Understanding Farmer Seed Systems in Sespond, North West Province

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Environment, Society and Sustainability

Supervisor

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DECLARATION

I, Mpho Clementine Kganyago, declare that this work has not been previously been submitted in whole, or in part, for the award of any degree. It is my own work. Each significant contribution to, and quotation in this dissertation from the work, or works, of other people has been attributed, and has been cited and referenced.

Signature: Signed by candidate

Date: ___11 September 2020____________________

DEDICATION

To my late grandmothers, my family and all the farmers of the Sespond community.

ACKNOWLEDGEMENTS

I would like to thank my LORD and Saviour, Jesus Christ for the strength that He has given me throughout this period.

I would like to thank my Supervisor, Professor Rachel Wynberg, for your support, guidance, patience and warm encouragement. With your persistent help and wisdom, I am honoured to have been your student.

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ABSTRACT

Farmer-led seed systems (FSS) provide the backbone for small-scale farmers and many rural communities that use traditional methods of farming to produce seeds that grow and adapt to local conditions. FSS differ from one community and farmer to the next, depending on the methods and practices used to maintain seed varieties. Seed diversity can enhance FSS by improving livelihoods and strengthening farmers' networks, thus contributing to resilient communities.

Although nuanced, the dualistic agricultural system in South Africa consists largely of subsistence (small-scale) and commercial (large-scale) farming and includes different crop management systems and post-harvest practices. In South Africa, maize (*Zea mays*) is a major staple grain crop with a significant role as animal and poultry feed. The North West region is one of the highest white-maize-producing provinces in South Africa. Maize seed systems include both traditional, open-pollinated varieties (OPVs) and cultivars such as modern hybrids and genetically modified (GM) seed varieties, including those engineered for specific purposes. The dominant GM maize is that designated for pest resistance using *Bacillus thuringienesis* (*Bt*), a soil bacterium which produces a toxin that is fatal to a wide variety of insects such as moths and flies. Many small-scale farmers prefer their own traditional seeds for breeding, planting, selection, selling and consuming. However, FSS based on traditional varieties are threatened by modern cultivars which may be introduced in different ways including through seed exchange, purchasing at shops or by pollination from nearby commercial farms.

This study was conducted in the Sespond community of the North West Province. The aim of the study was to understand how small-scale farmers in Sespond maintain traditional maize varieties through selection and storage in a complex agricultural landscape that incorporates both formal and informal seed systems. The formal system represents industrialised farms and companies that work with commercial seed. The informal system represents small-scale farmers who rely on their own seed.

Qualitative methods included mapping software which was used to obtain visual agricultural data in and around Sespond. Semi-structured interviews were conducted with 30 small-scale farmers to collect information about their farming practices, including the maize varieties planted. Quantitative methods included collecting 20 maize samples from different farmers for genetic analysis. Agdia® immunostrip tests were used to detect for the presence of Crystal protein (Cry protein) produced by the *Bt* bacterium, engineered to improve the resistance of maize against insects. The results showed that 13 samples were negative for the protein and seven samples were positive for the protein.

A key finding is that small-scale farmers are not able to detect the different maize varieties in their seed systems. This represents a threat for traditional seed varieties in the community as without this knowledge, farmers are not able to adequately manage their production and storage systems. Farmers made use of alternative storage methods such as the mill to reduce seed damage they experienced at home. However, the findings of this research showed that there was an increasing risk of farmers' traditional maize being mixed with GM maize at the mill. Farmers' rights to plant and consume traditional maize were therefore undermined. This study recommends that (a) efforts are made to increase awareness among farmers that help to distinguish transgenes from hybrids and traditional maize varieties; (b) measures are implemented at mills to both improve the transparency about the storage and processing of traditional maize and to separate traditional maize from hybrid and GM maize.

Keywords: *Farmer seed systems, formal and informal systems, maize, traditional, open pollinated varieties, genetically modified seed, hybrids, mills, farmers' rights*

TABLE OF CONTENTS

List of Figures

List of Tables

List of Boxes

Supplementary Data

List of Abbreviations

Bt	*Bacillus thuringiensis*
CIMMYT	International Maize and Wheat Improvement Centre
CRY	Crystal Protein
DNA	Deoxyribonucleic Acid
FNI	The Fridtjof Nansen Institute
FSS	Farmer Seed System
GIS	Geographic Information System
GM	Genetically Modified
GMO	Genetically Modified Organism
ISTA	International Seed Testing Association
PBR	Plant Breeders' Rights
NGO	National Governmental Organisations
NWP	North West Province
OPV	Open Pollinated Variety
SANBI	South African National Biodiversity Institute
SSV	Short Season Variety
StatsSA	Statistics South Africa
US	United States

CHAPTER ONE

INTRODUCTION

1.1 Background to study

This study focuses on farmer seed systems and their importance to small-scale farmers and their communities. A farmer seed system[1] is a system whereby seeds are cultivated through various local farming methods to ensure the production of good quality seeds that are able to grow and adapt to local conditions (Almekinders and Louwaars, 2002). FSS differ from one community and farmer to the next, depending on the methods and practices used to maintain their seed varieties. FSS are influenced by several factors ranging from seed procurement to dissemination; from harvest to storage; from soil to pest management; and remain an important source of local seed supply, particularly in poorer regions and communities (Almekinders and Louwaars, 2002). These systems can also be made up of more than one community where farmers in a region share their seeds (Almekinders and Louwaars, 2002; Coomes et al., 2015; McGuire and Sperling, 2016).

FSS serve as a connecting point between farmers and the community. However, it becomes a challenge for farmers to maintain their seed varieties if (i) availability and accessibility is limited, and (ii) farmers can't trace where they got their seed from, especially if the seeds are frequently procured from different sources (Vernooy et al., 2017). This can cause risks associated with seed varieties being mixed (Cromwell et al., 1992). This process is referred to as contamination, which can occur by pollination, through seed exchange, chicken feed, industrial post-harvesting processes or through seed distribution by the government (Almekinders, 2000). The four seed varieties described in this thesis include: traditional or farmers' varieties, open-pollinated varieties (OPVs), hybrids and *Bacillus thuringiensis* or *Bt*-seed varieties that have been genetically modified (GM) for insect resistance (Tripp, 2001a; Kutka, 2011; Jacobson and Myhr, 2013; Kotey et al., 2017). Many farmers prefer their own seeds for various purposes including breeding, planting, selection,

[1] These systems are also referred to as farmer-led seed systems.

selling and consuming (Almekinders, 2000). Ficiciyan et al. (2018) highlighted that traditional seed varieties are better adapted to changing environmental conditions which make them suitable for resilient FSS (Ficiciyan et al., 2018).

1.2 Problem statement

Traditional seed varieties are increasingly disappearing for several reasons, including their availability and yield-suitability (Wale, 2012; Vernooy et al., 2017). Industrial agriculture involves the use of modern seed varieties such as those bred with conventional breeding technologies and those that are genetically modified, typically based on monocultures and used in combination with high levels of inputs such as fertilisers, pesticides and herbicides (Reardon and Barrett, 2000; Satterthwaite et al., 2010). With the increase in high-yielding seed varieties, traditional seed varieties are at risk of being lost or replaced (Ficiciyan et al., 2018). Even with yield development boosted, the introduction of seed varieties that use conventional breeding technologies and those that are genetically modified into communities could be a problem for small-scale farmers especially given challenges with differentiating between the seed varieties. Although traditional seeds and OPVs can be saved and used again for planting in the next season, hybrids and GM seeds will not produce uniform yields when the same seeds are used repeatedly over subsequent planting seasons. This is due to loss of vigour (Petersen, 2014; van Niekerk and Wynberg, 2017). Vigour is defined as the retained qualities, such as yield or physical appearance, of crops grown from seed that is continually used in planting seasons (Birchler, 2016; Huang et al., 2017). Moreover, especially for GM seeds, it is illegal to reuse seeds from year to year, and farmers are thus forced to purchase GM seeds anew each year.

The agricultural economy in South Africa is largely made up of a dualistic farming system which is divided into a commercial agricultural sector and subsistence small-scale farming sector (Sandrey and Vink, 2008; Pienaar, 2013; Pienaar and Traub, 2015). The commercial sector is characterised by large-scale agriculture, which uses mainly hybrids or GM seeds, is mostly market driven and is capital intensive (Smalley, 2013). Subsistence farming in contrast is based on small-scale agriculture which typically uses traditional seeds or OPVs and focuses on farmers providing food for their families as well as sustaining their livelihoods (Khapayi et al., 2016). Agricultural activities include intensive crop production, mixed farming, cattle ranching and sheep farming throughout various regions (Shabalala et al., 2013). Along with their ways of adapting to the changing environment, farmers' knowledge, perceptions and cultural ways of living have been a useful mechanism in communities, not only in shaping traditional knowledge but also in sustaining their livelihoods, families and communities. However, over the years, there has been a growing concern around the conservation and diversity of traditional seed varieties (Smalley, 2013).

The seed system is divided mainly into the formal and informal sectors, characterised by a chain of activities involving the use of certified seed such as hybrids and GM seeds, and farmers' own seed harvest, respectively (Almekinders, 2000; Ficiciyan et al., 2018). There is increasing competition between the two sectors driven mostly by yield production as well as the promotion of new seeds and fertilisers. This is largely in connection to incentives associated with the Green Revolution (Scoones and Thompson, 2011). This gave rise to transgenic crops which are crops that contain genes that have been moved across species (Iversen et al., 2014). The detection of such genes is accomplished through molecular or biochemical testing for foreign protein or deoxyribonucleic acid (DNA) (Iversen et al., 2014). This is essential to validate seed varieties and to determine which seeds are found in a specific agricultural area.

1.3 Justification for the study

Originating from Meso-America, maize (scientifically classified as *Zea mays* ssp. *mays*) is one of the most commonly grown crops in many parts of the world, and is considered a major contributor to global agriculture (Strable and Scanlon, 2009). Maize is cultivated in various regions including the United States (US), China, Brazil and Africa and its production differs from country to country (Ranum et al., 2014). Maize can be used to produce feed for animals, pharmaceutical products, as well as for human consumption and industrial products such as starch (Ranum et al., 2014; Ceccarelli et al., 2015). In addition to its agricultural significance, maize has been considered an essential model in agricultural research and development not only for studying its genetic make-up, but also for providing a clearer understanding of the significance of maize systems to culture, livelihoods and diversity (Badu-Apraku et al., 2017).

The North West Province is one of South Africa's highest white-maize-producing provinces contributing approximately 19 percent of white maize to the South African agricultural sector (DAFF, 2017). The province is dominated by commercial agriculture with some areas divided into subsistence and livestock agriculture. Maize is the most widely grown crop in the province. It is usually planted between October and January, with the harvest season happening from May until August (DAFF, 2017). Most of the maize, cotton and soybean that are planted in South Africa is genetically modified (ISAAA, 2014). The main types of GM maize are: (1) *Bt* or insect resistant maize; and (2) Herbicide tolerant or Round-up Ready maize (Abidoye and Mabaya, 2014). With different maize varieties being introduced, questions have been raised about the impacts on traditional maize of GM maize. Since traditional maize has been around for much longer than GM maize, the question is how small-scale farmers are maintaining their maize in a complex and diverse agricultural landscape.

According to the International Panel of Experts on Sustainable Food Systems (IPES-Food), agroecology is defined as "*the science of applying ecological concepts and principles to the design and management of sustainable food systems*" (IPES-Food, 2016, p.11). Examples include sustainable farming, "*the study of sustainable agroecosystems as well as healthy networks and organisations that will help secure the future of food and farming*" (IPES-Food, 2016, p.3). Diversity is the essence of food systems and an important driver in agroecology (Frison et al., 2011). According to a report by IPES-Food and scientists at the International Maize and Wheat Improvement Centre (CIMMYT), there is a critical need for a paradigm shift from industrial agriculture to diversified agroecological systems (IPES-Food, 2016). This study aims to deepen understanding about how such shifts might occur in the context of smallholder farming communities who are increasingly managing multiple types of maize seed.

1.4 Study area

The study was conducted in the Sespond community in North West Province which, according to the North West Provincial Government (Republic of South Africa), is home to more than three million people and consists of four district municipalities ((Government, 2020). Sespond community is situated within the Moretele Local Municipality in the Bojanala Platinum District. The community represents farmers with diverse farming knowledge and experiences. Throughout the years, some farmers have relocated to Sespond from other regions and others have been raised in the community. The community also cultivates a diversity of crops, from maize to pumpkins and beans. This study focuses on understanding FSS in this community, particularly to gain more insight into the selection and storage processes that the small-scale farmers use to maintain their traditional maize. Although not much research has been done in the area, it is of interest as the community is in the middle of a commercial farming area. The study thus explores ways in which small-scale farmers manage their seed systems in the context of being surrounded by different maize varieties.

1.5 Aim and objectives of the study

The aim of this study is to understand how small-scale farmers in Sespond, North West Province, maintain traditional maize in a complex agricultural landscape that incorporates both formal and informal seed systems.

Its objectives are:

- to profile the demographics and agricultural practices of selected households in Sespond;
- to determine what maize varieties are planted in Sespond;
- to understand how maize varieties are selected for storage and planting;
- to establish the extent of transgene contamination by testing maize varieties for the presence of transgene protein; and
- to determine the implications of these findings for the maintenance of traditional seed systems.

1.6 Thesis outline

The dissertation is divided into six chapters. Following this chapter, Chapter Two provides a literature review detailing the origin of maize agriculture, the history of the study area as well as the impact of GM maize agriculture in South Africa. This chapter also outlines some of the threats to FSS. Chapter Three describes the methodology of the study which includes both quantitative and qualitative approaches. The chapter outlines the research design, study area, scoping visits, mapping and surveys. This section also provides details on the plant materials, seed extraction, immunochromatographic assay and analyses. Lastly, Chapter Three highlights the limitations to the study as well as ethical considerations. Chapter Four presents the results of the study. Chapter Five discusses findings and their implications for FSS. Chapter Six concludes the thesis.

CHAPTER TWO

LITERATURE REVIEW

2.1 The importance of Farmer Seed Systems

Seeds form the backbone of agriculture which spans across different cultures, traditions and livelihoods. Globally, seed systems are more than just a way of managing the genetic flow of information but are also seen as a significant way to preserve seed security (Sperling and Cooper, 2003). FSS can be characterised as a network of seed and crop varieties playing an important role towards seed sovereignty, diversity and conservation, and knowledge as well as identity (Kloppenburg, 2010; Bezner Kerr, 2013; Coomes et al., 2015; van Niekerk and Wynberg, 2017). For this study, FSS is understood in the context of traditional[2] or domesticated crops for use within a farmers' network from a range of sources such as farmers' fields, gardens, granaries and community seed banks (Coomes et al., 2015). It is important to note that FSS are not closed systems, as this study will highlight (van Heerwaarden et al., 2012).

Over the years, the terminology relating to seeds has been developed, including formal and informal seed systems which are respectively defined as improved or certified seed, or landraces and local seed (Biemond et al., 2013a). According to Almekinders and Louwaars (2002), FSS are integrated into a system that functions in parallel to the formal system (Almekinders and Louwaars, 2002). Although literature points out that the two systems remain poorly connected, much implementation is still needed to better integrate opportunities and improve the functioning of the overall seed system as highlighted in their framework (Figure 1) (Almekinders and Louwaars, 2002).

Seeds evolve continuously as a result of natural selection, evolution, conventional plant breeding as well as from artificial efforts to genetically manipulate them (Finch-

[2] Traditional maize varieties are understood and defined in different ways, but for the purpose of this study, the following definition will be used: Traditional maize varieties are those varieties that are locally grown and do not require breeding techniques to improve performance, yield, taste, texture, or other properties (Mazvimbakupa, 2015).

Savage and Bassel, 2016). Perceptions around seed knowledge and varieties differ vastly across stakeholders within the agricultural sector which include policymakers, government, scientists, the private sector commercial and small-scale farmers. These perceptions contribute broadly to the rationale that seed system interventions, such as variety development as well as seed supply and dissemination, are a vehicle to development programmes and innovation strategies that are resilient and sustainable (McGuire and Sperling, 2016; Christinck et al., 2018). For small-scale farmers and communities, seeds are a way of life. Almekinders and Thiele (2003) note that on-farm saved seeds are an important source of food production for most small-scale farmers and communities to sustain their livelihoods (McGuire and Sperling, 2016; Kusena et al., 2017). However, FSS are not ideal systems. They don't exist or operate in isolation and are often under threat.

2.1.1 Threats to FSS

There is growing interest in studying traditional farming practices. However, the introduction of modern seed varieties acts as a barrier to FSS**.** This was shown by Rodriguez et al. (2009) who described how the lack of proper infrastructure and land tenure could influence the perceptions and practices of small-scale farmers. Smart technology can play a key role in the social and economic development of the agricultural sector but ironically, can also have adverse impacts on small-scale agriculture and affect seed selection practices (Rodriguez et al., 2009; Gouse et al., 2016). Another threat is the patenting of genetically modified (GM) seed technology that continues to threaten and erode farmers' rights and practices in agriculture. This is also highlighted in section 2.8 and 2.9. In most instances, this is driven by the capitalist narrative to control the agricultural sector and inevitably, increase farmers' dependence on private, monopolised agricultural resources (Wijeratna et al. 2003).

Adapting the conceptual framework from Almekinders and Louwaars (2002) which highlighted the importance of the FSS in a functional national seed sector, the literature review draws insight from the framework to understand the relevance and linkages between the two systems (Figure 1). In communities where no formal breeding or seed supply exists, small-scale farmers rely more on their own seed which is usually the prominent source of food (Almekinders, 2000; Almiekinders and

Louwaars, 2002). Even though FSS too may have shortcomings, one of the most important challenges is around the effective linkage between FSS and the formal sector

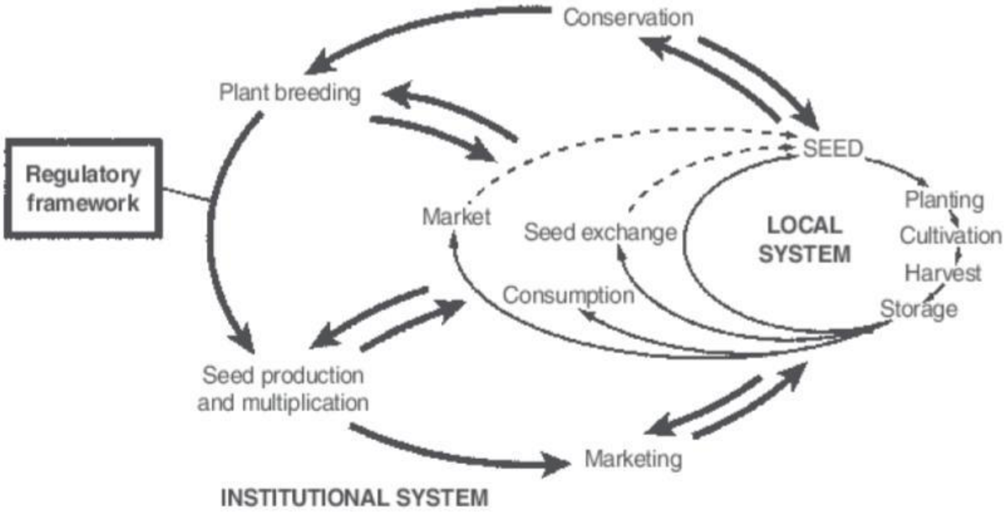

Figure 1: Image showing conceptual framework around the Importance of the Farmers' Seed Systems in a Functional National Seed Sector. Image also highlights how farmers and other organisations have multiple linkages in an integrated seed system (adapted from Almekinders et al., 2000). Solid arrows indicate direct influence and dotted arrows indicate indirect influence.

2.2 <u>Origin and domestication of maize</u>

Agriculture has taken many forms over more than 12,000 years since humans lived traditional hunter-gatherer lifestyles during the "Neolithic Revolution" (Bogucki, 1996; Weisdorf, 2005; Verhoeven, 2011). From plant domestication as food crops ranging from rice and millet to animal farming, the dynamics of agriculture continue to shape modern life (Cohen, 2009; Fuller and Stevens, 2019). Agriculture continues to adapt to different contexts over time, especially through the impacts of the environment, science and socio-economic influences. The history of maize begins with its ancestor, teosinte (*Zea mays ssp. parviglumis*), a wild lowland grass native to Mexico (Mammadov et al., 2018; Yang et al., 2019). Genetic and archaeological evidence and sequence data from maize cultivated 5,000 years ago support the fact that the domestication of maize originated from Mexico (Sluyter and Dominguez, 2006). Teosinte retains little resemblance to the modern maize found throughout the world today (Iltis, 2000; Benz 2001). Its physical characteristics included few and tiny kernels enclosed and protected by a nearly impenetrable outer casing (Malik et al., 2019). Through population genetics, the comparison between maize and teosinte showed that a bottleneck effect[3] caused changes in the genetic diversity through gene flow from teosinte to maize as a result of adaptation to diverse environments during domestication (Tenaillon et al., 2004; Yamasaki et al., 2007; Warburton et al., 2011; Hufford et al., 2012). Following exposure to natural and artificial selection as well as the bottleneck effect, modern maize remains rich in genetic variation and an ideal model organism in research and development (Vigouroux et al., 2002). The difference between teosinte and maize plants is shown by the image depicting a teosinte head with two rows of approximately 6 - 8 hard kernels each, and a typical maize ear with approximately 6 - 12 rows of softer kernels (Figure 2) (Tian et al., 2009).

Figure 2: Phenotypic differences between teosinte and the modern maize. Teosinte (left) has few kernels each encased in a hard covering called a glume, while maize (right) has more rows of softer kernels. (Image source: Tian et al., 2009).

Gradually, over the years, early farmers carefully selected for desirable traits that would continue adapting for generations to changing environmental conditions, and eventually developing into a cultural staple food.

2.3 <u>The culture of maize</u>

It was not until the 1920s and 1930s that the US sought ways to improve maize crop yields by introducing industrial nitrogen fertilizer and farm equipment to aid in sowing and harvesting largely for agribusinesses (McCann, 2001; Pretty and Bharucha,

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[3] The Bottleneck effect is the sharp lowering of a population's gene pool because of an environmental or human-induced change which is aimed at reducing genetic variation in a population (Ali and Roossinck, 2008).

2014). But the history of biotechnology in agriculture began in 1901 when the bacterium *Bacillus thuringiensis (Bt)*[4] was isolated from silkworm populations as a cause of death, leading to its use by farmers as a pesticide in 1920 (Morse and Mannion, 2009; Koch et al., 2015). This subsequently gave rise to controversies such as the toxicity of these pesticides to the environment and the possible risks to humans following long term exposure (Then and Bauer-Panskus, 2017). However, this didn't halt emerging research incentives in the 1950s to improve and increase pesticide commercialisation in the US (Van Norman and Eisenkot, 2017). Although in the 1970s research was funded to curb the harmful effects of *Bt* (Myers et al., 2016), the main goal behind the development of these pesticides remained the same: their effectiveness in killing insects while causing little harm to the environment (Aktar et al., 2009). Following this, in the 1980s, scientists began to develop genetically modified organisms (GMOs) with specific characteristics that were carefully selected to use in future plant propagation (Skogstad and Moore, 2004). In 1996, Monsanto[5] introduced the first genetically modified "Roundup Ready" soybeans which were followed by maize in 1998 (Benbrook, 2016; Rose et al., 2016; Raman, 2017). Most GM plants were created to be herbicide tolerant (Ht[6]), or to produce *Bt* insecticide, containing DNA that is naturally found in the *Bt* bacterium (Powell et al., 2009). This study focuses on *Bt*-maize variety. Throughout the study, *Bt*-maize refers to a variant of GM maize as its DNA does not occur naturally or through advanced breeding methods (Powell et al., 2009).

2.4 Why maize?

Maize is more than a staple food that feeds many people across the world (Figure 3). It also has an intrinsic cultural significance which gives a sense of identity to people of different traditions (Di Paola et al., 2016; Bellon et al., 2018). In most developing countries maize is an important source of income to small-scale farmers among

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[4] *Bacillus thuringiensis* (*Bt*) is a soil bacterium known for its inherent characteristic of expressing a crystalline inclusion of crystal or Cry proteins. These are classified as endotoxins of which there are more than 400 *cry* genes with a nomenclature consisting of different classes, subclasses and variants (i.e. Cry1, Cry1A and Cry1Ab, respectively) (Sanchis and Bourguet, 2009; Raman, 2017; Privalle, 2017).

[5] Monsanto is an agricultural company known for its controversial manufacturing of chemical products which are used in multinational seed companies and bio-genetic research incentives.

[6] Herbicide-tolerant plants have the ability to resist certain chemicals that are sprayed on crops to kill weeds.

whom many resources such as market and technology approaches are limited (Tagne et al., 2008). Figure 4 shows the global distribution of maize by country with South Africa ranking tenth in the world in terms of the scale of maize production. Despite the constraints that many farmers continue to face, maize farming remains strongly entwined in livelihoods, traditional knowledge and different traditions, while contributing to food security, economic stability and agricultural resilience within communities and countries (Di Paola et al., 2016).

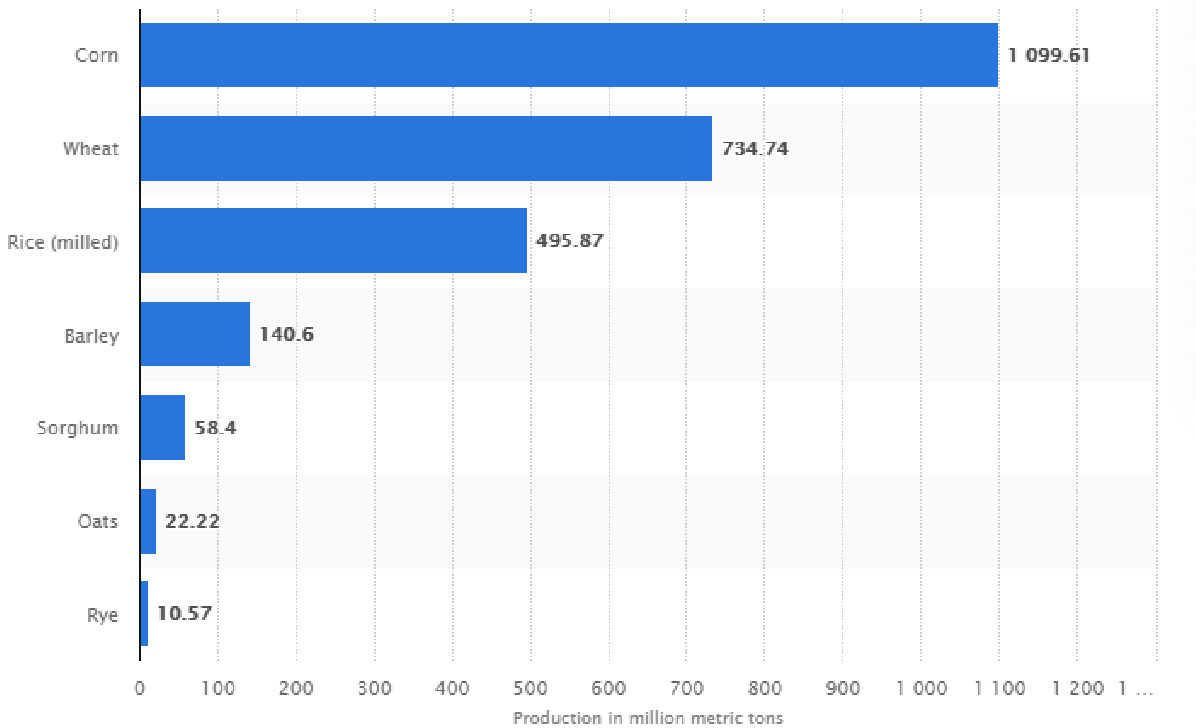

Figure 5: Global production of grain in 2018/19, by type. The most important grain was corn, based on a production amount of over 1.09 billion metric tons. Source: FAO; US Department of Agriculture; 2019

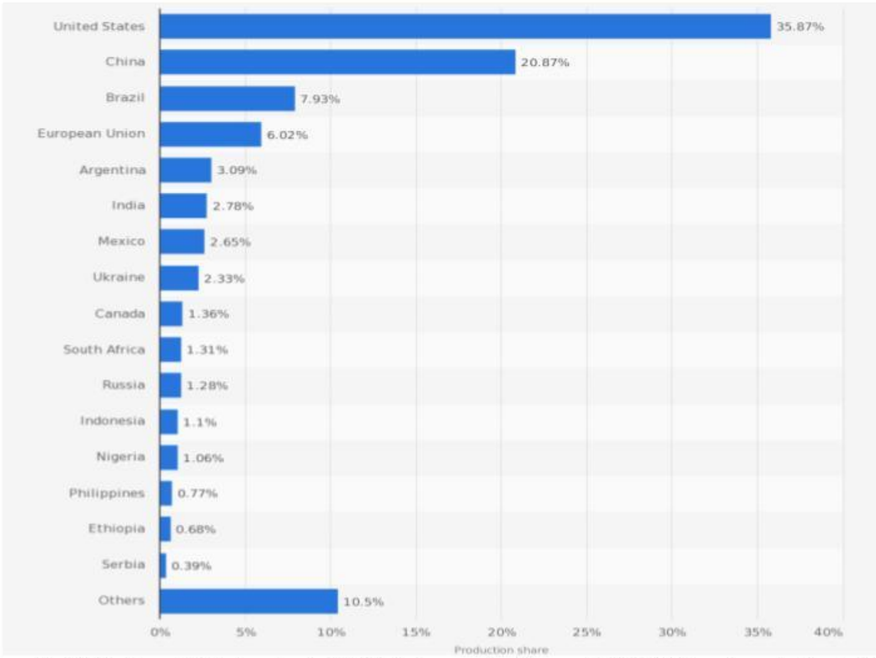

Figure 6: Distribution of global maize in 2017/18, by country. Source: FAO; US Department of Agriculture, 2019

Maize is also a model organism which has advanced research and development objectives such as improvements in breeding programmes to enrich crop genetic diversity. Over the years, selective breeding has shown how farmers' and scientists' preferences have influenced the evolution of maize (Ceccarelli, 2015). According to the International Maize and Wheat Improvement Centre (CIMMYT), maize diversity is attributed to many factors other than selection but has also been influenced by geographical distribution and biophysical elements such as temperature, soil type and water conditions (Bellon et al., 2018). Even though genetic variation is an imperative aspect for breeding, traditional landraces[7] remain an important element in terms of preservation for small-scale farmers (Villa et al., 2005). Today, in an effort to conserve the biodiversity of maize, CIMMYT's Maize Germplasm Bank has collected more than 28,000 varieties of maize seeds from different countries (Tuba 2003).

On-farm breeding by small-scale farmers globally also preserves maize diversity in communities and enriches cultural traditions (Mann, 2004). The diversity preserved on farmers' fields is somewhat reciprocal of the CIMMYT germplasm bank collection since populations are indicative of population sizes where diversity is subject to

[7] Landraces are defined by their historical origin, recognizable identity, lack of formal genetic improvements, high genetic diversity, local adaptation and association with traditional farming systems.

continuous natural and artificial selection under changing climatic conditions (Govindaraj et al., 2015; Dwivedi et al., 2017).

2.5 Agricultural dichotomy in South Africa

Agriculture is one of the significant drivers of the South African economy, contributing approximately 3.2 percent to the total gross domestic product (GDP) in the 2018 production season (DAFF, 2017). The sector is characterised by a dual economy which is comprised by large scale, commercial agriculture and small-scale, subsistence agriculture (Smalley 2013; Khapayi and Celliers, 2016). The augmentation of government interventions in agriculture were realised and achieved through legislative measures such as the Marketing Act of 1937 and the Co-operative Societies Act of 1939, to bring about distinct separation of farmers into categories such as small-scale black farmers as well as part-time farmers (Kirsten et al., 1994). The second phase included the increased mechanisation of commercial farming which was associated with substitution of capital for labour around the 1970s (Kirsten et al., 1994). The structural inequalities between white commercial and black subsistence agriculture was a result of political differences toward the two agricultural sub-sectors which manifested itself through limited access to good, arable land and agricultural support services for homeland farmers (Pienaar, 2013). There was a significant shift toward intensive large-scale agriculture and the concomitant increase of centrally managed agricultural development projects in black areas (Fènyes et al., 1988).

2.6 The Homelands

In 1951 when South Africa was under the rule of the Apartheid government**,** the Bantustans or homelands were established as independent states where the majority of the black population were separated from the white population and classified into different ethnic groups as indicated in the Bantu Self-Government Act, (Act 46 of 1959) (Figure 5) (Mbao, 2004). The effects of Apartheid saw the results of racially discriminatory laws and policies being reinforced upon mainly dispossessed indigenous peoples within the homelands (Christopher, 2001). Such laws included the Black Land Act of 1913, the Black Administration Acts of 1927 and the

Community Development Act of 1966[8]. Subsequently, the homeland policy saw the augmentation of millions of black South Africans relocated into the former homelands, which resulted in severe overcrowding (Mbao, 2004).

The homelands were classified as follows: Ciskei and Transkei were formed for Xhosa people; Bophuthatswana for Tswana people; KwaZulu for Zulu people; Lebowa for Pedi and Northern Ndebele speaking people; Venda for Vendas; Gazankulu for Shangaan and Tsonga people, and finally, the Qwa-Qwa homeland was for the Sotho speaking population (Butler et al., 1978; Christopher, 2001). The inception of these homelands was around the mid twentieth century, ending on the 27th April 1994 with the emergence of a democratic South Africa (Christopher, 2001). This study focuses on the former Bophuthatswana homeland which is known as the North West Province today.

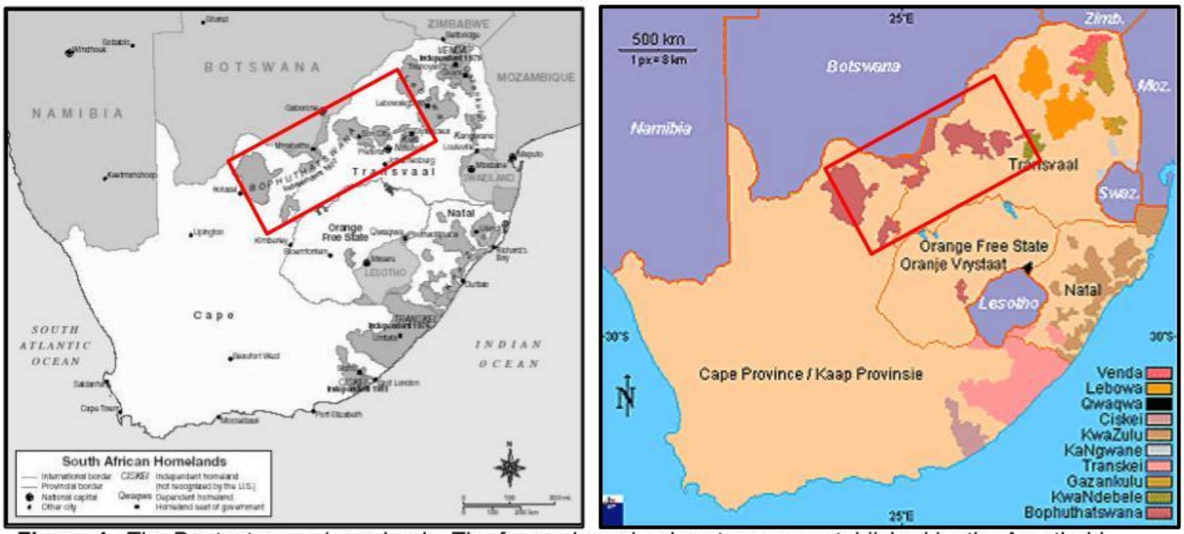

Figure 4 : The Bantustans or homelands. The former homeland system was established by the Apartheid government to separate Black people into different ethnic groups. Thirteen percent (13%) of the arable land (from the total fifty percent) in South Africa was divided into ten Black "homelands". The homelands were represented by ten ethnic groups (Davenport, 1977: p. 268). The North West Province is demarcated by the red block.

Some homelands were declared independent in the 1970s, and others remained self-governing, though their economies were not developed (Butler, 1978; King and McCusker, 2007; Khunou, 2017). Subsequently, many had to rely on white South Africa's economy (King and McCusker, 2007; Khunou, 2017). Economic activities such as farming were not sustainable because of poor agricultural land, exacerbated

[8] Other laws included the Development Trust and Land Act of 1936, the Group Areas Act of 1950 and 1966 as well as the Rural Coloured Areas Act of 1963.

by overgrazing and soil erosion. Moreover, the Natives Land Act 27 of 1913 prohibited black people from acquiring land aside from the 8 percent of land allocated to them (Kloppers and Piennar, 2014). Kgatla (2013) highlighted how segregation was characterised by the forced removals of black people onto poor and overcrowded land.

2.7 Types of agriculture in the North West Province

Post the democratic elections in 1994, the former homelands were incorporated into nine Provinces, namely: Northern Cape, Western Cape, Mpumalanga, Eastern Cape, KwaZulu-Natal, Gauteng, Limpopo, North West and the Free State (Kgatla, 2013). The North West Province is an economically important province, particularly in the mining and agricultural sectors. The province is characterised by diverse agriculture which includes commercial and subsistence farming. The commercial agricultural systems are large-scale and driven by capital intensive farming (Nolte and Ostermeier, 2017), while subsistence agriculture is characterised by small-scale farming and is labour intensive (Figure 6) (Waceke and Kimenju, 2007). Crop production in areas such as Sespond where subsistence agriculture thrives, is largely rainfed which means unpredictable rainfall patterns can contribute to crop failure and poor crop yield (Waceke and Kimenju, 2007).

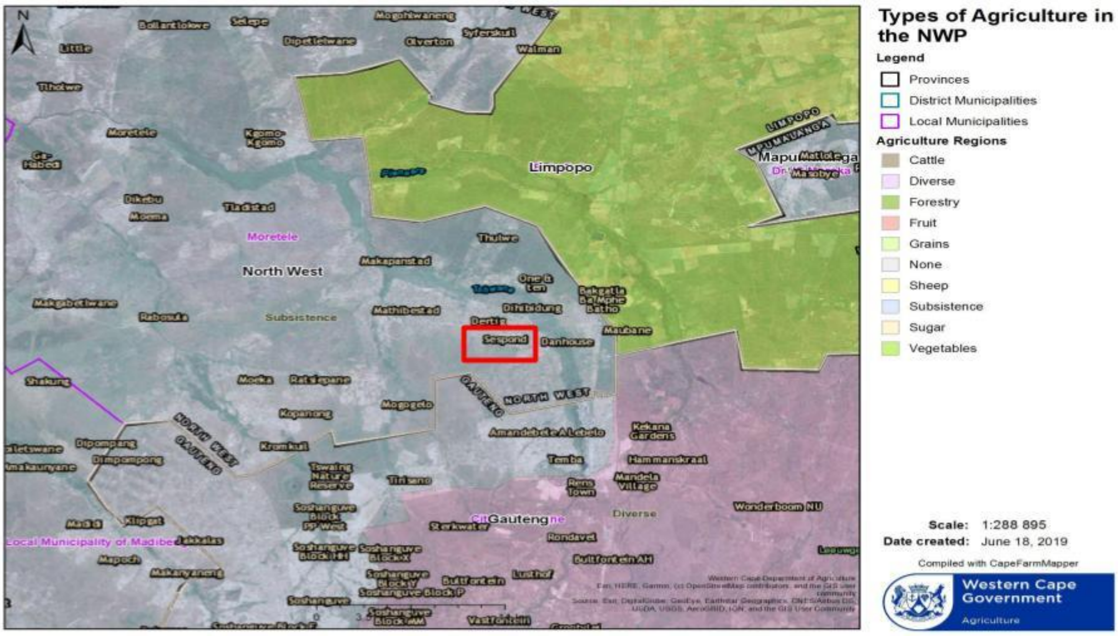

Figure 7: A zoom-in enhanced illustration of the types of agriculture in NWP. The light blue shaded regions represent subsistence farming; the green shaded regions represent grains (which is mostly commercial agriculture); and the purple shaded regions represent diverse farming (grains, cotton, livestock etc). Image generated using GIS Elsenburg - Cape Farm Mapper (CFM 2.2.0.4). The red block highlights the Sespond Community.

As a result of maize domestication more than 10,000 years ago, maize varieties have changed and continue to change (Bellon et al., 2018). In South Africa, the North West Province is the highest producer of white maize. Figure 6 illustrates the types of agriculture that are found in and around the study area. Divided largely into grains (green) and subsistence farming (blue) respectively, the varieties found range from traditional, to hybrids, open pollinated varieties (OPVs) and GM and non-GM hybrid maize varieties. These are discussed in the next section.

2.7.1 Maize varieties in different agricultural landscapes

Maize is a versatile and important crop in South Africa as both a major animal feed grain and the staple food for the majority of the population (Iversen et al., 2014; DAFF, 2011). Maize can be bred through self-pollination, known as inbreeding (crossing identical species), and can also be bred through cross pollination, known as outbreeding (crossing different species) (Dresselhaus et al., 2011). Traditional maize varieties are considered an integral part of small-scale farming practices in which crop varieties can maintain their integrity through different farmer’s selection methods. These varieties are known to adapt well to local growing conditions

(Denning et al., 2009) and are preferred by small-scale farmers who select these crops based on their performance in yield, pest tolerance, flavour, appearance, and nutritional value (Mabhaudhi et al., 2017; van Niekerk and Wynberg, 2017). Traditional seed varieties are inherently believed as being the essence of production, selection and saving, and exchange and trade in the formal and informal sectors (Louette and Smale, 2000; Kusena et al., 2017). OPVs are those whose seeds are subjected to random cross pollination and often have greater genetic diversity (Dao et al., 2014). These varieties are cost effective offering an economic advantage to small-scale farmers by allowing seeds to be saved and used in the subsequent planting seasons (Warburton et al., 2010). Even though OPVs have a broad genetic base, poor seed quality can affect seed germination resulting in weak competition against weeds (Finch-Savage and Bassel 2016).

A cross between two different but related species in a controlled manner of expressing traits of interest is used by farmers and scientists to yield the first generation (F1) known as hybrids (Kutka, 2011). This breeding technique generally requires low-technology methods and can result in seedlings with increased hybrid vigour[9] which results from the interaction of the different genes as well as impacts from different environmental conditions (Birchler, 2016; Huang et al., 2016). Many farmers across the world have adopted hybrid varieties as they have higher crop yields, improved vigour and uniformity (Arncken and Dierauer, 2006). However, the disadvantage of these varieties is that farmers cannot save them to use for planting in the next season due to reduced vigour, and, as a result, they have to be purchased every season (Schroeder et al., 2013).

In the 1980s, the United States Supreme Court issued an agreement for GM seeds to be patented and this meant that it was illegal for farmers to grow such crops and save the seed (Ahmad et al., 2012). GM varieties result from the use of sophisticated techniques such as gene-splicing[10] which usually crosses different and unrelated

[9] Hybrid vigour is defined as the retained qualities in the resulting seed and the yield of the plants grown from the seed is greatly increased. It is also defined as heterosis according to other academic literature whereby the organisms often harbour slightly damaging genetic variants.

[10] According to Ahmad et al (2012), gene splicing is the process of a segment of DNA is cut out and reinserted into a different sequence of DNA. It is believed that gene spliced plants can reduce the amount of fertilizer used in plants.

species (i.e. the plant is modified to carry additional genes from bacteria) to yield new transgenic species with desirable traits (Bothma et al., 2010). The view proposed by Lymbery (2014, p. 272) was that farmers had to purchase new seed each year or encounter the possibility of facing legal action. Biosafety South Africa notes that one of the main issues around the cultivation of GM maize is the increased risk management around the unintentional spread of GM material to other non-GM crop systems (Nangoti et al., 2004). Interestingly, studies have shown that it is becoming increasingly difficult for farmers to distinguish between maize varieties which can raise further concerns because of the observable features that are not always so obvious for small-scale farmers (Fitzgerald, 1993; Moseley and Tripp 2003; Nangoti et al., 2004).

2.8 South Africa's perspective toward GMOs

GMO trials were first conducted in South Africa in 1989 (Falck-Zepeda et al., 2013). The GMO Act was implemented in 1997, which saw the production and commercial release of genetically modified insect-resistant cotton and maize being approved (Prakash et al., 2011; Falck-Zepeda et al., 2013). Approximately 80 percent of cultivated maize is either white or yellow in appearance (Verheye, 2010). Despite being the African continent's leading producer of GM crops, South Africa, as a developing country with expectations of contributing towards food security, still has a long way to go in understanding the long-term implications of GM crops (Verheye, 2010).

2.9 Importance of seed vigour and how it affects small-scale farmers

Vigour[11] testing evaluates the percentage of viable seed as well as the ability of those seeds to produce normal seedlings under unfavourable environmental conditions (Marcos-Filho, 2015). It is also defined as the quality component in field performance differences among high germinating seeds (van de Venter, 2001). As seeds are constantly developed under biotic and abiotic stress, this may often result

[11] In 1977, the International Seed Testing Association (ISTA) congress adopted the definition of seed vigour as the totality of properties of the seed such as development, yield and quality which determine the level of activity and performance of the seed" during germination and seedling emergence (Hampton, 1993; Marcos-Filho, 2015).

in poor-vigour seed, which is why vigour testing is not only a crucial indicator of the storage potential, but is also an orthodox measure that indicates ideal conditions for seed development, storage, maturation and aging (Haneklaus et al., 2018; Sehgal et al., 2018).

The linkage between seed vigour and improved[12] maize varieties is better understood from a breeding perspective which explains how in the 1990s, the US government introduced patents which included licensing by commercial companies such as Monsanto (Netnou-Nkoana, 2017). Following genetic testing on seed and plant materials, the inference was that saving seeds was not legal for either GM or non-GM crops where licence restrictions were in place (Zilberman et al., 2018). Both hybrids and GMOs are associated with plant breeders' rights (PBR) or patents[13], but it is important to note that some hybrids can occur naturally or through conventional breeding technologies (Dubey et al., 2009; Baltazar et al., 2015). The distinction between the two is that GMOs require gene splicing while hybrids do not. Saving seeds from hybrids (F1), will not necessarily yield the same plants in the next season, instead they will produce plants with less vigour. Moreover, saving seed from GMO plants is an illegal act which may result in a lawsuit (Zilberman et al., 2018).

2.9.1 Biotechnology and FSS

Altieri (2002) and Ray et al. (2013) highlight that small-scale farmers remain disadvantaged due to insufficient resources and training to enable them to expand their agricultural knowledge in a holistic agroecological approach. According to Cooper and Conway (1998), small-scale farmers remain on the marginal end of the spectrum whereby they either cannot afford seeds, or the technology is not adapted to their needs. Agricultural biotechnology innovations such as *Bt*-crops are profit

[12] According to Nkonya (2001), an improved variety is that which has been refined by formal plant breeding methods. This includes varieties that have not lost their useful traits and as a result perform better than unimproved varieties. Furthermore, Perales, et al. (1998) and Morris et al. (1999) add that unimproved varieties refer to local landrace or traditional varieties which have not been altered through conventional breeding procedures.

[13] "A patent is an exclusive right granted for an invention, which is a product or a process that provides novel information or solution to a problem" (Acquaah, 2012, p.258). In South Africa the term is usually for a period of 20 years according to the Patents Act 57 of 1978 (Acquaah, 2012).

driven, so more legislation should be set in place in the seed markets to protect small-scale farmers in developing countries who do not have access to financial resources or markets from having to depend on expensive seed (Lapp et al., 1996). With modern agriculture improving its technology and adopting new methods of breeding and advanced biotechnology, the complexity of seed systems will keep growing (Harlander, 2002; Kingwell, 2011).

GM crop technologies are hailed by some as the panacea to the eradication of future global food hunger (Qaim and Kouser, 2013). With the commercialisation of GM crops, patents have become tickets to big companies, not only to threaten small-scale farmers' food security, but most importantly, to claim ownership of the seeds (Wynberg and van Niekerk, 2015). Autonomy allows for farmers to have the freedom to preserve their traditional knowledge and practices as well as maintaining maize crop biodiversity and sustainability in their households and communities (Binimelis et al. 2014).

One of the most debated topics in modern agriculture is around the implications of contamination between crop varieties, and how the introduction of transgenes into a maize pool could have drastic consequences for small-scale farmers (van Heerwaarden et al., 2012). This study does not focus exclusively on crop contamination but does, however, make use of a technique to determine the presence of a transgene in maize varieties. Despite the outcome of high yielding GM crops, there is a lot of controversy surrounding the use of herbicides, pesticides and other chemical fertilisers (Aktar et al., 2009). In the years 2008-2010, the South African National Biodiversity Institute (SANBI) together with a group of researchers from Norway looked at the impacts of GM maize (MON810 maize) (Bohn et al., 2010). One of the features of GM maize that emerged from the study was that it was characterised by the Crystal protein 1Ab, or Cry1Ab protein (which is a *Bt*-protein that originates from a soil bacterium that destroys the digestive system of maize insects by releasing a toxic form of the *Bt*-protein and kills the insect when activated) (Bohn et al., 2010). Several problems can emerge such as when there is uncontrolled management of different maize landscapes in close proximity to one another (which poses an increasing risk of pollination from a commercial farm spreading to a nearby small-scale farmer's field and mixing the maize gene pool) or when farmers lack the freedom of choice regarding their seed or when farmers do not have consent when it comes to management of their seeds. This can potentially lead to lawsuits being filed against such farmers where they can be held liable for infringing upon the GM company policy (Abidoye and Mabaya, 2014). Another major concern around contamination (whether controlled or uncontrolled) involves the lack of proper regulations or effective policies to protect small-scale farmers against unforeseen circumstances.

2.10 Farmers' rights

A report by Andersen and Winge (2010) from the Fridtjof Nansen Institute (FNI) Norway, highlights the relevance and importance of farmers' rights which include the protection of traditional knowledge and the rights of farmers to save, use and exchange seed material as appropriate[14]. In most African countries, FSS are not sufficiently recognised particularly within legislation. For instance, countries such as Uganda, Zambia and Tanzania are still trying to establish registration options for traditional or farmer varieties in order to take part in seed exchange and marketing (Omanga and Rossiter, 2001; Christinck, 2018). Another important element includes awareness about farmers' rights as well as their participation within the overall seed sector (Netnou-Nkoana et al., 2017). Despite the challenges, these dynamic networks must deal with different issues relating to good seed practices alongside Participatory Plant Breeding[15], crop germplasm characterisation from genebanks as well as seed diversification (Christinck, 2018). Inasmuch as crop diversity is important for FSS, the proper management of particularly traditional seed varieties is essential for farmers and their communities, and it is therefore important to understand the value of traditional varieties.

[14] The 2010 Global Consultations on Farmer's Rights were organised and led by the Fridtjof Nansen Institute, Norway and the Global Consultation Conference was hosted by Institute of Biodiversity Conservation, Ethiopia.

[15] Witcombe et al. (2005) described Participatory Plant Breeding as client-oriented plant breeding where market and germplasm are oriented towards farmers.

2.10.1 The importance of traditional maize seed

Traditional agricultural systems[16] and maize diversity have played an important role in farming methods used by small-scale farmers for more than 6,000 years (Bellon, 2004) and continue to have an impact on many farming communities across the world (Issa et al., 2014). It is believed that Mexico serves as the country of origin for the domestication of maize which led to the global cultivation of maize varieties in modern agriculture (Bellon, 2004). According to Bellon (2004) and Archer et al. (2008), factors such as socio-economic influences, which include markets and farmer-farmer interactions in traditional agricultural systems may negatively impact on the diversity of maize landraces. Farmer exchange systems are important in many communities to maintain agricultural biodiversity, farmer network systems, social cohesion[17] as well as food security through agroecology (Frison et al., 2011; van Niekerk and Wynberg, 2017). Though people's agricultural practices have been anchored by different knowledge systems for many years, the impacts of modern agriculture continue to exert pressure on local seed systems as well as on social, ecological, economic and cultural networks (Patel, 2009; van Niekerk and Wynberg, 2017). In most communities, these seed exchange systems are a relationship of trust between farmers, society and to an extent national governmental organisations (NGOs) (Westengen et al., 2019). However, the uptake of new and improved seed varieties is gradually shaping small-scale farmers' practices across South Africa (Mahlase, 2017). With the economic constraints that farmers experience, their dependence on multinational companies such as Monsanto (now Bayer) and Syngenta are becoming more evident. Subsequently, many questions around the ability of government to promote and enhance these farmer's rights remain unanswered. If traditional varieties are important to maintain, then small-scale farmers should be recognised more for their contribution to food security in South Africa (Baiphethi and Jacobs, 2009).

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[16] Traditional agriculture has been defined by scholars as the outcome of experiences provided by local farming practices which have been passed through thousands of years (Pulido and Bocco, 2003). For the purpose of the study, the researcher uses the term "traditional" with reference to such crop varieties that have not been altered in any way through biotechnological interventions, while most hybrids have been modified to display characteristics that fit breeders' criteria.

[17] A report written by the Department of Arts and Culture (DAC) of the Republic of South Africa, defined social cohesion as the extent of social integration within communities and society, whereby mutual agreements form as a common ground.

2.10.2 Seed selection as a farming practice to maintain seed varieties

Seed selection is considered as one of the important practices in small-scale farming methods, not only as a way to ensure continued ways of tradition and culture, but also to enhance genetic diversity which is central to climate resilience and food security, particularly within farmer communities (Louette and Smale, 1998). With abrupt changes in climatic conditions, management options to increase seed system resilience are essential as crops need to adapt to climate-related stress conditions (such as drought, salt and water stress - which are considered as molecular and biological indicators) (Rice et al., 1998). Seed selection practices can indicate how maize crop management links to crop production, soil, water and pest management (Reynolds et al., 2015). There is a growing interest in literature around the conceptual knowledge surrounding traditional seed selection methods as well as understanding the importance it contributes to modern agriculture, including its significance in (i) improving the structure of genetic diversity in farmers' varieties through seed exchange systems among households and communities; (ii) strengthening socio-economic ties and improving farmers' livelihoods; (iii) improving and acknowledging farmer-managed conservation efforts; as well as (v) ensuring farmer engagement in actively preserving traditional knowledge (Rice et al., 1998).

2.11 Summary

This chapter has covered the importance of as well as the threats to FSS which included the introduction of modern seed varieties. The role of maize was also highlighted indicating how it's important in giving different cultures a sense of identity. This chapter also covered the agricultural dichotomy in South Africa including the history of the homelands. The types of maize varieties found in this community were also emphasised looking into the impact that GMOs and biotechnology have on FSS. Lastly, this chapter highlighted the importance of farmers' rights as well as how seed selection is an important method and farming practice among the small-scale farmers.

CHAPTER THREE

METHODOLOGY

3.1 Outline of study area

The North West Province is home to more than three million people and consists of four district municipalities namely, Bojanala Platinum District (which consists of five local municipalities); Dr Kenneth Kaunda District (which consists of three local municipalities); Dr Ruth Segomotsi Mompati District (which consists of five local municipalities); and Ngaka Modiri Molema District (which consists of five local municipalities) (Figure 7) (StatsSA Census, 2011)[18]. The area of study for this project was the Sespond community situated within the Moretele Local Municipality in the Bojanala Platinum District. The name Moretele is derived from a river known in the local language of Setswana as *"Noka ya Moretele"* which translates to the Moretele River (StatsSA Census, 2011).

Figure 7: Map showing the North West Province District Municipalities highlighted in different colours. The Local Municipalities are also indicated on the map in black text. The study area was based in the Sespond Community in the Moretele Local Municipality (highlighted in red).

[18] Statistics South Africa. http://www.statssa.gov.za/?page_id=4286andid=10540

3.2 Demographic overview[19]

3.2.1 Sespond: Demographics

According to the 2011 Statistics South Africa survey (Stats SA), approximately 15 669 agricultural households were recorded with around 55 percent characterised by animal farming activity, 24 percent farmed crops only and 17 percent involving mixed farming. About 46,2 percent of households were female-headed households (StatsSA Census, 2011). The employment indicator is important for understanding economic growth whether it is on a local or a national level and is useful for introducing interventions to improve this sector. Working individuals in the informal sector include employees who do not get basic benefits such as pension or medical aid cover from their employer, and who do not necessarily have a written contract of employment (Moretele Demarcation Board, 2018)[20].

Most dwellings are in a rural settlement, with 93.7 percent of the households having access to a local water scheme (StatsSA Census, 2011). This is either in the form of communal taps located at different points, or from tanks either filled by rain or by municipal water trucks. The languages spoken by members of the Sespond community are diverse with Setswana, Sepedi, Xitsonga and Sesotho being the most spoken - recorded at 34.8 percent, 30.2 percent, 17.7 percent and 9.9 percent, respectively (StatsSA Census, 2011).

[19] All information was referenced from Stats SA as well as the Municipal Capacity Assessment 2018 document which details significant statistics regarding the Moretele Municipality (NW371). https://www.google.com/url?sa=tandsource=webandrct=jandurl=http://www.demarcation.org.za/site/wp-content/uploads/2019/04/MoreteleNW371-1.docxandved=2ahUKEwj2w67yoKjnAhUCilwKHVDTCqAQFjACegQIAxABandusg=AOvVaw0udKeBq6f6us4ZVkX7Jnux

[20] The youth unemployment rate refers to such individuals (usually between the ages of 15 and 24) who are without work but are actively seeking jobs. Youth who are not actively seeking work refers to such individuals who have not taken active steps to seek work. The unemployment rate indicates unemployed individuals as a proportion of those currently active in the labour force. This means that such individuals must be actively seeking work and available for work.

3.3 Land and Human Settlements

3.3.1 Land claims

Land claims[21] play an important role in the history of the area. The Bophuthatswana homeland was a geographically small part of what was the Transvaal province. which was dissolved in 27 April 1994. Table 1 below shows areas of the municipality under land claim processes.

Table 1: Table showing land claims in Moretele and North West Province

	Sum of Land Claims
Moretele municipality	46
NWP Total	2957
SA Total	20617

3.3.2 Traditional communities

Approximately 84.6 percent of Wards in Moretele had traditional authorities with 95.7 percent of the municipal area in Moretele having been situated in former homelands (**Supplementary Data**). The Sespond community is situated in ward 14 in the Moretele Local Municipality which consists of 23 other wards. These wards are made up of 66 villages and plots, of which most are ruled by traditional leaders or “Dikgosi” as known by the local people.

[21] A land claim is a request for the restoration of a right in land, lodged with the Commission on Restitution of Land Rights. According to the 2012/13 annual report by the Department of rural development and land reform, this is applicable to a person who was previously “dispossessed of a right in land after 19 June 1913 following past racially discriminatory laws or practices,” (Commission on Restitution of Land Rights, p.4 of 17) or had not received just and equitable compensation at time of dispossession (Ramutsindela et al., 2003).

3.3.3 Types of housing

About 84.5 percent of people live in formal dwellings, 0.9 percent live in traditional dwellings, 0.1 percent in other housing and 14.2 percent in informal housing (**Supplementary Data**).

3.3.4 Land use[22]

Land use assessments are based on categories such as soils, climate, erosion hazard and slope (Le Roux et al., 2007). Approximately 26.8 percent of the municipal area land cover is cultivated while 48.7 percent of land cover is natural surroundings. Figure 8 is a map that indicates more features of the land which includes natural plantations, houses in and around the Sespond community. Interestingly, commercial farming can be seen across the Limpopo border.

Figure 8: Google Image of the Sespond community (highlighted in red) including surrounding houses. Top right corner of this image shows commercial agricultural landscapes across the Limpopo border.

[22] Land use capability takes into consideration the risks of land damage from erosion as well as difficulties in owning land.

3.4 Research design

The participants for the study were selected on the following criteria: households that had maize crops growing in their fields, and farmers who were actively farming.

Information was gathered through interviews with 30 farmers. Although only a small subset of the total population of 1,500, resource and time constraints required fewer, in-depth interviews rather than a statistically representative sample. A scoping trip in June 2018 identified houses with maize fields to be part of the study. The selection criteria for farmers was based on their availability during the study, and the farmers also had to be actively farming. The households interviewed were dispersed throughout the community which helped to get as many different views from farmers as possible. Seed samples were collected from seven farmers with their prior informed consent.

The significance of the quantitative[23] approach enabled the researcher to gain a deeper insight and understanding of the dynamics of maize varieties (Kirsten, 2010). Quantitative techniques combine empirical data with analytical interpretations to establish correlations between the different sectors, institutions, farmers and communities (Kirsten, 2010).

3.5 Scoping visits

Two scoping visits were conducted before the commencement of the study. The first was conducted in June 2018 to assess the study site and identify farming areas. The second scoping visit was done in December 2018 where the researcher used the opportunity to introduce the purpose of the study to the selected households. A trial household survey and interview schedule were carried out to build a rapport with the farmers and served as a pilot phase for the research.

[23] A quantitative research approach is a method used to obtain data by measuring the interaction between different variables (such as in experiments) which can be controlled, manipulated or repeated. For this study, the testing of maize seeds was a quantitative method.

3.6 Mapping

3.6.1 GIS Cape Farm Mapper (version 2.2.1.3)

This online mapping tool designed to assist with geographical and spatial information was used to provide features such as different spatial and agricultural layers for the North West region.

3.6.2 Google Maps

Google Maps is a Web-based tool that provides more specific information about geographical region of interest. This tool helped obtain aerial and satellite visualisations as well as providing more context such as street names and coordinates.

3.6.3 Wazimap and Statistica South Africa (StatsSA)

Derived from the Xhosa word "*ulwazi*" for knowledge, Wazimap, is an online tool that provides easy access to population data for a specific region. Stats SA is an online tool that provides statistical systems for evidence-based decisions. Together these tools assisted the researcher to understand the historical perspective as well as the specific data relating to the study area. These tools were used to collect relevant information on national and local demographics.

3.7 Survey

3.7.1 Semi-structured interviews

The interviews were conducted with 30 selected households based on convenience sampling. Appendix 4 lists the farmers who participated in the survey. Convenience sampling is a non-probability sampling technique where subjects are selected because of their convenient accessibility and availability (Etikan et al., 2016). Language barriers continue to be considered limitations in many studies and translation can have a significant impact on the interpretation and validity of the information. Therefore, to avoid the misinterpretation of information from one language to the other, the researcher spoke Setswana and Sepedi with the farmers when conducting the interviews. For the purposes of capturing as much information as possible, with the farmers' consent, the interviews were recorded as audio clips in the native languages and were then translated into English. Information exchanged between the farmers and researcher was also written down.

The surveys took place during the months of December 2018 to April 2019. The harvest took place during the months of January through to April 2019. The questionnaire structure alternated between a closed question-based approach to an open-ended discussion approach. This was important as it allowed the researcher to assess the farmer's response such as their approachability and willingness to participate in the survey. During the second set of interviews (February 2019 - April 2019), the researcher memorised important questions to engage in during the survey. Through this approach, the researcher realised that the farmers became more comfortable, and the information was shared easily through conversation.

3.7.2 Sample collection

A total of 20 maize cob samples (*n*) were collected from seven farmers, including samples from the milling company in Hammanskraal, and stored at room temperature (between 18 - 30 °C). Only seven farmers were able to give a sample of their maize as others did not have enough in their storage. At household level, depending on the purpose for which a farmer wanted to use his/her maize, the maize was harvested at different times. This also depended on when the maize variety was planted. Some farmers selected the maize cobs in their fields while others selected maize cobs from their storage facilities.

One of the research objectives was to conduct tests on the samples collected in order to determine whether the presence of the Cry1Ab/Ac protein was detected in the samples. A total of 20 maize variety samples was collected including two samples from the Brenner Mills company. Informed consent was given prior to the collection and testing of all samples. A small handful of kernel collected from farmers and the mill was important to understand what was present at the molecular level.

Sample collection from the mill included seed from different farmers in the area. Each sample test was accompanied by a controlled variable, to eliminate uncertainty about the significance of the results. It is important to note that some farmers gave more than one sample, and in the case of one farmer who had planted more than one variety in the field, the farmer gave samples for each of the maize varieties. Therefore, each variety was treated as a separate sample. Table 2 summarises the maize varieties and number of samples given by the seven farmers.

Table 2: A list of the number of farmers, maize varieties (as named by farmers) and sample quantity.

Farmer	Maize variety	Samples given
Farmer 1	Traditional	1
Farmer 2	Hybrid	3
Farmer 3	Traditional	5
Farmer 4	GM	2
Farmer 5	Mixed*	2
Farmer 6	GM	3
Farmer 7	Hybrid	2
	Traditional	2

* This variety refers to the samples collected from Brenner Mills. There isn't enough evidence to say which maize varieties are mixed together. However, the presence of the Cry1Ab/Ac protein implies *Bt*-maize.

3.8 Participant observation

Participant observation is defined as "the method of learning through involvement by engaging in the daily activities of participants," (Schensul et al., 1999, p 91). This method allowed the researcher to gain a deeper insight into the ways of farming in the Sespond community and households by participating in some of the field activities such as helping the farmers select maize to eat and store. Participant observation also allowed the researcher to understand the different ways farmers store their seed and what mechanisms they use to combat pests either in the field or in storage. Participant observation allowed the researcher to notice the comparisons between the ways of farming in how they were different or similar among farmers within the same community. Even though this method did not present a comprehensive description of the decision-making processes about farmers' maize varieties, it provided a basic view of understanding the relationship that exists between small-scale farmers and the formal seed system.

It was important to get different views about the farming practices in and around the Sespond community. An employee from the Brenner Mills Company, who is also a farmer, was interviewed and asked the same questions as the farmers. With the consent of the employee, photographs were taken within the administrative facility, which included instruments such as the moisture content machine, display charts for analysing maize that comes in from different regions as well as computers for capturing and recording relevant information. Unfortunately, visitors were not allowed to go into the main facility where the silos were situated.

3.9 Immunochromatographic assay

Immunochromatography is a diagnostic technique in molecular biology that involves a sample being tested for a certain characteristic (Huang et al. 2012). This technique was used to determine which of the samples had transgenes or were transgenic crops[24]. The sample testing was also important because the Sespond community is surrounded by commercial agriculture, which predominantly consists of *Bt*-maize. The seed samples were tested for the presence of Cry proteins. Using the Agdia Immunostrip ® test kit, the maize seeds were tested for the detection of *Bt*-Cry1Ab/1Ac protein. The *Bt*-Cry1Ab/1Ac strips were placed in the beakers in a vertical position. The control line appeared within 3 to 5 minutes (depending on the flow characteristics of the sample). If the sample was positive, the test line appeared within approximately 15 minutes of the reaction time. If the sample was negative, the test line did not appear. If the control line did not appear, the test was considered

[24] A transgenic crop is one that undergoes artificial changes to its deoxyribonucleic acid (DNA) structure to improve certain traits and characteristics such as resistance to pests and herbicides and drought tolerance (Pandey et al., 2010). Species that have been modified by bringing exogenous DNA (DNA of a different and unrelated species) than the one being altered is a common biotechnology tool used in the modernisation of agriculture (Adenle, 2011; Adenle et al., 2011).

invalid[25]. Appendix 5 shows the seed extraction protocol, the Agdia® standard measurements table and extract buffer protocol used in this study.

3.10 Data analyses

This research made use of Excel software programme to generate graphs and charts from the statistical information gathered through the interviews and surveys. The significance of this tool helped in obtaining general pattern of the demographics and farming practices and traditions representative of only the Sespond community.

3.11 Limitations of the study

Several limitations were identified during the research fieldwork. Acquiring recent statistical data around the demographics was challenging as online tools such StatsSA showed data only from the 2011 National Census (conducted every ten years). Other sources included community-based surveys which were conducted in 2016. However, for data comparison purposes, the researcher relied on municipal reports and assessments from 2018.

Another limitation included language barriers, where translating between different languages was the most common challenge encountered. Being aware of the literacy rate in the community, the questionnaire was printed in the English language for the benefit of the researcher. As most farmers were not comfortable with reading, the researcher verbalised the questions.

Time, participant availability and resource accessibility were also identified as limitations to the study. All the farmers interviewed gave consent to be interviewed by signing the consent form. However, not all the farmers gave consent to share their maize samples for testing purposes. The samples that were collected from the seven farmers were all treated as individual and separate samples, even though some farmers gave more than one sample. This was an important part of the study because the community does not exist in isolation; the maize varieties were not

[25] According to the Agdia® protocol, maximum reaction time was 30 minutes after which the Immunostrip was removed from the buffer. In between uses, the immunostrips were stored at 4 °C.

grown in a closed environment and considering the implications around contamination. However, if more samples could have been acquired from the study, the results would have provided a broader indication of the maize dynamics within this community.

3.12 Ethical considerations

Prior to the commencement of the study, ethical clearance was obtained from the Faculty of Science Research Ethics Committee at the University of Cape Town. Informed voluntary consent forms to participate in the research study were developed and given to participants to complete prior to commencing the study. These forms highlighted the participants' rights, procedures such as audio recording, taking photographs, consent to giving samples as well as sharing their knowledge around the farming practices. These forms also highlighted that participants' confidentiality and/or anonymity would be maintained using pseudonyms. The participants were also made aware that their participation was voluntary and that they could withdraw at any time from the study.

CHAPTER FOUR

RESULTS

4.1 Social characteristics of participants: Demographics

Figure 9 (i) shows that 63 percent (*n* = 19) of the farmers interviewed were females and more than 37 percent (*n* = 11) were males. It is important to note that this statistic is a representation of the farmers present at the time of the interviews and does not necessarily indicate the presence or absence of males within the household. Thirty seven percent (*n* = 11) of farmers were between the ages of 40-50, with 10 percent (*n* = 3) between the ages of 30-40 years (Figure 9 (i)). Forty percent (*n* =14) of the farmers received education up to Grade 9, with 10 percent (*n* = 3) of farmers having received a higher level of education in the form of a degree and a diploma. Forty-three percent (*n* = 13) of farmers had received either primary school education or had no education (Figure 9 (ii)).

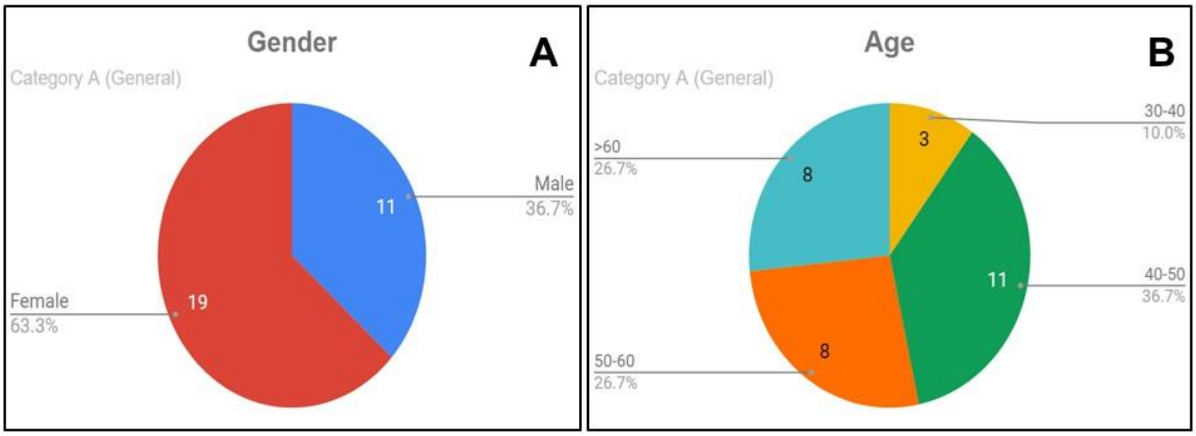

Figure 9 (i): Demographics: General category. Pie charts showing the demographics data for **(A)** gender and **(B)** age of the farmers who took part in the survey.

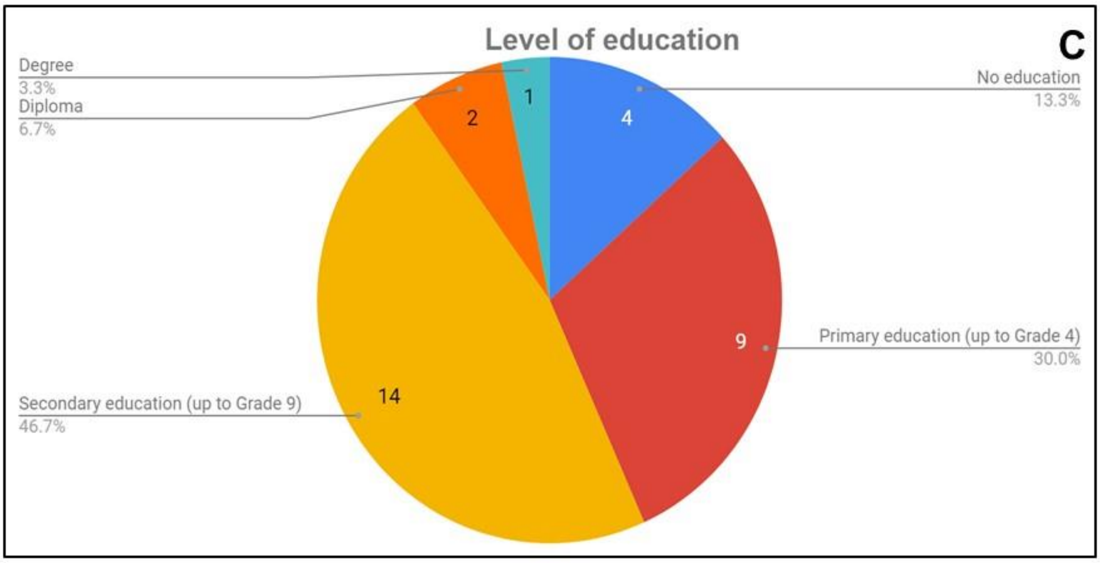

Figure 9 (ii): Demographics: General category. Pie chart showing data for the level of education of the farmers who took part in the survey.

4.1.2 <u>Traditional practices and beliefs</u>

The Sespond community, together with other communities, is overseen by a local chief. According to the information shared by the participants, during the late 1980s to 1990s, members of the community would show appreciation by bringing some of their crops as gifts to the chief and holding celebrations. Sometimes, other families would celebrate private functions, such as wedding ceremonies, with the chief present, to acknowledge his contribution toward the people of the community. Nowadays, this practice is not as common as it used to be, even though there is still a chief residing in the area. The Sespond community still has strong cultural beliefs. People with ancestral beliefs offer some of their crops as a sacrifice to the ancestors as they believe the ancestors watch over their fields and provide them with opportunities to farm and produce food for their families. During ceremonies such as weddings (*"lenyalo"* or *"magadi*"), a family invites the community to join the festivity, and guests bring maize seeds (*"mmidi"*), African spinach (*"morogo"*), beans (*"dinawa"*) or blankets (*"dikobo"*) as gifts. Food is an important part of the culture, which is highlighted by the crops that are planted, ranging from pumpkins and beans to cabbage and white maize.

4.2 An overview of farming and agriculture in Sespond

4.2.1 Knowledge

All farmers interviewed mentioned that they grew up in farming environments. Having gained the knowledge and experience around the ways of farming that were passed to them from previous generations, farmers used these to sustain their livelihoods (Figure 10). Some acknowledged learning mostly through observation, while the household head was working in the field. Only at such a time when the household head was unable to continue farming, would others take over. Three female farmers between the ages 30-40 said that even though they did not have much farming experience, they still worked on the farm in order to put food on the table. The older female farmers who had more experience in working on farms had more knowledge to share, particularly around which crops were more suitable and adapted to plant during different seasons, selecting crops for planting in the following season as well as different methods of storing their seeds. Male farmers would mostly attend to their livestock when they were in the field or pluck out weeds.

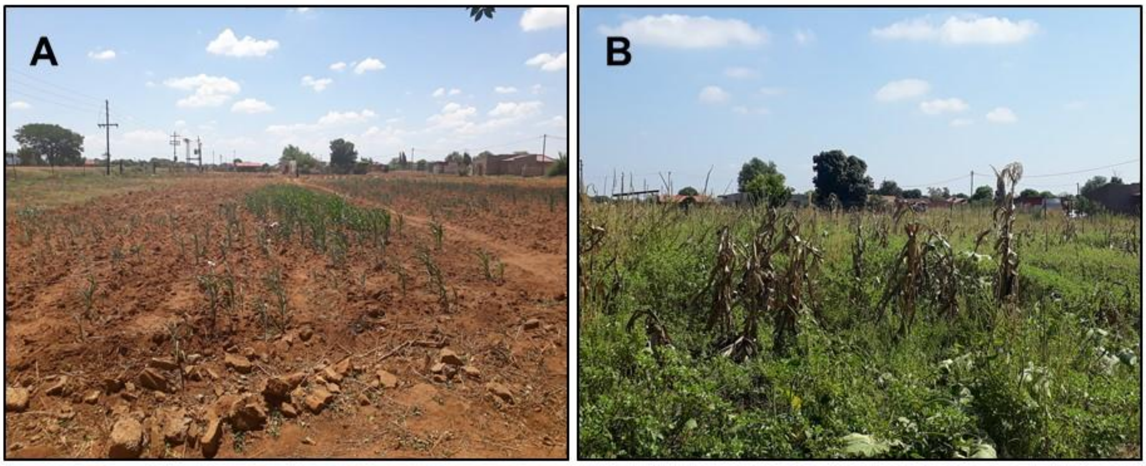

Figure 10: Photographs depicting traditional maize variety cultivated in a farmer's field. (**A**) Image taken on the 22nd December 2018 highlights how a farmer's fields does not have clearly separate rows between the maize. (**B**) As a result this image of the same field indicates how some of the maize were clustered together. This image was taken on the 18th April 2019.

"We are used to our knowledge and the old ways of observing what is done in the fields and from our storage."

~ Koko Thelma

18 April 2019

Koko Thelma's house, Sespond

Farmers also relied on their years of knowledge to understand how the different foods that they eat affect their health, as well as using different approaches such as dividing their fields into sections to use as trials during the planting season (Box 1).

Box 1: Farmers consider their knowledge as a significant aspect of their farming practices

I use the traditional seed ("Mmidi wa tlwaelo") in my yard and have been using it for many years. I never liked the taste of the seeds bought from the shops. Traditional varieties [foods] were believed to maintain our good health (even our parents and great-grandparents taught us that). The "mixing" of different ingredients used in modern agriculture to produce traditional foods ("dijo tsa setso") is the reason people don't know a lot of traditional foods.

From my own small field at the back of my house, I have divided my field into two sections: one as a trial and the other as an alternative planting section [for traditional maize]. This helps me to see which methods work best for my crops also considering the changing temperatures. I look at colour, size and if the seed is still healthy (not attacked by insects).

~ Ntate Jeffery
29 December 2018
Ntate Jeffery's house, Sespond

4.2.2 Farming practices and multi-cropping

The farmers' plots differed in size from household to household, ranging between 3,000 m^2 - 8,000 m^2. They varied from plots that could accommodate their houses and fields, to those that only accommodated their fields. Some households were as small as 1,000 m^2. Their fields consisted primarily of maize as the main crop, with other crop varieties such as pumpkin ("*lephutse*"), legumes and beans ("*dinawa*") as well as the African spinach ("*morogo*") planted in separate spaces. The farmers emphasised that the crop varieties were rain fed, with no alternative irrigation systems to water their crops. Farmers attributed certain characteristics such as texture and taste to the "natural" water cycle and believed that the rains were the reason their crops were in good health and tasted good.

"I can tell whether this crop variety (maize) was cultivated in the traditional way or if it was grown using their methods. They (commercial farmers) use many irrigation systems and fertilisers to boost the taste, the yield even the appearance of their crops. They taste different."

~ Ntate George
18 March 2019
Ntate George's house, Sespond

Male farmers with jobs apart from farming included working as carpenters in local shops, tractor operators or security guards in small companies. Female farmers would also sell food baked from their homes such as scones, fat cakes ("*magwinya*"), chips and vegetables. The number of dependants varied from household to household (and averaged three to five). Unlike commercial farmers who use synthetic fertilisers and integrate crop rotation methods to maintain their soil nutrients, these small-scale farmers used mixed farming systems for various reasons including space, where 30 percent (n = 9) of farmers interviewed remarked that the space they had in their fields was enough to plant more than one crop. For example, most of the household area used for farming was dedicated to the main crop which was white maize, and a small area used for growing other vegetables such as pumpkin, beans and the African Spinach (*"morogo"*). This would ensure that should the main crop not yield enough food, then the farmers could rely on these other crops for food, by not having to buy from the shops, as well as being able to sell any surplus for income. Table 3 provides information on some of the land and crop attributes in Sespond.

Table 3: Highlights of land and crop characteristics and farmers' household structures in Sespond.

● Land size	Farmers' yards accommodated a dwelling space (i.e. an average brick house or a shack) as well as an area designated for crop farming (3,000m^2 - 8,000m^2).
● Crops planted	White maize, pumpkin, beans, spinach

● Other crops	Tomatoes, watermelon, peppers, chilli
● Months of planting	October and November (for traditional maize); January and February (for hybrids and *Bt*-maize)
● Months of harvesting	March and April (for traditional maize); April and May (for hybrids and *Bt*-maize)

* Questions and responses extracted from questionnaire as well as through semi-structured interviews (formal conversations during interviews)

There was a perception among the farmers that most traditional crop varieties have gradually disappeared. Some farmers indicated that in their yards they had planted common and wild trees bearing fruit they grew up eating - "*Dijo tsa nageng*", which translates to foods of the wild, (Figure 11 (a-b)). Interestingly, farmers highlighted that over time the crops that they used to eat, were not as prominent as before, hence they kept some of the seeds and started planting them in their yards instead. However, not all traditional foods had disappeared from the community. As shown in Figure 12 (c-d), farmers grew traditional pumpkin ("*lephutse*") and melon ("*legapu*"). Figure 12 (e) provides an example of mixed farming where a farmer had dedicated the majority of his field to farming their main crop (which was maize in most cases), and dividing the remaining portions for planting other crop varieties such as beans ("*dinawa*") and wild or African spinach ("*morogo*"). The farmer also highlighted how taste is an important part of their traditional food and how he didn't like the taste of most foods bought from the shops. Farmers took pride with the crop varieties they produced and sold to their communities. As one farmer indicated,

"We used to have different kinds of traditional beans (red, brown, yellow) that we grew up eating. But nowadays people - especially older people - are complaining about many diseases relating to bones; and they say it's because of the food(s) from modern agriculture."

~ Ntate Patrick
18 January 2019
Ntate Patrick's House, Dertig

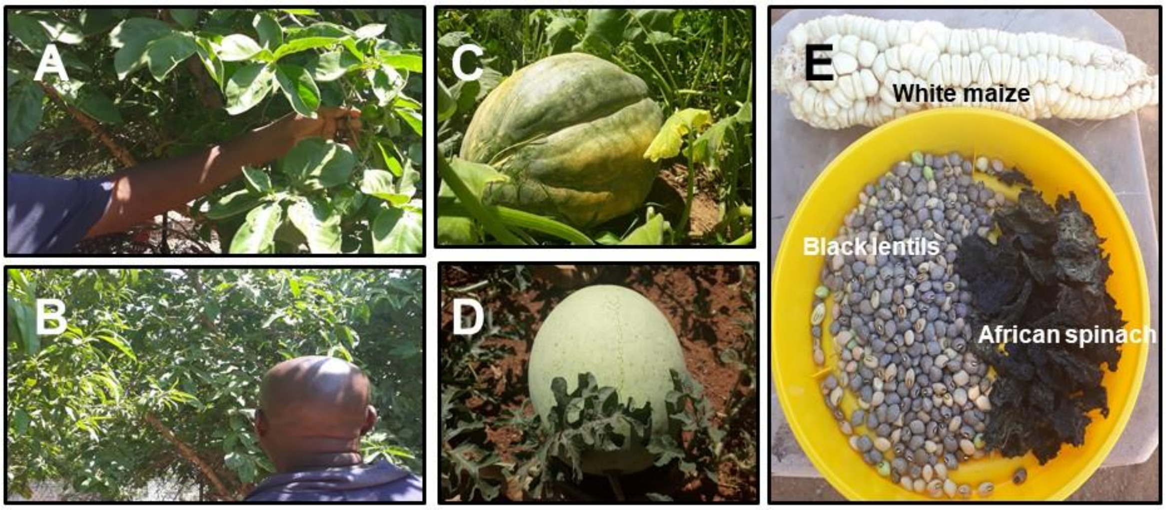

Figure 11: Traditional crop varieties and other plants grown in Sespond. **(A)** A farmer shows a tree growing oranges in his yard. **(B)** Farmer growing a wild tree of the Moringa plant (*Moringa oleifera*), which is believed to have medicinal properties. **(C)** A traditional pumpkin (*"lephutse"*). **(D)** A traditional melon (*"Legapu"*) grown in a farmer's field. **(E)** Image shows different crops grown in a farmer's field which includes white maize ("*mmidi*"), black lentils ("*dinawa*") and the wild or African spinach (*"morogo"*)

The farmers in this community generally farmed for themselves. However, one farmer highlighted how traditions and cultural practices have changed over the years:

"Long ago, we used to take some of our crops like beans, maize - some of our best crops to the local chief at Dihibidung [which is where he lives now]. It would be a huge celebration where farmers from Sespond, Dertig, Danhouse and other from the Moretele area would go because they believed that the chief was the reason that their fields produced crops. They also believed it was a way of showing respect to the chief as the leader of the different communities."

~ Aunty Debra
29 December 2018
Aunty Debra's house, Sespond

To the farmers in the Sespond community, farming meant more than just placing food on the table; it was also a way of them being connected to their heritage and culture.

4.3 Farmers’ maize varieties and growth conditions

The area of the community of Sespond is approximately 2,5 km^2 with houses that are sparsely situated. The maize fields differ in size and farmers plant different varieties. Figure 12 shows a map of the NWP which highlights the Sespond community and maize varieties planted.

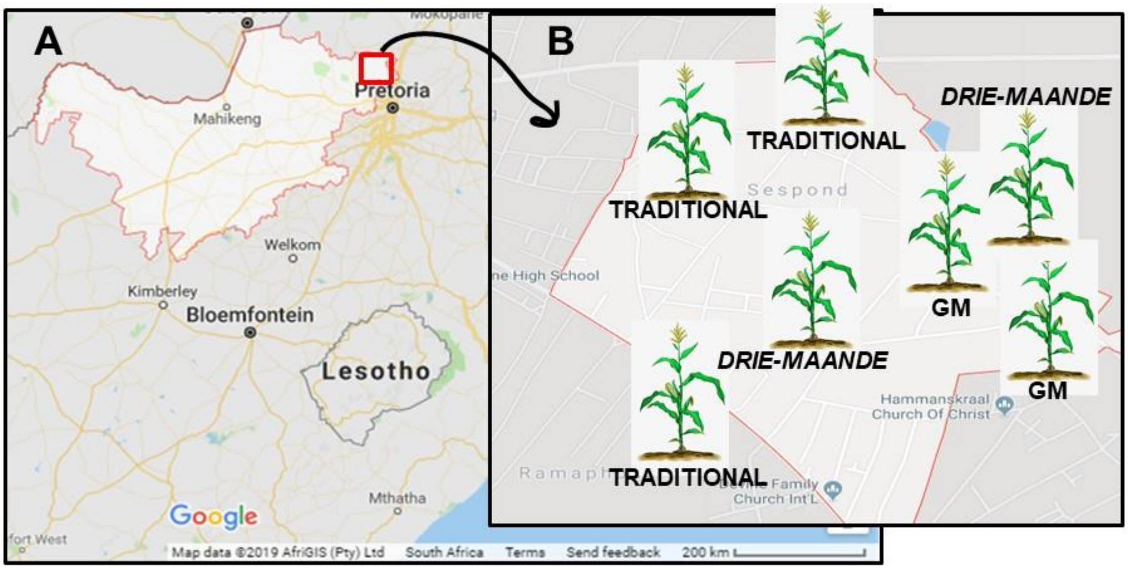

Figure 12: Geographic profile of maize varieties in the Sespond community. (**A**) Map data of the North West region. Red block indicates the Moretele Local Municipality, within which the Sespond community is located. (**B**) Map image with a zoom-in enhanced feature indicating the maize varieties found within the community.

Maize varieties were grown in farmers’ fields exposed to different weather conditions between the months of October 2018 and January 2019, ranging from average temperatures between 26 °C in October 2018 to 29 °C in January 2019. The average rainfall between October 2018 and January 2019 was recorded at 110.2 mm of rain (worldweatheronline, 2019). Although the maize grown in the Sespond community is rain-fed, some farmers used hose pipes to water their fields. Farmers who planted traditional maize varieties in October mentioned that it took approximately 6 months for the maize to mature for consumption purposes and to dry for subsequent selection processes. Scientifically, these types of maize were referred to as “late maturing” maize varieties (Ajambo et al., 2017). Some farmers who planted early in January (due to late summer rains) planted varieties that required less than six months before harvest. This type of maize was referred to, by the farmers, as “*drie-maande*” (three-months). These maize varieties are referred to as “short season” maize varieties (Mutungwe et al., 2016; Moeletsi, 2017).

4.3.1 Maize varieties planted in Sespond

In the 2018/19 season 47 percent (*n* = 14) of farmers interviewed planted traditional maize, with 27 percent (*n* = 8) planting hybrids. Ten percent (*n* = 3) of farmers planted traditional maize or hybrids and approximately 17 percent (*n* = 5) of the farmers planted *Bt*-maize. This showed that of the farmers interviewed, preferred the traditional maize more than other varieties. Figure 13 shows the maize varieties that were planted by farmers during the 2018/2019 season. Traditional maize was planted more frequently than other varieties, with 14 farmers having planted this variety compared to eight farmers who planted the hybrid variety and five farmers who planted *Bt*-maize. Three of the farmers mentioned that they sometimes mixed their seeds by either planting different varieties on different portions of their fields or switching to another variety when one did not produce a good yield.

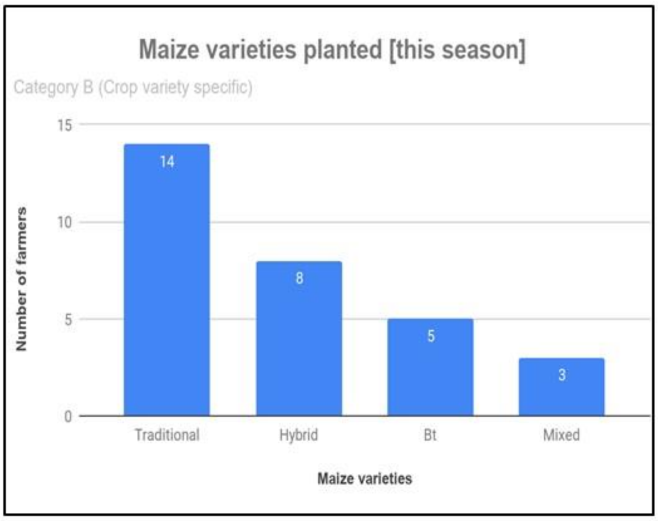

Figure 13: Crop specific category: Maize varieties planted. Bar graphs indicating data for maize varieties farmers used. Mixed varieties indicate farmers who used traditional and hybrid seed interchangeably depending on their previous yield.

The traditional varieties included fine maize flour (“*bogobe*”), samp (“*setampa*”) which is eaten with meat or vegetables, and “*mageu*” (a non-alcoholic drink made from fermented mealie pap) which is usually served at weddings and other social gatherings. Sometimes during a good season, the harvest would yield maize with kernel sizes equivalent to the average adult thumbnail in irregular rows (Figure 14 (i)). According to the farmers, six months is the time it takes for the traditional maize variety to fully mature which gives it its qualities such as texture and grinding quality.

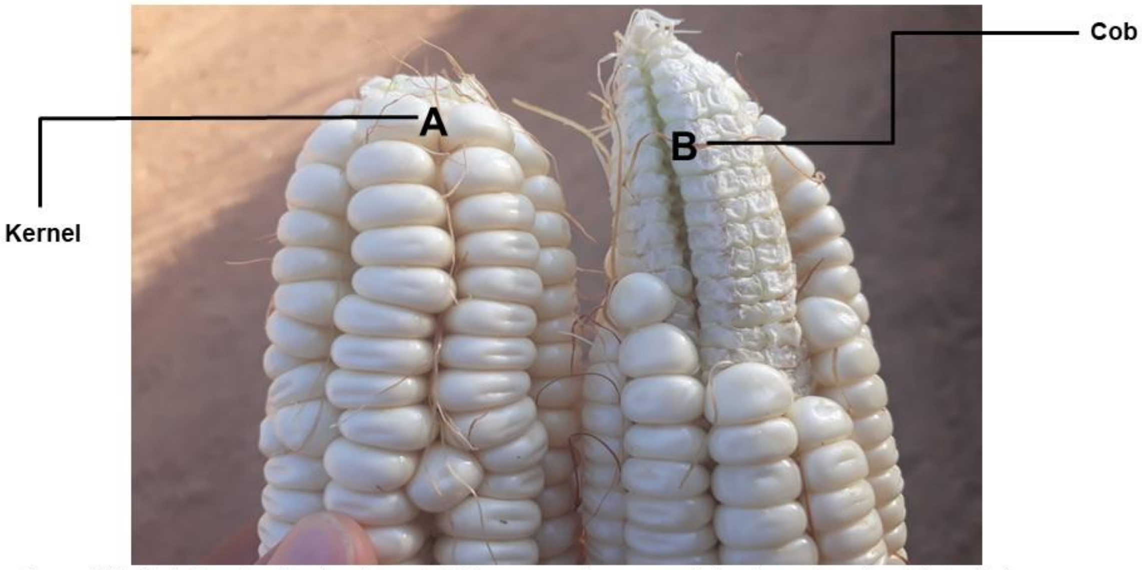

Figure 14 (i): Variations in maize development. Differences such as poor cob development can be attributed to low rainfall, poor soil, or insect damage. This image depicts phenotypic differences between two traditional maize cobs which were grown in the same field. Image A shows maize with seeds that cover all the way to the tip of the cob. Image B shows a cob with seeds that expose a part of the cob of the maize.

More than 30 percent (*n* = 10) of farmers spoke about the "*drie-maande*" maize variety they encountered during planting and harvesting season. Shroeder et al. (2013) also highlighted how the "*drie-maande*" maize variety, a short season variety (SSV), is a hybrid which requires about half the time period (~ 3 months) to mature compared to the traditional variety. It had a different phenotypic appearance compared to the traditional variety as seen in Figure 14 (a). The maize cob is thinner with 'neatly arranged' kernels on the cob (Figure 14 (b)). Farmers who planted this maize variety indicated that they would do so following seasons when they experienced low production yields with their traditional variety due to insufficient rain. These SSVs are bred to be tolerant to drought and most leaf diseases (Mutungwe et al., 2017). However, when selecting seeds to use for planting the following season, the farmers said the "*drie-maande*" varieties were not ideal, highlighting that the size of the kernels was not large enough and therefore not a desirable trait.

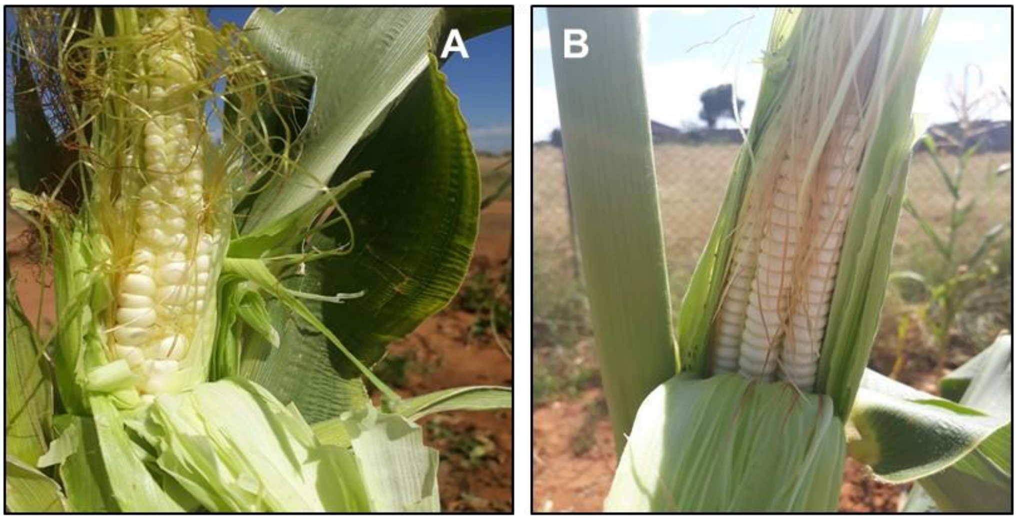

Figure 14 (ii): Maize variety in a farmer's field. (**A**) An example of traditional maize still early in its development stages shows how kernel sizes can vary from the bottom of the cob to the ear of the maize. (**B**) This image shows the "*drie-maande*" maize variety taken from the same farmer's field (but on a separate side). The contrast between the two images is the phenotypic appearances with particular focus to the size and shape of the maize. In most cases, the "*drie-maande*" is thinner compared to the traditional maize variety.

Only 17 percent (n = 5) of farmers resorted to store-bought seeds during previous low yield seasons. One farmer mentioned that it would sometimes be difficult for her to approach their neighbour for seed if they also experienced low production yields. After purchasing the seeds, Aunty Linda planted them in her field and stored the remaining in a plastic bag and other containers she used in the house. These seeds had an appearance different to the *Bt* seeds as they were covered in a pink-reddish powder[26]. Interestingly, a farmer mentioned that when she planted the maize in February 2019, it took only two months before she harvested in April 2019. Figure 14 (iii) compares the differences between the traditional and *Bt*-maize such as irregular rows as well as the size of the kernels and the length of the cobs. A striking feature is that the traditional maize can grow in different lengths while the *Bt*-maize is uniform.

[26] The powder coating is indicative of pesticide treatment. Although the name of the powder is not known, it is believed by the farmers that it contributes to or confers greater resistance against the maize weevil (Schier et al., 2012).

Figure 14 (iii): Crop diversity among farmers' fields in the Sespond community. (**A**) Image A shows a farmer with traditional maize in different sizes. (**B**) Image B depicts a farmer with *Bt* maize at relatively the same length. The differences between these two maize varieties range from the size of the kernels, how the kernels are arranged on the cob to the ears of the maize (which are well defined in the GM maize variety).

4.3.2 Farmers differentiating between maize seed varieties

Figure 15 indicates whether farmers were able to differentiate between traditional, hybrid and *Bt*-maize seed varieties. Approximately 23 percent (n = 7) of farmers said they could sometimes tell the difference, while 27 percent (n = 8) farmers said they didn't pay much detail to the seeds and 37 percent (n = 11) farmers indicated that they were able to tell the difference. When asked how they were able to differentiate seeds, the farmers mentioned that since they have been farming for a long time, they know which seeds they have been using by observing the size, shape and texture characteristics. Although this mechanism may not be as reliable today in modern agriculture, it was perceived to work for these farmers through their experience and traditional knowledge.

By spending a lot of time with their parents in the field, farmers gained experience which enabled them to select which seeds to use in the following planting season according to those with the most desirable traits such as size, insect resistance or drought tolerance. As one farmer mentioned:

"In the olden days when we only knew the seeds our fathers grew in their fields, we understood where the seeds came from and how they [seeds] adapted to the environment. We consider the size of the seeds, which a good yield

would produce kernels equivalent to the size of an average adult's thumbnail and the taste is also important. The modern seeds we find today differ from the ones we are used to in that they [seeds] have a dusty pinkish appearance which is a type of chemical fertiliser to kill grain pests such as the maize weevil ("Tshupa")."

~ Ntate Patrick
18 January 2019
Ntate Patrick's farm, Sespond

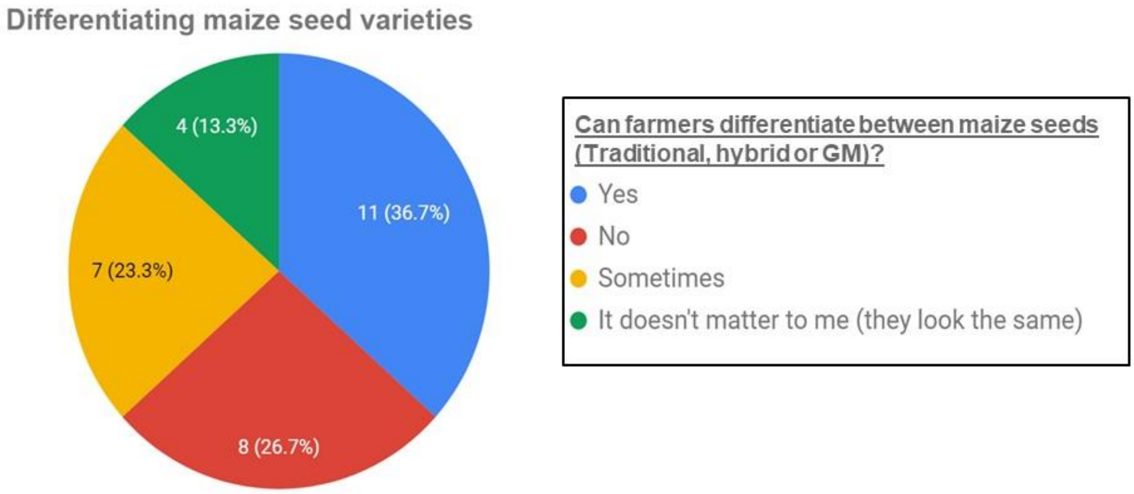

Figure 15: Differentiating maize seed varieties. Pie chart showing farmers' responses when asked about being able to tell the different maize seeds apart.

4.4 Farmers seed procurement

4.4.1 Where do farmers get their seeds from?

The farmers interviewed either used their own seeds that they had saved or obtained their seed from neighbours or from local shops. Depending on the previous seasons yields, some farmers changed their seed sources between planting seasons as their way of adapting to changing environmental and climatic conditions.

"I can't always be certain where my neighbour gets the seed from. I don't even know much about farming. At the end of the day, as long as I am able to feed my family."

~ Aunty Florence
18 March 2019
Aunt Florence's house, Sespond

Other farmers used their home-saved seed throughout planting seasons. Approximately 60 percent (*n* = 18) of farmers mentioned that they used their own saved traditional maize seed, while approximately 33 percent (*n* = 10) of the farmers acquired their seed from other farmers. Only 7 percent (*n* = 2) of the farmers bought their seeds from local markets (Figure 16). This emphasises the heavy reliance that farmers still place on traditional varieties, seed saving and exchange.

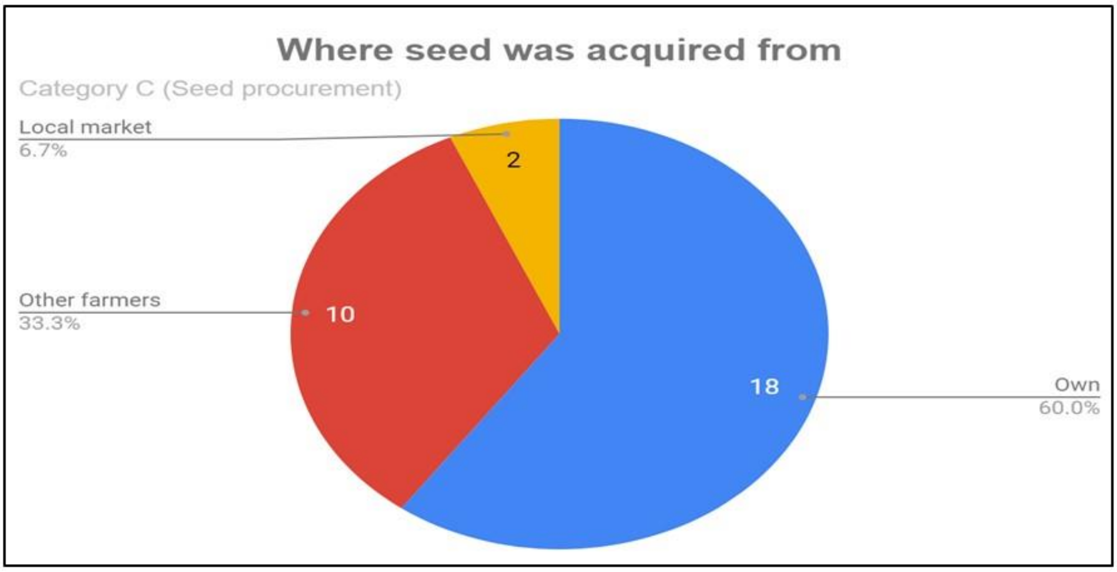

Figure 16: Seed procurement category. Pie chart showing where farmers acquired their seed.

4.5 How maize varieties are being selected: Understanding farmers' perceptions and practices

4.5.1 Reasons for selecting maize varieties

Farmers have their own criteria when they select seeds to plant in the next season, sell or consume. Figure 17 highlights some of the reasons, such as taste, colour and yield, that farmers preferred when planting seed varieties of their choice. All of the farmers who planted traditional and hybrid maize, preferred it for its taste. The distinct taste, texture and size of traditional maize, were reasons why this variety was preferred. The traditional maize is usually enjoyed when cooked in a pot or as mealie maize (*"pap*") while the hybrid maize is preferred when grilled over a flame. *Bt*-maize was not planted by most of the farmers interviewed, however, one farmer who planted *Bt*-maize, said he enjoyed the taste when cooked or grilled. Fifty percent of farmers who planted traditional (*n* = 7 out of 14[27]) and hybrid maize (*n* = 4 out of 8), mentioned nutrition as a contributing factor to their choice of maize, while 60 percent (*n* = 3 out of 5) of farmers who planted *Bt*-maize highlighting nutrition as an important aspect.

Yield is an important element that can have an impact on farmers in terms of how much they have in storage or to use for planting in the following season. For this category, farmers paired yield production with rain. Since the interviews were conducted prior to harvest season, farmers were giving their analysis of previous maize seasons. During a good rain season, which is usually during the months of December and January, 64 percent (*n* = 9 out of 14) of farmers who planted traditional maize mentioned that they would get good yields and the opposite during dry seasons. While 63 percent (*n* = 5 out of 8) of farmers who planted hybrid maize didn't have problems with their yields, 37 percent (*n* = 3 out of 8) farmers attributed yield difficulties to either insufficient rain or pest management problems. All of the farmers who planted *Bt*-maize (*n* = 5 out of 5) had good yields.

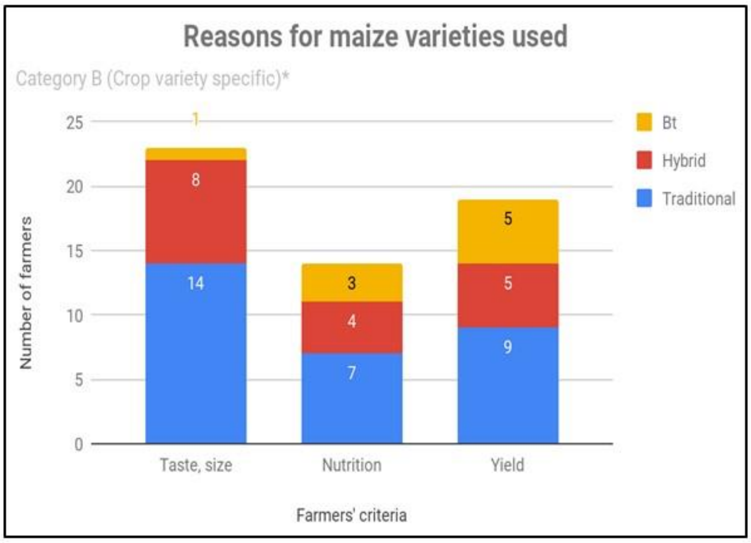

Figure 17: Farmers' reasons for choice of maize: Crop specific category. Bar graphs highlights reasons such as taste, nutrition and yield which stood out albeit there were other reasons farmers mentioned such as texture, colour, resistance to insects or drought tolerance. *Data captured are in order of preference and were pointed out the most by farmers.

[27] Refer to Figure 13 for the totals of maize varieties planted.

"I have been planting and growing maize for a long time. My friend (who used to be my neighbour) and I always planted traditional maize around the same time. Sometimes she would come help me work in my field and I would also go to help her in her field. We shared a lot of knowledge about the traditional maize we grew as well as the varieties other farmers spoke about which they grew in their fields. We have seen and tasted these other maize varieties and for us they were not good to taste. These varieties that they also sell on the streets - they were different from the traditional maize we grew. Although the traditional maize had a tough texture, we didn't experience digestion problems when we ate it - compared to the maize sold in the towns and on the streets."

~ Koko Carol
18 March 2019
Koko Carol's house, Sespond

"One of my grandchildren once bought Bt seed from the store a long time ago and I planted it in my field. It produced good yield, but I did not like the taste. it tasted different to the one I was used to. The texture was not as rough as the traditional variety. Since then, I have been planting my own maize even though sometimes I struggle with yields."

~ Koko Leah
21 March 2019
Koko Mary's farm, Sespond

4.5.2 Seed selection and storage

The role of seed selection is an important issue for small-scale farmers. Farmers have to decide which maize seeds to reserve for planting and which to eat. They can choose to eat the maize as it is or grind it to maize flour. At household level, after they grind the maize, farmers sift through the maize flour to remove debris and insects (Figure 18 (a - b)). It was highlighted that there are two distinct processes used by farmers during the selection process. The first, shown in the image below, is used by farmers to clean the maize flour before consumption. The second (not shown) known as winnowing, is used when they clean their maize seeds to remove any dust particles or other debris before storing or selling. At household level, farmers set their own criteria to select the best seeds for planting and consuming, which include size of kernels and taste or how much the seed has been damaged).

Figure 18: The role of seed selection at household level. (**A**) This picture illustrates how a farmer sifts through maize that was ground into flour. Farmers rely on this process to remove unwanted debris from the maize flour (*"bupi"*). (**B**) This close-up image shows the maize weevil and the corn borer that eventually grow in size as they feed on the maize flour. Farmers rely on the sifting process ("*fefenwa*") to make traditional beer (which is made from leftover pap).

Figure 19 (a) shows a farmer who planted traditional and *Bt*-maize seeds in separate parts of her field, with a container she used to store her seed varieties. In Figure 19 (b), the farmer shows the different seed varieties. She said the base of the kernel, which appears pink-red, was an indication for her of which seed it was. The farmer said that sometimes the cobs were either white or red in colour depending on which seed one used; a white cob indicated that the maize had not been treated with chemicals and if the cob was red in appearance, it indicated that the maize had been treated with chemicals. There are different varieties of insecticides and it may be difficult for the farmer to tell whether or not the maize seeds have been treated (Schaafsma et al., 2019). As one farmer said,

"Long ago we would also get cobs which appeared either white or red in colour. This was also a way we as farmers could tell if the maize had been treated with chemicals or not. Nowadays we can get maize that has been treated but still has a white cob. I think the chemicals change over time and this can confuse some farmers because they [farmers] can't always keep up with these methods and technologies."

~ Koko Thelma

18 April 2019

Koko Thelma's house, Sespond

Figure 19 (c) shows how the same farmer saved traditional and GM seeds in the same container. This farmer had divided her field into two portions where she planted traditional on one half of her field and GM variety on the other half.

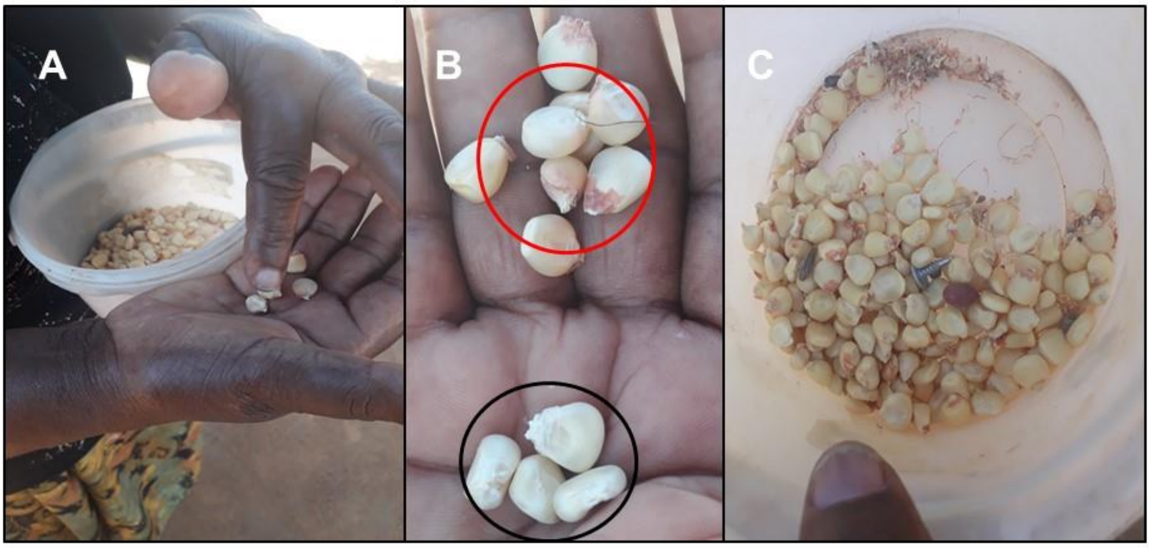

Figure 19: Traditional maize variety sown in the same field as the *Bt*-maize variety. (**A**) Farmer shows seeds that she selected for and saved. (**B**) Farmer separates seeds to highlight the differences with traditional varieties circled in black and GM varieties circled in red. (**C**) During harvest season, this farmer was one of the few who could differentiate between the two varieties in her field even though she saved all her seeds in one container.

The role played by seed selection on the farmers' system and the timing of seed selection is important to explore. Depending on what farmers want to use the maize for, they would harvest during or after the season (Figure 20). If they wanted to cook the maize in a pot for consumption, then they would choose maize while it was in the field. If they wanted to save the seeds or grind into maize flour, they had to wait and only harvest after the maize had dried. Some of the features that farmers also look out for when they want to cook maize, is the leaf colour, which should appear green (usually indicating soft kernels). And if they wanted to save the seed for later, the brown leaf appearance indicated that the maize had dried up (resulting in hardened kernels).

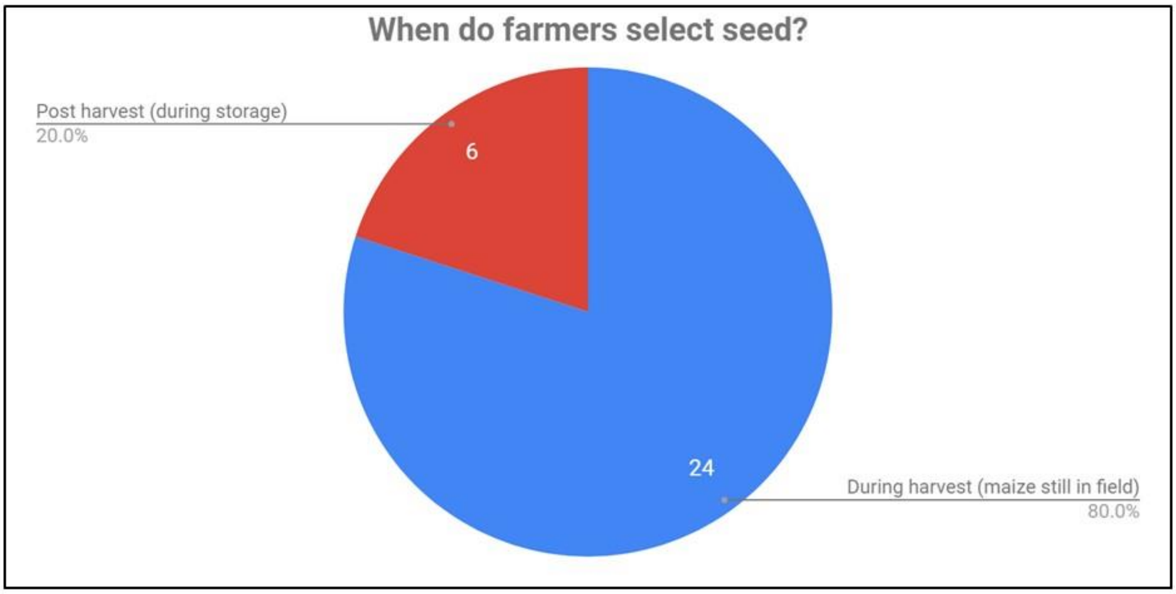

Figure 20: Time for seed selection. Pie chart indicating when farmers select for seed with most of the selection process taking place during harvest.

4.6 Factors influencing the selection and storage of maize seed

4.6.1 Temperature and yield

In the community of Sespond, farmers have, over the years, experienced increased temperatures and drought. As a result, many farmers have stopped planting and harvesting maize. This was evident in the vacant fields where farmers used to grow their crops (Figure 21 (a-b)).

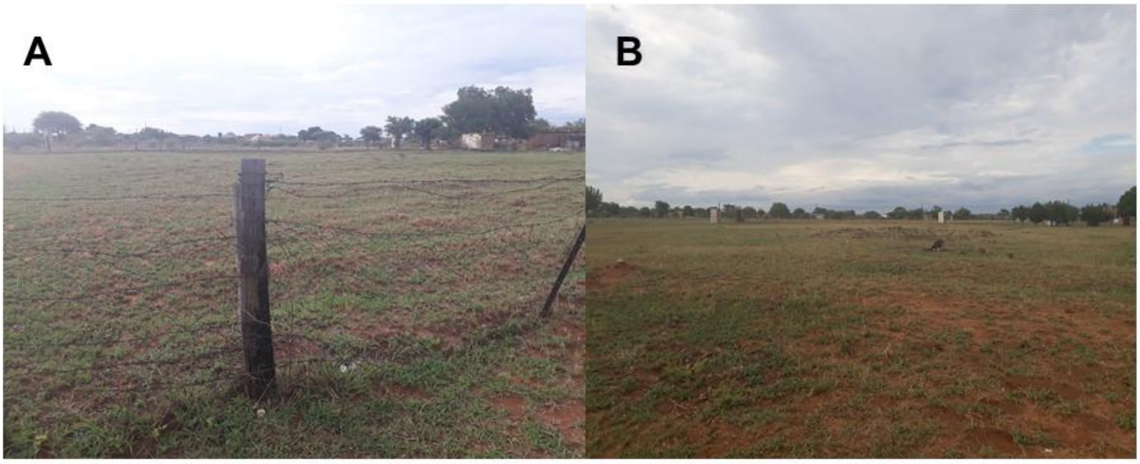

Figure 21: Fields of change in the Sespond community. (**A**) Image shows a vacant farmer's field that used to be a field of crop varieties. (**B**) As a result of the intense high temperatures, some farmers could not continue to farm maize or other crop varieties and instead converted their fields into grazing for cattle.

Approximately 53 percent of the farmers said they had to consider alternative sources of maize as their yields dropped significantly. One farmer mentioned how she suffered loss from her traditional maize after planting for a second consecutive time within the season,

"If you look at my field, you'll see that half of those stalks dried up in the field before producing any food. I had to get the guys with the tractors to plough up the soil again. It cost me a lot of money. But now I have planted again and hope for the rains to come."

~ Koko Carol
18 March 2019
Koko Carol's house, Sespond

4.6.2 Pest management

The maize weevil (*Sitophilus zeamais*), a common pest encountered by the farmers, is an increasing problem that attacks maize mostly in storage (Figure 22 (a - b)). The spotted stem borer (*Chilo partellus*) is also another common pest encountered by the farmers and usually attacks maize in the field Figure 22 (c). Approximately 60 percent (*n* = 18) of the farmers mentioned that animals such as the corn earworm, ground squirrels and smaller insects such as aphids also attacked the maize at any stage of growth. This resulted in little to no yield. A common practice among the farmers was the way they stored the seeds they had selected which they would either use for planting in the following season or grind into maize flour (*"bupi"*). They used charcoal ash (*"molora"*) and mix it with other household products such as peri-peri powder, coarse salt or the white insect powder commonly known as Blue Death[28]. One farmer said he used his own special mixture that he calls *"Bulala Zonke"* - which translates to "Kill All." During storage, he poured this mixture onto the seeds he selected which he washed off before using in the next planting season.

[28] Blue Death is a slow acting poison which is a white powder that you scatter where the ants are. The ants eat the powder and take some back to the nest where the rest of the colony also feed on it. The mixture, which contains coarse salt or coal ash, is used by farmers during storage.

"I have been using a fertiliser which is a mixture of different things such as Blue death powder, coal ash, coarse salt - a mixture I call " Bulala Zonke ", which I use to cover my maize seeds. In this way, the maize weevil ("tshupa") cannot attack my seeds, because once it destroys the seed embryo ("pelo ya mmidi"), the seeds become useless."

~ Ntate Albert

21 March 2019

Ntate Albert's house, Sespond

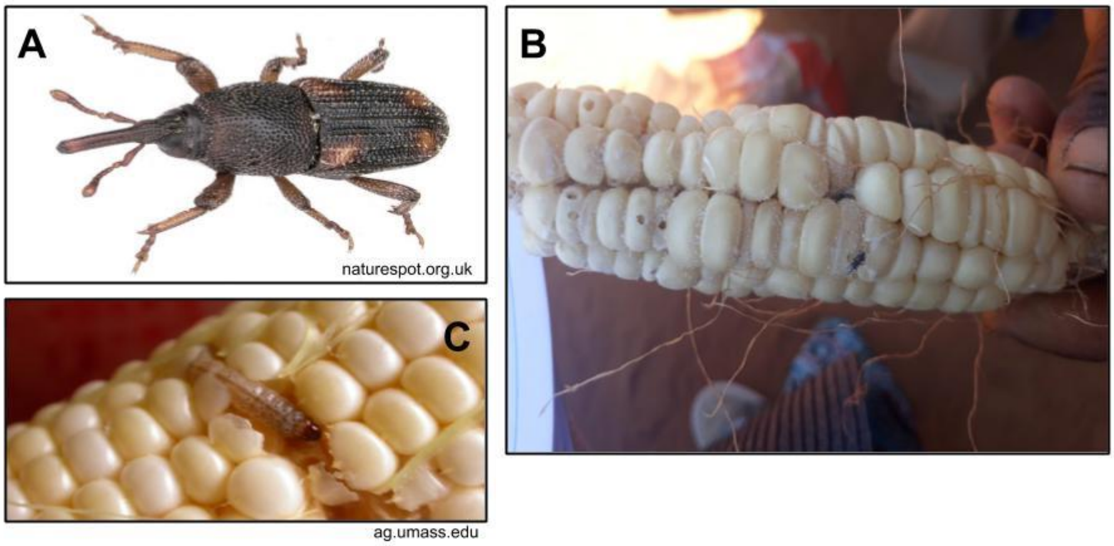

Figure 23: Insect and storage management strategies for farmers. (**A**) The maize weevil (*Sitophilus zeamais*) or "*tshupa"* as known by the farmers, is a common storage pest that can cause serious grain damage and loss. (**B**) A farmer shows how the maize weevil can cause damage and loss of grain by feeding on the interior of the kernel. Weevils subsequently lay eggs that feed from the inside out. (**C**) The European corn borer (*Chilo partellus*) is also another common grain pest.

Figure 22 (b) illustrates holes where the maize weevil chewed into the kernel to lay eggs that will develop inside the heart of the kernel, which is described by farmers as "*Pelo*", also known as the embryo (Dolfini et al., 2007). According to a report by Agronomic Spotlight (2017), in the manufacturing process, the seeds are treated with an insecticide which acts as a synthetic chemical or insecticide that kills insects when they are exposed to it (Wood and Goulson, 2017). Even though the seeds had a pink-red appearance, the maize harvested had a white appearance like the traditional and hybrid maize (Figure 23 (a - b)).

Figure 23: Maize varieties of influence - *Bacillus thuringiensis* (*Bt*). (**A**) A farmer shows an example of some of the genetically modified (GM) *Bt* maize grown in her field (**B**) *Bt* maize stored in a plastic bag after farmer has planted in her field. The pink-red dusty chemical comes from the *Neonicotinoid* insecticide group, commonly used to treat maize and other crops. The image also shows how the maize weevil fed at the kernels (as a result the powder that is seen) but died from the insecticide (circled in red).

4. 7 Post-harvesting processes and the milling company

4.7.1 Why farmers take their maize seed to the mill

Farmers used to rely on their own knowledge and skill to select and store their traditional seed. The farmers pointed out that some of the pests and insects they have problems with today, are ones that they didn't encounter in the past. As it became more challenging for the farmers to manage pests and insects, they had to depend on other facilities outside of their households and communities, such as the mill, for storage purposes (Box 2).

Box 2: The importance of taking maize seed to the mill - farmer's perspective

"If, as a farmer, I managed to gather 80 kg of maize seed from my harvest and I know that I will not consume everything within a week or a month, then I take it to the mill for storage so that my seeds do not get attacked by the common storage pest we call "Tshupa" (maize weevil). Similarly, when I go to the mill to request for a portion of either the stored seed or processed maize flour, I only pay the mill a certain amount to get what I came to ask for (which varies depending on the agreement between the farmer and mill). In other words, I

don't pay for the product, instead I only pay the mill for the either storing or grinding (process) and not the maize flour or seeds. And how the process works, is that following the agreement, the farmer is given a number for identification and admin purposes - which the farmer will use for every "transaction" with the mill company. For instance, if I am given number 86, and I go to the mill to request a 10 kg bag of maize flour, I may pay R25 - compared to retail prices at stores where a farmer would purchase a 12.5 kg of maize flour for approximately R55 - R100 (depending on the brand)."

~ Ntate Thomas

Ntate Thomas' house, Sespond
20 August 2019

The Brenner Mills company is an example of the multiple linkages between farmers or between farmers and agribusinesses. It was established since 1938 and has processed leading brands such as Shaya White Super Maize Meal, Brennco Bird Seed Range and Brennco Legumes and Popcorn, Cup Final Super Maize Meal, Magic Rice, Brennco Performance Driven Animal Feeds and Shaya Mabela Meal. It operates several major branded depot outlets as well as two maize milling sites. The company receives maize samples from different locations in and around the Hammanskraal and North West regions, where the maize is collected and processed, before being packaged and distributed to supermarkets and local markets within the specific area, (Figure 24).

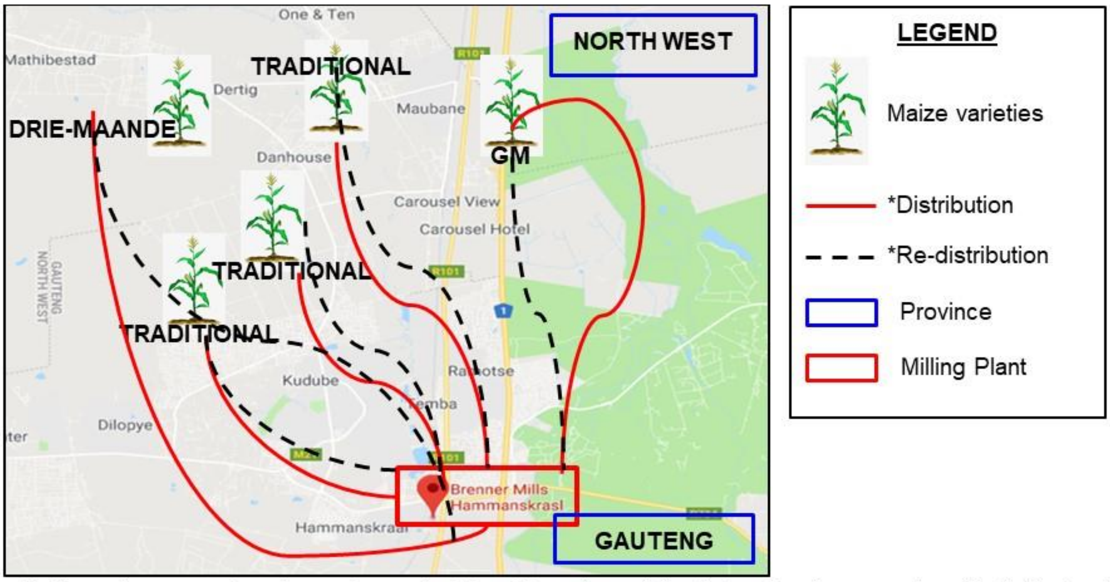

Figure 24: The maize open system. A zoom-in map depiction of the maize varieties that are found across regions (North West and Gauteng). As shown in the legend, the maize varieties are distributed and re-distributed between the industrial company (Brenner Mills), the farmers and local markets in the area. These interactions highlight the heterogeneous agricultural system in which small-scale farmers are also a part of.

Farmers noted that the seeds of GM varieties are mostly uniform, medium-sized kernels compared to the traditional varieties which can range from medium-sized to large kernels. With traditional varieties, farmers would separate the maize into those for consumption and those for grinding to make maize flour ("*bupi*"). However, in cases where the farmers were unable to grind the seeds themselves, they would collect the seeds into 12,5 kg bags[29] and take them to the maize mill company in exchange for the processed maize flour. Figure 25 (a) illustrates how farmers selected their maize by separating the maize they eat from the maize they would use as seed for the following season. In Figure 25 (b), a farmer stores her home-saved seeds in a bag.

[29] This was not the standard measurement. It varied depending on the farmers' yield.

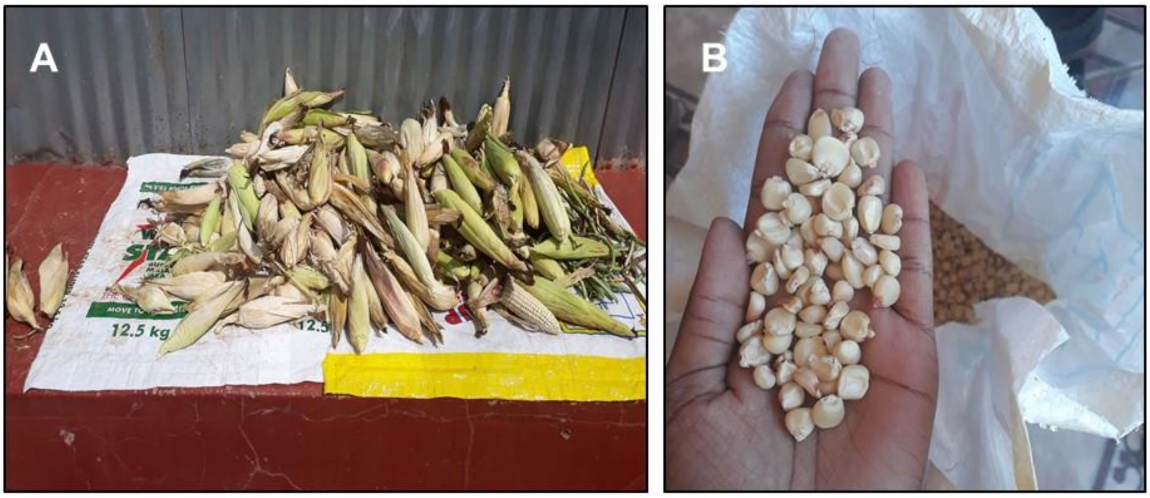

Figure 25: Maize quantity and quality. (**A**) A farmer's hard work after collecting maize from the field where he will separate maize for consumption from seed to be used in the following season. (**B**) Traditional maize seed collected and saved in bags. Seeds are then covered in coal ash, coarse salt, blue death or chilli powder during storage to protect from damage by grain pests. This is an example of farmers' innovative seed coating which they have learnt over time. Prior to planting, the seeds are washed. Farmers will cultivate these in the subsequent season.

4.7.2 Separation and Processing at the Milling company

From the informal to the formal seed systems, the industrial milling company is also integrated into the complex system. Just as farmers have their own criteria for separating their seeds, the milling company follows their own guidelines of specific characteristics for seed selection. Figure 26 (a - b) illustrates the standard criteria by Bayer[30] around pest management which includes some characteristics showing the classification of different pests. The other image is a standard assessment of the common poisonous seeds found in agricultural products. This is to ensure that the maize products are of good quality.

[30] "Bayer is a Life Science company with a more than 150-year history and core competencies in the areas of healthcare and agriculture. With our innovative products, we are contributing to finding solutions to some of the major challenges of our time." https://www.bayer.com/en/profile-and-organization.aspx

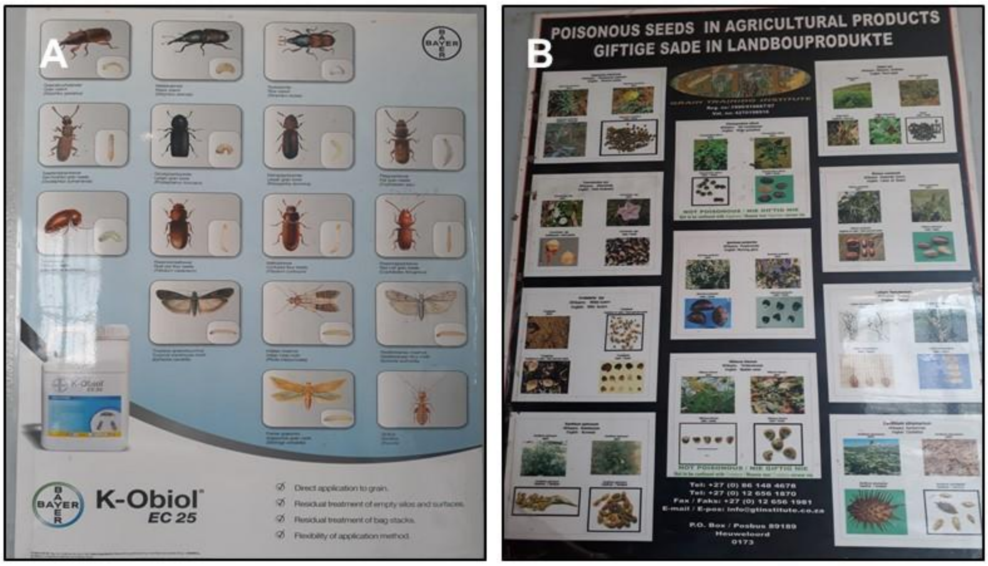

Figure 26: The selection criteria used at the mill. (**A**) Chart displaying common insect pests to look out for during inspection trials. (**B**) Standard chart highlighting some of the debris that can be found in maize that can have significant impacts on the quality of the products.

With the help of instruments that can measure qualities such as seed moisture, these companies can also select for seeds which are not only good for processing but also contribute to the maize value chain (Louwaars and De Boef 2012).

At the mill, processes are carried out to select for seeds with the best qualities. In Figure 27 (a), the debris found in seeds which come from farmers' fields, are removed before being transferred to a sifting instrument (which further removes any debris that was missed) (Figure 27 (b)). Thereafter, the seeds are measured for moisture content which, for several reasons, is important for storage and quality purposes. The ideal moisture content of maize should be approximately 12 percent before it can be stored. Moisture readings above 12 percent indicate that seeds are not storable. In this figure, the maize is suitable for storage (Figure 27 (c)).

Figure 27: The role of seed selection at the mill. (**A**) A worker from the Brenner Mills shows how they inspect the maize in various stages to select against unwanted debris prior to grinding process. (**B**) The maize is poured onto a wooden rack which acts as a sieve that will separate the 'good' seeds from the 'bad' seeds. (**C**) The seeds are then transferred to a machine that will measure the seed moisture content (mc) which measure the amount of water in seeds. This parameter is effective not only in measuring the quality of the seeds but also information relating to storage life of the seeds, seed maturity, seed longevity as well as insect and pathogen infestation.

4.7.3 The Farmers, the Mill and the Contract

After the harvest season when farmers have selected their seed for the following season's planting, farmers are also able to take some of their seeds to the mill where they deliver this seed in exchange for processed maize flour. This process has been done by these farmers for some time and it is an established relationship between farmers and the mill. The agreement between the farmer and the mill is based on a contract which can be renewed or terminated. The agreement depends on several factors including seed deformity, and the presence of debris in samples or maize colour, all of which can affect the value of the maize (Box 3).

Box 3: The Agreement between Farmer and Milling Company

"As per the agreement/contract between the two parties, if for example the farmer brings 50kg to be processed or stored, the farmer will not get back exactly 50kg. Instead, a portion (approximately 5%) from the farmer's input will be processed into samp, mealie rice or animal feed. The Mill does not work with farmers who do not have a contract. When the contract expires, and the farmer wishes to continue working with the mill, they must sign a new one.

Usually the maize that is being brought by trucks ranges from 35 - 20 tons, but you'll find small-scale farmers can only afford 5 - 10 tons (or less) of maize seed. At the Brenner Mills company, the criteria that is used is to check for any seed deformity (which is measured in % below sieve) and should not exceed 7%. If it exceeds 7%, the maize is classified as a Grade 2 (which means that it is not of good quality - and this ultimately affects the pricing). If the deformity of seeds below sieve is less than 7%, it is classified as Grade 1 maize (which means it is of good quality). When checking for foreign materials such as small pieces of stone and other debris - if the reading exceeds 0.3%, the maize is classified as a Grade 2. If the sample is below 0.3%, it is classified as Grade 1. Other characteristics such as colour are also considered. If the maize is yellow in appearance, it affects the entire assessment negatively as well."

~ Ntate William
Brenner Mills Company, Hammanskraal 22
August 2019

4.7.4 Risk threatening farmers' seed systems: Testing maize samples

Figure 12 show that there are different maize varieties in Sespond, which is a challenge for farmers when they must differentiate between the seeds during or post-harvest, as indicated in Figure 15. GM seeds can be purchased at local markets or agribusiness shops and are usually coated with a reddish-pink powder insecticide to keep maize weevils and other insects from destroying the seeds until they are used in the planting season. Post-harvest, the *Bt*-maize starts resembling the traditional maize and this emphasises the challenge that farmers face in differentiating between the seeds.

Figure 28 shows the results of maize samples from different farmers that were tested for the detection of the transgene protein, *Bt*-Cry1Ab/Ac. Overall, seven samples tested positive for the protein with 13 of the samples testing negative for the protein. This test provided insight into learning about the maize varieties within and around the Sespond community as well as showed the importance of using such methods to verify the maize seeds.

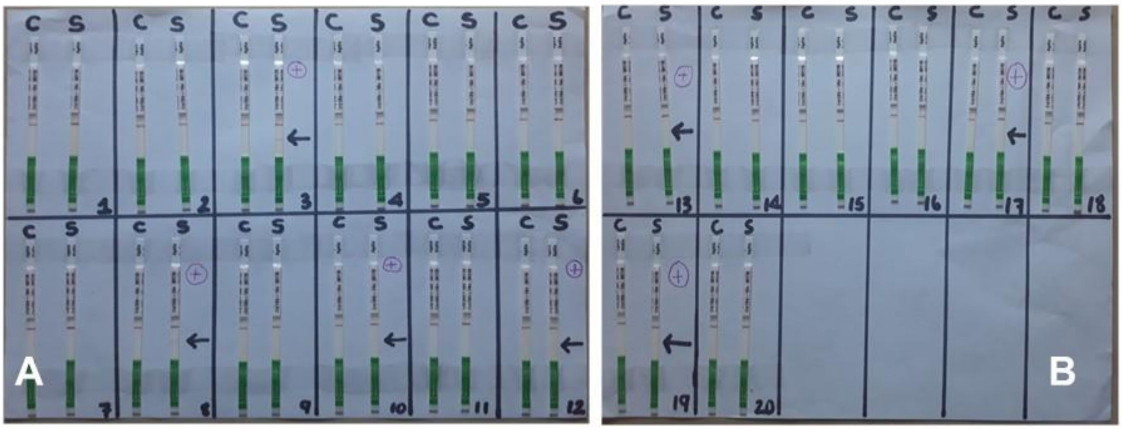

Figure 28: Immunostrip test results for expression of transgene protein. (**A**) Image displays results for 12 samples with 8 samples negative for the *Bt*-cry1Ab/1Ac protein and 4 samples positive for the *Bt*-cry1Ab/1Ac protein. (**B**) Image displays results 8 samples with 5 samples testing negative for the *Bt*-cry1Ab/1Ac protein and 3 samples testing positive for the *Bt*-cry1Ab/1Ac protein. Samples 3 and 8 were from Brenner Mills company; samples 10,12,13, 17 and 19 were from farmers who planted *Bt*-maize variety; while the remaining samples were collected from farmers who planted traditional (total 8) and "*3-maande*" (total 5) maize varieties. The "C" stands for control and the "S" stands for sample.

Each of the two immunostrips allowed to test for an individual sample, which was a simple way to quickly identify the expression of the transgene protein. The *control* immunostrip was used as a reference to measure against the *sample* immunostrip and is a useful way to interpret results. The samples from the Brenner Mills company had the most visible bands on the immunostrips, which could be attributed to the concentration of the protein Figure 29 (a-b). Additionally, the fainter appearing bands from the *Bt*-maize samples could also be due to the concentration of the *Bt*-Cry1Ab/Ac protein present Figure 29 (c-g). Therefore, the outcome of the results suggests that "unwanted" seed varieties are being introduced into FSS without farmers being able to properly manage their traditional seed varieties.

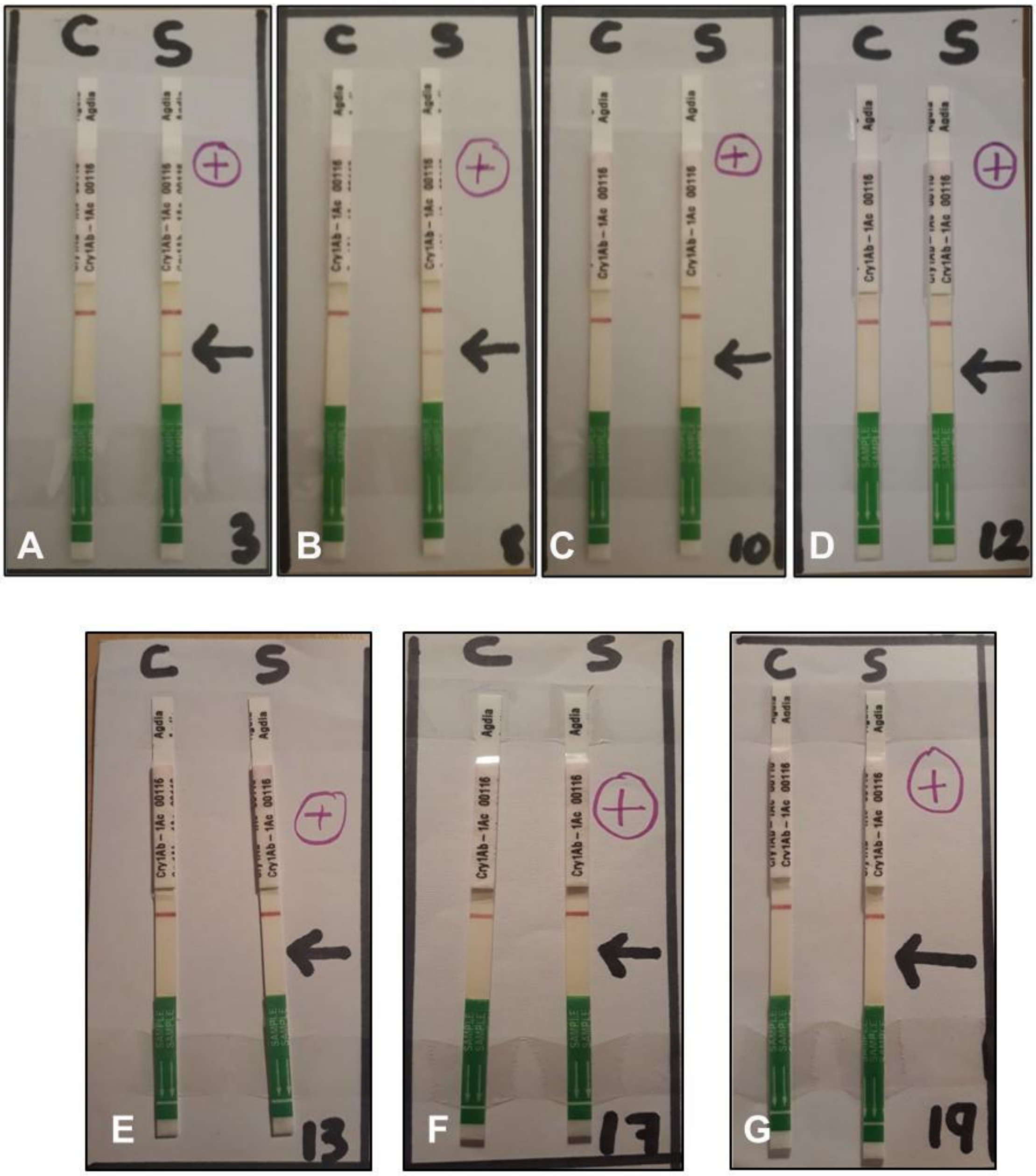

Figure 29: Interpretation of positive sample results for *Bt*-cry1Ab/1Ac protein. (**A**) Sample 3 and (**B**) Sample 8 from the Industrial plant display visible and prominent bands on the test lines. (**C** - **G**) Samples 10, 12, 13, 17 and 19 are GM maize varieties with faint bands appearing on the test lines.

4.7.5 Impact on the farmers seed system

Farmer seed systems play a significant role at the community and household level. The way farmers maintain their [traditional] maize seeds through selection and storage differs amongst farmers, households and communities. Even though the farmers of Sespond sometimes make use of their homes for storage where they can monitor their seeds more closely, the FSS is part of an open network made up of other parties which include plant breeders. Therefore, it was essential to aim to understand FSS not only from farmers' perspective but also look to other factors that influence the system. The results from the immunostrip tests, highlighted the fact that the farmers who bring their own home-saved traditional seed to the mill for processing are likely to receive back grain that is transgenic maize (Figure 28 and Figure 29).

4.8 Challenges that could potentially have a negative impact on FSS

4.8.1 Freedom of Choice

The outcomes following the testing of the samples pose ethical challenges that directly affect farmers. These challenges include farmers' freedom of choice and the rights of farmers in relation to their own seed, the procedures taken by the mill when farmers exchange their seed for the processed maize flour (*"bupi"*) and the lack of effective infrastructure to separate seed varieties. Farmers highlighted issues that they had with the quality of the maize bought from the shops,

"Sometimes the maize flour ("bupi") I buy from the shops contains so much debris such that I first have to sift the maize flour first before using it to cook."

~ Aunty Debra

29 December 2018

Aunty Debra's house, Sespond

Another farmer mentioned how he and his family have adapted to the changes around the maize varieties in their community, highlighting how they used to grind their maize including making their own traditional beer from sorghum (*"bojalwa ba Sesotho"),*

"Even us as adults (not elders) are not able to grind the maize ourselves anymore - we're used to buying from the shops now. So, it's not just maize that we would grind but other traditional crops such as mabele (sorghum) and the African samp - which we used to grind ourselves. The advantage about the mill is that farmers who would have a poor yield due to rain or pests, they could go to the

company and request a portion of the maize they have stored with the mill - they [farmers] would not have to worry about not being able to provide food for their families in such a case."

~ Aunty Neo
20 August 2019
Aunty Neo's house, Sespond

Another challenge discovered was the lack of proper infrastructure that needed to be put into place to ensure that separation at the mill was effective, such that when maize was brought to the mill, it must first be tested and then sorted into different categories of maize varieties. For farmers who don't have storage facilities at home or have problems with their storage, the mill is an alternative.

4.8.2 Government support

It was clear that farmers do not have a strong enough voice to articulate their needs, grievances and knowledge in the formal and informal seed systems at large. Farmers mentioned that government was not very supportive when it came to small-scale farmers' agricultural needs such as installing irrigation systems where farmers can water their crops during dry conditions,

"Government [local municipality] doesn't care about us. They keep on promising that they will try to install irrigation systems for us - because they know that our crops are rainfed. But they never get back to us; we always hear the same story about lack of funds."

~ Aunty Betty
29 December 2018
Mme Francina's house, Sespond

"Every time people come dressed in formal attire conducting these house visits, they tell us that they are from the government and that they are surveying the community to find out what the locals need. As farmers, we engage with them - but our expectations are met with disappointment as

many of them never keep their promises or even come back. I am sceptical of allowing people to come to my house to conduct house visits anymore, because nowadays everyone says they are from the government even if they produce the valid identification."

~ Ntate Albert
21 March 2019
Ntate Albert's house, Sespond

4.9 Summary

The results given in this chapter first highlighted the social characteristics of the participants in Sespond including the livelihoods, traditional practices and beliefs. The chapter presented demographic information which gave more insight into the area and the participants and provided an understanding of the maize varieties planted in Sespond. It provided some insight into how farmers differentiate between maize varieties, which can be a problem for their seed management strategies as they encounter challenges when monitoring different seeds. This chapter also highlighted farmers' experiences in Sespond, focusing on the knowledge, farming practices and where farmers obtain their seed, which is important as this helps improve farmers' seed management. Farming practices, including how maize varieties were selected, were also considered. This provided more understanding of the different farmers' perceptions, practices and reasons for choosing their maize varieties, including selection and storage. post-harvesting processes were also highlighted, and this chapter outlined what farmers do with their maize and what the mill does to separate and process the maize. The chapter stated some of the factors that influence selection and storage such as temperature, yield and pest management. It also presented results of what happens at the mill and showed how the effects of maize varieties being mixed together can have a negative impact on farmers, as risks may be introduced that could threaten farmers' seed systems. Finally, this chapter presented some of the challenges highlighted by farmers that could potentially have a negative impact on the FSS, and these included ethical considerations, and government support.

CHAPTER FIVE

DISCUSSION

5.1 Awareness and knowledge: Understanding the issues around contamination

Traditional seeds are an important aspect of farmers' systems and embody years of practical knowledge and experience with much focus on how farmers maintain the integrity and resilience of their seeds. However, the negative effect of farmers' seeds being mixed or contaminated with hybrid or GM seeds ultimately influences seed management, and often weighs down on farmers' seed systems - in turn affecting farming practices such as selection and storage. Cross contamination can occur in different ways, including through seed distribution by government agents, through seed markets where farmers exchange seeds, in storage facilities or by insect pollinators. In an open system, contamination is almost inevitable, and it remains a challenge to develop and implement regulations that will help prevent cross-contamination between fields, particularly in smaller areas surrounded by commercial farms. This underscores the view, such as presented by Cleveland et al. (1994) and Mann (2004), that traditional varieties are either at risk of disappearing or continuing to disappear from cultures and ecosystems. However, contamination is not the only factor leading to the loss of traditional varieties; other factors include changes in environmental conditions such as drought or insect damage, farmers' preferences for other varieties, biochemical changes such as soil properties, and breeding programmes.

Being surrounded by commercial farms puts small farmers at risk of losing their traditional varieties to contamination, which can happen in several ways, including pollination, seed exchange, storage or seed distribution (Thomison, 2004). In this study, the likelihood of contamination through pollination will be discussed, followed by seed storage practices. The distance between Sespond and the commercial farms in the Limpopo Province is approximately four to five kms and 56 kms from Brits in the North West Province. According to a report from the University of Nebraska Lincoln, seed saved from cross-pollinated plants results in varied array of characteristics in the next generation due to the mixing of traits (Browning, 2016).

In situations of increasing distance between different farms, as is the case with the Sespond community, the likelihood of cross-contamination decreases, which means there is little probability of such an outcome resulting from pollen drift. This finding is in line with results from Van De Wiel and Lotz (2006), which indicated that less than one percent of admixture was attained at a distance range of 10 - 12 metres in Spanish experiments. Similarly, Ma et al. (2004) highlighted an outcrossing rate of less than one percent at 28 metres in Canadian maize field experiments. Interestingly, in a study analysing isolation requirements for coexistence in Mexico, Baltazar et al. (2015) found the highest outcrossing values recorded at 12.9 percent at one metre. Since there are a number of variables that could affect cross-pollination contamination, it remains to be determined whether the small-scale farmers of Sespond who farm traditional varieties are affected and to what extent. Viljoen and Chetty (2011) highlighted that even though South Africa has been planting GM maize since 1997, there is no emphasis on management strategies regarding the coexistence of GM and non-GM crops. Price and Cotter (2014) expressed that even though cross-contamination can gain an entry point into traditional seed systems, the managing and detection thereof remains challenging. Kruft (2001) similarly highlighted that the preservation of traditional seeds is an increasing concern for small-scale farmers since it remains to be seen what regulations will be set for commercial farms when it comes to pollen drift that encroaches surrounding small-scale farms. Contamination through seed exchange is one of the most common mechanisms that has been highlighted across different studies and can result in significant changes in FSS. For instance, farmers who neither have accurate knowledge nor awareness could be growing maize that they think is traditional, only to later find that a neighbouring farmer gave them different seed to their traditional variety. This point was highlighted across the findings of this study.

Poor seed storage conditions, including insect damage, warm temperatures and increased moisture have been reported to cause up to 10 percent seed quality loss in tropical regions (Wambugu et al., 2009). This study demonstrated that a lack of adequate storage conditions was a central reason for farmers sending their seed to the mill, which was a primary site for mixing and contamination. Cross-contamination within storage facilities should be closely regulated, especially if mixed seed varieties are involved, as there is more control compared to the open field. Companies should provide detailed inventories of seed varieties and sources to help keep check of seed quality as well as the location of where each variety is stored. This would be helpful especially for milling companies that store both farmers' and commercial seed varieties together. Arguably, small-scale farmers who consider other methods of farming apart from their own, could be problematic as communities are shaped not only by what they grow but also dominated by a preserved history of traditional knowledge and practices around their seed varieties.

5.1.2 Where do farmers obtain their seed from?

Maintaining traditional varieties is becoming more challenging for small-scale farmers as there is increasing competition from hybrid and GM seed varieties (Setimela et al., 2007). Small-scale farmers are most likely to use their own seed if it is of a traditional variety - as they can save and use the same seed for planting in the following season. This is because they prefer the taste, texture and size of the kernels and the vigour of traditional maize is not easily lost over subsequent seasons (Govender et al., 2008; Wambugu et al., 2009). Despite factors such as rain or disease having a possible impact on the yield, it is believed that traditional seeds are more adapted to local conditions and can retain characteristics such as size, colour, taste or texture for a long time (Samberg et al., 2013). However, for farmers who use hybrid seeds, even though there is an increased yield, the vigour is lost over time and for farmers who use GMO seeds, it is illegal to save these seeds which means that they have to keep buying their seeds for every planting season, as was seen in the 2004 case of Monsanto versus Trantham (McEowen, 2003). As a result, the importance of reputable seed sources extends further than seed production, but also involves seed quality assessments, storage and distribution capacity (Moseley and Tripp, 2003).

The exchange of information between farmers about where they obtain their seed is vital, as this may give more insight into the biological characteristics such as morphological and varietal diversity, resilience, or an indication of the demand and supply costs (Coomes et al., 2015). However, since it is becoming more difficult to trace the origin of seeds, small-scale farmers rely on their own knowledge and years of farming experience to determine the seed variety and if it is suitable for sustaining their livelihoods. As highlighted by Moseley and Tripp (2003) and verified by this study, it remains a challenge for farmers to always know where their seed comes from, particularly in cases where farmers may have to come up with ways to verify the source and where molecular methods are needed to see whether the seed is a traditional, hybrid or GM variety. Moseley and Tripp (2003) challenged the mechanisms of information exchange among farmers and seed distributors, such as NGOs, emphasising that a more effective flow of management strategies is required to ensure that a stable relationship of trust is developed, particularly in the context of local communities where small-scale farmers are predominantly involved.

5.1.3 Differentiating between maize varieties

Being able to differentiate between maize seeds is one of the significant steps in ensuring effective seed management processes. It may be easier for farmers who have access to resources and facilities, but for small-scale farmers who have to rely on their experience and knowledge, the task is far from easy. Silwana (2000) reported that 75 percent of farmers in the Eastern Cape preferred to use traditional maize varieties. A similar pattern was seen in a study by Mudzingwa and Mambeva (2018) which reported that the majority (95 percent) of farmers in Zimbabwe also rely on their own traditional seed. There is an ongoing debate about which maize varieties farmers should adopt, depending on the geographical context, as well as on different levels of success in the adoption of improved varieties (Khonje et al., 2015). This study showed that farmers who use their traditional seed have different methods of storage, including at the mill, indicating that farmers were willing to preserve the integrity of their maize, provided that the mill has proper procedures to sort, separate and store different maize varieties.

5.1.4 Awareness about the implications of *Bt* and hybrid varieties

Results from this study showed that many farmers were not able to differentiate between different maize seed varieties. Low levels of knowledge of the existence of GM and *Bt*-crops is problematic as farmers are unaware of the effects of using the same hybrid or GM seeds over again. In comparison to traditional varieties, the result of hybrid and GM seeds being manipulated at a molecular level, leads to loss of vigour over time. From the interviews conducted in the study, some farmers' understanding of vigour was that seed which they bought from a shop, had to be purchased again in the following year, though there were farmers who saved hybrid and GM maize. Since the replanting of GM varieties is prevented by contracts and plant breeders' rights, small-scale farmers have little to no leeway when they have to defend themselves, especially if they had no knowledge of the presence of these varieties in their seed systems (Mugo et al., 2005; Heinemann, 2007; Iversen et al., 2014). Arguably, these results point to the lack of understanding regarding the implications of replanting hybrids and GM seed varieties, and the fact that information is not explained to farmers. Seed sellers and distributors also don't have the knowledge of the implications of replanting these varieties. Intellectual property infringement is illegal and for small-scale farmers, the process and the outcomes may not only have devastating effects for their economic, environmental and social reputations, but also have negative consequences for their cultural and traditional practices (Aheto et al., 2013; Iversen et al., 2014).

5.2 How effective are multiple linkages within small-scale farmer seed systems?

5.2.1 Link between formal and informal seed systems

Chapter Two described the different organisations involved in the seed sector as proposed by Louwaars and de Boef (2012). Formal seed systems can be characterised as the breeding and selection of certified seed varieties which include hybrid and GM seed, with targets that are usually market oriented (Louwaars, 2007). Informal seed systems, also referred to as local, traditional or farmer systems, involve traditional practices and methods in which farmers produce, access and share their own seeds themselves (Coomes et al., 2015; McGuire and Sperling, 2016). For this study, the milling company represented the interests of the formal sector, with Sespond farmers falling under the informal sector. The formal sector mostly dominates industrialised farms that work with commercial seed. Small-scale farmers rely on their own seed, due to relatively easy access to and flexibility of a supply of seeds, that will meet their needs which may not be offered by the formal sector. The findings of the study highlighted that most farmers preferred to use their own traditional seed for replanting. Only in the case where farmers were not able to use their own seed, would they purchase from shops. For example, in Kenya, approximately 75 percent of seed used comes from the informal sector (Muthoni and Nyamongo, 2008). As a result of these two seed sectors that exist in the same community, there are different methods and practices to manage the seeds. For example, selection and storage methods were orthodox for traditional maize seed but not for hybrids and GM maize, which was a problem when farmers used traditional seed methods for hybrids or GM. As highlighted by Almekinders and Louwaars (2002a), this could have problems for FSS if the methods are not properly separated, which highlights the overall weakness in the perception of FSS, particularly when it comes to integration between the two sectors.

5.2.2 Extension networks and the role of government

The participation of government is crucial in supporting FSS (Louwaars and de Boef, 2012). For example, the lack of government support for small-scale agriculture in Sespond, meant that Sespond farmers incurred transport costs in order to travel long distances to purchase seeds from either agri-businesses or from other farmers outside of their communities. These findings are affirmed in numerous other studies. Mutimba (2014), for example, stated that no noticeable improvement takes place at farmer level, instead the ineffectiveness of extension networks dominates, particularly across many Africa countries. He argued that despite several attempts at improving agricultural extension networks, this remains a challenge (Mutimba, 2014)

The role of extension services and agents to be able to offer advice, training and enhance support through education is crucial for the effective operation and management of agricultural systems. It is important to note that this study only considered the involvement of municipal agents as a support structure to the farmers of Sespond. When asked about the level of engagement in which government was involved, many farmers were quick to highlight that government is non-existent when it comes to the sustainability of farmers' livelihoods. Farmers mentioned that government was not involved in giving out seed or in installing irrigation systems or improving livelihoods and farming systems. This suggests that the approach of government towards small-scale farmers is one of disinterest and that officials are not well equipped with the knowledge to address farmer-specific problems. Baloch and Thapa (2019) argue that ineffective extension is one of the factors that can exacerbate the difficult interaction between farmers and government, especially when having to ensure that farmers' livelihoods are not neglected.

5.2.3 The role of institutions

Farmers who experienced problems storing their maize seeds at their homes, relied on the mill to store their maize for them. Depending on whether farmers had a contract with the mill or not, if they stored seed at the mill, they were able to obtain in return either their own seed or maize flour. For instance, the Brenner Mills Company operates in a centralised network by receiving maize inputs from different regions. The mill is an institutional example of an extension that should be managed according to clearly defined regulations regarding the processes that take place with farmers' seed. Even though milling processes have more to do with efficiency than diversity, which may incur additional costs with more modifications to the degree of processing (Reardon and Barrett, 2000; McCann, 2001), it is important to keep in mind that with such networks, there are possibilities of errors when it comes to efficient management, particularly when the mill services both subsistence and commercial farmers. From the results, it was clear that the mill was the main supplier distributing to local farms and stores across the region.

It is important to highlight that in terms of sorting and separating maize varieties, the mill should have infrastructure that is dedicated to these processes and that does not only cater for storage. Louw et al. (2010) pointed out that the lack of properly maintained infrastructure is one of the weaknesses in some maize-milling companies. The findings not only highlight interesting issues on the role of the mill but also raised questions about the quality of maize given to farmers. This was highlighted in section 4.9 and 5.3 emphasising that the lack of appropriate infrastructure can have a significant impact on qualities such as taste and nutrition of traditional maize. This suggests that transparency plays a significant role in that it can reduce the risks of maize varieties being contaminated on site, while providing farmers with their traditional maize seeds and products. The most important element when it comes to administrative capabilities, especially in the context of GM and non-GM varieties, is that greater emphasis should be placed on essential biosafety measures and regulations such as protecting humans and animals from the effects of GM risks, assessing the possible long-term impacts on the environment, as well as developing feasible management structures that are driven more by socio-political mechanisms than by purely scientific considerations (Prakash et al., 2011).

5.3 Post-harvesting processes

The findings from the study showed that farmers made use of storage facilities at the mill when they experienced insect damage in their own storage facilities. Kang'ethe (2011) analysed post-harvesting handling among Kenyan farmers and found that post-harvesting handling at household level remained inadequate. This was also seen for the Sespond farmers who experienced seed and crop damage which resulted in ineffective pest-management strategies. The integration between formal and informal sectors looks at how small-scale farmers make use of alternative storage facilities, such as the mill, to store their [traditional] maize seeds. However, there were standards that farmers had to consider when they wanted the mill to store their seed for them. From the results, the quality and quantity were the most emphasised factors, and the mill fell below the required standards, which, in turn, became a liability for both the farmers and the mill. This puts a strain on farmers to meet the standards, particularly if farmers have small areas of land for farming or experience inconsistent yields.

Practicing good seed management goes beyond knowing where seed comes from or testing to verify the variety, but also requires transparency between the farmers, and in the context of this study, on the part of the mill which stores farmers’ seed. The view presented by Kang'ethe (2011) that millers in Kenya are reliable and account for contaminated maize, was due to appropriate measures set in place to ensure good quality maize distributed to local markets. According to a maize value chain report by Grant et al. (2012), most maize millers in South Africa work predominantly with commercial seed, while local maize millers work with small-scale farmers. From this, it is clear that despite the size of the mill, there need to be optimal guidelines that are suitable not only for the handling of farmers’ maize, but also for testing maize varieties that are brought in from different regions prior to sorting and separating of the maize varieties. From the interviews in the study, farmers highlighted that the pressure on their side is to ensure good quality maize post-harvesting, since the mill takes a portion of seed for their own use depending on the contract. Arguably, from the perspective of farmers, the mill needs to ensure that farmers' seed is stored in good condition and not mixed with other varieties. It is a great inconvenience and a violation of their choice of traditional seed for the mill to mismanage traditional maize given to them for storage. A similar observation was reached by Almekinders et al. (2019), that more transparency as well as practical solutions are needed when working with small-scale farmers to avoid mismanagement of seed during post-harvesting processes.

Even though the mill also manufactures processed products such as samp or maize rice, the relationship between the farmer and the mill is particularly important for storage purposes. Depending on the contract between the farmer and the mill, the mill can allow the farmer to (i) store their seed and request for it when the planting season is approaching and (ii) request for the processed maize flour (*"bupi*") which farmers can cook at home. As mentioned in Box 2, the mill can process (for manufacturing purposes) a certain portion (i.e. 5 percent) of the farmer's seed into other products depending on how much the farmer brings to the mill, as the agreement is set to benefit both parties.

These findings corroborate the importance for milling companies to convey accurate information which, in turn, may have an impact on farming processes (Daly et al., 2016). This is only fair to the farmers, so that they know the consequences of storing their maize at the mill and thus understand what is at stake in terms of value when it comes to their traditional maize. As one farmer highlighted:

> *"I couldn't tell you what goes on after we send out maize to the mill. Only they will be able to answer that. All we, as farmers know is that we have taken our harvest to the mill [to be stored]."*
>
> *~ Ntate Albert*
> *21 March 2019*
> *Ntate Albert's house, Sespond*

5.4 Farmer's choices, rights and ethics

Farmers who plant traditional maize which has been passed down for generations have a sense of identity, culture and attachment to their seeds. This gives farmers the right to monitor their seeds as well as to save them or exchange their seeds with other farmers. As already highlighted, the introduction of GM or hybrid seeds within farmers' systems or communities can disturb local farming practices. As Setimela et al. (2007) argue, it is important for farmers to be able to monitor their maize even after they have taken it to the mill. The mill should respect the fact that farmers are bringing their best seed which they have selected in the hopes of being able to plant in the next season or use it for other purposes. Moreover, farmers often choose to plant traditional seed specifically for its tastiness and nutritional value. Mixing the seed removes this right of choice for farmers. This highlights the extent to which the relationships between different actors, farmer-farmer or farmer-mill, shapes the behaviour and perception towards FSS.

It is worth mentioning the potential psychological impacts that seed contamination could have on farmers. For instance, if farmers feel ignored and that their rights are not respected by the mill, or that their trust is violated, they might decide to stop planting altogether. Farmers become despondent about planting seed that they are familiar with and that has been passed down for generations if it is to be lost or mixed up with GM and hybrid varieties. This finding affirms the need for risk assessments to take social, environmental and economic impacts into account to minimise or control unwanted adverse effects of GM varieties coming into contact with farmers' seed varieties. Aheto et al. (2013) highlight that for African countries, it may be challenging to develop stringent and robust assessments that will be able to conduct wide spectrum analyses to scrutinise the environmental, social and economic implications of GM crops, particularly at the local level. This raises the question: How can regulations provide long-term solutions that reinforce the integrity of farmers' seed varieties, such that farmers can have freedom of choice when it comes to their seed? The question is important as it links to the aim of this study and may lead to other concerns including farmers having to fully exercise their rights and not feel embedded in uncertainty.

Overall, informed decision making is an important factor which proves difficult to accomplish without taking into consideration the points discussed above. Although policies and frameworks will not be developed over a short period of time, it is important to remember that small-scale farmers, such as those in Sespond, have not only been farming for a long time using traditional methods, but also see farming as a significant part of their tradition, culture and social networks. Kesan et al. (2007) argued that certain approaches erode farmers' freedom when it comes to their seed varieties, leaving farmers with the insecurity of whether they will continue to experience improvement or difficulty working with their seed. This can lead to farmers undermining the resilience of their own systems (Pionetti, 2005). As noted by Pionetti (2005), the shift of seed freedom for farmers must be explored in order to understand how this could affect farmers' capacity to produce, store and manage their own seed.

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

The purpose of this study was to understand the importance of farmer seed systems (FSS) and the role they play in small-scale farmer communities. Through exploring the different ways in which farmers maintain their traditional maize seeds, the study provided a better understanding of how the Sespond community manage their farming systems. The study analysed how farmer networks form part of a broader system where other stakeholders are also involved.

The aim of this study was to understand how small-scale farmers in Sespond, North West Province, maintain traditional maize in a complex agricultural landscape that incorporates both formal and informal seed systems. The objectives were:

- to profile the demographics and agricultural practices of selected households in Sespond;
- to determine what maize varieties are planted in Sespond;
- to understand how maize varieties are selected for planting and storage;
- to establish the extent of transgene contamination by testing maize varieties for the presence of transgene protein; and
- to determine the implications of these findings for the maintenance of traditional seed systems.

The chapters reviewed how FSS are under threat from other seed varieties, particularly if farmers' seeds are contaminated, and highlighted the impacts on farmers' seed selection and storage practices. Demographic data was gathered from different households to understand where the different maize varieties were planted within the community and how farmers managed different seed varieties. The testing of maize varieties that were collected from farmers, gave a biological indication of the make-up of maize, in terms of the presence of the transgene protein. This was helpful in distinguishing maize varieties instead of relying only on its physical properties. Moreover, this technique was advantageous as it gave more insight into the protein level of the GM maize that was planted in the community, making it possible to analyse without speculation. There is still a lot of research that needs to be done towards understanding the complex management around traditional maize, which can also provide more insight into how farmers keep or have adapted their farming practices to the changes occurring in their systems and communities.

The research found that even though there were different maize varieties within the community, farmers were still at risk of losing their traditional maize varieties as they were not aware that GM maize is a threat to their traditional maize. As the study has pointed out, farmers worked together with the mill mainly for storage purposes. The results highlighted that there was not much transparency between the farmers and the mill with respect to the storage and milling of farmers' maize and that farmers were not aware of the implications that GM seeds could have on their seed systems. As pointed out, with no appropriate infrastructure to adequately test maize and sort according to their varieties, this has significant consequences for the sustainability of small-scale farmers, the resilience of their seed systems and their rights to choose what to plant and what to eat.

This study recommends that in-depth studies focused on holistic scientific approaches be considered, which include educational initiatives within communities, schools and institutions, in order to raise awareness and share knowledge, especially using local languages. Researchers should work collaboratively with farmers to contribute to their knowledge and skills in order to identify and monitor appropriate seed pathways (Ortmann and King, 2007). With the adoption of new improved seed varieties, more stringent assessments should accompany strategies that will be able to equip more farmers with the ability to differentiate between seed varieties. Given that many farmers wish to continue using their own seed, there needs to be ongoing awareness-raising so that farmers are not pressured into using seed varieties that may require new farming practices and methods over a long period of time. This study also recommends that government should aim to facilitate a more decentralised approach to building an effective integration between small-scale farmers and other institutions such as the mill. Since *Bt*-maize closely resembles traditional maize at harvest season, the mill should have facilities dedicated to testing maize varieties, to help distinguish transgenes from hybrids and traditional varieties, and to enable traditional seed to be stored and milled separately.

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Appendices

Appendix 1: Participant Consent Form

DEPARTMENT OF ENVIRONMENTAL AND GEOGRAPHICAL SCIENCE

UNIVERSITY OF CAPE TOWN PRIVATE BAG X3 RONDEBOSCH 7701 SOUTH AFRICA	RESEARCHER: E-MAIL:	Mpho Kganyago KGNMPH001@myuct.ac.za

Informed Voluntary Consent to Participate in Research Study

Project Title: *Understanding farmer seed systems in Sespond, North West Province*

Invitation to participate, and benefits: You are invited to participate in a research study conducted with traditional maize small-scale farmers in Sespond community. The study aim is to understand how farmers in the Sespond community maintain the integrity of traditional maize in a diverse landscape of farming in the area. Your experience would be a valuable source of information and hope that by participating you may gain useful knowledge.

Procedures: During this study, you will be asked to take part in a survey, complete a questionnaire, share information on farming practices such as selection, storage. Your participation in the study will depend on your given consent, which may also include taking maize samples for testing.

Recording: We may take photographs, record audio, or record video as part of the study. If you object to this, please indicate this below. You will be allowed to review the information collected.

Risks: The harmful risks to you, related to your participation in this study, may be possible indications of contamination may in the fields which could influence your perception of the traditional methods of farming, your ways of knowing and living as well as your relationship with neighbouring smallholders. Socio-economic implications could ensue, and this could influence how you as a small-scale farmer adapt your ways of farming around contamination (should contamination be found).

Disclaimer/Withdrawal: Your participation is completely voluntary; you may refuse to participate, and you may withdraw at any time without having to state a reason and without any prejudice or penalty against you. Should you choose to withdraw, the researcher commits not to use any of the information you have provided without your signed consent. Note that the researcher may also withdraw you from the study at any time.

Confidentiality: All information collected in this study will be kept private in that you will not be identified by name or by affiliation to an institution. Confidentiality and anonymity will be maintained as pseudonyms will be used.

What signing this form means:

By signing this consent form, you agree to participate in this research study. The aim, procedures to be used, as well as the potential risks and benefits of your participation have been explained verbally to you in detail, using this form. Refusal to participate in or withdrawal from this study at any time will have no effect on you in any way. You are free to contact me, to ask questions or request further information, at any time during this research.

I agree to participate in this research (tick one box) ☐ Yes ☐ No __________ (Initials)

The following statements are suggested items only and may be replaced or deleted as appropriate for your study.

I agree to be photographed/audio-recorded (strikethrough as applicable)

☐ Yes ☐ No __________ (Initials)

I agree to the use of properly anonymized photographs/audio recordings in websites and publications for research purposes (strikethrough as applicable)

☐ Yes ☐ No __________ (Initials)

I agree to give consent for maize samples to be obtained from my farm for further molecular analysis (strikethrough as applicable)

☐ Yes ☐ No __________ (Initials)

Name of Participant	Signature of Participant	Date
Name of Researcher	Signature of Researcher	Date

Appendix 2: Questionnaire A (Key)

Sample and Questionnaire Design

The purpose of this questionnaire/survey is to gather information about the agricultural practices used in farming traditional maize varieties in the Sespond community. This information will be used in the current research project with the aim to gain more understanding around seed selection methods. Your cooperation will be highly appreciated.

Date: ……………………………………………………………………………………………

Name of Participant: …………….……………………………………………………………

(prefer anonymity)

Ward number: …………………………………………………………………………………

Name of Researcher: ……………..…...……………………………………………………..

***Section A**: General Information. To be filled in by participants.*

1. Gender — Male ☐ Female ☐

2. Age (in years) — 20-30 ☐ 30-40 ☐ 40-50 ☐ 50-60 ☐ >60 ☐

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

4. Highest level of education — No education ☐ Primary education ☐ Secondary education up to Grade 10 ☐ Matric certificate ☐ Diploma ☐

Degree ☐

Other (specify) ……………………………

5. Number of dependants (indicate number)

……………………………………………………………………………………

6. How big is your farm area? [Please indicate]

…………………………………………………………………………………….

7. Do you only plant maize crops or do you mix crop varieties on your farm?

Monocrop ☐ Mixed crop ☐ Other (specify)

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8. How do you water your crops? ….Canal irrigation ☐ Moveable sprinklers ☐ Watering can ☐

Motorised pump ☐ Open wells ☐ Drip irrigation ☐ Other (specify)

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

9. How often do you encounter pests and diseases on your traditional maize?....

Never ☐ Sometimes ☐ Frequently ☐ I am not sure ☐

10. Do you use the crops for yourself or for your family? Do you sell the crops?

Self ☐ Family ☐ Sell/Trade ☐Other (specify)

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Section B: *Maize Seed Characteristics. To be filled in by researcher.*

11. What maize seed varieties do you use?

Own traditional seed ☐ Hybrid seed☐ Mixed varieties ☐ Genetically Modified (GM) seed

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

12. Why do you use the seed varieties mentioned in (9)?

Preference ☐ Affordability ☐ Less financial constraints ☐ Influence from neighbour/farmers ☐

Nutrition ☐ Taste ☐ Yield ☐ Maturity ☐ Exchange initiatives ☐ Distributed by local seed

stores ☐ Other (specify)

………

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13. Where do you obtain your maize seed from?

Own ☐ Relatives ☐ Granary ☐ Local market (seed fairs) ☐ Other farmers (and/or neighbours)

☐ Agro-dealers ☐ Other (specify)

……

14. How often do you change your maize seed variety?

Never ☐ Sometimes ☐ Frequently ☐ Depending on the yield of previous season ☐ Uncertain ☐

15. Why do you change your maize seed varieties? Please indicate.

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16. How do you make decisions about the maize seed varieties you use on your farm? Please provide details.

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…………………………………………………………………………………………..…………………

***Section C**: Production Efficiency. To be filled in by researcher.*

17. On a scale of 1-5, how good was your maize yield last year?

1 (very poor) ☐ 2 (poor) ☐ 3 (average) ☐ 4 (good) ☐ 5 (excellent) ☐

18. Do you get high yields with your traditional maize variety?

Yes ☐ No ☐ Varies each season ☐

19. What do you as a farmer do when your crop doesn't produce enough? Please provide reasons

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………

……………………………..……………………………………………………………………..………

20. If applicable, what do you think is the most common cause affecting the production of your traditional maize variety?

Pest ☐ Disease ☐ Lack of rain ☐ Soil health ☐ Fertiliser ☐ Spacing ☐ Weed ☐ I don't know ☐ Other (specify)

………

……………………………………………………………

***Section D**: Seed Selection (methods). To be filled in by researcher.*

21. Where do you select your seed? On my farm ☐ In the granary ☐

22. What do you look for when you select for your seed?

Crop height ☐ Crop size ☐ Seed size ☐ Grain colour ☐ Taste ☐ Grain yield ☐ Disease tolerance ☐ Early maturity ☐ Pest tolerance ☐ Other (specify)

……………………………………………………………………………………

23. When do you select seed for planting the next season?

At planting ☐ Before harvesting ☐ At harvesting ☐ During storage ☐ Other (specify)

……………………………………………………………………………………

24. Who is responsible for the selection of maize seed?

Men ☐ Women ☐ Men and Women ☐ Youth ☐ Women and Youth ☐ Men and Youth ☐

25. Why is seed selection important to you?

Own consumption ☐ Storage (planting in subsequent season) ☐ Trade (government organisations, NGOs) ☐ Exchange of seed (between farmers) ☐ Seed fairs (local market) ☐ Cultural practices ☐ Relatives ☐ Other (specify) ☐

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***Section E**: Other Questions (open-ended). To be filled in by researcher.*

26. Can you tell the difference between traditional and other maize varieties (such as non-traditional maize varieties)? If yes, please provide reasons

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If no, please provide reasons

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27. What do you think makes your [traditional] maize variety different from the ones in the shops? Please provide reasons

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28. Have you been approached by seed dealers to buy their seed? How often?

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…………………………………………………...……………………………………………
No, I have not been approached by seed dealers/representatives because…
……………..………………………………………………………………………………………
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29. What kind of support or advice do you get from government officials/seed dealers/representatives/neighbours etc. regarding your traditional maize [seed] varieties? Please provide reasons
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……
No, I never receive support or advice from government officials/seed dealers/representatives/neighbours because…
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30. Is government involved in giving out maize seed in the Sespond community? If yes, please explain what seed it is and how it is distributed.
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If no, please provide reasons why you think it is so.
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31. Between the past and recent years, has there been enough solidarity among government representatives and smallholder farmers who farm traditional maize in Sespond? If yes, please provide reasons
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If no, please provide reasons why you think so

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32. If applicable, did you find the information provided (by the seed dealers) useful/helpful/informative when they were telling you about their seed? Please describe how the information was useful.

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No, I did not find the information useful because…

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33. How often are you involved in seed fairs/seed exchange in Sespond?

Never ☐ Sometimes ☐ Always ☐ I have never been to seed fairs/seed exchange initiatives in Sespond ☐ I am not sure ☐

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34. If applicable, do you notice any other differences with your traditional maize varieties that you use for your family and other traditional varieties that you sell?

If yes, please provide reasons

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If no, please provide reasons

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35. Are you aware if there are any other non-traditional maize seed varieties such as hybrid or GM maize varieties in Sespond?

If yes, please provide reasons

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If no, please provide reasons

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36. If applicable, do you think that smallholder farmers in Sespond influence one another in terms of their current methods of seed selection? If yes, please provide reasons

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If no, please provide reasons

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37. What are some of the advantages of using your own (traditional) seed?

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38. What are some of the disadvantages of using your own (traditional) seed?

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39. What influences your choices when you select your traditional maize varieties? Please provide reasons below.

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40. Do you think there is enough awareness among small-scale farmers about non-traditional seed varieties like hybrid and GM maize seed varieties in Sespond? Please provide reasons

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41. What can you suggest/recommend to help improve the integrity of traditional seed varieties in the Sespond community?

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42. Are other traditional maize farmers farming differently to the way you farm? Please provide reasons

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43. What does the government do best in terms of helping improve the lives of smallholder farmers in Sespond?

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44. If applicable, how do you think the government is failing to help improve the lives of smallholder farmers in Sespond?

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45. Do you sometimes get any seed from commercial farmers? Please provide reasons below

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46. What do you prefer about your traditional maize seed and why? (i.e. nutrition, taste, texture, yield etc.)

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47. Do you relate your traditional maize seed with cultural purposes/connections? If yes, please describe below.

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48. As a smallholder farmer, how do you think you could involve/engage more youth in sparking their interest in learning about traditional maize varieties?

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49. As a smallholder farmer, what do you think are some of the challenges (to people of all ages) in preserving the knowledge around traditional maize varieties in Sespond?

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Appendix 3: Questionnaire B (Follow up)

The purpose of this follow-up questionnaire is to gather information about the relationship between the farmers of Sespond and the milling company. This information will be used in the current research project with the aim to gain more understanding around seed selection methods. Your cooperation will be highly appreciated.

Date: ....

Name of Participant: .... (prefer anonymity)

1. How does the mill work?

2. Why do you take your maize seeds to the mill?

3. How long have you been taking your maize seeds to the mill?

4. Do farmers pay for their grain to be milled? If yes how much?

5. Do they get their own grain back? Explain briefly.

6. What is the quality of the milling. Are you happy/unhappy with it? Explain briefly.

7. What other options are there for you to mill your seed?

8. What did you do before the mill was there?

Appendix 4: List of farmers who participated in the household survey.

Survey number	Name of Informant*	Code **	Survey number	Name of Informant*	Code**
1	Aunty Debra	KI010_T	**16**	Ntate Albert	KI160_H
2	Aunty Betty	KI020_H	**17**	Ntate Walter	KI170_H
3	Aunty Martha	KI030_T	**18**	Koko Sarah	KI180_G
4	Ntate Jeffery	KI040_T	**19**	Ntate William	KI190_M
5	Ntate Patrick	KI050_T	**20**	Koko Sandra	KI200_M
6	Koko Carol	KI060_T	**21**	Ntate Paul	KI210_T
7	Aunty Christina	KI070_G	**22**	Koko Paulina	KI220_T
8	Aunty Florence	KI080_H	**23**	Ntate Isaac	KI230_T
9	Ntate George	KI090_T	**24**	Ntate Raymond	KI240_T
10	Koko Annah	KI100_T	**25**	Koko Jennifer	KI250_T
11	Koko Leah	KI110_G	**26**	Aunty Linda	KI260_H

12	Koko Nancy	KI120_G	**27**	Ntate Robert	KI270_G
13	Koko Tina	KI130_M	**28**	Koko Thelma	KI280_H
14	Ntate Nicholas	KI140_H	**29**	Ntate Thomas	KI290_T
15	Aunty Neo	KI150_H	**30**	Ntate Phineas	KI300_T

** The code stands for Key Informant, number of informant and the variety planted in the season (where T=traditional; H=hybrid; G=GM; M=mixed)

Appendix 5: Seed extraction protocol, the Agdia® standard measurements table and extract buffer protocol

A. <u>Seed extraction</u>

Seed samples were crushed into a powder using a hammer. The grounded seed powder was weighed and transferred to separate containers. Using the standard measurements provided by Agdia® as reference, the following calculations were used to determine the amount of seed weight (in grams) for each sample:

If 50 g (of seed powder) → 100 ml (volume of buffer), then x g (of seed powder) was equivalent for 25 ml (volume of buffer).

50 g X 100 ml

x X 25 ml

(50 g X 25 ml) → (100 ml X *x*)

1250 g/ml → (*x*100 ml)

1250g/ml ÷ 100ml → *x*100ml ÷ 100ml

∴ **12.5 g → *x***

∴ For each sample, 12.5 g of seed powder was measured for every 25 ml extract buffer.

B. <u>The Agdia® standard measurements table</u>

Crop	**Seed to SEB4 buffer ratio (weight/volume)**	**Sub sample weight**	**Volume of SEB4 Buffer**
Corn	1:2	50 grams	100 ml
Cotton	1:10	10 grams	100 ml

The buffer was added at the specified ratio and the extract was allowed to sit for at least 30 seconds before testing with the Immunostrip. Only the supernatant (top layer of liquid) was used for testing.

C. Preparing SEB4 Extract Buffer Powder

The sample extract buffer needed to be prepared prior to seed sample testing. In between uses, the sample buffer was stored at room temperature (~18 °C - 30 °C). Working 1X SEB4 was prepared directly from powder. The bottle was thoroughly shaken to ensure complete mixture of components. The following protocol for standard measurements were listed by Agdia®:

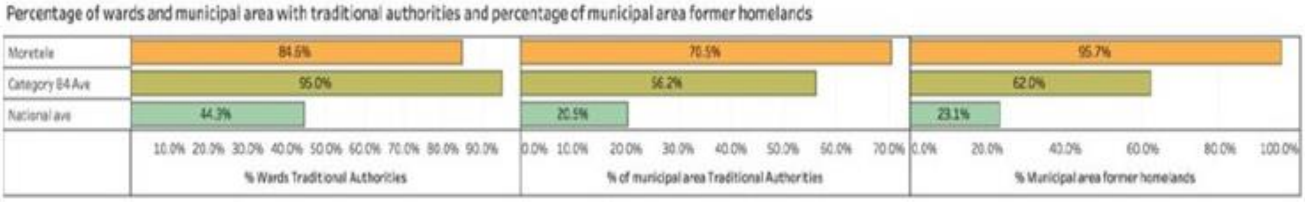
	Buffer Powder	5.7 g
	Distilled water	1000 ml (1 L)

To make 1000 ml of SEB4 sample extract buffer, a small amount of water was added to 5.7 g of powder to make a slurry. Then while mixing, the remaining amount of water was added to bring the final volume to 1000 ml (1 L). The solution was stirred for approximately 30 minutes or until dissolved.

Following the manufacturer's protocol, the calculations below show how the extract buffer was allocated to 250 ml beakers which was subsequently divided to make a final volume of 25 ml for the control and sample, respectively.

Step 1→ Making buffer→ 5.7 g buffer powder was added to 1000 ml of distilled water
Step 2→ Allocating 50 ml of extract buffer to beakers → 20 beakers total X 50 ml
Step 3→ Allocating 25 ml of extract buffer to beakers → 40 beakers total X 25 ml

Supplementary Data



Supplementary data 1: Moretele percentage distribution of land area containing traditional authorities and which were part of homelands. Bar graph showing data from the Municipal capacity assessment, 2018. Municipalities in South Africa are categorised as being either Category A (Metropolitan Areas) or Category B (Local) within Category C (district) municipalities. The data comparison is between all three categories.

Supplementary data 2: Moretele percentage distribution of households by type of housing. Pie chart showing data from the Municipal capacity assessment, 2018. Municipalities in South Africa are categorised as being either Category A (Metropolitan Areas) or Category B (Local) within Category C (district) municipalities. The data comparison is between all three categories.