cosmetics and Disinfectants Act
GE	Genetic engineering
GM	Genetically modified
GMO	Genetically modified organism
HT	Herbicide tolerant
IR	Insecticide resistant
MAB	Modern agricultural biotechnology
MB	Modern biotechnology
NEMA	National Environmental Management Act
NEMS	National environmental management system
OECD	Organisation for Economic Co-operation and Development
RDNA	Recombinant deoxyribonucleic acid
SA	South Africa
SPSS	Statistical Package for Social Sciences
TPB	Theory of planned behaviour
UNECD	United Nations Commission on Environment and Development
UNISA	University of South Africa
USRAF	United States Risk Assessment Forum
VIF	Variance Inflation Factor
WTO	World Trade Organisation

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CHAPTER 1
INTRODUCTION AND BACKGROUND

1.1 Introduction

This chapter is an introduction and it gives an overview of this dissertation. The chapter focuses on the background to research topic, background of the research problem, the problem statement, objectives, the scope of the study, theoretical framework, research methodology, research limitations, clarification of concepts and chapter layout. This chapter also presents the importance of carrying out this study. The primary aim of the study is to analyse public perception of genetically modified crops through investigating the beliefs and factors that influence public willingness to consume genetically modified crops[1] and accept modern agricultural biotechnology[2] in South Africa. An analysis of public perception towards consuming genetically modified in South Africa is significant for predicting reasons for low acceptance of modern agricultural biotechnology. Most recently, Gastrow, Roberts, Reddy and Ismail (2018:7) reported a low acceptance of modern agricultural biotechnology in South Africa. A similar topic has been studied in different countries, and findings were found to be very useful in improving the process of regulating genetically modified crops (Font 2009; Cheng 2016). There is an urgent need to provide the government with reasons and possible solutions for public unwillingness to consume genetically modified crops and low acceptance of modern agricultural biotechnology in South Africa. According to Aleksejeva (2016:157), beliefs, attitudes and socio-demographic factors are important predictors for public acceptance of modern agricultural biotechnology. This study intent to analyse the beliefs, attitudes and socio-demographic factors as predictors of public acceptance of modern agricultural biotechnology.

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[1] Transgenic crops and genetically modified crops are used interchangeably, and the two names refer to the same product.

[2]In this study modern biotechnology is the technological application of living or synthetic organisms to modify or produce goods and services in an economy

1.2 Background to research topic

Since the global introduction of genetically modified crops in 1996, people in different countries have raised risk concerns from genetically modified crops (Andriano 2015:549). Scholars, professionals, researchers and interested stakeholders have also published many publications expressing risk concerns from the public. Several scholars have studied public willingness to accept modern agricultural biotechnology and findings suggest a low level of public acceptance of biotechnology (Olivas & Bernabéu 2012:282; Mou & Scorz 2011:175). People in the European Union (EU) have been ranked the lowest in accepting modern agricultural biotechnology (Montesinos-López1 et al. 2016:6). Findings suggest that low acceptance of genetically modified crops in Europe was stimulated by public mistrust in genetically modified crop regulation processes. Anderson (2004:2) blames stringent laws on genetically modified organisms to have impeded public acceptance in Europe. Studies in Japan also show a low acceptance (Cheng 2016:427) while studies in United States, show a favourable acceptance (Mabaya, Fulton, Wafukho & Nang'ayo 2015:578) towards genetically modified organisms. In South Africa, several scholars reveal a low public acceptance of modern agricultural biotechnology (Gastrow et al. 2018). Reasons for low public acceptance in South Africa include public mistrust in the genetically modified crop regulation processes and the public perceived human health and environment risk beliefs.

South Africa has been pro-active in regulating genetically modified organisms through ratifying several international and regional treaties[3] as well as enacting several genetically modified organism laws[4]. However, South Africa's genetically modified organisms and environment management laws, specifically the Environment Impact Assessment regulation act of 2014, has been criticised

[3] The following are international and regional genetically modified regulations adopted in South Africa; Cartagena Biosafety protocol, United Nations Convention to Combat Desertification, the United Nations Framework Convention on Climate Change, United Nations Convention on Biological Diversity and the Southern African Development Community Protocol on Wildlife Conservation and Law Enforcement, the Biodiversity Act of 2004.

[4]These also include a National Biotechnology Strategy, and a National Strategy for Sustainable Development.

for being ineffective in regulating the release of genetically modified crops in the environment (Paul & Robertson, in Fuggle, Rabbie, Strydom & King 2015:945; McGeoch & Rhodes 2006:2; Poppy 2000:4; Wilkinson et al. 2003: 215; Andow & Zwahlen 2006:196). The environment impact assessment regulation act of 2014 is not capable of conducting complex, in-depth genetically modified crops environmental impact assessments (Gray 2000:54; Gormley, Pollard & Rocks 2011:8). Regulations of genetically modified crops must be apt in dealing with the release of genetically modified organisms into the environment and warrant the public of human and environment safety from modern agricultural biotechnology.

Public participation, engagement and transparency in the regulation of genetically modified crops is also central in predicting public acceptance of modern agricultural biotechnology. South Africa has been criticised for failing to engage the public meaningfully in regulating genetically modified crops (Gastrow et al. 2018:7). Several scholars have emphasised the importance of public participation, engagement and transparency in regulating genetically modified crops (Jacob & Schiffino 2011:991; Page 2013:1). The public has a pivotal role to play in regulating genetically modified crops. For instance, failure to engage the public in the regulation processes, raises public suspicions on the risks that might be involved. The moment the public become suspicious and uncertain on the human health and environment safety from genetically modified organism, resistance to modern agricultural biotechnology becomes more prevalent (Groenewald in Academy of Science of South Africa 2010:123). Clear guidelines for public participation, engagement and accountability, as a strategy for increasing transparency and public trust in regulating genetically modified crops must be put in place, and effectively implemented. Public engagement and transparency in regulating genetically modified crops will influence public perception towards consumption of genetically modified crops.

Several studies in different countries reveal a negative public perception towards genetically modified organisms (Cheng 2016:427; Komoto, Okamoto, Hamada, Obana, Samori & Imamura1 2016:2; Bernard & Gifford 2006:343; Font 2009:38). After almost three decades of commercialisation of genetically modified crops, public acceptance and willingness to consume these crops is still very low. Motives for the low acceptance of modern agricultural biotechnology, include lack of public trust in the regulation process, incomplete genetically modified organism expert knowledge, risk beliefs and negative attitude towards genetically modified crops (Yue et al. 2015:282). Policy makers and regulators of genetically modified crops must invest in developing strategies to deal with negative perception towards consuming genetically modified crops, for instance, regulators must avail reliable information to the public. Public negative perception largely builds on misinformation on genetically modified crops (Qaim 2019:163).

Perceived human health and environmental risks have been found to be significant predictors of public unwillingness to accept modern agricultural biotechnology (Massey, O'Cass & Otahal 2018:418; Zhou & Hu 2018:219; Sax & Doran 2016: 413). This suggests that people are uncertain about the health and environment safety of genetically modified crops. According to Kirsch (2001:171) and Tranter (2011:81) regulators are to be blamed for not applying a precautionary approach[5] when regulating genetically modified crops. However, a precautionary approach must be applied in-conjunction with public involvement. If the precautionary approach is not practised, with transparency, it will make the public uneasy with genetically modified crops resulting in public risk concerns. Environment risk belief is one of the public risk concerns that have influenced the way the public sees modern agricultural biotechnology. According to König, Frank, Heil and Coenen (2013:12) genetically modified organisms can negatively impact on the living species in the environment. Genetically modified organisms can be invasive and disruptive to the environment. Environment risk concerns have influenced the public to reveal a low public acceptance of modern agricultural biotechnology in different

[5] The Precautionary principle is a strategy to cope with possible risks of genetically modified crops.

countries (Carter-Johnson 2015:420; Vaque & Isabel Segura 2016:390). Public hesitancy to embrace biotechnology is a phenomenon that is rooted in public fear that genetically modified crops will worsen the current global environmental challenges.

According to Qaim (2019:159) studies in genetically modified crops' risks have shown that perceived health and environmental risks are unsubstantiated. There is little evidence, if any, to support that genetically modified crops are harmful to human health and the environment. For instance, the EU's uncertainty for genetically modified crops stem mainly from the regulatory system (Komoto et al. 2016:2). Europe had no central regulator for transgenic crops which made the public to doubt the effectiveness of genetically modified crop regulation process in ensuring public health and environment safety (Finucane & Holup 2005:1608; Stapleton 2016:527). According to Katzek (2002:1) and Gerasimova (2016:530) most risk scenarios perceived by European consumers have been disproved. Therefore, the public trust plays an important role in predicting acceptance of modern agricultural biotechnology. In South Africa, perceived health and environmental risk from genetically modified crops have been reported to originate from public mistrust in the regulation processes (Prince & Black 2010:10; Gastrow et al. 2018). On the contrary, in China and Netherlands acceptance of modern agricultural biotechnology was found to be influenced by a higher public trust in genetically modified crop regulations (Hanssen, Dijkstra, Sleenhoff, Frewer & Gutteling 2018:8; Curtis, McCluskey & Wahl 2004:71). Majority of scholars have pointed public mistrust as one of the reasons for the public to believe that genetically modified crops are harmful. High level of public trust is needed to influence high public acceptance of modern agricultural biotechnology. According to Phares (1991:90) genetically modified crops regulations must be trusted by the people to entice them to consume genetically modified crops.

Several scholars have reported that the public lacks trust in the genetically modified crop regulation process (Adnan, Nordin, Bahruddin & Ali 2018:834).

Public trust is critical in regulations and should exists between the public and regulators. Several scholars have found that public trust in regulations strongly predict high public acceptance of modern agricultural biotechnology (Ryu, Kim & Kim 2018:2; Thompson 2018:169). There are several reasons why the public fails to trust in regulations of genetically modified crops. Different approaches in regulating genetically modified crops have been cited as one of the reasons (Lee 2016:1; Bertheau 2013:7; Carter-Johnson 2015:420; Francis, Craig & George 2016:105). Some countries enact stringent laws and others less stringent, creating an impression that genetically modified crops may or may not be safe. Policies must be consistent and in-line with global modern agricultural biotechnology regulation standards (Rowe, Amijee, Brody, Wandrey & Dreyer 2012:336; Gostek 2016:762).

1.3 Background to the research problem

Fast growth in commercialisation of genetically modified crops, globally (Hallerman & Grabau 2016:4; Navarro, Tome & Gimutao 2013:20; Pruitt 2014:13) has been associated with low public acceptance of modern agricultural biotechnology (Gastrow et al. 2018; Costa-Font 2009:9; Sexton & Zilberman in Mou & Scorz 2011:179). Low acceptance of modern agricultural biotechnology, in different countries has been ascribed to several reasons. According to Rosculete, Bonciu, Rosculete and Teleanu (2018:3) low acceptance of modern agricultural biotechnology has been associated with the public perceived risk beliefs and attitudes from genetically modified crops. Wilson and Zhang (2018:27) mention public mistrust in regulators as one of the reasons for low acceptance. Public mistrust on regulators, as well as perceived risk beliefs (Baumber 2018:32) have both, been associated with public unwillingness to consume genetically modified crops. According to United Nations Environment Programme (2004:7), the environment hazards killing millions of people every year have been associated with modern technologies in food production. The public holds the view that genetically modified crops are not safe for human consumption and for environmental sustainability.

Despite, the perceived risks and mistrust in regulating genetically modified crops by the public, commercialisation of genetically modified crops has not declined. The commercialisation of transgenic crops has increased remarkably in most countries (Begley 2017:628; Mabaya et al. 2015:579; James 2016: 8) with new techniques, e.g. plant synthetic biology, being adopted rapidly (Fesenko & Edwards 2014:1927). Increasing commercialisation has led to increased consumption of genetically modified crops. Global statistics on genetically modified crops show a trend in growth of genetically modified crop consumption (Brookes & Barfoot 2016; Hallerman & Grabau 2016; James 2015). For instances, in United States, no genetically modified food was sold prior 1994 and by 2015 approximately 75% of processed foods in the country contained genetically modified organism ingredients (Begley 2017:628; Nat 2016:198) and in 2014 European Union countries imported over 19 million tonnes of genetically modified soya beans (Kou et al. 2015:2157). Therefore, countries importing food products from the United States and the European Union are exposed to genetically modified crops.

Commercialisation and consumption of genetically modified crops in South Africa is also rising. South Africa is one of the world leaders in producing genetically modified crops (Anderson & Jackson in McMahon & Desta 2012:157), and is involved in plant synthetic biology research, a technique in modern agricultural biotechnology (Oldham, Hall & Burton 2012:694). Evidence shows that South Africa is experiencing a rapid growth in genetically modified crops in the food market, despite the fact that most of these food products are not being labelled (Marx 2010:63; Gastrow, Roberts, Reddy & Ismail 2016:105). Food Stuff, South Africa (2016:1) reports that the products of synthetic biology are already available on the market in South Africa. Current, literature shows beyond doubt that most people in South Africa are consuming genetically modified crops. However, despite an increased consumption of genetically modified crops, Gastrow et al. (2018:7) found low level of public acceptance of modern agricultural biotechnology in South Africa. This finding suggests that people are consuming genetically modified crops unwillingly or the public is uninformed on the availability of genetically modified crops on the food market. However, the trend in South Africa, like in other countries, shows growth in commercialisation and consumption of genetically modified crops with low public acceptance of modern agricultural biotechnology.

Public perception has been ascribed to low public acceptance of modern agricultural biotechnology. According to Marx (2010:34), studies conducted in South Africa show that people have varied perceptions towards willingness to consume genetically modified crops and accepting modern agricultural biotechnology. Public perception is a significant predictor of public acceptance of modern agricultural biotechnology. Initially, public perception towards transgenic crops was positive until the publication by Losey, Rayor and Carter (1999:214) which suggested the risks associated with genetically modified crops (Yue et al. 2015:282). Public perception towards genetically modified crops has been influenced by the perceived health and environmental risks. Perceived health and environmental risks have pushed regulators to apply strict measures in regulating genetically modified crops, thereby increasing the cost and uncertainty in the development of genetically modified crops (Qaim 2019:163).

Several scholars have also suggested that socio-demographic factors are significant predictors of public acceptance of modern agricultural biotechnology (Thorne, Fox, Mullins & Wallace 2017:51; Ramya & Ali 2016:80; Popek & Halagarda 2016:330; Gheysen & Valcke 2018:600). Socio-demographic variables are potential factors that influence low acceptance of modern agricultural biotechnology (Antonopoulou et al. 2009:91; Gilovich, Dacher & Nisbett 2006:467). However, several studies in different countries reveal some contradictory findings (Komoto et al. 2016:15; Onyango & Nayga 2004:567; Hossain et al. 2002). Some scholars have shown the significance of socio-demographic factors in predicting public acceptance of modern agricultural biotechnology (Popek & Halagarda 2016:320; Nguyen & Gizaw 2014:20; Valente & Chaves 2018; Chmielewski, Ochwanowska, Czarny-Działak & Łuszczki 2017:4110) while some indicate that socio-demographic factors are non-significant (Paul, Trun, & Alan 1996:161; Zhu & Xie 2015:790; Oguz 2009:159). The arguments on the potential effects of socio-demographic factors in predicting public willingness to consume genetically modified crops and accepting modern agricultural biotechnology are inconclusive.

Lack of public participation in regulating genetically modified crops in South Africa has also been attributed to low acceptance of modern agricultural biotechnology. Several scholars argue that policy makers and regulators of genetically modified crops in South Africa have overlooked public participation, engagement and transparency in the regulation processes (Andanda 2009:5; Wozniak & McHughen 2013:8) which are the three fundamental principles in predicting a favourable level of public trust and acceptance towards comsumption of genetically modified crops (Johnson 2011:1474). Public participation, engagement and transparency are catalysts, speeding up the process of public acceptance of modern agricultural biotechnology. Gastrow et al. (2018:8) recommends that South Africa must develop new strategies for public engagement in regulating genetically modified crops.

The historical background to the commercialisation of genetically modified crops in South Africa has also been given as a reason for low public acceptance of modern agricultural biotechnology. The regulation of modern agricultural biotechnology in South Africa began in 1979 under the South Africa Committee for Genetic Engineering and was based primarily on laboratory safety (Peacock 2010:115), without any formal field trials on transgenic crops conducted (Koch 2002:48). The commercialisation of genetically modified crops which commenced in 1997 (Peacock 2011:115), therefore occurred without any field trials conducted in the country. It is also not clear whether the regulators of genetically modified crops informed the public about the decision to release genetically modified crops in South Africa for commercialisation in 1997. Hence, commercialisation of genetically modified crops seems to have takenplace without proper regulations to govern the release of genetically modified crops for commercialisation (Liebenberg & Kirsten 2006:214; Gastrow 2008:348; Swanby 2009:3).

According to Gastrow (2008:348) "in 1997, South Africa commercialised genetically modified maize and in 1998 the first laws regulating these crops came into existence". Policy makers violated the commonly agreed upon stages for policy making, as put forward by several scholars (Theodoulou & Cahn 1995:86; Venter & Landsberg 2011). The policy process started at the adoption stage, and it is not clear which other stages were followed, thereafter. Although there are several genetically modified crop regulations in South Africa, several scholars argue that the process of regulating genetically modified crops was not properly executed by the policy makers (Godfrey 2013:420; Molatudi & Pouris 2006:106). Lack of genetically modified crop environmental impact assessment guidelines in the South African Environment Impact Assessment Regulation of 2014 (Tshangela 2014:213; Harsh 2005:661; Kidd & Retief, in Fuggle et al. 2015:1021) suggests that South Africa adopted the commercialisation of genetically modified crops prematurely. There is little or no doubt in the positive impact of effective genetically modified crop guidelines in regulating the release of genetically modified crops for commercialisation and in predicting public acceptance of modern agricultural biotechnology.

1.4 Problem statement

There is low public acceptance of modern agricultural biotechnology in South Africa (Gastrow et al. 2018). The public is reluctant in accepting modern agricultural biotechnology. However, reasons for low public acceptance of modern agricultural biotechnology need to be investigated to assist policy makers and regulators to improve the regulation process and to predict policy outcomes. The biggest obstacles to high public acceptance of modern agricultural biotechnology are negative beliefs and attitudes for genetically modified crops. According to Liu and Stewart (2016:384) high public acceptance of modern agricultural biotechnology is required for farmers to increase the size of land planted with genetically modified crops. Low acceptance of modern agricultural biotechnology by the public will impede technological advancement and denies the public the benefits of genetically modified crops. According to Qaim (2019:159) the benefits of genetically modified crops are underrated, while risks are overrated. It is against this background that the researcher seeks to analyse public perception towards consuming genetically modified crops and acceptance of modern agricultural biotechnology. This will be done through investigating the beliefs, attitudes and socio-demographic factors that influence public willingness to consume genetically modified crops and accept modern agricultural biotechnology in South Africa.

1.5 Primary and secondary objectives

Primary objective

The study seeks to understand public perception towards genetically modified crops through investigating the beliefs, attitudes and socio-demographic factors that influence public willingness to consume genetically modified crops and accept modern agricultural biotechnology in South Africa. The study was carried out in Gauteng province in the city of Kempton Park.

Secondary objectives

1. To evaluate the applicability of the Theory of Planned Behaviour in analysing public perception towards public acceptance of modern agricultural biotechnology in South Africa.
2. To investigate the impact of psychological and socio-demographic factors on public perception and in predicting willingness to accept modern agricultural biotechnology.
3. To examine the impact of public health and environmental risk concerns from genetically modified crops.
4. To examine the impact of public trust in genetically modified organism regulations, in predicting public willingness to consume genetically modified crops and accepting modern agricultural biotechnology.

5. To outline and recommend environmental impact assessment guidelines to be followed by government relating to the release of genetically modified organisms.

1.6 Scope of the study

This study focuses on analysing public perception towards public willingness to consume genetically modified crops and accept modern agricultural biotechnology. The study will investigate the influence of beliefs and attitudes in predicting intention to accept modern agricultural biotechnology. The study will also analyse the influence of socio-demographics factors in predicting public acceptance of modern agricultural biotechnology. There are many socio-demographic factors, but this study is limited to age, education, gender, income and race, because of limited financial resources. Adding many socio-demographic variables makes it complex to gather data from a large sample size (Nass, Levit & Gostin 2009:214).

The study was carried out in Gauteng province (approximately 12 million people) of South Africa, in the city of Kempton Park with 220 participants. Gauteng is one of the biggest business sectors in South Africa (Struwig & Stead 2001:75) and is accessible to the researcher, a factor that will reduce the cost of the research. Mixed and multi-stage sampling was used to select the sample. Chi-square formula[6] measured how well the sample represents the population, in terms of demography. The theory of planned behaviour is the theoretical and analytical framework for this study, based on the theory being compatible for analysing the influences of beliefs and attitudes in predicting behaviour. The theory of planned behaviour predicts causal relationships between beliefs → attitudes; attitudes → intention; and intention → behaviour. Beliefs predict attitude, attitude predict intention and intention predict behaviour.

[6] Chi-square formula = $\chi^2 = \sum \frac{(O-E)^2}{E}$

1.7 Limitations of the study

Resources were limited. Time and funds were not adequate to conduct a research involving a larger sample size. According Khalilzadeh & Tasci (2017:90) using a larger sample size guarantees statistical significance and allows the discovery of rare statistical associations which cannot be revealed by smaller sample sizes. The researcher recommends further studies to verify the findings of this study with larger sample sizes and different population groups.

1.8 Theoretical analytical framework

The theory of planned behaviour proposed by Icek Ajzen (Ajzen 1991; 2001) was used in the study to analyse public perception towards willingness to consume genetically modified crops and accept modern agricultural biotechnology. The theory has been used in several studies involving beliefs and attitudes (Acarli & Kasap 2015:173; Saeri et al. 2014:354). Based on the theory of planned behaviour, behaviour is "public acceptance of modern agricultural biotechnology" and behavioural intention is the "intention to accept modern agricultural biotechnology" or the "intention to consume genetically modified crops". Several researchers have modified the theory of planned behaviour in analysing different phenomena in social sciences (Acarli & Kasap 2015; Fishbein & Ajzen 2005). Likewise, the theory was modified to incorporate the socio-demographic factors. The theory of planned behaviour is discussed in greater detail in chapter 3.

1.9 Research methodology.

The study will apply both descriptive and exploratory research techniques as it involves secondary (literature study of secondary sources relating to the topic under investigation) and primary investigation (collecting data specifically for this research study). The rationale of combining descriptive and exploratory research techniques in the study is based on the need to provide data that may not be achieved with one research technique (Litosseliti 2010:30). Exploratory approach is appropriate to the study for two important reasons. First, this approach will help the researcher to familiarise with the topic. Secondly, public human health and environmental risk concerns are persistent phenomena over genetically modified organisms in most countries. According to Babie (2014:94) exploratory studies are appropriate for more persistent phenomena. Descriptive approach can be used to study psychological and socio-demographic factors of a target population and permits the participants to be observed in their unchanged environment (Creswell 1994:167). Descriptive approach also allows the study to identify factors that impact public perception towards modern agricultural biotechnology warranting further study. Combining two techniques will shed light on the study and a better understanding of the phenomenon under investigation.

Quantitative research design was used in the study. The rationale for selecting this model is based on the desire to collect data from participants in an unchanged environment (Field 2005:1), then use the data to draw conclusions about public perception towards modern agricultural biotechnology in South Africa. The study makes use of data collection procedures that yield numerical data which was analysed statistically. Babie (2014:403) describes quantitative analysis as the numerical representation and manipulation of observations for describing and explaining the phenomena. The Statistical Package for Social Science (SPSS) was used in data analysis. According to Dornyei (2011:198) SPSS is mostly used in researches in human science. It was appropriate to adopt SPSS as a data analysis model for this study. The study utilises mixed sampling and multi-stage sampling designs in selecting the sample (Kumar 2011:42). Cluster sampling was used to group the population according to the geographical areas, taking cognisance of informal settlements around and within the city as well as the industrial and residential population. Quota sampling was used to determine the number of participants from each cluster (Yin 2011:4). Purposive sampling followed, selecting participants according to socio-demographic factors, and ensuring that gender and race are well represented in the sample. It was a challenge to sample participants by applying age, income level and education factors since participants were interviewed first, to determine these factors.

The study was conducted in Kempton Park, Gauteng province with 220 participants sampled from different clusters or groups. Clusters refer to residential, industrial and informal settlements in and around Kempton Park, that the researcher selected the participants. The study utilised survey method and self-administered questionnaire for data collection. As recommended by Babie (2014:94) public beliefs and attitudes were first explored through use of an open-ended questionnaire and beliefs and attitudes held by the public were used in constructing the 7-point Likert scale questionnaire. The theory of planned behaviour was applied as the data analytical framework. Internal reliability and validity of the final questionnaire was determined using Cronbach alpha[7] and Exploratory Factor analysis[8], respectively.

1.10 Importance of the study

This study is a learning curve across different sectors of the economy and institutions in South Africa. Findings will assist policy makers and regulators to improve genetically modified crops regulation processes and to predict policy outcomes. The study provides clear guidelines for regulating genetically modified crops. In addition, the study tests the feasibility of applying the theory of planned behaviour in analysing public perception towards consuming genetically modified crops and accepting modern agricultural biotechnology with a larger sample, for generalisability purposes. Last, but not least, the study will contribute to the growing body of knowledge on public willingness to consume genetically modified crops.

1.11 Clarification of key terms

Modern agricultural biotechnology. Modern agricultural biotechnology makes use of living or synthetic organisms to modify plants or animals for specific uses (Keener et al. 2014:1; Nair 2008:4). In this study, modern

[7] According to Arthur-Aidoo, Aigbavboa and Thwala (2017:174) Cronbach's alpha is a measure of internal consistency, that is, how closely related a set of items are as a group and it is a measure of scale reliability.

[8] Exploratory factor analysis is a statistical analysis model from the SPSS package, which measures validity of the test items.

agricultural biotechnology refers to the technology used to produce genetically modified crops.

Biotechnology. The term biotechnology refers to conventional and modern biotechnology (Santoso 2016:26), and the difference between the two lies in the application of living and synthetic organisms in crop modifications. There is no application of the living and synthetic organisms in conventional plant breeding.

Belief and attitude. A belief is a conviction that a person holds about genetically modified crops. An attitude is a consistent view of something that encompasses the belief as well as an emotional feeling and a related behaviour (Samuels 2016:90). An attitude about genetically modified organisms can be expressed as belief *(genetically modified organisms will kill people)*; feeling *(consuming genetically modified organisms will make me unhappy);* and behaviour *(I buy genetically modified organism every time l go shopping)*. Beliefs and attitudes can be positive, negative, or neutral, and can be based on opinions or facts.

1.12 Chapter layout

Chapter one is an introduction of this dissertation. It consists of the background to the topic; research problem; research statement; primary and secondary objectives; scope of the study; introduction to theoretical framework and research methodology; as well as the importance of the study. Chapters two and three comprise of literature review and theoretical framework. Key issues covered in chapter two include growth, arguments and regulations around genetically modified crops, as well as, public perception and awareness. Key issues covered in chapter three include environmental sustainability (i.e. to shed light where public environment risk is originating), strategies and assessment guidelines which may be used to integrate modern agricultural biotechnology into the national environment management system. Chapter four is made of the research design, population, sample size, sampling procedure, data collection and analysis methods, research reliability and validity, as well as ethical issues to be considered in this study. Key issues in this chapter include procedures followed in conducting elicitation and pilot studies. Chapter five deals with data analysis, presentation and interpretation. Key issues covered in chapter five include construct validity and reliability of the data collection instrument, determining assumptions of parametric analysis, hypothesis testing, data presentation and interpretation. Chapter six consists of the discussion of the findings, methodological limitations, research practical implications, recommendations and conclusion of the research study. The chapter highlights and cross references key findings of the study with other studies on public willingness to consume genetically modified crops in South Africa (Gatrow et al. 2018)

1.13 Conclusion

The study seeks to make an analysis of public perception towards consuming genetically modified crops and accepting modern agricultural biotechnology in South Africa. The background to the topic and the research problem has been discussed. The problem statement, primary aim and objectives of the study have been outlined. In this discussion, it is evident that modern agricultural biotechnology has been adopted and commercialisation of genetically modified crops is increasing, despite the growing public perceived risks from genetically modified crops. Quantitative research design has been adopted as the research methodology. A questionnaire designed following Ajzen (1991) guidelines was utilised in gathering data for analysis in-line with the theory of planned behaviour. The researcher stated the benefits of using both descriptive and exploratory approaches, and of carrying out this study. The definitions of biotechnology, modern agricultural biotechnology, beliefs and attitudes, as perceived in this study have been advanced, as well as the outlining of the chapter layout.

CHAPTER 2

MODERN AGRICULTURAL BIOTECHNOLOGY, PERCEPTION AND AWARENESS

The chapter focuses on explaining modern biotechnology and its application to agriculture in South Africa and other countries. The researcher will attempt to unpack the differences that exist in defining modern biotechnology and genetically modified crops, as well as describing several kinds of modern biotechnology as applied in different fields of study. The researcher will describe how transforming agriculture will address problems faced in trying to attain biotechnological sustainability in the modern world (Bahadur, Sahijram & Krishnamurthy 2015:753), and deliberate on some of the disagreements on the sustainability of biotechnology (Wozniak, Waggoner & Reilly 2013:3). The chapter will also discuss public perception and awareness, as well as other factors which may influence public willingness to consume genetically modified crops and accept modern agricultural biotechnology.

2.1 Modern biotechnology.

The Codex Alimentarius Commission[1] has adopted the following definition of modern biotechnology from the Cartagena Protocol on Biosafety,[2] which is much complex and reflects prejudice towards modern biotechnology. According to Cartagena Protocol on Biosafety (2000), modern biotechnology is "the application of in vitro nucleic acid techniques, or fusion of cells beyond the taxonomic family, that overcome natural physiological reproductive or recombination barriers and are not techniques used in traditional breeding and selection". In this definition, the phrase "in vitro" might be taken to mean that

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[1] The Codex Alimentarius Commission is a joint intergovernmental body of the Food and Agriculture Organization of the United Nations (FAO) and WHO with 187 Member States and one Member Organization (EU). Codex has worked since 1963 to create harmonized international food standards to protect the health of consumers and ensure fair trade practices.

[2] The *Cartagena Protocol on Biosafety to the Convention on Biological Diversity* is an international agreement which aims to ensure the safe handling, transportation and use of living modified organisms resulting from modern biotechnology that may have adverse effects on biological diversity, taking also into account risks to human health. It was adopted on 29 January 2000 and entered into force on 11 September 2003 (Unit 2018).

all genetically modified organisms are performed outside their normal biological context (Yanagida 2009:30) which is not always the case. The inclusion of the phrase also justifies the need for a precautionary principle in regulating genetically modified crops. The definition is very intimidating and portrays genetically modified organisms as harmful to human health and the environment. The Convention on Biological Diversity[3] defines biotechnology as: "any technological application that uses biological systems, living organisms, or derivatives thereof, to make or modify products for specific use" (Azadi et al. 2015:196). Although both definitions in Cartagena Biosafety Protocol and the Convention on Biological Diversity acknowledge that modern biotechnology entails the manipulation of living organisms' genetic make-up to produce goods and services for human use, the definition in Cartagena Biosafety Protocol (2000) incorporates the methods used (for instance in-vitro), and the reason behind crop modifications, which is to overcome natural recombination barriers.

The Organisation for Economic Co-operation and Development (OECD) defines biotechnology as: "the application of science and technology to living organisms as well as parts, products and models thereof, to alter living or non-living materials to produce knowledge, goods and services" (van Beuzekom & Arundel 2009:9). The two definitions by the Convention on Biological Diversity and OECD, are similar and straight forward and apply modern biotechnology to living[4] and synthetic[5] organisms. Thus, modern biotechnology is the technological application of living or synthetic organisms to modify or produce goods and services in an economy.

Modern biotechnology has several sub-fields. Bahadur et al. (2015:15) outline four colour-coded sub-fields namely, red, white, green and blue biotechnologies.

[3] The Convention on Biological Diversity is an international legally-binding treaty with three main goals: conservation of biodiversity; sustainable use of biodiversity; fair and equitable sharing of the benefits arising from the use of genetic resources. Its overall objective is to encourage actions, which will lead to a sustainable future (United Nations 2018).

[4] Living organisms are made of cells, which are the units of life and they produce offspring that are the same as themselves.

[5] Synthetic organisms are organisms for which a substantial portion of the genome or the entire genome has been designed or engineered.

According to Purohit (2005:64), red biotechnology is the application of modern biotechnology in medical fields, for instance in making antibiotics and other drugs. According to McCreath and Delgoda (2017:553), red biotechnology has contributed over the years in promoting health care. McCreath and Delgoda (2017:553) also argue that the application of modern biotechnology to the medical field has faced little resistance. People accept modern biotechnology if the technology is applied in research and manufacturing of medicine.

The white biotechnology refers to the application of modern biotechnology in industrial manufacturing of goods. Frazier and Westhoff (1993:56) explain it as the designing of organisms to produce a useful chemical. Efficiency becomes the motivation to the technological advancement of white biotechnology. As described in Kumar (2003:101), white biotechnology consumes less resources than petroleum-based processes. The technology is crucial in promoting sustainability. However, according to Lee and Jang (2006:563), there is need to improve the efficiency of white biotechnology. Currently, most of the chemical industries use petroleum-based technologies to white biotechnology, in the manufacturing of goods and services.

According to Frazier and Westhoff (1993:54) blue biotechnology is used to describe the marine and aquatic applications of biotechnology. Day, Hughes, Greenhill and Stanley (2016:6) state that blue biotechnology in recent years has become synonymous with marine biotechnology. The salmon fish[6] is an example of the application of blue biotechnology in marine and aquatic species. Several scholars acknowledge the potential benefits of blue biotechnology in providing sources of antibiotic drugs (Muller, Schroder & Wang 2017:82).

Green biotechnology refers to the application of biotechnology in agricultural processes referred to as modern agricultural biotechnology in this study. As discussed in Purohit (2005:67), modern agricultural biotechnology has some

[6] The salmon fish is engineered to grow faster than its non-genetically modified counterpart, reaching market size in roughly half the time — about 18 months (Waltz 2017).

advantages over the conventional or traditional agriculture[7]. Proponents like Katzek (2002:1), claim success of modern agricultural biotechnology while opponents like Hall (2010), refute the claim citing the technology as risk perceived. The scope of the study is on modern agricultural biotechnology, hence the literature review focussed on this kind of biotechnology.

2.2 Modern agricultural biotechnology

According to Purohit (2005:67), modern agricultural biotechnology is the application of living and synthetic organisms or bacteria to modify or produce crops or plants. There are several techniques used in the field of modern agricultural biotechnology which include transgenesis, cisgenesis, intragenesis and synthetic biology. Transgenesis involves transferring genes[8] between two species that could not naturally breed (Welch, Bagley, Kuiken & Louafi 2017:7), and can be facilitated by physical, chemical or biological techniques. These techniques are widely used in genetic engineering to modify crops and have proved their significance in modern agricultural biotechnology (Lee, Kim, Ono & Han 2017:1). Transgenesis has contributed largely in developing transgenic (genetically modified) crops. Most of the genetically modified crops, for instance soya beans and maize, are the products of the transgenesis technique.

Cisgenesis is the transfer of genes between the same species of a plant or between species that can breed naturally (Welch et al. 2017:7). According to Schouten, Krens and Jacobsen (2006:750), cisgenic plants are similar to traditionally bred plants and must be exempted from the regulations governing genetically modified organisms. The basis of the argument in Schouten et al. (2006), is that the cisgenesis technique does not target to change the genetic make-up of the plants. Plant improvements should happen without disturbing the genetic make-up of the plant, which is the case when using conventional plant breeding techniques in crop modification. However, the reason why the

[7] Conventional or traditional agriculture refers to the agricultural practices that do not apply any of the genetically modified seeds or chemicals in crop production (Liana 2002:410).
[8] A gene is the basic physical and functional unit of heredity. Genes, which are made up of DNA, act as instructions to make molecules called proteins. In humans, genes vary in size from a few hundred DNA bases to more than 2 million bases (Susman 2001:45).

cisgenesis technique is classified under modern agricultural biotechnology is based on the computer-aided techniques used in plant breeding.

Intragenesis involves the transfer of a series of genes between individuals of the same species or between species that can naturally breed with one another (Welch et al. 2017:7). Intragenesis and cisgenesis can be understood in the same context. The difference between these two techniques is that intragenes are hybrid genes, which can have genetic elements from different genes and loci (Espinoza, Schlechter, Herrera, Torres, Serrano, Medina & Arce-Johnson 2013:324). Transgenesis, cisgenesis and intragenesis techniques have been instrumental in modern agricultural biotechnology for almost three decades, specifically in crop improvements.

Plant synthetic biology is one of the computer aided techniques of modern agricultural biotechnology. Martin and Balmer (2008:5) define plant synthetic biology as the deliberate designing of biological systems and living organisms using engineering principles. In their definition, Olsen and Wendel (2013:47) regard plant synthetic biology as a new dimension of modern biotechnology. Welch et al. (2017:5) define plant synthetic biology as an engineering discipline incorporating genomic technologies and techniques. According to Murray (2014:106), it is a new research field seeking to modify existing organisms using living and/or synthesised artificial bacteria. Rai and Boyle (2007:58) consider it "as the use of computer-assisted, biological engineering to design and construct new synthetic biological parts, devices and systems that do not exist in nature and the redesign of existing biological organisms, particularly from modular parts". In other words, there are many definitions of plant synthetic biology depending on the academic discipline the definition was derived from.

Synthetic biology has introduced the use of synthetic or artificial living bacteria and is a multi-disciplinary approach to modern agricultural biotechnology. A multi-disciplinary approach involves combining knowledge and experiences from several academic fields to come up with new products (Luca, Molari, Seddaiu, Toscano, Bombino, Ledda, Milani & Vittuari 2015:1571). In this study, plant synthetic biology is a technological add-on to transgenesis, cisgenesis and intragenesis techniques seeking to incorporate the application of synthetic or artificial organisms and to provide a multi-disciplinary approach in crop improvement technologies. There are several techniques in modern agricultural biotechnology which can be grouped into plant genetic engineering and plant synthetic biology. In the next section, a brief historic outline of plant genetic engineering is presented followed by a brief explanation of the different generations of genetically modified crops.

2.3 Plant genetic engineering

Genetic engineering has been successful in modern crop biotechnology. The concept of genetic engeneering emerged with Joshua and Esther Lederberg in 1952, followed by the discovery of the phage plasmid[9], the tumor-inducing plasmid of *Agrobacterium tumefaciens*[10](Bahadur et al. 2015:22). William Hayes in 1953, established that the phage plasmid is a type of deoxyribonucleic acid[11] (DNA). Werner Arber in 1968 discovered the restriction enzymes[12]. In 1969, Jonathan Beckwith and his colleagues first isolated a bacterial gene. In 1970, Daniel Nathans and Hamilton Smith discovered many independent restriction enzymes. In 1973, Stanley H. Cohen and Herbert W. Boyer used restriction enzymes to isolate the desired genes and to insert the isolated genes into plasmids and made copies (cloning) of a gene. In 1989, Tansley and his colleagues obtained fragments of a gene of variable length, which were used as molecular markers for taxonomic purposes. According to Torrance (2010:643), these scientific discoveries led to the emergence of the transgene technology,

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[9] Phage plasmid is a kind of a gene which facilitates gene replication (Gielow, Diederich & Messer 1991:73).

[10] *Agrobacterium tumefaciens*, is a bacterium found in the soil. The mechanism this bacterium uses to parasitize plant tissue involves the integration of some of its own DNA into the host genome resulting in unsightly tumors and changes in plant metabolism. *A. tumefaciens* prompted the first successful development of a biological control agent and is now used as a tool for engineering desired genes into plants (Agrios 1988:558).

[11] Deoxyribonucleic is a gene found in organisms responsible for storing all information inherited from parents to offspring, the information is responsible for the development, survival and reproduction of organisms (Kaye-Blake 2006:7).

[12] A restriction enzyme is a protein that cleaves gene into fragments at or near specific recognition sites within the molecule known as restriction sites (Kessler & Manta 1990:98).

whereby desired genes from any organism can be isolated through restriction enzymes and then inserted into the gene of any other organism and allowed it to express in the new organism. The success of modern biotechnology has been made possible by these discoveries (Krogstad 2011:901).

Genetically modified crops are divided into three generations (Caserta & Alves de Souza 2017:1). The first and second-generation crops are concerned with the manipulation and transfer of the desired traits from one living organism to the other (genetic engineering), while the third-generation crops are more likely to be a result of both genetic engineering and plant synthetic biology.

There are approximately 30 traits engineered into the first-generation transgenic crops[13]. James (2010:215), and Krimsky and Murphy (2002:81), tablet the traits contained in the first-generation transgenic crops. Herbicide tolerant (HT), insecticide resistant (IR) and stacked traits in either maize, cotton, soya beans, corn and canola are the most popular traits (Hallerman & Grabau 2016:4; Barrows et al. 2014:99; Qaim 2010:552). Genetically modified soya beans enjoy a bigger share in the general global production of the first-generation transgenic crops with 50% of the total accumulated transgenic crop hectares (James 2015:1). There are other traits which are not popular but may be classified under the first generation. These may include improving stress tolerance, virus resistance and disease resistance traits (Cockburn 2002:81). Genes commonly used to confer insect resistance traits are isolated from the soil bacterium *Baccilusturingiensis* (Bt) encoding Cry or Vip proteins, used against lepidopteron and coleopteran pests (Alston et al. 2009:1209; Dunn 1998:150). HT crops express tolerance to glyphosates (Barrows et al. 2014:100; Hallerman & Grabau 2016:4). HT traits are given from genes like bar, pat, gox, which are isolated from the soil bacteria (Brookes & Barfoot 2016:25). Stacked traits are combination of IR and HT and are preferred by farmers. For instance, planted

[13] Transgenic crops and genetically modified crops are used interchangeably, and the two names refer to the same product.

“stacked maize” increased from 51.4 million hectares in 2014 to 58.5 million hectares in 2015 (14% increase) (James 2015:7).

The second-generation of genetically modified crops aim to deliver consumer-oriented benefits (Hartl & Herrmann 2009:552; Magaña-Gómez & Barca 2009:5). Some of the direct consumer benefits include reduced or healthier fats, increased protein, reduced carbohydrates and improved flavour. Examples of these crops include the Golden Rice, designed to provide vitamin A; a transgenic corn to make Ethanol fuel; pink pineapples engineered with lycopene which may fight cancer; and purple tomatoes engineered to have high levels of anthocyanins which may lower cardiovascular risks (Pollack 2011:1; James 2015:2). According to Caserta and Alves de Souza (2017:2), the second-generation crops might face less market resistance due to their direct advantages. However, more studies are recommended in South Africa to determine whether the public is willing to accept and consume the second-generation transgenic crops. According to Valles (2015:34), the second-generation products are not yet available at the market, at large. Barriers impeding the adoption of the second-generation transgenic crops might not be new and unique. Several factors which include the law against genetically modified crops, huge costs associated with research and development, as well as public perception against genetically modified crops (Gostek 2016:800; Smyth 2017:81; Font 2009:903), have played significant roles in preventing the commercialisation of second-generation genetically modified crops. Studies are recommended in South Africa to investigate the reasons why the commercialisation of the second-generation genetically modified crops is being delayed.

The third-generation crops apply mainly in synthetic biology to engineer plants with new input and output traits. According to Liu and Stewart (2016:385), plant synthetic biology can be viewed as a natural extension of plant genetic engineering. It uses both living and synthetic bacteria in crop modification (Fesenko & Edwards 2014:1929). Several scholars have written a substantial literature on the potential benefits of the third-generation crops (Halpin

2005:143; Stewart & McLean 2005, 718; Jenkins, Bovi & Edwards 2011:1830). The use of these crops has been associated with sustainable use of natural resources, as well as promoting human health. According to Kim and Yang (2010:62), some plants in the United States have been genetically engineered to grow edible vaccines for HIV, Hepatitis B, Non-Hodgkin's lymphoma, rabies and tooth decay, which are in various phases of field trials. Apart from crops, animals have been part of this project. For instance, genetically engineered chickens produce a drug in their eggs for lysosomal acid lipase deficiency, goats have been genetically engineered to produce an anticoagulant medicine in their milk, and genetically engineered rabbits generate a drug to treat hereditary angioedema (Becker 2015:43). Like the first and second-generation transgenic crops, applying the principles and methodologies of microbial synthetic biology into plant synthetic biology is currently slow and costly (Liu & Stewart 2016:397). Reasons for such a slow progress are not unique, as these are the same reasons preventing the first and second-generations to be accepted by most people. However, Liu and Stewart (2015:315) are of the opinion that the introduction of the third-generation crops might amplify existing human health and environmental concerns as increasingly larger amounts of DNA and proteins are incorporated into crops. It is yet to be seen how consumers will react to these crops.

Most of the studies that have been conducted in consumer awareness and acceptance of genetically modified crops in most countries, have focused primarily on the first-generation transgenic crops which has created a knowledge gap in the existing literature. Studies are recommended to give evidence on public attitude and to provide an insight on whether people are willing to consume the second and third-generation modified crops. As argued by Liu and Stewart (2015:315), direct consumer benefits provided by second and third-generation genetically modified crops might not be an incentive for the consumer to accept these crops. There may be several factors that will influence public decisions. The perception held by the public towards these crops must not be overlooked, as it shapes an attitude that influences an intention to accept the crops.

On the other note, there are several reasons given in support of genetically modified crops. According to Lee-Muramoto (2012:352), modern agricultural biotechnology has a significant role to play in feeding the increasing population without increasing the land size to cultivate. Lee-Muramoto (2012:353) argues that the world needs 82 percent of the earth's land size, instead of the current 38 percent, to feed the current population if the world resorts to organic farming. In this regard, modern agricultural biotechnology is expected to resolve shortages of food and land through planting genetically modified crops which yield higher production on a smaller piece of land. Scott et al. (2015:29) state that modern agricultural biotechnology advances agricultural efficiency and lessen negative environmental impacts.

In addition, modern agricultural biotechnology yields higher nutritional crops, for example, in creating mutation in rice (Li et al. 2012:391), and in producing synthetic biobased versions of valencene (orange) and nootkatone (grapefruit) (Bomgardner 2012:2). According to Scott et al. (2015:23), many other naturally-occurring molecules are expected to be produced in agricultural crops using different techniques of modern agricultural biotechnology. Liu and Stewart (2016:393) highlight some of the work that has been established in the field to-date, which include the development of the gene design software for plant synthetic biology, for instance the Gene Designer 2.0[14] , the e-cell[15] and the cell modeller[16] software. It is important to note that, although the benefits of modern agricultural biotechnology are many, its costs are also as many.

[14] According to Liu and Stewart (2016:311) the Gene Designer 2.0 software is ready for plant synthetic modification and the software is for gene, operon, and vector design, codon optimization, restriction site modification, open reading frames recoding and primer design.

[15] According to Liu and Stewart (2016:311) the e-cell is used in modelling and simulating the environment for cellular behaviour prediction by building integrative models of the cell based on gene regulation, metabolism, and signalling and running in silico experiments.

[17] Cell modeller is a generic tool for the analysis and modelling of multicellular plant morphogenesis by analysing hierarchical physical and biochemical morphogenetic mechanisms (Liu & Stewart 2016:311)

Importantly, opponents of genetically modified crops oppose modern agricultural technology based on human health and environmental risk perception (Snow & Smith 2012:766; Wright, Guy-Bart & Tom 2013:1223; Scott, Abdelhakim, Miranda, Höft & Cooper 2015:31). For instance, according to Carman and Parletta (2017:4) many genetically modified crops have been engineered to contain DNA that makes them resistant to antibiotics and if these antibiotic resistant DNA sequences are taken up by bacteria in the human biological system, it could make those bacteria resistant to antibiotics. In simple terms, if one contains antibiotic-resistant bacteria in his/her body, the antibiotic drugs prescribed to cure an illness, are resisted by the antibiotic-resistant bacteria, introduced in the body through genetically modified crops. According to Carman and Parletta (2017:4) the introduction of antibiotic-resistant bacteria in the human body cells will considerably worsen the current medical problems with antibiotic-resistant bacteria. Besides the emergence of antibiotic-resistant bacteria, there is also a concern for the potential production of new toxic proteins in genetically modified crops, which are harmful to humans (Carman & Parletta 2017:4). Some of the genetically engineered crops are allergic to humans.

According to Scott et al. (2015:31), the release of genetically modified crops results in the loss of biodiversity and a loss of species that can be used in medical researches. Besides the concern on the increased levels of herbicides and insecticides in food (Carman & Parletta 2015:5), humans fear losing medicinal species. Humans fear that the released genetically modified organisms might affect the non-targeted species, resulting in species extinctions. According to Bryne (2013:1), many medicines, such as antibiotics, come from plant and animal sources, and every time a plant or animal species becomes extinct, the prospects of valuable medicinal harvesting as well as possible future medical discoveries are affected. The benefits of genetically modified crops must be evaluated within the human and environmental risks context. Although, Drake (2003:12) argues that there is insufficient knowledge about potential negative health and environmental risks of genetically modified crops, it is important that preventative measures are considered when commercialising these crops.

Criticisms on genetically modified crops are also based on the regulatory system. As argued in Parr (2017:458), regulation of genetically modified crops continues to be an area of uncertainty. There are several reasons why regulating genetically modified crops is very difficult (Jones 2015:7; Bonawitz & Chappie 2013:337). For example, most people have a negative attitude towards modern agricultural biotechnology, due to health and environmental risk concerns over genetically modified crops (Carman & Parletta 2017:4). In most cases, the public is hesistant to give the government the go-ahead in commercialising genetically modified crops. Traynor, Adonis and Gil (2007:171) think that regulating genetically modified crops has been more complex because the public lack knowledge on how best to regulate modern agricultural biotechnology in an economy. Most countries face challenges in establishing clear guidelines and approaches for genetically modified crops environmental impact assessments. As a result, different countries have opted for the precautionary approach[17] (Mabaya et al. 2015:589). The precautionary approach has however, been criticised for preventing the public to accept the technology (Scott et al. 2015:45; Goklany 2000:02). In most countries, the precautionary approach has been applied in such a way that the potential benefits of genetically modified crops have not been considered. With the current application of the precautionary principle, critics of genetically modified crops do not see the public accepting modern agricultural biotechnology so easily (Lee 2013:1).

2.4 Commercialisation of genetically modified crops.

The global biotechnology industry grew by 5.8% in 2016 to reach a value of $358.9 billion and in 2021 it is forecasted to have a value of $528.4 billion, an increase of 47.2% from 2016 (Amgen 2016:2). The statistics given by Amgen

[17] The precautionary approach or principle states that if an action or policy has a suspected risk of causing severe harm to the public domain (affecting general health or the environment globally), the action should not be taken in the absence of scientific near-certainty about its safety (Taleb, Read, Douady, Norman & Bar-Yam 2014:1).

(2016), include green biotechnology industry. As an entity, agricultural biotechnology has also grown massively (Srivastava & Kolady 2016:311). The estimated global market value of transgenic seeds in 2015 was at US$15.3 billion and transgenic crop grains had an estimated value of more than US$153 billion (James 2015:11). The estimated global farmer benefits for the period 1996 to 2015 was over US$150 billion (James 2015:1). Of the US$150 billion, farmers in China and India gained US$17.5 billion and US$18.3 billion, respectively. The total cumulative economic benefits (for the period 1996-2014) for industrial countries was US$74.1 billion compared to US$76.2 billion generated by developing countries, including China and India (Brookes & Barfoot 2016:163).

On the other side, the global synthetic biology market value reached nearly $2.1 and $2.7 billion in 2012 and 2013, respectively, and the market is expected to grow to $11.8 billion in 2018 (Oldham, Hall & Burton 2012:695). Modern agricultural biotechnology has also grown to a global cumulative 2 billion hectares of transgenic crops, equivalent to almost twice the total land mass of China (956 million hectares) from 1996 to 2015 (James 2015:1). The technology has also experienced an impressive adoption rate in some parts of the world (Ramasundaram et al. 2014:73; Adenle 2011:83). According to James (2015:4), the global area of transgenic crops has increased 100-fold from 1.7 million hectares in 1996 to 179.7 million hectares in 2015. The United States has planted 70.9 million hectares (39%) of transgenic crops. Brazil, Argentina, India and Canada follow United States, respectively. South Africa is the largest producer of transgenic crops in Africa (Kangmennaang et al. 2016) and has become a major player in agricultural biotechnology industry. For instance, of the global total area of 148 million hectares planted in 2010, South Africa's share was 2.2 million hectares, which is approximately 1.5% (Adenle 2011:86), and out of the 20 developing countries producing transgenic crops globally, South Africa stands at the 8th position (James 2015:11).

Although a growth trend has been noted in the past 19 years in green biotechnology, 2015 has marked a slight decrease from the 181.5 million hectares in 2014 (Hallerman & Grabau 2016:4), to 179.7 million hectares in 2015, a marginal decrease of 1% or 1.8 million hectares (4.4 million acres) (James 2015:5). Such a decline has also been noted in South Africa, i.e. the country planted only 2.3 million hectares in 2015 compared to 2.9 million hectares in 2014. Interestingly, this decline occurred during the era of a growing public resistance to genetically modified crops (Costa-Font 2009:9).

Over the years the number of countries involved in the commercialisation of transgenic crops has not increased. In 2010, 29 countries planted transgenic crops, globally (Barrows et al. 2014:101) and in 2015 only 28 countries were involved (James 2015:1). The rate at which the other countries are adopting, and commercialising genetically modified crops is very slow. In 2015, only Vietnam introduced and regulated the commercialisation of transgenic crops (James 2015:5). Germany and Sweden have never been consistent (Santoso et al. 2016:27). Several factors might have contributed to such a trend, which include the fact that European countries have not embraced the technology fully. Denmark, for instance, has developed the most stringent regulations on genetic modified crops in the world (Saigo 2016:800). Other factors may include fear of the African countries to lose the European export markets. It is however, not clear whether this trend will continue. Some scholars argue that the demand of genetically modified crops will increase due to the introduction of the second and third generations crops (Bütschi et al. 2009:30); high population growth resulting in increasing food demand (FAO 2017:46), and the introduction of new crop improvement technologies. These factors might compel nations to relax laws on genetically modified crops, resulting in some increased trends in adopting the technology.

South Africa is the first country in Africa to regulate modern agricultural biotechnology. The commercialisation of transgenic crops in South Africa began in 1997 (Liebenberg & Kirsten 2006:214; Swanby 2009:3). The country may have been aiming at ensuring food security through this policy (Aerni 2005: 467). These crops are a result of recombinant DNA (Maghari & Behrokh

2011:109), and plant synthetic biology (Liu & Stewart 2016:397). The first regulatory policy was established in 1979 by the SA Committee for Genetic Engineering, focusing primarily on laboratory safety (Peacock 2010:115). It was only in the early 90s, when the first formal field trials on transgenic crops were established (Koch 2002:48). This move was driven by the potential socio-economic benefits of genetically modified crops. According to Aerni (2005:473), South Africa realised the potential of modern agricultural biotechnology in ensuring food security in the country.

South Africa has socially and economically benefitted from regulating modern agricultural biotechnology. Moodley (2015:1) claims that South Africa has realised an economic gain of $1.15 billion between 1998 and 2012 through the commercialisation of transgenic crops. Wafula, Waithaka, Komen and Karembu (2012:74) maintain that the economic gains in 2009 alone were estimated at US$142 million. Scholars argue that modern agricultural biotechnology has increased yields, farm incomes, reduced dependence and expenditure on chemicals in the country (Wieczorek 2003:02). According to Hartl and Herrman (2009:551), consumers were expected to benefit from increased crop yield and low commodity prices due to the increased supply. However, this portion of the gain is not clear and needs to be further quantified. Consumers in South Africa might have benefitted from the policy, but more studies are recommended to establish the percentage of the economic gain that went to the consumers. Modern agricultural biotechnology, in some countries like China and United States, has benefitted consumers (Adenle 2011:87). South Africa cannot afford to ignore the significant role of regulating genetically modified crops.

2.5 Regulations on genetically modified crops

The current global debates on climate change, and biodiversity have increased pressure on governments to regulate genetically modified organisms (Wickson 2007:325; Pechlaner 2012:448; Marcoux et al. 2013:658). The main challenges emerge from the inconsistences in national biosafety systems which have created export trade barriers and many uncertainties on the use of genetically modified organisms. The international and regional laws are supposed to address policy inconsistences among different countries (Jansen van Rijssen, Morris & Eloff 2014:2). Several studies have also shown inconsistences in national biosafety laws (Joss 2015:144; Snyder 2015:2142; Geng et al. 2015:2136; Kou et al. 2015:2158; Saigo 2016:800; Li et al. 2015:269; Zhou, Li & Liang 2015:2197). This might impose some technology and innovation setbacks in modern biotechnology. Following are some of the international and regional laws on genetically modified organisms.

The Codex Alimentarius[18] is among the laws that have been rectified in different countries. This law was established by the Food Agriculture Organisation and World Health Organisation in 1963, with the primary aim of coordinating international food standards and ensuring fair trade in food (Paoletti, Flamm, Yan, Meek, Renckens, Fellous & Kuiper 2008:70). It gives guidelines for risk assessment of genetically modified organisms and labelling (Marx 2010:40; Jansen van Rijssen et al. 2014:2). The convention on biosafety diversity which aims at protecting the environment from human activities, was signed in 1992 in Rio De Janeiro[19] and came into effect in 1993 (Taheri 2017:161). South Africa has rectified the convention and has adopted its second national biosafety action plan for the period of 2015-2025 in June 2015 (Government of South Africa 2015). The World Trade Organisation (WTO) is an international trade mediator on the planet consisting of two agreements binding on all WTO member nations (Teel 1999:683; Joss 2015:143). According to the WTO, member states cannot ban the importation of genetically modified crops without scientific data to prove its harmfulness (Malyska et al. 2015:531) and labelling must not discriminate against the importation of genetically modified crops (Smits & Zaboroski 1998:121). The Cartagena Biosafety Protocol (CBP) was both divisive and contentious during its negotiations (Zalewski & Paul 1999:216) with countries

[18] See section 2.1 for more details about Codex Alimentarius.

[19] Rio de Janeiro Earth Summit is the United Nations Conference on Environment and Development (UNCED), was a major United Nations conference held in Rio de Janeiro from 3 to 14 June 1992 where many countries deliberated and adopted a set of principles to guide the future development which ensure that development will not compromise the survival of the future generation.

of the South pushing for a restrictive regulation, while the North wanted a less-restrictive regulation (Redrick et al 1997:7; Saigo 2016:805). The CBP explicitly focuses on genetically modified organisms (Jaffe 2005:301) and stresses on the importance of the precautionary principle (Schmidt & Wei 2006:467; Applegate 2003:241; Winter 2016:137). It is a non-mandatory agreement which supplies genetically modified organisms' policy guidelines but leaves policy decisions to countries (Godfrey 2013:414).

At a regional level, there are two non-mandatory policies originating on the African continent which include: the African Union Model Law (AUML) and a 20-year African Biosafety strategy (Zerbe 2007:97; Munyi, Mahop, du Plessis, Ekpere & Bavikatte 2012:32). The African Union Model Law targets to protect the environment and human health (Mugwagwa 2012:142; Mugwagwa 2011:33). The 20-year African Biosafety Strategy was intended to harmonise national biosafety laws in Africa (Swanby 2009:3). Some scholars argue that these two policies are grounded in a precautionary approach (Bellevue 2017:26; Zander 2010:269; Godfrey 2013:417; Mnyulwa & Mugwagwa 2005:219; Kangmennaang, Osei, Armah & Luginaah 2016:38). Marchant (2001:144) criticises the precautionary principle for failing to provide clear guidelines for regulating genetically modified crops. As stated, African policies on genetically modified crops are aimed at providing general guidelines which African countries are to follow in regulating genetically modified crops. This was never the case, and one of the reasons could have been the lack of clear policy guidelines.

2.6 National regulations on genetically modified crops

In South Africa, there are several laws which regulate and approve the use of genetically modified organisms[20]. The Genetically Modified Organism Act 15

[20] These laws include The Genetically Modified Organisms Act No. 15, 1997; Genetically Modified Organism Amendment Act No. 23 of 2006; Biosafety Policy of 2005; National Environmental Management Biosafety Act no. 10 of 2004; National Environmental Management Act no. 107 of 1998 and National Environmental Management Amendment Act no. 8 of 2004; and the Regulations on labelling foodstuffs with genetically modified organisms

of 1997 and its Amendment Act 23 of 2006, are the principal laws for regulating genetically modified organisms in South Africa (Prince & Black 2010:5; Godfrey 2013:420). In other words, these are the special laws that specifically apply to genetically modified crops in the country. These laws are under the direct supervision of a multidisciplinary executive committee as prescribed in the law. According to Godfrey (2013:422), the multi-disciplinary executive committee comprises of the Scientific Advisory Committee[21].

In 2004, under the Consumer Protection Act (CPA) 2008, and the Foodstuffs, Cosmetics and Disinfectants Act (FCDA) 1972, the "Regulations on Labelling Foodstuffs with Genetically Modified Organisms of 2004", which requires labelling of food products containing genetically modified organisms, came into existence (Tung & Rock 2013:4). According to Mayet (2004:8), South Africa followed the United States approach in regulating the labelling of genetically modified crops. The use of genetically modified techniques on crop production in South Africa, does not trigger labelling for the genetically modified crops. The trigger for genetically modified organisms labelling is when food, containing genetically modified organisms, can cause allergies, or if their nutritive value differs from what consumers would reasonably expect (Mayet 2004:8). Labelling is only required when there is a significant difference in the final food. In 2008, South Africa adopted a mandatory labelling law of food products that do contain genetically modified organisms (Tung & Rock 2013:4) and this law is outlined in Section 24 of the CPA, 2008 (No 68 of 2008), which was signed into law on 24 April 2009 and came into effect on 31 March 2011 (Oh & Ezezika 2014:2)

South Africa has amended its National Environmental Management Act (NEMA) 107 of 1998 to include the Environmental Impact Assessment

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of 2004; Consumer Protection Act No. 68 of 2008; the Consumer Protection General Regulations Act; and the National Biotechnology Strategy of 2005.

[21] Scientific advisory committee on Genetically modified Organisms Act constituted of 10 persons, of which 8 had been appointed based on their knowledge and expertise in various fields and the other 2 individuals were from the public sector with knowledge on GMO and ecological matters (South Africa Parliamentary Monitoring Group 2003:1)

Regulations of 2014 (Republic of South Africa 2014). Before the amendment of NEMA, genetically modified crops were assessed under the Environment Conservation Act 52 of 1994, and the National Environmental Management: Biodiversity Act 10 of 2004 (Republic of South Africa 2009). As argued by Du Pisani and Sandham (2006:710), these acts were not appropriate in governing environmental impact assessment of genetically modified crops, partly because these laws came into existence before these crops were formalised in South Africa (Swanby 2009:3). According to Godfrey (2013:420), NEMA applies basic assessment guidelines in assessing the potential effects of genetically modified crops on the environment. By basic assessment guidelines, Godfrey (2013:421) means that genetically modified organisms are released into the environment by generally considering the particularities of the environment in question, the potential impact and cumulative effects of the release, measures to mitigate those effects, and the information on on-going monitoring and impact-management efforts. The regulation does not force the use of advanced scientific modelling, such as the Geographic Information Systems[22], to determine the impact of releasing genetically modified organisms in the long-term.

The Environmental Impact Assessment regulation of 2014 governs genetically modified organisms environmental impact assessment in South Africa (The Department of Environmental Affairs 2010:10; Department of Environmental Affairs & Tourism (DEAT) 2016:1; Tshangela 2014:213). This is the principal law meant to ensure that the environmental impact assessment of genetically modified crops in South Africa is comprehensive, systematic and appropriate (Ekasingh & Letcher 2008:142; Letcher, Merritt, Jakeman, Croke & Perez 2002:26). However, this regulation does not differ much from the previous laws. According to Godfrey (2013:420), this regulation does not elaborate on the content of risk assessments; neither does it mandate unique analytical steps with respect to genetically modified organisms beyond imposing a general obligation on users, of ensuring that appropriate measures are taken to avoid any adverse

[22] According to Jordan (2018:1) the application of Geographic Information Systems (GIS) in the Environmental Impact Assessment (EIA) process assists in identifying and analysing potential environmental risks.

impact of genetically modified organisms on the environment. In a way, this renders the law to be ineffective for the intended purposes and very difficult to enforce.

The assurance of human health and environmental safety of genetically modified crops is based on the effectiveness of the environmental impact assessment regulations (Nicolia, Manzo, Veronesi & Rosellini 2014:77). This regulation is of great importance in guaranteeing public safety over genetically modified crops. It is important to adopt and implement an effective regulation which guarantees effective environmental impact assessment before releasing genetically modified organisms into the environment (Mauro & McLachlan 2008:4640; Wolt, Keese, Raybould, Fitzpatrick, Burachik, Gray, Olin, Schiemann, Sears & Wu 2009:426). An effective environmental impact assessment system forms the basis for public willingness to accept and consume genetically modified crops (Garcia-Alonso, Jacobs, Raybould, Nickson, Sowig, Willekens, Van Der Kouwe, Layton, Amijee, Fuentes & Tencalla 2006:57).

Mayet (2004:4) is of the view that, there are no genetically modified crops environmental impact assessments ever conducted in South Africa. However, Mayet's (2004) statement is suspicious as there is evidence of small-scale assessments conducted in South Africa. For instance, the environment impact assessment of genetically modified maize was reported in as early as 2003 (Thomas 2003:1). Furthermore, the Department of Environmental Affairs (2010), also confirmed that there were several other small-scale environmental impact assessments that have been conducted on genetically modified crops. Nevertheless, conducting large-scale assessments on genetically modified crops is of critical significance and cannot be overlooked because such assessments have paramount implications towards biotechnology sustainability. Therefore, as recommended in Linacre, Gaskell, Rosegrant, Falck-Zepeda, Quemada, Halsey, and Birner (2005:4), environmental impact assessments, prior and after the release of genetically modified crops must be mandatory. Otherwise several national environmental laws in South Africa will be rendered pointless if environmental impact assessment on genetically modified crops are not carried out at a larger-scale in the country (Molatudi & Pouris 2006:106).

It is clear, from the discussion, that South Africa has laws governing the release of genetically modified crops. The commercialisation of genetically modified crops in South Africa is well supported by various laws, including the Environmental Impact Assessment regulation of 2014. However, several scholars have pointed out the existence of serious shortcomings in some of these laws (Mayet 2004:4; Tshangela 2014:213). For instance, the presence of these laws has failed to instil confidence in the public to accept genetically modified crops. Studies by Max (2010:34) and De Beer and Wynberg (2018:98), reveal that not all people in South Africa have a positive perception towards genetically modified crops. Public acceptance is determined by public perception towards modern agricultural biotechnology regulation framework. In the following section, the researcher will describe and explain public perception and how it fits within the scope of this study.

2.7 Public perception

Public perception is the difference between an absolute truth based on facts and a virtual truth shaped by popular opinion, media coverage and/or reputation (Insani 2013:77). As argued by Vainikka (2015:3), perception plays a major role in the processing of information and public decision making; thus, influence the decision to consume genetically modified crops. The decision to consume is determined by the beliefs, attitudes, motivations and personality of an individual.

The Gestalt theory may account for the varied public perception to modern biotechnology in South Africa. According to Luccio (2011:95), the theory of Gestalt psychology is important in the study of perception and thinking. The theory helps in understanding and explaining public perceptions. The Gestalt theory was proposed by Max Wertheimer and a group of German psychologists, who developed several theories of visual perception. The Gestalt theory is made up of several main ideas which are referred to as Gestalt principles. Gestalt principles describe how people perceive and process visual information. The principles of Gestalt include grouping, closure, continuance, the law of common fate, similarity, context and proximity. These principles of Gestalt will be explained below, as they are applied to public perception towards genetically modified crops. According to Hanna and Wozniak (2001:94), the public usually perceive environmental stimuli in a manner consistent with certain Gestalt principles.

The principle of closure states that people tend to perceive a complete object even though some parts are missing (Hanna & Wozniak 2001:95). There is a great deal of incomplete expert information to the public on the safety of biotechnology on human health and environment (Funk, Rainie & Page 2015:8) due to some difficulties in assessing the effects of genetically modified organisms (Yue et al. 2015:282). Although this is the case, the public act as if they have all information when making decisions on accepting modern agricultural biotechnology. According to the Gestalt, when the stimuli is highly ambiguous, individuals usually interpret them in a way that they serve to fulfil personal needs (Hanna & Wozniak 2001:95). Reliable sources of information on genetically modified crops must be made available and accessible to the public, so that there is complete knowledge about modern biotechnology. The public must not perceive biotechnology in a way that best reflect their beliefs and attitudes but must base their perceptions and decisions on facts.

The Gestalt grouping principle states that the public tends to integrate bits of information into an organised whole, which enables the public to evaluate products over a variety of product attributes (Hanna & Wozniak 2001:95). This principle implies that people consider debates and findings in other countries on genetically modified crops, when making decisions. In other words, a negative perception and unwillingness to consume these crops in other countries, influence public decisions to accept modern agricultural biotechnology in South Africa. For instance, multiple global food scandals (Olivas & Bernabéu 2012:282; Finucane & Holup 2005:1605) may have nothing to do with modern agricultural biotechnology, but the public might associate these food scandals with biotechnology, furthering the debate on genetically modified organisms.

The proximity principle states that objects close to each other seem to belong together or appear related in some way (Hanna & Wozniak 2001:95). Since South Africa has regulated genetically modified crops and enforced mandatory labelling of genetically modified food products, the country paved way for genetically modified crops to enter the South African food markets (Jaffer 2014:1). Both genetically modified and non-genetically modified crops are being sold on the same market or in one shop, and they can be identified by the public through labelling. By implication, when the public sees genetically modified crops in the supermarkets next to non-genetically modified crops, they perceive both genetically modified and non-genetically modified crops all as food products. According to the proximity principle, when the public sees both genetically modified and non-genetically modified crops in close proximity to each other, the public tends to perceive them as equal. In other words, this principle implies that the difference between the genetically and non-genetically modified crops tend to be overlooked when the public is used to seeing them marketed all as food in the same place.

The principle of proximity is also applicable to events happening in other countries, as people in different geographical areas tend to associate themselves with these events. The proximity principle implies that related events, regardless of the geographical boundaries, should be grouped together so that they will be viewed as a group, rather than as several unrelated events (Reynolds 2008:157). For instances, factors causing a decline of export markets (Einsiedel & Medlock, 2001 in Finucane & Holup 2005:1606), as well as the periodic global food scandals (Olivas & Bernabéu 2012:282) in different countries must be grouped, analysed and resolved together, as opposed to dealing with these events in isolations. Proximity principle implies that events taking place in other countries, for instance the growing resistance of genetically modified crops in the EU (Montesinos-Lopezl et al. 2016:6) may be associated with how the people in

South Africa perceive genetically modified crops. By implication, public perception towards genetically modified crops can change, depending on the events and debates, within a specific timeframe.

The Gestalt context principle states that the context in which some stimuli occur affects the way people perceive them (Hanna & Wozniak 2001:95). The context in which biotechnology has been adopted and regulated, as well as the context in which commercialisation of transgenic crops took place, has a direct impact on public perception. For instance, the South African new mandatory for genetically modified organisms labelling, which has been in effect since 2008 seem to have been enacted within a risk context due to the nature of the law (Prince & Black 2010:8). The wording "mandatory" create an impression of risk perception, and that consumers willing to consume such products, should consume at their own risks. The public could perceive the government as forcing firms to label genetically modified organisms to shift responsibilities to consumers. If the context in which the regulatory process of genetically modified crops takes place, is perceived by the public as transparent and reasonable, such a perception will facilitate the public to accept modern agricultural biotechnology.

The context plays a central role in shaping public perception. National biosafety legislations adopted and implemented in the public safety context (Siegel, 2001 in Marx 2010:16), are likely to be accepted by the public. In South Africa, some scholars claim that the laws are not adequate in guaranteeing public safety and that the environmental impact assessments are not being carried out upon the release of genetically modified organisms into the environment (Swanby 2009:3; Prince & Black 2010). The above context impacts on the public perception and acceptance of modern agricultural biotechnology.

The context in which genetically modified crops are regulated must be people-centred. In the EU, for instance, the government consults the public before the release of the genetically modified organisms. The public must be educated to contribute meaningfully in the regulation process. Laws must not be based on public opinions but on facts. For instance, Stapleton (2016:2016) suggests that low acceptance of genetically modified crops in the EU is not scientifically substantiated but based on public mistrust on the regulation process. There are several contexts that influence the public to perceive genetically modified crops as unsafe for human consumption, including laws based on public opinions. Policy makers must create a policy atmosphere and context that influence the public to accept modern agricultural biotechnology (Chong & Druckman 2007:104). The context in which genetically modified crops are regulated influences public perception towards genetically modified crops.

In the next subsection, factors that can influence public perception towards genetically modified crops and willingness to accept modern agricultural biotechnology will be discussed.

2.7.1 Factors influencing public perception.

Several factors have an influence on public perception towards genetically modified crops (Zarrilli 2005:1; Bazuin et al. 2011:908; Ghasemi et al. 2013:1201; Hawkins & Mothersbaugh 2010:274). Technological, psychological, as well as socio-demographic factors are among the factors that have been attributed to shaping public perception towards genetically modified crops. If the public perceive biotechnology as beneficial, attitude towards the use of biotechnology is likely to be positive and as a result biotechnology is accepted (Davis 1989:319). Public acceptance of biotechnology will influence the way in which the public perceives genetically modified crops. According to Gupta, Fischer and Frewer (2012:782), public rejection of biotechnology has frequently resulted in negative consequences for the commercialization of genetically modified crops. In other words, an acceptance behaviour will influence a positive perception. Acceptance of modern agricultural biotechnology will result in a positive perception towards biotechnology.

According to Vainikka (2015:3), psychological factors influence public perception towards genetically modified crops. Norton (2006) conceptualised psychological factors as shown in Diagram 2.1

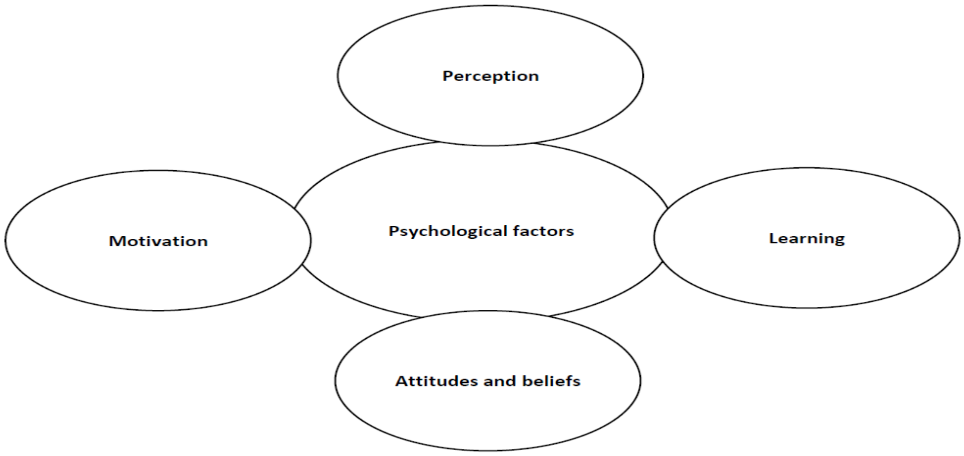

Diagram 2.1: Model of psychological factors (Norton 2006)

According to Norton (2006), psychological factors include perception, motivation, learning, attitudes and beliefs. . Although Vainikka (2015:3), added personality to the list, most scholars agree to the list as given in Norton (2006), model. In Norton's (2006) model, an individual must be motivated to consume a product, for instance, if there are health benefits in consuming genetically modified crops people are expected to consume the crops willingly, and the reverse holds. According to Norton (2006), consumer perception towards a product influences public decision to buy and/or consume the product.

Learning, according to Norton (2006), incorporates skills, knowledge or education, as well as the intention. The part will be dealt with later on in this section when discussing education as a factor that influence public perception to accept modern agricultural biotechnology. According to McLean (2003:243), attitude is one's immediate disposition towards a concept or an object, while beliefs are ideas based on one's previous experiences, and may not necessarily be based on logic or fact. According to McLean (2003:201), attitude towards something changes from time to time depending on several factors. Attitudes and beliefs are important factors in influencing a public decision to consume genetically modified crops. According to Norton's model (2006:244), individuals have certain beliefs and attitudes towards genetically modified crops on which their decisions to consume are based upon.

Several studies also found that socio-demographic factors influence public perception towards genetically modified crops (Missagia et al. 2012:1). According to the Business Dictionary (2018), socio-demographic factors are the characteristics of a population, such as age, sex (gender), education level, income level, marital status, occupation, religion and language. According to Nguyen and Gizaw (2014:20), socio-demographic factors have a significant impact on public consumption and purchasing behaviour. In Diagram 2.2 below, the researcher conceptualises socio-demographic factors.

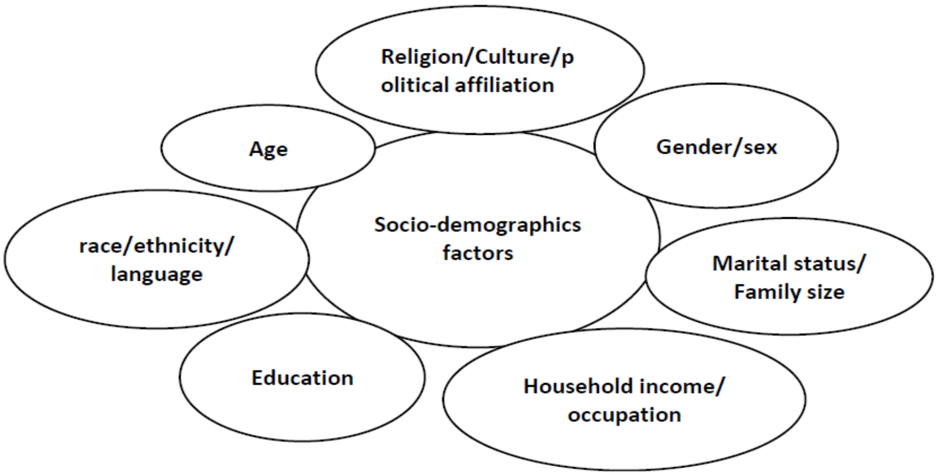

Diagram 2.2: Socio-demographics factors.

It is important to study and understand the socio-demography of the public, in relation to its willingness to accept genetically modified crops, to ensure effective policy making process.

Gender difference, as a socio-demographic factor has an influence on public perception towards genetically modified crops. As argued by Iakshmi, Aparajini and Lahari (2017:34), men and women have different characteristics which may influence their willingness to consume transgenic crops. Gender differences on expectation, want, need and life-style reflect their consumer behaviours (Akturan 2009:66). Men and women are expected to show a different preference towards genetically modified organisms. Several studies in other countries have established that women are less likely to accept transgenic crops (Prokop et al. 2013:137; Nistor 2015:2). A health seeking behaviour was identified as the reason for gender difference in willingness to consume genetically modified crops. Women exhibit a higher health information seeking behaviour (Reid 2004:12). According to the health information seeking theory, females have stronger health-oriented beliefs and healthier behaviours in general (Kassulke, Stenner-Day, Coory & Ring 1993:52; Dutta-Bergman 2004:276). Healthier behaviour makes women very sensitive to genetically modified organisms and any publicity influences the behaviour of women more than men.

Men often lack the motivation to engage with health-related information (Rothman & Salovey 1997:7; Mansfield, Addis & Mahalik 2003:94). According to Courtenay (2000:1386), men tend to be unaware of health-related information sources and they tend to purchase food stuffs without paying much attention to product information. On the other hand, studies on public awareness show a higher percentage of men being aware of modern biotechnology than women (De Steur 2010:124; Jiggins, Samanta & Olawoye 1997:5). According to Jiggins et al. (1997:5), agricultural biotechnology does not consider the need for information availability to women and the field of agricultural research and development is men-dominated. The views suggest that men are well-positioned (in the society) to gain access to new knowledge compared to women. The World Bank (2011:254) shares the same sentiments as it argues that the growing public resistance towards transgenic crops is the cost of gender inequality that exists in most countries. Public awareness campaigns must focus on educating women, because women are innovators for change (Fagerli & Wandel in Shafie & Rennie 2012:362). Educating women will yield a positive perception towards biotechnology. Closing the existing gender knowledge gap is a prerequisite in the field of biotechnology (Raidimi 2014:10; World Economic Forum 2013:16).

Race has been studied in relation to its influence on consumer decision making. Race continues to impact on the socio-economic and political life of the people in South Africa (Ledwaba 2012:7; Seekings 2008:1). Race is complex, politically sensitive, difficult to define and cannot be easily separated from culture, language and ethnicity (Pitta, Fung & Isberg 1999:240). Race encompasses elements of culture, language and ethnicity. There are many definitions to race (Taylor 2006:48). According to Wolf and Le Guin (2007:1) and Smedley (2007:1) race is a very controversial social construct. Separating humans by race is vague and fluid over time reflecting their social rather physical appearance. Race does not have a biological or genetic significance in terms of differentiating people. In South Africa, the Population Registration Act of 1950 classified people according to race i.e. as white, black, coloured or indian. The South African constitution defines race in terms of skin colour. This is the definition adopted in this study, race is taken to refer to white, coloured, indian and black people.

Woolard (2002:56), says that race determines poverty and inequality in South Africa. Race has been institutionalised to give some of the racial groups a socio-economic advantage over others. Bhorat, Leibbrandt, Maziya, van der Berg and Woolard (2000:41), argue that there is a big personal income gap among the four racial groups in South Africa. Thus, in South Africa, the wide personal income gap among the four racial groups may impact on the public’s willingness to consume transgenic crops. Ledwaba (2012:58), shows that race is a determinant for consumer buying behaviour focusing on a wide range of consumable products. Some studies in other countries reveal that race influences perception towards genetically modified organisms (Reid 2004:13; Oguz 2009:160). For instance, in a study by Oguz (2009:160), carried out in Turkey, young white people were more prone to accept genetically modified organisms. Contrary, a study by Bernard and Gifford (2006:348), in Delaware (United States of America) shows a negative public perception towards genetically modified organisms by non-whites.

Personal income is simply the income received by an individual from participation in production, public services, business transfer payments, and government social payments (Ruser, Pilot & Nelson 2004:4). According to Braveman, Egerter and Williams (2011:387), monetary earnings during a specified time period (income) is easier to measure than the accumulated material assets, such as the value of one's home, household possessions, vehicles and other property, bank accounts, and investments (wealth). The above definition will be adopted in this study. The influence of personal income on public perception towards genetically modified organisms has been studied in many countries (Freytag-Leyer & Wijaya 2015:56; Yi 2009:18; Lin, Chen, Tsao & Hsu 2017:77; Subramanian & Kawachi 2004, 269). For example, a study in Colorado, US, by Loureiro and Hine (2002:477), reveals that households with income over $75,000 prefer to buy and consume non-genetically modified crops. Non-genetically modified organisms in most countries are expensive and the price differential creates a perception in the consumer that high priced food is safer and healthier than low priced ones (Reid 2004:15). However, Urala (2005:152), argues that the likeliness of purchasing genetically modified organisms increases when a consumer positively perceives the health benefits. If people perceive benefits from the genetically modified crops, people are likely to buy the products and buying may increase with higher income.

On contrary, several studies also disapprove that higher income earners tend to consume more of non-genetically modified organisms (Lockie et al. 2004, Gil et al. 2000). In the study by Wandel and Bugge (in Shafie & Rennie 2012:363), there was no significant effect of income on the interest of consuming non-genetically modified organisms. The reason for the findings was that positive attitudes towards a healthy diet are expressed by people of all income levels. In this case, health becomes a determinant for the behaviour. This is supported by Shepherd et al. (in Reid 2004:16) study which found out that a decrease in income leads to a change in the variety and quantity of foods eaten and that an increase in income does not necessarily lead to increased expenditure on food. Thus, whether people earn low or high personal income, the desire for healthy eating is evident across all socio-economic classes, making non-genetically modified organisms highly in demand in the economy. Low income earners might as well prefer and consume non-genetically modified organisms depending on the values they attach on healthy eating.

Age is an important demographic factor that affects consumer behaviour (Pratap 2017:59). The needs of the people change with age and age brings changes to people's lifestyle. According to Pratap (2017:59) young people spend more on fashion and entertainment and as they grow older, their expenses on these things shrink. People's choice on products changes with age. Age differentiates consumer needs. According to Roszkowska–Hołysz (2013:336), it is with increasing age that the size and the structure of the consumption changes. Consumers have different needs and wants in different age groups. According to Khuong and Duyen (2016:46), people also change the goods and services they buy over the course of their life. Thus, age influences a change of life. The age factor has been widely studied (Anna et al. 2014:206, Olofsson & Olsson 1996, Koivisto-Hursti et al. 2002, 207), and findings vary significantly.

Some studies reveal that young people were less hostile to genetically modified foods (Bernard & Gifford 2006:348; Antonopoulou et al. 2009:98). According to Reid (2004:15), young people choose food based on price, taste and promotional offer. However, in other studies, young people regard genetically modified organisms as unsafe and prefer non-genetically modified organisms (Jurkiewicz et al. 2010:210; Al-Rabaani & Al-Shuaili 2014:28). In different populations presented above, young people show an opposing preference over genetically modified crops. The same contradicting situation has been noted among the older people. According to Kagai (2011:170), the willingness to consume genetically modified organisms increase with age among the public. In contrast, some studies observed that as age increases, people resist consuming genetically modified crops (Koivisto-Hursti et al. in Kagai 2011:170). In both the younger and older people, findings with regards to the age factor towards public willingness to accept genetically modified crops have been inconsistent and further enquiries are required.

The level of education has been widely studied in its relationship to public perception, attitude and awareness (Padel & Foster 2005:606; Stobelaar et al. 2006). Some studies show that the uninformed public have a negative perception towards genetically modified crops (Huffman et al. 2004 in Antonopoulou et al. 2009:90) compared to well-informed public (Bernard & Gifford 2006:350). In another study, the holders of postgraduate degrees perceived the risks due to genetically modified organisms as significantly lower as compred to those with less education (Hall & Moran 2006:29; Gaskell et al. 2003: 384; Montesinos-López et al. 2016:7). Contrary, some studies show that a higher level of education negatively influence perception towards genetically modified crops (Znidersic, Djokic & Djokic 2015:59; Lockie et al. in Shafie & Rennie 2012:361). As the level of education increases the public tend to be well-informed on the food safety challenges of genetically modified crops.

Hamstra (in Moerbeek & Casimir 2004:310) comments that knowledge encourages people to have more articulated opinions, whether positive or negative. Acquiring new information enhances a perception towards genetically modified crops either positive, negative or neutral (Lawrence et al. 2001; Grice & Lawrence 2003). Education on biotechnology must be objective showing pros and cons of genetically modified organisms. According to Antonopoulou et al. (2009:98), public perception will depend on the source, accuracy or partiality and the process of transferring the information. It is very important that education and public awareness programs are planned in such a way that discourages public bias and prejudices towards biotechnology. Education must be objective and comprehensive in presenting the facts about genetically modified organisms and it must be accessible to all the people through different channels e.g. formal and non-formal education systems, and all forms of media.

2.8 Public awareness of transgenic crops

Sayers (2006:10), argues that to raise awareness is to inform and educate people with the intention of influencing their attitudes, behaviours and beliefs. According to Sayers (2006:6), Wiio's theory of communication describes the communication laws that need to be considered in public awareness. According to Fried (2008:56), Wiio's theory of communications states that:

- If communication can fail, it will, and if communication cannot fail, it still usually fails. In other words, Wiio's theory emphasise that regardless of planning and preparation for communication, communicated messages may be misunderstood or misinterpreted.
- If a message can be understood in different ways, it was understood in just that way which does the most harm. Wiio's theory warns against messages being interpreted to mean the worst misunderstanding one could not have imagined.
- There is always somebody who knows better than what you meant by your message. According to Korpela (2010:3), "it might take some time before you see that they completely failed to see what you meant, but that does not prevent them for propagating their ideas as yours". The receiver might think he/she has understood the message very well, yet that will be the opposite.
- The more communication there is, the more difficult it is for communication to succeed. Communication must not be over-emphasised, otherwise it might cause more misunderstandings.

Wiio's theory explains the importance of well-planned awareness programs. Proponents of this theory explain why most of genetically modified organism's public awareness programs failed to cultivate a positive public attitude. Public awareness campaigns must ensure that messages to the public are clear, precise and free from making ambiguous statements. Statements that may be interpreted in several ways must be avoided at all costs. Public awareness on transgenic crops have raised more questions because of the incompleteness of the expert knowledge (Komoto et al. 2016:14). Communicating the correct message is critical to entice public acceptance of transgenic crops. Sayers (2006:53), further argues that public awareness campaign requires some measure of public involvement to be effective. Public involvement and cooperation must ensure successful and effective technological communication.

The social marketing theory is also crucial in explaining public awareness of genetically modified crops. According to Liman (2018:56) the social marketing theory focuses on identifying various social and psychological barriers that hinder the flow of information and offers suggestions to overcome these barriers. The features of social marketing theory include creating audience awareness, targeting the right audience, reinforcing the message, cultivating the images, stimulating interest and inducing the desired results (Liman 2018:58). According to Robinson (1998:12), the social marketing theory posits that successfully providing information through awareness-raising will not automatically result in lasting behavioural change. According to the social marketing theory, there is need to promote a behaviour through awareness. In a way, public acceptance of modern agricultural biotechnology behaviour must be promoted and not expected to develop without any inducement.

According to the social marketing theory, public awareness campaigns must target the right audience. For example, the study by Al-Rabaani & Al-Shuaili (2014:28) shows that younger people were not willing to consume genetically modified crops, whilst Koivisto-Hursti et al. in Kagai (2011:170) report that older people were willing to eat these crops. In this instance, the right audience will be the younger people. It is a waste of time and resources to target older people because they are willing to consume genetically modified crops. According to the social marketing theory, messages must be conveyed in the form of images and must be reinforced. People forget messages hence it is important to keep reminding them. Liman (2018:57) argues that image advertising is effective in sending a message to the public especially when the audience shows no interest in the information. It is crucial that genetically modified crops public awareness programs are repeated over and over, until the public is informed on the potential benefits and risks of these crops. The use of more appropriate awareness methods, e.g. focus groups and advertising, is of great importance in educating the public.

According to the social marketing theory, there is need to stimulate interest and induce desired results in the public. According to Liman (2018:56) in order to make the audience seek information, it is necessary to grab their attention and stimulate interest. There is need to stimulate public willingness to eat genetically modified crops through publishing the benefits of these crops. Public awareness campaign must achieve its aims and objectives, at the end. The public must be educated, first on the existence of genetically modified crops, and secondly on the potential benefits of these crops. The other means to ensure that the public is well-informed on genetically modified crops is to ensure that reliable sources of information are always available and accessible to the public.

The information literacy model also has a direct impact in public awareness of transgenic crops. Information literacy is defined as the set of skills required to identify, find, retrieve, evaluate, use and communicate information from a variety of sources (Wijetunge & Alahakoon 2005:51). The theory stresses the importance of the public to be able to identify, locate, evaluate, organise and communicate information to address a problem. The theory posits that public awareness may be effective if the public is provided with the skills to evaluate sources of information and to make more effective use of the information they receive (Sayers 2006:68). The public must be given an opportunity to acquire the information literacy skills to participate actively in making policy decisions and benefit fully from modern biotechnology. Public awareness must educate the public where they can locate reliable sources of biotechnology information. People should be able to distinguish between messages presented to influence public opinions and messages intended to provide facts on biotechnology. Critical to the information literacy theory is the ability of the public to communicate effectively, think critically and solve problems effectively (Wijetunge & Alahakoon 2005:53).

Another important proponent of information literacy theory is that of lifelong learning aspect. According to Wijetunge (2000:105), lifelong learning entails continuous learning. The formula L>C, *where L is the rate of learning and C is the rate of change,* explains the advantage of lifelong learning. This principle can be used to explain the importance of the public in continued learning or searching knowledge on modern biotechnology. The rate of biotechnology advancement/change (C) is much higher, as evidenced with the introduction of synthetic biology than the rate of learning (when most of the people were still debating about the first-generation crops). The rate of learning is slow compared to the rate of technological innovation. Public awareness on modern biotechnology must target to promote a lifelong learning aspect and stress the importance of individuals to be well-informed on the most recent type of biotechnology, its benefits and risks.

On the other hand, attitudes, behaviours and beliefs must be targeted though a well-planned and thoughtful awareness program. Public resistance or mixed perception is a consequence of an uninformed public (Ishak & Zabil 2012:109). An uninformed decision is a result of a public that is ignorant to biotechnology or resisting biotechnology. Changing the attitude and behaviour of the public is important in regulating transgenic crops in South Africa. Failure to empower the public with the right information will negatively impact on the regulation process of these crops. Barroso (2008:1), argues that consumer awareness influences a positive set of minds towards genetically modified organisms. Thus, a negative public perception towards genetically modified organism can be reversed, if the right approach to public awareness is adopted.

Like in most parts of the world, consumer awareness studies on transgenic crops have been conducted on the continent (Africa) and studies show that the majority of the people do not understand genetically modified organisms and are not even aware of the existence of transgenic crops (Kimeju & de Groote 2004; Kushwaha et al. 2004; Rule & Ianga 2005). In Kenya, for instance, 62% of consumers were unaware of transgenic crops and approximately 51% were concerned that it would affect the environment and result in loss of local varieties (Kimeju & de Groote 2004). In Nigeria, approximately 70% completely disapprove modern agricultural biotechnology due to the perceived risks involved in biotechnology (Kushwaha et al., 2004). In South Africa, 82% of consumers does not know what is meant by the term ‘biotechnology’ and 63% were unaware that they had ever consumed genetically modified organisms (Rule & Ianga 2005). South Africa is one of the largest producers of transgenic crops and its population must be better educated on biotechnology. Principles of information literacy theory must be applied in public awareness in South Africa and ensure that the public keeps up with the rapid development of modern biotechnology. The application of the information literacy principles in educating the people in South Africa will go a long way in facilitating public participation in regulating genetically modified crops.

2.9 Conclusion

In this chapter, modern biotechnology and modern agricultural biotechnology has been described, including the techniques which have been adopted in aiding the success of the technology in crop improvement. The current global and national trends on commercialisation of genetically modified crops have been presented and discussed. It is significant to highlight that the study has noted a slight decline in the planting area of genetically modified crops as a new phenomenon that needs to be monitored by academics and researchers. In this chapter psychological and socio-demographic factors which may cause the public to accept modern agricultural biotechnology have been discussed. Lastly the significance of public awareness has been deliberated as it related to the acceptance of modern agricultural biotechnology. Modern agricultural biotechnology is a very useful and important new technology in agronomy and animal husbandry. Biotechnology has contributed greatly to the socio-economic development of many countries, despite the technology receiving mixed perceptions. The following chapter focuses on the theories on environmental sustainability, environmental impact assessments and the theoretical framework of the study.

CHAPTER 3
THEORETICAL FRAMEWORK

This chapter focuses on the theoretical framework of the study. Several theories of sustainability and their implications to modern agricultural biotechnology sustainability will be deliberated. In this chapter, the researcher further describes the environmental management system in South Africa, critiquing laws relating to genetically modified crops environmental impact assessments. Steps and approaches to be followed in conducting genetically modified crops environmental impact assessment in South Africa will also be described. The chapter also outlines the theory of planned behaviour and its application in understanding public perception towards modern agricultural biotechnology. In the following section, sustainable development and sustainability will be discussed.

3.1 Sustainable development and sustainability

In this section, the researcher attempts to unpack the debate around sustainable development and sustainability. Understanding this debate is crucial in analysing the potential benefits of modern agricultural biotechnology and in understanding public environmental risk concerns over genetically modified crops.

Sustainable development and sustainability are concepts that carry multiple definitions and often used interchangeably. In 1987, the United Nations Commission on Environment and Development (UNCED) defines sustainability as development that meets the needs of the present without compromising the ability of future generations to meet their own needs (Sutton 2009:22). This definition denotes a holistic approach to sustainability and is inclusive of all species. Sustainability integrates social, economic and environmental issues stressing the importance of conservation and preservation of the ecosystem for the benefit of all species. Sustainability means that humans and non-humans are equal (Whitmore et al. 2006:2; Todes, Sim & Sutherland 2009:412).

According to Borland, Ambrosini, Lindgreen and Vanhamme (2014:295), the UNECD (1987) definition is frequently taken out of context, associated with sustainable development. Sustainability and sustainable development are separate concepts and they exist on a continuum[23]. To separate sustainability from sustainable development, Govender (2004:5) argues that sustainable development entails a progressive social betterment without going beyond ecological carrying capacity. According to this definition, sustainability refers to the ecological carrying capacity. Porritt (2007:31) supports this definition by stating that sustainable development is the path towards sustainability. It is clear from the assertions in Govender (2004), and Porrit (2007), that the separation between sustainability and sustainable development is a continuum, as sustainable development leads to sustainability.

According to Borland et al. (2014:295), the path towards sustainability consists of social, economic and environmental dimensions. Development initiatives cannot ignore one dimension at the cost of the other, because they are equally important as determinants of sustainability. Żak (2015:252) refers to the social, economic and environmental dimensions as the triple bottom line goals of sustainable development. They form the foundation on which development policies emanate and are assessed. The triple bottom line is used as the basis to measure the effectiveness and efficiency of sustainability policies. The interdependence of the three dimensions has been conceptualised in many ways to explain their function in sustainability. O'Riordan (in Flint 2013:34), for instance, has theorised the dimensions using the Venn diagram; Giddings et al. in Moir and Carter (2012:1482), has used the nested circles models; and Meadowcroft (2000) in Moir and Carter (2012:1482), used the democracy model. These models emphasised the importance of integrating the three dimensions towards sustainability. According to Munasinghe (1996:13), the three dimensions are interdependent, mutually supportive and are the reinforcing pillars of sustainability.

[23] Webster (2018) defines continuum as a continuous sequence in which adjacent elements are not perceptibly different from each other, but the extremes are quite distinct.

An attempt to understand sustainability, separate from social, economic and environmental dimensions will result in diverse theories (explaining sustainability from different viewpoints), while undermining sustainability from an integrated approach. For example, when using Munasinghe's (1993) model of sustainability below, sustainability would be attained somewhere near or at the centre of the diagram.

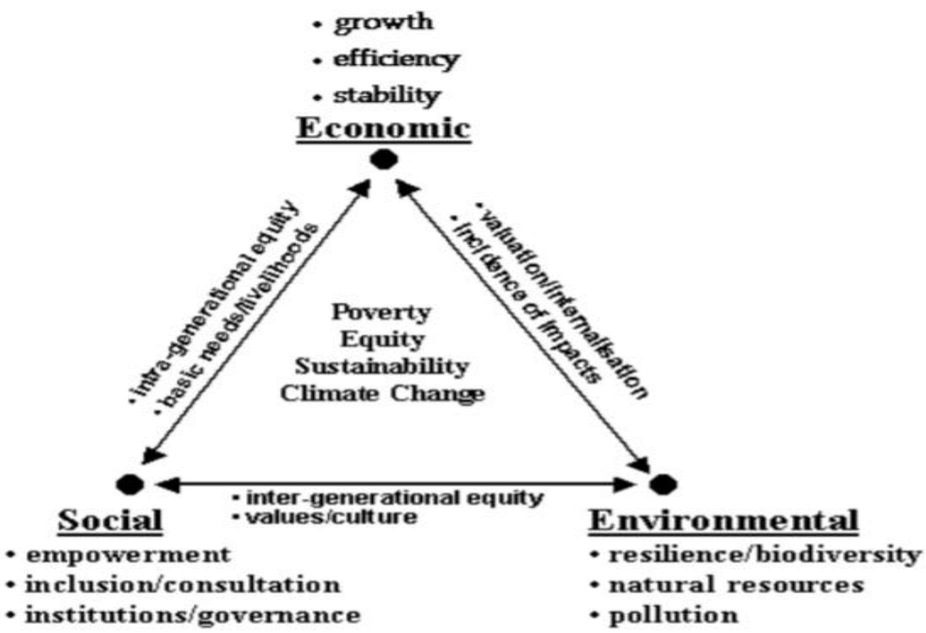

Diagram 3.1: Munasinghe's (1993) model of sustainability

Applying the above model of sustainability in the current biotechnology policies in many countries, including South Africa, will prompt policy makers to revise genetically modified crop regulations. Modern agricultural biotechnology must focus on long-term supporting of the existing biodiversity. Integration of genetically modified crops' environmental risk assessments into the national environmental management is one way of ensuring biotechnology sustainability (Todes et al. 2009:412; Basiago 1999:160).

Munasinghe's (1993) model of sustainability must form the basis for regulating modern agricultural biotechnological innovations. Several countries have enacted national biosafety frameworks to promote modern agricultural biotechnology sustainability (Sutton 2009:19; Schiele, Scott, Abdelhakim, Garforth, Castro, Schmidt & Cooper 2015:100). However, the development of genetically modified crops in most countries has failed to meet the standards of sustainability (Arpaia, Messéan & Birch 2014:79) because of economic models which prioritise socio-economic goals, for instance the neo-liberal policies[24], at the cost of the environment. According to Kotze (2000:73), neo-liberal policies increase environmental exploitation in solving socio-economic problems. Guest (2010:328), and Kotecha et al. (2013:22), argue that environmental laws in most countries fail to uphold the idea that resources are scarce. Environmental laws must emphasis the economic scarcity of resources and compel modern biotechnology sustainability.

The distinction between sustainable development and sustainability is rather a continuum, and sustainable development is generally a path towards sustainability. It is therefore important that social, economic and environmental policies are integrated and balanced in such a way that sustainability, as the main goal, is achieved in an economy. In the section that follows, the researcher will describe theories of sustainability in an attempt to give an insight on appropriate biotechnology sustainability models. The theories to be discussed are as follows: anthropocentrism, ecocentrism, the system, ecosystem, Gaia, law of energy conservation, populist and co-evolutionary theories.

3.2 Theories of sustainability

3.2.1 Anthropocentrism

According to Drag and Wolska (2010:4), anthropocentricism believes in human supremacy and it claims that the human thinking ability makes people different from other species. Anthropocentrism regards humans as the measure of all value (Dias 2002:204; Schultze & Stabell 2004:549). This perspective denies non-human species any inherent worthiness (Gladwin et al. 1995:877), as humans are regarded as superior to nonhumans (Borland et al 2014:295; Purser

[24] Neoliberalism is a policy model of social studies and economics that transfers control of economic factors to the private sector from the public sector (Investopedia 2018).

et al. 1995:1061; Brianson 2016:123). Anthropocentricism holds the view that the environment exists for human purposes. According to anthropocentrism, human beings are the central purpose of universal existence (Speed 2006:326). Anthropocentricism is the reason for the adoption of policies that prioritised socio-economic goals over the environment.

According to Speed (2006:326), it is the primary reason why humanity consistently attempts to dominate nature. In the anthropocentric perspective, modern agricultural biotechnology must be adopted if it is beneficial to humanity. According to Kilbourne (1998:642), anthropocentric thinking explains the dominant Western worldview which posits that land, not used for economic gain, is wasted and individuals have the right to develop the land for economic profit. The perspective is a common philosophy in several industrialised economies (Brianson 2016:122; Padelford & White 2009:69). Modern agricultural biotechnology originates within the limits of this perspective. According to Speed (2006:327), anthropocentrism is the root cause of the ecological crisis, including the extinctions of non-human species. The perspective is an obstacle to biotechnology sustainability.

3.2.2 Ecocentrism

According to Washington, Taylor, Kopnina, Cryer and Piccolo (2017:1), ecocentrism takes a much wider view of the world than anthropocentrism. Ecocentrism regards all living things as equal (Dunlap 2008 in Pires, Ribas, Lemos & Filgueiras 2014:611). Animals, including human beings and plants have equal opportunities in existence. The perspective represents a radical departure from anthropocentricism, fostering a deeper appreciation of the ecosystem and aligns with the ideas of sustainability (Brianson 2016:122). According to ecocentrism, living organisms have the ability for self-renewal, self-management, and self-regulation in a self-perpetuating, closed-loop cycle (continual cycling of nutrients and energy) (Borland 2009:557), and a healthy ecosystem does not require human management (Borland et al. 2014:298).

According to Washington et al. (2017:4), ecocentrism considers the importance of the ecosystem to all species. It is a key philosophy towards sustainability. As put forward in Montani (2005:33), agriculture will be sustainable if it embraces ecocentrism; for instance, using of biotechnology to facilitate restoration of ecosystems (Spilhaus 1972:712). Genetically modified organisms must fit in the continual cycling of nutrients and energy and assist in maintaining a healthy ecosystem, without altering species. Laws must compel all biotechnology firms to carry out environmental impact assessment before and after releasing genetically modified crops into the environment. Environmental impact assessments determine the harm or benefits of genetically modified organisms to the environment.

The law must monitor effectively, the effects of modified organisms. Clear guidelines on how to reverse negative effects, whenever they are reported, must be in place. Thus, some well-researched guidelines for genetically modified crops management are a prerequisite for effective implementation of modern agricultural biotechnology. In addition, Rolston (1994:194) argues that genetically modified crops must be environmentally friendly. The assertion has been supported in Bury (2016:3) who argues that the aim of modern agricultural biotechnology should be to reduce the impact of agricultural practices on the environment and to make food production more efficient. Genetically modified crops must be regulated on the basis of biotechnology sustainability.

3.2.3 The system theory

According to Mele, Pels and Polese (2010:127), system theory views a phenomenon as a whole and not as simply the sum of elementary parts. According to the system theory, the universe is a living and undivided whole (Friedman & Allen 2014:4); thus, a system of interdependent species. Humans and non-human species are mutually dependent in the system (Mosha 2002:13). In other words, the components of the universe are interdependent, interconnected, interrelated and they need each other for survival. Von Bertalanffy (1972:418) emphasises four philosophical elements in the system theory which are aim, communication, cooperation and relationship. The aim of the system relates directly to how life can be better for every member and it must be clear and communicated to every member within the system (Deming 1990:24). Each member participates in a win/win situation, setting the basis for all species negotiations. Communication within the system is inevitable, and the greater the interdependence, the greater the communication and cooperation.

Members of the system establish either a positive or negative dynamical relationship (Chen et al. 2014:1192). A selfish competitive mind set is an example of negative relationship and such relationship will be destroyed. A positive dynamical relationship survives and progresses (Chen et al. 2014:1192). Any form of competition among any parts of the system means that the system is competing with itself. System competition among species is regressive. By implication, genetically modified organisms must promote a positive dynamical relationship within the system. The potential development of insect species resistant to *Bacillus thuringiensis*[25] proteins (Ferré & Van Rie 2002 in Kotey, Obi, Assefa, Erasmus & Van den Berg 2017:206), will be a symptom of the existence of a negative dynamical relationship. As the system reinforces the aim of the system, all system units work towards achieving the aim. Species that do not work together with other species will be terminated. Species extinction is a system mechanism to deal with negative dynamical relationship.

3.2.4 Ecosystem theory

Ecosystem theory is another theory of sustainability that acknowledges the existence of three ecosystems (terrestrial[26], marine[27] and atmosphere[28]) (Moulton 2012:423). According to Balasubramanian (2008:1), the term ‘ecosystem’ was coined by A.G. Tansley in 1935. Ecosystem theory holds the

[25] Bacillus thuringiensis is a naturally occurring bacterium that lives in the soil and is found all over the world. Some types of Bacillus thuringiensis produce a protein crystal that is toxic to insects and have been used in organic farming for over 50 years to control insects. The genes producing Bacillus thuringiensis proteins are now engineered so that plants can make the protein in their cells (Glare & O’Callaghan 2000).

[26] Terrestrial ecosystems are habitats that exist on land.

[27] Marine ecosystems are habitats that exist in the water.

[28] Atmosphere ecosystems are habitats that exist in the air.

view that species operate at various feeding levels, and engage in a wide variety of positive, neutral, and negative interactions (Nielsen 2007:1642). Human and nonhuman species are perceived as interconnected, interrelated and interdependent, like in the systems theory. The ecosystem sustains all organisms on the planet through self-regulation (Dongfang, Fengyou & Youfu 2014:1). Self-regulation makes other species disappear and others to appear. Self-regulation maintains a balance in an ecosystem to avoid a decline in the functions of the ecosystem. Species must not be lost, and appearances of new species must be controlled because this may create changes in the environment with negative effects.

According to Hooper et al. 2005 in Whitmore et al. (2006:4), species' extinction affects and impacts on ecosystem functions. For instance, a decrease in pollinators (Bohnblust et al. 2016:146) will reduce the plant pollination rate, thereby affecting crop yield. Biotechnology must not increase species extinction rates, by ensuring that the release of genetically modified organisms is regulated. However, Whitmore et al. (2006:4) argue that biotechnology facilitates the restoration of the ecosystem. However, this restoration is highly dependent on the order in which the species are reintroduced into the system. The release of genetically modified organisms into the environment must be systematic and scientific-based (Whitmore et al. 2006:4). Scientific analysis of the ecosystems and new traits, as well as environmental impact assessments, must be carried out before any genetically modified crops are released into the environment. As stated by Stewart (2015:145), the appropriate application of computational modelling techniques, i.e. the use of computer software, is also crucial, under such circumstances.

3.2.5 The Gaia theory

The Gaia theory acknowledges the existence of a single ecosystem (Margulis 1998:119). The theory shares several views with the system and ecosystem theories but ignores the physics and chemistry part of the earth system.

According to the Gaia theory, the earth is governed by biological forces[29] (Free & Barton 2007:611). Biological systems consist of many living and non-living organisms including different kinds of genome and bacteria. The earth is a living system capable of self-organising and self-maintaining (Ogle 2005:275). Human activities are regulated and maintained through the earth's living systems (Heigh 2014:53) and are not superior from other living organisms; they all work together to sustain life on the planet.

The earth is a living organism and non-humans are conscious of their existence and function. According to the Gaia theory, there is no strict division [30]between life and non-life, living and non-living, because humans and non-humans are interconnected in the biological system (Simpson 1989:4). The Gaia theory was inspired by the remarkable stability of terrestrial conditions across long periods of time characterised by a small range of temperature variation (Ogle 2005:311). According to Heigh (2014:50), biological systems regulate the environment in ways that favour their existence. The earth system creates a better environment for its survival. All species are capable of conscious acts of empathy, both with members of their fellow species and with members of other species (Singer, 2006 in Brianson 2016:124). In conclusion, the Gaia theory holds the view that the earth is a single, self-regulating system and maintains conditions suitable for its own survival.

3.2.6 The law of energy conservation

The law of energy conservation[31] is another theory that has significance to agricultural biotechnology. When this law is applied to food (energy) pyramids, approximately 10 per cent of energy is absorbed by consumers at each feeding

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[29] A biological system is a group of parts that interact to make up a whole, they require ongoing and dynamic interactions to establish and maintain both the structure and function of biological entities. Biological systems are self-organizing and self-maintaining (Findlay & Thagard 2012:2).

A continuous sequence in which adjacent elements are not perceptibly different from each other, but the extremes are quite distinct.

[31]This law states that the total energy of an isolated system remains constant; it is said to be conserved over time. This law means that energy can neither be created nor destroyed; rather, it can be transformed from one form to another (Gottlieb & Pfeiffer 2013).

level and the rest is lost to the environment (McCauley, Gellner, Martinez, Williams, Sandin, Micheli, Mumby & McCann 2018:1). The energy lost affects biodiversity. According to McCauley et al. (2018:1), energy cannot be created or destroyed but it can be transformed from one form to another. The energy pyramid must be kept in a balance to minimise the energy lost. Energy loss increases the amount of heat to the atmosphere causing a temperature rise (Campbell, Hanania, Jenden & Donev 2018:1), which negatively affects biodiversity (Dudgeon, Arthington, Gessner, Kawabata, Knowler, Le´veˆque, Naiman, Prieur-Richard, Soto, Stiassny & Sullivan 2006:163).

According to Dongfang et al. (2014:1), increasing crop production to supply the food needs of a growing population worsens energy loss[32] in the energy pyramid. Therefore, agricultural biotechnology must increase crop production to meet the demand without producing surplus. Over-supplying food using genetically modified crops, will result in food ending up in the rubbish pit. All food dumped, will represent energy being lost. According to Gottlieb and Pfeiffer (2013:2), producing food in excess will cause the energy pyramid to collapse. McCauley et al. (2018) explain that the condition, whereby consumers consume more than the producers can produce, is called "system top-heaviness", whilst the condition when producers produce more than what consumers demand, is called "system bottom-heaviness". Both these conditions are not ideal, and they cause the collapse of the energy pyramid. According to Ibana (2015:153), increasing consumer population and food production will increase carbon emissions, processing, storage and transportation. Carbon emissions will finally lead to climate change such as global warming[33] (Satake et al. 2003:149).

[32] According to Gillam (2014:256) energy is lost in the food chain because not all the energy in one trophic level can ever pass to the next, for instance if a mice dies naturally and decompose, that energy in the dead mice is not passed to the next trophic level. According to Gillam (2014:256) the energy lost in the food chain adds up to around 90% of the energy in any trophic level and it ends up as heat that is dissipated into the environment.

[33] Carbon dioxide gas emissions are mixed up with the geochemical systems in the atmosphere that trap heat from escaping the biosphere and ultimately cause climate change, such as global warming (Satake et al. 2003:149).

In other words, genetically modified crops increase food production without increasing the consumers. As a result, food end-up being wasted and the demand of storage and cooling increases, causing more energy loss. Lost energy cannot be destroyed; hence it will be converted into heat energy, causing a rise in the atmosphere's temperature. A rise in global temperature causes species extinction, which affects how the ecosystem functions.

3.2.7 Populism theory

Another theory of sustainability is the populist theory (Manfredo, Teela, Sullivan & Dietsch 2017:304). According to Abulof (2015:660), populism has its origin from the 1892 Populist Party convention in Omaha, Nebraska, demanding reforms to lift the burden of debt from farmers and workers, and to give the people a greater voice in government. Populism has been linked to the basic-needs approach as it places more attention on social, environmental and cultural problems (Savory in Makamu 2005:20). Populism is considered a movement rather than a theory. It has taken multiple forms but, as put forward in Manfredo et al. (2017:304), populism has been directed by distrust in political elites and nationalism[34]. For instance, populists do not trust economic policies as they argue that these policies are pursued for the betterment of the political elites.

Fellbaum (2005:01) states that populism is a political movement that supports the rights and powers of the common people in their struggle with the privileged elite. Public participation and engagement, as well as the rise of democracy, have been attributed to populism. According to Manfredo et al. (2017:304), the populist movement has been instrumental in the democratisation process of many countries. The voice of the movement has been heard regarding the commercialisation of genetically modified crops. In short, populists are against genetically modified crops arguing that they will benefit the political elites (Schnurr & Smyth 2016:4). However, populists' arguments overlook the benefits of commercialising genetically modified crops.

[34] Nationalism is defined in Webster (2018) as an extreme form of patriotism marked by a feeling of superiority over other countries.

3.2.8 The co-evolution theory.

The co-evolution theory can be applied in understanding modern agricultural biotechnology. According to Baum and Singh (1994:379), co-evolution refers to the simultaneous evolution of organisms and their environments. According to Porter (2006:1), the theory holds the view that species evolve in relation to their environments, while at the same time the environments evolve in relation to the species. The species and environment are interdependent of each other and adaptation will happen to both. According to Thompson (1994:61), co-evolution is reciprocal to genetic change. In this case, the theory accommodates modern agricultural biotechnology innovations. Co-evolution involves a change in the genetic composition of one species or group in response to a genetic change in another (Ridley 2014:11). For instance, by introducing genetically modified organisms, the environment is expected to be altered to accommodate the new species. As argued in van Valen (1989:406), co-evolution is synonymous with mutualistic evolution, which is the adaptive response of one species to genetic change in the other species, which itself becomes genetic. Thus, when two species interact, it results in a permanent genetic modification of both species. The interaction can be facilitated by technology or it can be natural (Thompson 1994:62; Baum & Singh 1994:379).

3.3 Implications of sustainability theories to biotechnology.

In this section, relevant implications of the theories described above will be discussed with reference to modern agricultural biotechnology. Although many implications can be drawn from these theories, only those with relevance to modern agricultural biotechnology will be addressed.

Implication 1: Modern agricultural biotechnology policies must be integrated in national sustainability policy framework. As argued in Salonen and Ahlberg (2011:134), to attain sustainability many societies require technological innovations and new policies which have a crucial role in addressing the current sustainability challenges. Modern biotechnology is needed to conserve the environment (Kant 1994:98), and usher communities into sustainability. As discussed in section 3.3.2, modern biotechnology must be grounded on the ecocentric philosophy in facilitating global sustainability. As put forward in Kilbourne (1998:642), genetically modified crops must not be adopted on the anthropocentric principle, (i.e. on the basis that they benefit humans), but on ecocentrism. Modern biotechnology must address global social, economic and environmental challenges.

Implication 2: As previously discussed (see section 3.2.2, communities must capitalise on the benefits of modern agricultural biotechnology (Nang'ayo, Simiyu-Wafukho & Oikeh 2014:2). This can be achieved through the commercialisation of genetically modified crops under the effective environmental impact assessments guidelines. Countries can also control biotechnology investments (Maghari & Ardekani 2011:114) through several initiatives aimed at getting the most out of modern agricultural biotechnology without compromising the ability of the future generation to meet its needs. Such initiatives involve aligning national biosafety laws with sustainability ideas (Mayet 2000:1), to slow down the rate of stock depletion and climate change (Ellis & Ramankutty 2008 in Benayas & Bullock 2012:883). Lastly, modern agricultural biotechnology must be used only when it reduces pressure on biodiversity. For instance, plant synthetic biology[35] has the potential to reduce pressure on biodiversity (European Commission Science for Environmental Policy 2016:13).

Implication 3: As implied in sections (3.2.3 & 3.2.4), genetically modified organisms must adapt to the environment (Chen et al. 2014:1192). The earth is a community of human and non-human species that are interconnected, interdependent and interrelated to each species. Genetically modified organisms must interact with other species without changing the genetic make-up of non-targeted species (White 1997 in Ojalehto, Medin, Horton, Garcia & Kays 2015:1). The effective application of biotechnology is significant in preventing

[35] Plant synthetic biology is a technique which falls under modern agricultural biotechnology and makes use of synthetic genes in modification of plants (see a discussion in chapter 2)

species extinction or the emergence of foreign species. The development of "super weeds" (Meyers, Antoniou, Blumberg, Caroll, Colborn, Everett, Hansen, & Benbrook 2016:22), and the decrease in the population of pollinators (Bohnblust, Vaudo, Egan, Mortensen, & Tooker 2016:146), can be explained within this theory. Genetically modified organisms must adapt to the environment, without changing the genetic make-up of non-targeted species. The co-evolution theory explains how genetically modified organisms affect non-target species. The release of genetically modified organisms must not target other species other than the intended species (Banerjee 2003:145; Capra 2004:504).

Implication 4: Modern agricultural biotechnology must be adequately and effectively regulated and monitored (Balvanera et al. 2014:50; Renard et al. 2015:13412). As argued in Schiele et al. (2015:112), there exists a range of uncertainties if biotechnology is adopted in the absence of guidelines on monitoring the effects of genetically modified crops. Uncertainties on genetically modified crops arise from the emergence of foreign species, which invades the natural habitats (Conner, Glare & Nap 2003:23). The emergence of foreign species is caused by genetic contamination, or gene flow[36] (Cassuto & Levinson 2017:999). The genetically modified crop guidelines must ensure that gene flow is prevented (Tonui 2012:4). Guidelines must be established and implemented effectively. However, due to the complex nature of the ecosystem, regulating genetically modified organisms is difficult (Breckling, Reuter, Middelhoff, Glemnitz, Wurbs, Schmidt, Schroder & Windhorst 2009:1). Nevertheless, regulation of biotechnology must be in line with how the ecosystem functions, regardless of varied theories of sustainability.

Implication 5: Populism encourages public participation and engagement in policy making. The benefits of modern agricultural biotechnology must be communicated to the public so that it appreciates genetically modified crops

[36] Genetic contamination or gene flow occurs when newly introduced genetic material gets transferred into organisms or environments beyond those intended to be affected (Cassuto & Levinson 2017:999)

(Halford & Shewry 2000:64). The public must appreciate that commercialisation of genetically modified crops is based on their potential benefits to humanity[37]. Cases of communities, which have benefitted from genetically modified crops, need to be referenced in persuading the public to accept these crops. As stated in Roux (2002:429), the public cannot play a central role in regulating genetically modified crops if it is ill-informed and ignorant towards modern biotechnology. On the hand, regulators must communicate risks from genetically modified crops, in a manner that do not arouse public unwillingness to consume genetically modified crops.

According to Baba, Chereches, Mora and Ticlau (2009:6), public participation and engagement is effective in communicating policies. Public participation creates a platform on which genetically modified crops are debated. The platform facilitates the public to understand the rationale behind commercialisation of genetically modified crops. It gives policy makers opportunities to educate the public and to determine public opinions towards a policy. Failure to communicate the importance of biotechnology will be a drawback, especially if the public perceives agricultural biotechnology as beneficial to a few (Manfredo et al. 2017:304). Public participation promote transparency and objectively inform the public on the advantages of adopting biotechnology. Public participation must be prioritised because it is key to successful implementation of agricultural biotechnology (USAID 2015:2).

Summary

Understanding several theories of sustainability assists in regulating genetically modified crops. The knowledge of the theories will give policy insights to experts and policy makers on the necessary guidelines to be followed when releasing genetically modified crops into the environment. These theories provide an insight into the measures and steps to be followed in regulating genetically modified crops. In the following section, the researcher will describe

[37] See section 2.3 for potential benefits of genetically modified crops.

challenges faced in integrating genetically modified crops into the environmental management system.

3.4 Integrating GM crops into the Environmental management system

In the previous chapter, the national biosafety framework of South Africa, has been described. In this section, the complexity involved in regulating genetically modified crops will be described, and several strategies that can be used in integrating modern agricultural biotechnology into the broader national environmental management system in South Africa will also be discussed. As implied in OECD (2014:12), South Africa needs to deal with genetically modified crops regulation issues. Aerni (2005:464) criticises South Africa's legislation on genetically modified organisms for not paying enough attention to the public health and the environment risks concern.

3.4.1 Integrating GMOs in the environmental management system

As discussed in the section 2.6, the environmental management system of South Africa must be integrative. According to the Environmental Encyclopaedia (2018:1), integrated environmental management is concerned with finding the right balance to sustainable development. It seeks to involve different government departments, sectors of the economy and organisations in managing the environment (Jakeman & Letcher 2003:452; Merritt, Croke, Jakeman, Letcher & Perez 2004:282). As argued in Steiner, Kimball and Scanlan (2003:228), the approach seeks to share environmental management responsibilities in an economy. Several scholars support the integrated environmental management approach to agricultural biotechnology (Allen 2012:57; Gilmour, Letcher & Jakeman 2005:59). Therefore, it is imperative that South Africa adopt an appropriate environmental integrative strategy for genetically modified crops. According to Vardarlier (2016:470), integrated environmental management demands that the nations put together resources for effective management of the environment. For instance, the government must utilise biotechnology expertise and financial resources which lies heavily in the private sector (Marrero 2009:156). Although South Africa has adopted an integrative environmental management approach, more can still be done in integrating genetically modified crops in the national environmental management system. For instance, integrated environment management systems must be localised (Oelofse & Scott 2002:40) and made relevant to South Africa.

Modern agricultural biotechnology has emerged as a new phenomenon in the 21st century and is being adopted rapidly in many countries. However, as put forward in Chetty (2009:8), genetically modified crops have introduced some regulatory complexity within the "current environment system[38]" in South Africa. Van Rijssen, et al's (2015:5), supports this claim and mention several legal courts appeals against genetically modified organisms that have been conducted in the country, indicating difficulties of integrating biotechnology in the current environmental management system. In addition, some of the environmental laws, for example the GMOs Act of 1997, governing genetically modified crops in South Africa, have been criticised for being inefficient in monitoring the environmental impact of biotechnology (Mayet 2004:4; Max 2010:56).

According to Wessels and Muller (2012:31), the effectiveness of the environment management system in regulating genetically modified crops started with the first environmental laws. The environmental management system referred to in Wessels and Muller (2012) provides inadequate detail on the protection of the environment from genetically modified organisms. The phenomenon has been inherited in the current environmental system. Consequently, South Africa is currently facing problems in regulating the environmental impact assessment of genetically modified crops (Obonyo, Nfor, Craig & Ripandelli 2010:71). According to Van Rijssen, et al. (2015:7), South Africa is still in the process of finding ways to integrate biotechnology into the national environmental management system. In other words, after nineteen years of commercialisation of genetically modified crops, South Africa's genetically

[38] The "current environmental management system" refers to the system in which genetically modified crops are currently being controlled.

modified organism laws are questioned. Some joint efforts, between the public and private sector, as well as the civil society and organisations, are needed to resolve challenges faced in regulating biotechnology in the country.

Effective integration of modern agricultural biotechnology into the national environmental management system will enable the public to appreciate biotechnology (Chetty 2009:9; OECD 2014:11). The integrative approach to biotechnology will facilitate public willingness to accept biotechnology, because it facilitates public awareness and participation. The integrated approach to environmental management is critical in educating the public on environmental challenges (United Nations 2015:5; Bonnefoi, Belanger & Devlin 2010:893). The integrative approach to genetically modified crops is a starting point in addressing public health and environment risk concerns. Most of the people doubt the health and environmental safety of genetically modified crops (Zainol, Amin, Rusly, Hashim, Sidik, Akpoviri & Ramli 2011:12389), hence, efforts must be directed in building public confidence towards biotechnology.

Various strategies can be useful in integrating genetically modified crops into the national environmental system in South Africa. In the section that follows, the researcher will describe the strategy model for agricultural biotechnology integration. The model is intended to assist policy makers in the struggle for regulating genetically modified crops integration in South Africa (Van Rijssen, et al. 2015:7).

3.4.2 Strategy model for modern agricultural biotechnology integration

Against the background of the discussion in section (3.4), the following strategy model has been conceptualised (by the researcher) for integrating biotechnology into the national environmental management system of South Africa.

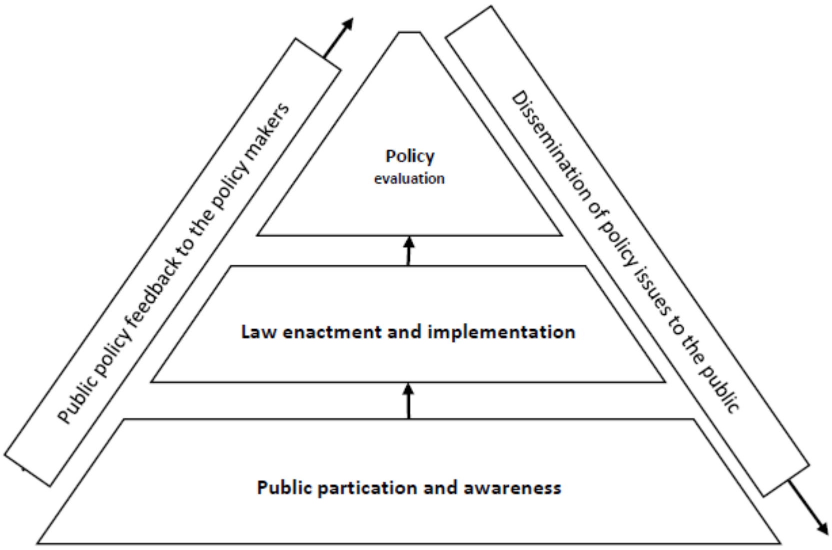

Diagram 3.2: Strategy model for integration

At the bottom of the pyramid is public participation and awareness, which forms the foundation for integration. The government must engage and educate the public on modern agricultural biotechnology. Public participation and awareness in biotechnology policy making is a prerogative (Marzuki 2015:21; Bastidas 2004:2). Access to reliable sources of information is vital in shaping an objective perception. An objective perception facilitates a meaningful contribution towards policy making (Litchfield 1996:32). South Africa must actively and meaningfully participate in regulating genetically modified crops (Republic of South Africa 2014:25). Participation can be in the form of researches in environmental management of genetically modified crops, awareness campaigns, debates and discussions. According to Tshoose (2015:15), the challenge in South Africa is to create new institutions which promote public participation and awareness. Success in integration of modern agricultural biotechnology lies upon meaningful public participation and awareness, as discussed in Section 2.8, in chapter 2, and new institutions as argued in Tshoose (2012) are a requirement.

The second level represents the process of law making and implementation. Well-thought out laws will be effective in promoting integration of genetically modified crops. South Africa has been involved in a broad range of genetically modified organisms' legislative development (Holmes-Watts & Watts 2008:436; Barendse, Roux, Currie, Wilson & Fabricius 2015:26). For instance, South Africa has revised its national environmental management act to include the environmental impact assessment regulation (Republic of South Africa 2014). The challenge lies in the enactment of effective genetically modified organism laws that facilitate environmental integration of biotechnology. For instance, the Environmental Impact Assessment law of 2014 does not elaborate on the genetically modified organisms' environmental impact assessment guidelines (Mayet 2004:4). The above stated law must serve its purpose, otherwise it serves no purpose to have it. South Africa must provide laws that effectively govern biotechnology (Patterson & Josling 2001:1; Tagliabue 2017:70).

In the second level, there is policy implementation, at equal terms with policy making. According to Hamann & O'Riordan (2000:32), implementation of a law is significant for obtaining the intended policy outcomes. Durlak (2011:1), states that policy implementation is critical and relevant for integration. A country can have well-crafted laws, but without effective implementation, it is as good as if there are no laws. South Africa will benefit significantly from effective policy implementation in its pursuit to integrate modern agricultural biotechnology.

At the top of the pyramid, is the policy evaluation. According to Windham (2018:1), policy evaluation helps to understand whether a policy has been integrated effectively into the broader environmental management system, its impact and in this case, how well the public have accepted genetically modified crops. Policy evaluation as a strategy for integration helps to confirm integration of biotechnology into the environmental management system. Thus, in policy evaluation, it is essential that policy evaluation is done on the content of the policy, on policy implementation and on policy impact (Brownson, Royer, Chriqui & Stamatakis 2009:1577). Policy evaluation informs decision makers of the effectiveness of the policy and determine the success of the implementation

(Mugwagwa, Edwards & de Haan 2015:2). Policy evaluation will eliminate the risks of having good policies on paper but yielding unexpected or no outcomes.

The two arrows on both sides of the pyramid emphasise that communication between policy makers and the public is a two-way communication channel. Effective communication as a strategy for integration is an important aspect (Enayati 1999:77). The left arrow represents communication from the public to the government. Communication can be in the form of research findings, public opinions, dissatisfactions or support. The right downward arrow represents dissemination of information from the policy makers to the public. The information can be findings from policy evaluations, feedback to the public on policy issues raised in previous discussions, or an update of national events on biotechnology.

As discussed in this section, enacting laws that are effective in serving the intended purpose facilitates biotechnology integration. In the previous chapter, under section (2.7), the researcher has described the laws in South Africa that govern modern agricultural biotechnology, including the Environmental Impact Assessment Regulation of 2014. In the next section, the researcher will briefly critique the South African genetically modified crops environmental impact assessment regulation of 2014, outline steps and approaches to be followed in genetically modified crops environmental impact assessment.

3.5 Environmental impact assessments guidelines

There is little doubt that environmental impact assessment guidelines stipulated in South Africa's Environmental Impact Assessment Regulation of 2014 and the Genetically Modified Act of 1997 and its amendment acts, are ineffective in governing the environmental release of genetically modified crops (Godfrey 2013:420; Aerni 2005:467; Mayet 2004:4). South Africa's regulatory system has failed to detail the guidelines for genetically modified crops environmental impact assessment. According to Aerni (2005:467), the Genetically Modified Act of 1997 and its amendment acts, does not specify guidelines for conducting genetically modified crops environmental risk assessment. In a way, the Act clearly neglects the environment impact assessment responsibility.

Genetically modified organism law must specify guidelines for environmental impact assessments (European Commission 2014:52; Brault, Kilpatrick, D'Amour, Contandriopoulos, Chouinard, Dubois, Perroux & Beaulieu 2014:9). Policy guidelines must be structured in a way that facilitates effective environmental impact assessment of genetically modified crops. According to OECD (2017:20), environmental impact assessment guidelines must be clear and involve different stakeholders. Guidelines must explain in detail the approaches and steps to be followed in conducting genetically modified crops environmental impact assessments (Nickson 2008:496). In the following section, the researcher describes steps to be followed when conducting environmental impact assessment for the release of genetically modified crops.

3.5.1 Steps to environmental impact assessment

The law on genetically modified crops environmental impact assessment in South Africa must follow and detail at least four steps in regulating genetically modified crops, namely hazard identification, exposure assessment, effects (or consequences) assessment and risk characterization (Romeis, Hellmich, Candolfi, Carstens, Schrijver, Gatehouse, Herman, Huesing, McLean, Raybould, Shelton & Waggoner 2011:3; Nickson 2008:499; Gary 2012:55). Below is a conceptualised diagram showing steps to be followed in the environmental impact assessment as described in Romeis et al. (2011); Nickson (2008) & Gary (2012).

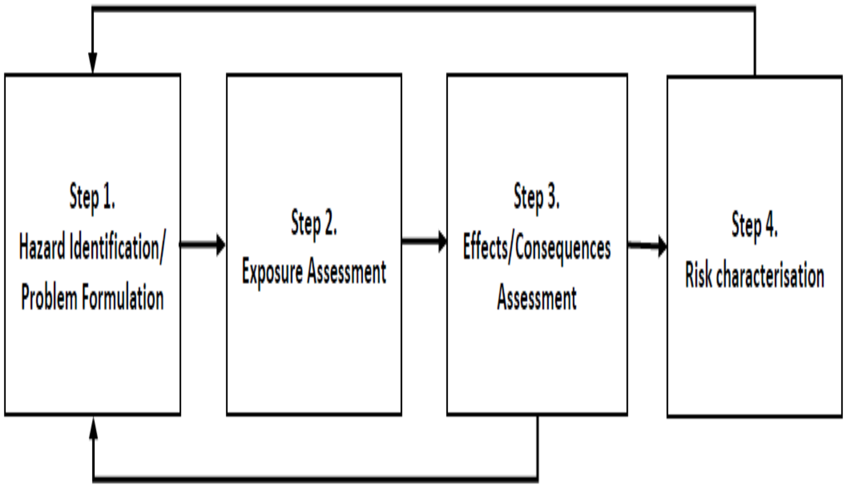

Diagram 3.3 Environnent impact assessment cycle (Romeis et al 2011)

The four steps have been identified as the appropriate risk assessment structure in the GMO Act and the Environmental Impact Assessment Regulation of South Africa, but there are no details on the guidelines for these steps (McGeoch & Rhodes 2006:8). According to the European Food Safety Authority (2014), each step must have guidelines. Guidelines for each step will standardise the environmental impact assessment of genetically modified crops.

Step1: Hazard identification. Hazard identification, also known as problem formulation (Wolt, Keese, Raybould, Fitzpatrick, Burachik, Gray, Olin, Schiemann, Sears & Wu 2009:426), is the first step in environmental impact assessment cycle. Below is a diagram to explain the guidelines for identification of a hazard described in Johnson (2018:1).

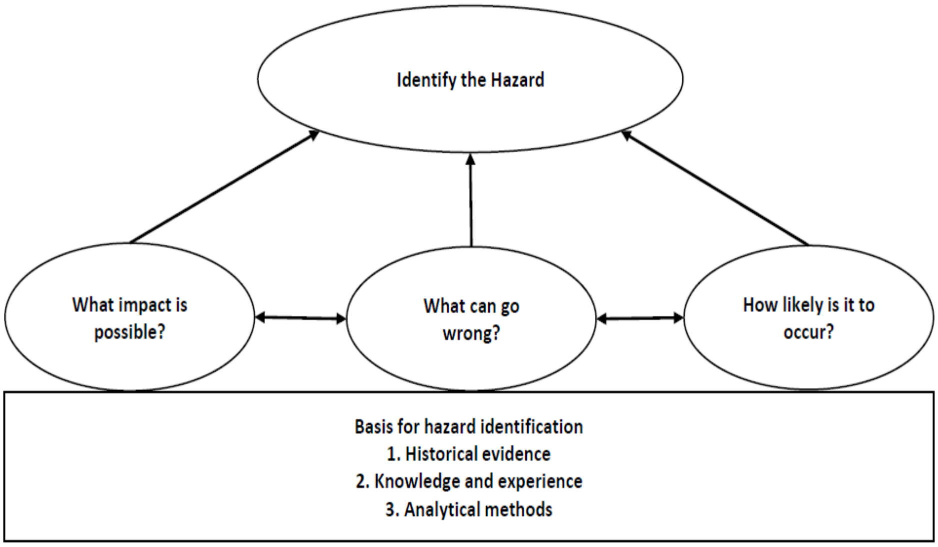

Diagram 3.4 Guidelines for hazard identification (Johnson 2018)

As described in Romeis et al. (2011:3), guidelines for hazard identification must be regulated and standardised. In the diagram by Johnson (2018) above, the basis for hazard identification are historical evidence, knowledge and experience, as well as analytical methods. Historical evidence is when historical events are taken into account in genetically modified crops environmental impact assessment. Examples of a historical evidence include cases of allergies in the past or people reported to have suffered from illnesses that may be attributed to consuming genetically modified crops. Knowledge and experience refer to what is already known about genetically modified crops, for example the nutritional benefits associated with these crops. According to Harich (2014:34), analytical methods refer to the scientific method of enquiry to be used to solve the problem.

In identifying a hazard, there are three questions that must trigger the process, as shown in the diagram. These questions maybe asked in isolation or as group questions. The answers to these questions lead to the identification of hazard. The process of hazard identification has at least three things to accomplish in environmental impact assessment. Firstly, hazard identification must define the scope of the assessment (Carstens, Anderson, Bachman, Schrijver, Dively, Federici, Hamer, Gielkens, Jensen, Lamp, Rauschen, Ridley, Romeis & Waggoner 2012:815). Secondly, it must define the goals of the environmental impact assessment (Wolt et al. 2009:435). Thirdly, it must identify minimum quantity of data needed for impact assessment (Raybould 2007:121). Hazard identification forms the foundation for environmental impact assessment. According to Keith, Martin, Ammie, Alan, Angelo, Timothy, Richard and Michelle (2016:840), hazard identification sets environmental impact assessment priorities. It directs or sets parameters for the process of environmental impact assessment.

Step 2: Exposure assessment. Hazards identification is followed by exposure assessment. A comprehensive review, including documentation of the hazard, is done at this step. According to Garcia-Alonso et al. (2006:59), exposure assessment estimates the likelihood of the hazards to be realised. As argued in United States Risk Assessment Forum (USRAF) (2010:32), the process of exposure assessments must be regulated. Guidelines should include establishment of exposure assessment plan, gathering data for exposure assessments, using data to estimate exposure, as well as presenting the results of the exposure assessment (USRAF 2010). Diagram 3.4 below summarises guidelines in USRAF (2010).

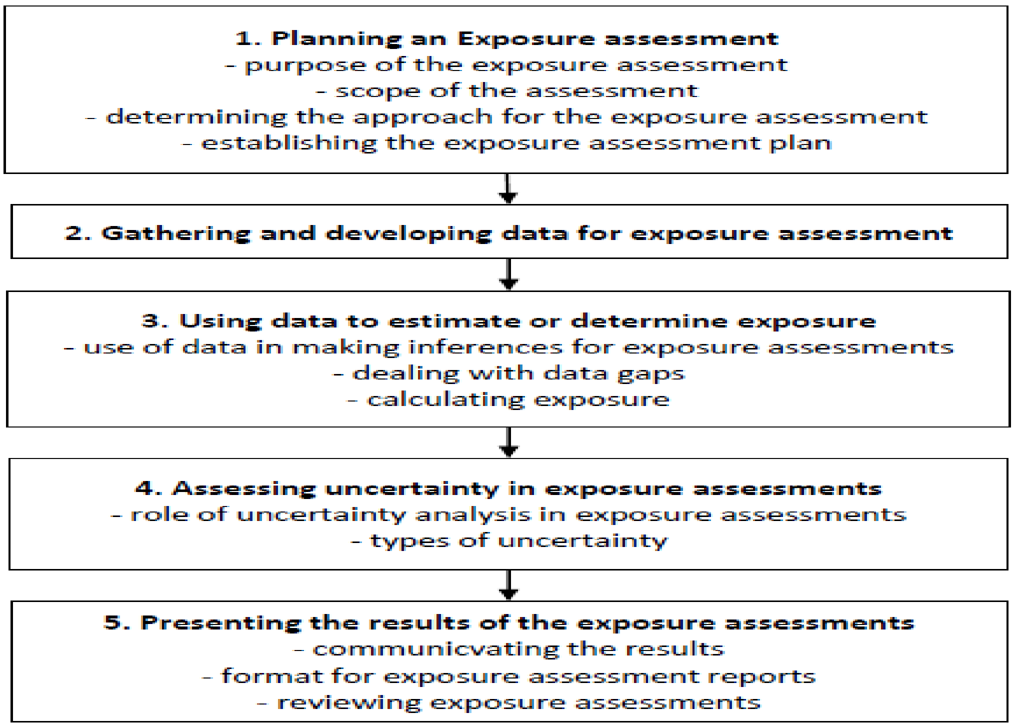

Diagram 3.5 Guidelines for exposure assessments (USRAF 2010)

Guidelines for exposure assessments, as shown in diagram 3.4, are crucial in genetically modified crops environmental impact assessment, hence they must be used as the basis for regulating guidelines for exposure assessment in South Africa. As put forward in the USRAF (2010:34), exposure assessment guidelines must stipulate procedures to be followed in conducting exposure assessment. For examples, procedures should include procedures for establishing an exposure plan, and communicating findings. Policy makers must not take for granted that environmental assessors will follow the procedures if they are not regulated. USRAF (2010:37), also describe several approaches available to conduct exposure assessments which can be followed in South Africa. Some of these approaches will be discussed in section (3.5.2).

Step 3: Effects assessment. According to DEAT (2004:5), effects assessment is a systematic analysis and evaluation of cumulative environmental change. Cooper (2004:2) defines effects as the net result of environmental impact from several projects and activities. South Africa do not have guidelines for effects assessment (Paul & Robertson, in Fuggle et al. 2015:945; McGeoch & Rhodes 2006:2) and establishing the guidelines promotes consistency across genetically modified crops environmental impact assessment in the country. Since, the scope of effects assessments are generally wider, (Reinhart 2010:153), guidelines will assist assessors in narrowing the scope of effect assessments. According to Reinhart (2010:155), the overall purpose of effects assessment is to ensure that national decisions consider the full range of consequences of actions. In this case, guidelines will ensure reliability in making policy decisions. Table 3.1 below shows types of effects which must be considered in the development of guidelines for effects assessments as described in Cooper (2004:3).

Type	Main characteristics
Time crowding	Frequent, repetitive and simultaneous impacts on an environmental resource.
Time lag	Long delays between cause and effect.
Space crowding	High spatial density of impacts on an environmental system.
Cross-boundary movement	Impacts occur some distance away from source.
Fragmentation	Change in landscape pattern.
Compounding/synergistic effects	Effects resulting from multiple sources or impacts which may be different in nature from the individual impacts.
Indirect effects	Secondary impacts resulting from a primary activity.
Triggers and thresholds	Fundamental changes in system behaviour or structure.
Nibbling	Incremental or decreasing effects.

Table 3.1 Types of effects (Cooper 2004:3)

Guidelines for effects assessment of genetically modified crops must consider several types of effects. As shown in Cooper (2004:3), different effects have different impact on the environment. Regulation on effect assessments must provide a clear guideline on how to deal with different effects in the assessment process. Challenges are going to be encountered in differentiating between direct, indirect and cumulative effects (Reinhart 2010:155). More research resources must be directed in this area of study in order to provide environmental assessors with a scientific methodology on distinguishing one type of effect from the other.

According to Callahan and Saxton (2007:799), guidelines for effects assessment must provide a conceptual framework and basic principles for conducting effects assessment. There is high possibility that in the absence of a guideline for effects assessment, effects will not be fully addressed. According Reinhart (2010:156), the scope of effects assessment is generally wider and there is lack of information on the consequences of genetically modified crops. Wider scope of effect assessments and lack of information of the risks of genetically modified crops as described in Reinhart (2010), will render effects assessment cumbersome in the absence of guidelines, and if these factors are not addressed, assessments will be inefficiency. Effects assessment must identify the potential effects of genetically modified crops, whether direct or indirect (Hill & Sendashonga 2003:86).

Step 4: Risk characterisation. Risk characterization is the final step and it integrates all steps (hazard identification, exposure and effects assessments) of environmental impact assessment (Pedersen 1997:1). Risk characterisation involves the process of communicating findings for decision making or for awareness purposes. Risk characterisation must be transparent, clear, consistent and reasonable (Fowle & Dearfield 2000:7). Risk characterisation must be objective and free from preconceived ideas and beliefs. Table 3.2 below summarises the risk characterisation principle namely transparency, clarity, consistency and reasonableness.

Principle	Definition	Criteria for a Good Risk Characterization
Transparency	Explicitness in the risk assessment process.	✓ Describe assessment approach, assumptions, extrapolations and use of models ✓ Describe plausible alternative assumptions ✓ Identify data gaps ✓ Distinguish science from policy ✓ Describe uncertainty ✓ Describe relative strength of assessment
Clarity	The assessment itself is free from obscure language and is easy to understand.	✓ Employ brevity ✓ Use plain English ✓ Avoid technical terms ✓ Use simple tables, graphics, and equations
Consistency	The conclusions of the risk assessment are characterized in harmony with other EPA actions.	✓ Follow statutes ✓ Follow Agency guidance ✓ Use Agency information systems ✓ Place assessment in context with similar risks ✓ Define level of effort ✓ Use review by peers
Reasonableness	The risk assessment is based on sound judgment.	✓ Use review by peers ✓ Use best available scientific information ✓ Use good judgment ✓ Use plausible alternatives

Table 3.2 Risk characterisation (Fowle & Dearfield 2000:19)

Fowle and Dearfield (2000) emphasise that risk characterisation must meet certain minimum requirements for a good risk characterisation. Transparency refers to the process of risk assessment being scientific[39]. According to Fowle and Dearfiel (2000:19), transparency involves clear problem formulation and an appropriate research plan. Clarity refers to risk characterisation reporting. Fowle and Dearfiel (2000:19) state that reporting must be easy to understand. Complex terminology used in environmental risk assessment must be simplified. By consistency, Fowle and Dearfiel (2000) imply that risk characterisation must be carried out within the confinement of relevant laws applicable to the environmental impact assessment. Reasonableness means that the findings must be systematic and reliable. Findings must be based on a theoretical framework (Fowle & Dearfiel 2000:19). Habicht (1992:56) concludes that risk characterisation in South Africa must meet the requirements of transparency, clarity, reasonableness and consistency. This will enhance the effectiveness of genetically modified crops decision making in the country.

3.5.2 Approaches to GM crops environmental impact assessment

There are several approaches that can be used in genetically modified crops environmental impact assessment. In this section, the researcher will briefly describe case-by-case assessment, tiered assessment, comparative approach and uncertainty analysis. The approaches must be incorporated in the environmental impact assessment cycle, described in the previous section (3.5.1).

Case-by-case approach. According to Hayes (2002:27) case-by-case assessment is a technique used in environmental impact assessments. Case-by-case approach deals with each environmental risk or benefit case individually rather than considering several cases when conducting environmental impact assessment. The approach is effective in providing a detailed environmental impact analysis in the individual case (Flyvbjerg 2006:239). At times, it is vital to narrow the scope of the assessment, so that a deeper analysis is carried out. Cassuto and Levison (2017:1011) recommend case-by-case assessment to be integrated in genetically modified organism's laboratory and field trials.

[39] The process being scientific implies the process is systematic and/or follows selected methods to arrive at a conclusion.

However, case-by-case assessment has its own disadvantages, as some cases are better understood when they are studied together (Hammersley 2012:393; Yin 2009:65).

Tiered risk assessment approach. The tiered risk approach is also used in environmental impact assessment. Tiered risk approach is appropriate when the risk identification process is complex (Cassuto & Levison 2017:1012). There is little doubt that genetically modified crops potential risks are complex, making the tiered risk approach relevant to biotechnology. The tiered risk approach is a three-stage assessment approach as shown in diagram (3.5), below.

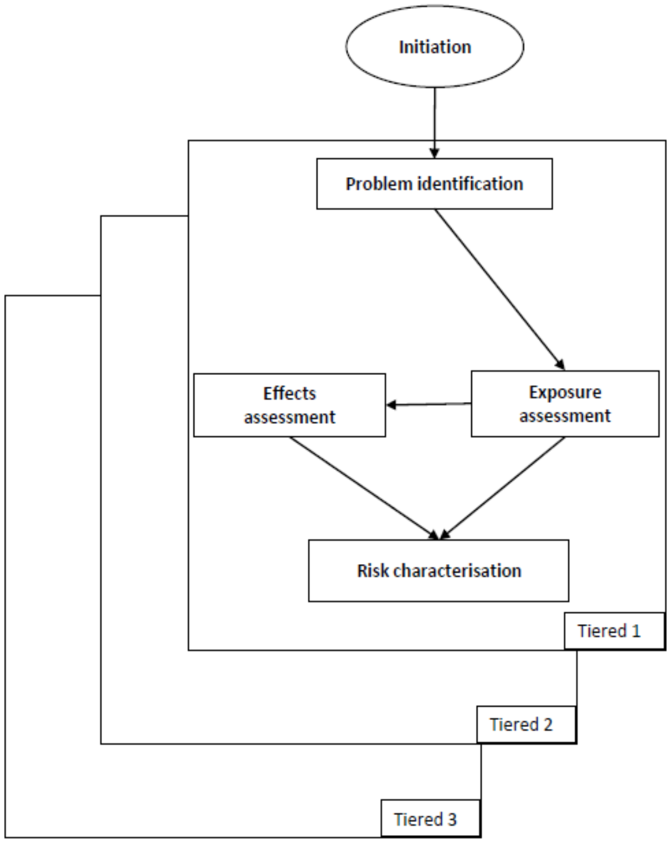

Diagram 3.6: Tiered risk assessment model (Liliburne & Philips 2003)

According to Liliburne and Philips (2003:1), once the need for a risk assessment has been identified, it will always be necessary to go through the preliminary risk assessment stage. At the preliminary stage, first tier, environmental risk assessors apply basic principles of assessments to determine whether risks are acceptable or unacceptable. According to Swartjes, Versluijs and Otte

(2013:277), if the outcome from the first tier shows that the risk is acceptable, the total assessment is stopped. On the other hand, if it shows unacceptable risks, the assessment proceeds into the next tier (Swartjes et al. 2013:277). The tier approach relies on more assessments in making decisions. It is an efficient way of risk environmental impact assessment (Swartjes 2011:653; Andow & Zwahlen 2006:206).

Comparative approach. The comparative approach has been popularised in genetically modified crops environmental impact assessment by the OECD, WTO and Cartagena Biosafety Protocol (Nicolia, Manzo, Veronesi & Rosellini 2014:80; Kuiper, Kleter, Noteborn & Kok 2001:504). According to Hill and Sendashonga (2003:84), the comparative approach envisages three principles namely, substantially equivalent[40]; substantially equivalent except for the inserted trait[41], and not equivalent at all[42]. The concept of substantial equivalence is part of a safety evaluation framework based on the idea that existing crops can serve as a basis for comparing the properties of genetically modified crops with the appropriate counterpart (Nicola et al. 2001:504). Several scholars agree on the ability of the comparative approach in facilitating an understanding of complex genetically modified organisms' assessment cases (Cassuto & Levison 2017:1010; O'Mahony & Reilly 2005:284). Comparative assessment promotes and facilitates an in-depth environmental impact assessment of genetically modified crops.

Uncertainty analysis approach. According to Henrich and Koch (1993:2), uncertainty can arise at any stage in the environmental impact assessment. This is supported by Wolt et al. (2009:426), who assert that, "uncertainty analysis approach is instituted on the basis that anything can go wrong, at any stage

[40] Substantially equivalent holds that the safety of genetically modified crops is assessed by comparing them with similar conventional crops that have proven safe (Kok & Kuiper 2003:439)
[41] Substantially equivalent except for the inserted trait implies that substantial equivalence would apply except for the inserted trait, and so the focus of the safety testing is on the inserted trait
[42] Not equivalent at all implies that the genetically modified crop will not match the conventional crops in colour, size or shape, and these crops may only be considered for human consumption only when proved safe for human consumption (Schauzu 2000:1).

during the environmental impact assessment process". Uncertainty analysis guidelines must outline the methodological aspects to be followed by environmental impact assessors because there are many ways to perform uncertainty analysis. According to Rubinstein and Kroese (2007:314), uncertainty analysis can be done in two general ways, which are quantitatively and qualitatively. However, under these two broad methods, there are several techniques which include the sensitivity analysis[43].

Summary

South Africa must establish and regulate guidelines for conducting genetically modified crops environmental impact assessment. The guidelines must specify and detail, among other things, steps and approaches to be followed during the assessments. Guidelines for environmental impact assessment will facilitate effective assessments of genetically modified crops in the country (Smyth & Phillips 2014:176; Godfrey 2013:420; Tshangela 2014:213). Guidelines will facilitate reliable decision making on genetically modified crops. In the next section, the researcher will describe the theoretical framework of the study and explain how it will be applied to the study.

3.6 Theory of planned behaviour

Diagram 3.6 is a schematic representation of the theory of planned behaviour as put forward in Ajzen (2015:126).

[43] Sensitivity analysis assesses how changing inputs to a model or an analysis can affect the results (Integrated Environmental Health Impact Assessment System 2007:1)

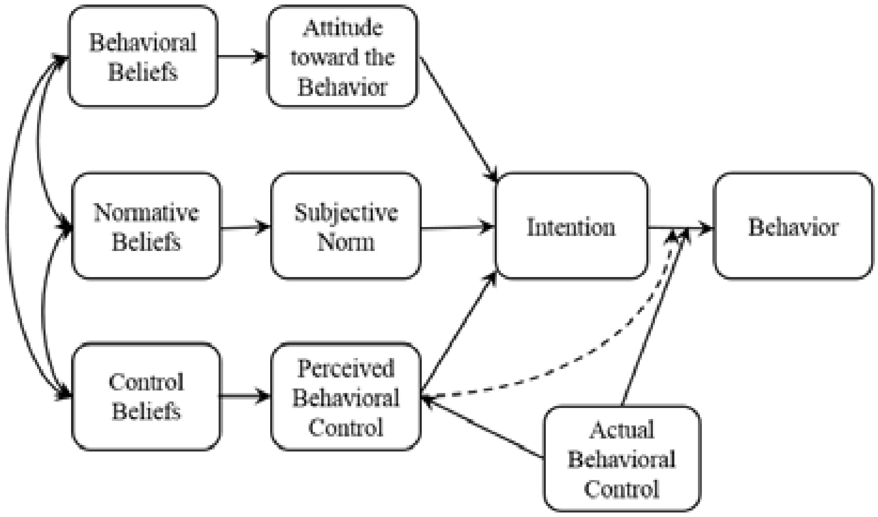

Diagram 3.7 Theory of Planned Behaviour (Ajzen 1991; 2005:182)

The theory makes two important assumptions. Firstly, the theory assumes that humans are rational and make systematic use of the information available in decision making (Carmack 2009:1; Ajzen, Joyce, Sheikh & Cote 2011:102). Experience and knowledge form the basis for deciding whether to consume genetically modified crops or not. Secondly, the theory assumes that an individual performs a behaviour voluntarily, an act referred to as volitional control assumption[44](Ajzen et al. 2011:102). Volitional control is one of the conditions which is required for accuracy in predicting a behaviour. The study assumes that participants are not forced to consume genetically modified crops.

According to the theory of planned behaviour, the immediate antecedent of a behaviour is the "intention" (Ajzen 2001:43). In this study "behaviour" refers to public acceptance of modern agricultural biotechnology. "Intention", also known as "behavioural intention", refers to public willingness to consume or accept modern agricultural biotechnology. By implication, Ajzen (2001:43), posits that acceptance of modern agricultural biotechnology is pre-determined by the willingness (intention) to consume or accept genetically modified crops. According to the theory of planned behaviour, before an individual accepts a

[44] Volitional control assumption implies that an individual should decide at will to perform or not perform the behaviour (Ajzen 1991:182).

product, that individual must be motivated to consume the product. The motivation is the intention. According to Wu (2015:154), intention predicts a behaviour. In short, there is a relationship between intention and behaviour. Intention represents an individual's conscious plan to acceptance or non-acceptance behaviour. Therefore, the researcher will have to determine individual intention, first, and then ascertain whether intention predicts behaviour. On the other note, intention is influenced by attitude and attitude is influenced by beliefs (Cameron 2012:3).

As explained in Sommer (2011:92), and Ajzen (2002:102), the theory assumes that intention and behaviour are the consequence of beliefs[45] mediated through attitudes[46]. Attitudes serve as direct determinants of the intention to perform the behaviour (Yakasai & Jusoh 2015:188). In other words, attitudes must be positive in order to predict a favourable intention towards a behaviour. The researcher used an elicitation study to determine beliefs, then a questionnaire to determine public attitudes. Beliefs and attitudes were correlated with public intention to determine the relationship between beliefs, attitudes, intention and behaviour. According to the theory of planned behaviour, beliefs refers to behavioural, normative and control beliefs; and attitudes refers to attitude towards behaviour, subjective norm and perceived behavioural control. These terms will be discussed below and how the researcher intent to apply them in the study.

3.6.1 Explaining some aspects of the theory of planned behaviour

As described in Lange, Kruglanski and Higgins (2012:441), behavioural outcomes are a result of performance associated with one's behavioural beliefs. For instance, an outcome behaviour from an individual's belief that genetically modified crops are less healthy. Behavioural beliefs are intrinsic and originate from an individual's way of seeing things. Behavioural beliefs predict an attitude towards a behaviour (Ajzen 2015:127). For instance, if an individual regards

[45] Beliefs refers to behavioural beliefs, normative beliefs and control beliefs.
[46] Attitudes referring to attitude towards behaviour, subjective norm and perceived behavioural control

genetically modified crops as less healthy, the theory of planned behaviour expects a negative attitude towards accepting genetically modified crops. Thus, behavioural beliefs and attitude towards behaviour are directly related (Cialdini, Reno & Kallgren 1990:1016).

Normative beliefs are extrinsic and is influenced by important people around an individual, e.g. the doctor, spouse, and dietician. Normative beliefs are associated with an individual motivation to comply with social pressure (Ajzen 2015:128; Louis, Davies, Terry & Smith 2007:60). Normative beliefs are influenced by the 'significant others[47]'. For instance, if one's spouse rejects genetically modified crops, that individual's attitude is expected to be negative towards genetically modified crops. Normative beliefs are directly linked to subjective norm attitude (Fishbein & Ajzen 2010:234). Subjective norm refers to an attitude that is influenced by the significant others (Rustiarini & Sunarsih 2017:193). For instance, if the important people around a person perceives genetically modified crops as healthier, the attitude derived from this belief is referred to as subjective norm. According to Kernsmith (2005:758), if an individual believes that a referent approves an intention then he/she will be motivated and feel the social pressure to perform the behaviour.

Control beliefs are associated with an individual having control of the situation or not. For example, the decision to consume genetically modified crops might be imposed to an individual, maybe because genetically modified crops are the only available crops. Control beliefs predict perceived behavioural control attitude (Hackman & Knowlden 2014:102). According to Clement, Henning and Osbaldiston (2014:49), the perceived behavioural control (e.g. the attitude of having resources and influences) can predict a behaviour, especially when the perceived behavioural control is out of an individual's capabilities and when it can be objectively detected. In this case, an individual does not have to develop an intention behaviour, because behaviour is not voluntary. In such an instance,

[47] Significant others refer to individuals with potential to influence a particular customer's behaviour especially in making a consumption decision (Yakasai & Jusoh 2015:189)

perceived behavioural control is realistic in predicting a behaviour (Bandura 1982:122). The theory of planned behaviour also assumes a relationship between the three beliefs, as well as between the three attitudes (Gellert, Witham, Crombie, Donnan, McMurdo & Sniehotta 2015:385; Saeri, Ogilvie, Macchia, Smith & Louis 2014:353). In other words, normative beliefs (e.g. beliefs held by significant others that genetically modified crops are healthier) will predict behavioural beliefs (e.g. beliefs that genetically modified crops are harmful to eat). According to Ajzen and Klobas (2013:206), and Brouwer and Mosack (2015:40), favourable beliefs and attitudes predict positive intention to perform a behaviour.

According to Ajzen (2015:126), beyond beliefs and attitudes, the theory recognizes that background factors predict behaviour. According to the theory of planned behaviour, background factors influence intentions and behaviour indirectly through beliefs[48] and attitudes[49] (Kim 2014:678; Ajzen & Klobas 2013:206). Examples of background factors are socio-demographic factors, among others. The study will determine whether socio-demographic factors directly predict a behaviour. Thus, socio-demographic factors are regarded as the actual control beliefs in this study. Actual control beliefs, according to the theory of planned behaviour, directly predict a behaviour, e.g. money and experience. If one has a higher income, that individual might decide to eat organic crops only, hence availability of money predicts a behaviour. Some scholars argue that socio-demographic factors predict behaviour (McDermott, Oliver, Svenson, Simnadis, Beck, Coltman, Iverson, Caputi & Sharma 2015:9).

3.6.2 Application of the theory to the study

Ajzen's (1991) theory of planned behaviour was used in this study as a theoretical and analytical framework. In using the theory, the researcher ascertained whether public beliefs (behavioural, normative and control) determine public attitudes (attitude toward the behaviour, subjective norm and

[48] Beliefs in this context referring to behavioural, normative and control beliefs
[49] Attitudes referring to attitude towards behaviour, subjective norm and perceived behavioural control attitudes

perceived control). The theory was also used to determine whether attitude influence an intention to perform and act, in this case, the willingness to consume genetically modified crops, and finally whether intention l influences a behaviour (i.e. acceptance of modern agricultural biotechnology). The theory was used to ascertain whether socio-demographic factors, also influence intention to perform a behaviour and/or a behaviour itself. In other words, the study assumes that there is relationship between beliefs, attitudes, intention and behaviour. Diagram (3.7), below illustrates the direction of the relationship.

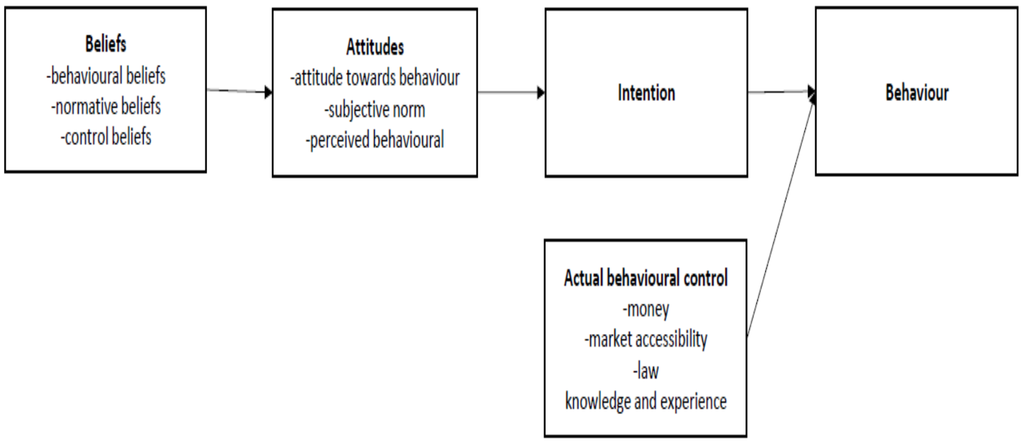

Diagram 3.8 Conceptualised theory of planned behaviour

This study seeks to establish the relationship between beliefs, attitudes, intention and behaviour, as well as the relationship between actual behavioural controls and behaviour. As shown in the diagram 3.7 above, there are three kinds of beliefs namely behavioural, normative and control beliefs. According to the theory of planned behaviour, these beliefs are influenced by background factors, e.g. education, age, race, experience, skills, etc (Shi, Ehlers & Warner 2014:1). In this study, the researcher conducted an elicitation study to determine and confirm beliefs held by the target population on genetically modified crops. The findings of the elicitation study were incorporated in the main data collection phase.

According to the theory of planned behaviour, beliefs predict attitudes. There are also three kinds of attitudes namely attitude towards behaviour, subjective norm and perceived behavioural control. According to Ajzen (1991), there is a relationship between beliefs and attitudes and this study seeks to ascertain the significance of the relationship. According to Ajzen (2015), the three kinds of beliefs are related to a specific attitude as shown in diagram 3.6 above. According to Sniehotta, Presseau and Araújo-Soares (2014:1), the effects of beliefs on a behaviour, are assumed to be mediated through attitude and intention. Thus, according to Ajzen (1991), there is also a relationship between attitudes and intention, as well as intention and behaviour.

However, as explained by Ajzen, Joyce, Sheikh and Cote (2011:102), humans are not always rational in decision making. Circumstances may compel individuals to consume genetically modified crops, for instance, the unavailability of a range of products to choose from. Other consumers are careless about what they consume leading to an irrational consumption decision. Thus, according to Ajzen (1991), behaviour is also determined by other factors which have been referred to as actual behavioural control. Examples of actual behavioural control factors include the law which allows the marketing of genetically crops without labelling and availability of money. The study also seeks to ascertain the relationship between actual behavioural control (in this study actual behavioural control factors include personal income, education, gender, race and age) and behaviour.

3.7 Conclusion

The chapter has described the debate surrounding sustainable development and sustainability, as well as different theories of sustainability and their implications to modern agricultural biotechnology. Environmental management system in South Africa, which include the environmental impact assessment of genetically modified crops has been described. Guidelines on genetically modified crops environmental impact assessment and the theory of planned behaviour have been described. The aim of the study was best explored within the proponents of the theory of planned behaviour. The significance of beliefs in predicting attitudes, attitudes in predicting intention, as well as intention in predicting behaviour, was predicted statistically. The theory of planned behaviour is of relevance to the current study as a theoretical and analytical framework, as the theory focuses on specific behaviour of interest. The next chapter outlines and describes the research methodology of the study.

CHAPTER 4
RESEARCH METHODOLOGY

This chapter describes the research design, approach and methodology followed in this study. It outlines how the researcher applied quantitative approach in the study, as well as how the case study is used to understand public perception towards consuming genetically modified crops and acceptance of modern agricultural biotechnology in South Africa, using the theory of planned behaviour. Research methodological aspects, for instance, research reliability and validity, sample size and sampling procedure, as well as data collection was outlined, discussed, described and/or justified in this chapter, with the main emphasis on how these research components were applied in this study.

4.1 Research aim and questions

In line with the primary objective (see section 1.4 in chapter 1) the study sought to analyse public perception towards consuming genetically modified crops and the acceptance of modern agricultural biotechnology in South Africa. The theoretical framework for this analysis was based on the theory of planned behaviour. Below is the conceptualised Ajzen (1991) theory of planned behaviour on which data analysis and interpretation is based on.

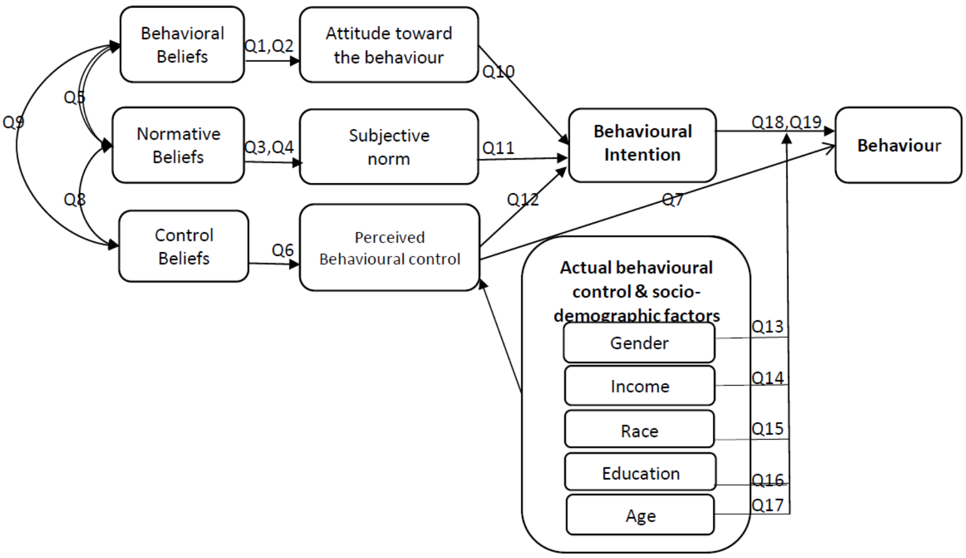

Diagram 4.1 Ajzen's (1991) Conceptualised theory of planned behaviour

Below are the research questions used in-line with the theory of planned behaviour.

Q1. Does people who perceive human health and environmental risks posed by genetically modified crops have a negative attitude towards accepting modern agricultural biotechnology?

Q2. Do individuals who trust the genetically modified laws in South Africa, have positive attitude towards accepting modern agricultural biotechnology?

Q3. Are there relationships among beliefs, attitudes, intention and behaviour?

Q4. Will gender predict willingness to consume and accept modern agricultural biotechnology?

Q5. Will lower personal income level predict willingness to consume and accept modern agricultural biotechnology?

Q6. Will race predict willingness to consume and accept modern agricultural biotechnology?

Q7. Will higher formal education predict willingness to consume and accept modern agricultural biotechnology?

Q8. Will age predict willingness to consume and accept modern agricultural biotechnology?

4.2 Research design

The study followed an explorative and descriptive research design, utilising case-studies, cross-sectional surveys, descriptive and exploratory research methods. A case study investigates real-life phenomenon (Ridder 2017:282) and in this study it is expected that the case-study will facilitate an in-depth psychological and socio-demographic examination of a target population pertaining its perception in accepting modern agricultural biotechnology (Kalu & Bwalya 2017:47).

According to Leary (2001:23) descriptive research describes the behaviour, attitudes or beliefs of a population. Descriptive research becomes one of the most appropriate methods in this study (Kumar 2011:31), as it allows an in-depth study of the public perception towards genetically modified crops. As described in Rholetter and Elena (2016:1) descriptive research is compatible with the use of Ajzen (1991) theory of planned behaviour. On the other hand, exploratory research aims at exploring the in-depth knowledge and behaviour of a targeted population (Brink 2012:120; Brown 2016:26). Exploratory research relies more on secondary research (Singh 2007:64). In this study, the researcher will conduct a review of the available literature to gain an insight on perception and environmental impact assessment. The benefits of using descriptive and exploratory research methods make them relevant and appropriate to be used in this study.

Quantitative approach involves the manipulation of statistical data and models to explain a phenomenon under an investigation (Field 2013:133). Quantitative can explain or predict relationships between measurable variables (Leedy 1993:67; Bryman 2012:35). This study will examine the relationship between beliefs, attitudes and behaviour, as well as between socio-demographic factors and behaviour, which are better explained within the confinements of quantitative paradigm. According to Kumar (2005:45) quantitative research begins with data collection based on a theory and it is followed with application of descriptive[1] or inferential[2] statistics.

Quantitative researches are grounded on theoretical frameworks which are approved or disapproved during the empirical investigation (Litosseliti 2010:52). In this regard, Ajzen (1991) theory of planned behaviour has been adopted as the theoretical and analytical framework. As described in Chapter 3 of this study, Ajzen (1991) theory of planned behaviour requires the formulation and testing of hypothesis, as well as consistence in data collection, using a questionnaire (Ajzen 1991:31). The researcher will formulate and test several

[1] According to Litosseliti (2010:70) descriptive statistics are indices that give information about the general shape or quality of data and it includes such things as mean, mode and median.
[2] According to Ary, Jacobs, Sorensen and Razavieh (2010:148) statistical inference is a procedure by means of which the researcher estimates the characteristics of populations from the characteristics of a sample.

hypotheses suggesting a relationship between beliefs, attitudes and behaviour. Given the above, quantitative analysis best suits this study. As argued in Quantitative analysis, in this study, will facilitate examining and making predictions about the relationship between different variables (Creswell 2013:65) using Ajzen (1991) theory of planned behaviour.

The study utilised the Statistical Package for Social Sciences (SPSS) software in ascertaining correlation between individual beliefs, attitudes or socio-demographics factors towards acceptance behaviour. SPSS assisted the researcher in determining the significance of the relationship between different variables. Determining the significance of the relationships between variables is a crucial process in drawing up the research conclusion as to whether beliefs and attitudes influence public perception towards genetically modified crops.

According to Rahman (2017:106) quantitative research findings are likely to be generalised to the target population. The researcher intended to generalise, to some extent, the findings of this study towards the population of South Africa. It was in the interest of the researcher to ensure that the sampling procedure followed in this study suffices the quantitative requirements for generalisability. However, this was to be determined during data analysis and interpretation.

4.3 Population frame, sampling and sample size.

The study was carried out in South Africa in the city of Kempton Park, which is situated in the Gauteng province. Kempton Park was selected on a convenient basis since the researcher lives in the city. As argued in Ponto (2015:169) it is not feasible to collect data from the entire population of Kempton Park, hence a sample was used to estimate the population responses. The researcher employed mixed and multi-stage sampling procedures in an effort to ensure the sample represents the population of Kempton Park (Cohen, Manion & Marrison 2018:212).

According to Statistics South Africa (2017:10) there are approximately 56.52 million people in South Africa, of which 12 million people live in the Gauteng province and approximately 171 575 people live in Kempton Park. Approximately 80% (45 656 401) of the people living in South Africa are black African people, 10% (4 493 523) White, 8% (4 962 922) Coloured and 2% (1 409 103) Indians and Asians (Statistics South Africa 2017:10). Sampling was carried out from the population living in Kempton Park. According to Singh (2007:89) sampling is the selection of a sample that reflects the target population. As discussed in Ary, Jacobs, Sorensen and Razavieh (2010:149) the sample must be statistically significant to enable generalisability of the findings within a reasonable confidence level.

The study utilised mixed sampling and multi-stage sampling designs (Kumar 2011:42) and measured the significance of the sample in representation of the target population using the Chi-square test[3]. The sample must have a small sampling error for the findings to be generalised within a reasonable confidence level (Kothari 2004:58). The cluster sampling was used to group the population in different geographical areas, i.e. residential, industrial, central business district and informal settlements in and around Kempton Park. As recommended by Leary (2001:112) participants were selected giving all individuals equal opportunities to participate in the study.

The sampling procedure targeted to yield a sample that was accurate, unbiased and representative of the target population (Leary 2001:109). After clusters were identified, the researcher recorded all street names in each cluster, placed them in a container and a street was randomly picked. The street which the researcher picked was listed for the study and participants were drawn out of these listed

[3] Chi-square test is a non-parametric test for group differences. As in Mooi, Sarstedt and Mooi-Reci (2018:142) the rationale for using the Chi-square test is to determine the significant difference between the sample and the population characteristics like age, gender, income level and race since these parameters are known in the target population through Statistics South Africa (2011). If the difference is significant the researcher might have to add more participants to the sample. The chi-square test is to ensure that generalisability of research findings is done with a reasonable confidence level.

streets. In each cluster, a minimum of five (5) streets were selected. As for informal settlements, there are three (3) informal settlements in Kempton Park. A simple random sampling was used to select only one of the three to participate in the study. In the absence of official street names, the entire settlement was regarded as a single street and all participants were given an equal chance to participate in this study. Once streets were selected, the researcher counted and gave a label number to all the houses in the street. The researcher conducted a second draw to select the houses that would automatically constitute the sample. As a rule, the researcher always started counting houses from North to South direction or East to West, and the house on the right-hand side was number one (1) and to the left, number two (2) in that order. The same rule applied to informal settlements and houses were selected by a draw to determine the participants. Any person above 18 years was eligible to participate in the study, hence every individual, residing at the houses selected from the draw was free to participate in the study.

Quota sampling was used to determine the number of participants from each cluster (Yin 2011:4; Dawson 2002:50). According to Masiteng and Schmidt (2016:1) 80% of the South Africa population lives in formal dwellings and 14% in the informal dwellings. Therefore, the researcher sampled only 14% (29) of the participants from the informal settlements, 80% (167) from the formal residential areas, 3% (6) from the central business district and 3% (6) from the population that are housed within the industrial areas. The researcher determined the sample size using *$p < .05$ or 5% margin of error, at 85% confidence level* (Field 2013:282). Thus, 220 participants were sampled, assuming a population size of 56.52 million people (Statistics South Africa 2017:10). On the other hand, assuming the population size of Kempton Park is 171 575 people, using the same parameters *($p < .05$ or 5% margin of error, at 85% confidence level)* to determine the sample size, there was no difference in the sample size. According to Field (2013:282) the significant value of a sample size doesn't change much for populations larger than 100,000 people. The researcher, based on the above assertion in Field (2013:282), is *85%* confident that the results will reflect the perception of the South African population towards modern agricultural biotechnology.

4.4 Data collection instruments

According to Creswell (2012:159) the researchers must select a data generating instrument that is appropriate to the study. The study utilised cross-sectional survey method. A cross-sectional survey can be utilised in examining attitudes, beliefs, opinions, or practices of a given population (Creswell 2012:377) making this method suitable for this study. According to Check and Schutt (2012:160) a survey research is the collection of information from participants through their responses to questions. A survey questionnaire was used to explore and describe the factors that influence perception towards modern agricultural biotechnology (Ponto 2015:168). Although a survey method may use different data collection methods (Ponto 2015:170), the researcher used only a questionnaire which was appropriate to the theory of planned behaviour (Rantanen, Lehto, Vuorinen & Coco 2018:1847; Neuman 2014:316).

In this study, the designing of the questionnaire was guided by Ajzen's theory of planned behaviour[4] and the statistical models[5] adopted for data analysis. A questionnaire is an instrument designed to elicit information from respondents (Babbie 2014:262). This study used 7-point Likert scale type of questionnaire. As recommended in Ajzen and Fishbein (1980), beliefs, attitudes, intention and behaviour, formed the main headlines in the questionnaire. The researcher distributed the questionnaire in person and whenever necessary the researcher assisted respondents in completing the questionnaire. As described in Winter and Cahusac (2014:19) the researcher conducted a Chi-square test to ensure that the sample was representative of the target population. Statistically, if the sample was not significantly representative of the target population, more participants were added to the study, by increasing the confidence level to 95% at 5%

[4] Ajzen (1991) theory of planned behaviour is the theoretical and analytical framework of this study.

[5] Statistical models refer to correlation, regression and MANOVA and these models are described under data analysis.

sampling error. A completed questionnaire was either emailed, or the researcher collected it from the participants.

4.4.1 The questionnaire

As recommended in Ajzen (2006:254) standard scaling procedures were used to construct measures except for background questions. The questionnaire was developed by the researcher in accordance with Ajzen (1991) theory of planned behaviour (Ajzen, 2005; Kilic & Yaman Kasap, 2014) and based on other studies conducted in different countries using the same theory in understanding public perception towards consuming genetically modified crops (Costa-Font 2009; López, Pérez, Fuentes, Luna-Espinoza & Cuevas 2015:2876). The questionnaire consists of three sections, section "A" elicits socio-demographic information; Section "B" consists of general questions with regards to genetically modified crops, and Section "C" consists of beliefs, attitudes, intention and behaviour questions. See table 4.1 below which summarises the breakdown of the questionnaire.

Sections	Headings		Nr of items
Section A	Socio-demographic information		6
Section B	General questions on genetically modified crops		20
Section C	Attitudes	Subjective norms	2
		Attitude towards behaviour	4
		Perceived control	5
	Beliefs	Behavioural beliefs	3
		Normative beliefs	3
		Control beliefs	3
	Intention & behaviour	Behavioural intention	1
		Behaviour	2

Table 4.1 Questionnaire breakdown

As recommended by Ajzen (2002) the questionnaire consists of the 7-likert type scales and the main components of Ajzen (1991) theory of planned behaviour as the main headings of the questionnaire. Socio-demographic factors section has 6 questions. Questions testing participants' general knowledge with regards to modern agricultural biotechnology are twenty (20) items. Questions directly linked to Ajzen (1991) theory of planned behaviour are twenty-three (23) and the breakdown is as follows; items on behavioural beliefs are three (3), attitude towards behaviour four (4), normative beliefs three (3), subjective norms two (2), control beliefs three (3), perceived control attitude five (5), behavioural intention one (1) and behaviour two (2). The questionnaire incorporated variables identified from the elicitation study. As argued in Padden (2013:411) elicitation study can uncover beliefs that change the structure of the questionnaire.

4.5 Data analysis and interpretation

As recommended in Ary et al. (2010:581) the researcher planned data analysis, interpretation and presentation in advance, through coding the questionnaire and developing a data capturing excel sheet which was exported into SPSS. Data was analysed using descriptive and inferential statistics models (Leary 2001:37). As in Makaure (2016:105) preliminary analyses was carried out to check for normality[6], independent of errors[7], homogeneity and multicollinearity[8] of variables, as well as the significance of the sample size. The final data analysis was based on group comparisons, correlations and regression analyses. SPSS was appropriate in this study to analysis and interpret data (Bryman & Carmer 2012:21). The researcher made use of tables and graphs to present the data.

[6] Normality assumption determines whether scores are normally distributed across the sampleas seen by the shape of the diagram (a normally distributed sample has a bell-curved shape (Field 2005).

[7] Independent of error determines whether variables are correlated, and the assumption assumes that variables are uncorrelated (Field 2005).

[8] Multicollinearity means that the variables of interest are highly correlated, and high correlations should not be present among variables of interest (Statistics Solutions 2018:1).

4.5.1 Demographic analysis

The demographic profile of the participants was grouped into different groups based on race, age, gender, income level, as well as education and analysed through descriptive statistics to determine the resemblance of the participants in the study. The independent samples t-test[9] was used to analyse gender differences in predicting acceptance of modern agricultural biotechnology. Spearman's correlation coefficient was used to measure the association between different variables to age, household and education, because these are ordinal scale[10]. Race and academic field group differences were analysed using the analysis of variance (ANOVA)[11] test. ANOVA measured the effect of race and academic fields on acceptance of modern agricultural biotechnology. The results on group differences were correlated with the acceptance of modern agricultural biotechnology behaviour and were used to predict public acceptance of modern agricultural biotechnology in South Africa.

4.5.2 Chi-square analysis

Chi-square test analysis was used to determine the significant difference between the sample and the target population (Neuman 2014:396; Singh 2006:226). The data analysed using the Chi-square, was the data based on gender, race, income level, age and formal education across the sample since the population data is available through the department of Statistics in South Africa. The researcher compared the sample and the target population to determine the significance of the sample in representing the population.

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[9] "Independent samples t-test is used to test different groups of people and assumes that variances in the populations are roughly equal (homogeneity of variance) and that scores are independent (because they come from different people)", say Lumley, Diehr, Emmerson and Chen (2002:154).

[10] In analysing ordinal scale data, Field (2005) recommends researchers to use non-parametric analyses, and Spearman's rank correlation coefficient was selected on this basis.

[11] According to Marczyk et al. (2005:223) "ANOVA is used to determine whether there are any statistically significant differences between the means of two or more independent (unrelated) groups".

4.5.3 Correlation between variables

According to Neuman (2014:414) the purpose of a correlation coefficient (*r*) is to show how much two variables "go together" or vary in correlation. The nature of the relationships between beliefs (behavioural, normative and control), attitudes (attitude towards behaviour, subjective norm and perceived behavioural control), behavioural intention and behaviour was established through correlation testing. According to Dörnyei (2007:223) the strength and direction of the relationship between variables is measured through correlational analysis.

Spearman's rank order correlation coefficient (*r*) was used to measure the relationship between variables. According to Jackson (2009:57) Spearman's *r* measurement of greater than *.50* is considered a moderately high coefficient, demonstrating a strong relationship between the variables whilst an *r* of below .30 is indicative of a weak correlation. Correlation coefficient (*r*) will determine whether there is a relationship between beliefs, attitudes and behaviour in public acceptance of modern agricultural biotechnology.

4.5.4 Linear regression and AMOS path analyses

Regression[12] analysis explored the possible relationships between socio-demographic factors, beliefs, attitudes and behaviour. Firstly, regression analysis assessed the predictive power of beliefs (independent variables) on attitude towards consuming genetically modified crops (dependent variable). Secondly, regression analysis assessed the predictive power of attitudes (independent variables) on the intention to accept modern agricultural biotechnology (dependent variable). Thirdly, regression analysis assessed the predictive power of intention (independent variable) on the behaviour i.e. acceptance of modern agricultural biotechnology (dependent variable). Lastly, regression analysis assessed the predictive power of independent variables, for instances socio-demographic factors on dependent variable (modern agricultural biotechnology behaviour).

[12] Regression analysis evaluates the relative impact of a predictor variable on an outcome (Zou, Tuncali & Silverman 2003:618; Kothari 2004:141).

AMOS path analysis[13] was used to ascertain the applicability of the theory of planned behaviour in analysing public perception towards accepting modern agricultural biotechnology. The relationships between beliefs, attitudes and behaviour towards modern agricultural biotechnology were analysed within Ajzen (1991) theory of planned behaviour. According to Ajzen (1991) behaviour is an outcome of beliefs and attitudes mediated through the intention towards the behaviour. Socio-demographic factors were also assessed through Ajzen (1991) theory of planned behaviour but not as background factors as theorized in Ajzen (1991) theory of planned behaviour (Ajzen 2006:134)[14]. The study sought to determine the significance of socio-demographic factors in influencing behaviour without being mediated through the theory of planned behaviour.

4.6 Research reliability and validity

According to Ary et al. (2010:236), reliability is the degree of consistency with which an instrument measures whatever it is measuring. Research procedures ensured the questionnaire guaranteed reliability by ensuring that similar answers are obtained repeatedly (Kumar 2012:98). A test-retest method was used in this case. The questionnaire was administered to 5 participants who completed the questionnaire twice, at a two-week interval and data analysis determined whether similar answers were obtained.

In addition, the researcher applied Ajzen (1991) theory of planned behaviour guidelines for developing a questionnaire for the study. Using Ajzen (1991) theory of planned behaviour questionnaire guidelines enhances the reliability of the questionnaire (Javadi, Kadkhodaee, Yaghoubi, Maroufi & Shams 2013:52). The Cronbach's alpha[15] was applied in calculating the reliability of the

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[13] SPSS AMOS path analysis is best used when there are two or more dependent variables (Field 2005).

[14] According to Ajzen (1991) theory of planned behaviour background factors may influence behavioural, normative or control beliefs and they can guide the theory (Ajzen,2005:134).

[15] According to Arthur-Aidoo, Aigbavboa and Thwala (2017:174) Cronbach's alpha is a measure of internal consistency, that is, how closely related a set of items are as a group and it is a measure of scale reliability.

questionnaire. According to Field (2013:2036) the Cronbach's alpha can measure Likert scale questionnaire with accuracy. The Cronbach's alpha result is a number between 0 and 1, with the acceptable reliability score being *.7* and higher (Heale & Twycross 2015:67).

According to Field (2013:114) validity refers to whether an instrument measures what it was designed to measure. As argued by Bernard (2006:38) validity is often an important issue when using a questionnaire and when measuring abstract concepts such as attitudes and beliefs. However, validity does not focus only on the research instruments but also on data analysis and interpretation (Ary et al. 2010:225). Validity is the degree to which data and theory support the data interpretations (Downing 2003:830). The researcher has put in place several procedures to ensure research validity.

The sample size has been determined using SPSS i.e. at 5% margin of error and 85% confidence level, 220 participants participated in the study. Elicitation study was conducted to determine public salient beliefs towards genetically modified crops in South Africa and the findings were incorporated in the questionnaire. When using the theory of planned behaviour, elicitation studies are recommended in establishing the people's salient beliefs (Downs & Hausenblas 2005:1). Pilot study determined the feasibility of the study, and evaluated the complexity of questionnaire (Hassan, Schattner & Mazza 2006:7; Pilot, Beck & Hungler 2001:467; Punch 2009:43). As recommended in Litosseliti (2010:52) research questions were clearly-defined, to ensure the study generated appropriate data. The stated procedures guaranteed research validity. Exploratory Factor Analysis[16] was used in measuring the validity of the questionnaire.

[16] Exploratory factor analysis determines the validity of test or questionnaire and is used to reduce the data into smaller sets of constructs (Field 2005:619).

4.7 Ethical considerations

The researcher guaranteed ethical practices throughout the research process and took full responsibility in specifying and adhering to procedures safeguarding participants' rights and dignity (Altermatt 2011:2). The researcher sought informed consent from participants. Informed consent is the cornerstone of human rights protections (Marczyk, DeMatteo & Festinger 2005:246). As described in O'Mathúna (2012:81) participants participated on a voluntary basis. Participants were briefed on the nature and purpose of the study, as well as informed of their right to withdraw their participation from the study at any point without any consequences.

The researcher reported the findings truthfully, accurately and the work of other scholars was cited appropriately (Scott 2013:86). It was in the interest of the researcher to respect the participants and other academics through reporting the results accurately and avoiding plagiarism at all cost. For instance, the researcher refrained from making inappropriate and biased conclusions based on data analysis (Doyal & Tobias 2001:41; Cohen, Manion & Morrison 2018:197). The findings of this study might be used in policy making hence the study guaranteed validity by avoiding inappropriate conclusive statements. Participant's anonymity and confidentiality were guaranteed and respected (de Raeve 1996:114). Data collected was considered confidential and will not be shared with anyone outside of research (Creswell 2012:169). The completed questionnaire will be made available to the supervisor or the University of South Africa, who shall treat the information as confidential.

As a requirement in UNISA Policy on Research Ethics (2007:3) the researcher sought the ethical clearance from the UNISA Ethics Review Committee, to collect data from participants. An ethical clearance confirms that the study meets the minimum level of ethical considerations required to conduct a study of this scope in South Africa. As recommended in Creswell (2009:87) the researcher followed the procedures set by the UNISA Ethics Review Committee which promote research integrity. Lastly, it is important to highlight that there are no risks identified in conducting this study by the researcher or known risks published by other researchers who have conducted similar studies in South Africa and other countries.

4.8 Preliminary studies

Two preliminary studies were carried out before the main data collection commences, namely elicitation and pilot studies, to ensure research reliability and validity.

4.8.1 Elicitation study

Elicitation studies are recommended when using Ajzen (1991) theory of planned behaviour to establish public beliefs and attitudes towards a phenomenon under investigation (Downs & Hausenblas 2005:1). As described in Hickey and Davis (2003:1) elicitation study will determine behavioural, normative, and control beliefs towards genetically modified crops in South Africa. As noted by Sutton, French, Hennings, Mitchell, Wareham, Griffin, Hardeman and Kinmonth (2003:236), there is little elicitation research that has been published in South Africa on public beliefs and attitudes towards genetically modified crops. Thus, the elicitation study identified public salient beliefs and the researcher confirmed the beliefs identified through literature review.

The elicitation study was carried out with 20 purposively sampled participants. According to Palys (2008:698) the general guiding principle for using purposive sampling is that the researcher focuses much on participants that have the largest potential for advancing the researcher's understanding. The sample must be representative of the target population (Downs & Hausenblas 2005:3). The researcher administered an open-ended questionnaire. The researcher acknowledged that 20 participants make a small sample size. Given the 220 participants sampled in the study, at 80% confidence level and 5% margin of error, the elicitation sample must have 92 participants. For these reasons, the elicitation findings were not reported, but were used to assess whether salient beliefs were included in the study.

Participants were asked to write answers to open-ended questions regarding their beliefs on genetically modified crops. To induce behavioural beliefs, participants were asked to specify advantages and disadvantages of modern agricultural biotechnology. Participants were asked to list individuals who would approve or disapprove their decisions to buy and/or consume genetically modified crops to provide data on their normative beliefs. Finally, in order to elicit control beliefs, participants were asked to tally factors or circumstances that would facilitate or hinder their decision to buy and /or consume genetically modified crops.

4.8.1.1 Analysis of elicitation data

Content analysis is recommended to analyse elicitation data (Ajzen 2006). Content analysis focused on identifying people's salient beliefs towards modern agricultural biotechnology. Content analysis enables the data to be explored quantitatively (Sutton et al. 2003:237). After identifying themes, beliefs were ranked, statistically. Popular beliefs were included in the main study. Studying the beliefs that do not characterise the target population can compromise the research reliability and validity (Bellows-Riecken, Mark & Rhodes 2013:791). Therefore, elicitation study was carried out to determine popular beliefs in South Africa towards genetically modified crops and modern agricultural biotechnology.

4.8.2 Pilot study

Pilot study determines the feasibility of the study (Hassan et al. 2006:7; Pilot et al. 2001:467). Pilot study was conducted with 5 participants. The pilot study is significant in guaranteeing research validity and reliability (Padden 2013:410). T and was used in this study in order to evaluate whether the question items were clear (Punch 2009:43). The test-retest method constituted part of the pilot study intending to measure the reliability of the questionnaire. The pilot study ascertained whether the questionnaire was not too long and time consuming. A very long questionnaire frustrates and exhausts the respondent (Steenekamp 1989:234). Like with the elicitation study, the pilot study had no statistically significant results, and it was conducted to determine the feasibility of the study and to test the reliability of the questionnaire.

4.9 Conclusion

This chapter outlined the research methodology used in studying public perception towards modern agricultural biotechnology using Ajzen (1991) theory of planned behaviour. This study adopted quantitative research design and data analysis was facilitated using the SPSS package. Descriptive statistics, correlation and regression models were adopted in data analysis and interpretation. Procedures to ensure research validity and reliability, as well as ethical considerations have been described and explained. The next chapter will focus on the actual data analysis, presentation and interpretation.

CHAPTER 5

DATA ANALYSIS, PRESENTATION AND INTERPRETATION

This chapter focuses on analysis, presentation and interpretation of data generated through the questionnaire. The primary objective of the study is to understand public perception towards genetically modified crops through investigating beliefs and factor that influence public willingness to consume genetically modified crops and accept modern agricultural biotechnology in South Africa. The researcher used a series of statistical analysis, both parametric and non-parametric, in answering the research questions. This chapter firstly outlines, construct validity and internal reliability of the questionnaire, using the exploratory factor analysis[1] and Cronbach's Alpha (α)[2], respectively. Constructs[3] were determined by exploratory factor analysis and Cronbach's α. Secondly, the results of parametric assumptions[45] are presented. Parametric assumption tests determine statistical models to be used for the data (Field 2005). Thirdly, the researcher presented the descriptive statistics of the sample (*N=220*) descriptive statistics and Chi-square test results. The Chi-square[6] was used to ascertain the significant difference of the sample (*N=220*) from the target population. Fourthly, the descriptive statistics for the constructs was presented, followed by the presentation of data using t-test, correlations, one-way analysis of variance, multiple linear regression and the path analysis. Lastly, the researcher presented the concluding remarks and highlighted the content of the next chapter.

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[1] Exploratory factor analysis is a statistical analysis model from the SPSS package, which measures validity of the test items.

[2] Cronbach's Alpha is a SPSS statistical analysis model which measures reliability of test items (Williams, Onsman & Brown 2010).

[3] concepts measured with the question items

[4] Parametric statistical procedures rely on assumptions about the shape of the distribution (i.e., assume a normal distribution) in the underlying population and about the form or parameters (i.e., means and standard deviations) of the assumed distribution (Hoskin 2000:2).

[5] Assumptions tests for parametric conducted in this study are normality, independent error, multicollinearity and homogeneity of variance (Hair, Black, Babin & Anderson 2014)

[6] Chi-square model is used to test the association between categorical variables and it helps in determining whether the observed items are significantly different from the expected (Lani 2018:2).

5.1 Research validity and reliability

The researcher used exploratory factor analysis to determine the construct validity of items and Cronbach's α to check for internal consistency. Exploratory factor analysis was instrumental in summarising and defining fundamental constructs contained in the questionnaire (Scharf & Nestler 2018:119). Data generated for this study was substantial, due to the design of the questionnaire as recommended in Ajzen (1991), hence, it was significant that factor analytic techniques were applied. Factor analysis reduced variables into manageable sets (Williams et al. 2010:2).

Exploratory factor analysis statistically determines the extent to which items measure the intended constructs (Heale & Twycross 2015:66). Exploratory factor analysis reduces the researcher's bias in grouping items for specific constructs (Hair et al. 2014:602). It is, therefore, an objective grouping technique. Objective techniques are not subjected to researcher biases (Jahedi & M´endez 2013:79). Since the researcher intended to use parametric and structural equation modelling[7], it was important to determine construct validity. Structural equation modelling provides researchers with a comprehensive way of assessing the applicability of a theory to a given scope (Anderson & Gerbing 1988:411). Construct validity is, therefore, instrumental in determining the appropriateness of parametric analysis. In this study, exploratory factor analysis was used to summarise data, measure construct validity, and determine the suitability of conducting parametric analysis.

The internal consistency[8] of a questionnaire, as determined by Cronbach α was an important factor in ensuring that the research findings were reliable.

[7] Structural equation modelling (SEM), as a concept, is a combination of statistical techniques such as exploratory factor analysis and multiple regression. The purpose of SEM is to examine a set of relationships between one or more Independent Variables (IV) and one or more Dependent Variables (Schumacker & Lomax 2004:324).

[8] Conceptually, the internal consistency of a questionnaire indicates whether items on a questionnaire that are intended to measure the same construct, produce consistent scores, for instance, if, ten items are designed to measure the same construct, an individual should answer these items in the same way, which would suggest that the questionnaire has internal consistency (Tang, Cui & Babenko 2014:206; Cortina 1993:98).

Determining the internal consistency of the questionnaire was significant because of numerous items measuring few constructs. Cronbach's α, as a statistic value, shows how items fit to measure a construct (Taber 2016:1). Cronbach's α[9] is an important statistic value in determining internal reliability. Internal reliability is an extent to which data collection instruments produce the same results on repeated trials (Bolarinwa 2015:198). The results for exploratory factor analysis and Cronbach's α are presented in the following section.

5.1.1 Construct validity

Exploratory factor analyses are performed with large sample and often discouraged with a sample size of less than 50[10] (de Winter, Dodou & Wieringa 2009:214). Large sample size ($N > 50$) yields reliable factor analysis results (Surastina & Dedi 2018:17). Therefore, the sample ($N=220$) was sufficient for the researcher to use exploratory factor analysis in determining construct validity.Results from exploratory factor analysis are presented in the Table 5.1 below.

The first column contains the research constructs, e.g. the researcher intended to measure "Public knowledge on genetically modified crops", with questionnaire items, "B1a & B1b" in the second and fourth columns. The third, and fifth columns contain "factor loading" values[11]. The sixth and seventh columns contain "percent of variance explained"[12] by selected items for a given construct and the Cronbach's α coefficient[13], respectively.

[9] Cronbach's alpha measures the reliability of a test or questionnaire items, and it should not be misunderstood with the general research reliability. However, internal consistency of a questionnaire forms part of the general research reliability.

[10] A sample size of 50 in factor analysis is considered a reasonable absolute minimum threshold (Velicer & Fava, 1998:236).

[11] Factor loading is the relationship of each items to the underlying construct (Rahn 2018:1). For instance, item C3c, its factor loading value is .979 implying that 0.979 or 97.9%, of the variability in "Labelled GM crops are safe" is explained by item C3c.

[12] The 'total variance explained' is the amount of variance in each construct (e.g. "Labelled GM crops are safe" in Table 5.1) that can be explained by the retained items (for instance C3a, C3b & C3c in the Table 5.1) after running factor analysis (Field 2005:654).

[13] Cronbach's α reliability coefficient measures the internal consistency (reliability) of the questionnaire (Gliem & Gliem 2003:87; Streiner 2003:101).

Construct	Items	Factor Loading	Items	Factor Loading	Total variance explained	Cronbach's α
Public knowledge on GM crops	B1a	.983	B1b	.983	96.604	.965
Public awareness	B10a	.990	B10b	.990	98.052	.980
Public engagement in GMOs policy making	B3a	.983	B3b	.983	64.858	.966
Public trust on GM crops regulations	B5a	.878	B6a	.890	77.518	.903
	B5b	.876	B6b	.878		
Public wants GM crops to be labelled	B8a	.971	B8b	.971	94.28	.939
Public eating GM crops willingly	B9a	.975	B9c	.984	95.683	.977
Public accepting GM crops	B11a	.965	B11c	.974	94.742	.972
Public perceived human health and environmental benefits over GM crops	B12a	.866	C1b	.786	70.394	.915
	B12b	.884	C2a	.868		
	C1a	.775	C2b	.850		
Human health and Environment safety beliefs	C1a	.980	C1b	.980	95.985	.958
Labelled GM crops are safety	C3a &C3b	.978	C3c	.979	95.695	.977
Important people's approval of GM crops	C5a	.922	C5d	.952	89.201	.969
	C5b	.949	C5e	.946		
Important people's eating of GM crops	C6a	.973	C6c	.979	94.983	.973
Will eat GM crops if less expensive	C8a	.980	C8c	.975	94.290	.979
	C8b	.982	C8d	.947		
Will eat GM crops if I know how they are produced	C9a	.973	C9c	.978		
	C9b	.975	C9d	.965	94.627	.981
Will eat GM crops if they are available always	C10a	.970	C10c	.980	93.685	.977
	C10b	.957	C10d	.965		
Positive healthy attitude	C11b	.979	C11c	.982	95.723	.977
Positive eating attitude	C12a	.913	C12d	.959	90.220	.972
	C12b	.965	C12e	.948		
Positive production of GM crops attitude	C13a	.951	C13c	.976	89.900	.961
	C13b	.980	C13d	.882		
Positive accepting MAB attitude	C14a	.959	C14c	.980	94.632	.981
	C14b	.971	C14d	.981		
Significant others' eating of GM crops	C16a	.985	C16b	.985	97.067	.970
Significant others approve that I eat GM crops	C17a	.991	C17b	.991	98.150	.981
My eating of GM crops is the significant others' decision	C18a	.991	C18b	.991	98.109	.981
Will eat GM crops if I can afford organic crops	C19a	.970	C19c	.969	94.333	.970
Will eat GM crops if government bans them	C20a	.972	C20c	.988	96.434	.981
Will eat GM crops if they are always available	C21a	.986	C21c	.981	96.974	.984
Will eat GM crops because I'm knowledgeable they are safe to eat	C22a	.982	C22b	.982	96.461	.963
Will eat or not eat GM crops, freely	C23a	.991	C23b	.991	98.212	.982
Will intent to buy genetically modified crops	C24a	.978	C24c	.985	96.443	.987
	C24b	.983	C24d	.982		
Will intent to eat genetically modified crops	C25a	.984	C25c	.990	97.228	.990
	C25b	.990	C25d	.981		
Will intent to accept MAB	C26a	.984	C26c	.991	97.464	.991
	C26b	.988	C26d	.986		
Will intent to support farmers of genetically modified crops farming	C27a	.987	C27c	.995	98.226	.994
	C27b	.991	C27d	.992		
Will accept eating genetically modified crops	C28a	.978	C28c	.988	96.077	.986
	C28b	.976	C28d	.979		
Will accept MAB in crop production	C29a	.986	C29c	.992	97.689	.992
	C29b	.993	C29d	.983		

Table 5.1 Construct validity and internal consistency items results (2018).

Factor loading determines the strength of the relationships between items and constructs. The possible values for factor loading range from *-1* to *+1*. Factor loading is the correlations between items and constructs (Scharf & Nestler 2018:121). The closer the value to *-1* or *+1* the stronger the relationship, and closer to zero, explains a weak or no relationship between items and constructs

(Yong & Pearce 2013:84). Although loading value of *.3* can be significant, the significance, mainly depends on the sample size (Field 2005:637). According to Sevens (1992:382) for a sample size of 200, loading values should be greater than *.4 (point four)*. In this study, factor loading values are above *.7*, indicating strong relationships between items and constructs. High factor loading implies that items strongly correlate with constructs (Rietveld & Van Hout 1993:264).

Total variance explained is expressed as percent, and the higher the percent, the more significant the factors in explaining the variance in a construct. According to Williams et al. (2010:6) there is no fixed percent threshold for the acceptable total variance explained percent. Hair et al. (2014:107), suggest a total variance of 60 percent to be acceptable. The total variance explained value for items C3a, C3b and C3c in Table 5.1, is 95.695% which implies that 96% of the variability in “Labelled GM crops are safe” is explained by these 3 items (C3a, C3b and C3c) combined. In Table 5.1 all the constructs obtained more than 70% of the total variance explained, which is greater than 60%, implying that construct validity was statistically significant.

5.1.2 Internal consistency

The researcher used the Cronbach’s α to measure the internal consistency of the questionnaire. Results are also shown in Table 5.1. Cronbach’s α reliability coefficient ranges between *0* and *1* (Gliem & Gliem 2003:87) and the closer to *1,* the greater the internal consistency of the questionnaire (Streiner 2003:101). When the questionnaire is perfectly uncorrelated, the α coefficient equal zero; and when items are perfectly correlated the α coefficient equal *1* (Ritter 2010:09). Low internal consistency implies that data becomes less useful for analysis. The researcher conducted the elicitation and pilot study before the main data collection and the findings of both studies were implemented. Findings of elicitation and pilot studies include reversing and rephrasing some of the questionnaire items, as well as identifying beliefs held by the people on genetically modified crops.

The researcher used the Cronbach's α to determine internal consistency of data collected for the main study. As in Maiyaki and Mokhtar (2011:194) the Cronbach's α could have been used to analyse data from the pilot study, but the pilot study sample size was too small (*N=20*), to warrant reliable reliability results. However, in this study, the researcher used the Cronbach's α to determine internal consistency of selected items for given constructs. For instance, in Table 5.1, Cronbach's α measured with items C3a, C3b and C3c in relation to the construct "Labelled genetically modified crops are safe to eat" shows a high Cronbach's α coefficient of *.977*, therefore internal reliability of these questionnaire items (C3a, C3b and C3c) was statistically significant. According to Cronbach in Field (2005:668), if several factors exist in the questionnaire, Cronbach's α must be applied separately to items relating to different constructs. Thus, the researcher applied the Cronbach's α, separately on different items, to determine internal reliability of items.

Questions B2, B4, B7, C4, C7 and C15 were dropped after failing to satisfy exploratory factor analysis (construct validity) and Cronbach's α (internal consistency). Questions B4b, C1a, C1b, C19a, C19b, C19c, C20a, C20b and C20c were reversed *(1=7; 2=6; 3=5; 4=4; 5=3; 6=2 & 7=1)* since the responses were recorded on a different scaling to the other items. In the following section, the results from the assumption tests of parametric analysis are presented and interpreted.

5.2 Assumptions of parametric analysis measures

The researcher used parametric and non-parametric analysis. According to Neideen and Brasel (2007:93) parametric analyses require less data to make stronger conclusions. However, parametric analysis cannot be used to analyse ordinal data (Mircioiu & Atkinson 2017:10), thus Spearman's ranked correlation coefficient[14] was conducted instead, to analyse the data pertaining to age,

[14] Spearman's ranked correlation coefficient is a non-parametric data analysis technique which is used when data violates the assumptions of parametric data analyses or when analysing ordinal Likert scales for example household income and age.

household income and education, because these factors cannot be ranked[15]. The researcher conducted four assumption tests to determine the appropriateness of parametric analysis[16] (Williams, Grajales & Kurkiewicz 2013:1). Parametric assumptions include randomization, independence, normality, linearity and variance (Nimon 2012:1) and the researcher measured normality, independent errors, multicollinearity and homogeneity of variance. Serious assumptions violation compromises the research reliability and validity.

5.2.1 Normality

Normality must be met or assumed for researchers to conduct parametric analysis (Field 2000:93). Normality measures whether the sample is normally distributed. Normal distribution in a population occurs naturally and a sample is normally distributed when data splits into approximately two equal halves on a histogram (Ahsanullah, Kibria & Shakil 2014:7), when the distribution is bell-shaped (Stahl 2006:96), the skewness[17] number is between *−½* and *+½* and the kurtosis[18] is exactly *3* (Brown 2011:5)[19]. Normality can be assessed using the Chi-square, Kolmogorov-Smirnov, Anderson-Darling and Shapiro Wilk tests. In this study, normality was assessed using the Shapiro-Wilk test. Shapiro-Wilk test is the best choice for testing normality (Ghasemi & Zahediasl 2012:489). Normality is achieved when the Shapiro-Wilk test is non-significant $(p > .05)$ (Field 2005:93).

[15] By ranking the researcher implies that one cannot place these variables in order of importance, for instance an academic qualification from the Faculty of Science cannot be ranked higher than the qualification from Human Sciences, nor can one place household incomes in a hierarchical order starting the highest ranked income to the least income.

[16] According to Neideen and Brasel (2007:93) researchers can assume (that is when the assumptions of parametric analyses are violated) data as having met the requirements of parametric data analysis.

[17] Skewness is a measure of the symmetry of a distribution compared to a normal distribution. A positively skewed distribution has relatively few large values and tails off to the right, and a negatively skewed distribution has relatively few small values and tails off to the left. Skewness values falling outside the range of -1 to +1 indicate a substantially skewed distribution. (Hair et al. 2014:34).

[18] Measure of the peaked-ness or flatness of a distribution when compared with a normal distribution, whilst a positive value indicates a relatively peaked distribution, and a negative value indicates a relatively flat distribution. (Hair et al. 2014:33).

Table 5.2 summarises results of the Shapiro-Wilk test, skewness and kurtosis coefficient. Results show that normality was violated, i.e. *($p < .05$)*.

Construct	Shapiro-Wilk			Skewness	Kurtosis
	Statistic	df	Sig.		
Public knowledge on genetically modified crops	.868	220	.000	.259	-1.405
Public awareness on genetically modified crops	.683	220	.000	1.458	.838
Public engagement in genetically modified crops policy making	.618	220	.000	2.160	4.105
Genetically modified crops must be labelled	.587	220	.000	-2.465	5.967
Public eating genetically modified crops, willingly	.871	220	.000	.451	-1.141
Public acceptance of genetically modified crops	.916	220	.000	.173	-1.202
Public perceived human health and environmental risks over genetically modified crops	.930	220	.000	.590	-.574
Genetically modified crops are labelled in shops	.801	220	.000	.878	-.423
Harmful to environment beliefs	.889	220	.000	.363	-1.125
Human health safety beliefs	.869	220	.000	.430	-1.174
Labelled genetically modified crops are safety to eat	.887	220	.000	.062	-1.397
Important people approval of genetically modified crops	.937	220	.000	.231	-.920
Important people eat genetically modified crops	.862	220	.000	.424	-1.229
Will eat genetically modified crops if less expensive	.882	220	.000	-.140	-1.462
Will eat genetically modified crops if I know how they are produced	.925	220	.000	-.203	-1.150
Will eat genetically modified crops if they are available always	.925	220	.000	-.058	-1.164
Healthy attitude	.886	220	.000	.448	-1.065
Eating attitude	.916	220	.000	.459	-.870
Growing/farming attitude	.926	220	.000	.089	-1.006
Acceptance attitude	.908	220	.000	.120	-1.253
Significant others eat genetically modified crops	.878	220	.000	.544	-.896
Significant others approve that I eat GM crops	.878	220	.000	.544	-.896
Eating genetically modified crops is the significant others' decision	.843	220	.000	-.500	-1.227
Will eat genetically modified crops is affording organic crops	.798	220	.000	.833	-.653
Will eat genetically modified crops if government bans them	.830	220	.000	.758	-.681
Will eat genetically modified crops if they are always available	.921	220	.000	-.051	-1.153
Will eat genetically modified crops because I'm knowledgeable they are safe to eat	.897	220	.000	.413	-.922
Will eat or not eat genetically modified crops, at will	.860	220	.000	-.379	-1.293
Will intend to buy genetically modified crops	.888	220	.000	.362	-1.187
Will intend to eat genetically modified crops	.850	220	.000	.520	-1.160
Will intend to accept modern agricultural biotechnology	.881	220	.000	.355	-1.249
Will intend to support farmers in growing genetically modified crops	.889	220	.000	.133	-1.391
I accept eating genetically modified crops	.866	220	.000	.441	-1.212
I accept modern agricultural biotechnology in crop production	.899	220	.000	.109	-1.323

Table 5.2 Measure of normality (2018).

The skewness and Kurtosis coefficients confirm non-normality of the sample distribution. Data in Table 5.2 shows both positive and negative skewed distribution, with a relatively flat distribution across variables.

However, as argued in Tabachnick and Fidell (2007) the sample size (*N=220*) of this study was sufficient to be considered a normal distribution. Ghasemi and Zahediasl (2012:486), argue that in large samples ($n > 30$), sampling distribution tends to be normal, regardless of data shape. The argument in Ghasemi and Zahediasl (2012) is in-line with the empirical law of large numbers.[20] The sample size *(N=220)* is large to estimate the population parameters and to meet normality. Based on the empirical law of large numbers, normality of the sample can be assumed.

5.2.2 Independent errors

Independent error assumes predictor values to be uncorrelated (Field 2005:170) and violation[21] of assumption leads to biased estimates of standard errors (Williams et al. 2013:9). Assumption violation occurs when each predictor is related to its immediate predecessor (Schneider, Hommel & Blettner 2010:777). Errors of one variable should not affect other variables. Table 5.3 shows the results of independent errors with ZRESID, ZPRED, and Durbin-Watson[22].

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	1.000[a]	1.000	1.000	.000	2.011

Table 5.3 Durbin-Watson statistic value for independent errors

[20] The empirical law of large numbers states that larger samples generally lead to more accurate estimates of population means (Sedlmeier & Gigerenzer 1997:35).
[21] When independence of errors is violated standard scores and significance tests will not be accurate (Stevens 2009:341).
[22] The Durbin Watson statistic is a number that tests for autocorrelation in the residuals from a statistical regression analysis and values from 0 to less than 2 indicate positive autocorrelation and values from more than 2 to 4 indicate negative autocorrelation (Investopedia 2018).

Durbin-Waston statistic varies between *0* and *4*, with a value of *2* meaning that the residuals are uncorrelated (Field 2005:170). Durbin-Watson statistical value of *2.011* was obtained, which is very close to the value of *2*. Data satisfied the independence of errors assumption, as the results show data to be uncorrelated.

5.2.3 Multicollinearity[23]

Multicollinearity causes redundant information (Yoo, Mayberry, Bae, Singh, Peter & Lillard 2014:10). As multicollinearity increases, interrelationships among variables also increase making it more difficult to ascertain the effect of a single predictor variable (Yoo et al. 2014:10). Multicollinearity between variables makes it difficult to assess the individual importance of a variable in predicting behaviour. Variables must not be correlated. For example, question items measuring beliefs, attitudes and intention must be uncorrelated. If question items are correlated, it would be difficult to single out variables which statistically significantly predict behaviour.

The researcher used collinearity tolerance and variance inflation factor (VIF) statistics to measure the multicollinearity between variables. According to Field (2005:175) the reciprocal of tolerance is known as VIF. A tolerance close to *1* means there is little multicollinearity, whereas a value close to *0* suggests multicollinearity. VIF indicates whether a variable has a strong linear relationship with other variables (Field 2005:175). A strong relationship among variables is a violation of multicollinearity assumption. The accepted values for VIF ranges from *.1* and *10* (Myers 1990:356; Bowerman & O'Connell 1990; Menard 1995) showing variables to be uncorrelated or weak correlations between variables. Table 5.4 below shows the VIF and tolerance statistics for study variables.

[23] Causes of multicollinearity may include improper use of variables (e.g. failure to exclude one category), including a variable that is computed from other variables in the equation and including the same or almost the same variable twice. The above all implies some sort of error on the researcher's part, but it may just be that variables really and truly are highly correlated (Hair et al. 2014).

All variables reported in Table 5.4 have obtained a VIF value within the recommended range of *.1* and *10*. However, there are variables with tolerance statistic values closer to *0*, suggesting multicollinearity of variables. Comparing the two collinearity statistics (tolerance and VIF) the researcher concluded that the assumption of multicollinearity holds for the variables.

	Collinearity Statistics	
Constructs	**Tolerance**	**VIF**
Public knowledge on genetically modified crops	.662	1.512
Public awareness on genetically modified crops	.813	1.229
Public engagement in genetically modified crops policy making	.742	1.347
Public trust on genetically modified crops regulations	.614	1.627
Genetically modified crops must be labelled	.819	1.221
Public eating genetically modified crops, willingly	.413	2.424
Public acceptance of genetically modified crops	.348	2.875
Public perceived human health and environmental risks over genetically modified crops	.294	3.401
Genetically modified crops are labelled in shops	.627	1.595
Labelled genetically modified crops are safety to eat	.523	1.912
Important people approve genetically modified crops	.338	2.956
Important people eat genetically modified crops	.388	2.580
Will eat genetically modified crops if less expensive	.250	4.007
Will eat genetically modified crops if I know how they are produced	.356	2.809
Will eat genetically modified crops if they are available always	.185	5.398
Healthy attitude	.178	5.628
Eating attitude	.132	7.584
Growing attitude	.170	5.889
Acceptance attitude	.162	6.156
Significant others approve that I eat genetically modified crops	.357	2.805
Eating genetically modified crops is the significant others' decision	.635	1.575
Will eat genetically modified crops is affording organic crops	.380	2.630
Will eat genetically modified crops if government bans them	.548	1.825
Will eat genetically modified crops if they are always available	.347	2.884
Will eat genetically modified crops because I'm knowledgeable they are safe to eat	.459	2.181
Will eat or not eat genetically modified crops at will.	.748	1.336
Will intend to eat genetically modified crops	.106	9.399
Will intend to buy genetically modified crops	.134	7.472
We intend to accept modern agricultural biotechnology	.129	7.780
Will intend to support farmers for farming genetically modified crops	.211	4.746
I accept eating genetically modified crops	.144	6.922
I accept the use of modern agricultural biotechnology	.186	5.379

Table 5.4 results for the assumption of multicollinearity (2018).

5.2.4 Homogeneity of variance

According to Abdi (2008:01) homogeneity of variance is one of the critical assumptions underlying parametric analysis. According to Lani (2013:1) homogeneity of variance is an assumption of the Analysis of Variance (ANOVA)[24] which checks for group differences. According to Abdi (2008:02) homogeneity of variance tests include Hartley's F_{max}, Cochran's, Levene's and Barlett's tests. Several of these tests have been found to be too sensitive to non-normality, hence Levene's test is frequently used to test for homogeneity of variance (Lani 2013:2). The researcher, also, used Levene's test in this study. Levene's test is calculated by diverging data for each group from the group mean, and then comparing the absolute values and it is presented with the F statistic (Field 2005:97). Homogeneity of variance is met when test results are non-significant ($p > .05$) and is violated when $p < .05$. According to Field (2005:99) when Levene's test is significant ($p < .05$), variances are not the same and the homogeneity of variance assumption has been violated. Table 5.5 below contains Levene's test results of homogeneity of variance.

Generally, the homogeneity of variance assumption has been met in approximately 75% of the variables. As recommended in Field (2005:98) the researcher also tested the Levene's test when exploring inferential statistical data and results were discussed on constructs analyses basis.

[24] ANOVA is the abbreviation for analysis for variance. ANOVA is a statistical model which tests for group difference.

Constructs	Age		Gender		Race		Household income		Education		Academic Field	
	Levene Statistic	Sig.	Levene Statistic	Sig.	Levene Statistic	Sig.	Levene Statistic	Sig.	Levene Statistic	Sig.	Levene Statistic	Sig.
Public knowledge on GM crops	.328	.805	1.030	.311	1.478	.221	2.904	.023	1.658	.146	1.274	.276
Public awareness on GM crops	4.209	.006	.680	.410	4.318	.006	3.940	.004	1.611	.158	6.887	.000
Public engagement in GM crops policy making	.947	.419	.189	.664	1.609	.188	8.113	.000	2.594	.027	3.115	.008
Public trust on GM crops regulation	.750	.524	.055	.814	1.598	.191	.493	.741	.518	.762	1.152	.338
GM crops must be labelled	13.174	.000	5.190	.024	3.395	.019	2.245	.065	2.527	.030	1.393	.225
Public eating GM crops willingly	3.195	.024	1.345	.247	.560	.642	1.988	.097	.382	.861	.841	.541
Public acceptance of GM crops	2.829	.039	1.633	.203	1.245	.294	1.132	.342	2.239	.052	.420	.214
Perceived human health and environmental risks over GM crops	3.082	.028	2.308	.130	1.226	.301	1.529	.195	2.464	.034	1.633	.145
GM crops are labelled in shops	2.368	.072	.664	.416	7.862	.000	.992	.413	3.579	.004	3.241	.006
Harmful to environment beliefs	4.139	.007	3.724	.055	.522	.668	2.729	.030	1.859	.103	.656	.685
Human health safety beliefs	4.725	.003	.269	.605	.117	.950	.612	.655	1.621	.156	1.604	.153
Labelled GM crops are safety to eat	.500	.683	.760	.384	2.934	.034	1.416	.230	1.644	.150	.414	.868
Important people approve that I eat GM crops	.976	.405	.198	.657	1.827	.143	3.049	.018	2.304	.046	1.418	.215
Important people eat GM crops	1.846	.140	2.729	.100	4.054	.008	4.765	.001	5.469	.000	1.236	.294
Will eat GM crops if less expensive	1.027	.382	.235	.628	1.923	.127	1.864	.118	2.756	.020	1.512	.181
Will eat GM crops if I know how they are produced	1.087	.355	.081	.777	1.172	.321	.939	.442	2.521	.030	.405	.874
Will eat GM crops if they are available always	.861	.462	2.628	.106	.696	.555	.864	.487	2.199	.056	1.204	.310
Healthy attitude	4.352	.005	1.627	.203	1.761	.156	2.193	.071	1.426	.216	2.078	.062
Eating attitude	1.467	.224	1.672	.197	2.075	.104	2.683	.033	1.701	.136	.878	.514
Growing attitude	.917	.434	.054	.817	.945	.420	1.316	.265	.797	.553	1.136	.347
Acceptance attitude	1.419	.238	.111	.740	2.207	.088	2.588	.038	2.245	.051	2.306	.039
Significant others eat GM crops	3.592	.014	1.197	.275	.760	.517	2.622	.036	1.522	.184	1.063	.389
Significant others approve GM crops	3.592	.014	1.197	.275	.760	.517	2.622	.036	1.522	.184	1.063	.389
Eating GM crops is the significant others' decision	1.255	.291	2.221	.138	.790	.500	.616	.651	2.299	.046	1.623	.148
Will eat GM crops if affording organic crops	2.101	.101	.229	.633	4.682	.003	1.687	.154	2.773	.019	2.495	.027
Will eat GM crops if government bans them	4.339	.005	.085	.771	3.028	.030	1.645	.164	.960	.443	2.205	.048
Will eat GM crops if they are always available	1.577	.196	.073	.788	3.179	.025	.766	.549	2.535	.030	1.857	.095
Will eat GM crops because I'm knowledgeable they are safe to eat	5.707	.001	.371	.543	1.971	.119	.494	.740	1.337	.250	.371	.896
Will eat or not eat GM crops at will	2.115	.099	.922	.338	.207	.892	2.727	.030	1.384	.231	1.957	.078
Will intend to buy GM crops	1.840	.141	1.498	.222	3.405	.019	2.973	.020	1.063	.382	1.142	.344
Will intend to eat GM crops	4.406	.005	.694	.406	1.452	.229	1.016	.400	1.077	.374	1.799	.106
Will intend to accept modern agricultural biotechnology	3.813	.011	.107	.744	.521	.669	.440	.779	.830	.529	1.591	.157
Will intend to support farmers for growing GM crops	1.342	.262	.084	.772	2.566	.056	1.614	.172	.875	.498	1.176	.325
I accept eating GM crops	3.136	.026	.090	.765	.373	.773	1.880	.115	1.422	.218	2.603	.022
I accept the use of modern agricultural biotechnology	.939	.422	.170	.681	2.547	.057	1.213	.306	.368	.870	.576	.749

Table 5.5 Homogeneity of variance results (2018).

Four assumptions of parametric analysis were tested. Firstly, the assumption of normality was met based on the empirical law of large numbers. The sample size *(N = 220)* was large to be considered a normal distribution (Tabachnick & Fidell, 2007; Ghasemi & Zahediasl 2012:486). The other three assumptions for parametric analysis were also met, i.e. independent errors, multicollinearity andhomogeneity of variance. Given the results of these assumptions, it was justifiable for the researcher to use both parametric and non-parametric analysis. In the next section, the researcher presents the frequency and descriptive statistics of the sample.

5.3 Frequency and descriptive statistics

According to Manikandan (2011:54), frequency distribution is convenient and permits researchers to view the distribution of data across the entire sample. The researcher used frequency distribution statistics to assess whether observations were fairly distributed across different race groups, as well as gender, age, education and academic field groups. Table 5.6 below shows the frequency distribution of the sample.

Variable	Category	Frequency	Percent	Valid Percent	Cumulative Percent
Age	18-25 years	59	26.7	26.8	26.8
	26-50 years	97	43.9	44.1	70.9
	50-64 years	43	19.5	19.5	90.5
	64+ years	21	9.5	9.5	100
Gender	Male	107	48.4	48.6	48.6
	Female	113	51.1	51.4	100
Race	Black/African	163	73.8	74.1	74.1
	White	36	16.3	16.4	90.5
	Coloured	16	7.2	7.3	97.7
	Indian/Asian	5	2.3	2.3	100
Household income	R0-R189 880	139	62.9	63.2	63.2
	R189 881-R296 540	44	19.9	20.0	83.2
	R296 541-R410 460	22	10.0	10.0	93.2
	R410 461-R555 600	11	5.0	5.0	98.2
	R555 601+	4	1.8	1.8	100
Education	High School Cert	108	48.9	49.3	49.3
	Post-High Sch Cert	35	15.8	16.0	65.3
	Diploma	38	17.2	17.4	82.6
	First Degree	21	9.5	9.6	92.2
	Hons Degree	10	4.5	4.6	96.8
	Masters' Degree	7	3.2	3.2	100
Academic Field	Agric & Environ Sci	11	5.0	9.9	9.9
	Acc, Econ & Mgt Sci	33	14.9	29.7	39.6
	Education	13	5.9	11.7	51.4
	Human sciences	6	2.7	5.4	56.8
	Law	6	2.7	5.4	62.2
	Sci, Eng & Tech	33	14.9	29.7	91.9
	Health Sci & Med	9	4.1	8.1	100

Table 5.6 Frequency distribution table (2018).

Information contained in Table 5.6 shows that the sample consisted of 73.8% African/Black, 16.3% White, 7.2% Coloured and 2.3% Indian/Asian population. 48.4% were male and 51.1% were female. 26.7% of people were in the age category of 18-25 years, 43.9% in 26-49 years category, 19.5% in 50-64 years category and 9.5% in 65+ years category. The 0-17-year category was left out because the age category lacks the autonomous to decide on what to consume. According to Bansal (2015:2) a child (0-17 years) is usually directed by his family on the decisions of what to eat. Bansal's (2015) argument suggests that children have little or no decision on what they consume.

48.9% of the participants were in possession of high school certificates, 15.8% post-high school certificates, 17.2% diplomas, 9.5% first degrees, 4.5% honours degrees and 3.2% masters' degrees. Statistics for academic field were as follows, 5% obtained academic qualifications in agriculture and environmental sciences, 14.9% accounting, economics and management sciences, 5.9% education, 2.7% human sciences, 2.7% law, 14.9% science, engineering and technology and 4.1% in health sciences and medicine. Frequency statistics for household income were as follows, 62.9% were in the bracket of R0-R189 880, 19.9% in R189 881-R296 540, 10% in R296 541-R410 460, 5% in R410 461-R555 600 and 4% in R555 601+. The researcher used the Chi-square test to statistically significant of the sample against the population. Chi-square test results are presented below.

5.3.1 The chi-square test

The chi-square test formula, Fig 5.1, was used to calculate the significant association of the sample to the population. Chi-square test is a non-parametric test (Rana & Singhal 2015:69) and is used to test if there is statistically significant association between two categorical variables (Hollander 2011:116). The Chi-square formula used is shown below:

$$\chi^2 = \sum \frac{(O-E)^2}{E}$$

Equation 5.1 Chi-square test formula

To calculate the Chi-square, we take the square of the difference between the observed (*o*) and expected (*e*) values and divide it by the expected value (Hair et al. 2014). The observed values are derived from the sample and the expected values have been calculated based on the statistical data published in Statistics South Africa on demography publications. For instances, Statistics South Africa publishes that 80% of the people in Kempton Park are Black/African, hence the expected values were 80% of the 220 participants (176 Black/African) (Stats SA, 2018). Table 5.6 contains the observed and expected values of age, gender, race and education. The researcher failed to locate the published household income distribution in South Africa which was matching data of this study, to be able to calculate the chi-square value for household income.

Variable	Category	Observed	Expected	Statistic Value	Sig. *(p < .05)*
Age	18-25 years	59	44	34.45	1.000
	26-50 years	97	77		
	50-64 years	43	23		
	64+ years	21	12		
Gender	Male	107	108	.018	.671
	Female	113	112		
Race	Black/African	163	176	13.364	.996
	White	36	22		
	Coloured	16	18		
	Indian/Asian	5	11		
Household income	R0-R189 880	139	-	-	-
	R189 881-R296 540	44	-		
	R296 541-R410 460	22	-		
	R410 461-R555 600	11	-		
	R555 601+	4	-		
Education	High School Cert	59	20	134.92	1.000
	Diploma + Certificate	73	68		
	First Degree	21	64		
	Hons Degree	10	24		
	Masters' Degree	7	34		

Table 5.7 Chi-square value for the sample demography (2018).

According to Turner (2000:91) a common accepted standard is to reject the hypothesis of no association between the two variables if the p-value is less than *.05* $(p < .05)$. Results of the Chi-square test shown in Table 5.7 above, show a statistically significant association between the sample and population $(p > .05)$. All tested variables had a p-value which was greater than *.05*, thus the sample shows statistically significant association with the population.

5.3.2 Descriptive statistics for constructs

As put forward in Dornyei (2011:209), the researcher used descriptive statistics to summarise the research data. Descriptive statistics give an overview on the shape and quality of data (Litosseliti 2010:70). In using descriptive statistics, the researcher assessed whether the sample was normally distributed and how well the mean (μ) represents the data (Field 2005:6). Descriptive statistics for the data are shown in Table 5.8 below.

The standard deviation (σ) in the sample are close to *2*, and it is as large as the μ. According to Brown (1982:940) if σ is as large as the μ, then the lower tail of the bell-shaped curve will go below zero suggesting a normal distribution. In addition, Brown (1982:940) argues that the $\mu \pm 2\ \sigma$ embraces that about 95% of values are normally distributed. The characteristics of descriptive statistics shown in Table 5.8 fit well into Brown's (1982) assertion suggesting that the sample is normally distributed. Thus, this conclusion is in-line with the results of the normality which the researcher concluded that data met the normality due to a large sample size $(N=220)$. As described in Field (2005:6) the μ (in this study) is a good fit of data and it accurately represent the sample.

However, descriptive statistics do not allow the researcher to draw any general conclusions that would go beyond the sample (Dornyei 2011:209). Conclusions arrived from descriptive statistics cannot be generalised to a larger population. Although (in my sample) most of the scale rating falls within the scale rating 3 (disagree) and 4 (neutral), the researcher further conducted inferential statistical models to confirm statistical significance of these findings.

Constructs	N	Min	Max	Mean	Std. Dev
Public knowledge on GM crops	220	1	7	3.55	2.21
Public awareness on GM crops	220	1	7	2.19	1.87
Public engagement in GM crops policy making	220	1	7	1.79	1.44
Public trust on GM crops regulation	220	1	7	3.58	1.72
Genetically modified crops must be labelled	220	1	7	6.30	1.34
Public eating GM crops willingly	220	1	7	3.15	2.04
Public acceptance of GM crops	220	1	7	3.50	1.96
Public perceived human health and environmental benefits over GM crops	220	1	7	3.09	1.70
GM crops are labelled in shops	220	1	7	2.58	1.87
Environment safety beliefs	220	1	7	3.30	2.03
Human health safety beliefs	220	1	7	3.14	2.03
Labelled genetically modified crops are safety	220	1	7	3.78	2.19
Important people's approval of GM crops	220	1	7	3.39	1.67
Important people's eating of GM crops	220	1	7	3.10	2.02
Will eat GM crops if less expensive	220	1	7	4.11	2.23
Will eat GM crops if I know how they are produced	220	1	7	4.16	1.99
Will eat GM crops if they are available always	220	1	7	3.90	1.99
Positive healthy attitude	220	1	7	3.10	1.93
Positive eating attitude	220	1	7	3.19	1.84
Positive production of GM crops attitude	220	1	7	3.61	1.91
Positive accepting MAB attitude	220	1	7	3.65	2.06
Significant others' eating of GM crops	220	1	7	2.92	1.86
Significant others approve that I eat GM crops	220	1	7	2.92	1.86
My eating of GM crops is the significant others' decision	220	1	7	4.66	2.25
Will eat GM crops if I can afford organic crops	220	1	7	2.58	1.89
Will eat GM crops if government bans them	220	1	7	2.79	1.97
Will eat GM crops if they are always available	220	1	7	3.86	1.99
Will eat GM crops because I'm knowledgeable they are safe to eat	220	1	7	3.19	1.90
Will eat or not eat GM crops, freely	220	1	7	4.46	2.25
Will intent to buy genetically modified crops	220	1	7	3.21	1.98
Will intent to eat genetically modified crops	220	1	7	3.04	2.06
Will intent to accept MAB	220	1	7	3.24	2.02
Will intent to support farmers of genetically modified crops farming	220	1	7	3.63	2.14
Will accept eating genetically modified crops	220	1	7	3.15	2.06
Will accept MAB in crop production	220	1	7	3.70	2.11

1=very strongly disagree; 2=strongly disagree; 3 disagree; 4 = neither disagree nor agree; 5=agree; 6=strongly agree; 7=very strongly agree.

Table 5.8 Descriptive statistics for the variables (2018).

In the following sections, the researcher presented the results from several inferential statistical models (parametric and non-parametric analysis). Gender was analysed using t-test since it is a nominal variable. Age, household income and education were analysed using Spearman's ranked correlation coefficient and Pearson's correlation coefficient, because these variables are ordinal scale, testing bi-directional relationships. Racial and academic field groups were analysed using ANOVA. Multiple linear regression and path analysis was used to test relationship between beliefs, attitudes, intention and behaviour.

5.4 Inferential data analysis and interpretation

The researcher, in this section, presented the data that were statistically significant. However, the following eight hypotheses was tested in this section.

Q1. People who perceive human health and environmental risks posed by genetically modified crops have a negative attitude towards accepting modern agricultural biotechnology.

Q2. Individuals who trust the genetically modified laws in South Africa, have positive attitude towards accepting modern agricultural biotechnology.

Q3. Gender differences predict willingness to consume and accept modern agricultural biotechnology.

Q4. Age differences predict willingness to consume and accept modern agricultural biotechnology.

Q5. Lower personal income levels predict willingness to consume and accept modern agricultural biotechnology.

Q6. Higher formal education levels predict willingness to consume and accept modern agricultural biotechnology.

Q7. Race differences predict willingness to consume and accept modern agricultural biotechnology.

Q8. Academic field of study predicts individual knowledge on genetically modified crops.

Q9. There are bi-directional relationships among beliefs, as well as casual relationships between beliefs, attitudes, intention and behaviour.

5.4.1 Human health and environmental risks.

To test the hypothesis that *people who perceive human health and environmental benefits posed by genetically modified crops have positive attitude towards* *consuming genetically modified crops and accepting modern agricultural biotechnology* Spearman's rank correlation coefficient was used. Spearman's ranked correlation coefficient can be used successfully for analysis of non-normally distributed data (Chok 2010:27). The researcher was being cautious on the normality of data, hence decided to perform both parametric and non-parametric analysis.

Correlations assess the strength and direction of linear relationships between two variables and is measured by correlation coefficient (Mukaka 2012:71). Correlation coefficient describes a relationship between no association *(ρ = 0)* to perfect monotonic relationship *(ρ = –1 or +1)* (Schober, Boer & Schwarte 2018:1766). Correlation coefficient of zero (*ρ = 0)* indicates a no linear relationship between two continuous variables, and correlation coefficient of *-1 or +1 (ρ = –1 or +1)* indicates a perfect linear relationship. The closer the correlation coefficient is to ±*1* the stronger the relationship. The closer the correlation coefficient is to *0*, the weaker the relationship. Table 5.9 shows the strength of correlation coefficient as stated in Asuero, Sayago and Gonz´alez (2006:47).

Size of r	**Interpretation**
.90 to 1.00	Very high correlation
.70 to .89	High correlation
.50 to .69	Moderate correlation
.30 to .49	Low correlation
.00 to .29	Little if any correlation

Table 5.9 The strength of correlation (Asuero et al 2006).

If the coefficient is a negative number, variables are inversely related, i.e. values of two variables oppose each other (Sedgwick 2012:2; Swinscow 1997:57). Spearman's rank correlation coefficient results are shown in Table 5.10, below.

Constructs	Spearman's correlation coefficient.	Public acceptance of GMOs	Acceptance of MAB Behaviour	Labelled genetically modified crops are safety to eat	Eating attitude	Will eat genetically modified crops even if I can afford organic crops
Public perceived human health and environmental benefits over genetically modified crops	Correlation Coefficient	.652**	.715**	.438**	.720**	.582**
	Sig. (2-tailed)	.000	.000	.000	.000	.000
	N	220	220	220	220	220

Table 5.10 People perceiving human health and environment benefits over modern agricultural biotechnology (2018).

Spearman's rank correlation coefficient results show a statistically significant association between public perceived human health and environmental benefits over genetically modified crops and acceptance of genetically modified crops ($r = .652, p = .000$); acceptance of modern agricultural biotechnology ($r = .715, p = .000$); labelled genetically modified crops are safe to eat ($r = .438, p = .000$); a positive eating attitude ($r = .720, p = .000$); and public willingness to eat genetically modified crops even if they can afford organic crops ($r = .582, p = .000$). Generally, there are moderate to high correlation between public perceived human health and environment benefits over genetically modified crops and the acceptance of genetically modified crops and modern agricultural biotechnology, as well as with constructs shown in Table 5.10.

Table 5.11 shows the descriptive statistics for the constructs which were correlated with public perceiving human health and environment benefits over genetically modified crops.

Constructs	N	Min	Max	Mean	Std. Deviation
Public perceived human health and environmental risks over genetically modified crops	220	1	7	3.09	1.70
Acceptance of MAB Behaviour	220	1	7	3.43	1.99
Public acceptance of GMOs	220	1	7	3.50	1.96
Labelled genetically modified crops are safe to eat	220	1	7	3.78	2.19
Eating attitude	220	1	7	3.19	1.84
Will eat genetically modified crops even if I affords to buy organic crops	220	1	7	2.58	1.89

1 = very strongly disagree; 2 = strongly disagree; 3 disagree; 4 = neither disagree nor agree; 5 = agree; 6 = strongly agree; 7 = very strongly agree.

Table 5.11 Descriptive stats perceived human health and environmental risks (2018)

Descriptive statistics shows that the public disagrees that there are human health and environmental benefits over genetically modified crops *(M = 3.09; SD = 1.70*), and this response correlates with acceptance of modern agricultural biotechnology *(M = 3.43, SD = 1.99)*; public acceptance of genetically modified crops *(M = 3.50, SD = 1.96)*; labelled genetically modified crops are safe to eat *(M = 3.78, SD = 2.19)*; positive eating attitude *(M = 3.19, SD = 1.84)* and will eat genetically modified crops even participant affords to buy organic crops (*M = 2.58, SD = 1.89)*. Therefore, descriptive statistics show that people who perceive human health and environment risks over genetically modified crops are not willing to consume genetically modified crops and accept modern agricultural biotechnology.

5.4.2 Public trusting genetically modified laws.

To test the hypothesis that *individuals who trust the genetically modified laws have positive attitude towards accepting modern agricultural biotechnology*, the researcher used Spearman's rank correlation coefficient. Correlation coefficient results are shown in Table 5.12.

Constructs	Spearman's correlation	GMOs must be labelled	Public eating GMOs willingly	Labelled GM crops are safe to eat	Eating attitude	Acceptance attitude	Acceptance of GM crops	Acceptance of MAB
Public trust on GMOs regulation	Correlation Coefficient	-.084	.362**	.252**	.249**	.296**	.229**	.289**
	Sig. (2-tailed)	.217	.000	.000	.000	.000	.001	.000
	N	220	220	220	220	220	220	220

Table 5.12 Public trust on genetically modified crops (2018).

Spearman's rank correlation coefficient results show a statistically significant association between public trust on genetically modified crops and public eating genetically modified crops willingly *(r = .362, p = .000)*; labelled genetically modified crops are safe to eat *(r = .252, p = .000)*; positive eating attitude *(r = .249, p = .000)*; acceptance of genetically modified crops *(r = .229, p = .001)* and acceptance of modern agricultural biotechnology. Generally, the correlation is low (Asuero et al. 2006). Table 5.13 below shows descriptive statistics for constructs correlated with public who have trust on genetically modified crops regulations.

Constructs	N	Min	Max	Mean	Std. Deviation
Public trust GMOs regulations in South Africa	220	1	7	3.58	1.72
GMOs must be labelled	220	1	7	6.30	1.34
Labelled genetically modified crops are safe to eat	220	1	7	3.78	2.19
Positive eating attitude	220	1	7	3.19	1.84
Acceptance attitude	220	1	7	3.65	2.06
Acceptance of genetically modified crops	220	1	7	3.15	2.06
Acceptance of modern agricultural biotechnology	220	1	7	3.70	2.11

1 = very strongly disagree; 2 = strongly disagree; 3 disagree; 4 = neither disagree nor agree; 5 = agree; 6 = strongly agree; 7 = very strongly agree.

Table 5.13 Descriptive stats on public trust on genetically modified crops (2018).

Descriptive statistics shows that the public do not trust genetically modified crops regulations in South Africa *(M = 3.58; SD = 1.72)*, and this correlates with labelled genetically modified crops are safe to eat *(M = 3.78, SD = 2.19)*;

positive eating attitude *(M = 3.19; SD = 1.84)*; acceptance attitude *(M = 3.65, SD = 2.06)*; acceptance of genetically modified crops *(M = 3.15, SD = 2.06)*; and acceptance of modern agricultural biotechnology *(M = 3.70, SD = 2.11)*. Descriptive statistics show that people who do not have trust with the genetically modified crops regulations in South Africa are not willing to accept modern agricultural biotechnology.

5.4.3 Gender differences and modern agricultural biotechnology.

To test the hypothesis that *gender differences will predict acceptance of modern agricultural biotechnology*, the researcher conducted an independent samples test. An independent samples test assesses whether the means of two groups are statistically different from one other (Kim 2015:540). An independent samples test (t-test) was the most appropriate statistical model in comparing male and female. T-tests have sufficient statistical power in predicting two samples of data (Lumley et al. 2002:154). The results for gender differences are shown in Table 5.14 below.

Constructs	Assumption	Levene's Test		T-Test for equality of means		
		F	Sig.	t	df	Sig.(2-tailed)
Public acceptance of genetically modified crops	Equal variances assumed	1.633	.203	2.317	218	.021
	Equal variances not assumed			2.311	213	.022
Farming of genetically modified crops attitude	Equal variances assumed	.054	.817	3.145	218	.002
	Equal variances not assumed			3.144	216.87	.002
Will intend eating genetically modified crops	Equal variances assumed	.694	.406	2.168	218	.031
	Equal variances not assumed			2.167	216.957	.031

Table 5.14 Gender group independent samples test (2018).

Three constructs show statistically significant association with gender differences in accepting modern agricultural biotechnology. Firstly, there is a statistically significant difference between male (*M = 3.82, SD = 2.04*)[25] and female (*M = 3.21, SD = 1.84*)[26], on public acceptance of genetically modified crops, *t (218) = 2.317, p = .021*. Secondly, there is a statistically significant difference mean between male (*M = 4.021, SD = 1.89*)[27] and female (*M = 3.228, SD = 1.85*) on the growing of genetically modified crops attitude, *t(218) = 3.145, p = .002*). Thirdly, there is a statistically significant difference mean between male (*M = 3.35, SD = 2.05*) and female (*M = 2.75, SD = 2.02*) on the intention to eat genetically modified crops, *t(218) = 2.168, p = .031*).

The results show that the constructs: growing of genetically modified crops *F(218) = .054, p = .817),* public acceptance of genetically modified crops *F(218) = 1.633, p = .203),* and intention to eat genetically modified crops (*F(218) = .694, p = .406*) satisfies the homogeneity of variances assumption as shown by the Levene's *F* test. Table 5.15 below contains the descriptive statistics of the three variables that were found to be statistically significant associations with gender differences in accepting modern agricultural biotechnology.

Construct	Gender	N	Mean	Std. Deviation
Public acceptance of genetically modified crops	Male	107	3.82	2.04
	Female	113	3.21	1.84
Farming of genetically modified crops attitude	Male	107	4.021	1.89
	Female	113	3.228	1.85
Will intend eating genetically modified crops	Male	107	3.35	2.05
	Female	113	2.75	2.02

1 = very strongly disagree; 2 = strongly disagree; 3 disagree; 4 = neither disagree nor agree; 5 = agree; 6 = strongly agree; 7 = very strongly agree.

Table 5.15 Gender group descriptive statistics (2018).

[25] See Table 5.15
[26] See Table 5.15
[27] See Table 5.15

Gender differences towards willingness to accept and consume genetically modified crops have been observed and is statistically significant from the population. Females are unwilling to accept and eat genetically modified crops as compared to males. Females are There is also statistically significant association between females and a negative attitude towards modern agricultural biotechnology.

5.4.4 Age difference and modern agricultural biotechnology

To test the hypothesis that *age differences will predict acceptance of modern agricultural biotechnology*, Spearman's ranked correlation coefficients was performed.

Table 5.16 presents the results for Spearman's rank correlation coefficient for age groups.

Constructs	**Age**			
	Spearman's rho	**Coefficient**	**Levene Statistic**	**Sig.**
Acceptance of genetically modified crops	Correlation Coefficient	-.173*	.939	.422
	Sig. (2-tailed)	.010		
	N	220		
Genetically modified crops are labelled in shops	Correlation Coefficient	-.147*	2.368	.072
	Sig. (2-tailed)	.029		
	N	220		
Important people approve that l eat genetically modified crops	Correlation Coefficient	-.158*	.976	.405
	Sig. (2-tailed)	.019		
	N	220		
Will eat genetically modified crops if l know how they are produced	Correlation Coefficient	-.134*	1.087	.355
	Sig. (2-tailed)	.047		
	N	220		
Eating genetically modified crops is the significant others' decision	Correlation Coefficient	.193**	1.255	.291
	Sig. (2-tailed)	.004		
	N	220		
Will intend buying genetically modified crops	Correlation Coefficient	-.141*	1.840	.141
	Sig. (2-tailed)	.036		
	N	220		
Will accept modern agricultural biotechnology in crop production	Correlation Coefficient	-.157*	.939	.422
	Sig. (2-tailed)	.020		
	N	220		
***. Correlation is significant at the 0.01 level (2-tailed).*				
**. Correlation is significant at the 0.05 level (2-tailed).*				

Table 5.16 Spearman's rank correlation coefficient for age (2018).

Spearman's rank correlation coefficient reveal a statistically significant negative association between age and acceptance of genetically modified crops ($r = -.173$, $p = .010$); genetically modified crops are labelled in shops ($r = -.147$, $p = .029$); important people approve that they eat genetically modified crops ($r = -.158$, $p = .019$); will eat genetically modified crops if they know how they are produced ($r = -.134$, $p = .047$); will accept modern agricultural biotechnology in crop production ($r = -.157$, $p = .020$); will intend buying genetically modified crops ($r = -.141$, $p = .036$). Spearman's rank correlation coefficient has also determined a statistically significant positive association between age and eating genetically modified crops if it is the significant others' decision ($r = .193$, $p = .004$). The association between age and the variables in Table 5.16 is further shown in the descriptive statistics Table 5.17 below.

Construct	Age Category	N	Mean	Std. Deviation	Min	Max
Acceptance of genetically modified crops	18-25 years	59	3.63	2.05	1	7
	26-50 years	97	3.62	2.01	1	7
	50-64 years	43	3.44	1.85	1	7
	64+ years	21	2.76	1.59	1	7
	Total	220	3.50	1.96	1	7
Acceptance of modern agricultural biotechnology	18-25 years	59	3.70	2.03	1	7
	26-50 years	97	3.67	2.03	1	7
	50-64 years	43	2.92	1.83	1	7
	64+ years	21	2.57	1.65	1	7
	Total	220	3.43	1.99	1	7
Will eat genetically modified crops if I know how they are produced	18-25 years	59	4.22	1.98	1	7
	26-50 years	97	4.49	2.02	1	7
	50-64 years	43	3.78	1.97	1	7
	64+ years	21	3.27	1.58	1	7
	Total	220	4.16	1.99	1	7
Important people approve that I eat genetically modified crops	18-25 years	59	3.59	1.75	1	7
	26-50 years	97	3.46	1.75	1	7
	50-64 years	43	2.98	1.84	1	7
	64+ years	21	2.93	1.57	1	7
	Total	220	3.35	1.76	1	7
Acceptance attitude	18-25 years	59	3.92	2.19	1	7
	26-50 years	97	3.74	2.06	1	7
	50-64 years	43	3.56	1.99	1	7
	64+ years	21	2.70	1.68	1	7
	Total	220	3.65	2.06	1	7
Will intend buying genetically modified crops	18-25 years	59	3.41	2.07	1	7
	26-50 years	97	3.44	1.99	1	7
	50-64 years	43	2.76	1.83	1	7
	64+ years	21	2.50	1.72	1	7
	Total	220	3.21	1.98	1	7
Will intend supporting farmers for growing genetically modified crops	18-25 years	59	3.85	2.19	1	7
	26-50 years	97	3.79	2.13	1	7
	50-64 years	43	3.38	2.21	1	7
	64+ years	21	2.80	1.73	1	7
	Total	220	3.63	2.14	1	7
Genetically modified crops are labelled in shops	18-25 years	59	2.81	1.85	1	7
	26-50 years	97	2.74	1.91	1	7
	50-64 years	43	1.84	1.59	1	7
	64+ years	21	2.67	2.06	1	7
	Total	220	2.58	1.87	1	7
Eating genetically modified crops is my significant others' decision	18-25 years	59	4.11	2.28	1	7
	26-50 years	97	4.62	2.29	1	7
	50-64 years	43	5.16	2.08	1	7
	64+ years	21	5.33	2.06	1	7
	Total	220	4.66	2.25	1	7

1 = very strongly disagree; 2 = strongly disagree; 3 = disagree; 4 = neither disagree nor agree; 5 = agree; 6 = strongly agree; 7 = very strongly agree.

Table 5.17 Age descriptive statistics (2018)

The constructs, found to have negative t association with age, have shown that as age increases, unwillingness to accept modern agricultural biotechnology increases. There is a decrease in acceptance of modern agricultural biotechnology as age increase from 18 years (18-25 years *M = 3.70, SD = 2.03*; 26-49 years *M = 3.67, SD = 203*; 50-64 years *M = 2.92, SD = 1.83*; 65+ years *M = 2.57, SD = 1.65*). An increase in years has been associated with lower scaling of variables, i.e. from disagree to strongly disagree.

The construct "eating genetically modified crops is the significant others' decision" was found to be statistically significantly associated with age (*r = .193, p = .004*). Descriptive statistics confirm that as age increases, people agree that eating of genetically modified crops is the significant others' decision (18-25 years *M = 4.11, SD = 2.28*; 26-49 years *M = 4.62, SD = 2.29*; 50-64 years *M = 5.16, SD = 2.08*; 65+ years *M = 5.33, SD = 2.06).* There is mean increase in the variable "Eating genetically modified crops is the significant others' decision" of *0.51* between 18-25 and 26-49 categories; *0.54* between 26-49 years and 50-64 years categories; and *0.17* between 50-64 years and 64+ years. An increase in years has been associated with higher scaling, i.e. from disagree to strongly agree.

5.4.5 Household income and modern agricultural biotechnology

Spearman's rank correlation coefficient was performed to test the hypothesis of *association between lower household income level and acceptance modern agricultural biotechnology, as well as of association between higher formal education and acceptance of modern agricultural biotechnology.* Results for education are presented in section 5.4.4 below, whilst the results for household income are presented in Table 5.18 below.

Construct	Household income			
	Spearman's rho	**Coefficient**	**Levene Statistic**	**Sig.**
Public knowledge on genetically modified crops	Correlation Coefficient	.288**	.328	.805
	Sig. (2-tailed)	.000		
	N	220		
Labelled genetically modified crops are safety to eat	Correlation Coefficient	.148*	.500	.683
	Sig. (2-tailed)	.028		
	N	220		
Eating genetically modified crops is my significant others' decision	Correlation Coefficient	-.163*	1.255	.291
	Sig. (2-tailed)	.015		
	N	220		
*** Correlation is significant at the 0.01 level (2-tailed).*				
** Correlation is significant at the 0.05 level (2-tailed).*				

Table 5.18 Spearman's rank correlation coefficient for household income (2018)

Spearman's correlation reveals a statistically positive association between household income and knowledge on genetically modified crops (*r = .288, p = .000*); labelled genetically modified crops are safe to eat *(r = .148; p = .028*); and negative association between household income and eating genetically modified crops is my significant others' decision (*r = -.163, p = .015*). Associations are shown in descriptive Table 5.19 below.

Construct	HH income	N	Mean	Std. Dev	Min	Max
Public knowledge on genetically modified crops	R0-R189 880	139	3.14	2.14	1	7
	R189881-R296540	44	3.45	2.27	1	7
	R296541-R410560	22	5.27	1.55	1	7
	R410461-R555600	11	5.00	1.95	1	7
	R555 601+	4	5.25	1.50	1	7
	Total	220	3.55	2.21	1	7
Labelled genetically modified crops are safety to eat	R0-R189 880	139	3.51	2.21	1	7
	R189881-R296540	44	4.46	1.94	1	7
	R296541-R410560	22	4.10	2.30	1	7
	R410461-R555600	11	3.54	2.03	1	7
	R555601+	4	4.75	2.87	1	7
	Total	220	3.78	2.19	1	7
Eating genetically modified crops is my significant others' decision	R0-R189880	139	4.95	2.20	1	7
	R189881-R296540	44	3.99	2.17	1	7
	R296541-R410560	22	4.68	2.39	1	7
	R410461-R555600	11	4.23	2.48	1	7
	R555601+	4	2.75	1.50	1	7
	Total	220	4.66	2.25	1	7

1=very strongly disagree; 2=strongly disagree; 3 disagree; 4 = neither disagree nor agree; 5=agree; 6=strongly agree; 7=very strongly agree.

Table 5.19 Household descriptive statistics (2018).

The association between household income and the three (3) constructs shown in Table 5.19, is further analysed using ANOVA. Results are shown in Table 5.20 below.

Construct		Sum of Squares	df	Mean Square	F	Sig.
Public knowledge on genetically modified crops	Between Groups	124.120	4	31.030	7.049	.000
	Within Groups	946.426	215	4.402		
	Total	1070.545	219			
Labelled genetically modified crops are safety to eat	Between Groups	37.125	4	9.281	1.969	.100
	Within Groups	1013.203	215	4.713		
	Total	1050.327	219			
Eating genetically modified crops is my significant others' decision	Between Groups	48.445	4	12.111	2.453	.047
	Within Groups	1061.395	215	4.937		
	Total	1109.840	219			

Table 5.20 Household income ANOVA analysis (2018).

There was a statistically significant different mean (as determined by one-way ANOVA) between household income groups and public knowledge of genetically modified crops (*F (4,215) = 7.049, p = .000*); as well as between household income and eating genetically modified crops is my significant others' decision (*F (4,215) = 2.453, p = .047*). Labelled genetically modified crops are safe to eat construct was not found to be statistically significant.

5.4.6 Education and modern agricultural biotechnology

The hypothesis that *higher formal education predicts willingness to accept modern agricultural biotechnology,* was tested using Spearman's rank correlation coefficient. Results are shown in Table 5.21 below.

Construct	Spearman (r) Coefficient	Education
Public knowledge on genetically modified crops	Correlation Coefficient	.351**
	Sig. (2-tailed)	,000
	N	219
Public trust on genetically modified crops regulations	Correlation Coefficient	-.219**
	Sig. (2-tailed)	,001
	N	219
Genetically modified crops must be labelled	Correlation Coefficient	.138*
	Sig. (2-tailed)	,042
	N	219

Table 5.21 Education Spearman's rank correlation coefficient (2018).

Spearman's correlation shows a relationship between education and public knowledge *(r = .351, p < .001)*; public regulation trust *(r = -.219, p < .05)*; and labelling *(r = .138, p < .05)* on genetically modified crops. This study has established that an increase in the level of education correlates with an increase in knowledge on genetically modified crops, as well as an increase in public's need for genetically modified crops labelling. The results show a negative relationship between education and public trust on genetically modified crops regulations, impliying that an increase in education causes a a decrease in public trust on genetically modified crops regulations.

Construct		Education level	Mean Difference	Std error	Sig
Public knowledge on genetically modified crops	High Sch Cert	Post-High Sch cert	.183	.393	.997
		Diploma	-1.627*	.381	.000
		First degree	-2.074*	.482	.000
		Honours degree	-2.274*	.667	.010
		Master's degree	-2.360*	.788	.036
	Post-High Sch cert	High Sch Cert	-.183	.393	.997
		Diploma	-1.810*	.473	.002
		First degree	-2.257*	.557	.001
		Honours degree	-2.457*	.724	.011
		Master's degree	-2.543*	.836	.031

Table 5.22 Education Tukey post hoc tests results (2018).

Tukey post hoc tests were further conducted to compare multiple mean differences. Results in Table 5.22 above confirms a statistically significant different mean between education level and knowledge on genetically modified crops, for instance between high school certificate and diploma *(p = .000)* and post-high school certificate and first degree *(p = .011)*.

5.4.7 Racial groups and modern agricultural biotechnology

The hypothesis that *race predicts willingness to accept modern agricultural biotechnology* was tested using ANOVA analysis. According to Field (2005:310) ANOVA tells us whether three or more means are the same. It tests the hypothesis that all group means are equal. An ANOVA produces an F-statistic or F-ratio which compares the amount of systematic variance in the data to the amount of unsystematic variance. According to Field (2005:324) the assumptions under which ANOVA is reliable are the same as for all parametric tests. However, these assumptions are not completely inflexible (Field 2005:324).

Table 5.23 shows the ANOVA analysis output for racial groups. There is a statistically significant mean difference between racial groups and genetically modified crops are labelled in shops, (*F(3,216) = 3.964, p = .009*) as determined by one-way, but the assumption of homogeneity of variance was violated, since p-value must be greater than *.05*.

Construct	Racial groups	Sum of Squares	df	Mean Square	F	Sig.	Levene Statistic	Sig.
Genetically modified crops are labelled in shops	Between Groups	40.058	3	13.353	3.964	.009	7.862	.000
	Within Groups	727.628	216	3.369				
	Total	767.686	219					
Labelled genetically modified crops are safety to eat	Between Groups	31.027	3	10.342	2.192	.090	2.934	.034
	Within Groups	1019.301	216	4.719				
	Total	1050.327	219					
Will eat genetically modified crops is less expensive	Between Groups	36.937	3	12.312	2.518	.059	1.923	.127
	Within Groups	1055.972	216	4.889				
	Total	1092.909	219					

Table 5.23 ANOVA for racial groups (2018)

5.4.8 Academic field

Table 5.24 shows the output for academic fields ANOVA analysis. There is a statistically significant mean difference between academic groups (as determined by one-way ANOVA) on public knowledge of genetically modified crops (*F (6,104) = 2.201, p = .049*), public perceived human health and environmental risks over genetically modified crops (*F (6,104) = 2.200, p = .049*), and human health safety beliefs (*F (6,104) = 2.508, p = .026*) .

Construct	Academic Fields	Sum of Squares	df	Mean Square	F	Sig.	Levene Statistic	Sig.
Public knowledge on genetically modified crops	Between Groups	61.721	6	10.287	2.201	.049	1.274	.276
	Within Groups	486.027	104	4.673				
	Total	547.748	110					
Public perceived human health and environmental risks over genetically modified crops	Between Groups	32.724	6	5.454	2.200	.049	1.633	.145
	Within Groups	257.828	104	2.479				
	Total	290.552	110					
Human health safety beliefs	Between Groups	51.750	6	8.625	2.508	.026	1.604	.153
	Within Groups	357.673	104	3.439				
	Total	409.423	110					

Table 5.24 ANOVA for academic groups (2018).

Descriptive statistics in Table 5.25 on academic field shows how academic field groups differed on public knowledge on genetically modified crops: Agriculture and Environmental Science, (*M =5.36, SD = 1.57);* Accounting, Economics and Management Sciences *(M =4.30, SD = 2.30)*; Education (*M = 3.69, SD = 2.29*); Human Sciences (*M = 2.50, SD = 2.07*); Law (M = 3.67, SD = 1.75); Science, Engineering and Technology *(M = 3.82, SD = 2.19)*; and Health Sciences and Medicine (*M = 5.67, SD = 2.24*).

Academic field groups also differ on perceived human health and environmental risks over genetically modified crops:Agriculture and Environmental Science, (*M = 3.18, SD = 1.95*); Accounting, Economics and Management Sciences (*M = 3.31, SD = 1.60*); Education (*M = 2.01, SD = 1.01*); Human Sciences (*M = 2.25, SD = 1.15*); Law (*M = 2.78, SD = 1.71*); Science, Engineering and Technology (*M = 3.68, SD = 1.64*); and Health Sciences and Medicine (*M = 3.19, SD = 1.50*). The results also show that academic field groups also differ on human health safety beliefs: Agriculture and Environmental Science (*M = 3.32, SD = 2.08*); Accounting, Economics and Management Sciences (*M = 3.26,* *SD = 1.92*); Education (*M = 1.85, SD = 1.23*); Human Sciences *(M = 2.08, SD = 1.56*); Law (*M = 3.17, SD = 2.56*), Science, Engineering and Technology (*M = 3.98, SD = 1.80*) and Health Sciences and Medicine (*M = 3.17, SD = 1.94*).

Construct	Academic Field	N	Mean	Std. Dev	Min	Max
Public knowledge on genetically modified crops	Agric & Environ Sci	11	5.36	1.57	1	7
	Acc, Econ & Mgt Sci	33	4.30	2.30	1	7
	Education	13	3.69	2.29	1	7
	Human Sciences	6	2.50	2.07	1	6
	Law	6	3.67	1.75	1	5
	Sci, Eng & Tech	33	3.82	2.19	1	7
	Health Sci & Med	9	5.67	2.24	1	7
	Total	111	4.17	2.23	1	7
Public perceived human health and environmental risks over genetically modified crops	Agric & Environ Sci	11	3.18	1.95	1	7
	Acc, Econ & Mgt Sci	33	3.31	1.60	1	7
	Education	13	2.01	1.01	1	7
	Human Sciences	6	2.25	1.15	1	7
	Law	6	2.78	1.71	1	7
	Sci, Eng & Tech	33	3.68	1.64	1	7
	Health Sci & Med	9	3.19	1.50	1	7
	Total	111	3.16	1.63	1	7
Human health safety beliefs	Agric & Environ Sci	11	3.32	2.08	1	7
	Acc, Econ & Mgt Sci	33	3.26	1.92	1	7
	Education	13	1.85	1.23	1	7
	Human Sciences	6	2.08	1.56	1	7
	Law	6	3.17	2.56	1	7
	Sci, Eng & Tech	33	3.98	1.80	1	7
	Health Sci & Med	9	3.17	1.94	1	7
	Total	111	3.24	1.93	1	7

1=very strongly disagree; 2=strongly disagree; 3 disagree; 4 = neither disagree nor agree; 5=agree; 6=strongly agree; 7=very strongly agree.

Table 5.25 Academic group descriptive statistics (2018).

To determine specific groups that differed on public knowledge, perceived human health and environmental risks, as well as human health safety beliefs, a multiple comparisons table, (which contains the results of the Tukey post hoc test) is shown Table 5.26 below.

Construct	Field	Academic field groups	Mean Difference (I-J)	Std. Error	Sig.
Public perceived human health and environmental risks over genetically modified crops	Education	Agric & Environ Sci	-1.169	.645	.543
		Acc, Econ & Mgt Sci	-1.300	.516	.162
		Human Sciences	-.237	.777	1.000
		Law	-.765	.777	.956
		Sci, Eng & Tech	-1.669*	.516	.026
		Health Sci & Med	-1.172	.683	.606
Human health safety beliefs	Education	Agric & Environ Sci	-1.472	.760	.461
		Acc, Econ & Mgt Sci	-1.411	.607	.243
		Human Sciences	-.237	.915	1.000
		Law	-1.321	.915	.777
		Sci, Eng & Tech	-2.139*	.607	.011
		Health Sci & Med	-1.321	.804	.656
*. *The mean difference is significant at the 0.05 level.*					

Table 5:26 Tukey post hoc test on perceived health and environmental risks and human health safety beliefs (2018).

There is a statistically significant mean difference on public perceived health and environmental risks over genetically modified crops between people that graduated with an Education (*M = 2.01; SD = 1.01*) and Science, Engineering and Technology qualifications (*M = 3.68; SD = 1.64*) with a significant value of .026 (*p = .026*); as well as on human health beliefs between Education (*M = 1.85, SD = 1.23*) and Science, Engineering and Technology qualifications (*M = 3.98, SD = 1.80*) with a significant value of *.011* (*p = .011*). However, there are no statistically significant mean differences between other groups. Descriptive statistics also showed the mean for Education (*M = 2.01, SD = 1.01*), compared to the mean from other academic field groups, Agriculture and Environmental Sciences (*M = 3.18, SD = 1.95*), Accounting, Economics and Management Sciences (*M = 3.31, SD = 1.60*), Human sciences (*M = 2.25, SD = 1.15*), Law (*M = 2.78, SD = 1.71*), Science, Engineering and Technology (*M = 3.68, SD = 1.64*) and Health Sciences and Medicine (*M = 3.19, SD = 1.50*).

5.5 Psychological factors and acceptance of agricultural biotechnology

As in Maichum, Parichatnon and Peng (2016:9) the theory of planned behaviour was assessed through exploratory factor analysis and the Cronbach's α. Total variance explained ranged from 60% to 88%, and Cronbach's α coefficients ranged from *.835* to *.989*.

Construct	Items	Factor Loading	Items	Factor Loading	Total Variance Explained	Cronbach's α
Behavioural Beliefs	C3c	.824	C2b	.806	59.597	.886
	C3b	.816	C1a_R	.661		
	C3a	.815	C1b_R	.650		
	C2a	.808				
Normative Beliefs	C5d	.854	C5b	.807	61.236	.950
	C5e	.848	C6a	.747		
	C4c	.841	C6c	.731		
	C4b	.836	C6b	.714		
	C4a	.827	C7c	.703		
	C5c	.814	C7b	.697		
	C5a	.811	C7a	.694		
Control Beliefs	C10d	.931	C10b	.880	76.009	.971
	C10c	.916	C8d	.862		
	C10a	.896	C9c	.841		
	C8a	.893	C9b	.831		
	C8c	.888	C9d	.825		
	C8b	.886	C9a	.802		
Attitude Towards Behaviour	C12b	.931	C14b	.896	81.192	.984
	C12c & C14c	.926	C11a	.893		
	C12d	.923	C11b	.889		
	C14d	.914	C13a	.871		
	C13b	.909	C12a	.862		
	C12e & C14a	.908	C13d	.859		
	C13c	.903	C11c	.896		
Subjective Norms	C16a	.911	C17b	.815	56.238	.855
	C16b	.891	C17a	.805		
	C15b	.880	C18a	.129		
	C15a	.870	C18b	.119		
Perceived Behavioural Control	C20b	.882	C19c	.873	76.746	.939
	C20a	.879	C19a	.868		
	C19b	.874	C20c	.879		
Actual Behavioural control	C21b	.867	C22b	.765	52.792	.835
	C21a	.855	C22a	.752		
	C21c	.851	C23a & C23b	.412		
Behavioural Intention	C25b	.948	C24d	.928	85,.585	.989
	C25c	.942	C24c	.927		
	C26d, C25a & C26c	.938	C27c	.901		
	C25d & C26a	.934	C27d	.900		
	C26b	.931	C27a	.894		
	C24a & C24b	.929	C27b	.888		
Behaviour	C29b	.949	C28a	.939	88.256	.981
	C29c	.944	C28d	.938		
	C28c	.941	C28b	.920		
	C29d	.940	C29a	.944		

Table 5.27 Exploratory factor analysis and Cronbach's α *for beliefs, attitudes, intention and behaviour (2018).*

The researcher grouped and averaged all beliefs before performing exploratory factor analysis and Cronbach's α. Descriptive data is shown in Table 5.28, below, for beliefs, attitudes, intention and behaviour.

Construct	N	Min	Max	Mean	Std. Deviation	Variance
Behavioural beliefs	220	1	7	3.46	1.64	2.69
Normative Beliefs	220	1	7	3.64	1.53	2.34
Control Beliefs	220	1	7	4.06	1.86	3.45
Attitude Towards Behaviour	220	1	7	3.39	1.81	3.27
Subjective Norms	220	1	7	3.47	1.53	2.34
Perceived Behavioural Control	220	1	7	2.69	1.73	3.01
Actual Behavioural Control	220	1	7	3.84	1.47	2.16
Intention to accept modern agricultural biotechnology	220	1	7	3.28	1.92	3.69
Acceptance of modern agricultural biotechnology behaviour	220	1	7	3.43	1.99	3.95

1=very strongly disagree; 2=strongly disagree; 3 disagree; 4 = neither disagree nor agree; 5=agree; 6=strongly agree; 7=very strongly agree.

Table 5.28 Descriptive statistics showing beliefs, attitudes, intention and behaviour (2018).

Descriptive statistics in Table 5.25 show a relationship between beliefs, attitudes, intention and behaviour. Most mean (μ) falls in the scale rating of 3, with a few variables with mean falling in the scale rating of 4. Standard deviation (σ) values are close to 2, suggesting normality of the sample (Brown 1982:940).

5.5.1 Relationship among beliefs and attitudes

The researcher performed Spearman's rank correlation coefficient to test the hypothesis that there are *statistically significant bi-directional relationships among beliefs (behavioural beliefs, normative beliefs and control beliefs) and attitudes (attitude towards behaviour, subjective norms and perceived behavioural control)*. The researcher used Spearman's rank correlation coefficient as a precautionary measure, in case the normality of the sample was to be questioned (Field 2005:129). Results are shown in Table 5.29 below.

Constructs	Spearman's rho	Behavioural beliefs	Normative Beliefs	Control Beliefs	Attitude Towards Behaviour	Subjective Norms	Perceived Behavioural Control	Actual Behavioural Control	Intention to accept MAB	Acceptance of MAB Behaviour
Behavioural beliefs	Correlation Coefficient	1,000	.518**	.642**	.735**	.253**	.528**	.637**	.689**	.689**
	Sig. (2-tailed)		.000	.000	.000	,000	.000	.000	.000	.000
	N	220	220	220	220	220	220	220	220	220
Normative Beliefs	Correlation Coefficient		1.000	.706**	.669**	.618**	.441**	.567**	.638**	.629**
	Sig. (2-tailed)			.000	.000	,000	.000	.000	.000	.000
	N		220	220	220	220	220	220	220	220
Control Beliefs	Correlation Coefficient			1,000	.809**	.470**	.419**	.683**	.767**	.719**
	Sig. (2-tailed)				,000	.000	.000	.000	.000	.000
	N			220	220	220	220	220	220	220
Attitude Towards Behaviour	Correlation Coefficient				1,000	.417**	.549**	.676**	.838**	.810**
	Sig. (2-tailed)					.000	.000	.000	.000	.000
	N				220	220	220	220	220	220
Subjective Norms	Correlation Coefficient					1.000	.180**	.321**	.395**	.362**
	Sig. (2-tailed)						.008	.000	.000	.000
	N					220	220	220	220	220
Perceived Behavioural Control	Correlation Coefficient						1.000	.448**	.560**	.565**
	Sig. (2-tailed)							.000	.000	.000
	N						220	220	220	220
Actual Behavioural Control	Correlation Coefficient							1.000	.678**	.652**
	Sig. (2-tailed)								.000	.000
	N							220	220	220
Intention to accept MAB	Correlation Coefficient								1.000	.901**
	Sig. (2-tailed)									.000
	N								220	220
Acceptance of MAB Behaviour	Correlation Coefficient									1.000
	Sig. (2-tailed)									
	N									220

Table 5.29 Spearman's rank correlation coefficient for beliefs, attitudes, intention and behaviour (2018).

Spearman's rank correlation coefficient shows a statistically significant relationship between beliefs and attitudes. There is a statistically significant bi-directional relationship between beliefs, i.e. between behavioural and normative beliefs ($r = .518, p = .000$); behavioural and control beliefs ($r = .642, p = .000$), as well as between normative and control beliefs ($r = .706, p = .000$). There are also statistically significant bi-directional relations between attitudes, i.e. between attitude towards behaviour and subjective norms ($r = .417, p = .000$), attitude towards behaviour and perceived behavioural control ($r = .534, p = .000$); and between subjective norm and perceived behavioural control ($r = .161, p = .017$). These findings confirm that behavioural beliefs, normative beliefs and control beliefs have bi-directional relationships, as well as attitude towards behaviour, subjective norms and perceived behavioural control.

5.5.2 Multiple regression analysis for beliefs, attitudes, intention and behaviour.

The researcher performed multiple regression analysis to determine whether there are unidirectional relationships among beliefs, attitudes, actual behavioural control, intention and behaviour.

Multiple regression can be used to examine relationship between several independent variables and a single continuous dependent variable (Williams 2007:11). The researcher had to perform several linear regressions to determine the predictive power of beliefs on attitudes, attitudes on intention and intention on behaviour. Multiple regression was useful in this study in providing the correlations with the predictive power of beliefs, attitudes, intention and behaviour (Field 2005:144). In short, regression analysis predicts the value of dependent variable from one or more independent variables. Multiple linear regression models were used to explore the extent to which beliefs, attitudes and actual behavioural control predict intention and behaviour.

To perform multiple regression, the assumption of normality must be satisfied or met. However, the researcher performed the multiple regression analyses based on the empirical law of large numbers. In other words, the sample size *(N = 220)* is large sample to be considered a normal distribution (Tabachnick & Fidell 2007). Multiple regression results are shown in Table 5.30 below.

Independent Variable	Dependant Variable	B	Std. Error	Beta	Sig.
Behavioural beliefs	Attitude towards behaviour	.661	.042	.729	.000
Normative Beliefs	Subjective norms	.626	.053	.626	.000
Control Beliefs	Perceived behavioural control	.411	.067	.383	.000
Attitude Towards Behaviour	Intention to accept MAB	.796	.034	.844	.000
Subjective Norms	Intention to accept MAB	.321	.049	.403	.000
Perceived Behavioural Control	Intention to accept MAB	.482	.052	.534	.000
Actual Behavioural Control	Perceived Behavioural Control	.489	.073	.414	.000
Actual Behavioural Control	Intention to accept MAB	.527	.038	.688	.000
Intention to accept MAB	Acceptance of MAB	.880	.027	.910	.000

Table 5.30 Regression analysis for beliefs, attitudes, intention and behaviour (2018).

It was found that behavioural beliefs significantly predicted attitude towards behaviour *(β = .729, p = .000)*; normative beliefs predicted subjective norms *(β = .626, p = .000)*; and control beliefs predicted perceived behavioural control *(β = .383, p = .000)*. The intention to accept modern agricultural biotechnology was significantly predicted by attitude towards behaviour *(β = .844, p = .000)*, subjective norms *(β = .403, p = .000)*, perceived behavioural control *(β = .534, p = .000)*, and actual behavioural control *(β = .688, p = .000)*. Theintention to accept modern agricultural biotechnology significantly predicted the acceptance of modern agricultural biotechnology behaviour *(β = .910, p = .000)*.

5.5.3 Multiple regression analysis for socio-demographics factors.

Multiple regression analysis was performed to determine whether there are relationships between socio-demographics factors (age, gender, race, household income and education) and behaviour towards acceptance of modern agricultural biotechnology. Multiple regression results are shown in Table 5.31 below.

Independent variable	Dependent variable	B	Std. error	Beta	t	Sig.
Age	Acceptance of MAB behaviour	-.631	.236	-.266	-2.672	.009
Gender	Acceptance of MAB behaviour	-.751	.379	-.190	-1.982	.050
Race	Acceptance of MAB behaviour	.275	.269	.105	1.024	.308
Household income	Acceptance of MAB behaviour	-.236	.198	-.123	-1.195	.235
Education	Acceptance of MAB behaviour	-.074	.168	-.044	-.442	.660
Academic Field	Acceptance of MAB behaviour	.056	.091	.058	.613	.541

Table 5.31 Regression analysis for socio-demographics factors (2018).

It was found that age *(β = -.631, p = .009) and gender (β = -.751, p = .050)* negatively predicts acceptance of modern agricultural biotechnology behaviour. However, the other socio-demographic variables were not statistically significant in predicting acceptance of modern agricultural biotechnology behaviour. It was also found that the predictive power of these variables was very low (Race *β = .275, p = .308*; Household income *β = -.236, p = .235*; Education *β = -.074*, *p = .660*; and Academic field *β = .056, p = .541*).

5.6 Theory of planned behaviour path analysis

Path analysis was performed to observe the impact of the Theory of Planned Behaviour in understanding public perception towards modern agricultural biotechnology. Path analysis is a powerful statistical technique that allows for more complicated and realistic models than multiple regression (Streiner 2005:122) and it has increasingly been used to quantify causal pathways in networks of interactions (Smith, Brown & Valone 1996:29). The strength of path analysis is its ability to breakdown the relationships among variables and to test the validity of a theoretical perspective (Stage, Carter & Nora 2004:11). The researcher first performed exploratory factor analysis and the Cronbach's α. as shown in Table 5.27. As discussed earlier on, in this chapter, a loading factor greater than *.4*, (Sevens 1992:382) and a Cronbach's α. coefficient greater than *.7* (Tavakol & Dennick 2011:54), were accepted. The variables satisfied the requirements for construct validity and internal reliability, making path analysis appropriate. According to Steele (2017:1) to perform a path analysis the relationship among variables must be linear, there should be no interactions among variables, endogenous variables must be continuous and relatively normally distributed. Thus, the assumptions of homogeneity of variance, multicollinearity and independent errors have been satisfied[1]. The sample is also large to be considered a normal distribution.

Path analysis allowed the researcher to study direct and indirect relationship among beliefs, attitudes, intention and behaviour (Stage et al. 2004:6). The theory of planned behaviour creates a platform for beliefs to influence behaviour through attitudes and intention (Baron & Kenny 1986:1180). Since path analysis is a variation of multiple-regression analysis (Stage et al. 2004:1), it was useful in analysing the impact of beliefs and attitudes on intention and behaviour. According to Smith et al. (1996:29) path analysis breaks down the overall correlation between two variables into the direct effects of one on the other, indirect effects mediated by other variables, and spurious effects due to common causes and the computed path coefficients indicate the amount of change expected in the dependent variable due to a unit change in the independent variable.

Path model was used to test the direct and indirect relations among the variables. Acceptance of modern agricultural biotechnology behaviour was the dependent variable. Exogenous independent variables were behavioural beliefs, normative beliefs, control beliefs, gender, age, household income, race, education and academic fields. Endogenous independent variables were acceptance of modern agricultural biotechnology (MAB) behaviour, intention to accept MAB, attitude

[1] See section 5.2.2; 5.2.3 and 5.2.4

towards behaviour, subjective norms, perceived behavioural control and actual behavioural control.

5.6.1 Hypoheses testing

Goodness of fit of the path model was assessed by the goodness of fit indices, such as Chi-square model test, Root Mean Square Error of Approximation (RMSEA), goodness-of-fit index (GFI), adjusted goodness of fit index (AGFI), normed fit index (NFI), relative fit index (RFI) and comparative fit index (CFI). Goodness of fit indices are shown in Table 5.32, below.

Fit Indices	**Criteria**	**Indicators**	**Sources**
Model square	p>.05	.000	Kline (2005)
Goodness of Fit Index (GFI)	> .900	.761	Kline (2005)
Adjusted Goodness of Fit Index (AGFI)	> .900	.551	Kline (2005)
Relative Fit Index (RFI)	> .900	.645	Kline (2005)
Normed Fit Index (NFI)	> .900	.763	Kline (2005)
Comparative Fit Index (CFI)	> .950	.773	Kline (2005)
Root Mean Square Error of Approximation (RMSEA)	< .08	.266	Kline (2005)

Table 5.32 Goodness-of-fit indices of the theoretical model (2018).

Results were as follows, chi-square p value *(p = .000)*, RMSEA = .266, GFI = .761, NFI = .763, CFI = .773, AGFI = .551 and RFI = .645. Values for GFI, NFI and CFI range from 0 to 1 with recommending values greater than 0.90 indicating a good fit. There is a good fit if RMSEA is less than 0.05, and there is adequate fit if RMSEA is less than 0.08 (Hair et al. 2014:237). The results given above show a poor fit of the model. As stated in Yuan, Zhang and Deng (2018:2), a poor fit may have been the result of a misspecification in the covariance and mean structures. However, since the researcher was testing a published theory, goodness of fit indices results of this study, could not be used to reject the null hypotheses of this study, hence interpretation was carried out.

5.6.2 AMOS path analysis squared multiple correlations

This section shows the results of the AMOS path analysis squared multiple corrections.

Constructs	Estimate
Perceived Behavioural Control	.132
Subjective Norms	.392
Attitude Towards Behaviour	.531
Intention to accept MAB	.654
Acceptance of MAB Behaviour	.792

Table 5.33 shows AMOS path analysis squared multiple correlations (2018).

According to Kwan and Chan (2014:225) squared multiple correlation coefficient *(R^2)* measures the proportion of total variance on the dependent variables, Y, that is accounted for by a set of predictors, X1, X2, ..., providing estimates for the overall predictive power of a set of predictors. In comparison with Cohen's criterion (1988), the effect size of R^2 is generally large for all variables expect perceived behavioural control *(R^2 = .132)* (Cohen 1988:224).

5.6.3 Path analysis regression weights

Table 5.34 contains the results of the SPSS AMOS path analysis. SPSS AMOS path analysis reveals significant bi-directional relationships between beliefs (behavioural and normative beliefs (*r = .518, p = .000*) and behavioural and control beliefs (*r = .631, p = .000*), as well as between normative and control beliefs (*r = .716, p = .000*). There is a statistically significant positive relationship between beliefs and attitudes, i.e behavioural beliefs and attitude towards behaviour *(β = .804, p = .000)*; normative beliefs and subjective norms *(β = .627, p = .000)*; and control beliefs and perceived behavioural control *(β = .201, p = .000)*. Path analysis has also found the relationships between attitude towards behaviour and intention to accept modern agricultural biotechnology *(β = .666, p = .000)*; between perceived behavioural control and intention to accept modern agricultural biotechnology *(β = .124, p = .003)*; as well as between actual and perceived behavioural control *(β = .318, p = .000)* to be statistically significant.

Constructs	Direction	Constructs	Estimate	Standardised estimates	S.E.	C.R.	P
Behaviouralbeliefs	←→	NormativeBeliefs	.519	1.297	.19	6.818	***
NormativeBeliefs	←→	ControlBeliefs	.716	2.024	.235	8.613	***
Behaviouralbeliefs	←→	ControlBeliefs	.631	1.915	.242	7.897	***
Behavioural beliefs	>	Attitude Towards Behaviour	.804	.729	.051	15.756	***
Normative Beliefs	>	Subjective Norms	.627	.626	.053	11.891	***
Control Beliefs	>	Perceived Behavioural Control	.201	.227	.056	3.597	***
Actual Behavioural Control	>	Perceived Behavioural Control	.318	.283	.071	4.501	***
Perceived Behavioural Control	>	Intention to accept MAB	.124	.123	.042	2.952	.003
Attitude Towards Behaviour	>	Intention to accept MAB	.666	.728	.038	17.736	***
Subjective Norms	>	Intention to accept MAB	.071	.065	.044	1.592	.111
Actual Behavioural Control	>	Intention to accept MAB	.244	.217	.047	5.23	***
Intention to accept MAB	>	Acceptance of MAB Behaviour	.934	.881	.033	28.535	***
Gender	>	Acceptance of MAB Behaviour	-.086	-.024	.108	-.793	.428
Age	>	Acceptance of MAB Behaviour	-.116	-.06	.059	-1.956	.05
Household Income	>	Acceptance of MAB Behaviour	-.101	-.056	.055	-1.817	.069
Race	>	Acceptance of MAB Behaviour	.034	.014	.075	.451	.652
Education	>	Acceptance of MAB Behaviour	.111	.089	.039	2.875	.004
Academic Field	>	Acceptance of MAB Behaviour	.016	.019	.037	.439	.661

Table 5.34 shows AMOS path analysis results (2018).

The relationship between subjective norm and intention to accept modern agricultural biotechnology was found to be statistically insignificant and weak *(β = .071, p = .111)*. There is also statistically significant relationship, as determined by path analysis, between actual behavioural control and intention to accept modern agricultural biotechnology *(β = .244, p = .000)*; intention to accept modern agricultural biotechnology and acceptance of modern biotechnology behaviour *(β = .934, p = .000)*.

As shown in Table 5.34, SPSS AMOS path analysis shows a negative significant relationship between age and acceptance of modern agricultural biotechnology *(β = -.116, p = .05)*, as well as a positive significant relationship between education and acceptance of modern agricultural biotechnology *(β = .111, p = .004)*. Gender was found to be statistically non-significant, as determined by SPSS AMOS path analysis *(β = -.086, p = .428)*, as well as race *(β = .034, p = .652)*; household income *(β = -.101, p = .069)*; and academic field *(β = .016, p = .661)*. Diagram 5.1 below shows the path analysis diagram for the results.

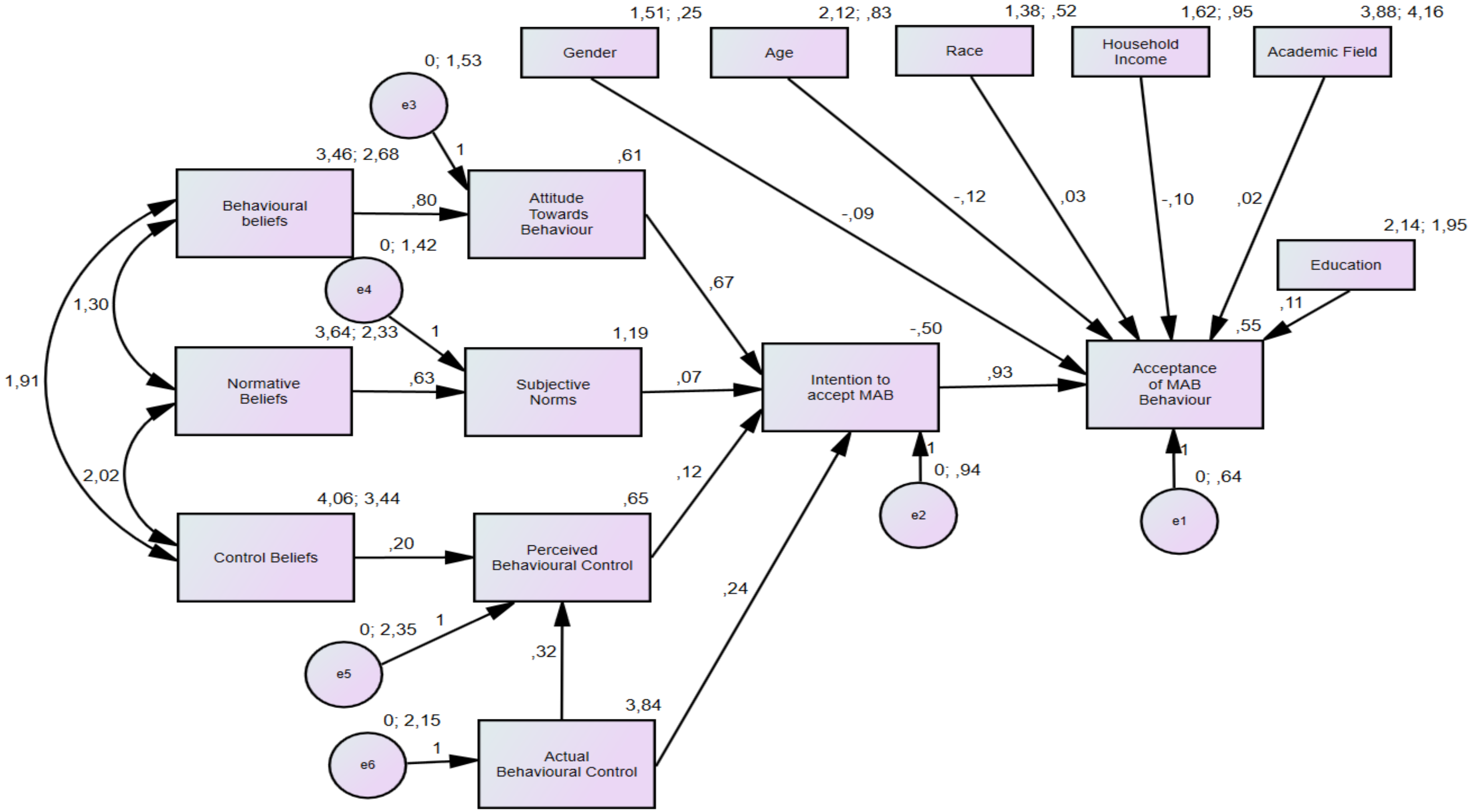

Diagram 5.1 Path analysis for acceptance of modern agricultural biotechnology.

SPSS AMOS path analysis shows statistically significantly bi-directional relationships between beliefs (behavioural, normative and control beliefs), as well as causal relationships between beliefs, attitudes, intention and behaviour, apart from subjective norm and intention to accept modern agricultural biotechnology. It was statistically ascertained that actual behavioural control and predict perceived behavioural control and intention. Generally, there is a weak causal relationship between socio-demographic factors and acceptance of modern agricultural biotechnology, despite the fact that age, and education have a statistically significant relationship with acceptance behaviour.

5.7 Conclusion

The researcher has analysed, presented and interpreted data in this chapter, through multiple statistical models, this was done to accommodate different variable which requires different approaches in analysing data. For instance, the researcher used the t-tests to analysis gender difference in perception towards modern agricultural biotechnology, ANOVA for racial and academic field groups, and linear regression to investigate the relationship between beliefs, attitudes, intention and behaviour, as well as Spearman's rank correlation coefficient to ascertain the bi-directional relationships among beliefs and attitudes. AMOS path analysis was performed in order to explain how the theory of planned behaviour can explain public perception towards accepting modern agricultural biotechnology. In the next chapter (Chapter 6), the researcher presents a discussion of the findings, followed by methodological limitations, conclusion and recommendations.

CHAPTER 6
FINDINGS, CONCLUSION AND RECOMMENDATIONS

This chapter focuses on six important research report aspects, i.e. the discussion of research findings, methodological limitations, practical implications, summary of the findings, recommendations and conclusion of this study. As a recap, the study analysed public perception towards genetically modified crops through investigating beliefs and factors that influence public willingness to consume genetically modified crops and accept modern agricultural biotechnology in South Africa. The researcher used descriptive and exploratory research design and 220 participants were sampled from Kempton Park using mixed and multi-stage sampling procedures. Chi-square was used to test how well the sample represented the population of Kempton Park. In line with the secondary objective 1, the applicability of theory of planned behaviour has been evaluated in analysing public perception towards consuming genetically modified crops and acceptance of modern agricultural biotechnology. Data was collected through a 7-point Likert scale questionnaire designed following guidelines from Ajzen (1991).

SPSS was the main statistical software package used for data analysis in this study. Internal validity and reliability of the questionnaire were tested using the Exploratory factor analysis and the Cronbach's alpha, respectively. Four assumptions of parametric data analysis were tested, which were normality, homogeneity of variance, multicollinearity and independent errors. The researcher performed several other SPSS models during data analysis which include Spearman's rank correlation, independent sample t-test, ANOVA, post hoc multiple comparisons, linear regression and path analysis[1]. This study has been justified on the basis that: (i) the study will add valuable missing knowledge in literature; (ii) provides policy makers, regulators and interested entities some policy insights on how to improve the current genetically modified regulations; (iii) as well as testing the feasibility of undertaking a large-scale study for

[1] See chapter 4 for more details on SPSS model which were used in data analysis.

instance carrying out a study involving ±1000 participants, in South Africa for generalisability of the findings.

6.1 Discussion of the findings

6.1.1 Human health and environment risks.

This study has confirmed the perceived human health and environment risks to be a barrier to public acceptance of modern agricultural biotechnology (Massey et al. 2018; Zhou & Hu 2018; Sax & Doran 2016). The researcher presented findings of people who perceives human health and environmental risk in three dimensions. The first dimension is based on the perceived human health/environmental risks and the acceptance of modern agricultural biotechnology. The second involves the perceived human health/environmental risks and the willingness to consume genetically modified crops. The third dimension covers the perceived human health/environmental risks and the labelling of genetically modified crops. These findings, as categorised above, are discussed below.

Perceived risk and modern agricultural biotechnology.

Spearman's rank correlation indicated high correlations between the perceived human health and environmental risks from genetically modified crops and public unwillingness to accept modern agricultural biotechnology. Perceived human health and environment risk from genetically modified crops was found to have high correlation with public unwillingness to accept modern agricultural biotechnology *($r = .715$, $p = .000$),* despite the widespread adoption of genetically modified crops (Batista & Oliveira 2009:283; Rosculete, Bonciu, Rosculete & Teleanu 2018:3; Herman, Zhuang, Storer, Cnudde & Delaney 2018:9; Kim et al. 2018:947). This finding suggests a low level of public willingness to accept modern agricultural biotechnology in South Africa.

The finding replicates several studies (Kim, Hwang, Lee, Song, Kang & Rhee 2018; McFadden & Smyth 2018; Lusk, McFadden & Wilson 2018; Gao, Yu, Li & McFadden 2019; Marangoz, Paksoy, Paksoy, Özçalici & Çelikkan 2014) which found significant correlation between perceived human health and environmental risks and unwillingness to accept modern agricultural biotechnology. The relationship between these two constructs is negative (Senarath & Karunagoda 2012:284) and perceived human health and environment risk predicts the unwillingness to accept modern agricultural biotechnology. According to Lucht (2015:4260) the perceived human health and environment risk factor is a primary determinant in acceptance of biotechnology in crop production.

Several scholars have warned policy makers that the acceptance of modern agricultural biotechnology depends on public perception towards genetically modified crops (Moschini, Bulut, & Cembalo 2005; Hudson, Caplanova & Novak 2015:303).This study confirms the above assertion by Moschini et al. (2005) and Hudson et al. (2015). Public unwillingness to accept modern agricultural biotechnology is a result of perceived risks from genetically modified crops (Çabuk & Tanrikulu 2014:101). It is therefore significant for policy makers and regulators to develop policy strategies which influence positive public perception towards genetically modified crops. According to Wang, Wang, Lin and Li (2019:358) policy makers must take necessary measures to reduce genetically modified perceived risks. More studies are needed in South Africa to determine policy approaches to be implemented in addressing genetically modified public perceived risks.

Perceived risk and non-genetically modified crops

Spearman's rank correlation indicated moderate correlation between the perceived human health and environmental risks from genetically modified crops and the willingness to eat non-genetically modified crops ($r = .582$, $p = .000$). The finding suggests that the reason for public willingness to consume non-genetically modified crops, is based on public expectation of healthier and environmentally friendly means of crop production (Basha, Mason, Shamsudin, Hussain & Salem 2015:444; Sangkumchalianga & Huang 2012:87). The finding replicates several studies that have shown that the perceived human health and environmental risks from genetically modified crops influences people's intention to consume non-genetically modified crops (Saher, Lindeman & Hursti 2006:324; Sanchez 2015:215; Sangkumchalianga & Huang 2012:87).

Public preference for non-genetically modified crops has also been attributed to public awareness of human health and environmental challenges faced in the contemporary world (Basha et al 2015:451). Hence, scholars suggest that public willingness to consume genetically modified crops depends very much on the ability of modern agricultural biotechnology to address global human health and environmental problems (Lassoued, Smyth, Phillips & Hesseln 2018:2). Genetically modified crops developers must consider health and environmental dimensions in plant biotechnology development. Efforts to convince the public on health and environmental benefits from modern agricultural biotechnology must be made.

This finding is inconsistent with studies that have shown the public's willingness to pay premium on genetically modified biofortified crops[2] (De Steur, Blancquaert, Strobbe, Lambert, Gellynck & Van Der Straete 2015; Britwum, Yiannaka & Kastanek 2018). Genetically modified biofortified crops are products of the second-generation genetically modified crops[3]. Second-generation genetically modified crops are developed to benefit the consumer more than the farmer as was the case with the first-generation genetically modified crops (Carzoli, Aboobucker, Sandall, Lübberstedt & Suza 2018:89). These findings by De Steur et al. (2015) and Britwum et al. (2018) suggest that the public might be willing to accept modern agricultural biotechnology if genetically modified crops directly benefit the consumer. Several studies must

[2] Transgenic biofortified crops are classified as second-generation genetically modified crops and are modified with pro-vitamin A, folate or vitamin C. These crops are potentially beneficial to people suffering from Vitamin A or C deficiencies.

[3] The second-generation of genetically modified crops aim to deliver consumer-oriented benefits (Hartl & Herrmann 2009:552; Magaña-Gómez & Barca 2009:5). Some of the direct consumer benefits include reduced or healthier fats, increased protein, reduced carbohydrates and improved flavour. Examples of these crops include the Golden Rice, designed to provide vitamin A; a transgenic corn to make Ethanol fuel; pink pineapples engineered with lycopene which may fight cancer; and purple tomatoes engineered to have high levels of anthocyanins which may lower cardiovascular risks (Pollack 2011:1; James 2015:2).

be carried out to confirm the findings by De Steur et al. (2015) and Britwum et al. (2018).

Perceived risk and labelling of genetically modified crops

Spearman's rank correlation indicated low correlations between the people who perceive human health and environmental risks and mandatory labelling of genetically modified crops *(r = .438, p = .000)*. Several scholars have found that consumers who perceive risks from genetically modified crops, demand the labelling of these crops (Rosculete et al. 2018:10; Molen 2015:2; Fraboni 2017:563; Sebastian-Ponce et al. 2014:154; Roe & Teisl 2007:49; Chang & Huang 2010:512). This group of consumers demand the labelling of genetically modified crops in order to avoid purchasing and consuming genetically modified crops (Knowles, Moody & McEachern 2007:43; McHughen 2011:33). Labelling becomes a consumer strategy to avoid genetically modified crops (Bovay & Alston 2018:19). However, South Africa have implemented mandatory labelling of genetically modified crops (Viljoen & Marx 2013) and this finding suggest that people are not aware of this requirement.

The researcher recommends further studies analysing the determinants and costs for labelling, public willingness to purchase labelled genetically modified crops and the suitability of mandatory labelling law in South Africa. Labelling of genetically modified crops can be beneficial to regulators. In the United States, the level of public willingness to consume genetically modified crops increased by 19% as a result of mandatory labelling law (Kolodinsky & Lusk 2018:1). In this study, though, the reasons for the public to demand the labelling of genetically modified crops is not clear. These reasons are worthy to be known so that regulators can plan communication strategies, accordingly.

On the other hand, several studies have found that people are not willing to purchase labelled genetically modified crops (Marchant, Cardineau & Redick 2010; Huffman & McCluskey 2014; Bansal & Gruère 2012). Philips and Hallman (2013:741) found out that the public were willing to pay a premium for non-genetically modified crops. Several other studies reported that mandatory labelling incurs additional costs to consumers (Bruschi et al. 2015:421; Marchant et al. 2010:323; Huffman & McCluskey 2014:158; Pakseresht 2017:80). Policy outcomes of mandatory labelling are not known beforehand. Hence, policy makers must ensure that the economic and political forces at work in mandatory labelling are well estimated or calculated to ensure the effectiveness of the policy implementation. For instances, regulators need to ascertain the amount of information expected by the public on genetically modified labels (McFadden 2017; Sunstein 2016).

In summary, the perceived human health and environmental risks from genetically modified crops have been found to play a significant role in predicting the acceptance of modern agricultural biotechnology. Perceived human health and environmental risks have been found also to predict the public willingness to consume non-genetically modified crops and the demand mandatory labelling.

6.1.2 Public trusting genetically modified regulations

Public trust in regulating genetically modified crops is an important predictor of acceptance of modern agricultural biotechnology (Ryu et al. 2018:2; Thompson 2018:169). Trust building is one of the greatest challenges in regulating genetically modified crops (Adnan et al. 2018:834). The researcher presented and discussed the findings on public trust in regulating genetically modified crops in three dimensions, below.

Public trust and labelling of genetically modified crops

The study has found that there is a low level of public trust in genetically modified crops regulations in South Africa *(M = 3.58, SD = 1.76)*[4] and a higher level of public demanding the labelling of genetically modified crops *(M = 6.30,*

[4] 1 = very strongly disagree; 2 = strongly disagree; 3 disagree; 4 = neither disagree nor agree; 5 = agree; 6 = strongly agree; 7 = very strongly agree

SD = 1.34)[5]. Spearman's rank correlation indicated a negative correlation between public trust and labelling of genetically modified crops. The lower the level of trust *(M = 3.58, SD = 1.76)*[6], the more the public wants genetically modified crops to be labelled *(M = 6.30, SD = 1.34)*[7]. These findings are in-line with several studies that have found public trust to be negatively correlated with labelling of genetically modified crops (Ghoochani, Ghanian, Baradaran, Alimirzaei & Azadi 2018; Ruth, Rumble, Gay & Rodriguez 2016; Chen & Li 2007; Hendriks, Giesbertz, Bredenoord & Repping 2018; Gonzalez et al. 2009). This suggests that public trust to be a determinant for labelling of genetically modified crops.

When the public has trust in genetically modified crops regulations, perceived risks from genetically modified crops becomes smaller, attitude becomes favourable, leading towards acceptance of modern agricultural biotechnology (Aleksejeva 2012:7; Ryu et al. 2018:15; Baumber 2018:32). Aleksejeva (2012) and Ryu et al. (2018) suggest a causal relationship among trust → perception → attitude → acceptance. However, public trust has been criticised for being subjective and more of an ethical factor (Tanaka 2013:69; Ribeiro, Barone & Behrens 2016:125; Viklund 2003:727). Violations of human and environmental ethics will influence public mistrust. Regulators of genetically modified crops must ensure that there are no violations of human and environmental ethics to entice public acceptance behaviour.

The public's demand for mandatory labelling can be reduced by cultivating public trust in the regulation of genetically modified crops. The researcher recommends further studies to determine the significance of public trust in predicting acceptance of modern agricultural biotechnology. Spearman's rank correlation found a non-significant association between trust and labelling

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[5] 1 = very strongly disagree; 2 = strongly disagree; 3 disagree; 4 = neither disagree nor agree; 5 = agree; 6 = strongly agree; 7 = very strongly agree

[6] 1 = very strongly disagree; 2 = strongly disagree; 3 disagree; 4 = neither disagree nor agree; 5 = agree; 6 = strongly agree; 7 = very strongly agree

[7] 1 = very strongly disagree; 2 = strongly disagree; 3 disagree; 4 = neither disagree nor agree; 5 = agree; 6 = strongly agree; 7 = very strongly agree

constructs, despite descriptive analysis showing sizeable differences between the constructs.

Trust and attitude towards genetically modified crops.

Spearman's rank correlation coefficient has determined statistically significant association between public trust and attitude towards consuming genetically modified crops *($r = .249, p = .000$)*. Public trust has been found to be a predictor of attitude towards consuming genetically modified crops (Rana & Paul 2017; Hu & Deng 2016; Rzymski & Królczyk 2016; Baker & Burnham 2001; Huffman et al. 2004). In this study the public was found to have a low level of trust on genetically modified crops regulations *($M = 3.58, SD = 1.76$)*[8] and a negative attitude towards consuming genetically modified crops *($M = 3.19, SD = 1.84$)*[9].

This finding replicates several studies that have found public mistrust in genetically modified crops regulations to predict a negative attitude towards consuming genetically modified crops (Rodríguez-Entrena & Salazar-Ordóñez 2013; Asifa, Xuhuia, Nasirib & Ayyub 2018; Wilson & Zhang 2018:27; Rodriguez-Entrena, Salazar-Ordonez & Sayadi 2013; Salgado-Beltrán, Beltrán-Morales, Velarde-Mendivil & Robles-Baldenegro 2018; Hu & Deng 2016; Mallinson, Russell, Cameron, Ton, Horton & Barker 2018). According to Qiu et al. (2007:67), Chinese consumers' trust in genetically modified crops regulatory process predicted a positive attitude towards accepting modern agricultural biotechnology. Failure of people to trust the genetically modified crops regulatory process leads to risk perception, as well a negative attitude and an intention not to accept modern agricultural biotechnology.

Several scholars have recommended governments to increase public trust in genetically modified crops regulation processes (Apaolaza, Hartmann, D'Souza & López 2018; Rodríguez-Entrena & Salazar-Ordóñez 2013; Andrew, Ismail &

[8] 1 = very strongly disagree; 2 = strongly disagree; 3 disagree; 4 = neither disagree nor agree; 5 = agree; 6 = strongly agree; 7 = very strongly agree

[9] 1 = very strongly disagree; 2 = strongly disagree; 3 disagree; 4 = neither disagree nor agree; 5 = agree; 6 = strongly agree; 7 = very strongly agree

Djama 2017; Dincer & Fredriksson 2018). Higher level of public trust positively impacts on the public willingness to accept modern agricultural biotechnology. A strategy for increasing public trust in regulating modern agricultural biotechnology in South Africa is a requirement. Lessons can be learnt from Netherlands and China where public trust has resulted in a higher level of public acceptance (Hanssen et al. 2018:8; Curtis et al. 2004:71). Public trust outweighs the provision of information about benefits and risks of genetically modified crops (Prati et al. 2012:169) and it's a key factor in predicting public perception (Priest 2001:97; Gutteling, Hanssen, Der Veer & Seydel 2006:103).

Trust and behaviour

Spearman's rank correlation coefficient shows statistically significant association between public trust on genetically modified crops regulations and acceptance of modern agricultural biotechnology ($r = .289, p = .000$). This study found low public trust ($M = 3.58$[10]$; SD = 1.72$), to correlate with low public acceptance of modern agricultural biotechnology ($M = 3.70; SD = 2.11$). There is a significant association between trust and behaviour.

This finding is consistent with several studies that have attributed acceptance of modern agricultural biotechnology to a higher level of public trust (Lucht 2015; Siegrist 1999; Siegrist, et al. 2012; Tanaka 2004; Roosen, Bieberstein, Blanchemanche, Goddard, Marette & Vandermoere 2015; Goddard, Muringai & Boaitey 2018; Marques, Critchley & Walshe 2015; Cui & Shoemaker 2018:1; Puduri, Govindasamy & Vellangany 2011:54; Mellentin 2018:46; Lucht 2015; Wunderlich & Gatto 2015). In this study, it is clear that the level of public trust in genetically modified crops regulations in South Africa is low. This finding replicates Gastrow et al.'s. (2018:6) recent finding that the majority of the South African population felt that genetically modified crops were not effectively regulated by the government. According to Landrum, Hilgard, Lull, Akin and

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[10] 1 = very strongly disagree; 2 = strongly disagree; 3 disagree; 4 = neither disagree nor agree; 5 = agree; 6 = strongly agree; 7 = very strongly agree**.**

Jamieson (2018:1) public trust in genetically modified crops is affected by misinformed criticisms on modern agricultural biotechnology.

Policy makers and regulators must develop strategies to counter unfounded criticisms, myths and negative opinions about genetically modified crops. The process of public participation and engagement must be transparent and inclusive (Ishii & Araki 2016:1513; Zilberman et al. 2013:206). In addition, the government must handle food safety incidents in a way that leaves the public without doubt on its ability to manage risks associated with modern agricultural biotechnology. In short, public trust in genetically modified regulations is one of the predictors of accepting modern agricultural biotechnology (Molnar, Ryan, Pradhan, Eby, Louis & Zakrajsek 2018:326; Ding, Veeman & Adamowicz 2015:97).

6.1.3 Gender differences and acceptance behaviour

Ascertaining the gender differences in public perception towards consuming behaviour is important to policy makers and regulators of genetically modified crops (Armando, Roberta & Francesco 2016; Bellows, Alcaraz & Hallman 2010; Żelazna, Kowalczuk & Mikuta 2002). An independent samples t-test found a statistically significant mean difference between male and female on acceptance of genetically modified crops, $t\ (218) = 2.317,\ p = .021$. Regression analysis shows statistically negative significant predictive value of gender towards acceptance of modern agricultural biotechnology $(\beta = -.751,\ p = .050)$. The study suggests that females have a low acceptance of modern agricultural biotechnology compared to males. This finding is consistent with studies which reveal that gender predict the unwillingness to accept of modern agricultural biotechnology (Ling, Santos & Poletti 2013:66; Elder, Greene & Lizotte 2018:500; Maes, Bourgonjon, Gheysen & Valcke 2018:600; McFadden 2016:11; Mucci, Hough & Ziliani 2004:559).

There are several reasons given by scholars in explaining gender differences in public acceptance of genetically modified crops (Kim 2012:193; Ruth & Rumble

2017:78; Dass, Lu, Chowdhury, Lampl, Kamalanathan & Nygard 2016:5; Das, Angeli, Krumeich & van Schayck 2018:1; Kraljević & Filipović 2017:5; Krystallis 2005:320). First, gender differences in accepting genetically modified crops have been attributed to difference in information processing mechanism between male and female (Żelazna et al. 2002:94; Hu & Jasper 2004:113; Dorota 2013; Sajdakowska, Królak, Zychowicz & Jezewska-Zychowicz 2018:1). Females tend to be comprehensive information processors and engage more in complex information search than men before deciding to purchase a product. Secondly, females tend to show a higher health-seeking behaviour than males (Bellows et al. 2010:541; Rana & Paul 2017:159). Females are much knowledgeable on food nutrition, eat healthier and engage in food-related activities than males. Thirdly, women decide on behalf of families on what to consume (Davidson & Freudenburg 1996; Naik et al. 2015:116). The role that women play in a family make them to be very particular on the healthy status of the food they intent to consume. Gender remains a highly significant predictor of public acceptance of modern agricultural biotechnology (Elder, Greene & Lizotte 2017:6).

However, there are studies that found gender differences towards the acceptance of modern agricultural biotechnology to be non-significant (Dass et al. 2016; Surmeli & Sahin 2010; Saleh, Alothman & Alhoshan 2013; Simon 2010). These findings suggest that the significant gender differences in accepting modern agricultural biotechnology, characterise the population under study, but gender, as a variable, is not a predictor of acceptance of modern agricultural biotechnology. This is confirmed by results from AMOS path analysis that have found gender to be non-significant in predicting behaviour. The researcher recommends further studies to be carried out in South Africa to determine the significance of gender differences as a predictor of acceptance of modern agricultural biotechnology.

6.1.4 Age differences and acceptance behaviour

Linear regression analysis *(β = -.631, p = .009)* and AMOS path analysis *(β = -.116, p = .05)* found age differences to be a significant predictor of modern agricultural biotechnology acceptance. This study established that an increase in years, increases the level of unwillingness to accept modern agricultural biotechnology, i.e. an increase in years has been associated with lower scaling of variables, i.e. from disagree to strongly disagree.

This finding is consistent with several studies (Bellows et al. 2010:549; Valente & Chaves 2018:4115; Popek & Halagarda 2016:330; Hervé & Mullet 2009:306; Ramya & Ali 2016:80; Jisana 2014:35) which have observed a similar pattern in age differences and acceptance of modern agricultural biotechnology. Several scholars have stated various reasons for such a consumption pattern (Borg 2018:338; Yoon & Cole 2006:259; Dorota 2013). Firstly, older people are more particular on health issues than younger people (Borg 2018:338). Secondly, younger people are more informed on the latest technology than older people (Yoon & Cole 2006:259). These two points suggest that either the older people are not aware of the existence of genetically modified crops or they are aware, but they perceive human health risks from these crops. Both assumptions can be correct, hence further studies can be carried out to determine the reasons for this age consumption pattern.

However, there are studies which reveal the willingness of older people to accept and consume genetically modified crops (Popek & Halagarda 2016:330). This shows that age differences in consuming genetically modified crops and accepting modern agricultural biotechnology is inconclusive. Age difference related conditions for accepting of modern agricultural biotechnology must be investigated, for the benefit of policy makers and regulators of genetically modified crops.

6.1.5 Household income

Household income and acceptance behaviour

Household income is a major factor in predicting consumer behaviour because it gives families or individuals a purchasing power (Al-Jeraisy 2008:241). However, in this study, linear regression analysis predicted a negative, low and non-significant predictive power for household income ($\beta = -.236$, $p = .235$), as well as AMOS path analysis ($\beta = -.101$, $p = .069$). This finding suggests that as household income increases, acceptance of modern agricultural biotechnology decreases, as people opt for non-genetically modified crops. Although, these findings were not found to be statistically significant ($p > .05$), they are consistent with several studies (Puduri et al. 2011; De Steur et al. 2010; Ramya & Ali 2016).

On the other hand, the finding is inconsistent with several findings that have established a significant association between household income and acceptance of modern agricultural biotechnology (Puduri et al. 2011:55; De Steur et al. 2010:122; Paul et al. 1996:161). Household income gives household the power to purchase; thus, higher income implies more purchasing power. Participants with lower household income are expected to be willing to consume genetically modified crops if they are cheaper. Individuals from higher household income are expected to disapprove of genetically modified crops based on perceived health risks. Willingness to consume genetically modified crops differs according to levels of household income (Ramya & Ali 2016:80).

Household income and knowledge on genetically modified crops

The study found a significant association between household income and public knowledge on genetically modified crops. There was a statistically significant different mean (as determined by one-way ANOVA) between household income groups and public knowledge of genetically modified crops ($F(4,215) = 7.049$, $p = .000$); as well as between household income and eating genetically modified crops because of “my significant others' decision” ($F(4,215) = 2.453$, $p = .047$). These findings were consistent with several studies which have found the level of income to predict consumer knowledge on genetically modified crops (De Steur et al. 2010; Puduri et al. 2011: Ramya & Ali 2016).

These findings suggest two important concepts. Firstly, people with high incomes are very particular and catious of what they consume making them seek information on products they consume. Hence, descriptive analysis shows that individuals in high income categories were more informed on genetically modified crops.[11] Secondly, individuals with lower household income do not have much choice on whether to consume genetically modified crops or not, compared to individuals with high income levels[12]. High income earners have the choice to eat genetically modified crops without being influenced by "significant others". According to Al-Jeraisy (2008:250) high income people can afford to buy the quantity and quality of products they want, whereas limited income ones cannot. Circumstances may end-up force people to consume genetically modified crops, unwillingly.

6.1.6 Education level and acceptance of modern agricultural biotechnology

There was a statistically significant different mean (as determined by one-way ANOVA) between education level and acceptance of modern agricultural biotechnology *(F (33,218) = 1.668, p = .019)*. AMOS path analysis determined a low, positive significant relationship between education and acceptance of modern agricultural biotechnology *(β = .111, p = .004)*. Higher level of education is associated with higher level of modern agricultural biotechnology acceptance. This finding is consistent with several studies (De Steur et al. 2010; Rollin, Kennedy, & Wills 2001; Singhal 2017; Puduri et al. 2011) which have found education levels to predict the acceptance of modern agricultural biotechnology. The finding has been justified on the basis that higher levels of education increases an individual knowledge on modern agricultural biotechnology (Thorne et al. 2017:51; Gurau et al. 2016:34; Pardo, Midden & Miller 2002:9; Uşak, Erdogan, Prokop & Özel 2009:123). These findings

[11] See section 5.4.5 for descriptive analysis
[12] See section 5.4.5 for descriptive analysis

suggest a strong correlation between education levels and acceptance of modern agricultural biotechnology.

Education levels which were found to have a significant mean difference in accepting modern agricultural biotechnology were between individuals who have obtained high school certificates and those with diplomas, as well as between individuals with post-high school certificates and those with first degrees. An increase in the level of education was found to positively correlate with an increase in knowledge. Prokop, Lešková, Kubiatko and Diran (2007:895) found that the level of knowledge correlated positively with attitudes.

However, this finding is inconsistent with other studies (Castera, Clement, Munoz & Bogner 2018; Jikun & Bowen 2015; Naik et al. 2015) reporting a non-significant association between education levels and acceptance of modern agricultural biotechnology. Jikun and Bowen (2015:2398) have found that less-educated consumers trust and are willing to consume genetically modified crops more than the highly-educated consumers. Highly-educated consumers are strongly influenced by human health and environment risk information than the less-educated consumers (Znidersic et al. 2015:59; Lockie et al. in Shafie & Rennie 2012:361; Zhu & Xie 2015:790). Thus, an increase in education leads to an increase in public mistrust and an increase in the level of unwillingness to accept modern agricultural biotechnology, i.e. *(↑level of education → ↑ public mistrust →↑ level of unwillingness to accept modern agricultural biotechnology*).

6.1.7 Race and acceptance of modern agricultural biotechnology

This study has established a very low and non-significant predictive power of race towards acceptance of modern agricultural biotechnology, through linear regression analysis ($\beta = .275, p = .308$), and AMOS path analysis ($\beta = .034, p = .652$). Therefore, race differences were not found to predict public willingness to consume genetically modified crops and accept modern agricultural biotechnology. This finding is inconsistent with other studies (Chen & Chern 2002; Reid 2004; Bernard & Gifford 2006) which have suggested that race influences public acceptance of modern agricultural biotechnology. For instance, Tanius and Seng (2015:22) found a significant difference between race and attitude towards genetically modified crops, as shown in the analysis of variance between Malay and Indian *(p-value* $= 0.001 < \alpha = 0.05$*)* and between Malay and Chinese *(p-value* $= 0.001 < \alpha = 0.05$*)*.

In South Africa, a study by Gastrow et al. (2018:7) has reported that “White and Indian people were more likely to see biotechnology as an overall risk to human compared to black and coloured South Africans”. The researcher recommends that further studies are carried out to investigate whether there is significant mean difference in acceptance of modern agricultural biotechnology based on racial groups in South Africa. The findings of the study might be instrumental in designing communication or awareness programs that are effective in persuading South Africans to accept modern agricultural biotechnology which are cost efficient to the public, since awareness programs are based on a specific-group needs and not generalised.

6.1.8 Academic fields and acceptance of modern agricultural biotechnology

Linear regression[13] and AMOS path[14] analyses established a low and non-significant predictive power of academic fields towards acceptance of biotechnology. Academic fields of study were not found to predict acceptance of modern agricultural biotechnology. However, academic fields of study were found to predict individual knowledge on genetically modified crops. There is a statistically significant mean difference between academic groups (as determined by one-way ANOVA) on public knowledge of genetically modified crops ($F\ (6,104) = 2.201, p = .049$). The significant differences towards genetically modified crops knowledge were found between individuals with Education and Science, Engineering and Technology qualifications. This finding

[13] Linear regression results *(*$\beta = .056, p = .541$*)*.
[14] AMOS analysis *(*$\beta = .016, p = .661$*)*.

is consistent with findings from other studies (Surmeli & Sahin 2010, Weisenfeld & Ott 2011; Wnuk & Kozak 2011; Folkerth 2015; Funk & Kennedy 2016; Chmielewski et al. 2017).

However, the finding is inconsistent with Lamanauskas and Makarskaite-Petkeviciene's (2008) study which found non-significant differences between students taking biology and non-biology courses. Lamanauskas and Makarskaite-Petkeviciene (2008) recognized that the biotechnology knowledge of students was largely based on general education rather than on specific knowledge gained at university. Therefore, there is a need to carry out a comprehensive study assessing the effects of different areas of study towards willingness to accept modern agricultural biotechnology in South Africa. As recommended in Šorgo, Ambrožič-Dolinšek, Ųsak and Özel (2011:2) South Africa can make use of its national education curricula to deepen the public knowledge on genetically modified crops.

6.1.9 Psychological factors

As in Knauder and Koschmieder (2019), this study investigated the relationships among beliefs, attitudes, intention and behaviour, as it relates to public willingness to consume genetically modified crops and acceptance of modern agricultural biotechnology. Spearman's rank correlation, linear regression and AMOS path analysis were performed to measure bi-directional and unidirectional relationships among the components of the theory of planned behaviour, as well as their predictive power. The findings are discussed below.

Bi-directional relationships among beliefs

Spearman's rank correlation[15] and AMOS path analysis[16] have confirmed significant bi-directional relationships among beliefs, as hypothesized in the

[15] Spearman's ranked correlation results: behavioural beliefs ↔ normative beliefs ($r = .518, p = .000$); behavioural beliefs ↔ control beliefs ($r = .642, p = .000$); and normative beliefs ↔ control beliefs ($r = .706, p = .000$).
[16]SPSS AMOS path analysis results: behavioural ↔ normative beliefs ($r = .518, p = .000$); behavioural ↔ control beliefs ($r = .631, p = .000$), as well as normative ↔ control beliefs ($r = .716, p = .000$).

theory of planned behaviour (Ajzen 1991, 2001; Parker, Manstead and Stradling 1995). Using Asuero et al's. (2006:47) strength of correlation model[17], bi-directional relationships correlation among beliefs (behavioural, normative and control beliefs) range from a moderate to ahigh correlation. These findings confirm that behavioural, normative and control beliefs are correlated, implying, for instance, that control beliefs influence behavioural beliefs and vis-versa.

Bi-directional relationships among attitudes

Spearman's rank correlation[18] has confirmed significant bi-directional relationships among attitudes as hypothesised in the theory of planned behaviour (Ajzen 1991, 2001). Using, Asuero et al. (2006:47) strength of correlation model[19], bi-directional relationships among attitudes (attitude towards behaviour, subjective norm and perceived behavioural control) ranges from little (if any) correlation to moderate correlation. Bi-directional relationship between subjective norms ↔ perceived behavioural control, as well as between attitude towards behaviour ↔ subjective norms, though statistically significant, have been found to be low, implying that there is low, if any, relationship among these attitudes. The relationship between attitude towards behaviour ↔ perceived behavioural control was found to be moderate, in other words, the influence between these two attitudes is also not very strong. The implication though, is that attitudes influence each other, regardless of the strength of correlation. These findings suggest that policy makers and regulators of genetically modified crops must address public perceived beliefs and attitudes in a holistic approach, knowing that although the strength of influence might be low, it does exist, and it depends on a set of the beliefs or attitudes under considerations.

[17] Asuero et al. 2006 strength of correlation has been described in section 5.5.1 in Chapter 5.

[18] attitude towards behaviour ↔ subjective norms *(r = .417, p = .000)*; attitude towards behaviour ↔ perceived behavioural control *(r = .549, p = .000)*; and subjective norms ↔ perceived behavioural control *(r = .180, p = .008)*

[19] Asuero et al. 2006 strength of correlation has been described in section 5.5.1 in Chapter 5.

Causal relationships among beliefs and attitudes

This study through linear regression[20] and AMOS path[21] analyses confirmed significant causal relationship *($p < .05$)* between beliefs and attitudes as hypothesised in the theory of planned behaviour (Ajzen 1991, 2001). This study has also confirmed a significant relationship *($p < .05$)* between actual behavioural control and perceived behavioural control through linear regression[22] and AMOS path[23] analyses. These findings replicate studies that have found beliefs to be significant predictors of attitudes (Ajzen 1991, 2001; Chmielewski et al. 2017; Ajzen & Fishbein 2008). In other words, perceived risk beliefs about genetically modified crops shape a negative attitude towards consuming these crops. Perceived benefit beliefs will shape a positive attitude and willingness to accept modern agricultural biotechnology. Policy makers and regulators of genetically modified crops must investigate the beliefs held by the public about genetically modified crops and address them accordingly in policy implementation.

Causal relationships among attitudes and intention

This study through linear regression[24] has confirmed significant relationship between attitudes → intention as hypothesised in the theory of planned behaviour (Ajzen 1991, 2001). However, AMOS path analysis has confirmed a significant causal relationship between attitude towards behaviour → intention to accept modern agricultural biotechnology *($\beta = .666, p = .000$),* as well as between perceived behavioural control → intention to accept modern

[20] Linear regression analysis: behavioural beliefs → attitude towards behaviour ($\beta = .729, p = .000$); normative beliefs → subjective norms ($\beta = .626, p = .000$); control beliefs → perceived behavioural control ($\beta = .383, p = .000$).

[21] AMOS path analysis results: behavioural beliefs → attitude towards behaviour ($\beta = .804, p = .000$); normative beliefs → subjective norms ($\beta = .627, p = .000$); and control beliefs → perceived behavioural control ($\beta = .201, p = .000$).

[22] Linear regression analysis results: actual behaviour control → perceived behavioural control ($\beta = .489$, p = .000)

[23] AMOS path analysis: actual behavioural control → perceived behavioural control ($\beta = .318, p = .000$)

[24] Linear regression results: attitude towards behaviour → intention to accept modern agricultural biotechnology ($\beta = .844, p = .000$), subjective norms →intention to accept modern agricultural biotechnology ($\beta = .403, p = .000$), perceived behavioural control → intention to accept modern agricultural biotechnology ($\beta = .534, p = .000$), and actual behavioural control → intention to accept modern agricultural biotechnology ($\beta = .688, p = .000$).

agricultural biotechnology *(β = .124, p = .003)*. The results obtained from AMOS path analysis on the relationship between subjective norms → intention to accept modern agricultural biotechnology *(β = .071, p = .111)* is inconsistent with the theory of planned behaviour and other studies (Zhang et al. 2018; Cook et al. 2002; Ghoochani et al. 2017) that have found subjective norms to be a significant predictor of intention.

These findings suggest a high predictive power for behavioural beliefs → attitude towards behaviour (*β = .804, p = .000*), and attitude towards behaviour → intention to accept modern agricultural biotechnology *(β = .844, p = .000)*. In other words, this study has found that South Africans have a higher level of risk perception from genetically modified crops (M = 3.46[25], SD = 1.64), hence their attitude towards accepting modern agricultural biotechnology is not favourable (M = 3.28[26], SD = 1.92), and their intention to accept biotechnology in crop production is also low (M = 3.39[27], SD = 1.81). These findings are consistent with several studies (Zhang, Jing, Bai, Shao, Feng, Yin & Zhang 2018; Vecchione, Feldman & Wunderlich 2014; Kim et al. 2014; Ghoochani et al. 2017) which have reported behavioural beliefs and attitude towards behaviour to play important roles in shaping behavioural intention. These findings emphasise the importance of perceiving benefits from genetically modified crops. Once studies have ascertained public perceived risk beliefs from genetically modified crops, corrective actions by policy makers and regulators must be treated as a matter of policy urgency.

There is also low predictive power between control beliefs → perceived behavioural control (*β = .201, p = .000*), perceived behavioural control → intention to accept modern agricultural biotechnology *(β = .534, p = .000)* as well as between subjective norms → intention to accept modern agricultural

[25] 1 = very strongly disagree; 2 = strongly disagree; 3 disagree; 4 = neither disagree nor agree; 5 = agree; 6 = strongly agree; 7 = very strongly agree.
[26] 1 = very strongly disagree; 2 = strongly disagree; 3 disagree; 4 = neither disagree nor agree; 5 = agree; 6 = strongly agree; 7 = very strongly agree.
[27] 1 = very strongly disagree; 2 = strongly disagree; 3 disagree; 4 = neither disagree nor agree; 5 = agree; 6 = strongly agree; 7 = very strongly agree.

biotechnology *(β = .071, p = .111).* Cook et al. (2002:568) found out that perceived behavioural control was a more substantial determinant of intention than subjective norms. This finding in Cook et al. (2002) is in-line with the finding of this study, as subjective norms were found to be less prominent and non-significant in predicting the intention to accept modern agricultural biotechnology.

Causal relationships between intention and behaviour

The study has confirmed through linear regression[28] and AMOS path[29] analyses the significant causal relationship between intention and behaviour, as hypothesised in the theory of planned behaviour. These findings support previous studies that found intention to be a strong predictor of behaviour (Ajzen 2015; Kim et al. 2014; Cook et al. 2002; Spence & Townsend 2006; Prati et al. 2012). The results show that the people in South Africa have low intention of accepting modern agricultural biotechnology (M = 3.39[30], SD = 1.81) which predicted low public acceptance of modern agricultural biotechnology (*M = 3.43, SD = 1.99*), in general. This finding is consistent with several studies (Kim et al. 2014; Popek & Halagarda 2016; Gastrow et al. 2018). The theory of planned behavioural have confirmed findings by Gastrow et al. (2018) that in South Africa, public willingness to accept modern agricultural biotechnology and genetically modified crops is at a low level.

In summary the theory of planned behaviour is applicable in analysing public perception towards genetically modified crops and acceptance of modern agricultural biotechnology. This finding is consistent with several studies (Zhang et al. 2018; Latif & Ayob 2014; Maichum et al. 2016; Sanne & Wiese 2018). In

[28] Linear regression analysis results: intention to accept modern agricultural biotechnology → acceptance of modern agricultural biotechnology behaviour (β = .910, p = .000).

[29] AMOS path analysis results: intention to accept modern agricultural biotechnology → acceptance of modern biotechnology behaviour to be significant and very strong (β = .934, p = .000).

[30] 1 = very strongly disagree; 2 = strongly disagree; 3 disagree; 4 = neither disagree nor agree; 5 = agree; 6 = strongly agree; 7 = very strongly agree

addition, the theory has confirmed Gastrow et al.'s (2018) finding that there is a low acceptance of modern agricultural biotechnology in South Africa.

6.2 Methodological limitations and considerations

6.2.1 Poor fit of model

The goodness of fit results shows poor fit of the model *(RMSEA = .266, GFI = .761, NFI = .763, CFI = .773, AGFI = .551 and RFI = .645*). Values for GFI, NFI and CFI were expected to be greater than .90, and less than .08 for RMSEA (Yuan et al. 2018). Poor fit of model indices suggests that there were too many questionnaire items testing a single construct. Having too many questionnaire items (as was the case) result in misspecification of covariance and mean structure[31] (Zhang & Deng 2018:2). The researcher recommends that when similar studies are being carried out, the questionnaire items must be reduced, and goodness of fit must be tested using pilot study results.

6.2.2 Summing up beliefs

The researcher used the mean for a set of beliefs, for instance, the researcher used the mean for questionnaire items which where testing for human health and environmental beliefs to calculate behavioural beliefs average score. The same principle was applied to normative and control beliefs, in-line with the theory of planned behaviour (Ajzen 2001). However, the limitation associated with this way of summing up beliefs, is that the researcher was not able to test the predictive power of individual beliefs and did not use the data to determine the significance of salient beliefs, e.g. perceived health risk and public mistrust, in predicting attitudes towards accepting modern agricultural biotechnology. Presenting clear and specific variables predicting attitudes (attitude towards behaviour, subjective norms and perceived behaviour control) will facilitate the designing of strategies that are meant to address specific policy challenges.

[31] Misspecification of covariance and mean structures refer to potential biases in the parameter underestimating the true variability of the questionnaire items (Heggeseth & Jewell 2013:12).

6.2.3 Sample size too small for categories

Although the sample size (*N = 220*) was adequate to assume that normality assumption has been satisfied based on the empirical law of large numbers[32] (Ghasemi & Zahediasl 2012), some of the subgroups consisted of too few participants in terms of frequency analysis (e.g. the masters' degree *(N = 7)*, R555 601+ household income *(N = 4)* and Indian/Asian *(N = 5)*), to generalise their opinions to the entire population. According to Ghasemi and Zahediasl (2012:486), large samples ($n > 30$) tend to be normally distributed, hence the sample sizes of all categories were supposed to be greater than 30, regardless of the entire sample being *(N = 220)*. Similar studies must be replicated in South Africa with a larger sample size in order to counter this methodological limitation.

6.2.4 Problem of redundancy

Although several scholars argue in favour of a high Cronbach's α of .90 (Viladrich, Angulo-Brunet & Doval 2017:756), a very high reliability of 0.95 or higher is not necessarily desirable, as this indicates that the items may be entirely redundant[33] (Zaiontz 2018:76). Most of the constructs, for instance the construct "will accept modern agricultural biotechnology" has a Cronbach's α of .992. The researcher suggests that this very high Cronbach's alpha could have been caused as a result of too many questionnaire items intended to measure a single construct. Once again, the researchers who intent to replicate this study must consider eliminating redundant questionnaire items using Cronbach's alpha (Baguley & Brunsden 2013:3).

6.3 Practical implications of the study.

The study has significant practical implications to policy makers, regulators and developers of genetically modified crops in South Africa and countries that have adopted or plan to adopt genetically modified crops; not to leave out the

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[32]The empirical law of large numbers states that larger samples generally lead to more accurate estimates of population means (Sedlmeier & Gigerenzer 1997:35).

[33] Questionnaire items are said to be redundant if the Cronbach's alpha value is close to 1.0, and redundant items do not contribute to the measurement in the construct they are intended to measure (Hair et al 2014).

researchers, academics, investors, anti-genetically modified movements, consumers, and interested parties as this study intent to give a general forecast on the future of modern agricultural biotechnology.

Firstly, the findings of the study imply that policy makers and regulators of genetically modified crops must invest more in public awareness, with an aim to influence positive attitude towards modern agricultural biotechnology. Developers or crop scientists must find appropriate strategies of communicating the benefits of second and third generations genetically modified crops before these crops reach the food market. Commercialising the second and third generations genetically modified crops, when the public perceive risks on first-generation genetically modified crops, will risk public resistance and deny the public the benefits associated with the second and third-generations genetically modified crops.

Secondly, reinforcement of positive beliefs and attitudes towards modern agricultural biotechnology must be prioritised. Positive reinforcement can result in acceptance behaviour as the public is continuously encouraged to consume genetically modified crops. In other words, any perceived benefit belief held by the people on genetically modified crops will predict positive attitude towards accepting modern agricultural biotechnology and ultimately an acceptance behaviour. However, negative beliefs on the risks of genetically modified crops held by the public must be avoided in public debates or discussions. However, when the public brings the subject for debating, regulators must make sure that they give the public satisfactory responses to criticism on modern agricultural biotechnology. In short policy makers and regulators must encourage the public to consume genetically modified crops through adverts, public awareness campaigns, press releases and many other available communication channels to them.

Thirdly, the government must strive to build public trust in genetically modified crops regulators, as well as increasing public participation and transparency.

Public trust building must not be overlooked because of its role in shaping attitude (Molnar et al. 2018; Ding et al. 2015). If fact, more must be done by policy makers and regulators to ensure that the process of regulating genetically modified crops is undoubted. People should know what is taking place anytime and anywhere within and outside South Africa on matters that relate to genetically modified crops. Making any issue on genetically modified crops, private and confidential will create unnecessary food safety uncertainties. The public should have access to accurate information and the opportunity to interact with the information to search for the 'truths on genetically modified crops" without any interference. The regulators' role is to make sure that the public is not misguided.

Fourthly, this study[34] has outlined guidelines that are very useful, and which can be applicable to genetically modified crops environment impact assessment in South Africa. Several scholars have criticised South Africa's environmental impact assessment regulation for failing to govern the release of genetically modified crops into the environment (Swanby 2009; Peacock 2010; Prince & Black 2010). Th researcher has taken it upon himself to set the stage through outlining and recommending guidelines that can be followed by the government of South Africa in regulating genetically modified crops. These guidelines are only a starting point. Policy makers, regulators, researchers and academics are expected to evaluate the applicability of these guidelines in South Africa and are welcome to dismiss and/or to build on these guidelines.

Fifthly, this study confirms the applicability of the theory of planned behaviour in analysing public perception towards genetically modified crops and modern agricultural biotechnology acceptance behaviour. There are limited studies in South Africa (if any) that have used the theory of planned behaviour in this field of study. However, the researcher recommends further studies to be carried out in other parts of the country to confirm the appropriateness of the theory in

[34]See section 3.5 for a discussion on the steps and approaches to environmental impact assessment.

analysing public perception and acceptance of modern agricultural biotechnology. The researchers interested in replicating this study must also take note of the methodological limitations of this study[35]

6.4 Summary of the research findings

An analysis of public perception towards consuming genetically modified crops and the acceptance of modern agricultural biotechnology in South Africa was carried out. The study provides an insight into factors that predict public willingness to consume genetically modified crops and acceptance of modern agricultural biotechnology. The key findings of this study are outlined below.

The study found a low acceptance of modern agricultural biotechnology in South Africa and an unwillingness to consume genetically modified crops.

The study has shown that the main reasons for the people's unwillingness to accept genetically modified crops and modern agricultural biotechnology is the public's perceived potential human health and environmental risks from genetically modified crops and the public mistrust over genetically modified crops regulations. These findings replicate studies that have found out that public unwillingness to accept modern agricultural biotechnology is based on the public perceiving human health and environment risk from genetically modified crops and failure to trust genetically modified crops regulatory authorities (Kim et al. 2018; McFadden & Smyth 2018; Lusk et al. 2018; Gao et al. 2019; Roosen et al. 2015; Goddard et al. 2018; Marques et al. 2015; Cui & Shoemaker 2018). These findings emphasise the role that can be played by beliefs in influencing consumer behaviour. However, there are other beliefs which were not within the scope of this study, which can influence genetically modified crops acceptance, which must be taken also into consideration.

The study found that the people in South Africa prefer to consume non-genetically modified crops to genetically modified crops.

[35] See section 6.2 of this chapter.

The people in South Africa were found to prefer non-genetically modified crops to genetically modified crops. This finding is consistent with several studies (De Steur et al. 2015; Britwum et al. 2018; Basha et al. 2015; Sangkumchalianga & Huang 2012; Sanchez 2015). The study has also shown that this group of people that prefer non-genetically modified crops would prefer labelling of genetically modified crops and they have low level of trust in genetically modified crops regulations. These findings replicate studies that have found a low level of trust on genetically modified crops regulation process to strongly correlates with mandatory labelling, as well as a negative attitude towards genetically modified crops (Salgado-Beltrán et al. 2018; Hu & Deng 2016; Mallinson et al. 2018; Ghoochani et al. 2018; Hendriks et al. 2018). These findings emphasise the importance of public participation and transparency in regulating genetically modified crops. The government needs to invest more resources in ensuring that trust is build between genetically modified crops regulators and the public (An 2017; Kumar 2016). Failure to culminate public mistrust in this area will see a continued public resistance to accept modern agricultural biotechnology in South Africa.

The study found that gender differences exist in public willingness to consume genetically modified crops and acceptance of modern agricultural biotechnology.

The study found out that gender differences exist in the genetically modified crops preference in South Africa. Females have shown a higher level of unwillingness to accept modern agricultural biotechnology compared to males. This finding confirms the findings from several studies that have found the differences between females and males in accepting modern agricultural biotechnology to be significant (Simon 2010; Ling et al. 2013; Elder et al. 2018; Maes et al. 2018; Dass et al. 2016). This finding shows that a one-size-fits-all approach might not work when it comes to designing communication strategies. Differences in gender perception towards modern agricultural biotechnology need further in-depth research, in order to investigate possible ways to address gender differences towards willingness and acceptance of the technology. In general, the researcher believes that the success and acceptance of modern agricultural biotechnology lies with women. Several scholars argue that women are very sensitive and better informed on health-related issues, and they are willing to engage with complex health information than men(Bellows et al. 2010; Rana & Paul 2017; Hu & Jasper 2004). Policy makers and genetically modified crops developers must ensure that modern agricultural biotechnology innovations consider the healthy requirements for women.

The study has found that age difference impacts on public willingness to accept modern agricultural biotechnology.

The study found that an increase in age predict the unwillingness to accept modern agricultural biotechnology. This finding is consistent with other studies that have found age difference to predict public willingness to accept modern agricultural biotechnology (Bellows et al. 2010; Valente & Chaves 2018; Hervé & Mullet 2009; Ramya & Ali 2016; Al-Jeraisy 2008; Popek & Halagarda 2016). This finding emphasises the importance of taking age differences into account when regulating genetically modified crops, i.e. certain age groups face challenges in accessing new products information (Yoon & Cole 2006). Policy makers and regulators must develop guidelines for communicating information to all age groups. In today's world, there are many media platforms that can be used as a medium of communication by policy makers and scientists, hence there is need to determine the most appropriate media for specific age groups.

The study found a very low correlation between household income and acceptance of modern agricultural biotechnology.

Household income as a predictor of acceptance of modern agricultural biotechnology was found to be very low. This finding is inconsistent with several studies that have found household income to be a strong predictor of acceptance of modern agricultural biotechnology (Puduri et al. 2011; De Steur et al. 2010; Ramya & Ali 2016). Further studies must be conducted to confirm the finding of this study, since the finding could be a result of a methodological limitation as discussed in section 6.10, above. In fact, only 5 participants were in the category of R555 601+; this could negatively impact on the validity of this group results. According to Ghasemi and Zahediasl (2012:486) the recommended sample size when using SPSS, is a sample size which is greater than 30 *(N > 30)*.

On the other hand, this study found that people with high income were very knowledgeable on genetically modified crops and are less influenced by significant others on what to consume. This finding is consistent with the theory of planned behaviour as high income is considered as an actual behavioural control and can influence behaviour directly without being mediated through subjective norms (Ajzen 1991, 2001). In addition, these findings suggest that people with high household incomes are very particular with what they consume, hence they have a higher information seeking behaviour. In general, several studies found that information seeking behaviour correlates with knowledge on modern agricultural biotechnology (El-Maamiry 2017; Hussain & Ahmad 2014; Zhong et al. 2018; Farzan & Brusilovsky 2019). Policy makers and regulators must educate people about the importance of reading the product labels when they are purchasing food products to improve consumer food knowledge.

This study found education differences to exist in public acceptance of modern agricultural biotechnology.

This study shows that people with higher education qualifications tend to accept modern agricultural biotechnology more than people with low education qualifications. This finding is consistent with studies that have reported that higher education predicts acceptance of modern agricultural biotechnology (Gurau et al. 2016; Thorne et al. 2017; De Steur et al 2010; Singhal 2017; Puduri et al. 2011). In addition, this study found that there is a significant mean difference between people that have graduated with an education qualification and those that have graduated with science, engineering and technology qualification on their knowledge about genetically modified crops. In fact, graduates from education academic field of study show that they have low modern biotechnology knowledge compared to graduates from science, engineering and technology. This finding is also consistent with studies that have correlated academic fields and knowledge on genetically modified crops (Surmeli & Sahin 2010; Weisenfeld & Ott 2011; Wnuk & Kozak 2011; Folkerth 2015; Funk & Kennedy 2016; Chmielewski et al. 2017). This finding suggests the importance of integrating biotechnology education into the national education curriculum.

This study found race differences not to exist in predicting public willingness to accept modern agricultural biotechnology.

This study shows race differences in public acceptance of modern agricultural biotechnology not to exist in South Africa. This finding is inconsistent with t most recent study carried in South Africa which have reported race difference in modern agricultural biotechnology (Gastrow et al. 2018). There are several studies that have also reported race differences in modern agricultural biotechnology (Chen & Chern 2002; Reid 2004; Oguz 2009; Bernard & Gifford 2006). As mentioned earlier in this discussion, the subsample size for racial groups were too small $(N < 30)$ which could have been the reason for a low and non-significant predictive power of race towards acceptance of modern agricultural biotechnology. The researcher recommends further studies in analysing different racial groups towards acceptance of modern agricultural biotechnology.

This study confirms that there is a bi-directional relationship among beliefs (behavioural, normative and control beliefs), as well as among attitudes (attitude towards behaviour, subjective norms and perceived behaviour control).

This study confirms the theory of planned behaviour (Ajzen 1991; 2001) that there is a bi-directional relationship among beliefs and attitudes. This finding emphasises that one belief influences other beliefs. For instance, "perceived human health risks" (behavioural belief) will influence "getting approval from significant others to eat genetically modified crops (normative beliefs) and vice versa. The finding emphasises the role that can be played by beliefs in influencing public acceptance of genetically modified crops. Policy makers and regulators of genetically modified crops in South Africa must invest more in changing public perceived negative beliefs and the best strategy is to target all three kinds of beliefs as identified in Ajzen (1991; 2001).

The study confirms that causal relationship exists among components of the theory of planned behaviour and its relevance in analysing public willingness to accept modern agricultural biotechnology.

The study confirms that causal relationship exists among the components of the theory of planned behaviour (Ajzen 1991; 2001). However, the study found out that there is a high predictive power between behavioural beliefs, attitude towards behaviour and intention to accept modern agricultural biotechnology. This finding is in-line with studies that have found and reported a high predictive power between behavioural beliefs, attitude towards behaviour and intention (Zhang et al. 2018; Vecchione et al. 2014; Kim et al. 2014; Ghoochani et al. 2017). This finding suggest that policy makers and regulators must pay more attention in initiatives that influence public positive beliefs and attitudes. This makes the second and third-generation genetically modified crops of great importance in influencing positive attitude.

The study confirms that behavioural intention is a strong predictor for behaviour (Ajzen 1991; 2001; 2015).

The study found intention to accept modern agricultural biotechnology to strongly predict acceptance of modern agricultural biotechnology. This finding is in-line with studies that have found intention to be a stronger predictor of behaviour (Sanne & Wiese 2018; Zhang et al. 2018; Latif & Ayob 2014; Maichum et al. 2016). Since intention is the strongest predictor for behaviour (Ajzen 1991; 2001), researchers, policy makers and regulators must investigate factors that predict public intention to accept modern agricultural biotechnology.

6.5 Summary of the research study

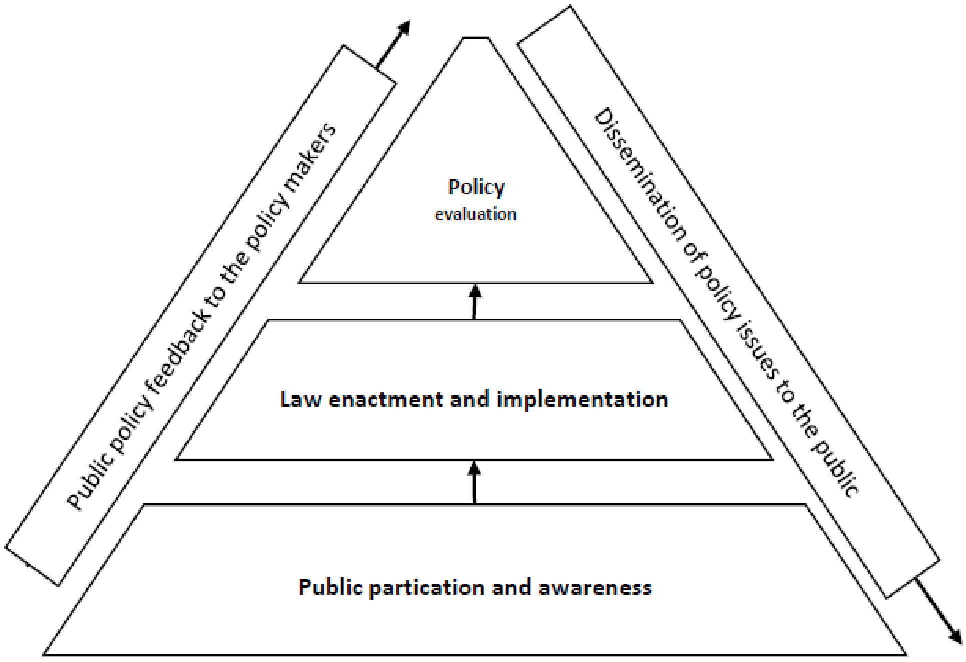
In concluding this study, the researcher presented the chapters review. According to Obeng-Odoom (2014:82) writing research chapters review helps the researchers to reflect on important research aspects, such as research aims and objectives, research statement and methodology, and it helps researchers to become more informed about their research ideas.

Chapter 1. In this chapter, the researcher introduces the study by describing the research background. The background to the study has shown that people in different countries have perceived several risks from genetically modified crops (Andriano 2015; König et al. 2013; Sexton et al. 2011) and that modern agricultural biotechnology is faced with a growing public safety uncertainty. Several scholars point out that psychological and demographic factors were among some of the reasons for the public to perceive risks from genetically modified crops. It also emerged that South Africa has not done much to address public risk concerns from genetically modified crops, with several scholars pointing to the weaknesses of the genetically modified crops Environmental Impact Assessment regulations (Kidd & Retief, in Fuggle et al. 2015:1021). In short, chapter one clearly defined the research problem, aim and objectives, as well as outlining the research plan to be followed by the researcher. The significance of the study was levelled on the ability of the research findings to improve the process of regulating genetically modified crops, as well as on checking the feasibility of replicating the study with a larger sample for future studies.

Chapter 2. In this chapter, the researcher described modern biotechnology, providing a clear distinction between different kinds of modern biotechnology. The science and techniques behind crops modification have been detailed. Important points that have been spelt out loud and clear are the fact that adoption of genetically modified crops is at a faster rate and the fact that second and third generations genetically modified crops have potential benefits (Stewart, 2015; Leong, Lim, Lam, Uemura & Ho 2018: Romeis, Naranjo, Meissle & Shelton

2018). Global and national genetically modified crops regulations have been criticised for their inefficiency in guaranteeing the public health safety from genetically modified crops. The chapter also presented discussions on public perception and awareness, several theories have been applied in this discussion including the Gestalt theories, with the main emphasis placed on how these theories may be applied in consumer behaviour.

Chapter 3. In this chapter, the researcher provided a critical analysis of the South Africa national environmental management system, as it relates to genetically modified crops. Strategies to integrate modern agricultural biotechnology into the national environment management system have been deliberated and below is a conceptualised model which policy makers and researchers can adopt or further modify.



Several steps and approaches to be taken when considering genetically modified crops environmental impact assessment have centred this chapter. An attempt was made to provide scientific solutions to the problem of the ineffectiveness of the South African environment management system in regulating genetically modified crops. Lastly, this chapter also describes and applies the theoretical framework (theory of planned behaviour) in analysing public perception towards willingness to consuming genetically modified crops and accepting modern agricultural biotechnology.

Chapter 4, 5 and 6. Chapter 4 has clearly outlined the research plan of the study. Research aim, objectives and hypothesis have been outlined, the population and sample size were defined. The researcher was very clear in the statistical model to be used in analysing data. Preliminary studies, i.e. the elicitation and pilot studies were justified. The research reliability and validity, as well as ethical issues to be considered during the study were highlighted.

In chapter 5, the researcher has applied different statistical models in analysing data. Various parametric assumptions were tested, and choices of statistical model were based on assumptions. This chapter has applied SPSS in data analysis. More than one SPSS models have been used in this study. Findings of this study are also presented in this chapter. Among several findings, the study confirms the applicability of the theory of planned behaviour in analysing public perception towards consuming genetically modified behaviour.

In chapter 6, the researcher presented the discussion of the research findings. Two important findings, among others, are that (i) this study confirms that beliefs are significant predictors of attitudes, attitudes predict intention, and intention is high predictor of behaviour; (ii) this study also confirms the finding of Gastrow et al. (2018) that the acceptance of modern agricultural biotechnology in South Africa is on a very low level. In this chapter, methodological limitations, and recommendations were also presented.

6.6 Recommendations of the study

Public willingness to consume genetically modified crops will predict the success of modern agricultural biotechnology in South Africa and other countries. It is, therefore, important to attend to factors and beliefs that stops the public from eating genetically modified crops, willingly. The researcher makes the following recommendations:

Modern biotechnology learning and teaching content to be increased across the national education system

Ruth et al. (2016:169) argue in favour of integrating modern biotechnology education into the education curricula. Increasing public scientific knowledge on modern biotechnology would induce favourable attitudes toward genetically modified crops (Chen, Chu, Lin & Chiang 2016; Burcu 2017; Altawallbeh, Soon, Thiam & Alshourah 2015; Kim et al. 2018). This study has found that the level of education correlates with the acceptance of modern agricultural biotechnology. This suggests that education is a significant factor in predicting the acceptance of modern agricultural biotechnology.

Policy makers and regulators of genetically modified crops must develop guidelines for genetically modified crops risk communications.

It is imperative that policy makers, regulators and developers (plant biotechnologists) invest in better science communications and regulations to tackle unethical research and misinformation about genetically modified crops (Raman 2017:205). Misconceptions and risks associated with genetically modified crops must be addressed and communication on the perceived risks of genetically modified crops must be increased.

Public participation and engagement must be increased in regulating genetically modified crops.

Public participation, engagement and transparency in regulating genetically modified crops must be improved. The public must trust the regulatory process of genetically modified crops. This can be done by strengthening public participation legal system, formulating the public participation evaluation criteria, increasing transparency in the process of regulating genetically modified crops (An 2017:24; Kumar 2016:66; Shackleton et al 2019:22) and supporting anti-genetically modified crops movements in conducting scientific-based studies.

Environmental impact assessment regulation must be revised to include guidelines to be followed at each stage of genetically modified environment impact assessment.

Several scholars have pointed out the need for South Africa to revise genetically modified regulations (Prince & Black 2010; Swanby 2009; McGeoch & Rhodes 2006; Kidd & Retief, in Fuggle et al. 2015). If genetically modified crops environmental impact assessment regulation is criticised as ineffective, the public become uncertain about the safety of genetically modified crops and modern agricultural biotechnology (Li & Wang 2017:43) leading to perceived risk beliefs and negative attitudes. South Africa must seek to improve genetically modified crops regulations as a matter of urgency. Kumar (2016:63) and Shackleton et al. (2019:22) recommend formulating special genetically modified organism safety management laws.

Further studies must be carried out to fill the gap created by this study in investigating a few psychological and socio-demographic factors.

This study focused on only a few psychological and socio-demographic factors, leaving out most of the factors that can influence attitude and acceptance of modern agricultural biotechnology; for instance, socio-economic and cultural factors (Shackleton et al. 2019:22). The researcher recommends further research in this field to fill this knowledge gap that has been created by this study.

Similar studies must be carried out in South Africa with a larger sample.

This study was justified based on testing the feasibility of conducting a study of this nature with a larger sample size (N = ±1000). The findings of this study show that it is feasible to replicate this study with a larger sample. Therefore, further studies must be carried out to evaluate the consistency and generalizability of the findings of this study (Sarathchandra & McCright 2017:8). The methodological limitations identified in this study also need to be considered in replicating this study. In addition, carrying out a similar study with a larger sample size will facilitate a better and an in-depth analysis of public perception in predicting the future of modern agricultural biotechnology (Cole, Keller & Garbach 2016; Cole, Keller & Garbach 2019).

Government needs to roll-out public awareness campaigns on genetically modified crops.

The regulators of genetically modified crops in South Africa must consider rolling-out public awareness campaigns educating people on genetically modified crops. In the process, regulators need to address misconceptions and evaluate the beliefs held by the people on modern agricultural biotechnology, among other things. It is also recommended that genetically modified crops developers must educate the public on the second and third generation genetically modified crops and carry out further studies to determine the public attitude towards the second and third-generations genetically modified crops (Lucht 2015:4261). It is imperative to carry out such studies because there are few studies on public attitude towards second and third generation genetically modified crops, globally (Frewer et al. 2014; De Steur et al. 2014).

Recommendation for further research studies

There are several areas which future researchers may focus on. Firstly, the study and application of the longitudinal approach, aiming to explore whether public perception towards consuming genetically modified crops vary in space and time, as well as to establish the trend. Secondly, the applicability of the labelling regulations in South Africa, as well as determining the product information consumers prefer to see on genetically modified crop products. Lastly, a focus on longitudinal studies to establish the side-effects of genetically modified crops and modern agricultural biotechnology.

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APPENDIX 1: RESEARCH QUESTIONNAIRE

Dear Respondent
The study seeks to understand your thinking towards genetically modified organisms/foods and to establish whether the majority of the people approve the new technology in food production. Your participation in this study is highly appreciated although participation is voluntary. Information is private and confidential and is only going to be used for the purpose of the study.

You are free to check my credentials with UNISA by providing them with my student number 49227858

Regards
Cleopas Makaure (MA UNISA student)

Questionnaire
Note that this questionnaire has THREE sections. Section A asks about demographic information; Section B asks on the general information on genetically modified oragnisms; and Section C measures the predictor variables and intentions.

A. DEMOGRAPHIC QUESTIONS

1 Indicate your age range?

18-25yrs	☐
26-49yrs	☐
50-64yrs	☐
65yrs +	☐

2 Indicate your gender

Male	☐
Female	☐

Other (please specify) ________________________________

3 What is your race/ethnicity?

Black/African	☐
White	☐
Coloured	☐
Indian	☐

Other____

4 Indicate your total household income range per year

R0 – R189 880	☐
R189 881 – R296 540	☐
R296 541 – R410 460	☐
R410 461 – R555 600	☐
R555 601 +	☐

5 Indicate your highest education and academic qualification?

- High school certificate ☐
- Post-High school certificate ☐
- Diploma ☐
- First Degree ☐
- Honours Degree ☐
- Master's Degree ☐
- Other (please specify___________________________________

6 Indicate in which field did you obtain your certificate, diploma or degree

- Agriculture and Environmental Sciences ☐
- Accounting, Economic and Management sciences ☐
- Education ☐
- Human Sciences ☐
- Law ☐
- Science, Engineering and Technology ☐
- Medicine ☐
- Other (please specify)___________________________________

B. GENERAL QUESTIONS ON GENETICALLY MODIFIED ORGANISMS IN SOUTH AFRICA.

1 **You have a good knowledge, and/or you understand genetically modified crops**

Strongly disagree	1	2	3	4	5	6	7	Strongly agree
Very untrue	1	2	3	4	5	6	7	Very true

2 **You may be eating genetically modified organisms in your daily diet/meals**

Strongly disagree	1	2	3	4	5	6	7	Strongly agree
Very untrue	1	2	3	4	5	6	7	Very true

3 You were once involved in debates, discussions, interviews on genetically modified organisms sponsored by the government

Never	1	2	3	4	5	6	7	Every time
Very untrue	1	2	3	4	5	6	7	Very true

4 You must be involved in genetically modified crops policy making process

Never	1	2	3	4	5	6	7	Every time
Strongly agree	1	2	3	4	5	6	7	Strongly disagree
Absolutely inappropriate	1	2	3	4	5	6	7	Absolutely appropriate
Not at all important	1	2	3	4	5	6	7	Extremely important

5 You trust all laws on genetically modified organisms are being implemented in South Africa, effectively

Never	1	2	3	4	5	6	7	Every time
Very untrue	1	2	3	4	5	6	7	Very true

6 You trust the government will never allow genetically modified organisms if not safe for people to eat

Never	1	2	3	4	5	6	7	Every time
Very untrue	1	2	3	4	5	6	7	Very true

7 All foods that contain genetically modified organisms in retailer shops are labelled

Strongly disagree	1	2	3	4	5	6	7	Strongly agree

8 All foods that contain genetically modified organisms must be labelled

Strongly disagree	1	2	3	4	5	6	7	Strongly agree
Absolutely inappropriate	1	2	3	4	5	6	7	Absolutely appropriate

9 You eat genetically modified crops willingly

Strongly disagree	1	2	3	4	5	6	7	Strongly agree
Never	1	2	3	4	5	6	7	Every time
Very untrue	1	2	3	4	5	6	7	Very true

10 You believe you have never tested or ate genetically modified organisms in your life

Strongly disagree	1	2	3	4	5	6	7	Strongly agree
Very untrue	1	2	3	4	5	6	7	Very true

11 Genetically modified crops must be produced for eating in South Africa

Strongly disagree	1	2	3	4	5	6	7	Strongly agree
Not at all important	1	2	3	4	5	6	7	Extremely important
Absolutely inappropriate	1	2	3	4	5	6	7	Absolutely appropriate

12 Genetically modified crops are like crops produced through traditional breeding and they are not harmful to human and the environment

Strongly disagree	1	2	3	4	5	6	7	Strongly agree
Very untrue	1	2	3	4	5	6	7	Very true

C. QUESTIONS BASED ON THE THEORY OF PLANNED BEHAVIOUR

BEHAVIOURAL BELIEFS

1 Genetically modified crops will harm the environment

Strongly disagree	1	2	3	4	5	6	7	Strongly agree
Very untrue	1	2	3	4	5	6	7	Very true

2 Genetically modified crops are safe for human to eat

Strongly disagree	1	2	3	4	5	6	7	Strongly agree
Very untrue	1	2	3	4	5	6	7	Very true

3 You will feel safe to eat genetically modified crops when they are labelled

Strongly disagree	1	2	3	4	5	6	7	Strongly agree
Very untrue	1	2	3	4	5	6	7	Very true
Never	1	2	3	4	5	6	7	Every time

NORMATIVE BELIEFS

4 People close to me approve that l eat genetically modified crops

Strongly disagree	1	2	3	4	5	6	7	Strongly agree
Very untrue	1	2	3	4	5	6	7	Very true
Never	1	2	3	4	5	6	7	Every time

5 People close to me regards eating genetically modified crops as

Not at all important	1	2	3	4	5	6	7	Extremely important
Harmful	1	2	3	4	5	6	7	Less harmful
Less healthy	1	2	3	4	5	6	7	More healthy
Bad	1	2	3	4	5	6	7	Good
Totally unacceptable	1	2	3	4	5	6	7	Perfectly acceptable

6 You eat genetically modified crops because people close to you wants you to eat

Strongly disagree	1	2	3	4	5	6	7	Strongly agree
Very untrue	1	2	3	4	5	6	7	Very true
Never	1	2	3	4	5	6	7	Every time

7 People close to me eat genetically modified crops willingly

Strongly disagree	1	2	3	4	5	6	7	Strongly agree
Very untrue	1	2	3	4	5	6	7	Very true
Never	1	2	3	4	5	6	7	Every time

CONTROL BELIEFS

8 You will eat genetically modified crops if they are less expensive

Strongly disagree	1	2	3	4	5	6	7	Strongly agree
Very untrue	1	2	3	4	5	6	7	Very true
Never	1	2	3	4	5	6	7	Every time
Will not consider	1	2	3	4	5	6	7	Definitely consider

9 You will eat genetically modified crops if l know how they are produced

Strongly disagree	1	2	3	4	5	6	7	Strongly agree
Very untrue	1	2	3	4	5	6	7	Very true
Never	1	2	3	4	5	6	7	Every time
Will not consider	1	2	3	4	5	6	7	Definitely consider

10 You will eat genetically modified crops if they are available always

Strongly disagree	1	2	3	4	5	6	7	Strongly agree
Very untrue	1	2	3	4	5	6	7	Very true
Never	1	2	3	4	5	6	7	Every time
Will not consider	1	2	3	4	5	6	7	Definitely consider

ATTITUDE TOWARDS BEHAVIOUR

11 Genetically modified crops are safe and healthy for human to eat them

Strongly disagree	1	2	3	4	5	6	7	Strongly agree
Very untrue	1	2	3	4	5	6	7	Very true
Never	1	2	3	4	5	6	7	Every time

12 Eating genetically modified crops is

Not at all important	1	2	3	4	5	6	7	Extremely important
Harmful	1	2	3	4	5	6	7	Less harmful
Less healthy	1	2	3	4	5	6	7	More healthy
Bad	1	2	3	4	5	6	7	Good
Totally unacceptable	1	2	3	4	5	6	7	Perfectly acceptable

13 Growing or farming genetically modified crops is

Not at all important	1	2	3	4	5	6	7	Extremely important
Totally unacceptable	1	2	3	4	5	6	7	Perfectly acceptable
Absolutely inappropriate	1	2	3	4	5	6	7	Absolutely appropriate
Unfriendly to environment	1	2	3	4	5	6	7	Friendly to environment

14 Government must promote farming or production of genetically modified crops

Strongly disagree	1	2	3	4	5	6	7	Strongly agree
Not at all important	1	2	3	4	5	6	7	Extremely important
Totally unacceptable	1	2	3	4	5	6	7	Perfectly acceptable
Absolutely inappropriate	1	2	3	4	5	6	7	Absolutely appropriate

SUBJECTIVE NORMS

15 You eat genetically modified crops because people close to you eat them

Strongly disagree	1	2	3	4	5	6	7	Strongly agree
Very untrue	1	2	3	4	5	6	7	Very true

16 You eat genetically modified crops because people close to you want you to eat them

Strongly disagree	1	2	3	4	5	6	7	Strongly agree
Very untrue	1	2	3	4	5	6	7	Very true

17 You eat genetically modified crops because people close to you regards genetically modified crops as healthy

Strongly disagree	1	2	3	4	5	6	7	Strongly agree
Very untrue	1	2	3	4	5	6	7	Very true

18 Eating genetically modified crops is never your decision

Strongly disagree	1	2	3	4	5	6	7	Strongly agree
Very untrue	1	2	3	4	5	6	7	Very true

PERCEIVED BEHAVIOURAL CONTROL

19 You will not eat genetically modified crops if you afford to buy organic crops

Strongly disagree	1	2	3	4	5	6	7	Strongly agree
Very untrue	1	2	3	4	5	6	7	Very true
Never	1	2	3	4	5	6	7	Every time

20 You would not eat genetically modified crops if the government do not allow them

Strongly disagree	1	2	3	4	5	6	7	Strongly agree
Very untrue	1	2	3	4	5	6	7	Very true
Never	1	2	3	4	5	6	7	Every time

21 You will eat genetically modified crops if they are always available

Strongly disagree	1	2	3	4	5	6	7	Strongly agree
Very untrue	1	2	3	4	5	6	7	Very true
Never	1	2	3	4	5	6	7	Every time

22 You eat genetically modified crops because you have knowledge that they are safe for human to eat

Strongly disagree	1	2	3	4	5	6	7	Strongly agree
Very untrue	1	2	3	4	5	6	7	Very true

23 You are confident you can eat genetically modified crops if you want to do so

Strongly disagree	1	2	3	4	5	6	7	Strongly agree
Very untrue	1	2	3	4	5	6	7	Very true

BEHAVIOURAL INTENTION

24 You are willing to buy genetically modified crops

Strongly disagree	1	2	3	4	5	6	7	Strongly agree
Very untrue	1	2	3	4	5	6	7	Very true
Never	1	2	3	4	5	6	7	Every time
Extremely unlikely	1	2	3	4	5	6	7	Extremely likely

25 You are willing to eat genetically modified crops

Strongly disagree	1	2	3	4	5	6	7	Strongly agree
Very untrue	1	2	3	4	5	6	7	Very true
Never	1	2	3	4	5	6	7	Every time
Extremely unlikely	1	2	3	4	5	6	7	Extremely likely

26 You are willing to accept genetically modified crops/modern agricultural biotechnology

Strongly disagree	1	2	3	4	5	6	7	Strongly agree
Very untrue	1	2	3	4	5	6	7	Very true
Never	1	2	3	4	5	6	7	Every time
Extremely unlikely	1	2	3	4	5	6	7	Extremely likely

27 You are willing to support farming of genetically modified crops in South Africa

Strongly disagree	1	2	3	4	5	6	7	Strongly agree
Very untrue	1	2	3	4	5	6	7	Very true
Never	1	2	3	4	5	6	7	Every time
Extremely unlikely	1	2	3	4	5	6	7	Extremely likely

ACCEPTANCE OF MODERN AGRICULTURAL BIOTECHNOLOGY BEHAVIOUR

28 You accept eating of genetically modified crops in South Africa

Strongly disagree	1	2	3	4	5	6	7	Strongly agree
Very untrue	1	2	3	4	5	6	7	Very true
Never	1	2	3	4	5	6	7	Every time
Totally unacceptable	1	2	3	4	5	6	7	Perfectly acceptable

29 You accept the use of modern agricultural biotechnology in crop production in South Africa

Strongly disagree	1	2	3	4	5	6	7	Strongly agree
Very untrue	1	2	3	4	5	6	7	Very true
Never	1	2	3	4	5	6	7	Every time
Totally unacceptable	1	2	3	4	5	6	7	Perfectly acceptable

APPENDIX 2: PARTICIPANTS CONSENT LETTER

03 September 2018

Dear Sir/Madam

You are being invited to participate in a research study on the public's willingness to consume genetically modified foods/organisms.

In particular, we are interested in factors that influence the people willingness to consume genetically modified foods/crops and to accept modern biotechnology in crop production.

This research will require about 20 minutes of your time. During this time, you will complete a closed-ended questionnaire. There are no anticipated risks or discomforts related to this research. You are free to conduct the University of South Africa by giving them my student which is 49227858 to check my credentials.

By participating in this research, you may also benefit others and the nation at large as the findings of the study might assist the government in formulating policies governing genetically modified crops in South Africa.

Several steps wastaken to protect your anonymity and identity;

1. you are not going to be asked to write your name or address
2. the questionnaire will not be given to any individual or group of people or any institution besides the University of South Africa upon a written request
3. all information wasdestroyed upon the completion of the study.

Your participation in this research is completely voluntary. However, you may withdraw from the study at any time for any reason.

If you wish to receive a copy of the results from this study, you may contact the researchers by emailing at 49227858@mylife.unisa.ac.za requesting a copy.

If you have any other questions regarding your rights as a participant in this research, you may also contact the University of South Africa Ethic Review committee.

I have read the above information regarding this research study and consent to participate in this study.

____ (Signature)

____ (Date)

APPENDIX 3: OPEN-ENDED QUESTIONNAIRE FOR ELICITATION STUDY

Dear Respondent
The study seeks to understand your thinking towards genetically modified organisms/foods and to establish whether the majority of the people approve the new technology in food production. Your participation in this study is highly appreciated although participation is voluntary. Information is private and confidential and is only going to be used for the purpose of the study.

You are free to check my credentials with UNISA by providing them with my student number 49227858

Regards
Cleopas Makaure (MA UNISA student)

ELICITATION STUDY QUESTIONNAIRE

1. **Write advantages of using modern agricultural biotechnology in South Africa**
   i. ______________________________
   ii. ______________________________
   iii. ______________________________
   iv. ______________________________
   v. ______________________________

2. **Write disadvantages of using modern agricultural biotechnology in South Africa**
   i. ______________________________
   ii. ______________________________
   iii. ______________________________
   iv. ______________________________
   v. ______________________________

3. **List the people that may approve you to eat genetically modified crops e.g my wife**
   i. ______________________________
   ii. ______________________________
   iii. ______________________________
   iv. ______________________________
   v. ______________________________

4. **List the people that may disapprove you to eat genetically modified crops e.g my husband**
   i. ______________________________
   ii. ______________________________
   iii. ______________________________
   iv. ______________________________
   v. ______________________________

5. List factors that would facilitate you to eat genetically modified crops

i. ______________________________
ii. ______________________________
iii. ______________________________
iv. ______________________________
v. ______________________________

6. List factors that will hinder you from eating genetically modified crops

i. ______________________________
ii. ______________________________
iii. ______________________________
iv. ______________________________
v. ______________________________