On farms and in laboratories: Maize seed technologies and the unravelling of relational agroecological knowledge in South Africa.

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Abstract

When Europeans settled in South Africa in the 17th century, maize was already being grown as part of diverse and traditional cropping systems. Over centuries maize has become embedded in a web of social, ecological, economic and political relations. Since the 1900s the development of maize seed has increasingly shifted location as scientific maize breeding has come to dominate its production. In this time maize seed has changed form, from open pollinated varieties (OPVs) to hybrid seed, and most recently to genetically modified (GM) seed. While the progression of seed developments alongside their co-technologies such as pesticides, fertilizers and herbicides has greatly boosted yields, the development of maize has become increasingly generic and disconnected from the specificities of local agroecosystems.

Like all technologies, maize seed technologies are not neutral but are rather deeply entangled in the history and politics of knowledge production. Commercial technologies such as hybrid and GM seeds are products of a particular lineage of thought rooted in the post-enlightenment age of modernist, dualist science. This has resulted in a conceptual dualism in which humans are seen as separate from nature. Studies on the impacts of new seed technologies have tended to replicate this dualism, focusing either on social or ecological aspects. Few investigate the effects on relationships between humans and agro-ecosystems.

This thesis aims to address this knowledge gap by exploring the effects of the technification of maize seed on knowledge and practices within two sites of agricultural knowledge generation and practice in South Africa: smallholder maize agriculture and maize research and development. These offer two unique sites of knowledge creation and practice, and historically have had a turbulent relationship, rooted in colonialism and apartheid histories. Through exploring human-agroecosystem interactions, the research hopes to contribute to a broadened understanding about the impacts of maize seed technification and implications for agricultural knowledge generation and sustainability.

Drawing conceptually and methodologically on posthumanist theory, this thesis investigates the changing nature of social-ecological relationships of and between smallholder farmers and scientists and the agro-ecological systems in which they work. Building on the concept of agricultural deskilling, it argues that modern seed technologies have contributed to ecological deskilling both on smallholder farms and within research and development, as seed technologies become increasingly disconnected from the environments in which they are used.

Increasingly, however, there is renewed interest by both farmers and scientists in ecological-reskilling as new 'silver bullet' seed technologies reveal many setbacks.

The thesis concludes that in order to rebuild displaced ecological knowledge an ontological shift is needed to move beyond dualist science-based approaches to farming and research, towards those that learn from relational ways of knowing. Approaches should be embraced that acknowledge the relational knowledge of smallholder farmers that has been displaced and devalued for centuries and that builds this relationality into research. This could contribute to restoring cognitive justice and fostering more resilient agricultural futures.

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FIGURE 1.1: Photograph of variation in shape of maize grains. Source: Burtt-Davy, 1914.

1.CHAPTER ONE: Introduction

1.1. Introduction

Agricultural landscapes entangle humans and other life forms in a complex set of inter-relationships. Over millennia agricultural seed has come into being through a collaborative process between humans and a multiverse of organisms, from mammals to microbes, making it an ever changing and truly socio-ecological entity (van Dooren, 2012; Stone, 2007).

Over the last century agricultural seed has shapeshifted from open pollinated traditional seed also known as farmer seed which has been developed by farmers through selection of seed from plants with desirable traits over time (van Dooren, 2012). Moulded by scientific processes and guided by commercial priorities and the promise of ever increasing yields, traditional seed has been bred into so-called ‘modern’ or ‘industrial’ seed which is produced with the use of various scientific breeding techniques in laboratories and test fields rather than by farmers themselves. Whilst traditional seed is adapted to local contexts, industrial seed is reliant on co-technologies like pesticides and fertilisers for their success, rather than on the relationships with the agroecological system in which it is grown. Most often industrial seed is planted as monocrops, thus eliminating many ecologically important relationships with other plants and organisms (van Dooren, 2007). The transformation of seed has not only affected relationships and ecosystems but also the socio-ecological knowledge related to them. The term ‘socio-ecological knowledge’ is integral for this thesis; it is intended to refer to knowledge that is established through a co-evolutionary relationship between humans and ecological systems (Gual & Norgaard, 2010).

The development of conventional hybrid seed in the 1930s signalled a significant shift in the history of agriculture (Fitzgerald, 1993). Hybridization of seed is a breeding technique developed by maize breeders that allows for the production of consistency of certain traits in the seed. In order to do this, breeders develop inbred lines though facilitating self-pollination of plants with desirable traits (McRobert et al., 2014). Plants produced from inbred lines are identical. Naturally plants are cross pollinated, while inbreeding produces uniform traits it also produces less vigorous plants that produce low yields. Breeders then cross two unrelated inbred lines to produce a hybrid. This process creates what is called hybrid vigor, which can produce high yielding varieties with controllable traits (MacRobert et al. 2014). Hybrid seed creates the possibility for private seed companies to develop seed specific varieties with recognisable traits and assume ownership over them. This has become possible through the standardisation of traits in which scientists are able to claim ownership over a variety of seed that had homogeneous characteristics. These varieties are typically unable to be successfully replanted and have the same effectiveness, meaning that farmers need to buy seed each year from seed companies (Kloppenberg, 2005). Prior to this, farmers developed their own unique seeds that were adapted to their practices and the agroecosystems in which they were formed (Kloppenberg, 2014).

Since the 1990s, the development of genetically modified (GM)[1] seed has enabled seed companies to present associated traits as novel and patentable technologies (van Dooren, 2012). This, alongside other factors, has paved the way for seed to become a highly profitable global commodity. In recent decades smaller seed companies have been bought by just a few powerful agrochemical companies, resulting in a highly consolidated global seed system (Howard, 2009). In the process of the corporatisation of seed, the place-based knowledge of farmers has become increasingly undermined; smallholders around the world have adopted modern seed and the external inputs and techniques associated with it (van Dooren, 2007).

In his critique of the industrial capitalist reorganisation of work, Braverman (1974) coined the term "deskilling" to describe the loss of workers' skills and knowledge due to the substitution of their tasks with machines in order to minimise labour costs and maximise profits. Fitzgerald (1993) elaborated on this concept, by describing how hybrid corn seed led to agricultural deskilling in corn agriculture in the United States of America. Her study drew attention to the powerful agency of seed to change a

[1] According to the World Health Organisation (2021) "Genetically modified organisms (GMOs) can be defined as organisms (i.e. plants, animals or microorganisms) in which the genetic material (DNA) has been altered in a way that does not occur naturally by mating and/or natural recombination. The technology is often called "modern biotechnology" or "gene technology", sometimes also "recombinant DNA technology" or "genetic engineering". It allows selected individual genes to be transferred from one organism into another, also between nonrelated species".

spectrum of agricultural practices. The impacts of hybrid seed specifically on socio-ecological knowledge, however, has not been widely studied in the global literature. Studies have, however, looked the importance of social-ecological resilience in retaining Indigenous and traditional seed and practices related to seed that have been eroded for multiple reasons such as the introduction of green revolution technologies including hybrid seed (Bèye and Wopereis, 2013; Saxena, 2020; Kleim and Sievers-Glotzbach, 2021).

The impacts associated with the introduction of controversial GM seed technologies introduced in the 1990s gained significant attention worldwide. By crossing the boundaries of different species, and combining their various DNA in GM seed, biotechnologists blurred conceptions of nature and culture in new ways, raising questions about their potential impacts and acceptability (Goodman, 2001; van Dooren, 2012; Herrerro et al., 2015). The introduction of GM seed technologies has over the last three decades spurred a heated global debate concerning a range of topics, including ethics, human and animal health, ecological and economic risks and benefits, and more (Herrero et al., 2015). These concerns feed into a growing literature on the merits and associated risks and impacts of GM crops. Due to the highly controversial nature of these seeds, and a global outcry against their use and potential dangers, it was deemed necessary internationally to develop a risk assessment process to guide the introduction of these seed technologies[2] into agroecosystems (Herrero et al., 2015). In 2003, the Cartagena Protocol on Biosafety, a supplement to the Convention on Biological Diversity, was adopted. It is an international treaty governing the movement of living modified organisms (LMOs).[3] Initially the treaty sought to protect biological diversity from the potential effects of modern biotechnology but, in

[2] In recent years, a growing literature has developed around how technology is understood. As Glover et al. (2019:170) explain there has been a growing movement away from seeing technologies as "discrete, generic and mobile packages that are capable, in theory and principle, of being transferred smoothly from one setting to be adopted and implemented in another" towards understanding technologies as operating within a network of "encounters and exchanges between actors inhabiting different worlds of knowledge and practice" (Glover et al. 2019:171).

Seed technologies are defined here as seeds that have been altered by scientific breeding methods including the altering of genetic make up and physical characteristics. Drawing on science and technology studies, this thesis views seed technologies as created and utilized within a relational network of actors, human and non-human and the biophysical environment and in relation to other technologies.

[3] The terms GMO and LMO are often used synonymously however there are some technical differences resulting from modern biotechnology. For more see: Husby, (2007)'

time, it also came to include a focus on impacts on human health. More recently the Cartagena Protocol has emphasised the need to include socio-economic concerns in the wider risk assessment process (Herrero et al, 2015; Binimelis & Myhr, 2016). Contrary to this approach, however, studies assessing the risks and impacts of GM seeds tend to have a dualist approach, focusing either on social or ecological impacts rather than socio-ecological impacts as an interrelated concept (Herrero et al, 2015).

Herrero et al. (2015:11322) assert that GM seed technologies are complex "socio-technical" objects. When they enter into an environment they have agency and the ability to deeply affect relations. The fields of Science and Technology Studies (STS) and Postcolonial STS draw attention to the importance of studying the politics of technologies and the ways in which these technologies shape the environments and relations into which they enter and from which they come. Within this lens technologies are not "merely value-neutral chunks of hardware" but rather "artefacts [that] have politics" (Harding, 2008:6); they come into being within a particular lineage of ideas. Commercial maize seeds, meaning both conventional hybrids and GM, have been fashioned within a lineage of industrial agriculture. Industrial agriculture in turn has its roots in modernist, dualist science, which cannot be disentangled from colonialism and the growth of capitalist extractivism (Eddens, 2019).

The separation of social and ecological impacts in the assessment of risk reflects a dualism characteristic of modern society in which humans are conceptualised as separate from nature (Moore, 2015). Stemming from the European Age of Enlightenment, this dualism is pervasive, referred to by social theorists as a modernist ontology. A dualist ontology underpinned colonial and capitalist exploitation through the conceptualisation of nature as separate from humans; in this way nature became understood as a category separate from humans that could be exploited (Latour, 2007; Moore, 2015). Industrial agriculture based on modernist science greatly perpetuates this dualism, reducing nature to something that can and should be controlled for the benefit of some humans through the exploitation of others (Moore, 2015). This binary, in which nature is conceptualised as separate from the social realm, is deeply entrenched in industrial agriculture and Green Revolution-based approaches to agricultural development, which focus predominantly on yields and profit through "putting nature to work" (Moore, 2015b:2) In the same vein, Goodman (2001:183) argues that agrifood studies remain "rooted in a dualist ontology" characteristic of modernist science. He argues that this dualism prevents agrifood studies from engaging in the complex biopolitical concerns we face today. This same conceptual dualism has arguably obscured the importance of studying the socio-ecological effects of modern seed technologies, which remain under explored.

Given that agricultural seed has by its very origin emerged out of a socio-ecological relationship – a "natureculture" entanglement, the focus of this thesis was shaped by an interest in how this fundamental engagement has been affected by the increasing technification[4] of seed (Harraway, 2007; De la Bellacasa, 2012). As the development of seed has moved from the hands of farmers working within local agroecological contexts to the hands of scientists working in distanced laboratories and test fields, how have socio-ecological relationships and knowledge been impacted? This thesis seeks to contribute to developing knowledge on the effects of modern seed technologies beyond the prevalent human vs. nature divide, by focusing on the socio-ecological effects of modern maize seed technologies. In this way the research hopes to contribute to furthering the local and global discourse on the impacts of modern seed technologies, and to highlight the importance of focusing on socio-ecological knowledge for the future of agriculture in the South African context and beyond, in the face of ever uncertain socio-ecological futures and climates.

Fitzgerald's (1993) work on agricultural deskilling and hybrid corn, and Stone (2007, 2011) and Stone and Flach's (2018) work on GM cotton and agricultural deskilling, provides a basis from which to think through the power of seed to shift agricultural practices and knowledge. Interested in the impacts of modern seed on socio-ecological relationships and knowledge, this thesis argues for adding the term 'ecological' to the concept of agricultural deskilling. The term 'ecological deskilling in agriculture' is suggested to draw specific attention to the displacement of relationships and knowledge within agroecosystems of both farmers and scientists.

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[4] Technification has been defined as "the action or fact of making technical; the adoption or imposition of technical methods" (OUP, 2021). In this thesis it is used in relation to the scientific transformation of seed through breeding and genetic modification. It also included the devloepmnt of seed alongside co-technologies such as herbicides.

To develop the focus on socio-ecological relationships the thesis draws conceptually on interdisciplinary literature from key bodies of work, including Postcolonial STS, Posthumanist Studies and Decolonial Studies. In various ways these studies are connected to what can be understood as an ontological turn that arose to challenge Western modernist and dualistic ways of understanding the world, and therefore to develop a more relational ontology (Rojas, 2016). In different ways, this work provides insight into how a dualist ontology has been entrenched and used to exploit nature since the European enlightenment and through colonialism and capitalism, disrupting relational understandings of the world that are characteristic of many indigenous philosophies (Qujano, 2007; Moore, 2015). Dualism underpins modern science and technology (including agricultural), which postcolonial STS theorists show has been used to assert colonial power and domination of people and landscapes, and to dismantle socio-ecological interconnections and relational philosophies (Seth, 2017). Decolonial theorists draw attention to how coloniality carries on into the present through structures, institutions, technologies, development interventions and hegemonic adherence to modernist ways of being in the world (Quijano 2007, Mignolo, 2011, 2012). Drawing on a relational approach embedded within many Indigenous philosophies, decolonial theorists advocate for the importance of restoring socio-ecological justice through cognitive justice[5] (De Sousa Santos, 2016; Escobar, 2016). As De Sousa Santos (2016) argues, the conceptual divide between humans and nature underpins vast social and ecological injustices and this cannot be addressed without restoring justice, thus fundamentally challenging this ontological dualism and repairing relations. While posthumanist studies and postcolonial STS do much to draw attention to dualism and the need to dismantle the divide between humans and all life, decolonial theorists bring awareness of how this divide is part of dualist ontology that is not universal, it has oppressed 'other' more relational ways of knowing and being in the world. (Wynter, 2003; De Sousa Santos 2016; Shculz, 2017). These bodies of work in relation to one another offer different undertsandings of what it means to be 'human', in a world in which this catergory has been used to oppress both people and non-humans in the formation of colonial and capitalist systems of power (Wynter, 2003; Moore, 2015; Schulz, 2017).

[5] The term cognitive justice is borrowed from De Sousa Santos (2016). His framing of congntive justice implies "a new epistemology, which contrary to hegemonic epistemologies in the West, does not grant supremacy to scientific knowledge (heavily produced in the North). It must allow for a more just relationship among differet kind sof knowledge" (De Sousa Santos, 2016:70)

The thesis suggests that in failing to question the socio-ecological impacts of modern seed technologies, the hegemony of modernist, science-based approaches to agricultural development and their effects on other ways of knowing is limiting and cannot be fully understood. As technologies exert agency and have the ability to perpetuate the ways of knowing in which they are fashioned, they have the ability to perpetuate colonial ontological systems. With the growing spread of modern seed and the increasing use of GM seed this is pertinent. Decolonial theorists tell us that if modernist approaches are not questioned we cannot open up pathways for more resilient and socio-ecologically just agricultural futures. As agricultural systems in South Africa and globally continue to become increasingly industrial, and modernist dualism continues to erode relational practices and knowledge, this thesis hopes to draw attention to the importance of understanding the role of seed in this process, and the necessity of broadening our understanding of the importance of socio-ecological impacts and the implications for agricultural futures.

1.2. Aim and objectives

1.2.1. Aim

This thesis aims to examine the socio-ecological effects of the technification of maize seed on knowledge, relationships and practices within two sites of agricultural knowledge generation and practice in South Africa: smallholder maize agriculture and maize R&D.

Through exploring human-agroecosystem interactions, the research hopes to contribute to a broadened understanding about the impacts of maize seed technification and implications for agricultural sustainability.

1.2.2. Research objectives

1) Through the use of posthumanist and multi-species approaches, to incorporate novel methodological and conceptual ways to examine the effects of modern seed technologies on socio-ecological knowledge, relationships and practices within agroecosystems.

2) To investigate the effects of maize seed technification on social-ecological knowledge, relationships and practices within smallholder maize agriculture over time.

3) To investigate the effects of technification of maize seed on social-ecological knowledge, relationships and practices within maize R&D over time.

4) To explore how the technification of maize seed has affected and may continue to affect relationships of knowledge between smallholder farming and R&D sites.

5) To examine what the implications of this research might mean for future agricultural pathways and sustainability in South Africa and beyond.

1.3. Focus and rationale

Maize is considered one of the most important commercial crops globally, with annual harvests second only to wheat. The USA is the largest maize producer, followed by China and Brazil (McCormick, 2020). South Africa produces the 10th largest annual yield of maize globally (McCormick, 2020). . The history of maize is well documented by historical records and through tracing its genetic origins and pathways across the world (Matsuoka et al., 2002; McCann, 2007; Van Heerwaarden et al., 2011; Blake, 2015). Human interactions with this one crop offer a window into the enormous shifts that have taken place materially and ideologically in agriculture over the last century.

Maize is not indigenous to South Africa but since precolonial times has become embedded in the country's social, ecological, economic and political history. Although the crop's specific route of entry into Southern Africa remains in question, it is likely that maize arrived via Portuguese trade routes and potentially multiple entry points (Jeffreys, 1954; Miracle, 1965; McCann, 2001). When Europeans settled in South Africa, maize was already being grown by Indigenous farmers as part of diverse and traditional cropping systems (Jeffreys, 1954; McCann, 2001). In the early 1900s colonial farmers earmarked maize as a potentially highly profitable crop (Burtt-Davy, 1914). A robust maize R&D system was established to support the commercial success of this crop. In the 1930s interest in the potential of maize to be a high-yielding and profitable crop was bolstered by the advent of hybrids (Greyling and Pardey, 2019). During the colonial period and then apartheid, maize R&D was utilised as a tool through which to support white farmers in boosting their success within maize farming, while simultaneously marginalising black smallholder farmers from this same oppourtunity. After South Africa's transition to democracy, maize continued to be a vital economic crop, and commercial maize agriculture was seen as a tool through which to level the playing field between white commercial agriculture and black smallholder agriculture. In 1998, four years after democracy, GM maize was introduced (Gouse et al. 2005), making South Africa the first country in Africa to allow the cultivation of GM maize, and the first country in the world to approve a GM staple crop, which was planted by both large scale commercial and smallholder farmers (Jacobsen, 2013). It was envisioned that smallholders could achieve commercial success through farmer development programmes, which focused largely on industrial maize farming techniques and, often, the use of GMOs. In this way, smallholders found themselves on the receiving end of technologies and knowledge transfers developed within scientific spaces, including that of GM seeds and their co-technologies. At the same time scientists found themselves increasingly involved in the growing field of GM maize research.

To date little research in South Africa has focused on the impacts of hybrid maize technology on socio-ecological relationships and knowledge. Over the last two decades, there has been increased attention to the risks and benefits of introducing GM maize into South African farming systems and landscapes. However, these studies tend to assess either the social-economic (Gouse, 2012; Abidoye & Mabaya, 2014; Gouse et al., 2016) or ecological risks and benefits of GMOs in the southern African context (Morse & Bennett, 2006; Van den Berg et al. 2013; SANBI, 2012; Horn et al.,2019; 6; du Pusani et al.,2019). There is little research that goes beyond this dualistic approach to explore the relational socio-ecological dynamics that have emerged in response to the introduction of GM maize into South African farming systems.

While the impacts of modern seed has been looked at in relation to smallholder farming, there has been little research to investigate its impacts on socio-ecological knowledge, relationships and practices. Moreover, few studies explore how knowledge generation and transmission has been affected within maize R&D by the continued modernisation of seed technologies and the introduction of GMOs (Buhler et al., 2002). There has also been scant attention paid to changing knowledges of seed across both R&D and farming-based locations. Smallholder farming and the R&D system in South Africa have historically had a turbulent relationship, rooted in colonial and apartheid history. The relationship between these 'spaces' is significant in South Africa and throughout the Global South, as modernist agricultural science has deeply affected smallholder farming knowledge. This has occurred due to its undermining by colonialism and through modernist development paradigms in the postcolonial period and extending into the present.

While both the work of farmers and scientists is important for the generation and continuation of agricultural knowledge and skills, modern industrial, scientifically based agricultural knowledge has repressed smallholder farming knowledge (van Dooren, 2012; Eddens, 2019). Within industrial agricultural systems, a hierarchical relationship has developed between smallholder farming and R&D in which scientific knowledge is often valued over the knowledge of farmers van Dooren, 2012). For reasons explored later in this thesis, these areas of agricultural science and smallholder farming are often separated conceptually, geographically and, in many ways, ontologically. This divide makes the exploration of these areas and the changing socio-ecological knowledge and practice in both, as well as the interconnections and disconnections between them, of particular interest.

There is increasing global recognition of the need to rebuild diversity of knowledge and relational knowledge in agriculture for social and ecological wellbeing, and that the place-based knowledge of smallholder farmers – which is under threat – is an integral part of this (UN, 2013; Šūmane et al., 2018; IPES, 2018). There is also an increasing awareness that dualist agricultural science or silver bullet solutions cannot tackle the pressing issues such as climate change and food insecurity that we face; we need diversity in science and knowledge to build more resilient agricultural futures from the remaining fractured relational knowledge in both sciences and smallholder knowledge systems. It is the hope of this thesis that in exploring the impacts of modern seed technologies on the knowledge of farmers and scientists a conversation can be developed concerning the wider loss of ecological knowledge and, from this, how to approach a process of rebuilding this fractured knowledge.

1.4. Methodological approach and study sites

While the effects of modern seed are felt throughout the food system, this thesis deliberately chose to focus on two particular nodes or areas within the food system, namely smallholder maize farming and maize R&D. Given the particular interest of this thesis on seed and changing ecologically based relationships, knowledge and practices, these two nodes stood out early on in the research process. These are both areas in which agricultural knowledge and practice are generated and which change over time in relation to social, political, ecological and technological shifts. While a distinction is made between smallholder farming and R&D, this is to work towards developing a conversation about the experiences in both and between them. Historically, these sites have been treated differentially as sites of knowledge production, with smallholder farmer knowledges and practices often treated as less valid than those fashioned in the realm of science (Schnuur, 2019). The distinction made is not intended to present these 'spaces' as bounded locations inhabited by either 'scientists' or 'farmers', as these are not static locations or identities. A smallholder farmer can be a scientist and a scientist a smallholder farmer. Further, 'science' is not a bounded discipline as post-colonial theorists have shown what is commonly perceived as 'western science' has been deeply influenced throughout history by 'other' knowledge systems rarely given the same weight as 'western science' (Seth, 2017). The intention in using these two focuses for the research is not to reinforce these categories but rather to draw attention to how a polarization has existed in their treatment and continues to do so.

In this thesis R&D institutions and small-scale farming systems were approached both as places where knowledge and practices concerning agriculture are generated and continuously change in relation to social, political, technological and ecological factors, and as complex networks of relationships. In both spaces data was gathered through a range of ethnographic methods, including life history interviews and participant observation. In-depth life history interviews of farmers and scientists were carried out in order to understand how their work and the generation of socio-ecological knowledge changed over time and in response to the introduction of modern seed technologies.

In addition, visual data and archival data were collected. In both spaces a multispecies lens was adopted in which particular consideration was given to the changing relationships between farmers and scientists and the more-than-human world around them.

The research on smallholder maize farmers was carried out in Northern KwaZulu-Natal in the uPhongolo Local Municipality. The study area is predominantly rural, and is located near the town of Pongola. This particular area was a focus of the research, because farmers here grow a range of maize seed, including traditional varieties, commercial Open Pollinated Varieties (OPVs), conventional hybrids and some GM seed. Prior relationships with an NGO affiliated with farmers in the area made contacting these farmers possible.

Maize R&D is not confined to a single geographical area but is conducted throughout South Africa; therefore, unlike that on smallholder farming, the research on maize R&D took place at multiple sites. For this project, scientists in Cape Town, Stellenbosch, Pretoria, Roodeplaat, Potchefstroom, and Pietermaritzburg were interviewed physically, and scientists in other locations in South Africa were interviewed on Skype where it was not possible to travel physically.

1.5. Chapter outline

The thesis is presented in nine chapters. Chapter 2 provides a literature review, the first part of which describes the ways in which the impacts of modern seed technologies in South Africa and globally have been studied to date, thereby illustrating the limited attention paid to their socio-ecological impacts. The second part describes the conceptual literature used. Chapter 3 presents the methodological approach to the research, while chapters 4 and 6 provide historical overviews and contextual information about smallholder maize farming and maize R&D respectively. These chapters are intended to provide context for chapters 5 and 7, whose findings focus on the effects of modern maize seed technologies on smallholder farming and maize R&D respectively. A choice was made to separate the findings between these nodes in chapters 5 and 7, for clarity. However, on a conceptual level, the intention of the thesis in general was ultimately not to separate these spaces, but rather to bring them into the same conversation. For this reason, the discussion in chapter 8 draws on the findings from both smallholders and R&D sites; it discusses commonalities and differences, such as the themes of ecological deskilling between these spaces, and considers how this may inform different ways of relating within and between these spaces. Chapter 9 concludes the thesis and provides recommendations based on the findings.

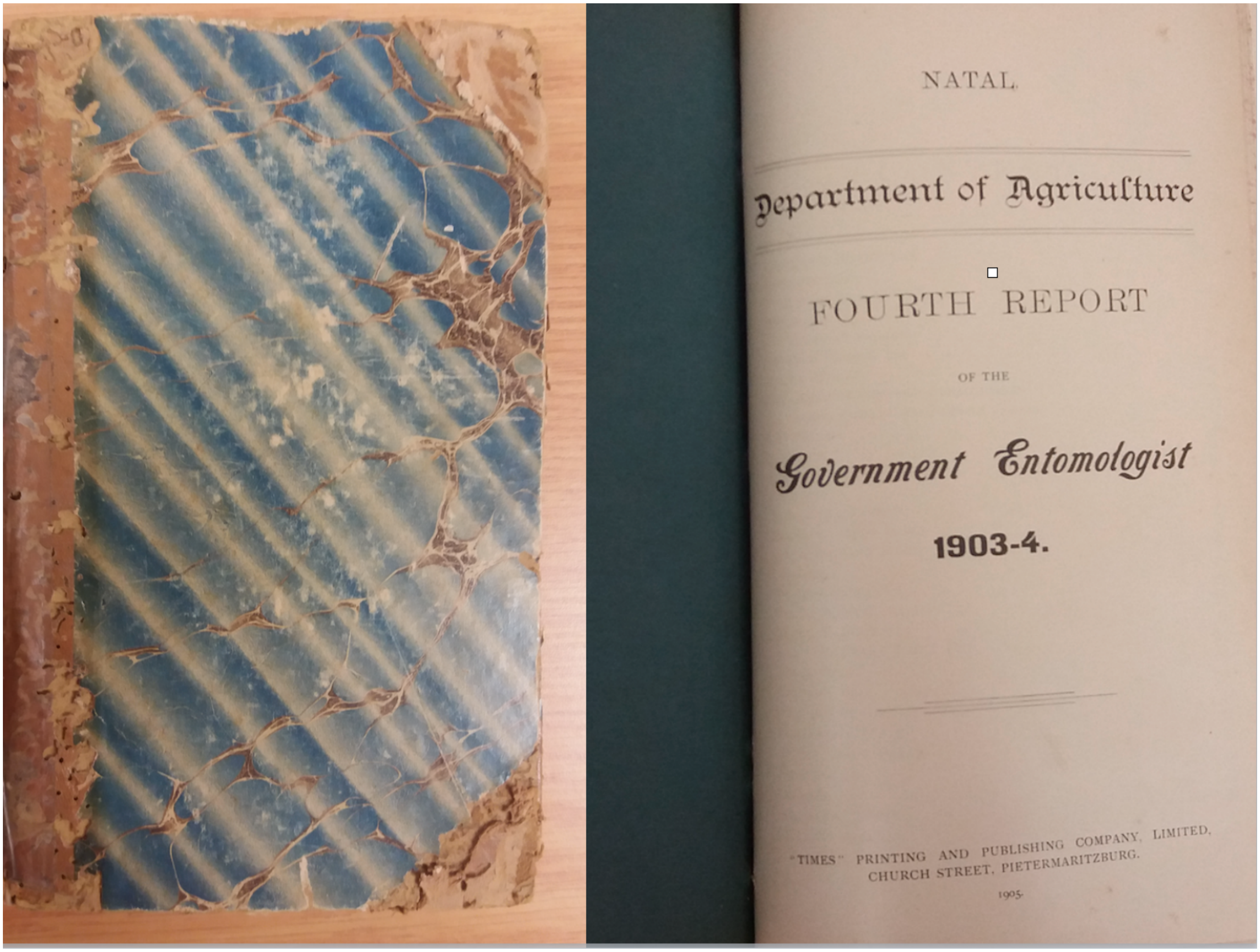

FIGURE 2.1: Department of Agriculture Fourth Report by the Government Entomologist of Natal. Ironically, this book was full of borer holes. Source: Photographs taken by Maya Marshak in the KwaZulu-Natal Provincial Archives in Pietermaritzburg.

2. CHAPTER TWO: Literature Review

2.1. Introduction

The first part of this review situates the study within the wider literature on the politics of agricultural seed and how its generation has shifted from the hands of farmers to scientists over time (Kloppenberg, 1991; Shiva 1997; van Dooren, 2008, 2009, 2012). It looks at how the effects of modern seed technologies (conventional hybrids and GM) have been studied globally over time. Since the introduction of controversial GM seed, there has been a growth in assessments of their impacts, which has informed global policies and decision making concerning their acceptability and use. However, to date, assessments of the risks and impacts of GM seeds in policy and literature have tended to focus on social or ecological impacts separately. This binary reflects a deeper dualism that is characteristic of modernist scientific thought, and that continues to pervade contemporary agrifood studies (Goodman, 2001; Herrero, Wickson & Binimelis, 2015).

This thesis seeks to address an epistemological gap concerning the impacts of modern seed on socio-ecological knowledge and relationships within agroecosystems, by examining the changes brought about by modern maize seed technologies in South Africa. This is done by focusing on how the introduction of new, modern seed has brought about change in two key nodes of agricultural knowledge production, namely smallholder maize farming and maize research and development (R&D). While impacts of hybrids and GM seed on farmer knowledge have been explored in some detail globally (Fitzgerald, 2003; Stone, 2007, 2011), the impacts of changing seed technologies on knowledge creation and transmission within agricultural science has not been a focus of exploration. To date the literature also has not focused on the changing knowledge related to seed in these sites collectively. This obscures the complex knowledge politics and tension between them, and the ways in which modern seed technologies may be contributing to widening the rift between these spaces and deepening a disconnect with agroecosystems. In addition, studying these spaces separately can also obscure patterns and similarities experienced in both and the importance of seeing these spaces in relation to each other.

The second part of this literature review presents a set of distinct but interconnected bodies of literature that are conceptually important for this thesis. This interdisciplinary literature engages in the politics of knowledge and how to move beyond the epistemic and ontological dualism underpinning modernist thought. This dualist ontology, which took root in the post-enlightenment West, has underpinned the separation of the world into binaries (such as social/ecological, nature/culture, modern/primitive, scientific knowledge/Indigenous knowledge, and humans/non-humans), and laid the foundations for deep social and ecological injustices that have been carried out through colonialism and the capitalist world order (Merchant, 1980; Harding, 2008 Mignolo, 2011(a); De Sousa Santos, 2016). Collectively this literature, which is connected to activism and social movements in the global South, works to decentre and decolonise Western dualist and anthropocentric concepts of reality, and bring in 'other ways of knowing' and understanding the world that have been marginalised (Rosenow, 2019). Within this work, the hegemony of modernist scientific reason is decentred by exposing science's claims to be able to uncover objective truths about existence. Rather, theorists show that modernist science, like all knowledge systems, is cultural and political; it has a particular agenda and upholds a particular version of reality. As a result, scientific technologies are not neutral objects and carry these politics with them when they enter the world outside the laboratory (Harding, 2008).

2.2. Positioning the research in the wider literature

2.2.1. The politics of seed: from farmers' seed to corporate seed

Over the last century, agricultural seed has shapeshifted dramatically, as have the agricultural environments connected to it. Through the growth of scientific breeding, seed has gone from being developed in the hands of farmers within specific agroecological contexts to being increasingly developed by scientists in laboratories, for use by large-scale farmers and to be controlled by corporations (Shiva, 1997; McCann, 2007; van Dooren, 2012; Bonny, 2017). Through developments in breeding techniques, seed has gone from open pollinated varieties (OPVs), to conventional hybrid seed and, most recently, GM hybrid seed. Open pollinated maize cultivars are most often farm bred and result from farmers or scientists allowing plants to cross pollinate themselves as they would naturally in a maize field and then choosing to save seed from the plants that exhibit favourable characteristics (Kutka, 2011). By contrast, hybrid seeds involve more manipulation of the breeding process. Hybrid seeds are developed through what are called in-bred lines. These are achieved through encouraging self-pollination of plants that exhibit certain favourable traits (MacRobert et al., 2014). This produces seeds which produce plants with fixed or stable traits (MacRobert et al., 2014). As maize is normally cross-pollinated, self-pollination usually results in a phenomena called in-breeding depression whereby grain is smaller and plants have less vigour (MacRobert et al., 2014). Therefore, breeders will intentionally cross two or more in-bred lines, or cross an in-bred line with an OPV and in this process they renew the vigour of the plant; this is referred to as hybrid vigour (MacRobert et al. 2014). GM seeds embody another level of genetic manipulation in which DNA is combined beyond the species boundary. In the process of creating GMO seed, biotechnologists have developed methods for incorporating new genes from one species into another species in order to bring to its DNA a desirable characteristic not present in that species previously (Phillips, 2008).

Scientific breeding initially took place in public research facilities (Buhler et al., 2002; Bonny, 2017). Commercial farmers were also involved in breeding varieties and were encouraged to do so through competitions or maize shows, in which they would try to develop varieties to be judged by certain characteristics deemed desirable (Burtt-Davy, 1914: Hallauer & Filho, 1988; Lee & Tracey, 2009). OPVs were developed through mass selection breeding techniques; these varieties could be planted and the seed saved and replanted. Before 1909 in the United States almost all maize breeding was done by farmers or farmer-seedsmen who produced open pollinated seed (Hallauer & Filho, 1988; Lee and Tracey, 2009). The first hybrids can be traced back to 1909 when experiments on heterosis (crossing two plants with desirable traits) and inbreeding were conducted in the United States (Lee & Tracey, 2009). The process of hybridisation aimed to enhance certain traits of maize and then standardise these traits in the population. The inbreeding technique means that while seed can be saved and replanted they will likely not produce a very successful crop, which is the case too with GM seed. These experiments gave rise to the conventional hybrid seed industry (Lee & Tracey, 2009). OPVs have most often been the focus of public breeding programmes, while hybrids, which are more commercially exploitable, have been of more interest to seed corporations (Shiva, 1997). While for thousands of years an intrinsic quality of seeds was their ability to be (re)produced and exchanged by farmers, scientists sought to change this, as it was a "built in barrier to capital accumulation" (Kloppenburg 2005; Peschard & Randeria, 2020). The development of hybrid seed brought about radical change, because it allowed 'capital to overcome social and biological barriers to the capitalisation of agriculture by constraining farmers' ability to save seeds' (Peschard & Randeria 2020:616).

Hybrid seed (which from this point will be referred to as conventional hybrid seed to distinguish it from GM hybrid seed) came to be regarded as essential for boosting agricultural production and was foundational in the development methods of the Green Revolution in Asia and South America (Schnurr, 2019). Here, development projects encouraged farmers to adopt conventional hybrid seed and its co-technologies under the auspices of agricultural development, poverty alleviation, and economic growth. However, the Green Revolution-focused development programmes have been widely critiqued, due to their top-down approaches and failure to achieve these goals (Schnurr, 2019). Africa, which was largely left out of the initial wave of the Green Revolution, achieved this level of attention more recently in the early to mid-2000s through what is known as the Alliance for a Green Revolution in Africa (AGRA) (Schnurr, 2019). AGRA aims to increase the productivity of African smallholder agriculture by supporting modern breeding programmes on the continent to boost productivity of major food crops (AGRA, 2021). This approach is market-led and technology-centred (Scoones & Thompson, 2011). Within this approach GM seed is envisioned as an important part of the set of suggested tools that is envisaged to help overcome biophysical constraints and boost production (Scoones & Thompson, 2011). This recent wave of Green Revolution-style development is often termed the Gene Revolution and is highly controversial, as GM seed is deeply embedded in systems of power (Parayil, 2003; Schnurr, 2019).

The ownership of seed is a critical factor within the agrifood chain and seed companies are thus considered powerful actors within the global food system (Schnurr, 2019). While the actual value of seed on the global market is smaller than other agricultural commodities, seed is an especially powerful commodity for big corporations, because the kinds of seed being used direct the kinds of farming and inputs associated with them (Schnurr, 2019). An example is that of herbicide-resistant GM seed, which is designed to work alongside Roundup, a herbicide that will not damage the GM seed itself but remove all other plants around it.

Until recent years, the seed industry was considered a heterogeneous sector because of the wide variation in stakeholders and suppliers, from public breeders to small and large companies specialising in different types of seed (Schnurr, 2019). The origins of the companies are diverse too, with many of the smaller companies having grown out of agricultural research, while many of the larger ones came into the seed industry from the chemical sector, which had vested interests in linking seed to co-technologies such as pesticides and fertilisers (Bonny, 2017). The development of modern biotechnology further increased the interests of big corporations in seed, as it allowed for the ownership of certain traits through intellectual property regimes (Schnurr, 2019). This desire to own traits and genetic material set forth a process whereby larger seed companies began buying smaller ones. As Shiva (1998) warns, seed companies that started out as many smaller separate companies have become increasingly consolidated over time into giant multinational corporations with influence throughout the global farming system. This trend towards consolidation has intensified over the thirty years since GM seed has been on the market (Howard, 2009, 2015; Bonny, 2017), particularly through a large number of acquisitions over the last five years (Bonny, 2017). Notable consolidations include those between Monsanto, Syngenta and DuPont (Bonny, 2017). Most recently this has included the 2016 purchase of Monsanto by Bayer and the 2019 consolidation of DuPont Pioneer, DuPont Crop Protection and Dow AgroSciences under Corteva Agriscience.

The shift from farmer seed to corporate-driven and owned seed (with public-bred seed somewhere in the middle) has led to intense debates around the politics of seed (Bonny, 2017). Proponents of the modernisation of seed argue that scientific breeding is vital for a number of reasons, such as boosting crop yields to keep up with population growth, enhancing efficiency, reducing poverty through improving smallholder production, increasing the resilience of crops in the face of climate change, improving the nutrient quality of certain crops, and reducing environmental impacts (Bonny, 2017). However, while these arguments may be attractive, scholars and activists have warned about the power imbalances and injustices that have arisen from the corporatisation of seed that was made possible through hybridisation and bolstered by the introduction of GMOs (Fitzgerald, 1993; Kloppenberg, 2005; Shiva, 2007; van Dooren, 2012; Bonny, 2017).

One of the most contentious issues is that over time, the development of scientific breeding has allowed for private companies to claim proprietary rights over seed varieties (Van Dooren, 2012; Bonny, 2017). Breeders have claimed that, through the use of modern scientific breeding techniques, they have been able to create uniform, 'new', 'stable' or unique varieties, which can therefore be patented and owned (van Dooren, 2012; Bonny, 2017). While conventional hybrids allowed for breeders to assert intellectual property rights, such as plant breeder's rights and patents, genetic modification has intensified the process. By inserting DNA from another organism, the GM seed is effectively viewed as a new invention and is thus eligible for intellectual property protection (Peschard & Randeria 2020). Seed laws, patents and private licensing contracts entered into upon the purchase of GM seeds ensure that farmers are legally prohibited from saving this seed; therefore, seed effectively becomes a commodity that must be bought annually, resulting in a captive market for seed companies. While hybrid seed requires that new seed is bought annually to ensure consistency in performance, it is not a legal requirement. With GM seed, not only do seeds need to be repurchased annually for performace reasons but their use and re-use is also legally tied to contractual obligations through licenses that are signed. These legal mechanisms, alongside the technologies themselves, have helped build a corporate hold over the global seed system (Peschard & Randeria 2020: De Wit, 2017). Scholars have documented how Western-centric intellectual property regimes related to seed have come to remove the rights of Indigenous farmers to their own seed, giving breeders rights over them instead (van Dooren, 2012; Eddens, 2019; Peschard & Randeria, 2020). Van Dooren (2012:684) argues that farmers and their knowledge have been "backgrounded" through the enforcement of the idea that farmer seed is "natural" or "partly cultural". Yet when seed has passed through or been 'purified' via the research and development process, it is considered an "invention" and thus liable to be claimed as intellectual property.

The appropriation of genetic material (germplasm) from farmers' seeds has been used to fuel the development of the commercial seed industry. This has been widely debated and opposed by scholars and activists (van Dooren, 2008; Eddens, 2019).

Since the early 1900s, this process has involved a problematic 'collection' of genetic material from smallholder farmers, often without permission, and the storing of this material in seed banks from where it can be accessed by government research institutions or private companies wishing to develop commercial varieties (van Dooren 2008; Eddens, 2019). This was often done under the auspices of modernisation and development, which, it was argued, was necessary for economic growth and feeding the world. Eddens (2019:6) shows how in Mexico the collection of farmers' maize varieties during the 1940s and onwards by the Rockefeller Foundation in collaboration with the Mexican Department of Agriculture was justified by racist developmentalist agendas that claimed to assist in improving Mexico's 'inefficient' and even 'primitive' agriculture. Indigenous farmers were described in a Rockefeller Foundation report published in 1941 as 'lack[ing] agricultural skills' (Eddens, 2019:7). Yet these scientists sought to appropriate these same farmers' seed, because of their awareness of its great value. The narrative that scientists could improve on varieties appropriated from farmers through the development of 'modern' seed, and then teach these same farmers how to 'improve' their operations through increased yields, became pervasive within developmental discourses and continues today (Shiva, 1997). Yet, seed is not just a commodity; it is a meeting point of the past and the future of 'nature' and 'culture', and its transformation therefore has far-reaching consequences (Shiva, 2007; Herrero, Wickson & Binimelis, 2015).

2.2.2. Exploring the impacts of 'modern' seed technologies within and beyond maize R&D

Seed created using 'modern' breeding techniques is often termed 'modern' seed to distinguish it from farmer's seed. Unlike farmer's seed, commercially developed seed is bred to be uniform and to perform under generic and controlled conditions (Murphy et al., 2005). Its success is most often reliant on the use of co-technologies or inputs such as fertilisers, herbicides and pesticides (Murphy et al., 2005). As the introduction of this seed is typically associated with other inputs and related farming methods, the introduction of modern seed can have far-reaching effects within the systems it enters. The way in which these effects have been studied globally has shifted over time in relation to global discourses on agriculture and technologies. While hybrid seeds started being used in the 1930s (Lee & Tracey, 2009), it was only in the 1980s that their impacts on agricultural systems started to be explored in the literature. This was led by scholars and activists concerned with the impacts of these commercial seeds on farmers' rights and knowledge, as well as their environmental impacts (Peschard & Randeria, 2020). The introduction of controversial GM technologies drew increased attention to the notion of exploring the impacts of seed technologies. Studies of these impacts were deemed important alongside their release for testing and commercial use and to aid decision-makers in making choices about their release. The following section reviews themes in the global literature on the effects of modern seeds, starting with conventional hybrids before moving on to GMOs.

2.2.3. Agricultural deskilling and modern seed

The concept of agricultural deskilling, first used by Fitzgerald (1993), can be useful to grasp some of the dimensions of change brought about by newly-introduced technologies. This concept is based on Braverman's (1974) concept of deskilling, which emerged from his observations of industrial capitalist re-organisation of work. Deskilling was a reaction to the concept of upskilling, which emerged in the period after the Second World War (Heisig, 2009). This was a time of widespread economic growth and excitement about the potential social and economic benefits of technological change (Heisig, 2009). Upskilling celebrated the new job opportunities being created by modern technologies and the transformation of production systems. It was envisioned that older (manual, repetitive and 'unskilled') jobs would be replaced by new ones that required training and higher levels of education, and that workers would be upskilled in this way (Heisig, 2009). However, by the time Braverman (1974) wrote on deskilling it was becoming clear that, while new technologies were creating opportunities, the division of labour and growth of 'unskilled' jobs was increasing. Furthermore, working conditions were not improving as promised. Braverman (1974) used 'deskilling' to describe the loss of workers' skills and knowledge, due to the substitution of manual tasks with machines in order to minimise labour costs and maximise profits. This, he argued, was a form of disempowerment brought about by the removal of the specialised knowledge held by workers. This concept became useful for analysing the changing nature of work in light of the introduction of various forms of mechanisation. Evidence of this lies in its application to a myriad of professional profiles, such as factory workers, nurses, teachers, social workers, migrant workers, artists and farmers (Fitzgerald, 1993; Rinard, 1996; Carey, 2007; Roberts, 2010; Creese & Wiebe, 2012; Cuban, 2013; Stone, 2007, 2011).

Fitzgerald (1993) used the concept of agricultural deskilling to illustrate the widespread impacts she witnessed of hybrid seed technologies on farmers' knowledge. She suggested that the deskilling process was largely overlooked within the agricultural context, because farmers were often receptive to new agricultural technologies, as they offered a way to break from certain arduous tasks. However, Fitzgerald (1993:327) goes on to argue that this hybrid seed had significant impacts on agricultural systems and the skills of farmers and "effectively deskilled" them. Similarly, Bell, Hullinger & Brislen (2015:8) describe agricultural deskilling as "a form of disempowerment in which specialised knowledge and skills that have traditionally been at the core of farming are removed from the farmer". Based on her study of US maize, Fitzgerald (1993) showed how, by adopting hybrid seed, farmers came to lose knowledge and skills attached to their own saved seeds that had been cultivated over generations. With the emergence of breeding programs in both private companies and public institutions, farmers became increasingly reliant on seed and knowledge produced by seed companies. Fitzgerald (1993) goes on to describe how hybrid seed technologies "effectively locked farmers out from an understanding of their own operations" and their knowledge and expertise were "delegated to geneticists"; while "open pollinates were transparent, hybrids were opaque" (Fitzgerald, 1993:343).

While Fitzgerald effectively used the concept of agricultural deskilling to unpack the loss of skills happening on American corn farms, this concept has not been widely used globally. Gilbert (2013) draws on this concept to warn of the use of genetically heterogeneous cultivars in British allotment farming. Just a few other scholars have utilised the concept of agricultural deskilling in relation to hybrid seed. Beyond seed, scholars have applied the concept to explain how various industrially-driven, agricultural innovations such as agrochemical inputs have affected farmers' knowledge (Vandeman, 1995; Wyckhuys & O'Neil, 2010).

More recently, Stone (2007) uses the concept to explore the uptake of GM cotton in Warangal, India, and identified that GM seed was contributing to a process of agricultural deskilling. He argues that although the phenomenon of agricultural deskilling clearly pre-dated the introduction of GM seeds, this newer technology has exacerbated and accelerated the process significantly (Stone 2004, 2007; Stone & Flachs, 2018).

Drawing on cultural evolutionary theory, Stone (2007) proposes the idea that the agricultural deskilling process involves an imbalance between social and environmental learning. Social learning is described as the learning farmers do by gaining information from others, while environmental learning refers to learning farmers do in relation to their own practice and specific environment, year after year. For Stone (2007), new GM technologies have contributed to an imbalance between social and environmental learning, whereby farmers have become more reliant on outside seed and, in doing so, have lost their connection to and knowledge of their seed. Furthermore, Stone offers three factors related to GM seed that have contributed to the process of deskilling: inconsistency (the inevitable change of the effects of technologies over time, for example on pest populations), unrecognisability (because with so many seed varieties available in the market, it is difficult for farmers to tell them apart), and accelerated technological change (because in just four years, GM events have been incorporated into hundreds of hybrids). The constant turnover of technology makes it hard for farmers to keep up with the skilling needed to develop a working relationship with each new seed variety. In this way, Stone (2007) shows how the relationship between farmers, their seed and the wider environment has been altered over time through the introduction of GM seed in Warangal. Looking at rice, cotton and vegetables, Stone & Flachs (2018:3) argue that farmers' "knowledge and commodification are inversely related", as commercial seed disrupts farmers' knowledge. They also argue that it disrupts social relationships between farmers that would have shared seed, the relationships that tie farmers to place and ecological skills (Stone & Flachs, 2018:3).

The literature on agricultural deskilling is conceptually important in this thesis. It provides a lens through which to explore how seed technologies can contribute to disruption in the skilling process of farmers. In addition to its impact on farmers' knowledge, the concept of agricultural deskilling has not been utilised to explore the impacts of changing seed technologies on agricultural knowledge and skills within agricultural R&D. As yet, the concept of agricultural deskilling has not been used in the literature to explore the displacement of skills within the R&D context. This is because the available literature on agricultural deskilling focuses on skilling predominantly in relation to farmers. As such, agricultural deskilling is adopted in this thesis as a concept that can be used both on farms and in R&D institutions to look at how relationships and knowledge between farmers and scientists and the agroeosystems within which they work have shifted or become displaced in relation to changing seed technologies. Consequently, given the specific interest of the thesis in socio-ecological knowledge and moving beyond an anthropocentric lens, it expands its conceptual scope beyond the literature on agricultural deskilling. This additional conceptual literature is outlined later in this review.

Despite the profound effects conventional hybrid seeds have had on agriculture globally, unlike with GM seed, the introduction of hybrids did not require risk assessments that were prescribed by regulation. As a result, this happened in an ad hoc way. The introduction of hybrid seed technologies perhaps came at a time in which the hegemony of science, scientific method and its objectives was rarely questioned (Roosth & Silbey, 2009). Prior to and during the introduction of GMOs in the 1990s, a great deal of controversy surfaced because of the perceived novelty of recombinant DNA and the wide range of possible safety concerns (Herroro, Wickson & Binimelis, 2015). The next section of this review looks at the assessment of the impacts of GMOs in the global literature.

2.2.4. Assessing the impacts of genetically modified seed

The introduction of GMOs broadened the debates concerning the introduction of seed technologies into agricultural systems and incorporated the idea that their impacts and associated risks should be systematically assessed. This resulted in the development of a web of both international protocols and national regulatory policy (Binimelis & Myhr, 2016). The Cartagena Protocol on Biosafety (CPB), an agreement made under the Convention on Biological Diversity (CBD), was adopted in 2003. This international agreement aims to guide the handling, transportation and use of living modified organisms (LMOs) resulting from modern biotechnology. It acknowledges the potential adverse effects on biological diversity, also taking into account risks to human health (Secretariat of the Convention on Biological Diversity, 2000).

Initially led by the CPB, studies of the potential impacts of GMOs focused mainly on either environmental- or health-related concerns (Herrero, Wickson & Binimelis, 2015; Binimelis & Myhr, 2016). In recent years there has been growing pressure to incorporate broader considerations into assessment frameworks (Binimelis & Myhr, 2016). One aspect that has been deemed important is the consideration of the socio-economic impacts of GM technologies. According to the Interorganizational Committee on Guidelines and Principles for Social Impact Assessment, socio-economic considerations include 'the consequences to human populations of any public or private actions that alter the ways in which people live, work, play, relate to one another, organise to meet their needs and generally cope as members of society' (Binimelis & Myhr, 2016:62). The term also includes "cultural impacts involving changes to the norms, values, and beliefs that guide and rationalise their cognition of themselves and their society" (Binimelis & Myhr, 2016:62). The AdHoc Technical Expert Group on Socio-Economic Considerations of the CBD suggest five dimensions of socio-economic assessment, including economic, social, ecological, cultural/traditional/religious/ethical, and human health-related (Binimelis & Myhr, 2016:62).

Binimelis & Myhr (2016) explore how these considerations have been operationalised in Norway, which is one of the first countries in the world to broaden impact assessments in this way. However, a review of recent literature by Catacora-Vargas et al. (2018) suggests that there is still very limited empirical research on the socio-economic impacts of GM crops within the literature globally. They explain that the main focus is still on economic aspects with "few empirical studies on social and non-monetary" aspects (Catacora-Vargas et al., 2018:489). Furthermore, they suggest that local contexts and the particularities of different cultures of agriculture are still rarely included. Instead, studies on impacts tend to make generalisations that end up being transferred across widely different contexts. Another observation is that the literature tends to compare the impacts of GMOs to conventional farming, rather than to other "substantially different agricultural systems" (Catacora-Vargas et al., 2018:489). This in itself reflects the dominance of dualist modernist science-based assessment approaches that tend to take conventional farming as a benchmark (Hererro, Wickson & Binimelis, 2015). Overall it is clear that socio-economic assessments are still very limited and methodologies to improve them are needed (Hererro, Wickson & Binimelis, 2015; Catacora-Vargas et al., 2018).

2.2.5. Towards the assessment of GM technologies in complex socio-ecological contexts

A number of scholars have pointed out the unique nature of GM crops, which makes assessment of them complex (Herrero, Wickson & Binimelis, 2015:11322; Goodman, 2001). Since their introduction these seeds have caused great controversy, as they appear to exist in a realm that is not natural nor purely cultural/human-made but rather somewhere in between (Goodman, 2001). As Goodman (2001) explains, these new seeds have necessitated asking new questions to understand more deeply what risks they might pose within complex ecosystems and within the socio-cultural fabrics in which they work. Herrero, Wickson & Binimelis (2015:11322) describe GM seeds as complex "hybrid techno/organisms" and suggest that due to this nature, they need to be assessed in ways that can accommodate this complexity (Herrero, Wickson & Binimelis, 2015:11322). However, the standard tool of risk assessment has shown itself to be very limited in its "ability to address the panoply of concerns that exist about these hybrid techno/organisms" (Herrero, Wickson & Binimelis, 2015:11322). They argue that rather than focusing on narrow impacts (such as the impact on one species or aspect of human health), assessments need to try to incorporate the 'material networks of relations' surrounding seed (Herrero, Wickson & Binimelis, 2015:11322). Here Herrero, Wickson & Binimelis (2015) draw conceptually on science and technology studies (STS) and Actor–Network Theory (ANT) to assert the importance of viewing technologies in a more relational way.

From the 1970s STS and the field of postcolonial STS (PCSTS), which introduced a critique positioned from the global South, emerged to challenge the hegemonic status of science and its technologies, which have created unprecedented changes in the environments into which they have been introduced. STS theorists have argued that science, like any knowledge system, is cultural and not devoid of values and systems of power (Harding, 2009). Drawing on this work, Herrero, Wickson & Binimelis (2015) make a series of important observations about what has been omitted in the study of the impacts of GMOs. Three of these observations are particularly useful for the framing of this thesis. The first is that the assessment of GMOs has failed to really account for “scientific uncertainties, paradigms and values in the development of knowledge” (Herrero, Wickson & Binimelis, 2015:11322). The second is that studies have not widely addressed the “domineering or hubristic relationship between humans and nature that GMOs perpetuate” (Herrero, Wickson & Binimelis, 2015:11322). Lastly, ‘competing narratives of development and diverging visions for the role of the bioeconomy and the future of agriculture’ (Herrero, Wickson & Binimelis, 2015:11322) have not been significantly addressed.

While the importance of understanding the impacts of GM seed technologies is now widely recognised, this review shows the dualistic nature of the study of these impacts; these studies look at either social or ecological impacts but rarely at the impacts on socio-ecological relationships and knowledge. Given the lack of attention that has been paid to the socio-ecological impacts of GMOs, this thesis aims to contribute to broadening this area of research. Attention to the socio-ecological is a way of attempting to move beyond the three omissions identified by Herrero, Wickson & Binimelis (2015) above. A focus on changing socio-ecological knowledge requires attention to how relationships between humans and the agroecosystems are co-created and are fluid, and how newly-introduced seed technologies become part of this co-production, thus shifting relationships.

While the gap concerning socio-ecological impacts on relationships and knowledge is globally relevant, this thesis suggests that it is extremely important in the context of the global South. In this context, agricultural development programmes such as the Green and Gene Revolutions, modernist and, by extension, dualist interventions have greatly affected farmer knowledge and practices that were underpinned by place-based relational practice and engagement with agroecosystems (Zuma-Netshiukhwi et al. 2013). Yet critiques of modern seed technologies in this context rarely look at the effects of these technologies on socio-ecological knowledge and relationships.

The next section of the review explores the local context of this study, by reviewing how modern maize seed technologies have been assessed in South Africa. This is followed by a review of the conceptual literature that is used to further this study.

2.2.6. The impacts of modern maize seed in South Africa

Maize, while not indigenous to South Africa, has been part of the country's Indigenous agricultural systems from as early as the mid-sixteenth century (Jeffreys, 1954; McCann, 2007). Since its arrival on South African soil, it became integrated into traditional farming practices, which relied on what would today be described as agroecological principles. It is well-known and documented that maize became embedded in the systems of intercropping used by Indigenous farmers (Burtt-Davy, 1914; van Onselen, 1996). When colonial settlers arrived they, too, adopted the growing of maize as part of their farming systems, relying, as Van Onselen (1996) shows, on Indigenous farming knowledge, because they had no understanding of how to grow food in South African soils and climates (van Onselen, 1996). Burtt-Davy (1914) also illustrates the interest maize attracted from settler farmers. During the early 1900s maize was identified as a key commercial crop for settler agriculture and the boosting of its yields became a priority. Later, from the 1940s, hybrid maize started diffusing into South Africa's agricultural systems (Greyling, Vink & van der Merwe, 2018). This seed was adopted enthusiastically by white commercial farmers seeking to boost yield and profits, becoming a vital area of agricultural research and development. During apartheid (see chapter six), hybrid maize came to be integral in political and economic visions. By the late 1970s, 98 percent of maize grown commercially was hybrid maize (Greyling, 2019).

Similar to the global literature, the impacts of conventional hybrid maize seed technologies are not widely explored in the South African context. However, GM maize received lots of attention when it entered South Africa in the late 1990s. South Africa was the first country to approve the use of GM crops for smallholders and, in particular, to approve the use of a GM staple crop (Gouse, Pray & Schimmelpfennig, 2005). This meant that this process received both widespread local and global attention. South Africa became a key case study site globally for researchers and countries interested in understanding more deeply the risks of these technologies.

2.2.7. The impacts of genetically modified seed in South Africa

Unlike with conventional hybrids, when GMOs entered South Africa, they did so in a global climate that was highly attuned to the controversies of this technology. However, they also arrived into a new democracy enthusiastic about building into its policy and strategy the prospect that science and technology would play a major role in rebuilding a deeply fractured and unequal nation. While heated debates on the safety of releasing GMOs took place across the globe, South Africa approved the commercial release of GM crops. Alongside their introduction in South Africa, a large amount of literature emerged supporting their uptake (Thompson, 2002; Gouse, Pray & Schimmelpfennig, 2005; Gouse et al., 2006). GMOs were put forward as a silver bullet solution to a multitude of complex problems, including poverty reduction, boosting food security and reducing hunger, reducing the use of pesticides, as well as helping smallholder farmers out of historical marginalisation (Thompson, 2002; Gouse et al, 2005; Gouse et al., 2006). In response, there was an expansion of the literature critiquing GMOs and warning of their potential dangers (Pschorn-Strauss, 2005; Mayet, 2007; Scoones, 2008; Wynberg & Fig, 2013). Over the last two decades, increased attention has been paid to the risks and benefits of introducing GM maize into South African farming systems and landscapes. Similar to the global trends, however, these studies only narrowly assess social and economic impacts on human health (Gouse, 2012; Abidoye & Mabaya, 2014), or ecological risks and benefits (Department of Environmental Affairs, 2012). Few move beyond this dualistic approach to explore the relational socio-ecological dynamics that emerged with the introduction of GM maize into South African farming systems.

In addition, little research in the South African context explores the specific effects of GMOs on agricultural knowledge systems. As such, this thesis is particularly interested in assessing the impacts of GM seed on agricultural knowledge, both that of smallholder farmers and scientists within R&D, which it sees as intrinsically based on socio-ecological engagements developed over time (van Dooren, 2012).

2.2.8. The impacts of GM maize on smallholder farming systems in South Africa

A significant and growing number of studies have explored the presence of GM crops in smallholder farming contexts in South Africa since the mid-2000s. As previously stated, this is predominantly due to the fact that South Africa was the first country in the world to approve GM crops for a staple crop grown in smallholder production (Gouse, 2012). This meant the experiences of smallholders was of great interest to decision-makers in other countries who were tasked with approving the use of GMOs (Gouse, 2012).

The literature on smallholder use of GM seed in South Africa can be divided into two bodies: firstly, those that view GMOs as beneficial and support the use of GM seed for smallholder farming and, secondly, those that argue against their applicability and appropriateness in this context. The former, prominent in the early 2000s, argue for the use of GM seed in the smallholder context from an economic angle (Thompson, 2002; Gouse et al.,2005, 2006). The focus of these studies is on the potential of GMOs to raise smallholder yields and profit and therefore reduce poverty. The latter aims to look beyond a narrow, economic and yield-centred focus and instead to assess more broadly the impacts of GMOs in smallholder farming environments.

During the latter part of the 2000s, there was increasing recognition that the adoption of GMOs by smallholders was not as widespread as anticipated. Ten years after their introduction, Gouse, Kirsten, & van Der Walt, (2008) reported that only approximately 10 500 farmers (about 23% of smallholders in the country at the time) planted GMOs in the 2007 season (Gouse, 2012:164). At this time, the area of research focused on socio-economic and socio-cultural impacts associated with the introduction of GMOs began to expand, partly to understand the social and economic reasons for the low levels of adoption. An increasing number of these studies critiqued the appropriateness of GM maize for smallholder farmers when taking into account wider socio-economic and socio-cultural considerations (Assefa & Van den Berg, 2010; Hendrickson et al., 2014; Fischer & Hajdu, 2015).

Assefa & Van den Berg (2010), in a study of the adoption of GM maize by smallholders, show how informed choice is rarely involved in smallholder farmers' decisions to adopt GM seed. They found that rather than specifically choosing GM seed, farmers selected the seed because of other factors. These factors included "incentives from projects, the tying of adoption to credit programs, prestige, participation in seminars/tours and the availability of a seed market from projects promoting the technology" (Assefa & Van den Berg, 2010:221). Mahlase (2017) found this to be true in her own research, arguing that farmers' 'choices' to adopt GM maize were influenced by a range of factors, most notably institutional influence. Both these studies also point to how farmers within their study sites were often unsure about the difference between hybrids and GMOs (Assefa & van den Berg, 2010; Mahlase, 2017). Fischer & Hajdu. (2015) also drew attention to the fact that farmers were not always aware of the difference between conventional hybrids and GM seed. This is a common problem that has ethical, as well as significant technology management and safety, implications (Assefa & van den Berg, 2010). Assefa & Van den Berg (2010) found that the farmers they interviewed were in general not using refugia (a section of non-GM maize planted alongside GM maize), noting that this could lead to the development of stem borer resistance, which could have devastating consequences for those farmers and also those wider afield. They questioned whether GM cultivation can be used in smallholder farming systems where "maize is grown in small fields either mixed with or planted close to other crops" (Assefa & Van den Berg, 2010:221). This consideration is important because while it is not the key focus of the study, it is an attempt to contextualise the use of these technologies within a wider agroecological knowledge system. Here, Assefa & Van den Berg (2010) acknowledge what may be lost through the introduction of GMOs and the resultant need to develop new planting methods.

Framed using a livelihood perspective, Fischer & Hajdu (2015:305) point out that "the narrow focus on raising yields" of development projects such as the Department of Agriculture's Massive Food Production Programme (MFPP) is problematic, as it does not take into account" the wider livelihoods situation" in which farmers are working and living. Economic-centred projects and assessments tend to treat farmers as passive recipients of technologies rather than agricultural practitioners working in complex agricultural systems. Fischer & Hajdu (2015:312) suggest that rather than simply narrowly focusing on improving crop yields, more attention needs to be paid to understanding the "knowledge, needs and practices" of smallholder farmers, whereby other forms of assistance could prove much more beneficial than intensive inputs. Fischer & Hajdu (2015) argue that GM maize has not benefited smallholders and is not useful for their needs. They suggest that GM seed is therefore inappropriate for smallholders (due its to cost and the generic nature of the technologies that have been developed for large-scale commercial farming), and that rather than trying to make GM seed more appropriate and accessible, government money would be better spent on developing less costly, stress-tolerant OPVs for smallholders, and supporting such research and development initiatives.

A study by Iversen et al. (2014) explores the long-term socio-economic and ecological impacts of transgene introgression (the crossing of GM crops with nearby non-GM crops via pollen drift) into locally recycled seed in smallholder farming systems in the Eastern Cape. Their findings show that due to seed-saving practices and farmers' general unawareness of the problem of transgene introgression, it was common for GM traits to have spread. This study, while primarily based on scientific research, draws on the socio-ecological dimensions implicit in any farming system, demonstrating how one cannot separate them when thinking through the impacts of newly-introduced seed technologies.

Hendrickson et al. (2014:666) draw attention to the marginalisation of smallholders in terms of "their access to land, their knowledge of improved maize production practices, their involvement with extension services, and in their access to markets, both for inputs and for surplus production". They argue that there is a need to incorporate the voices of smallholders in assessing the utility of GMOs, which is rarely done. They suggest using a community of practice as a method by which to incorporate the views of smallholders and assess questions concerning how new seeds may be "adapted to smallholders" ecological, social and economic contexts' (Hendrickson, et al., 2014:665) so that smallholders and policy-makers can make better decisions. This paper is unique within the local literature, because it asserts the importance of smallholder knowledge and incorporating this in the assessment of GMOs.

As shown above, there has been an expansion over the last decade of literature concerned with smallholder GM maize production in South Africa. Over time this literature has looked at economic, social, and ecological impacts. However, there is little that documents the specific impacts on socio-ecological knowledge, practices and relationships between agroecosystems and smallholder farmers in South Africa.

The first part of this literature review has described the history of modern seed development and how the effects of these seeds have been explored over time. It has shown how, while studies on the effects of modern seed technologies emerged in the 1990s when the impacts of conventional hybrids began being acknowledged in the deskilling literature, the impacts of GM seed drew widespread interest. However, despite the prolific literature on the subject of the impacts of GM seed, most studies look at the effects of new technologies through a dualist lens, resulting in social and ecological impacts being studied separately. The binary is deeply entrenched in industrial agriculture and Green Revolution-based approaches to agricultural development, which focus on yields and profit (Goodman, 2001; Schnurr, 2019) by "putting nature to work" (Moore, 2015:2;). Arguably, this dualism obscures the importance of studying the socio-ecological effects of modern seed technologies, which are under-explored. In failing to question socio-ecological impacts of seed technologies, the hegemony of modern science-based approaches to agricultural development and their effects on other ways of knowing is limiting and cannot be unpacked.

While there is a growing body of literature on the effects of modern seed on farming, little of it looks specifically at the R&D systems and the impacts of changing seed on scientific knowledge, which has also been affected by the introduction of GM seed. This blindspot in the literature reveals something about the nature of agrifood studies, which tend to focus on continual progress, rarely slowing down to look at itself. The fields of STS and PCSTS draw attention to the need for scientific spaces to be more reflexive, to interrogate their ontological standpoints and how these become embedded in their technological outputs and knowledge production and go out to have real effects on the world (Harding, 2009). There is a need to interrogate the kind of science being produced and the systems it upholds and perpetuates. This thesis suggests that if the knowledge of farmers is to be investigated so too should the knowledge of scientists, as these systems are in constant, often deeply conflicted, relation. Within this set of relations, it becomes necessary to question the politics of knowledge, what kind of knowledge is prioritised and marginalised, and what the effects on the future of agricultural knowledge and, ultimately, socio-ecological wellbeing are. The next part of this literature review provides an outline of the conceptual literature used in this thesis in order to think through these questions, exploring the impacts on socio-ecological knowledge, the practice of farmers and scientists, and the relationships of knowledge between them.

2.3. Conceptualising knowledge systems

This thesis draws on conceptual literature concerned with the politics of knowing (epistemology) and being (ontology) in the world. An overall theme of this literature is that of de-centring the modernist conception of reality that took root in Europe in the

Enlightenment period, and that has underpinned colonialism and capitalism, perpetuating coloniality into the present (Merchant, 1980; Bhambra, 2014). This thesis draws on STS, PCSTS, decolonial theory and posthumanist theory, all of which stems from varying concerns, spatial and political contexts, and intellectual fields (Lyons et al., 2017:1). Different authors argue important positions on the divergences and overlaps between these fields and this is a subject of widespread debate in the current literature (Grosfoguel, 2007; Mignolo, 2011; Bhambra, 2014; Atanasoki and Vora, 2015; Schultz, 2017; Subramarian et al., 2017; Zembylas, 2018). Drawing inspiration from Lyons et al., (2017:5) this thesis aims to 'teeter' on the edge of these boundaries, learning from their overlaps and differences so as to help think through the central interests and questions in this thesis, which is twofold: firstly, to explore and conceive of the effects of modern seed technologies beyond a dualist (social or ecological lens) to better understand their impacts on socio-ecological knowledge and relationships within agroecosystems; and secondly, to reflect on the effects of these technologies over time and on collective agricultural futures. Related to this is the need to consider how focusing on the socio-ecological might bring to light alternative pathways that restore socio-ecological wellbeing and justice.

Limited space does not allow for adequate summaries of these complex bodies of literature and thought; however, the following section introduces each and explains what parts draw relevance for this thesis methodologically and conceptually. Figure 2.2 depicts the relationships and connections between these bodies of literature, which are deeply connected and flow into each other like a web, rather than in any linear form.

FIGURE 2.2: Diagram showing relationships between conceptual literature used in this study.

2.3.1. The ontological turn: decentring modernist Eurocentric conceptions of reality

Shaped by a growing scholarship and activism from the global South, literature from recent decades is increasingly concerned with off-setting the Western domination of knowing and understanding the world (Bhambra, 2014). While this scholarship comes from diverse fields, the ontological turn is a useful concept for understanding the shift in theoretical lens (Holbraad & Pedersen, 2017). As Baker (2019:1) explains, work affiliated with the ontological turn "suspend[s], alter[s] or replac[es] the conceptual presuppositions that made and maintain modern, technological rule over the real".

Scholars across the social sciences have grappled with the concept of modernity and how it impacts socio-ecological relations and the wellbeing of all life on the planet. Modernist thought is associated with the post-Enlightenment period in Europe. This saw a growing trust in modern science as a tool for understanding reality, the rise of industrial capitalism, imperial and colonial domination, and a perceived divide between humans and nature (Murphy, 1992; Harraway, 1991; Latour, 1993; Merchant, 2006; Mignolo, 2000). Ecofeminist philosopher Caroline Merchant (1980) explores how the narrative of the scientific revolution and ideas of progress deeply transformed relations with the earth from organic to increasingly exploitative in the name of progress and efficiency. The philosopher Bruno Latour (1993:47) describes modernity as enacting a "purification" of reality, by separating the world into dualisms – nature/culture, subject/object, and social sciences/natural sciences. What followed was a reshaping in the West of ideas of man's place in the universe and in relation to nature. Underpinned by colonial expansion, the idea that human beings are above nature and that the West is the pinnacle of civilisation began to take root and develop with the growth of economic and political expansion into the global South (Mignolo, 2000). Sociologist and decolonial theorist Aníbal Quijano (2007) refers to the ongoing-ness of this mode of thinking as modernity/coloniality, which is a fundamental concept in the field of decolonial theory (Mignolo, 2000, 2001; Bhambra, 2014). Philosopher and semiotician Walter Mignolo (2011), explains that it is impossible to conceive of modernity without colonialism, or of colonialism without modernity, and that the two were co-constituted. Sociologist Jason Moore (2015) argues that imperialism and capitalism could not have taken place without the fashioning of the modernist concept of nature as something separate from man that could then be exploited for the benefit of some humans through the subjugation of others. This unravelling of the concept of nature as something separate from humans underpins posthumanist scholarship, which works to move beyond this dualism by drawing on non-dualist understandings of socio-ecological connectedness (Bird Rose et al., 2012).

Modernist thought and knowledge production including modernist science (that assumes to be able to capture reality) fails to reflect on its own assumptions, and how it imposes upon the world through producing particular relaties and shutting out others (Baker, 2019). The ontological turn has encouraged the interrogation of disciplines of knowledge creation from science to anthropology, asking them to be reflexive about how knowledge has been perceived and created, and the effects this has had on the world (Baker, 2019; Kim, 2019). Modernist science is a key area in need of this kind of interrogation. It is within this space that STS and, later, PCSTS emerged in the 1970s to question the hegemonic place modernist science has come to assume in the world and bring in other ways of knowing that have been marginalised through modernity (Bhambra, 2014).

As shown above, understanding modernity, the name given to the period and process of world-making, is vital for the discourses that have emerged to challenge and offer alternative ontological positions to it. In the literature that follows, modernity takes a central position in discussions concerning how to offset the dualist thought that has become globally dominant over the past 500 years, subjugating other ways of knowing the world and mediating relationships between people and all other life.

2.3.2. Science and technology studies and postcolonial science and technology studies

Today science is often conceptualised as an established field; however, this status involved a process of world making in which science came to be viewed as a coherent entity (Roosth & Silbey, 2009). By the 1930s science was considered as a "bounded activity" that was based on a "value free" and "amoral" method that was vital for "human progress" (Roosth & Silbey, 2009:454). The idea that science was timeless, universal and irrefutable, and was assembled by building on "scientific facts" that could be reached via the scientific method became widely accepted (Roosth & Roosth &

Silbey, 2009). It was thought that these facts could be separated from the realm of social and cultural knowledge, which were instead considered the business of the social sciences (Roosth & Silbey, 2009).

By the 1960s social scientists had begun to question the supposed immunity of modern sciences from the complexities of the social world (Roosth & Silbey, 2009). The historian Thomas Kuhn in his classic work *The Structure of Scientific Revolutions* (1962), published long before STS had a name, questioned the progressive accumulation of 'rational' modernist scientific knowledge. In Kuhn's work and in the work of those inspired by it, science is seen as providing not a whole truth but, rather, a set of partial truths that may be considered truthful by those who hold views that align with them (Khun, 1962; Sismondo, 2011). Thus science cannot be a "transcendent mirror of reality" (Jasanoff, 2004:3), nor can it be neutral or rational; rather, it reflects particular ideologies, power structures and societal beliefs (Biagioli, 1999; Jasanoff, 2004; Harding, 2009). Anthropologists such as Donna Haraway (1988), Sharon Traweek (1993) and others began to explore the idea that science itself is a culture, a social activity that could be studied. Using ethnographic research in laboratories through observing the work of scientists they showed how scientific knowledge and inquiry could not exist outside of a community of people with norms and standards (Franklin, 1995; Sismondo, 2011).

The assertion of science as cultural also brought into question science's claims about universality. Another area that STS theorists have explored is how technologies fashioned within the realm of modernist science affect the worlds into which they are introduced (Sismondo, 2011). Escobar (1995) uses the idea of "technoscapes" to explore how new technologies are taken up and "culturally negotiated" (Franklin,1995:174). The impacts of technologies and products of science in the real world once they leave the controlled, sheltered environment of the laboratory is therefore an important area of focus within STS. Theorists argue that creations of science and technology are released into the world where they interact with other contexts, cultural arrangements, ecological systems and ontological frameworks. They then go on to cause effects and create interactions, as technologies cannot be regarded as inert (Harding, 2009).

STS is important in this thesis, as it offers a way to think about the field of agricultural science in South Africa as a cultural space that reflects the ideas and interests of the society and the systems of power that shape it. It also helps to conceptualise technologies as agents of change that, when introduced, interact with all other actors – both human and non-human – thereby altering relations and pathways. This is useful both conceptually and methodologically – conceptually, in terms of positioning new seed technologies within a cultural discourse, rather than simply being a logical product of scientific progress; and, methodologically, as it provides a basis for thinking about seed technologies not only as static objects but, rather, as agents in a wider system of both human and non-human actors (Goodman, 2001; Herrero, Wickson & Binimelis, 2015). This, alongside posthumanist theory and multispecies ethnography (discussed later), informed the lens of this thesis, which sought to look closely at the entanglements between human actors and the more-than-human world.

Over the past two decades, PCSTS has endeavoured to reframe STS from the context of the global South in which science and technology have a particularly difficult history (Harding, 2009). The origins of postcolonial theory are often attributed to Edward W Said, Homi K Bhabha, Gayatri C Spivak and Dipesh Chakrabarty (Chakrabarty, 2000; Bhambra, 2014; Seth, 2017). Particularly within academia, Said's work on Orientalism 'opened up the question of the production of knowledge from a global perspective' (Bhambra, 2014:116), showing how Western modernity has used constructs of "other" in its making and understanding of the world (Bhambra, 2014:116). In reaction to Western representations of the global South and constructions of modernity, PCSTS theorists worked to rewrite STS from the perspective of the global South (Bhambra, 2014). As its name suggests, postcolonial theory emerged in reaction to questions of colonialism in a world in which decolonisation was taking place, but in which the effects of its violence were very much part of the present. Postcolonial theory questions discourses of modernity and development, which assume that modernist science should underpin modes of development in the global South.

Suman Seth (2017) identifies two prominent areas of PCSTS that are important for this thesis. The first critiques the effects of modernist science "on the bodies, environments and epistemologies of the third world" (Seth, 2017:65). PCSTS scholars show the sciences, played a significant part in shaping colonial power and control over people and landscapes (Fanon, 1952; Shiva, 1997; Anderson, 2002; Harding, 2009; Tilley, 2011).The second area is a body of PCSTS writing that pushed back against earlier writings that tended to frame Western science as completely separate to 'other' ways of knowing and, in doing, so hid the role that these other ways of knowing had in the development of scientific knowledge. Within PCSTS there is both a recognition of conceptual dualisms such as first world/ third world, global/local, Western/ Indigenous, modern/ traditional and the role these have had in shaping the world and human experience. However moving beyond this conceptual dualism by examining borderlines, margins, hybridity and overlaps is also a focus of interest. Focusing only on binaries can also obscure a more complex reality beneath that duality, for example how modernist science has drawn on Indigenous knowledge (Seth, 2017).This work has been vital for thinking through the relationships between scientists and their work, as well as between farmers' knowledge and the knowledge produced in the realms of science.

2.3.3. Decolonial theory

Similar to PCSTS, decolonial theory encapsulates the work of scholars from the global South in response to Eurocentric narratives of the global South and pathways to development (Bhambra, 2014). While postcolonial theory originated in the Middle East and South Asia, decolonial theory emerged in South America. Decolonial theory sees the development of modernist thought and colonialism as co-constitutive (Quijano, 2007; Rosenow, 2019; Mignolo, 2000). The concept of coloniality introduced by Quijano (1989) is vital to decolonial theory, as it is distinguishable from the term colonialism, which refers to an historically distinct political order or period that ended when states gained political sovereignty from colonists (Quijano, 2007; Rosenow, 2019). Coloniality, by contrast, is not defined by a distinct period but refers instead to the "extension of western Capitalism" and the associated western epistemology and ontology into the non-European world from the 15th and 16th centuries as modernity and colonialism took root (Rosenow, 2019; Mignolo, 2002:58-59). Coloniality did not end with the end of colonial rule but continues into the present (Quijano, 2007; Rosenow, 2019).

John Law (2015) uses the term "One-World World (OWW)" ontology to denote the modernist stance that there is one version of reality against which all other perspectives are measured (Law, 2015; Escobar, 2016). By contrast, a "decolonising ontology implies acknowledging that there are multiple actual "worlds" rather than just multiple perspectives on the "One World"" (Rosenow, 2019:82). Decolonial theorists actively engage with non-modern, non-Western realities in their own right, not just as realities to be compared with or added to Western versions, but to offset this Eurocentric construct entirely (Kim, 2019; Rosenow, 2019). This provides a powerful critique of often taken-for-granted modernist Western dualisms – a key one being the supposed binary between humans and nature (Kim, 2019). Decolonial theory is useful for this thesis because it provides a theoretical base from which to critique the historical dominance that modern and dualist agricultural science has come to assume over Indigenous relational knowledge through the periods of colonialism, apartheid and into present day capitalism.

Decolonial theory provides a conceptual basis for questioning the ability of modernist ontology in providing pathways forward in the face of the current global social-ecological challenges. As De Sousa Santos (2016:40) explains, a modernist ontology is not equipped to get us out of the social-ecological injustices it has created, and can only provide "weak answers" that do not "challenge the horizon of possibilities". Decolonial theorists assert that in order to move forward we need to be able to approach these questions from alternative epistemological and ontological places and from the understandings and experiences of scholars, activists and people from the global South. De Sousa Santos (2016:8) articulates this using three assertions 1) the understanding of the world is much greater than that which fits within 'Western' rational-based undertakings; 2) given the history of epistemicide and the problems of dualist Western thought, social justice cannot be achieved without cognitive justice; and 3) transformation will require new maps or ways of engaging in the world beyond those based in a Western-centric critical theory. This thinking provides a basis for challenging Western modes of development based on modernist ideas of rationality and progress. De Sousa Santos (2016) highlights the South American concept of *buen vivir*, which translates as "good living, or collective wellbeing according to culturally-appropriate ways", and moves beyond just human interests to incorporate the value and rights of nature (Escobar, 2016:25).

Decolonial theory is useful in this thesis because it provides material with which to think with multiple ways of knowing the world. This is particularly useful when thinking about the relationship between the knowledge of farmers and scientists, and about each of these bodies of knowledge in their own and connected existences. Furthermore, it is useful in helping to bring about understanding of the role that binary categories have within coloniality as categories of power and under which great injustices have and continue to occur, as well as insights into how to move beyond the dualist categorisation of life, which does not fit into binaries.

Decolonial work is useful when thinking about how to move beyond the hegemony of modernist agricultural science-based knowledge, in the context of perceptions of GMOs in South Africa. A decolonial approach creates space for the knowledge of farmers and of scientists to be placed side by side, through the acknowledgement of the politics of knowledge between and within each, and offers a space within which to pay attention to both realities and the relationships between the two.

2.3.4. Posthumanism: beyond the nature culture divide

The connections between decolonial theory and posthumanism are complex (Rojas, 2016; Schutlz, 2017; Zemblayas, 2018). While in various ways these bodies of work relate to a wider ontological shift in social-ecological theory, there exist both similarities and frictions. Both work to challenge the domination of Western dualistic thought in which humans are conceived of as separate from and superior to all other life. However, this comes from different vantage points, with posthumanist theory emerging largely in the global North and decolonial theory coming from the global South (Schultz, 2017).

Posthumanist scholars problematise the assumed distinctions between humans and nature so central to modernist thought and Western understandings of the world (Whatmore, 2006). Posthumanist theory thus works to position humans as part of an interrelated set of processes and co-creations with all else. It also questions the divide between the natural and social sciences, which, until the last few decades, remained deeply entrenched (Whatmore, 2006). Moore (2015) argues that the concepts of 'society' and 'nature' are part of the problem, both intellectually and politically; the binary of Society/Nature is directly implicated in the colossal violence, inequality, and oppression of the modern world. Furthermore, the view of Nature as external is a fundamental condition of capital accumulation. Bruno Latour's foundational book within posthumanist literature, *We Have Never Been Modern* (1993), questions human separateness, exposing the illusion of our supposed progress through the domination of nature.

In many ways, this growing research interest has been fuelled by controversies that have emerged since the 1990s, such as nanotechnology, genetic modification and climate change, all of which blur boundaries between the social and the natural and require interdisciplinary engagement that moves beyond binaries (Whatmore, 2006).

Posthumanist scholars grapple with the ways modernist thought paved the way for setting humans and nature apart, and explore what it means to move beyond humanist/dualist perspectives to find new ways of living together, which might help us find new, lighter ways of living on this planet (Haraway, 2007). Anna Tsing, who states that "human nature is a multispecies relationship" (Tsing n.d.; see Haraway 2008:19) also calls for a deeper attunedness and understanding of the interconnectedness of human existence and wellbeing and of the lives of all 'others' on the planet who have been deeply impacted by (some) human behaviours. Posthumanist theory has contributed to the direction of this thesis conceptually and methodologically, in thinking through how to study socio-ecological meeting points beyond the binary of 'social' or 'ecological' within agricultural contexts dominated by dualism.

Importantly, this growing field of study has also been developed and challenged through a growing decolonial scholarship from the global South that draws attention to how Western, dualistic thinking came to be so dominant in the world order, and how it disregarded and violently subjugated other, more relational ways of knowing the world that offer an alternative, more sustainable way of life (Escobar, 2016; De Sousa Santos, 2016. Non-dualist philosophies – also referred to as cosmovisions – such as *Muntu* and *Ubuntu* in parts of Africa, and *Pachamama* or *Mama Kiwe* among South American indigenous peoples "reflect a deeply relational understanding of life" (Escobar, 2016:22).

While I have drawn on STS, posthumanism and decolonial theory, there are important tensions here that must be aknowledged. While STS and posthumanism may be able to speak to decolonial thought in useful ways there are also key differences to note between these bodies of work that have been pointed out by decolonial thinkers (Wynter, 2003; Rojas, 2016; Schultz, 2017; Zembylas, 2018), with some questioning whether the two theories are "commensurable" given these differences (Zembylas, 2018:254). These tensions are important to acknowledge so as not to mistake the methods and projects of this theory as the same.

Schultz (2017), explains how fields such as political ecology and by extension the theories used in this thesis, STS and posthumanism "adher[e] to research practices and paradigms that have been developed in the West" despite their attempt to work beyond the confines of western dualism (Schultz, 2017). Decolonial scholars draw attention to the category "human", which posthumanists argue needs displacing in the interests of offsetting anthropocentrism (Wynter, 2003; Zembylas, 2018). Yet in the posthumanist agenda to off-set anthropocentrism there can be a disregard of the complexity of what it means to be "human" in a world in which not all humans have been treated equally and in which some have, as Wynter (2003:262) expresses it, been "rung of being human". As Wynter explains, the category "human" cannot be generalised in theoretical work, as the "present ethnoclass (i.e. Western bourgoise) conception of the human, Man … over-represents itself as if it were the human itself" (Wynter, 2003:260). In over-representing human/man in this way there is a disregard for "the Racism/Ethniscism complex, on whose basis modernity was brought into existence" (Wynter, 2003:264).

Further, it is only some humans, and especially those operating in the paradigm of the modernist West, that have seen themselves above all other life (Wynter, 2003, de Sousa Santos, 2016; Schultz, 2017). This ontological difference is noted in decolonial work in which the hierachies of being embedded in coloniality are called into question and compared with "other" ways of knowing and being in the world (De Sousa Santos, 2016). The tensions between these bodies of work bring forth the question if it is in fact necessary to move beyond humanism or rather find new ways to move beyond a modernist scaffolding of what human means (Wynter, 2003; Schulz, 2017: Zembaylas, 2017).

Posthumanism and the work connected to it, has been important both conceptually and methodologically (see Chapter Three) to this thesis in relation to decolonial theory.

These approaches have not been utilised in South Africa in the agricultural context but provide material for thinking about the modernist and anthropocentric assumptions underpinning dominant agricultural practices and how this can be understood in different ways. As agriculture and the food system in general revolve around relationships with other species, this work offers a conceptual basis from which to explore nature-culture relationships and imagined 'contact zones' (van Dooren et al, 2016:13) within the R&D space and small-scale maize agriculture systems, and how these relationships have changed through time alongside changing seeds.

2.4. Conclusion

The first part of this literature review looked at how modern seed technologies have been studied globally and within the context of South Africa. This illustrated how, while modern seed technologies were rapidly adopted around the world from the 1930s onwards, it was only in the 1990s that studies emerged critiquing their impacts. When controversial GMO technologies were introduced in the early 1990s, a vast range of studies grappled with their possible impacts and effects. However, until recently, these studies have been largely dualistic in that they have studied social and ecological impacts separately. This thesis aims to work within this epistemological gap and, in order to do so, draws on a wide range of epistemological and ontological theory, which has been outlined above.

The second part of this literature review drew on a wide set of interdisciplinary literature connected to the epistemological and ontological turns within the social sciences and beyond. This work includes a number areas of study, including STS, PCSTS, decolonial theory and posthumanist theory. These areas of study possess specific strengths and points of focus, and are vital for the various conceptualisations of this study. STS and PCSTS provide a basis for thinking about the agency and politics of technologies, which are by no means inert and have the ability to create fundamental change in the social and ecological environments in which they are introduced. Furthermore, these technologies cannot be seen ahistorically, and they bring with them certain ideas and ontological bias. Posthumanist studies have inspired the methodology of this thesis in advocating for moving beyond the modernist human-nature divide that has until recently been so entrenched in academic knowledge inquiry and production. Decolonial theory furthers the theoretical work that challenges

Western modernist understandings of the world and of the category human in relation to all other life. In this thesis, this work is important for thinking through the relationship of knowledge between science and smallholder farming and the roles seed technologies have played in perpetuating systems of power and modernist knowledge bias. The next chapter introduces the research sites and presents the methodology used in this thesis.

FIGURE 3.1. Image of the footprints and markings of multiple species and tyre tracks on wet ground on a maize farm in the Eastern Cape. Source: Maya Marshak, 2015.

3. CHAPTER THREE: Research Design and Methodology

3.1. Introduction

The focus of this thesis is on the effects of new, maize-seed technologies on ecological knowledge within agriculture in South Africa. Although a multi-sited approach was used, exploring the entire maize agriculture system in South Africa was beyond the scope of this study. Given the particular interest in seed and changing ecologically-based relationships, knowledge and practices, two nodes stood out early on in the research process as being of particular interest: firstly, maize research and development (R&D); and, secondly, small-holder maize farming systems. These are both spaces in which agricultural knowledge and practice are generated and which change over time in relation to social, political, ecological and technological context. While both these spaces are important for the generation and continuation of agricultural knowledge, industrial, scientifically-based agriculture over time has become dominant, globally, in agriculture. Within industrial agricultural systems, a hierarchical relationship has developed between these spaces in which scientific knowledge often has come to be valued over the knowledge of farmers. For reasons explored later in this thesis, these areas of agricultural science and smallholder farming are often separated conceptually, geographically and in many ways ontologically. This divide makes the exploration of these spaces and the changing social-ecological knowledge and practice in both, as well as the interconnections and disconnections between them, of particular interest.

3.2. Study sites

3.2.1. Smallholder farms

The first node of research focused on smallholder farms. Data were gathered in Northern KwaZulu-Natal, in the uPhongolo Municipality. The study area was located near, and to the west of, the town of Pongola between the areas of FS2 and FS1 (See Figure 3.2). This area is predominantly rural with Pongola being the nearest town.

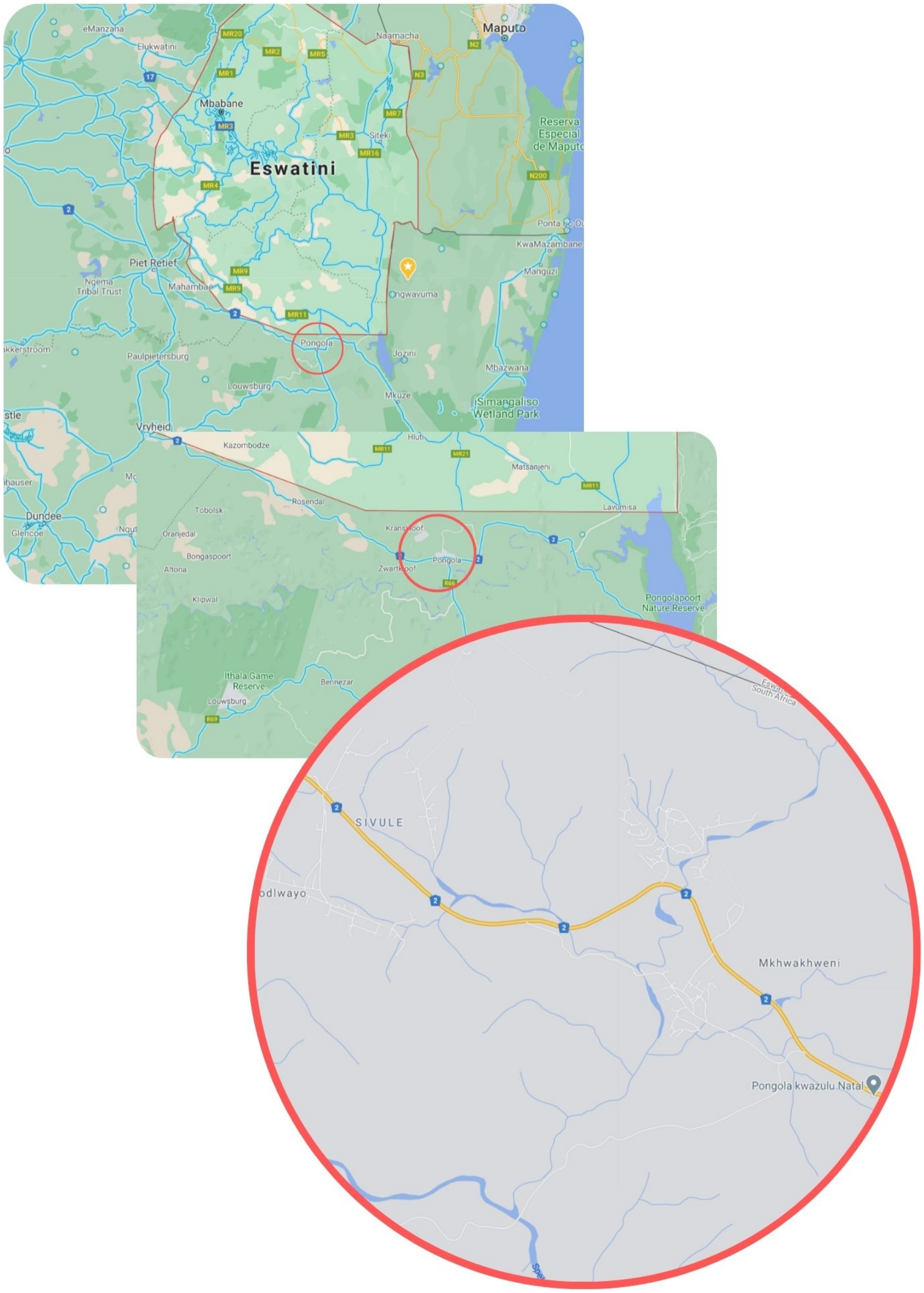

FIGURE 3.2: Maps showing location of research sites outside the town of Pongola on the border of Eswatini and South Africa. The red circled area shows the areas between FS1 and FS2 where the research took place. Source: Google Maps, accessed February 2021.

Unemployment rates were high in the municipality, with an estimate of 35.5% in the latest census (2011). Of 28 772 households, 11 545 were recorded as agricultural households, with 48% engaged in crop farming, or mixed farming including animals and crops. Pongola falls within the summer rainfall region of South Africa (See Figure 3.3).

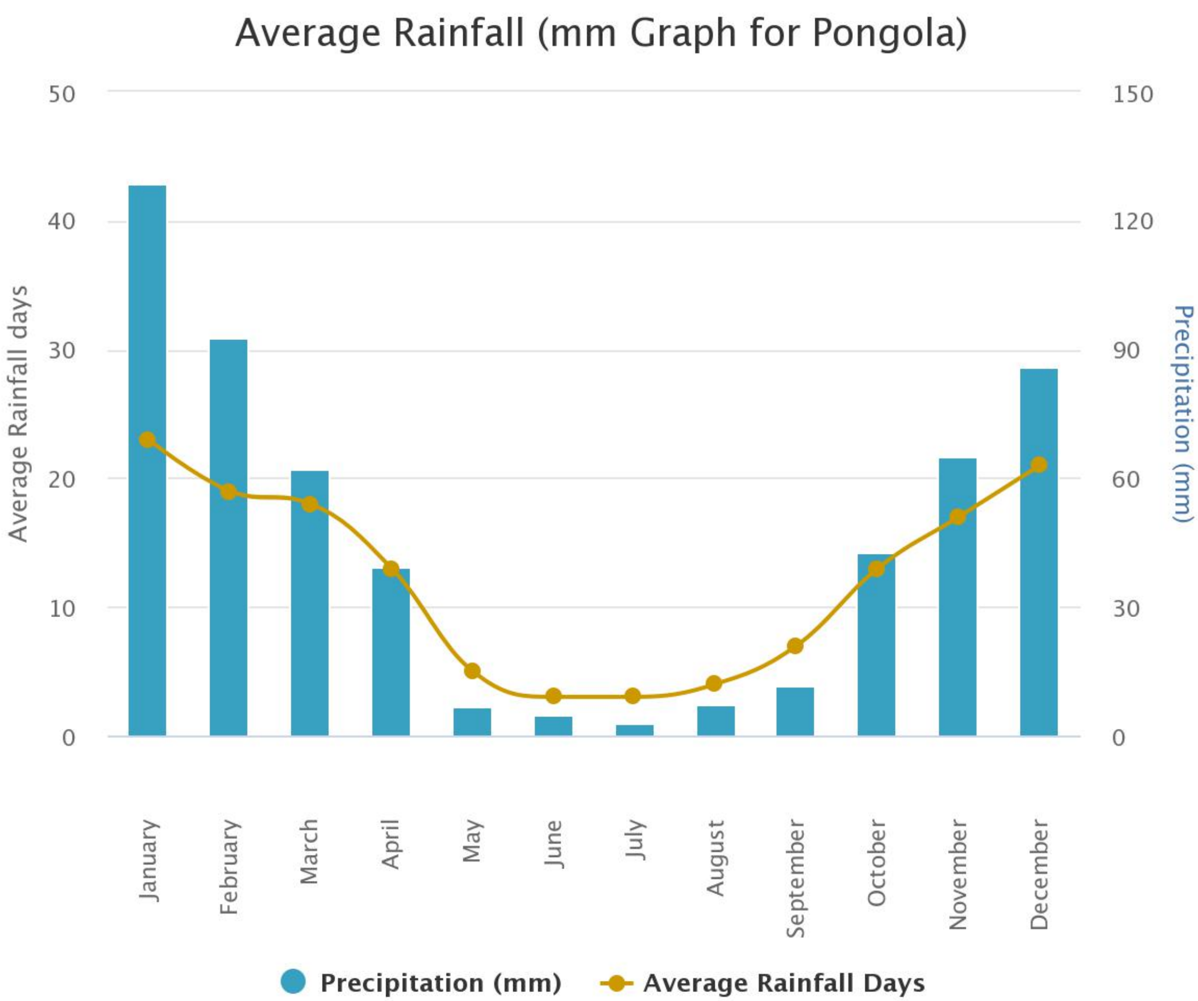

FIGURE 3.3: Graph showing average rainfall in Pongola. Source: worldweatheronline.com, accessed February, 2021.

This area was chosen because smallholder farmers use various types of maize seed, from heirloom maize, to store-bought open pollinated varieties (OPVs) to hybrid and GM seeds. The diversity of maize seed being planted in the area was important because the purpose of the study was to explore changing social-ecological relationships, knowledge and practices over time.

3.2.2. Research and development institutions

Maize R&D is not confined to a single geographical area but is conducted throughout South Africa and, therefore, the R&D component of research for this study took place at multiple sites. For this project, scientists, incuding agronomists, entomologists, weed scientists, plant protection scientists, and soil scientists, in Cape Town, Stellenbosch, Pretoria, Roodeplaat, Potchefstroom, and Pietermaritzburg were interviewed physically, and scientists in other locations were interviewed on Skype. Given the interest in R&D the scope did not include social-scientists however it could be important and interesting to expand the research in this direction in further work.

Maize R&D is now a global industry which includes government institutions, multinational and national, corporations and academic institutions. The maize R&D system in South Africa dates back to the late 1800s when the first private seed companies were established. In the early 1900s, the then colonial government had begun to set up experiment stations dedicated to research maize as a mono-crop (ACB, 2013).

Maize R&D consists of various branches, including the development of new cultivars for certain traits (incorporating GM traits), crop protection (research into how to protect maize from diseases, pests and weeds), and agronomy (how to boost maize production and success through farming techniques).

3.3. Concepts informing methods of data collection

In this study, seed is viewed not as a static object but as an actor that has come into being through 'complex environmental interactions in which many different communities of humans have played important roles for a very long time (but in which humans are definitely not the only actors)' (van Dooren, 2008: 681). Thus, when seed is altered, relationships between seed and the environment in which it is used change too. Since the purpose of this study was to examine ongoing changes in ecologically-based relationships, knowledge and practices, a methodology was required that lent itself to exploring processes over time and that was attuned to social-ecological interactions. The rationale was that this would allow me to ask questions and notice changes in relationships between humans, seeds and the ecological systems/multi-species environments in which they function over time. Given this requirement, an interdisciplinary approach that went beyond an anthropocentric perspective (which places humans outside nature) was important for the study. For this reason, a multi-species approach was adopted.

3.4. Methods of data collection

3.4.1 Multispecies ethnography

> We humans are suspended in many webs that go far beyond those of signification, in webs that human animals are far from alone in weaving.
>
> (Geertz, 1977 as cited in Tsing, Mathews & Bubandt, 2019:S187)

> The multi-dimensional crises of our times call for an anthropology, we propose, that takes landscapes as its starting point and that attunes itself to the structural synchronicities between ecology, capital, and the human and more-than-human histories through which uneven landscapes are made and remade.
>
> (Tsing, Mathews & Bubandt., 2019: S187).

Over the past decade, an effort has been made to move beyond an anthropocentric perspective in social research associated with post-Enlightenment thinking and modernism (Latour, 1993; Whatmore, 2006; Tsing, 2019). This area of study, with its focus on de-centring human exceptionalism, is referred to as posthumanism (van Dooren et al., 2016). Multi-Species Studies have developed out of this school of thought over the past decade. The methods associated with this perspective encouraged me to include and take notice of "non-human" actors in social science research (Kirksey & Helmreich, 2010). A multi-species study explores the overlaps and engagements between humans and all other life. multispecies studies offer an insightful way to think about, "think with" and rethink relationships between humans and the world around them (Harraway, 2003). As explained by van Dooren et al.

(2016:3), a “multispecies approach focuses on the multitudes of lively agents that bring one another into being through entangled relations”.

There is no clear set of steps for conducting a multispecies study, and it has varied significantly from study to study as researchers have attempted to apply it (Kirksey & Helmreich, 2010; van Dooren, Tsing, Matthews & Bubandt., 2019). However, a key feature is that this approach does not focus on any single organism (as animal studies do) but rather attempts to map a network of changing relationships between humans and other species within the context in which they live and/or work.

In this thesis, Posthumanist Theory and Multi-Species Studies were used to provide a conceptual framework for carrying out the field research and a way of becoming attuned to social-ecological relationships within the field research sites. The conceptual framework helped to direct research questions and observations towards where and how farmers and scientists were engaging in the ecological systems around them and how this had shifted over time. In the area of farming, this was conceptualised as farmer’s engagements with the agro-ecosystem (seed, soil, water, weather patterns, animals, insects, plants, and micro-organisms). In the area of R&D, this was conceptualised as researchers’ and scientists’ engagements with what was termed laboratory ecologies, or the ecological entanglements or worlds of seeds, plants, animals, and micro-organisms with which they engaged conceptually and physically in the laboratory, on test plots and beyond in order to carry out their work. These ecologies were conceptualised as partially overlapping in some way with the agro-ecologies that farmers encountered and worked with on a daily basis and the different ecological perceptions and realities were mapped as different, ecological worlds with overlaps and disconnects.

In addition to gathering qualitative data through interviews, visual and sensory data were gathered as a way to focus attention on human/more-than-human interactions in the field research areas visited. In this way, the meeting points between human actors and their subjects, collaborators, and “enemies” that came in the form of weeds, companion plants, beetles, worms, fungi, bacteria and other creatures within these systems were observed.

3.4.2. Overview of data collection methodology

3.4.2.1 Life-history interviews

Life-history interviews are a qualitative method of collecting data. The purpose of this method is to gain an understanding of a respondent's experiences over a period of their life according to a personal timeline. These interviews are often used to study processes that have happened over time in a particular place, or as they have been experienced by a group of people. The focus often is on points of change, such as how someone experienced something before or after a political shift or event. In the case of this study, transitions to the use of new seed were of interest. This kind of interview is subjective and is intended to help build up an understanding of a process or time in history. The interviews make it possible to map changes and important events over time (Roulston & Choi., 2018). Life-history interviews were used to gather data from the farms visited and from the research and development institutions. Since this method relies on respondents recounting their experiences, an effort was made to find respondents who had been farming or working in R&D for a long period of time and, thus, had seen and experienced many changes over their lifetimes. During the interviews, each participant was asked to describe how their work (farming or research) had changed over time, paying close attention to the seeds with which they were working and their interactions over time with non-humans and the ecological systems in which they worked. For farmers, the ecological system was envisaged to be the farm and area in which they worked. For scientists, this was envisaged to be the laboratories, test plots, and other places in which they worked.

The interviews were translated where necessary and transcribed. They were then printed and read over for emerging themes. On follow up visits I would go back and ask farmers and scientists again about the themes I had identified to try and gain more understanding and see if what I had picked up was valid and if participants identified with what I had seen. I further compared what I had found with existing related literature and studies.

3.4.2.2. Participant observation

Participant observation is a qualitative research method in which the researcher participates in activities within their study site. While this was not the key methodology used, in both study sites, I took part in various participatory activities. These included helping farmers to carry out daily tasks, or other activities that needed to be done, as well as attending farming-related meetings that were taking place in the community to which I was often invited. This led to opportunities for dialogue about the research topic as well as general daily life in the area. In the R&D institutions, i spent time observing where possible and, where permitted, assisting with experiments that were being conducted.

3.4.2.3. Visual data collection

> Visual technologies are changing the ways that [researchers] do research and opening up new possibilities for participatory approaches appealing to diverse audiences.
>
> (Pink, 2011: 439).

In addition to gathering qualitative data through in-depth life-history interviews and participatory observation, visual data were gathered for this study. This included taking photographs, making drawings, and collecting records of visual elements encountered in the research, such as models, posters and other items. These items, and the collection of them, were useful in a number of ways.

The visual/sensory perspective offered a way of being receptive to, and noticing, social-ecological relationships and possibly uncovering 'invisibilities' and hidden narratives that might not have been noticed otherwise. For example, in one R&D institution, I came across a badly lit cabinet containing a series of large models of maize pests. Pursuing an interest in these led me to the person who had made the models - a retired entomologist who was able to explain in detail how entomological research in maize agriculture had shifted over the years. Subsequently, scientists directed me to other artefacts, such as pinned insect collections or old fieldwork notebooks which offered valuable information about the focus of researchers in the past.

Secondly, visual elements, specifically photographs, were a useful tool with which to facilitate dialogue with participants. For example, during the research on farms, I photographed pests, weeds, seeds, maize cobs and other elements with which the farmers were engaging. Many farmers were unsure of the name of various pests but, when provided with an image of a stem borer, for example, they were able to share a great deal of information about it and its presence and management over the years on their farms.

Finally, collected visual materials were used to create a set of communication pieces based on the research. In 2018, the author collaborated with musician and sound artist Cara Stacey to make a hand-drawn animation titled In/Visibilties communicating the loss of insect and knowledge diversity of insects in agriculture. In 2019, the author collaborated with Zayaan Khan to bring a visual component to the Agroecology for the 21st Century Conference in Cape Town. The exhibition called Insecthibition featured a series of works by artists from South Africa working with insects to draw awareness of the threat they face and importance of these creatures in agriculture. A version of In/Visibilities was included in which the dancer Diana Ocholla danced as an insect with the animation of insects projected over her. The author also included a series of photographs of old agricultural entomology collections taken within the R&D institutions visited (See Figure 3.3(a) and (b)). The visual material became useful to facilitate interdisciplinary dialogue about the research. This material will also be used in feedback to research participants.

The specific methods used in each research node are explained in further detail in the following sections.

a

b

FIGURE 3.4(a): Photograph of a pinned brown veined white butterfly (*Belenois aurota*); and (b) pinned maize stemborers (species unclear) from an agricultural entomology collection of maize pests and other insects found in maize fields. These photographs were exhibited at Insecthibition to tell a story of a changing agricultural research and development system in which agroecological knowledge and relationships are becoming lost. Source: Maya Marshak.

3.5. Data collection on smallholder maize farms

3.5.1. Overview of methods used

Multiple, qualitative research techniques were combined during the field research in order to understand how the introduction of commercial seeds, and the related inputs and recommended farming practices, has shaped, affected and altered ecologically-based practices and knowledge of South African, smallholder maize farms. It is noted that this was just one case study and smallholder experiences throughout the country differ significantly from area to area.

Methods used to collect data from smallholder farms included semi-structured interviews with key informants, life-history interviews with farmers, and participant observation while assisting with farm-related activities, and attending agricultural-related events and farmers' meetings. The field research also involved doing transect-walks with farmers on their land. In this way, farmers were able to show what they were growing and explain their methods of farming in more practical detail. I was able to ask questions and the farmers were able to point out organisms such as weeds and pests. Extensive reviews of documents and material gathered from the provincial archives in Pietermaritzburg were also carried out. Finally, visual data were used as a tool for both data collection and communication. Photographs of various aspects, such as seeds, techniques, insects, and weeds were taken in the field. These, and images accessed from the internet, served not only as a form of data collection and record keeping, but also as reference points for farmers. For example, although farmers might not have known the name of an insect, they were able to speak about it having seen an image of it.

3.5.2. Scoping

Access to carry out research was facilitated initially by the NGO, Biowatch, who ran a project in this area. The aim of the Biowatch project was to train farmers in agroecology and to revive traditional seed and farming practices and, thus, promote local livelihoods and food security. The research in Pongola was carried out over a three-year period, involving 11 weeks of intermittent fieldwork between April 2016 – March 2021. In April 2016, myself and members of the wider Agri/cultures Project visited Pongola for a scoping trip facilitated by Biowatch to meet farmers who they were working with. A meeting was also set up with the department of agriculture and a group of farmers who were growing GMOs. Before starting interviews with farmers, I visited the research area again to attend various events linked to the NGO. In August 2016, I attended a local seed festival and a workshop in Pongola, attended by Biowatch affiliated farmers and seed custodians and researchers from the SADC region linked to the Seed and Knowledge Project (SKI). In March 2017, I attended a meeting between farmers working with the agroecology NGO and the local Department of Agriculture who had come to learn about their work. At this time, I also attended another meeting arranged by the agroecology NGO with university students who were working with some of the farmers affiliated with the NGO. These events provided an opportunity to become familiar with the area and to meet people from the area. During this time, I was also introduced to the person who became a fieldwork assistant, translator and guide. The assistant's work was invaluable as she had grown up in the area and had wide knowledge of it. She also knew many farmers and was able to introduce me to farmers who grew different types of maize. However, once the fieldwork for this study began, I worked independently from the NGO.

3.5.3. Conducting the research

I was able to conduct the first set of interviews with the farmers from the agroecology NGO in March 2017. On subsequent trips to Pongola, I conducted interviews with the help of the fieldwork assistant who arranged interviews using a snowballing method. This involved interviewing farmers who knew the assistant and then asking them to refer farmers who they thought might be interested in participating in the study. Biowatch farmers as well as the local field assistant were able to help me to identify other farmers who were not linked to biowatch who were willing to be part of the research. For these interviews a second translator, also accompanied me and assisted in conducting interviews. Most interviews with the farmers were carried out in Zulu with the help of the translator. Some interviews were carried out in English when participants indicated that they were able and would prefer to do so. All interviews were voice recorded except for one, where the participant preferred not to be recorded. Interviews lasted between 40 minutes and two hours. Sometimes, the interviews included walking into the farm fields so farmers could explain how they farmed or point out things they wanted to show the interviewers in response to their questions. Apart from one group of young women, and one young woman and one young man, who were part of a co-operative, all the farmers interviewed were senior members of the community and were born between the 1940s and 1960s. Farming was carried out mostly by elderly farmers, with the youth having lost interest in farming. However, being elderly meant that the farmers were able to recount many changes they had endured during their lives as farmers. There was a fairly even mix of men and women farmers, with the exception of those from the NGO who were all women.

Initially, the aim was to interview farmers who were growing bought seed – either OPV, hybrid or GM. Although the focus of the original interviews was on asking farmers about their experiences of growing different types of maize seed (i.e. heirloom varieties or hybrids or GM), once in the field, it became clear that this line of questioning was too simplistic. Many of the small-scale farmers in this area grew more than one type of seed. For example, a farmer growing GM seed in larger fields might also grow local traditional *maize* (also referred to as *mdala,* meaning old) nearer to their home. Many farmers also shifted the seed they grew from time to time. Furthermore, many farmers were not able to categorise their seed and did not always keep a record of the specific seed they had used over the years. These factors made it difficult to group farmers into distinct categories according to the seed they were using.

During the 11 weeks of fieldwork, visits were planned where possible to coincide with key times of the agricultural year. These included being in the field during planting season (when the first rains are expected between October and December). I was in the field during a drought season, then a season when the rains came late, and during a harvesting season (from March and April). During the first year (2015/16), the worst drought since the early 1980s occurred in the region. The year 2015 was recorded as the driest year on record for maize farmers. This seriously affected farmers who grew rain-fed maize and had little access to alternative water sources. Many did not harvest any maize during 2015 and 2016. The second growing season was more successful and I witnessed the harvesting process in 2017.

3.5.3.1 Sampling approach

During the research period, 39 interviews were conducted, of which 32 were with farmers (individual or groups), nine of whom were affiliated with the agroecology NGO grew heirloom maize known in the area as *ummbila wesiZulu* (Zulu maize), which is how it is referred to in this study[6]. Zulu maize. The other 16 were not affiliated with the NGO and were growing commercial OPV, hybrid or GM maize farmers. The farmers interviewed were able often to direct the interviewers to other farmers who lived nearby. The size of the farmers' land varied from subsistence gardens to larger commercial fields. Interviews were also conducted with three groups of co-operative farmers, where a group of neighbouring farmers combined their plots and worked collectively on land of up to 100ha although not all the land was farmed. The area cultivated varied from year to year). In addition to interviews with farmers, in-depth interviews were conducted with 11 key respondents details can be found in Table 3.1.

Table 3.1. Interviews, meetings and event undertaken or attended in Pongola between 2016 and 2020

Respondent code/ Event	**Affiliation**	**Location (these have been anonymised to Field Site (FS)**	**Date**
Scoping meeting with Biowatch farmers	Biowatch members	FS2	April 2016
Scoping meeting with cooperative maize farmers	Farmers linked to department of agriculture	Outside Pongola	April 2016
Seed festival	Biowatch	Pongola	August 2016
Meeting with Biowatch and researchers	Biowatch / UKZN	FS2	August 2016
Group meeting	Biowatch members	FS2	March 2017

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6 Through speaking to farmers and consulation with an NGO employee, a botanist and an agroecologist working to restore traditional seed systems in South Africa it became clear that naming maize is a topic that is open to a diversity of opinions. While farmers spoke of ummbila wesiZulu, the NGO emplyee suggested that while this was the term farmers used often, ummbila wesintu could be more accurate because this includes ownership by other Nguni people. The botanist and agroecologist suggested that this maize cannot be called traditional because it is not indigenous and therefore should be called simply ummbila. The NGO representive felt traditional could be used to describe this maize but not indigenous. In this thesis traditional and ummbila wesiZulu and traditional maize have been used.

Farmer 1	Biowatch	FS2	March 2017
Farmer 2	Biowatch	FS2	March 2017
Farmer 3	Biowatch	FS2	March 2017
Farmer 4	Biowatch	FS2	March 2017
Farmer 5, 6, 7	Former Biowatch members	FS2	March 2017
Farmer 8	Biowatch	FS2	Mach 2017
Farmer 9	Biowatch	FS2	March 2017 and and June 2019
Farmer 10	Former Biowatch member	Between FS2 and FS1 off the N2	May 2017
Farmer 11, 12, 13	Maize and vegetable farmers	FS3	May 2017
Farmer 14	Maize farmer	FS4	May 2017
Farmer 15	Maize farmer	FS2	May 2017
Farmer 16	Biowatch farmer	FS6	May 2017
Farmer 17	Maize farmer	FS2	May 2017
Farmer 18, 19	Maize farmers	FS5	May 2017
Farmer 20	Maize farmer	FS2	May 2017
Farmer 21	Maize farmer	FS2	May 2017
Farmer 22	Cooperative farmer	FS1	May 2017
Farmer 23	Cooperative farmer	FS1	May 2017
Farmer 24	Maize farmer	FS7	May 2017
Farmer 25	Maize farmer former biowatch member	FS2	May 2017
Farmer 26	Maize farmer	FS2	May 2017
Farmer 27	Maize farmer	FS2	May 2017
Farmer 28	Maize farmer	FS2	May 2017
Agricultural supply company employee 1		Pongola	May 2017

Government employee 1	Department of Agriculture, Forestry and Fisheries, Subsistence Farming directorate	Pretoria	March 2018
Government employee 2	KZN Agriculture and Rural Development Department	Pongola	May 2017
Extension officer 1	KZN Agriculture and Rural Development Department	Pongola	May 2017
Farmer 29	Maize farmer	FS2	June 2019
Farmer 30	Maize farmer	FS2	June 2019
Farmers 31	Cooperative farmer group	Off the N2	
Agricultural supply company manager 2		Pongola	June 2019
Seed festival	Biowatch associated farmers from KwaZulu Natal, researchers from The Seed and Knowledge Initiative	KZN	Oct 2017
Sound recording of maize fields and checking in with farmers	Multiple farmers	Pongola and surrounds	Feb 2018
NGO employee 1	Biowatch	Pongola	April 2016
NGO employee 2	Seed Justice NGO	Johannesburg	Nov 2017
NGO employee 3	KZN Agriculture and Rural Development Department	Pongola	Nov 2017
Government employee 3	KZN Agriculture and Rural Development Department	Pongola	June 2019
GM contamination workshop	Biowatch farmers, Biowatch employees, scientists, researchers	Mtubatuba, KwaZulu Natal	January 2018

Farmer development coordinator 1 Farmer development coordinator 2	GrainSA	zoom	May 2020

3.5.3.2 Life-history interviews

Life history interviews were a key method used to collect data from smallholder farms. Since this method depends on respondents recounting their experiences, it was important to find respondents who had been farming or working in R&D for a long period of time and, thus, had seen and experienced many changes during their lifetimes. Many of the farmers interviewed were born between the 1940s and 1960s and had learned to farm as children from their parents. As most of the farmers who participated were elderly, in their sixties, seventies and eighties, many were able to offer valuable life experiences of the changes in agriculture and seed in the area over time.

During these semi-structured interviews, participants were asked to reflect on historical changes in maize agriculture in the area, including how farming methods (theirs and those around them) had changed over the years. The focus was on changes associated with the introduction of new commercial seed varieties – hybrids initially and then GMOs – and also on the farmers' experiences with the seeds they had used over the years. Given the focus of this project on continuous changes in agro-ecological knowledge, specific attention was given to developments in multi-species engagements/social-ecological relationships and ecological knowledge, for example, how farmers had related to soil, climate, pests, weeds, seed, and weather conditions over time, and how this had changed with the introduction of new seed. Analytic interpretations were made using interview data alongside data gathered through observations on farms, and at specific events as noted above.

3.5.3.3 Participant observation, transect walks and collection of visual data

The methodology included the gathering of visual materials. This involved taking transect-walks with farmers through their fields, taking photographs, and making drawings of elements encountered, such as insects, maize cobs, patterns on maize leaves left by borers, and methods of farming such as inter-cropping. Observations played a central role in data collection, as farmers often struggled to name particular pests or weeds but were able to point them out easily while in the fields, which expanded the dialogue about their practices and engagement with the ecosystems of their crops. The collection of visual material was useful both for keeping a set of visual records, and for facilitating discussion. Many farmers were unsure of the name of certain pests but, when provided with an image of a stem borer, for example, they were able to share a lot of information about its presence and management on their farms over the years.

While participant observation was not a key method in this research, when opportunities arose, I was involved in helping farmers with their daily tasks and attended meetings or events when invited. This led to opportunities to understand farming practices and the issues under discussion more deeply.

3.5.3.4 Key respondent interviews

Key respondent interviews are qualitative, in-depth interviews with people who are familiar with an area or issue. The information obtained was important to gain a broader understanding of the area and, particularly, government interventions in the area and how these were aligned to the broader agenda, policy and strategy for smallholder agriculture in South Africa. Interviews were conducted with: one employee from the agroecology NGO; an employee from an international NGO based in Johannesburg, working to restore traditional seed and farming practices in South Africa; three employees from the local Department of Agriculture in Pongola; two employees of the National Department of Agriculture in Pretoria; three mangers from agri-dealers in the Pongola area; and one employee of GrainSA, who was working with smallholder farmers in the municipality as part of GrainSA's farmer development programme.

3.6. Data collection in research and development institutions

3.6.1 Overview of methods used

As was the case with the field research about farming, multiple, qualitative research techniques were combined in order to understand how the introduction of GMOs has altered the work of researchers and scientists, and has affected ecological knowledge and social-ecological relationships in R&D institutions. As on the farms, the empirical data for this component were collected by using a series of ethnographic research methods. Data collection methods in this node included desktop research, semi-structured life/work-history interviews with key respondents, and participant observation where possible.

3.6.1.1. Scoping and mapping the maize research and development system

The first component of data-gathering involved extensive desktop research of sources available in the public domain (websites, news articles, magazines, documents such as company annual reviews and catalogues). A search of all the scientific literature available about maize in South Africa also was conducted. There were two purposes for this review: firstly, to map the elements of the maize R&D system i.e. what research was being done, in which organisations and by whom; secondly, to gain insight into how this system had emerged and changed over time because this was not recorded formally in any one document. The review made it possible to plan the interviews and participant research components that would follow.

3.6.1.2. Sampling approaches for interviews and key respondent interviews

Once key stakeholders and stakeholder organisations in the maize R&D system had been identified, they were contacted by email to request interviews. While it was impossible to interview all stakeholders in the maize R&D system, which is large and dispersed, the aim was to interview scientists and researchers, working in the private, in government, and in educational institutions. The aim also was to find scientists, researchers or technicians who had worked for a long time in maize R&D (since before the introduction of GMOs) because they would be able to explain significant shifts that had taken place in their work and in the R&D system over time. From the literature search, scientists in maize agriculture were identified (such as agronomists, entomologists, weed scientists, plant protection scientists, soil scientists), whose academic literature had been published for a long time. After each interview, a snowballing technique was used to obtain referrals to other people who knew a great deal about maize research or who had worked in the field for a long time. This led to several recommendations of key respondents in the field.

A total of 40 interviews were conducted with institutions throughout South Africa that responded favourably to requests. All interviews were voice recorded and conducted in English. Table 3.1 shows a summary of the interviews conducted.

Table 3.2: Summary of R&D interviews conducted between 2016-2020.

Respondent code	**Institution**	**Location**	**Dates**
Entomologistst 1. Entomologist 2. Entomologist 3. Entomologist 4. Weed Scientist 1. Plant protection scientist 1. Agronomist 1. Agronomist 2. Plant breeder and geneticist 1.	Agricultural Research Council Grain Crops Institute (ARC GCRI): Plant Protection Unit / WEMA	Potchefstroom	2016-2019
Biocontrol scientist 1. Biocontrol scientist 2. Biocontrol scientist 3.	ARC, Plant Health and Protection Research Institute (ARC-PPRI)	Roodeplaat	2017
Taxonomist 1. Entomologist 5.	ARC Biosystematics Unit	Roodeplaat	2017
Seed Scientist 1 Seed Scientist 2.	The Plant and Genetic Resources Institute (PRGI) (Department of Agriculture Forestry and Fisheries)	Roodeplaat	2017
Entomologist 6.	SANBI	Cape Town	2017

Entomologist 7 Agronomist 1. Soil scientist 2. Biotechnologist 1	North West University (NWU)	Potchefstroom	2016-2020
Microbiologist 1. Microbiologist 2.	University of Cape Town (UCT)	Cape Town	2016
Biotechnologist 2.	University of the Western Cape (UWC)	Cape Town	2017
Biotechnologist 3.	Biosafety South Africa	Somerset West	2016
Manger 1.	AfricaBio		2017
Agronomist and plant pathologist 1. Crop scientist 1. Agronomy PhD student 1	University of KwaZulu Natal (UKZN) and African Centre for Crop Improvement (ACCI)	Pietermaritzburg	2017
Weed scientist 1 Plant Pathology PhD Student 1	University of Pretoria (UP)	Pretoria	2017
Manager 1	Maize Trust	Centurion	2019
Scientist/researcher 1 Scientist/ researcher 2	GrainSA	Centurion	2019
Agronomist 2.	Seed company	Skype	2019
Agronomist 3.	Seed Company	Pretoria	2019
Policy expert 1.	Department of Agriculture Forestry and fisheries	Pretoria	2017

3.6.1.3. Life/work-history interviews

The focus of the life-history interviews was on the participants' work and how it had changed over time in relation to the kind of maize seed with which they worked. During the interviews, participants were asked what they had studied, how they had become involved in the work they were doing, how they had chosen their research area and how it had developed with changes in maize seed technologies and co-technologies available in South Africa over time. Given the focus of this study on continuous changes in social-ecological knowledge, specific attention was given to changes in multi-species engagements/social-ecological relationships and ecological knowledge, for example, how scientists had related to the more-than-human world around them, including bacteria, plants, weeds, insects and other species with which they and the scientific world had engaged in their work over time. This was envisaged to be a process of mapping laboratory ecologies to show how the ecological elements, with which researchers and practitioners had been engaged, and the nature of their work had had developed as maize seed had changed from hybrids to GMOs over time. For example, how had the focus of entomologists, working in maize research, shifted over time? Were they exploring a different species? Were agronomists doing their work differently from what they did before?

3.6.1.4. Participant observation and collection of visual data

In addition to interviews, permission was requested also to undertake participant observation when scientists were engaged laboratory work, where possible. It was explained to participants that I was interested also in gathering visual and sensory data. This made it possible to take photographs and participants directed me to any visual data they had. For example, insect collections, old books, charts, pamphlets and posters were provided for consideration during the research process. This often to interesting conversations discoveries of long-forgotten artefacts in laboratories, such as old sketchbooks or insect collections. These were useful in compiling record of the changing research environments and, ultimately, the changing social-ecological relationships within them.

3.6.1.5. Literature review

Finally, the third component of the research in this node was an in-depth literature review of scientific papers that had been published in the maize R&D system since the 1900s. The review included documents available through the universities' library system and online journal portals Inter-institutional information that might not have been published was not included. However, based on this review, it was possible to identify trends in research and how they had shifted over the years, and to identify key scientists in the maize R&D system who were contacted for interviews where possible.

3.7. Ethical considerations

GMOs, by their nature, are controversial entities. Thus, ethical considerations had to be given stringent attention during this study. Permission to carry out this study was applied for and granted formally through UCT's Faculty of Science Research Ethics Committee (See the Ethical Clearance form in Appendix A).

While certain ethical standards are important in any research setting, given the dynamics of both of the research nodes explored in this study, the ethical approach used in each has been explained separately in the following subsections.

3.7.1. Ethical considerations in researching smallholder farms

Interviews with farmers were carried out with the help of a fieldwork assistant and translator. Both the fieldwork assistant and translator were given an in-depth understanding of the project's goals so that they could explain these to participants before each interview. It was understood that, in areas where access to information and resources was limited, farmers would be expecting something in return for their participation. Thus, it was important to make sure that they clearly understood that we were students and not extension personnel. It was made clear that we were not from government or a private company and were not offering agricultural assistance or information on how to farm as this was not their area of expertise.

All participants were informed that their names would not be used and that their identity would be kept confidential. It was explained that, rather than recording information about individual farmers, the purpose of the research was to understand the experiences of a broad sample of farmers in using different maize seeds in the area. Since most farmers interviewed were elderly, they did not all know how to read and write. After using consent forms initially, it was noted that farmers were often uncomfortable signing these. Therefore, we decided to rely on verbal consent. A commitment was made to the farmers to inform them of the outcomes of the research during a follow-up visit and discussion towards the end of the project. Farmers were also made aware that they could contact the research assistant if they had any further queries or concerns.

The farmers did not always have a clear understanding of the value of research and it was often necessary to explain in-depth why the research was being undertaken. The farmers in general were more interested in immediate action that would lead to the change at which the academic research was aimed. They often wanted to know whether we would be reporting to government and requesting assistance for them. It was explained that, hopefully, the research findings would be noted by government and policy-makers but promises could not be made about direct change. Once provided with a full explanation, most farmers felt comfortable to engage in interviews and only one turned down being interviewed as he felt he had little to gain from taking part.

A snowballing method was used to identify farmers who were willing to be interviewed. The rationale was that this method would result in only farmers who were connected in some way being interviewed, which would enable farmers in the area to build up an understanding of the project and that only farmers who were willing would partake. The fieldwork assistant from the area made calls beforehand to set up interviews with farmers and make sure they were willing to take part and set up convenient times for them. During the time in the field, a number of farmers approached us and asked to be interviewed, once people whom they knew had been interviewed. Farmers were often enthusiastic about sharing their life experiences. At times, interviews became an opportunity for younger people to learn about the knowledge that the older farmers had or had used in the past as they shared their life stories connected to farming.

As tangible outcomes of change in the area were not guaranteed from the research, it was important to me that participants were compensated somehow for their participation. The fieldwork assistant from the area helped me choose gifts to offer farmers i In exchange for their time and sharing their knowledge. We gave farmers fruit trees, vegetable seeds and fruit. These were well received because farmers value these items greatly and they are not easily available to many farmers. If farmers wished, I took family photographs which were given to the farmers on return visits. The farmers were informed that no photographs of people would be used in the research, to protect anonymity, and that these photographs were purely for them and their families. The only photographs that were used in the research did not include people's faces or were of plants, insects, landscapes and non-human subjects.

I was mindful of coming from a different part of South Africa and cultural background being a white, English-speaking, female, and not fluent in isiZulu and working in a study area with a deeply segregated history. Doing research through translation in an area where you are not familiar with customs and ways of life requires that the researcher takes care to learn how to be sensitive. I relied on insights from my fieldwork assistant on how to carry out interviews, approach people in a way that was sensitive to what their concerns may be, and how to get the correct permissions. Furthermore, the fieldwork assistant was consulted throughout the research so as to ensure that relevant permissions were obtained from local authorities and leaders.

Government officials and company employees who were interviewed were asked to sign consent forms which provided detailed information about the project as well as contact details (See Appendix B). A detailed, spoken description of the project was also given before interviews were conducted. These participants were assured that all efforts possible would be made to ensure anonymity and all said they were satisfied to take part. They were informed that they could ask to review the report should they be interested in it and requested to do so. After the conclusion of the study feedback will be given to the particpants to inform them of the findings of the study and the relevance of the research going forward. This will also include discussions with particpants about what follow up research may be useful for them in future research.

3.7.2. Ethical considerations in research and development institutions

All interviews in research and development institutions were conducted in English. Therefore, the information gathered did not have to be translated. All participants from these institutions were given an in-depth overview of the project via email or in person. They were asked to sign consent forms and were assured of their anonymity (See

Appendix B). They were informed that they could review the report should they request to do so.

Since GMOs are highly controversial, this aspect of the research involved many layers of secrecy and power hierarchies. The sources of the project's funding and research affiliations were made clear so that stakeholders could respond from an informed position. A typical question from many pro-GM participants was whether I was opposed to GMOs. My response was that the approach of the research, similar to the funder's philosophy, was to be pro-transparent research and information about GMOs. With some stakeholders it was evident that their responses to questions were carefully calculated, and that some interviews may have been turned down due to my research affiliations. However, since the focus of the research was not on critiquing GMOs in a direct manner, most stakeholders were open and interested in discussing the topic. While, at first, they seemed confused about the relevance of the research, this usually became evident during the interview.

3.8. Limitations

A limitation of this research methodology was its wide scope, which focused on multiple sites across the country. While this allowed for interesting and often unexplored comparisons between farmers and scientists, it also sometimes limited the depth of the case studies.

Another aspect of the research which added to the experimental approach but also limited the depth of analysis for each case study was the interdisciplinary nature of the research. While my social science background enabled an interrogation of the epistemological and social dimensions of the research, this could have been strengthened by a stronger understanding of aspects of plant science before entering the field. This would have allowed for more nuanced questioning such as concerning maize seed varieties. A recommendation for future studies would be the collaboration with an agricultural scientist in undertaking the research. This interdisciplinary collaboration may lead to both parties being able to ask more nuanced questions which in turn could lead to a range of different analyses.

Another important consideration was my inability to speak Zulu fluently, all information was obtained through a translation process in the field and again when being transcribed. As with all translation processes, this gave rise to the possibility of misunderstandings. At times transcribed interviews contained ambiguities. I tried to get to the bottom of these ambiguities in follow-up visits by asking questions in different ways where previous questions had provided a lack of clarity. One area where it was challenging to gain clarity was around what exact maize seeds farmers had planted over the years. This has been noted in the findings. It is suggested that the involvement of a researcher fluent in the local language would allow for more nuanced findings about social-ecological and cultural knowledge which requires a deeper level of conversation that was not always attainable. I felt it was important not to interpret interviews in which cultural aspects were referred to from a place of limited understanding. An example was some of the historical practices described by farmers that needed a more in-depth cultural understanding which I chose out of respect to rather not claim to understand and therefore write on. However this could be an area of much greater and richer research.

FIGURE 4.1: Road signs outside Pongola. Source: Photograph taken by Maya Marshak, Pongola, 2018.

4. CHAPTER FOUR: Setting the Scene - The Context of the Research on Smallholder Maize Farms

4.1. Introduction

The focus of Chapters Four and Five is on the first node of research identified for this multi-sited project, being smallholder maize farms in northern KwaZulu-Natal. Contextual information provided in Chapter Four and the data collected about the effects of new seed technologies on ecological knowledge and practice in smallholder farming systems presented in Chapter Five. Together, the aim of these two chapters was to address the question: how have commercial seed varieties and their co-technologies (fertilisers, pesticides, and herbicides) affected farmers' ecological knowledge, practices and relationships with the agro-ecological system within which they farm. While the focus is on the effects of seed technologies, these are not introduced into a static system. Agricultural systems, by their nature, are always in a state of change (van Dooren, 2008; Stone et al., 2007). They are constantly affected by social, political, economic, and ecological factors. This was true of smallholder agriculture in South Africa which has experienced pressures from all these factors since colonial times. In the context of these pressures, smallholder farmers in the case study areas have continued to grow maize, adapting to difficult circumstances, such as changing land tenure regimes, forced removals, restriction of the sale of their crops, drought and other social, political, economic and environmental challenges. These challenges have been documented in this chapter to place seed technologies in the broader context of change affecting smallholder farmers[7].

4.2. Geographical location of the fieldwork

As explained in the methodology, the research fieldwork was carried out near the town of Pongola in Northern KwaZulu-Natal, in the Umkhwakhwa Mountains bordering

[7] Parts of the research in this chapter have been published in a journal paper co-authored with Amaranat Hererro, Fern Wickson and Rachel Wynberg (2021): However Maya Marshak led the conceptualisation, research, writing and analysis of the paper See: https://www.tandfonline.com/doi/abs/10.1080/21683565.2021.1888841.

Eswatini (formerly Swaziland). For reasons of anonymity, the names of the areas in which the research interviews were conducted have not been used in this report and are referred to in general under the area name of Pongola.

This region has a long history of smallholder maize agriculture, with many families in the area having grown maize for generations. All of the 35 farmers interviewed, with the exception of one who had attended agricultural college, had learned how to grow maize as children from their parents, when they used to help in the fields. In this area, farmers still grow various types of maize alongside store-bought varieties, including OPVs, Hybrids and GM seeds.

While maize was not grown as a large-scale commercial crop in this area, many households and some farmer co-operatives (formed by neighbouring farmers who combined their land and registered with the Department of Agriculture as a co-operative in order to gain assistance) were involved in maize agriculture on a small-scale either for subsistence or commercial purposes.

Viewed from the top of the uMkhwakhwa Mountains, shown in Figure 4.2 below, the landscape showed clear signs of past agricultural activities. On the foothills of the mountains, there were pockets of settled areas where homes were set alongside small household farming plots. Between these settled areas were large tracts of contoured fields on the slopes.

These large terraced fields were mostly overgrown and not in use. These fallow fields raised questions about farming in this area. According to respondents, some were created by white, commercial farmers who had farmed fruit in the area in the past, and some were the result of government maize farming interventions which had since stopped. Respondents also spoke of large fields that had been farmed by their parents in the 1940s and 50s that had contained large tracts of Zulu[8] maize inter-cropped with other vegetables.

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[8] Zulu maize refers to farmers' varieties of maize which have been saved each year for replanting.

FIGURE 4.2: Image showing the view from a smallholder farm outside Pongola. Source: Photograph taken in 2018 after the drought period by Maya Marshak.

Beyond the slopes on which smallholder farmers farmed, the lower lying valleys appeared to be perpetually green, regardless of the season (see Figure 4.3.(b)). Even during the drought period of 2015 to 2016, the landscape was filled with the green colour of sugar cane. Sugar cane was one of South Africa's oldest, large-scale, commercial crops that have been present throughout the social-political history of the region and the changing agricultures. In this area, sugar-cane farmers used water irrigation all year round, while smallholders relied almost entirely on rain-fed agriculture, although some had access to water storage tanks. This disparity, evident in the landscape, reflects South Africa's social-political past. In the Google Map images (Figure 4.3.(a) and 4.3(b), the difference in access to water between the two farming areas is starkly evident. In these two images captured at the same time, the sugar cane fields appear green and thriving, even though it was the dry season, and the smallholder maize growing area appears dry and without water. These images reflect the inequality in water access and farming conditions between smallholder farming and commercial framing in the area surrounding the town of Pongola.

FIGURE 4.3(a): This aerial image shows the water scarce conditions in the research area outside Pongola where smallholder farmers rely on rain for maize farming. Source: Google Maps, screenshots captured by Maya Marshak, 2017.

FIGURE 4.3(b): This aerial image is contrasted with 4.3(a), it shows the irrigated commercial sugarcane fields surrounding Pongola which have access to water year-round from the Pongolapoort Dam. Source: Google Maps, screenshots captured by Maya Marshak, 2017.

4.3. The effect of colonialism and apartheid on smallholder farming

Colonial rule had a significant impact on smallholder agriculture in South Africa (Bundy, 1979; Bernstein, 1998; van Onselen, 1996) examined how the livelihoods of rural, agricultural, South African smallholders were affected by colonialism and industrialisation. According to Bundy (1979: 1):

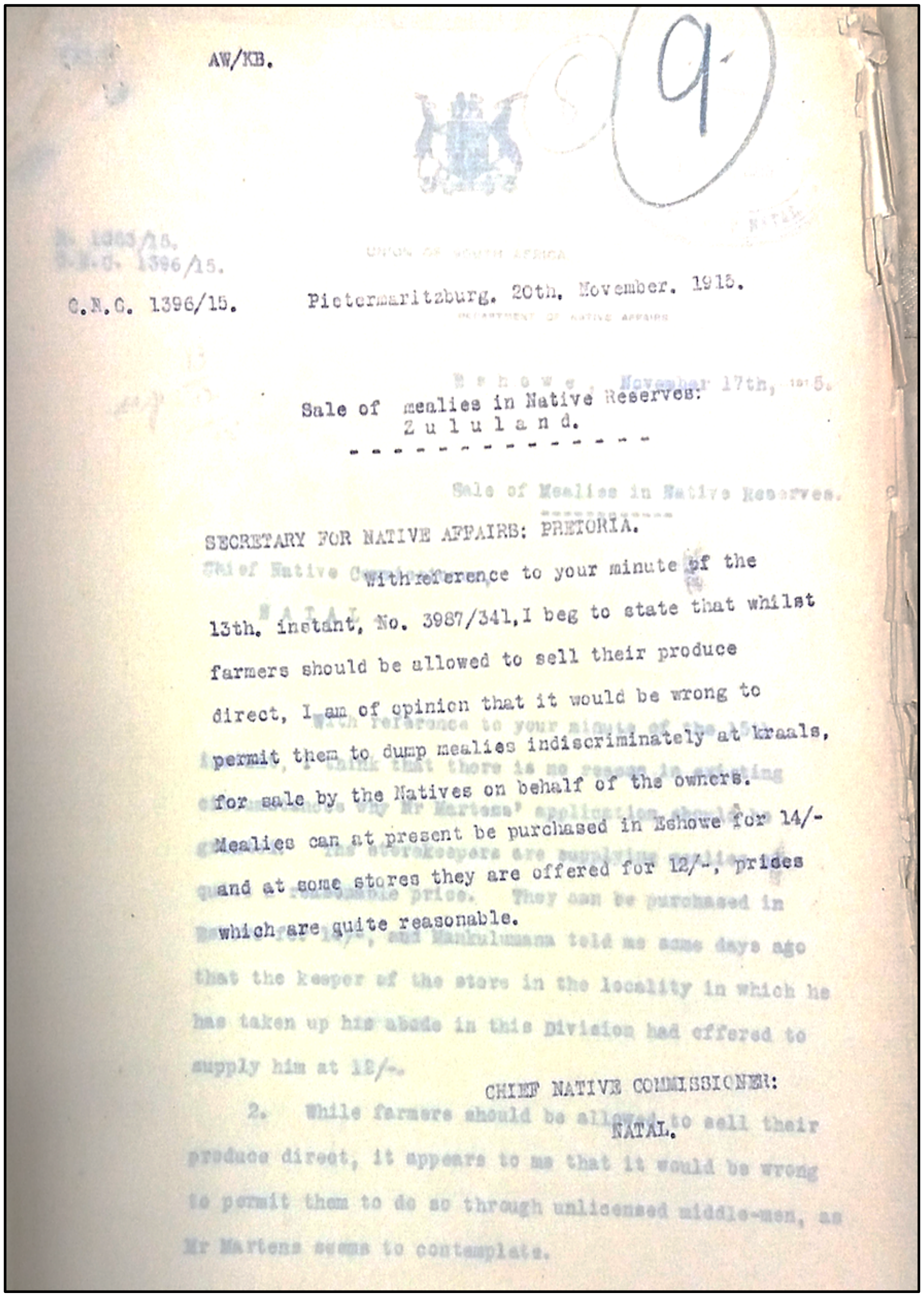
> At the core of South Africa's social history, lies the transition of a majority of her people – the rural Africa population - from their pre-colonial existence as pastoralist-cultivators to their contemporary status: that of subsistence rural dwellers, manifestly unable to support themselves by agriculture and dependent for survival upon wages earned in white, industrial areas or upon "white farms".

During the late 1800s, white farmers settled on land about which they had no knowledge and relied on the skills and knowledge of black farmers to develop systems of agriculture (van Onselen, 1996). These settler farmers entered into share-cropping arrangements with black farmers. In this way the traditional, local knowledge of black farmers played a role in the development of white commercial agriculture. Through the biographical account of a South African share-cropper, Kas Maine, van Onselen (1996) explained how this share-cropping system was replaced as white farmers secured means of production and were supported by the state and government policy. This transition was accelerated by an increase in agricultural research and development, and the development of new seed varieties. Chemicals and technology, such as tractors, boosted production and decreased the reliance on share-cropping systems (van Onselen, 1996).

In 1913 the Land Act was passed which provided the basis for groups of native South Africans to be moved to reserves, known as homelands, defined by ethnic categorisation. While formally passed in 1913, the Act had its origins in the late 1800s. The Glen Grey Act of 1894, which was established by Cecil John Rhodes in the Cape Colony, sought to secure cheap labour for white-owned farms and mines by changing land tenure rights and assigning taxes (Ntsebeza, 2000; Bienart & Delius, 2014). This process greatly affected the livelihoods and agricultural practices of black farmers in South Africa who, under the 1913 Land Act, were confined legally to areas set aside by the colonial powers. According to McCann (2007), this was common throughout Colonial Africa, where settlers occupied favourable agricultural land, and relocated black smallholder farmers onto land with lower and more unpredictable rainfall and unfavourable soils.

While the people confined to homelands initially engaged in agriculture successfully, this decreased considerably by the 1920s (Simkins, 1981, Wolpe, 1995). Farming productivity decreased and malnutrition became a serious problem in the homelands (Simkins, 1981). According to Simkins (1981), although the situation in Zululand was better than other areas, and most families still continued to produce some food, there was an increasing reliance on cash to buy food. There were many reasons for the shift away from a reliance on subsistence agriculture. Farmers faced several drought periods but, while these caused short-term food shortages, according to McKinnon (1999), there were several, systemic reasons for the decline in agriculture. These included: the unequal distribution of land and resources between white areas and homeland areas, and within homeland areas; the increase in labour migration and a rise in wage labour; a decline in soil fertility owing to overcrowding; and the impact of a "white-dominated market". Not only was white-dominated agriculture supported by the state, but also access to the market by black farmers was restricted. McKinnon (1999:106) states further how white farmers were "consistently hostile to African peasant production of food and cash crops" and "undermined the sale of maize to stores by the Zulu". Further, since black farmers did not have state support, they could not compete with white farmers "who received generous state subsidies and support, expanded their grain production, and came to dominate the local market in maize" (McKinnon, 1999: 106). Commercial seed as well as increasing mechanisation caused further disparities amongst poorer farmers in homelands and between white and black farmers. After a search through the state archives in Pietermaritzburg, a body of correspondence between white settler farmers and colonial administration was found, dated 1912 to 1916, that was typical at the time concerning the sale of 'mealies' (maize) (See Figures 4.4.(a), (b), (c) and (d)). As seen in these documents, the regulation of the sale of maize was highly restricted according to race. Figure 4.4.(c) shows the Native Commissioner's letter warning white farmers about "dumping" maize in Native Reserves. He states that, in his opinion, "it would be wrong to permit them [white farmers applying] to dump mealies indiscriminately at kraals, for sale by the natives on behalf of the owners". From this correspondence, it is evident that black people confined to homelands became increasingly reliant on maize from white farmers and white farmers were competing for the rights to sell their produce in homelands, where they would have a captive market. Black farmers bought this maize because people in the homelands faced many challenges to growing enough food. This has been attributed to the disruption of black, smallholder agriculture by colonial land policies, forced removals, and migrant labour. According to McKinnon (1999, 103) "African production of the principal crop, maize, fluctuated dramatically over time, however, after the advent of white settlement...the overall trend, at least until 1948, was a shortfall in even the most conservatively-estimated food needs".

McKinnon (1999) argued that, at the time of the first colonial settlement, rural Zulu livelihoods were based on two key economies, food production and cattle farming, but this changed significantly during the colonial period. In the first half of the 1900s there was a substantial increase in migration from the homelands as people left to search for work on white farms or in the mines. This contributed significantly to changes in agricultural practices and a "rapid decline in African agriculture in Zululand" (McKinnon, 1999: 103). At the same time there was a marked shift towards "increasing cattle herds which were a valuable source of food" (McKinnon, 1999: 103). At the turn of the century, it was mainly men who migrated in this way but women also left their homes. In 1900 it was estimated that nine percent of men in demarcated homeland areas left in search of work. By 1919, this rose to 14 percent and, by 1930, it increased to 17 percent (McKinnon, 1999: 101-104). The 1930s were a period of drought and economic depression, which caused more people to abandon farming and search for wage labour. It was during the 1930s that women first began to be involved in migrant labour significantly. Many Zulu women went to work on white-owned farms. As McKinnon (1999) explained, this meant that women who would have been responsible for household food production, left their food gardens in search of work. Many of the men, who would have been responsible for helping to cultivate the larger fields, also left.



AW/KB.

C.N.C. 1396/15. Pietermaritzburg. 20th, November. 1915.

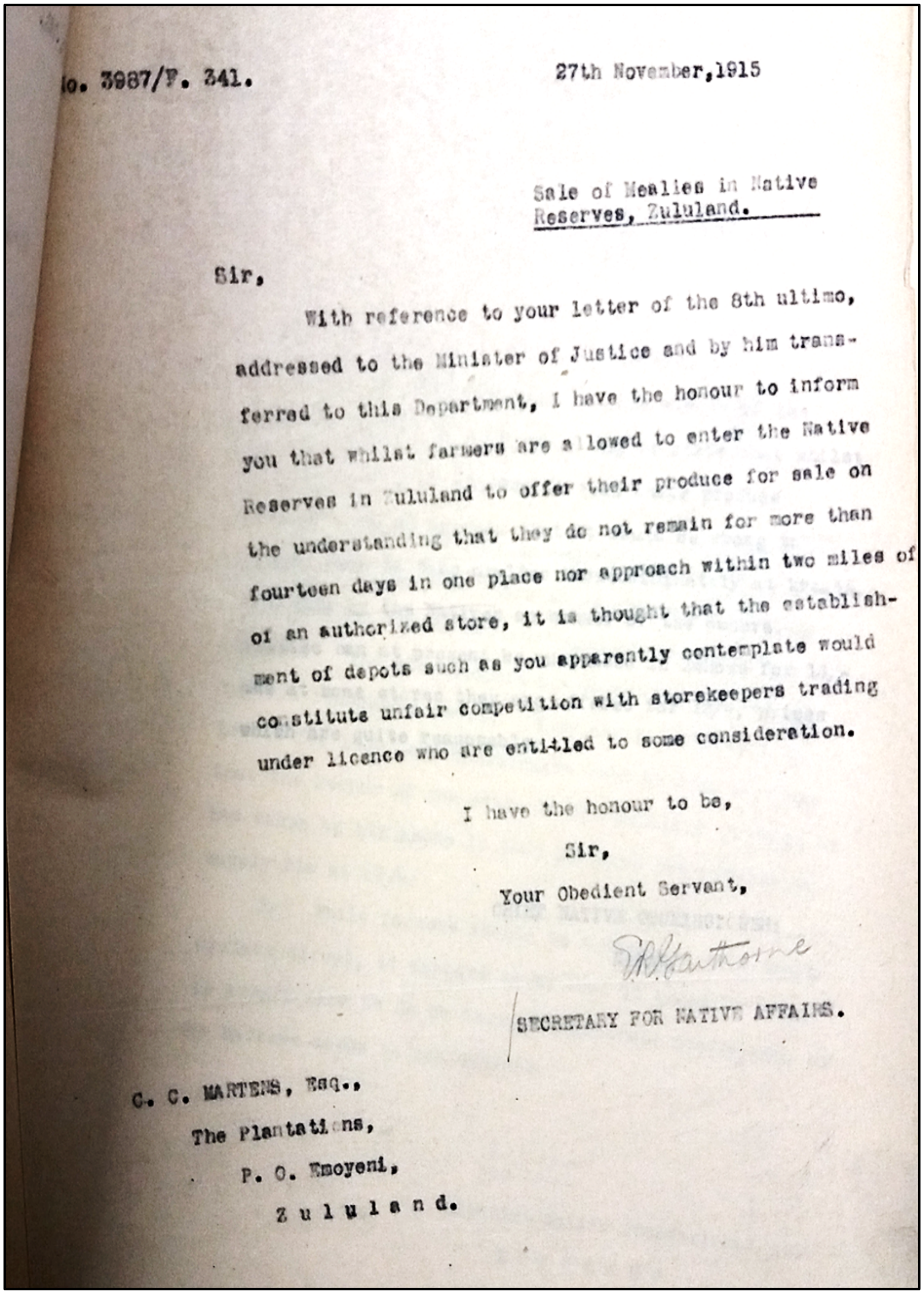
Sale of mealies in Native Reserves:
Zululand.

SECRETARY FOR NATIVE AFFAIRS: PRETORIA.

With reference to your minute of the 13th. instant, No. 3987/341, I beg to state that whilst farmers should be allowed to sell their produce direct, I am of opinion that it would be wrong to permit them to dump mealies indiscriminately at kraals, for sale by the Natives on behalf of the owners. Mealies can at present be purchased in Eshowe for 14/- and at some stores they are offered for 12/-, prices which are quite reasonable.

CHIEF NATIVE COMMISSIONER:
NATAL.

FIGURE 4.4.(a): Letter by the Chief Native Commissioner, Natal, titled: Sale of mealies (maize) in Native Reserves. Source: State archives, Pietermaritzburg.



No. 3987/F. 341.

27th November,1915

Sale of Mealies in Native Reserves, Zululand.

Sir,

With reference to your letter of the 8th ultimo, addressed to the Minister of Justice and by him transferred to this Department, I have the honour to inform you that whilst farmers are allowed to enter the Native Reserves in Zululand to offer their produce for sale on the understanding that they do not remain for more than fourteen days in one place nor approach within two miles of an authorized store, it is thought that the establishment of depots such as you apparently contemplate would constitute unfair competition with storekeepers trading under licence who are entitled to some consideration.

I have the honour to be,

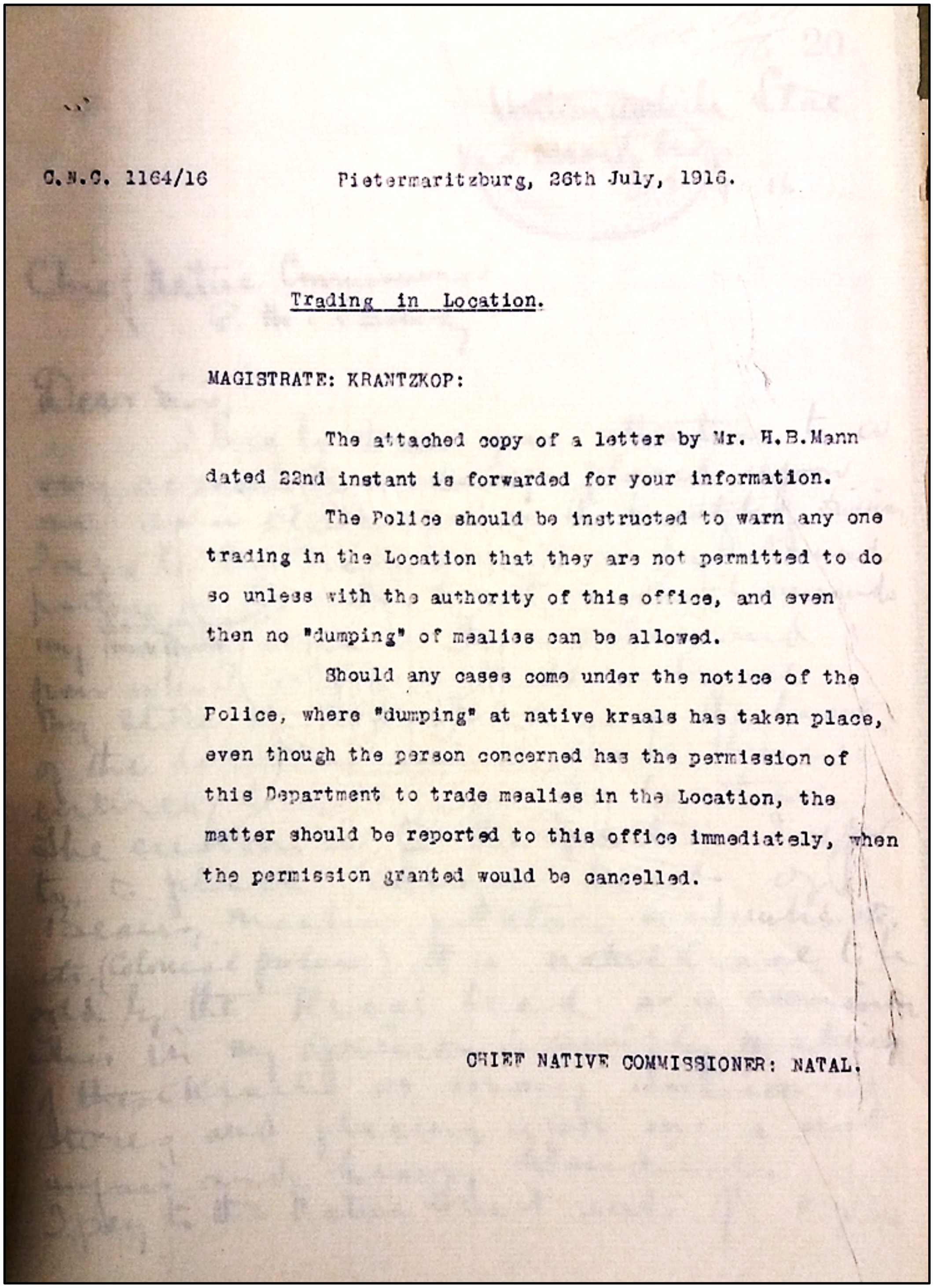
Sir,

Your Obedient Servant,

SECRETARY FOR NATIVE AFFAIRS.

C. C. MARTENS, Esq.,
The Plantations,
P. O. Emoyeni,
Z u l u l a n d.

FIGURE 4.4(b): Response letter by the Secretary for Native Affairs, Pretoria, titled: Sale of mealies (maize) in Native Reserves. Source: State archives, Pietermaritzburg.



C.N.C. 1164/16 Pietermaritzburg, 26th July, 1916.

Trading in Location.

MAGISTRATE: KRANTZKOP:

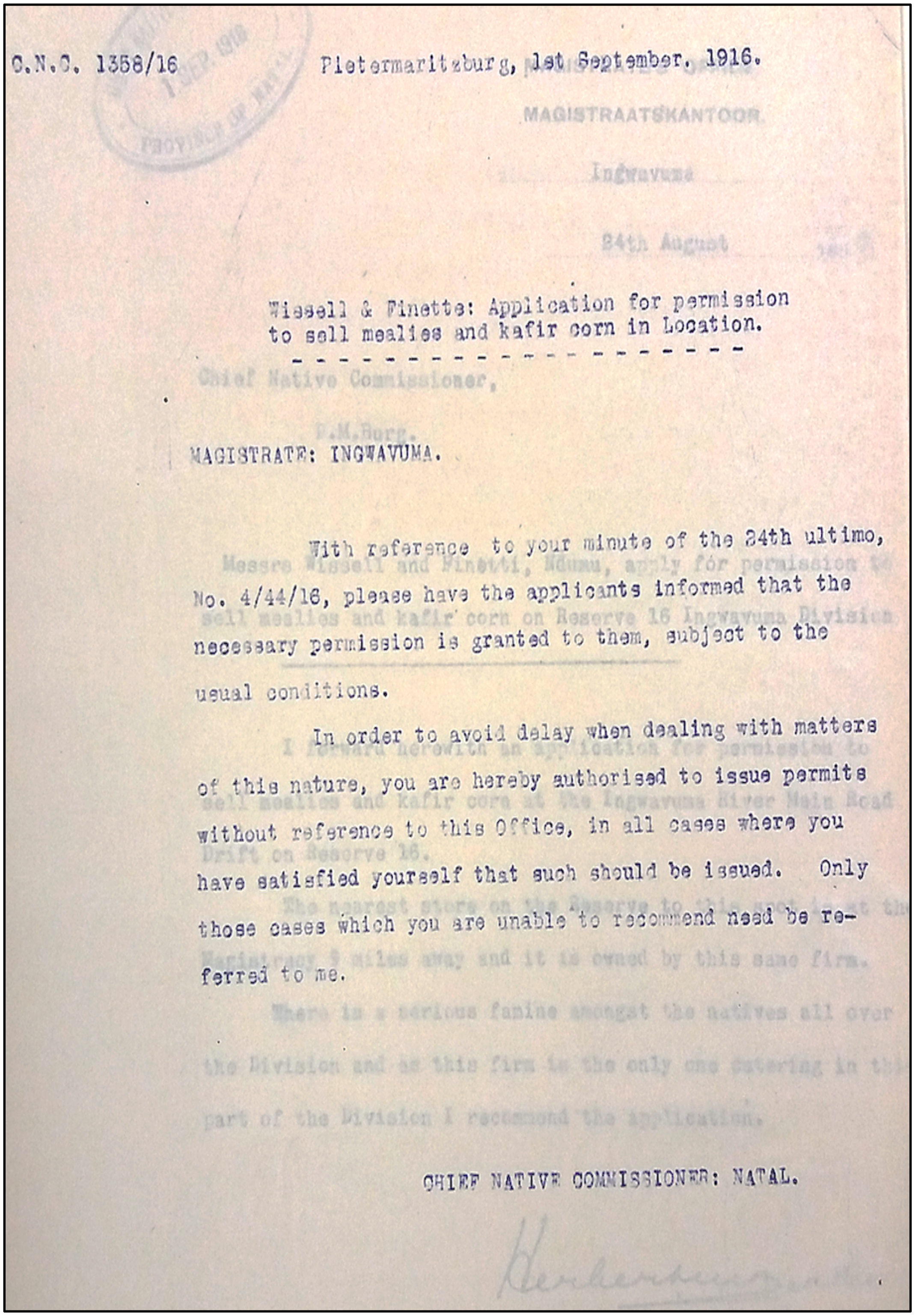
The attached copy of a letter by Mr. H.B.Mann dated 22nd instant is forwarded for your information.

The Police should be instructed to warn any one trading in the Location that they are not permitted to do so unless with the authority of this office, and even then no "dumping" of mealies can be allowed.

Should any cases come under the notice of the Police, where "dumping" at native kraals has taken place, even though the person concerned has the permission of this Department to trade mealies in the Location, the matter should be reported to this office immediately, when the permission granted would be cancelled.

CHIEF NATIVE COMMISSIONER: NATAL.

FIGURE 4.4(c): Letter by the Chief Native Commissioner, Natal titled: Trading in Location. Source: State archives, Pietermaritzburg.



C.N.C. 1358/16 Pietermaritzburg, 1st September, 1916.

Wissell & Finette: Application for permission to sell mealies and kafir corn in Location.

MAGISTRATE: INGWAVUMA.

With reference to your minute of the 24th ultimo, No. 4/44/16, please have the applicants informed that the necessary permission is granted to them, subject to the usual conditions.

In order to avoid delay when dealing with matters of this nature, you are hereby authorised to issue permits without reference to this Office, in all cases where you have satisfied yourself that such should be issued. Only those cases which you are unable to recommend need be referred to me.

CHIEF NATIVE COMMISSIONER: NATAL.

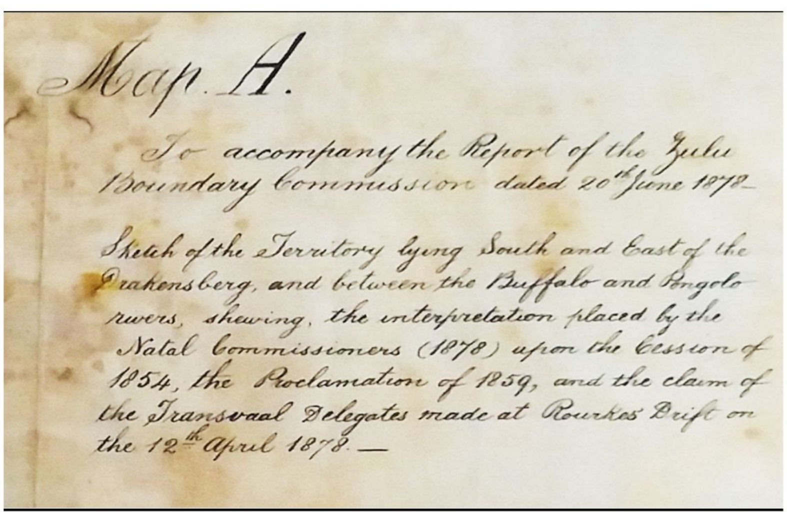
FIGURE 4.4.(d): Letter by the Chief Native Commissioner. The title and subject of this letter illustrates the extent of use of racist and derogatory language and restrictions to market access based on race. Source: State archives, Pietermaritzburg.

4.4. The effect of the commercial sugar cane industry on smallholder maize farming

In the region of Pongola, as throughout KwaZulu Natal, the expansion of the commercial sugar industry into some of the most fertile areas had significant effects on smallholder agriculture. The Colony of Natal was settled by British immigrants during the second half of the 1800s. Settlers were given free land on which they were encouraged to grow sugar cane (Cochet et al., 2015: 16). Sugar cane was first brought to South Africa by the British between 1847 and 1851 from Reunion Island and was planted just north of Durban (Lewis, 1990). Subsequently, plantations spread steadily northwards along the coast of Natal (now KwaZulu Natal), eventually reaching Pongola much later. According to Williams (1959), prior to the spread of sugar plantations, the coastal belt was considered to be "underexploited". Although small-scale cultivation of maize, vegetables, subtropical fruits, and export crops, such as arrowroot, indigo, coffee, and tea had been tested for their suitability, they were abandoned owing to their lack of profitability (Williams, 1959). The discovery that sugar cane could be suited to the region as a cash crop boosted the interest of commercial agriculture in the area. From the outset, indentured labourers were brought from India to work on the sugar cane plantations (Williams, 1959).

By 1878, a Boundary Commission had been established to settle boundary disputes between Boer settlers and the Zulu Kingdom. This was a time of growing tension between the British and the Zulu Kingdom and the restriction of Zulu access to land was put into practice. Figure 4.5 shows a survey map found in the Pietermaritzburg State Archives drawn by the Boundary Commission, who were appointed to investigate which land to reserve for white people and where to establish Native Reserves.

a



b

FIGURE 4.5.(a) and (b): Survey map (a) of 'territory lying South and East of the Drakensberg between the Buffalo and Pongolo Rivers', drawn by the Boundary Commission, who were appointed to investigate where to establish Native Reserves. Image (b) provides a close up of the text on map (a).

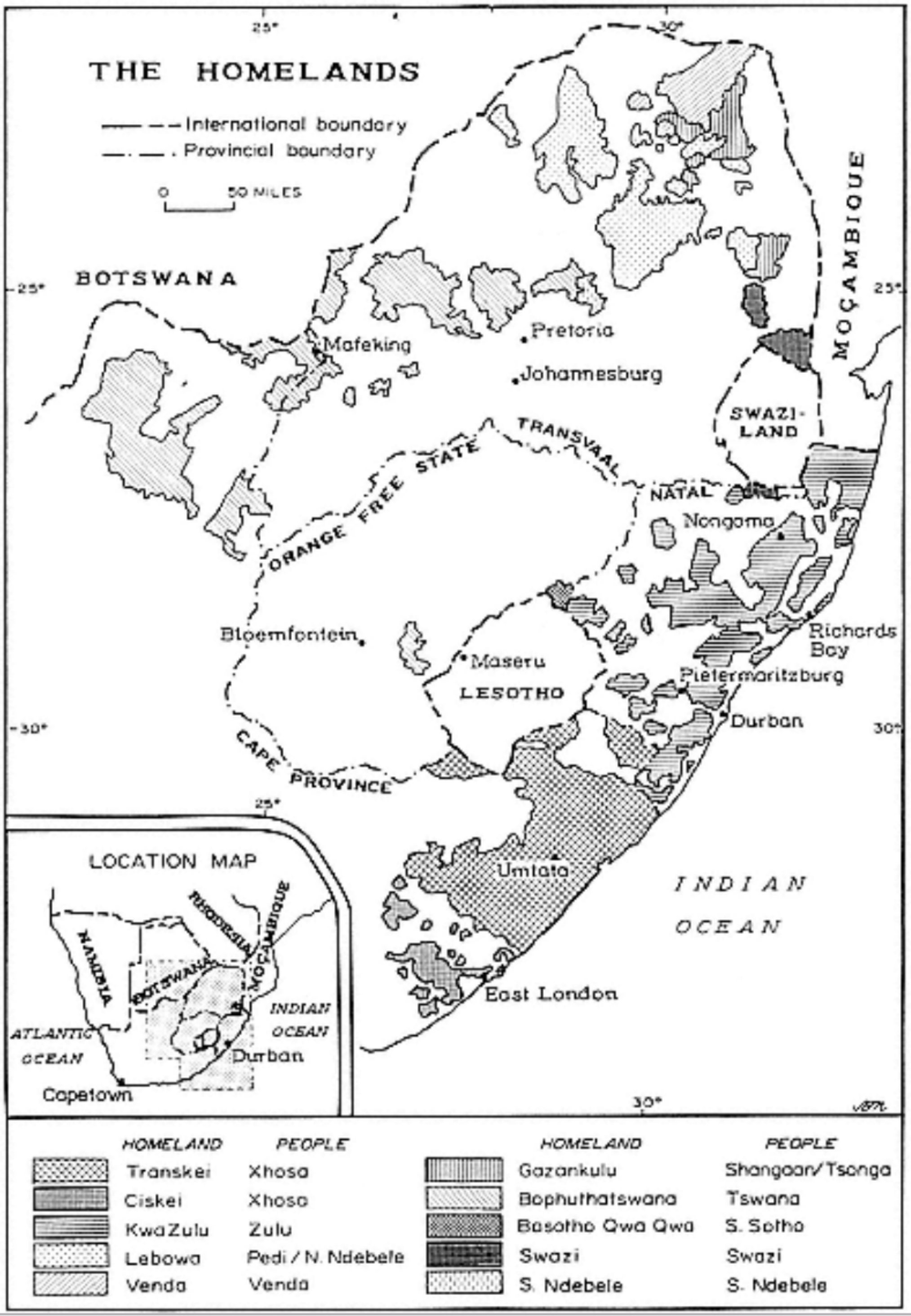


FIGURE 4.6: Map of former homelands of South Africa. Source: Butler, Rotberg, & Adams (1977).

Between 1902 and 1904, the Native Reserves and Crown Lands of Zululand were demarcated by the 1902 Lands Delimitation Commission. During this process, black people were forced into Reserve areas (MacKinnon 1991). The area north of the Tugela River, along the newly constructed railway line, was demarcated for European settlement. This land was considered to be "perhaps the best in Zululand" (MacKinnon, 1999: 105). It was deemed to be prime agricultural land, and agriculture was seen to be of prime economic importance as well as a way of colonising the land (Williams, 1959). The commission demarcated 3 881 991 acres for Africans and 2 769 114 acres for white settlement (MacKinnon, 1999). As MacKinnon (1999: 101) explained: "African farmers suffered both from the loss of some of the most arable and well-watered land in the region and from the concomitant pressure of increasing congestion as evicted families poured into the reserves".

White settlement was encouraged by the government and took place rapidly in areas allocated for whites, especially after the Union of South Africa in 1910 and continuing into the 1920s. In KwaZulu Natal, much of this land was developed by sugar cane farmers. In order to increase sugar production, black populations within the reserves were "encouraged" to plant sugar cane as a commercial crop so they could afford to pay taxes (Cochet et al., 2015).

Between the 1930s and 1960s, hybrid varieties of sugarcane were introduced into Natal. The development of hybrids aided the spread of sugar plantations further north into the drier but fertile lowveld regions. Building dams for irrigation was also integral to the expansion of sugar plantations into Northern Natal. Being far north, the area of Pongola was one of the last sugar-cane growing regions to be established. During the mid-1950s, a sugar mill was constructed to process the large amounts of sugar being grown (Lewis, 1990). Prior to this, based on interviews with local farmers, white farmers in the area had grown a range of crops such as maize, citrus and cotton, and reared livestock. However, according to an interviewee from a chemical company in Pongola in 2017, sugar cane was described as "a very easy crop to grow" and was supported by the state. The development of dams for irrigation and a mill made sugar an increasingly appealing crop for farmers to produce.

In order to cultivate the area around Pongola, dams had to be built which would feed water into canals to be used for spray irrigation. The Pongola Port Dam was opened in 1973, providing water to irrigate sugar cane, which continues to be the dominant crop in the area today. Sugar cane farmers also pumped water directly from the Pongola and Mkuze rivers as required. From the 1970s onwards, some black farmers and Indian farmers began to grow sugar cane. Historically, sugar-cane pioneers chose the low-lying valley areas adjacent to the Pongola River for their fertile soils, closeness to water and slightly higher rainfall compared with the neighbouring slopes. During the first visit to Pongola, during the maize growing season, for this research study, the region was experiencing the worst drought since the 1980s. Smallholder farmers had little access to water for irrigation and most had lost the rain-fed crops which they had planted. Concurrently, however, the commercial sugar-cane plantations surrounding the maize fields had access to irrigation water throughout the season. Smallholders having to rely on rainwater to keep their maize alive continues to affect food security and livelihoods, as the bulk of the available land water is channelled into hundreds of thousands of acres of sugarcane.

4.5. The history of land tenure in Pongola

In the most recent KwaZulu Natal Agrarian Transformation Strategy (2015), the sometimes violent processes that caused dislocation and fragmentation of people from land and agrarian livelihoods in the country were highlighted. In the strategy, it was explained how, since the 1913 Land Act black South Africans were forced to live in Native Reserves which were "predominantly hilly, rocky areas with thin topsoils, and unpredictable rainfall, and located in the remotest parts of the country". This spatial pattern "remained the norm for most of the century and the resultant impact inherited by today's generation is that rural areas are characterised by land degradation, poor soil quality, food insecurity, poor infrastructure and basic services, and high levels of unemployment" (Agrarian Transformation Strategy in KwaZulu Natal, 2015).

In this landscape, where low-lying areas are dominated by sugar cane, maize is not a highly commercial crop but, rather, a small-scale farming crop confined to the mountain slopes. Slopes are generally less fertile and receive less rain than the low-lying areas. Based on an interview with farmers from farming co-operative in Pongola in

2017, the wetter and more fertile slopes in this area were cultivated often by community leaders, suggesting a relationship between power and land.

However, despite the numerous historical and contemporary challenges faced, farmers continued to grow maize, both on small plots attached to their homesteads, known as "home gardens" and, to some extent, on large fields, which were located in communal areas usually some distance from the farmers' homes. Within communal areas, families usually had access to a large field, but this was not always the case as some fields had been lost to development over time. According to Shackelton & Luckert (2015), home gardens throughout South Africa are known to be cultivated usually by women but, in Pongola, this was not strictly the case. Many of the farmers cultivating home gardens were men, or men and women working together. Many households in Pongola planted at least a small crop of maize on household plots located near their homes. Some farmed in larger fields if they had enough assistance from family members or became part of a co-operative project.

From interviews with farmers born between the 1940s and 1950s it was evident that maize had once been a widely planted, smallholder crop in the Pongola area together with other commercial crops which were planted by commercial white farmers. During their lifetimes, the farmers in Pongola had grown different types of maize seed, ranging from traditional varieties to various kinds of commercial seed. Some still grew Hybrid or GM varieties of maize as well as their own traditional maize. Many had experienced dramatic agrarian change in their lifetimes. As one farmer explained, his family had come to settle in the area in the 1900s. They had experienced white settlers moving into the area to farm large tracts of land with "tobacco, oranges, maize and there were cattle and sheep" (Farmer 8, 2017: FS2). In his life-time, the white farmers had come and gone, while he had continued to farm with whatever means he had.

Two elderly farmers who were interviewed, had lived and farmed in the Pongola area for their entire lives and explained how, when they were born in the 1940s, their families had worked for a white, large-scale landowner in the area. They explained how white farmers had owned large areas of land in Pongola at that time and that it was likely that they had been given this land by the colonial government, who were trying to establish commercial agriculture as well as political control over the land. Data from interviews collated with archival and historical sources revealed that what existed at the time was a labour tenancy/share-cropping system where farmers were permitted to live on the land on which they had always lived and farm small plots of their own in exchange for providing labour on the large landowner farms. This also correlated with the processes of ownership and labour tenancy described by van Onselen (1996). According to the farmers interviewed, white landowners introduced new types of maize seed "with bigger grains" and, later, maize seed with "red powder on it", referring to hybrid varieties treated chemically against insects. They explained that some labour tenants started to use this new kind of maize seed and others continued to grow traditional/Zulu maize alongside.

One farmer explained how white farmers had to leave the land in the mid-1930s and it became "a Zulu place":

> In 1936 when the land was relocated, the white farmers left and Zulu people took over and it fell under the Zulu King and that was discussed in Cape Town in history making, so, from 1936, my family came here and I was born in 1940 immediately after, and this was now a Zulu place (Farmer , 2017:FS 1).

The Land Act was passed in 1936, pre-apartheid legislation that was brought about to formalise the separation of native and white people in rural areas. The Act set out the basis for the South African Native Trust (SANT) which sought to re-organise South Africa's rural land distribution and agricultural system. The Trust purchased and secured land for the purpose of Native Reserves. SANT began to control agricultural and grazing land, livestock and also residential planning, which was referred to as "betterment" planning. This was promoted as having the intention to modernise African agricultural systems, but an elaborate system for registering and controlling the distribution of labour tenants and squatters was introduced under the Act. Under these provisions, any black African unlawfully resident on white-owned land could be evicted. Land owned by black people, in areas allocated to white people, were called "black spots", and the state began to implement measures to remove the inhabitants of this land to the reserves. The 1936 Act provided the basis for formalising African Reserve areas, and the eviction of tenants from farms until transition to democracy (Butler, Rotberg & Adams, 1977).

From the available maps of the former homeland areas (see Figure 4.6 above), it appeared that Pongola fell in-between formally demarcated areas of the Zulu Homeland, which was not one consolidated area but made up of sections. This lack of clarity seemed to be consistent with the varied accounts given by farmers in the area of how they had experienced land-use change during their lifetimes. One farmer explained that the area in which they lived had been demarcated as a "Zulu place" during the 1930s and, by the 1960s, white farmers had left the area. However, in another, nearby village, farmers gave a different account that white farmers had only left during the transition to democracy (after 1994), when the government allocated formerly white-owned land to black people in the area. Before this, local people had lived as labour tenants working on white farmers' land, often working either for very little pay or for some of the harvest in return. The research fieldwork assistant, who was in her forties, explained how this had worked in the area where she grew up:

> It was not easy in those days…I can remember I was also employed by those farmers when I was eight years old. They were paying us fifty cents for picking up their crops when it was harvest time. But before 1980 [when compulsory education was legislated and many political shifts were underway towards dismantling apartheid] people were not even getting one cent. If you were living on a farm your children were supposed to work for the whole year, not getting paid. Then after 1994 people were told about the department of rural development, that is when the white farmers started to leave the land in the hands of those who were working on it (Farmer 15, May 2017:FS2).

The timelines of when significant changes of land use, political changes, introduction of seed, and climatic changes occurred varied between interviews with farmers. This could be attributed to the number of changes that had occurred over a long period of time and also that people's memories of dates varied. In one interview, a farmer explained vividly how much land use and land ownership had shifted and changed during his lifetime:

> So, those big fields that you see over there, they were made by white farmers. There were oranges and guavas…and then the places that were owned by [white] farmers were allocated to different people… in fact we are the natives of this place

> until today. History changes everything - we were a homeland then a Trust [South African Native Trust (SANT)], then now I don't even know what we are. Since I am not at school, I don't even know anymore…I mean, we just look at the TV to know what's going on…so now, this place is known by the name of the chief but different people live here (Farmer 18, 2017: FS5).

While farmers in different areas might have had different experiences, accounts reflected the extent of which farmers livelihoods and farming systems had been disrupted.

4.6. Historical changes in agrarian practices

The large tracts of terraced fields seen on the hill slopes (see Figure 4.7) below, were characteristic of the areas where research interviews were carried out. Near each settlement, the shape of contoured fields was evident on the adjacent slopes.

FIGURE 4.7: Photograph taken in Pongola, 2017, showing contoured fields. Source: Photograph by Maya Marshak.

However, most of these fields lay fallow and were signs of agrarian change, which gave rise to several questions: who made these fields? When were they made and used? What was grown in these fields using what methods? For how long were they cultivated? When did people stop using them and why?

Many farmers spoke of how the big terraced fields once were full of maize inter-cropped with other plants such as beans and pumpkins. Farmers explained how, in the past, they would harvest also certain edible, wild plants from between the maize. One farmer remembered, as a child, how there was "so much production that you couldn't harvest by yourself". Another remembered how:

> People were growing maize in the big fields, and also peanuts and sweet potatoes - that was the favourite. When I was a child, all kind of vegetables were grown by the people (Farmer 17, 2017: FS2)

While some farmers continued to use these big fields to cultivate maize, for the most part, maize was no longer inter-cropped with other food crops. According to the farmer above, by the 1970s, these fields were less evident. Different farmers gave different dates for when these fields were established and by whom, as well as for when they stopped being cultivated. Some farmers said these fields were made by white farmers who had tractors before the area became a Zulu place. When they left, the white farmers took the machinery and irrigation systems with them and farmers from the area did not know how to obtain new kinds of seeds. This made it difficult to maintain such large fields. Some local farmers reportedly bought tractors with the money they were given when they were retrenched from the mines. Other farmers said their large fields had been made with the help of tractors as a part of government agricultural projects during the transition to democracy. However, these projects had been implemented in some places only and were not consistent in reaching all the interested farmers nor consistent in their provision of support (Farmer 29, 2019:FS2).

Dates given for when people stopped farming on the big fields ranged from the 1980s to as recently as 2013 when farmers began experiencing drought. It was likely that a combination of factors led to the abandonment of these fields over time. Many scholars believe that "field abandonment" in South Africa dated back to the 1940s (or earlier) when people were forcibly relocated into homelands (Hebinck & van Averbeke, 2013). However, on the basis of their research in Gatyana in the Eastern Cape, Shackleton & Luckert (2015) argued that this process had occurred most notably during the time of transition to democracy. Shackleton and Luckert (2015: 1069) cite several reasons for this including: "an increase in social welfare", "lack of access to markets; exhausted soils; unpredictable weather; lack of labour; poverty and lack of access to credit; infrastructure decline, especially fencing and roads; resultant destruction of crops by cattle and wild animals and the loss of child labour for herding; a decline in farming knowledge; and lack of land and tenure rights. Many of these factors were apparent in Pongola.

4.7. Compulsory education and changing agrarian roles

Farmers explained that, when children in the area began to attend school during the late 1980s and early 1990s, there was no longer enough capacity to farm the big fields. Up until the mid-1980s, education for black children in South Africa was neither compulsory nor free (Johnson, 1982: 220).

Prior to this time, children had played an important role in helping with planting, weeding and protecting the crops from birds and livestock. Farmers were unable to afford fences to keep livestock away from crops once children were no longer available to herd them.

Without the help of children in the fields, farmers became more open to using new technologies as they no longer had the capacity to perform the tasks that children had done, such as weeding. Also, younger family members obtained jobs outside of rural areas, leaving only the elderly to farm. For many farmers, this necessitated the use of herbicides, as weeding was too taxing a task. It is for this reason that GM Round-Up Ready maize seed became a popular choice in the area because it removed the need to weed fields. One farmer explained:

> I bought this Round-Up Ready thing that goes with the chemical. You just plant and then when you want to weed just use a boom sprayer…it was Pannar [seed]…it works good and I had plenty of maize. It is a popular seed here in this area. I chose

> this because you don't have enough labour here so you battle with weeds. Sometimes I use the reaper on the tractor to go between the rows and then I use the chemicals to destroy the rest (Farmer15, 2017: FS2)

4.8. The changing relationship between livestock and maize farming

In the past, livestock played an integral role in the agricultural system. Their manure was used in the fields as fertiliser and oxen were used as draught animals in the fields. Young boys were responsible for herding cattle during the day and, at night, cattle were kept in a *kraal* (enclosure). This system had multiple benefits. Apart from keeping the cattle safe at night, it allowed for the collection of manure. Seed was stored underneath the compacted earth where it was kept cool and away from pests. The urine from the cattle created a sterile environment (NGO employee 1, 2016: Pongola). In the past, oxen were used for ploughing the large fields. At the time of this research study, there were very few oxen trained for ploughing or people who knew how to do this in the area. During the research we did not meet any farmers who still used oxen in their fields. Cattle were left largely unattended and were not kept in kraals any longer. The lack of fences and destruction of crops by wandering livestock (including goats) was cited often as being a major challenge for farmers and a reason for the fields being abandoned. Farmers often expressed that they wished the department of agriculture would assist them with fencing. When asked what farmers did before fencing, they explained how customary laws had prevented farmers from allowing their cattle to destroy a neighbour’s fields after the planting season. Herdsmen during the day and enclosures at night kept the cattle from destroying crops. However, these laws no longer applied in the area as farming systems and livelihoods had changed.

4.9. Shifting climatic conditions

During the research interviews, several farmers drew attention to how rain patterns had changed significantly over the years, making it harder to grow rain-fed maize on a large scale as they had done before. In a study on adaptation to climate change, Thomas et al. (2007; 308) cited that the Province of KwaZulu Natal had experienced increasing variability in annual rainfall and notably later rainfall in 1990 and 1994. During interviews conducted with farmers and other affected parties there was "an acute awareness of the changing climate trends" and the difficulties associated with changing rain patterns (Thomas et al*.*, 2007: 308).

Traditionally, maize seed was planted after the first rainfall of the season. Many farmers spoke of how the first rains, *imbozisa amahlanga*, that marked the beginning of the planting season were coming later and later in the year and the maize planting season, which had been as early as August before, could be as late as November. The start of the rainy season was vitally important to farmers who relied on rain-fed crops. During the first year of this study and the previous two years (2014, 2015 and 2016), farmers experienced the worst drought since the early 1980s and had no harvest from their fields (Abbas, Bond & Midgley, 2019). Some had managed a small harvest mainly of traditional maize in their home gardens, which was hardier in water-scarce conditions. Historically, throughout the region, an understanding of rain patterns was vital for human survival and the survival of agricultural crops. The elderly farmers interviewed gave clear descriptions of the changing rain patterns. Reflecting on the past, a farmer spoke about how rains fell early when he was a child and harvests were abundant:

> In those days, the rain was also in favour…August, that was the first rain. In September, we started ploughing. In December, it's midsummer. You could not harvest by hand in that time. You had to call many people to help because there was so much harvest - it was the 1960s, but in 1970s it was already changing…that is the history of this place (Farmer 22, 2017:EFS1).

The quotation above and many of the interviews gave a perspective on a time when maize production was abundant in the Pongola area. Despite the complex and difficult history that people in this area had experience until the 1970s, the farmers described a thriving agricultural system in which people farmed maize together with other crops, such as pumpkins and beans, in harmony with raising livestock.

4.10. The effects of the transition to democracy on smallholder maize farms

South African policy after the transition to democracy in 1994, and related developmental projects, promised to support smallholders previously disadvantaged during the colonial and apartheid eras. Since the transition, several development projects for farmers have been established to boost smallholder maize agriculture, with maize being regarded as a central crop in the transformation process (Kepe & Tsesaro 2014; Fischer & Hadju 2015; Greyling & Parley 2018). Many of these projects have promoted GM technologies and have been supported by multinational seed companies (Assefa & van Den Berg 2010; Fischer & Hadju 2015). For example, the Monsanto's Seeds of Success Programme distributed free GM maize seed in a package with fertilisers and herbicides (Mayet, 2007; Gouse et al., 2016). Through Government supported maize development projects, such as the Massive Food Production Programme, smallholders were supplied with free or subsidised Bt maize and fertiliser (Gouse et al. 2005; Jacobson & Myhr 2012; Jacobsen 2013; Fischer & Hajdu 2015; Mahlase, 2017).

The motive and appropriateness of supplying smallholders with GM seed have been critiqued widely (Fischer & Hadju 2015; Gouse et al., 2005; Mahlase, 2017). Over time, several of these projects have collapsed, especially as subsidies have been withdrawn and farmer debt has increased. Some programmes continued to function to some extent. However, these programmes also led to shifts in farming approaches over the years, often leaving farmers unsure of what support to expect, having experienced previous disruptions.

Co-operative projects became a feature of government agricultural interventions in post-apartheid South Africa. In 2005, the government passed the Co-operatives Act (No 14 of 2005). In this Act co-operatives were defined as:

> An autonomous association of persons united voluntarily to meet their common economic and social needs and aspirations through a jointly owned and democratically controlled enterprise organised and operated on co-operative principles. Moreover, it is unlawful to use the term co-op or co-operative for any entity not registered as such.

Following this Act, a model of co-operative development was created, based on several policies and frameworks, including the National Development Plan (NDP) of 2012 and, also in 2012, the Framework for the Development of Smallholder Farmers through Co-operative Development. In this framework co-operatives are identified as 'one of the central pivots by which to reduce poverty, unemployment and high levels of inequality and to accelerate empowerment and development for the benefit of previously disadvantaged majority' It was stated that co-operatives:

> …offer prospects that smallholder farmers would not be able to achieve individually such as helping them to secure land rights and better market opportunities. Smallholder farmers can gain big benefits from agricultural co-operatives including bargaining power and resource sharing that lead to food security and poverty reduction for the millions.

It was stated further in the framework that co-operatives could also:

> …help in tackling rural poverty by increasing productivity and income of smallholder farmers by helping them collectively negotiate better prices for seeds, fertilizer, transport and storage. They further help farmers expand market access and capture more of the value chain by getting involved in agro- processing activities (DAFF, 2012: 2).

The vision of the Framework for the Development of smallholder Farmers through Co-operative Development shows how the government intended to use the model of co-operatives to bring smallholders into the industrial, commercial, agricultural system and this is regarded as a route to addressing a myriad of rural and national needs.

Following the NDP, cooperatives were mentioned prominently in the government's 2014-2019 Medium-Term Strategic Framework (MTSF) as part of radical economic transformation. It was observed that co-operatives would support excluded and vulnerable groups, such as smallholder producers (MTSF, 2014). This included creating decent employment through inclusive growth and vigorously implementing BBBEE[9] and reducing the high levels of market concentration and monopolies (MTSF, 2014).

Co-operatives were considered also to be a way of utilising "under-utilised land" efficiently within "communal areas" as part of land reform and commercial agricultural projects (DAFF, 2015: 10). The Agrarian Policy Action Plan 2015-2019 stated that better use of these areas could create 300 000 jobs by 2030 (DAFF, 2015).

A government official in the Subsistence Agriculture Directorate at national level, explained how the government tried to help people collectively rather than individually as this was regarded as a way of maximising resources and the number of people reached.

> With government, we are on a drive to promote co-operatives, while we do have programmes that assist individual farmers, but we really would want to promote co-operatives because there are a lot of advantages with co-operatives…well, some would argue that there are a lot of challenges too, in dynamics, group fighting and such but government wants to see their resources touching many lives at the core (Government employee 1, 2017: Pretoria)

Co-operative projects have been considered to be a necessary way of creating equitable opportunity through creating economies of scale. They are posed as solutions in relation to past injustices and the inaccessibility of markets to smallholder black farmers during apartheid and colonial period in which white cooperative farmers were given unequal access to markets.

> Most of the white farmers are commercial farmers and they were supported by government during apartheid. So now, with this type of intervention (smallholder co-operatives)… we are trying to close the gap that existed in the past. So, in closing the gap, we are trying to push those farmers that do not have the means to become commercial (Government employee 1, 2017: Pretoria).

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[9] Broad-based Black Economic Empowerment (BBBEE) is an integration programme launched by the South African government to address the inequalities of apartheid by attempting to compensate for land that was dispossesed from Africans.

The same official also explained the challenges in trying to use cooperatives as a way of "catching up" with large commercial farmers who previously had the advantage of government support. Often, farmers working hard in co-operatives only generated enough money to buy food (Mahlase, 2017). It was also very difficult, even for successful smallholder farmers to compete with long-established commercial farmers.

While co-operatives have been promoted as a way of making the most of resources, in reality, co-operatives experience many problems as well. One key criticism that arose in the field research was that using co-operatives assumed that people living alongside each other are interested in collaborating and did not take into account politics and the complex, historical issues that had arisen. As one farmer explained:

> I'm just not interested anymore in co-operatives. You see, the problem is everyone gets involved but you will find only two people working, and you can't do all the work for another man…the co-operative system doesn't make sense. It's better to support one person who is interested because, if someone has a vision, they can push their vision, but grouped people are not interested in the same way… I think at the department they only see the money and say, let's spend it, but they don't look at the end result. (Farmer 29, 2019: FS2)

This farmer, as well as others, felt frustrated that their efforts, as individual farmers, were not supported. Most individual farmers did not ask for a huge amount of support. According to the interviewees, what was needed most were water tanks and fencing and, while many had tried to access this through the government, few had been successful. Many of these farmers had been part of co-operatives that had failed for various reasons. Subsequently, they continued to farm with whatever resources they had available.

As stated in the quotation below, the top-down approach used to implement cooperative projects in Pongola was a source of a great deal of frustration for farmers who were committed to making it work when first presented with the idea. The farmer below suggested that co-operative projects promised farmers a great deal of help and then did not deliver this and the process further disrupted farming practices.

> … the new government only gave people seed after 1994 and I was so angry about that. I've been trying over the years to put people together so we can farm and improve our production. I've been in and out of these so-called co-operatives, that doesn't work. The first time we made a proposal in the early 1990s to ask the government to help us with fencing an area where there is water near the fields, and interested people could join in. But then it turned upside down. They said we were not going to do what we proposed, but that we must pool our land for one crop - we chose dry beans. The whole area was farmed with dry beans and they told people, "We will till the land, we will plant, we will reap and you can have the profit". If you want a man to grow, you need to give support and let him do it…you know what happened? That is why the place is like that [pointing to the empty fields]. After that, people didn't want to farm anymore. The big fields used to be full, and now people were saying, "When is the government coming back again? That project was just one thing that they used to pick up money. Some fields were done, other fields were not done and those beans grew with weeds that high [waist high] and it was a mess (Farmer 29, 2019: FS2).

4.11. Conclusion

In this chapter, the complex and sometimes violent changes that smallholder farmers have experienced in the case study area of Pongola and in South Africa have been described. The purpose of this chapter was to provide a context within which to consider the broader, social-political context into which new maize seed varieties were introduced and the various factors affecting agricultural change. Seed is a relational object and has been changed, and has played a part in affecting change, in a context of social-political transformation. While GMOs are promoted often by government and developmental projects as "seeds of success", holding many answers to the problems faced by smallholder farmers, the historical social, political and ecological context of their development and use is rarely reflected upon critically. Over-time, these factors have disrupted farmers' practices and farming knowledge and their relationships with the land, soil, ecosystems.

FIGURE 5.1: Biowatch farmer displaying her Zulu maize harvest, Pongola, 2017. Source: Maya Marshak.

5. CHAPTER FIVE: Modern Maize Seed Technologies and Ecological Deskilling in Smallholder Farming

5.1. Introduction

Farmers are makers and keepers of agricultural knowledge. This knowledge and the ways in which it is generated is always shifting in relation to economic, political and biophysical factors, and a constant negotiation and renegotiation of relationships (Stone, 2007). The introduction of new agricultural technologies can bring significant change to the systems they enter (Goodman & Redcliff, 1983; Herrero, Wickson & Binimelis, 2015; Wickson et al., 2017; Green, 2017). Based on qualitative research carried out in a rural area outside the town of Pongola, KwaZulu-Natal, this chapter explores how the introduction of modern maize seed technologies, such as conventional hybrids and genetically modified (GM) varieties and their co-technologies, have impacted the ecological-based knowledge and practices of smallholder maize farmers[10].

The research relied on the collection of life history interviews with farmers, visual data collection, participation in activities and meetings. Key informant interviews were also conducted with other local stakeholders, such as government officials and agridealers in the area, as a way of understanding the wider socio-political context. A multispecies approach was used as a way to tune into a web of changing relationships between farmers, seed and the agroecological environment in which they work. Interviews enquired into farmers' interactions over time with "more-than-humans" (such as insects, pests, weeds, wild plants, birds, soils, rain patterns and seasons) within the agroecological systems. Farmers were asked how various practices, such as planting, storage, selection and treatment of the soil, changed when they began using store-bought modern seed and its co-technologies. Pests and weeds became a particularly

[10] Parts of the research in this chapter have been published in a journal paper co-authored with Amaranta Hererro, Fern Wickson and Rachel Wynberg (2021): However Maya Marshak led the conceptualisation, research, writing and analysis of the paper See: https://www.tandfonline.com/doi/abmayas/10.1080/21683565.2021.1888841.

useful set of collaborators in the interviews[11]. The methodological approaches used are explored in more detail in Chapter Three.

The case study area was chosen, as smallholder farmers in this location grow a range of maize seed, from farmer heirloom varieties to commercially available open pollinated varieties (OPVs), conventional hybrids and GMOs. Farmers in this area often refer to heirloom maize as *ummbila wesiZulu* (Zulu maize). Despite – and potentially because of – being located in a commercial sugar-growing region, as opposed to a commercial maize-growing region, a diversity of Zulu maize still exists (See Figures 5.2(a) and (b)). Zulu maize is grown by many of the elder farmers in the area who have retained their seed, as well as by a small group of farmers who are associated with the NGO Biowatch promotes agroecology, as well as the reclamation of traditional seed and farming practices in the area, by building communities of practice and offering training. The most commonly planted commercial maize seed in the area was store bought OPVs and conventional hybrids, because these are most accessible to smallholders and are much more affordable than GM seed. Few farmers buy GM seed, as it is expensive. However, the local department of agriculture advocates for the use of GM seed when farmers can afford it. Yet over the years, as development and procurement projects have shifted, farmers have received OPVs, conventional hybrids and GM seed varieties. The less common use of GM seed is consistent with studies elsewhere in South Africa that have shown that the adoption rate of GM seed by smallholders is relatively low, due to it being much more expensive (Gouse et al., 2016; Jacobson and Myhr, 2012).

It was initially anticipated that it would be possible to carry out separate sets of interviews with farmers who were planting different types of seed and thus reveal how farming practices differed according to the seed planted. In practice, however, it was not possible to create such artificially distinct boundaries. Reasons for this were threefold: firstly, many farmers varied the seed that they planted from year to year, depending on what was accessible to them; secondly, most farmers did not understand

[11] Agricultural insects which have become known as pests have had a huge role to play in how farmers farm and in the developemnt of modern seed and co-technologies which have specifically targeted pests, therefore being shaped by these creatures. Bt maize for example specifically targets stem borer.

the difference between OPVs, conventional hybrids and GMOs, and often did not keep detailed records of what they planted from year to year; and, thirdly, many farmers planted more than one type of seed at a time in any one season. Many farmers planted a range of seed over their lifetimes and the majority of farmers – now in their sixties, seventies and eighties – had decades of farming experience, over which time they had tried many types of seed. While the challenge of defining clear systems made comparative research extremely challenging, it highlighted an important set of dynamics around farmers' relationships with their seed and the impacts of the modern seed market on farmers' agricultural practices, knowledge and agency.

As a result, what emerged was an interlocking set of narratives that showed overlapping practices around growing maize in relation to a multitude of factors and realities. This was shaped by, but not limited to, the use of different seed varieties. The one exception to this was the group of farmers affiliated with NGO Biowatch. Many of these farmers had worked with Biowatch since 2012 and were committed to only planting heirloom Zulu maize or OPV maize seed, and using agroecological methods that draw on traditional methods similar to those that were used in the past. It was difficult to find farmers who grew maize in a traditional fashion, both because tradition is not fixed and farmers adapt their practices in response to a myriad of factors, and because farmers in this area have faced significant pressures that have greatly shifted farming systems. However, the group affiliated with Biowatch had a very different relationship with their seed and were growing a community of learning and practice, year by year.

a

b

FIGURE 5.2(a): A smallholder maize farmer's display of her maize harvest and (b) (below) A Biowatch farmer’s Zulu maize harvest, Pongola 2017. Both photographs show a diversity of traits. Source: Maya Marshak.

5.2. Modern seed technologies and agricultural deskilling

This chapter draws on the literature on agricultural deskilling. Fitzgerald (1993) first used this concept to articulate the changes she saw in farmers' skills, due to the introduction of conventional hybrid corn seed in the United States. Stone (2007) used this concept in relation to the adoption of GM cotton seed and the concurrent loss of skills by smallholder farmers in Warangal, India.

This thesis is interested specifically in changes in socio-ecological relationships and knowledge. Consequently, the research design has incorporated a posthumanist lens. In order to draw attention specifically to the loss of knowledge and relationships of farmers (and scientists) to ecological systems, this chapter recommends the use of the term 'ecological deskilling in agriculture'[12]. This builds on the prior concept of agricultural deskilling and also draws on the concept of coevolution. Coevolutionary theory understands social-ecological systems as coming about and changing "through coevolution between their social and ecological components" (Gual & Norguaard, 2010). While this concept may be understood "intuitively" as Gual & Norguaard (2008) have pointed out, it has been widely disregarded within academia due to the separation between the social and natural sciences which have "for the most part ignored the existence of interlinked/ interdependent evolutionary processes between cultural and biotic systems (Gual & Norguaard, 2010:1).

Drawing on coevolutionary theory the term ecological deskilling in agriculture emphasises the disruption of the coevolution of agricultural knowledge and practice between humans and the more-than human world. Historically agricultural knowledge and practice was generated through cumulative observations and interactions within the agroecosystems and with its more-than-human inhabitants over generations of farming. This arose from the complex environmental and social learning processes that form part of a continuous "agricultural skilling" (Stone, 2007) and often lead to culturally situated and sustainable practices (DeWalt, 1994). The term implies a move

[12] The concept of ecological deskilling in agriculture was developed during the research and in collaboration with colleagues. The research is published in Marshak, M., Herrero. A., Wickson., F., Wynberg. R, 2021, Losing practices, relationships and agency: ecological deskilling as a consequence of the uptake of modern seed varieties among South African Smallholders.

beyond an anthropocentric lens towards one that considers the lives of farmers and all other beings in the agroecosystem and how they work together.

The research revealed three intertwined and sequentially related dimensions of the concept of ecological deskilling in agriculture[13]. These are: loss of ecological-based practices, loss of relational knowledge and loss of socio-ecological agency. Furthermore, the parallel concept of 'ecological reskilling' is also articulated to describe the work farmers and Biowatch are doing to restore relational agroecological knowledge and practice.

5.2.1 Loss of ecological-based practices

Primarily, the process of ecological deskilling refers to the total loss, partial loss or displacement of traditional, ecologically based practices, due to the adoption of modern technologies, such as agrochemicals or GM seeds. It must be noted that this cannot be seen outside wider contextual factors such as changing climate and land-use change that contribute to processes of changing knowledge and practice. Traditional, labour-intensive practices are typically based on understanding multi-factorial information about the agroecosystem, in order to address agricultural challenges, such as insect infestations or overgrowth of weeds.

In maize agriculture in South Africa, African stem borer, including the larger *Busseola fusca*, and the smaller spotted stem borer, *Chilo partellus,* known collectively as *isihlava* in Zulu, are well known in maize fields, and when shown pictures of these insects farmers were well aware of them. Historically, farmers had a range of traditional techniques for keeping stem borer numbers under control. These included:

> sowing when the weather conditions are not favourable for stem borers; placing ash or soil in the tunnel between the leaves of new maize to stop insects entering the maize stem; or, sprinkling the maize with a mixture of bitter indigenous herbs (Fieldnotes, 2017/18:Pongola).

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[13] These three dimensions of ecological deskilling were developed during the research and in collaboration with colleagues. The research is published in Marshak, M., Herrero. A., Wickson., F., Wynberg. R, 2021, Losing practices, relationships and agency: ecological deskilling as a consequence of the uptake of modern seed varieties among South African Smallholders. Agroecology and Sustainable Food Systems

FIGURE 5.3(a): A Biowatch farmer's seed collection showing saved maize seed, beans and sorghum, Pongola, 2017. Source: Maya Marshak.

FIGURE 5.3(b): A Biowatch farmer's maize seed collection, Pongola, 2017. Source: Photograph taken by Maya Marshak.

With the appearance of hybrid and GM seeds, however, these practices have been substituted either by synthetic pesticides or by GM crops such as Bt maize, which incorporates the production of an insecticidal protein produced by the bacterium *Bacillus thuringiensis* (Bt) in its DNA. Using GM seeds that produce an insecticidal protein means that farmers no longer have to use the methods they once used. Out of the twenty-five farmers interviewed, only the nine affiliated with Biowatch still used traditional, non-chemical methods of pest control. This was because Biowatch had been encouraging farmers to reclaim these methods by making them aware of the dangers of pesticides and the potential risks of GMOs. Over time, the increased reliance on pesticides has contributed to a loss of ecological-based practices for stem borer control. This loss can become devastating if the pest insects develop resistance to the GM traits, as has already occurred in South Africa (van den Berg, Hilbeck & Bøhn, 2013).

In Pongola, pesticides are now widely used by smallholders, both for growing and storing maize. The latter would once have been achieved using traditional methods that kept insects away. These traditional techniques included burying seed under the cattle *kraal* (byre), which was a compacted and sterile environment, due to the animals' urine in the soil; hanging the maize cobs above the cooking fireplace, where smoke would keep insects away; or, storing it in bottles with ash (Fieldnotes, 2017: Pongola).

a

b

FIGURE 5.4(a). Maize is hung above the fireplace so that the smoke keeps insects away from eating the seed. FIGURE 5.4(b). A farmers' storage supply of harvested hybrid white maize. This is commonly stored using a pesticide tablet. Source: Maya Marshak.

Another area where a similar loss of ecologically-based practices is visible is in the management of 'weeds' in between the maize plants. The use of broad spectrum herbicides and, more recently, herbicide-tolerant GM seed, has also widely displaced traditional inter-cropping farming methods. Whereas farmers would have traditionally grown maize intercropped with other crops and even allowed the growth of edible wild foods (typically seen as 'weeds' in industrialised farmscapes), the use of herbicides such as glyphosate inhibits this (Tsubo et al., 2004).

> We used to grow pumpkins and beans in the big fields in between the maize, but now we use the Roundup to spray, so we can't grow vegetables in between the maize (Farmer 15, 2017: FS2).

The intercropping system that farmers refer to is similar to the well-known *milpa* technique, which was used historically by Indigenous farmers throughout Mesoamerica and is still practised today. It has become a well-established agroecological method

(Waldmueller, 2015). In addition to allowing farmers to produce a nutritious combination of foods, this technique allows plants to support each other's growth. For example, grain crops such as maize, millet or sorghum have different 'spatial and temporal' patterns to legumes such as beans. They therefore have a different use of environmental resources, such as sunlight (radiation), water and nutrients, which do not detract from each other's wellbeing, but rather improves it (Tsubo et al., 2004:381). As explained by elder farmers and those affiliated with Biowatch, a pumpkin's leaves can provide shade to the newly emerging maize plants, as well as help retain moisture in the soil. The beans can improve the quality of the soil and the maize can support the climbing beans to stay upright. Retaining moisture in the soil through the provision of shade by intercropped plants is a type of mulching referred to as 'live mulching' (Tsubo et al., 2004). In Pongola many of the farmers mentioned planting sweet potatoes with maize, which also worked well to cover the soil. Studies have shown that this, too, helps increase the yield of the range of crops planted and creates a cover to improve the moisture content of the soil (Willey, 1990; Tsubo et al., 2004; Islam et al., 2014). Farmers were also aware of other wild foods that would emerge among the planted crops, such as *imfino*, a type of wild spinach with a high nutritional value. These wild foods would provide a nutrient dense food source available for consumption before other crops were ready to be harvested and consumed (Modi and Hendriks, 2006).

The application of broad spectrum herbicides for the removal of weeds removes all plants other than the focus crop, thereby automatically denigrating all other plants into the category of 'weeds', including the edible ones. While Roundup is designed to be used with Roundup Ready® Maize, which can withstand the toxicity, four farmers in the area reported using Roundup for weed treatment in conjunction with hybrids or OPVs. According to an agridealer manager, in these cases farmers will use Roundup to remove all the weeds before planting, or in the first 7–14 days of planting, and then use a broad-leaf herbicide once the crop is above ground (Agricultural supply company manager 2, 2019: Pongola). This use of chemicals over the maize's lifecycle makes intercropping impossible and removes wild edibles from the system. This in turn has implications for nutrition and food security.

By its very nature, GM Roundup Ready® Maize is designed to remove all potential competition, ensuring that it is the sole surviving robust monocrop. Essentially, this technology therefore continues to undermine ecological-based intercropping practices. While the aim is to remove all possible weeds using a broad-spectrum herbicide, in order to boost the productivity of maize (as, theoretically, it doesn't have to compete for moisture and nutrients), this is done at a huge cost and is based on a narrow, industrialised idea of what productivity entails. Intercropping in maize systems can, in fact, improve the productivity of all the crops in the system through the mutual benefits certain plants can provide to one another, and the health and moisture content of the soil (Tsubo et al., 2004). When speaking to elder farmers in the area, many spoke of their childhood, in which there was abundance in the fields of maize but also in other crops, signalling a different understanding of abundance beyond a solo crop of maize.

> You could not harvest by hand in that time; you had to call many people to help because there was so much harvest. It was the 1960s, but in 1970s it was already changing…that is the history of this place. (Farmer 22, 2017:EFS1)

Gouse et al (2016) argue that the use of herbicides is often welcomed by farmers due to their labour-saving ability. Such sentiments were affirmed by extension officers and many farmers in the study area, illustrating some of the changes that have occurred with the use of the new seed and its co-technologies. One farmer explained:

> They [extension services] came and taught us this new way, so now we are following it and it's difficult to go back. For instance, I have many fields. It would be very difficult if I weeded them; it would take forever. However, if I use these new chemicals, I'll just spray for one day and all the weeds will be gone and the [GM herbicide-tolerant] maize continues to grow (Farmer 30, 2019: FS2).

Here, the farmer feels it is difficult to go back to a previous practice, indicating how the new technology leads to a loss of previous practices, rather than simply adding another useful tool to the toolbox. The previous way of doing has become displaced, even unthinkable, now and, although in this case the change is seen as desirable by the farmer, the example illustrates how farming practices can be lost in a very short period. In the above excerpt, the farmer refers to an inability to return to a practice of manual weeding. Within a relational system of farming, however, manual weeding is just one example of a range of approaches. Intercropping, for example, can also reduce weed competition, if done correctly. This illustrates how the introduction of a new technology can displace the imagination and implementation of alternative, more relational practices that were once used. Literature on lock-in technologies describes the way technologies such as pesticides may become commonplace even when more integrated alternatives may be more suitable in the given context (Cowan & Gunby, 1996). Because of these new technologies, agroecosystems have changed (such as through an increase of pests, due to a loss of natural enemies), and farmers may find themselves in a dependency loop in which they no longer know how to utilise the practices they did before, and from which they are unable to easily revert (Cowan & Gunby, 1996; Hu and Rahman, 2016).

Tsubo *et al*. (2004) argue that intercropping can in fact save time and labour, as efforts, resources and multiple objectives are concentrated in one place. By growing maize farmers can simultaneously grow pumpkins and beans and build the soil fertility. This relational way of understanding time, labour and resource use contrasts with modern industrial concepts of efficiency, which have led to a 'silver bullet' approach embodied in the way herbicides remove all weeds to reduce the 'competition' with maize.

Many smallholder farmers today choose to use herbicides, because they do not have enough help to weed the fields, and because they are finding that weeds are getting 'bigger' than before, likely as a result of ecosystem imbalance and resistance to chemicals. Two elderly farmers commented that they have 'no choice' in doing so these days, as they are getting old and have no help in the fields. Furthermore, the removal of 'weeds' affects the moisture content of the soil; where intercropped soil would have shaded and retained moisture, soil left bare after the used of herbicides does not retain moisture.

The local department of agriculture now encourages farmers to utilise a no-till method of planting, in order to reduce the loss of moisture content in the soil. The encouragement of no-till agriculture is part of a wider drive towards conservation agriculture in the country. The method is also encouraged locally, as the previous mechanisation programme, which promoted the use of tractors, became untenable and the tractors could not reach all the farmers every season (Government employee 1, 2019: Pongola). While a pragmatic and more ecologically sensitive approach than tractor tilling, no-till agriculture tries to remedy the degradation of the soil while continuing the use of chemical sprays and maintaining a focus on monocrop-style agriculture. While this might improve the moisture content of soil to some extent, it is not comparable to the benefits of intercropping, which are multiple and relational (Tsubo et al., 2004). The simple evaluation that no-till agriculture is better than conventional agriculture poses the danger of "encouraging development that is no worse than the unsustainable systems we already have" (Herrero, Wickson & Binimelis, 2015:11326) rather than exploring the other ways we could conceive of what is "socio-ecologically desirable for the future" (Wickson, 2014:11327).

The displacement of alternative options is visible in the way that the local government sees the role of new seed technologies as fulfilling a need in the area. One local agriculture department employee explained:

> As you have noticed, most of our farmers are old and we don't have much in terms of the youth, so when people are old they need to use easier methods of farming… that is why Roundup Ready® and stacked varieties are popular – both Pannar and Monsanto, but we usually use Pannar because it is easy to procure in KwaZulu-Natal (Government employee 2 2017:Pongola).

This sentiment was echoed in another interview with another employee from the local department of agriculture who explained how, in their opinion, smallholders preferred using stacked (Ht + Bt) varieties if they had a choice.

Gouse et al. (2016) argue that weeding has traditionally been women's work and that GM seed and pesticides are helping to remove this burden on women. While a gendered perspective is an important addition to the literature on the impacts and benefits of GMOs for smallholder farmers, weed killer is presented as the only possible labour-saving alternative; the possibility of other, more ecologically based practices is not considered within dominant perspectives such as this one. Again, as Herrero, Wickson & Binimelis (2015) argue, this kind of perspective promotes new technology as a remedy to a problem within a conventional framework, rather than looking towards more systemic solutions.

Seed-saving is another practice that has increasingly been lost, due to the introduction of commercial seed varieties to farming systems. In this area, most farmers (apart from the farmers linked to Biowatch) no longer save their maize seed. This was true even for farmers using OPV varieties, which are available at the local agridealers. Some farmers were not aware that OPVs could be saved and others felt that buying seed was easier or better. There was a common perception that bought seed was 'better' and that it gave 'more production', 'more harvest' or 'bigger cobs', incidentally described twice as 'cobs the size of your forearm' (Fieldnotes, 2017-2019:Pongola). However, when asked to recount how the Zulu maize performed when farmers were younger, many spoke enthusiastically about an abundance of maize. Often, farmers would first say that commercial seed was better, as if this was something of a general consensus and perhaps expected from outsiders coming to ask questions about maize. (Most outsiders coming to the area had been promoting new seed varieties; in fact, we were often asked if we didn't have seed for farmers to use or try.) However, when asked deeper questions about the attributes of Zulu maize specifically, farmers would often start to explain that Zulu maize had many positive attributes. Zulu maize was often described by older farmers as tastier, denser, more satisfying and more nutritious. It was also often described as hardy and resistant to 'hot sun' or drought periods. During the drought period, which coincided with the first interviews conducted with Biowatch farmers in Pongola, all the farmers had managed to grow some Zulu maize and were enthusiastic about its ability to survive harsh conditions with little input. For these reasons many elderly farmers who had grown up eating this maize chose to continue growing it for subsistence purposes. However, milling companies are not interested in buying Zulu maize as it is dense and not compatible with their machinery, which is designed for milling standardised hybrid and GM varieties that have softer kernels. Zulu maize thus has little value commercially; although some farmers do sell to their neighbours, they have not been able to establish wider markets.

As more farmers have converted to buying modern seed, practices of seed-saving are disappearing. As mentioned earlier, past methods of saving maize seed were adapted to local conditions and lifestyles, and included saving seed in bottles or calabashes (dried gourds) with wood ash, hanging maize cobs above the fire to keep insects from eating the seed, and storing maize seed under the cattle kraal. Many spoke of how these methods of saving Zulu maize would ensure that the seed lasted for a longer time. They also explained that traditional seed, which is much denser, lasted longer, with one farmer saying he kept his seed for over three years using these methods. In the past, this would have ensured the survival of seed during times of drought during which the stored maize would serve as a backup food source, as traditional seed and food was interchangeable. Farmers told of how, by comparison, the 'new' maize seed did not survive well in storage, sometimes only as little as six months.

Water-saving is another area that has shifted since the introduction of new seed and co-technologies. While water-saving techniques in the past included mulching, digging furrows or intercropping with beans or pumpkins through live mulching, the spread of hybrids and GM maize and their associated use of agrochemicals has made these practices increasingly difficult, if not impossible.

These changes, illustrate how new seed technologies not only displace traditional practices, but can also directly impede the ability of traditional practices to be performed alongside the planting of GM seed. In other words, the use of some seeds instead of others lock farmers into specific paths of action that are not easily – or always – reversible.

As Stone (2007) argues, the loss of ecologically based practices also disrupts ongoing processes of social and environmental learning. Farming is not a static process. Traditionally, it has been based on careful observations of and responses to natural systems and ecological dynamics. This required that farmers engage in detailed record-keeping, whether physically or through awareness of patterns over time. The use of commercial seed and co-technologies means that farmers are engaging less with the landscape and its shifting ecological relations. For example, new technologies have seemingly made careful practices of observation (such as pest insect behaviour) redundant, as shown in the excerpt below from fieldnotes:

> One farmer, now in his 80s, explained how, as a young man, he had learned from a commercial farmer how to keep records about the stem borer. He started keeping a journal and recording when the stem borer would appear and what the weather was like when it did, and was able to know when the best time to

> plant was from this information. However, when I asked if he still kept records, he no longer did. He also now used store bought seed and sprays to control stem borer when an explosion of its population occurred (Fieldnotes, 2017:Pongola).

Keeping records like this was not necessarily a practice carried out widely by smallholder farmers. However, it marked the loss of a potentially valuable practice – part of an integrated pest management approach that may have garnered more interest should a reliance on pesticides not have become so widely adopted.

The loss of ecologically based agricultural practices constitutes a dimension of ecological deskilling, because it involves a disconnection between the activity on the farm and the specific conditions and relations taking place in the local environment. This disconnection has the effect of reducing the spectrum of practices that farmers have on hand to face agricultural challenges, such as maintaining soil health or responding to or avoiding insect infestations. In turn, it may degrade their ability to maintain traditional practices, and inhibits the farmers' abilities to respond and adapt to specific and changing local environments. As a consequence, farmers may lose touch with a cumulative understanding of particular ecological conditions, which become less visible to them as a result. Locally-adapted solutions are valued less, with the uptake of new technologies that are sold as homogenised packages of a one-size-fits-all solution. The loss of ecological practices sensitive to local conditions and based on locally available resources arguably reduces the resilience of small-scale farmers to processes of environmental change.

5.2.2. The loss of relational knowledge

A second dimension of ecological deskilling linked to the loss of ecologically based practices is the loss of relational knowledge. This dimension describes a partial or total loss of the ability to understand and work with the interrelations within an agroecosystem. Relational knowledge is "emplaced" knowledge (Muir *et al.*, 2010). It refers to context-dependent information about how different components of an agroecosystem are connected to and affect one another. This includes knowledge related to the interconnections between animals, plants, people and/or weather patterns in an agroecosystem (Zuma-Netshiukhwi, Stigter & Walker. 2013). Muir *et al.*

(2010) argue that relational knowledge is a feature of local knowledge, which is developed in particular contexts. This contextual knowledge is based on an awareness of "connections and patterns" that are unique to that place and have been observed over time and through practice (Muir et al., 2010:260). Furthermore, this kind of contextual knowledge by its very nature "recognises its own limits" or the limits of the context, due to the fact that it does not rely on external inputs or conceptions of success. Another feature is that it "does not create artificial boundaries between human and non-human systems" (Muir et al, 2010:260), because an interdependence is vital for existence.

Farmers' seed varieties have been developed within these relational contexts and systems of knowledge over time (van Dooren, 2012). Even though maize is not indigenous to South Africa and only entered traditional farming systems approximately 500 years ago, the planting of maize by smallholders historically came to rely deeply on relational knowledge embedded in farming systems. Choosing the right moment to plant maize is crucial for its success. Timing it according to rainfall is important, as this crop is rain-fed and farmers do not have access to irrigation. Planting it alongside companion plants and using water-saving techniques are also important for its survival. Planting it according to the right temperature and the related lifecycle of pests also affects the success of a crop.

One NGO key informant explained:

> It was not a question of the [sowing] ritual being done in October… you had to check whether the environment is in sync with the human; you check the position of the moon, what the trees are doing or saying, what is the sky doing or saying, and out of the combination of all those relationships they would say, let's perform those [sowing] rituals. There was not a date like we have now, which is more like an event (NGO employee 2 2017:Johannesburg).

When asked about how they chose the date to plant maize, farmers said it was common practice for them to wait for the first rains to do so, but other factors were also mentioned. Some elderly farmers explained how the maize-sowing time has historically been linked to the migration pattern of *Phezukomkhono* (Zulu for red-chested cuckoo [*Cuculus solitarius*]), a migrant bird that returns to KwaZulu-Natal in the spring. Literally translated, *Phezukomkhono* means 'on top of your arm', referring to the manner in which one carries a hoe when heading into the fields to plant. This phrase, which also sounds just like the bird's call, means that it is time to pick up your hoe and start planting the maize. One farmer illustrated the relation between the bird and the time of sowing maize as follows:

> When the *inyoni* [bird] sings you know it's time to sow maize. When you don't hear the bird you can't sow. When there was the drought [2016/17], you never heard that bird (Farmer 26, 2017:FS2).

This relational knowledge, based on identifying relevant interconnections (i.e., between the appearance of the cuckoo and the first rains), relies not only on knowledge passed down through generations but also on living knowledge practiced and adapted year after year and often embedded in cultural aspects of everyday life.

While relational knowledge of the whole ecosystem has previously been crucial for smallholders to determine the appropriate times for planting in order to maximise the likelihood of success, today the planting of maize by smallholders in Pongola is often reliant on a new set of factors. This is because relying on commercial seed adds complexity to an already difficult task. Farmers may have to wait until they can afford to buy and transport seed, or when seed is delivered via extension services, or when they can get access to a tractor for ploughing. A changing climate offers an additional, complicating factor. Elderly farmers spoke of how, when they were children, the first rains had come as early as August and now they could come as late as November. With all these factors continually in flux, it becomes extremely difficult for farmers to maintain a close relationship with their environment.

The changed relations between farmers and seeds, and the limited ability of farmers to identify the new maize seeds being used, is a further example of a loss of relational knowledge. Echoing Stone's (2007) findings, this has been exacerbated by the introduction of constantly changing seed varieties over the years, and is further complicated by the use of new GM seed varieties, which has only added to the types of seed available. As a result, farmers are often increasingly confused about the specific kind of maize seed they are sowing or have sown in previous years. As interviews revealed, farmers were usually unsure of which seed company had produced the seed, what cultivar it was and whether it was OPV, hybrid or GM. Instead, seeds were often identified based on the shop from where they were purchased, or from the description of the package they had come in, such as whether it was plastic, or green or had an illustration on it. Most smallholders were not well-informed of the wider seed market and the kinds of seeds available in the country when making decisions about what to purchase. As one maize farmer put it:

> I don't have the knowledge of what kind of products are in the maize. I just pick the best seed from what they [agridealers] tell me. I just ask for which seeds give the most production (Farmer 9, 2017:FS2).

This quote demonstrates the lack of farmers' understanding of the seed they buy or acquire, as well as how the seed is produced and who may own its intellectual property. In fact, most of the farmers interviewed (except those with some formal agricultural training) did not understand what GM seeds were or how their genetic make-up is fundamentally different from traditional OPV or hybrid seeds. The smallholders interviewed were largely ill-informed of the wider seed market and the kinds of seeds available in the country, when making decisions about what to purchase. The fact that smallholder farmers in South Africa are often unaware of the difference or unable to tell the difference between GMOs and other store-bought seed has also been noted by Mahlase (2017) and Jacobson and Myhr (2012). Fizgerald (1993:338) showed how farmers who once bred ther own seed, and also knew how to select it "from the field or from the seed dealer, according to visial characteristics" began to lose this ability. With hybrid seed the properties of that seed were "visually indistinguishable due to their genetic similaritiy" (Fizgerald, 1993:338). In this way there is a process of spatial relocation of the knowledge of the characteristics of seed away from farmers and the knowedge of farmers (Fitzgerald, 1993).

It was common for farmers to describe seed by the colour of the kernels, including by the insecticidal coating on some commercial seed varities. This visual way of identifying seed would have in the case of Zulu maize been extremely effective, as one can tell a lot by the colour of the kernel of heirloom maize.

> The first maize we used to use was plain white but as time went by it changed to red, green and yellow. You see, this is not a red maize; it's just a powder. The maize is white (Farmer 20, 2017:Emkwakweni).

Jacobson & Myhr (2012) found that smallholders in the Eastern Cape identified seed according to "kernel size, ear size, or the colour of the chemical coating" (p.111). These descriptions indicate how new seed technologies are reaching farmers in ways that do not match their understanding of seed. Hybrids and GMOs are difficult to tell apart both visually and conceptually, as the differences embedded therein are invisible to the eye, and farmers are therefore unaware of them. It appeared that scientific methods of classifying seed did not translate well to people's local methods of knowing and relating to seed. It also illustrated that farmers were not receiving adequate training related to the seed that they were buying or receiving from projects and extensions services. This 'nameless' seed in a sense represents the kind of disconnect that emerges when seed is introduced from elsewhere, along with different value criteria and invisible markers. Laboratory-developed seed varieties are named not using sensory names or names associated with place, but rather using codes and numbers related to copyright and traits. These codes are not indicative of any tangible qualities related to that seed.

One co-operative farmer explained how he has been frustrated because he knows commercial farmers have more knowledge about how to choose the right seeds for their land, because they have access to the knowledge necessary to do this. Whereas farmers would have once had a deep understanding of how the seed they were planting related to the specific environment they were working in, there is now a deep disconnect between farmers, their knowledge, seed and the agroecosystem. While the introduction of new seed, their co-technologies and generic growing methods are not the only factors at play, they have significantly contributed to a loss of relational knowledge. Essentially, privately created hybrid seed varieties means that farmers no longer need a hands-on, practical knowledge of how seeds are generated, their traits, or how they respond to certain weather conditions and pest infestations, etc. This loss of knowledge is further exacerbated by GM seeds, where the relational chain of ownership and production is even further distanced and abstracted from the farmers' practical knowledge. Collectively, this constitutes a dimension of ecological deskilling because it represents a cognitive disconnect between farmers and key elements of the agroecosystem, as local farming knowledge becomes devalued in favour of expert-led innovations.

5.2.3. The loss of socio-ecological agency

The third dimension of ecological deskilling relates to the loss of socio-ecological agency. This refers to the partial loss of an ability to act autonomously, to make free and informed choices (such as the suitability of seed), and to respond to socio-environmental changes affecting the local environment. The use of the 'socio-ecological' component here aims to transcend the human–nature divide and emphasises the idea that human agency is rarely isolated from the environmental and social structures that condition it (Buzinde & Manuel Navarrete, 2010).

Farmers' limited choices of seed is an area in which the loss of socio-ecological agency was striking. Although in theory farmers can access commercial seeds in various ways – such as through local agridealers, government assistance programs, seed companies or development projects – in practice, access to seed for smallholders in South Africa involves multiple interlocking factors. These include: 1) the ability to access market information about seed and its different attributes; 2) financial resource constraints, which often vary from year to year; 3) the advice or support offered by different institutions, often with vested interests (e.g. connections with assistance programmes or co-operative projects offering free or discounted seed and inputs; and, 4) the availability of seed at local agridealers or transport to suppliers further afield.

The series of excerpts below illustrate the kinds of challenges farmers face in accessing seed and how often 'choices' about what to plant are made according to the above constraints:

> The kinds of seed I was looking for I didn't find, so I just picked this one [showed me a bag of seed with a monkey logo on it]. I know these are not the right seeds but I only found these seeds left… the year before I bought seed at Corporasie [an agridealer in Pongola that changed its name many years ago] but this year they did not have any… I don't know if it's going to be a good product or not (Farmer 19, 2017: FS5).

This farmer was late in getting to the agridealer, as she was waiting on funds and was therefore unable to obtain the seed she had intended to buy. In situations like these, it was common for farmers to buy another option, taking a risk in terms of its performance. The excerpt below illustrates how farmers often have to make decisions about what to plant according to financial constraints.

> Due to lack of finances, I'm going to use the same kind of seeds I bought at the agridealer last year – red maize [marked by the colour of the seed treatment] and yellow maize. I will buy the cheapest one. Usually I change the seed but this year I will keep the same (Farmer 15, 2017:FS2).

When asked what he would buy if he had the funds available, this farmer said he would like to buy the kind of maize that works with Roundup, because he was getting old and weeding was therefore difficult. But this was very expensive and so he made do with what he could afford. The 'choice' of Roundup-ready seed is thus not a choice so much as a necessity. Many farmers were aware that chemical sprays were potentially dangerous but felt they had little choice but to use them, given their age and lack of help in the fields.

In addition to being affected by logistical and financial constraints, farmers' choices are also influenced by the information they are exposed to. More than one farmer explained how they had been told in the past by extension services and at 'farmer days' that their 'old maize' seed was inferior to the new varieties for various reasons, such as the new varieties having shorter growing seasons and higher yields. This is a widely-held perception, regardless of whether farmers had been told this directly or not. This has led to farmers believing that bought seed is superior to local varieties. Over time, through governmental programmes and seed marketing campaigns, farmers have begun to adopt different criteria for evaluating the worth of their seeds. Traditional seed, valued for its relational qualities, has been increasingly replaced by seed valued by economically-related criteria and 'rational' scientific qualities.

As farmers do not have a wide network of agricultural information available to them, the role of institutions is paramount. Typically, the middlemen (government extension services, employees linked to development projects, or agridealers) who provide farmers with seeds act as a gateway for the type of agricultural information that reaches the farmers, and they strongly encourage the use of certain seeds over others. This dynamic is also noted in Mahlase's (2017) research conducted in northern KwaZulu-Natal, in which she states that farmers generally accept the seed they are given when they receive inputs from development programmes, regardless of whether or not those seeds are the ones they prefer to sow. As a farmer from a co-operative explained:

> This year we would like to have white maize but if we are given yellow we will plant it. [...] I don't know where the leader of our cooperative gets the seed; he just delivers it. When I get this seed, I sow it (Farmer 22, 2017: EFS1).

This farmer had in fact not planted a crop during the last season, as the seed being distributed through the co-operative he was affiliated with had not arrived. In the year preceding that, he planted a yellow GM variety that was given to his co-operative by a development project that was promoting the use of yellow maize. While farmers in this area generally do not plant yellow maize because there is no market for it, they were assured by this development project that they would be assisted in gaining access to market. However, when harvesting season came they were not assisted as promised and were instead left to try to sell the maize themselves. Despite this, the farmer stated that while he preferred white maize he is willing to plant the yellow if given it again, illustrating how farmers in this area often make do with what they can access.

This scenario demonstrates a loss of socio-ecological agency. Not only are farmers unaware of what they are sowing, but they are very often unable to choose the types of seeds they sow. While the loss of socio-ecological agency is not only connected to the spread of GM seeds and the way these have historically been distributed to smallholders in South Africa, the introduction of transgenic technologies certainly intensified this phenomenon.

Connected to the loss of socio-ecological agency is farmer disempowerment. The perceived lack of knowledge and access to alternatives by farmers combines to contribute to a lack of confidence about their ability to farm successfully without expert advice. This in turn creates a dependency loop in which they look to external actors to tell them what to do each season, with the underlying assumption that their lack of awareness means they are not able to make important farming decisions on their own. As one co-operative farmer explained:

> You see this farming business, we ourselves can't do anything unless we have someone come and teach us how to do things. Even the names of different seeds we don't know. We need someone else to come and teach us (Farmers 31, 2019:N2).

This excerpt reflects the disempowerment experienced by farmers as a result of the introduction of new seed varieties, of which they have no relational knowledge. As these seed varieties are introduced into their systems, the farmers become increasingly dependent on external experts, not only to provide them with the latest seed technology, but to provide them with the knowledge of what they are and how they should be grown. As one crop scientist explained;

> Farmers have become reliant on people selling inputs, so the farmer cannot rely on himself/herself and the environment (Crop Scientist 1, 2017:Pietermaritzburg)

The reliance on outside inputs leads to an expanding disconnection between farmers and their seed, as well as between the seed and the agroecological context, and removes the farmer from the practices, knowledge and agency they need to act effectively and autonomously, especially in a way that is sensitive to their unique ecological context.

5.3. Ecological reskilling in smallholder agriculture

So far, this chapter has presented some of the ways in which commercial maize seed technologies have contributed to various dimensions of ecological deskilling. This section looks at how a growing number of farmers in this same area are also undertaking an ecological reskilling process, by rebuilding knowledge and relationships with the agroecosystems in which they work. Biowatch has been working with farmers since 2012 to build on "traditional farming knowledge to strengthen agroecology practice" (Biowatch, 2020). While Biowatch does not use the term 'ecological reskilling', in many ways they are working towards facilitating this process in the areas they work. They provide training in agroecological farming practices; work with farmers to save their own seed; utilise natural pest control methods; and, use intercropping and other agroecological techniques, such as making compost and using cattle manure to improve soil quality. They also encourage farmers to build up a community of practice by taking careful note of and recording what is happening in their fields over the years and comparing their records with other group members, neighbours, and other Biowatch-affiliated farmers in the country. In so doing, they can rebuild relational knowledge and form a deeper understanding of their own farms. Many of these methods, as well as the use of low cost, local resources and circular systems, draw on traditional methods that were once widely used by smallholder farmers in South Africa.

Implicit in building an agroecological approach is trying to restore relationships with seed. The goal is to move beyond the view of maize seed as a packaged commodity attached to a set of generic instructions and encourage farmers to save seed, get to know it and how it works – or does not – in their context, trade it, and share information about it. Most of the farmers associated with Biowatch now grow either traditional maize seed or OPVs that can be saved year after year. They are able to draw on the fragmented pieces of knowledge that they still remember from their parents or grandparents and build onto these over time through their practice and the support of the wider group. In this way, Biowatch has helped a group of farmers within the research area to establish and boost their home gardens, through the use of low cost inputs. Some are working towards scaling their farms so that they can sell their surplus product, but most use their plots for subsistence farming.

At present, in the province and more widely in South Africa, if smallholders wish to gain assistance from the Department of Agriculture, the options available to them are limited, as they fall within an industrial agricultural paradigm. Farmers who require assistance are able to apply for it from the local department in the areas of commercial sugar growing, commercial maize farming and winter vegetable production. Farmers are most often encouraged to form cooperatives rather than farm on their own commercially. The work of Biowatch offers alternative assistance for smallholders who fall outside of this industrial farming paradigm.

This co-operative model has proven to have many setbacks. Moreover, it promotes a strongly industrialised approach, which includes the use of chemical inputs, monocropping and GM seed. The research described here suggests that farmers have tended to receive unequal access to resources, have had little choice in what approaches they can use, and have been treated as mere recipients of knowledge rather than co-creators. In many ways, this system leads to a level of agricultural deskilling. While farmers might acquire some skills, such as no-till, conservation agricultural methods, pesticide use, or herbicide use, the transfer of skills often happens in a very ad-hoc manner. This was evident through interviews where farmers mentioned having once been part of a government project in the past that was discontinued. Furthermore, farmers are given only partial access to information and reliable assistance, so the transfer of technology is poor, thereby resulting in disempowerment and disconnection. This is strongly evident in the way that GMOs have been transferred through the extension service to farmers, leading to debates about the appropriateness of these technologies for smallholders in the face of limited extension capacity (Gouse et al., 2005; Jacobsen, 2013, Fischer and Hajdu, 2015).Within this approach, there is little regard for the knowledge farmers hold in relation to their work, the agroecological contexts in which they live and work, and how new seed technologies and the projects that support them force industrial ontology on to smallholder farming.

If a smallholder farmer wishes to gain assistance with alternative forms of agriculture, such as using organic or agroecological principles, this can be supported in a small way through the Department of Social Development. However, these methods are not considered commercially viable, but rather as methods suitable only for smallholder subsistence farming (Government employee 2, 2017:Pongola). As this research has shown, many agricultural scientists and government employees are sceptical about whether ecological-based farming practices can offer successful and reliable benefits to smallholders wishing to farm commercially. While Biowatch offers an alternative to the mainstream development-based approaches offered by the government, it has yet to scale up its farming practices in a way that significantly supports farmers looking to use agroecological methods on a commercial scale. This is a key area in need of development and so working models that can communicate these possibilities must be established. The gap in available options for smallholders in growing food on a commercial scale using ecologically sensitive methods is one that desperately needs to be addressed in South Africa.

5.4. Conclusion

As Stone (2004:127) notes, "cultural agricultural practices change all the time, as does the indigenous knowledge on which practices are based". He likens each farm and each crop to "an experiment" that can change each year in relation to "population density market signals; the arrival of new crops, tools, or neighbours; pests and diseases; government policies; and even new ideas" (Stone et al. 2004:127).

While maize is not indigenous to South Africa, on its arrival in open-pollinated form it found its way into relational farming practices of smallholder farmers. Over time, farming practices around maize became rooted in ecological, biophysical and socio-cultural relationships. However, the introduction of modern commercial seed, such as conventional hybrids and GMOs, has had different, wide-reaching effects, particularly on farming systems and farmers' knowledge (Fitzgerald, 1993; Stone et al., 2007).

In the case of smallholder farmers in South Africa, as seen in Pongola, traditional maize has widely been replaced with commercial maize seed, which is developed outside of these farming contexts and within which particular priorities are embedded. Commercial seed is produced in a way that is intended to be generic and packaged with external inputs. The adoption of this seed through market forces and development programmes has over time led to significant shifts between farmers and their relationship with their own seed, and therefore with associated farming methods and the knowledge related to the context in which they farm.

This chapter built onto the concept of agricultural deskilling by articulating the concept of ecological deskilling in agriculture, which was illustrated through the discussion of three dimensions: loss of ecologically based practices, loss of relational knowledge and loss of socio-ecological agency. By illustrating the links between the adoption of new seed and these processes, this chapter explained how new seed technologies have the ability to undermine farmers' practices, knowledge and relationships with agroecosystems and, in so doing, undermine farmers' agency. This chapter also highlighted the process of ecological reskilling in agriculture in the research area where farmers, with the assistance of Biowatch, are working to rebuild relational knowledge and relationships through agroecological methods and the reclamation of traditional farming principles and ontologies.

Chapters 6 and 7 which follow turn their attention to the maize research and development space in South Africa, to examine how the progression of modern seed technologies has impacted the knowledge, practices and agency of scientists working in these spaces.

FIGURE 6.1: Maize damaged by stem borer. Source: Burtt-Davy (1914: 91).

6. CHAPTER SIX: Maize Research and Development in South Africa

6.1. Introduction

> Agricultural research has always been behind the achievement of successful adaptations to the often difficult farming conditions in Southern Africa. The distance to the lucrative European and American markets has required technical innovation that could be seen as unique in the world (Cronje, 2007:4).

In the previous chapter, it was argued that the introduction of new maize seed technologies into smallholder farming systems contributed to a process of ecological deskilling. The focus in Chapters Six and Seven is on the second node of this research study: maize research and development (R&D). This chapter provides a historical overview of the development of maize R&D in South Africa.

Since maize R&D began in South Africa in the early 1900s, different types of maize seed have been developed, ranging from open pollinated, to hybrid and, finally, GM seed. McCann (2007:1) argued that "agronomic malleability" afforded this crop a "particular symbiosis with its human hosts and the land they inhabit", as it "is a versatile player and takes the shape of the societies that cultivate it". Since it was brought to South Africa, maize has gone from being adopted and integrated into Indigenous farming systems to becoming a key industrialised, agricultural crop. As this has evolved, the agricultural knowledge and practices related to growing it have shifted as well.

During the late 1800s, maize was recognised as having the potential to be a crop of great commercial success in South Africa. The science of maize cultivation became a means of pursuing colonial agronomic visions for the development of the South African agricultural landscape. Burtt-Davy (1914:7) highlighted how European corn brokers in the early 1900s had begun to refer to South Africa as "the future maize granary of Europe". This vision of South Africa as a major producer of maize continues to be upheld. The growth and economic importance of maize agriculture is often regarded as “one of the continent’s major successes” (Smale & Jayne, 2011: 71). Throughout the apartheid era and during the transition to pluralist democracy, maize has been central to visions of economic development and sustenance in the country. Maize has been, and still is regarded as a vital crop for food security, the economy and for the future of South African agriculture.

6.2. The emergence of maize research and development in South Africa

6.2.1. Open pollinated seed varieties developed during the colonial period

According to Buhler et al. (2002), agricultural sciences played a key role in controlling landscapes and peoples’ lives during the colonial period, both in South Africa and elsewhere. Unlike agricultural institutions in Britain, which had been shaped over time with the input of farmers, their partner institutions in British colonies were autocratic and guided foremostly by an interest in colonial control and resource extraction (Buhler, 2002). In a book titled: *Africa as a Living Laboratory*, Tilley (2011) explained how agricultural research was regarded as a vital component in the colonial agenda. She wrote that “agricultural departments and research institutes...were second only to medical departments in the number of bio-scientists and technical officers they employed” (Tilley, 2011: 117). The purpose of increasing production was the commercialisation of cash crops for export throughout the empire (Buhler, 2002). This aimed to spread plantations and grow single crops on the same pieces of land year after year. Monocultures were convenient as they made mechanisation suited specifically to that crop easy and management of farms simpler. It was for these reasons that maize became of great interest as illustrated by the following quotation:

> No other plant we grow will produce 3,172 lbs. of digestible food on one acre of land at so little expense. No cereal crop yields the farmer so large a return for his labour as Indian corn…It is the king of the cereals (Plumb, 1908).

The maize R&D system in South Africa dates back to the early 1900s, when colonial scientists began to recognise the commercial potential of maize. Aware of the success that commercial American farmers were having with maize, white farmers pressed the government to assist in the science of developing maize seed (Burtt-Davy, 1914;

Ruisike,1995). Increasingly, farmers and scientists were interested in developing genetically homogenous maize varieties that were high yielding and were appealing also to millers because they were conducive to designing standard machinery for efficient processes (McCann, 2007; ACB, 2013). During this time, maize had already become a staple crop in South Africa and demand for maize further afield was growing. There was a concern that, if maize production was not boosted, these market opportunities would be lost. Furthermore, the discovery of precious minerals on the Witwatersrand in 1886 and in Kimberley in 1867, and the establishment of mines together with other factors, such as taxation and poor rural conditions, had set in motion a process of migration in which men from rural parts of the country went to work in the mines and live there in hostels. The result was that there was not only less food being produced in rural areas, but there was also a growing need for a cheap food source that could supply growing urban populations and be a staple source of food in mining hostels (Trapido 1971; Wolpe, 1972; Morrell, 1988; ACB, 2013). Maize was recognised as a crop that could fulfil the need for an abundantly productive, monoculture crop. Yields in South Africa in the early 1900s were regarded as low compared with American standards, but great potential was seen for improving them through research and development as seen in the quote below:

> At the present time the country has only begun to show that it is possible to produce good maize. The traveller is impressed with the enormous areas of fertile land, suitable for growing maize, which are at present untouched by the plough, virgin sod like the American prairies. So far, the average yield has been low; but it has been clearly demonstrated that, by means of good farming and good management, it can be trebled and even quadrupled (Burtt-Davy, 1914: 8)

By the early 1900s, the South African Department of Agriculture had established experimental stations for developing maize seed. In 1902, an agricultural research station was established at Cedara in Natal (present day KwaZulu Natal). This was part of policy instituted after the Anglo-Boer War to focus on the development of agriculture through agricultural science research (Guest, 2010). At Cedara, a Government experiment station, a large array of seed varieties were tested. For example, during the 1905 - 1906 growing season, 75 different varieties of maize were tested. Figure 6.2 shows results of seed tests on 35 of the varieties for which scientists were comparing yields and other traits between varieties.

In 1904, the Transvaal Department of Agriculture established the Potchefstroom Government Experiment Station for developing maize seed. Foreign-sourced maize varieties, mostly from the United States, with a small number of local varieties were planted, selected and tested at the station. Other stations also multiplied the varieties that were found to be favourable for distribution to farmers. Varieties from the United States included Hickory King, Iowa Silver Mine, Champion White Pearl, Eureka, Golden Beauty, and Reid Yellow (Saunders, 1930; Ruisike, 1995). The names of these varieties indicated the competitive tradition of maize agriculture in the United States at the time and which was being pursued in South Africa. There was great excitement about the potential of maize to produce ever-increasing yields. This potential was realised through three methods. Firstly, by increasing the area of maize planted commercially, secondly, by increasing the population of farmers growing maize; and, thirdly, by increasing the yield per acre by "scientific maize breeding" (Burtt-Davy, 1914: 127). In terms of scientific research, another three factors were considered in order to improve yield. These included: improving the quality of seed, improving the soil conditions and improving methods of cultivation. These were the specific areas in which agricultural scientists became involved.

In 1914, the year after the promulgation of the 1913 Native Land Act (see Chapter Four), Burtt-Davis published a book titled: *Maize its history, cultivation, handling and uses: with special reference to South Africa*. Burtt-Davy, who was a government agronomist, dedicated the book to Louis Botha, who was the Prime Minister and then Minister of Agriculture of the Union of South Africa, "in appreciation of his efforts to develop the maize industry" (Burtt-Davy, 1914: v). This dedication demonstrated the importance of maize research and development politically and economically at the time. The in-depth study involved in this extensive book showed how much importance was being placed on this crop.

RESULTS OF MAIZE BREED TESTS, CEDARA, NATAL, 1905-6.

No.	Variety.	Source.	Average Height Feet.	Yield. Grain.	Yield. Stalk, etc.	Date of Harvesting.
1	Hickory King . .	Trelawny Adams	7	5,990	9,869	30 May
2	Virginia White Dent 1	Henderson	7	5,220	18,385	,, ,,
3	Early Mastodon .	,,	7	4,844	5,755	,, ,,
4	Boone County White .	,, through W. Pepworth	7	3,662	8,242	,, ,,
5	Yellow Hogan . .	Hawkesbury Ex. Farm, N.S.W.	7½	4,219	9,241	,, ,,
6	Mastodon Improved .	Dammann	8	4,206	7,214	14 ,,
7	Queen of the Prairie .	Henderson	8	4,140	5,443	,, ,,
8	Zulu Red, Zululand Mealie . . .	Rawlins	8	4,075	18,789	30 ,,
9	Golden Beauty . .	Henderson	9	4,010	6,745	14 ,,
10	Late White Horsetooth	Vilmorin	6½	3,906	15,729	30 ,,
11	Extra Early Huron .	Henderson	8½	3,737	5,013	14 ,,
12	Horsetooth and Hickory King, Greytown	Thresh	7½	3,633	8,507	30 ,,
13	Hickory King . .	Henderson	7	3,542	5,482	,, ,,
14	Improved Early Horsetooth . . .	,,	7½	3,515	5,469	,, ,,
15	Virginia White Dent 2	,,	6	3,411	4,662	,, ,,
16	Burlington Hybrid, Ingogo . . .	Panzera	7	3,398	4,453	3 ,,
17	White Cap Yellow .	Henderson	8	3,372	5,182	14 ,,
18	Japanese Striped .	Sutton	4	3,268	4,844	30 ,,
19	Southern Horsetooth .	Henderson	7½	3,255	12,696	,, ,,
20	Henderson Eureka .	,,	8½	3,255	5,560	14 ,,
21	Improved Leaming .	,,	7	3,216	3,776	,, ,,
22	Iowa Silver-mine .	Dammann	7	3,190	6,107	12 ,,
23	Large Yellow Flint .	Henderson	7	3,060	3,515	3 ,,
24	Horsetooth or Curagua, N.S. . .	Vilmorin	6½	3,008	11,042	30 ,,
25	Rural Thoroughbred .	Henderson	8	3,008	10,663	14 ,,
26	Early Butler . .	,,	7	2,956	4,779	3 ,,
27	Curagua . . .	Dammann	7¼	2,903	7,214	12 ,,
28	King Philip . .	Henderson	6½	2,786	4,375	3 ,,
29	Brazilian . . .	C. Harding	6	2,760	7,865	30 ,,
30	White Flint . .	Henderson	6¼	2,760	3,763	3 ,,
31	Evergreen Sweet .	,,	6¼	2,760	3,620	12 ,,
32	Compton Early . .	,,	6½	2,708	3,685	3 ,,
33	King Philip Early Brown . . .	Vilmorin	6	2,682	6,797	12 April
34	Longfellow . .	Henderson	6½	2,630	5,651	3 May
35	Kansas King (in the Husk) . . .	Dammann	7	2,408	5,521	14 ,,
36	Mammoth . . .	,,	6¾	2,356	4,271	2 ,,
37	Small Yellow S. American, N.S. . .	Natal Agricult. Dept.	5½	2,356	4,219	30 ,,
38	King Philip Early Brown, N.S. . .	Vilmorin	6	2,253	4,948	12 April
39	Late Bicolor Pearl, N.S. . . .	,,	5	2,161	5,654	30 May

FIGURE 6.2: Table showing results of breed tests for 39 varieties between 1906 and 1906. Source: Burtt-Davy 1914.

Over the years, agricultural scientists selected the varieties that had proven to be high yielding and suitable for certain regions. Maize was categorised into ten botanical varieties of which five were of interest for their grain: flint, dent, flour, sugar and pop-corn (Burtt-Davy, 1914: 274). The role of scientists was to remove "unfit" and "untrue" types from the genetic pool and to improve the varieties by substituting desirable characteristics for undesirable characteristics (Burtt-Davy, 1914: 126). Burtt-Davy (1914: 127) likened the process of artificial selection to a "magician's wand" with which man could "summon up and bring into existence any form of animal or plant useful to him or pleasing to his fancy". This quotation illustrated the kind of thinking that characterised colonial agricultural science at the time, which was that the purpose of agriculture was to control and adapt environments and species to satisfy human needs and desires.

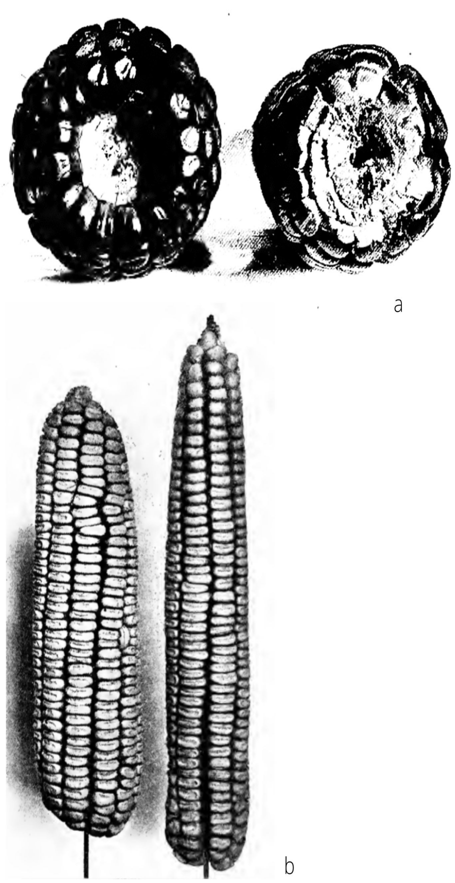


FIGURE 6.3(a) and (b): The cob on the left has kernels all the way down to the "butt" while the other does not. Breeding to have kernels covering the whole cob was seen as a way of increasing yield. Image (b) shows two cobs with very different traits - a wider cob with more rows of kernels and a longer cob with less rows. Source: Burtt-Davy, 1914

Particular criteria were regarded to be important, of which yield was paramount. The improvement of yield in maize through careful strain selection took many factors into consideration, such as more drought-resistant varieties, or early maturation qualities. Other factors that were considered to improve yield were: finding the optimal number of rows on a cob; identifying the optimal grain shape, depth and width; a narrow sulci (the space between grains in a row); developing varieties that had grains all the way down the cob to the "butt" (see Figure 6.3a); developing varieties with narrower inner cobs and larger diameters (see Figure 6.3b); developing disease resistant varieties; developing varieties with strong stalks; developing varieties with "pure" cobs (not mixed in colour which was not favourable for markets); and developing varieties with with a favourable starch content (Burtt-Davy, 1914: 125-159).

Ideas of homogenisation, control and purity (tenets of the Green Revolution) informed the practices and racial ideologies with which colonial science was bound up (Eddens, 2019). Thus, through seed development, the diversity of maize varieties (valued in Indigenous societies, from whom all maize germplasm originated) were reduced to "yellow" and "white" maize and lost their value beyond yield.

In 1910, the first South African Citrus and Maize Show was held in Johannesburg (see Figure 6.4) According to Burtt-Davy (1914: 235), the purpose of these shows was to educate farmers about "the need for, and the means of, improving his own crops" and where to obtain good seed.

While the idea that farmers should be involved in creating better seed still existed, these shows were intended to serve also as sites of technology transfer. According to Burtt-Davy (1914: 235), the shows "offer[ed] one of the most effective methods of diffusing knowledge". Detailed scoring methods were used to judge the winning maize. Thus, the shows became platforms for standardisation, on which ideas of what was good maize were formed.

FIGURE 6.4: Photograph of maize presented for a competition in Johannesburg, 1910. Source: Burtt-Davy, 1914: 235.

6.2.2. Hybrids and private seed during the apartheid era

In 1925, the South African Government initiated a hybrid seed programme in Potchefstroom, dedicated to testing varieties (Saunders, 1942; Greyling, 2019). At this stage, the breeding of hybrids was a government-controlled endeavour. In 1910, Potchefstroom Pearl was developed through an accidental hybridisation of Champion White Pearl and Hickory King or Iowa Silver Mine (Saunders, 1930). This variety was grown widely during the 1920s and 1930s and was used as a development strain. Subsequently, Natal Potchefstroom Pearl became the mainstay of the hybrid maize industry in South Africa as well as in Zimbabwe, Zambia and Malawi (Greyling, 2019).

The first hybrid maize experiments were carried out at the Kroonstad and Potchefstroom Government Experiment Stations in 1925 and 1928 respectively, and were led by A. R Saunders (Saunders, 1940). The key focus was on developing drought tolerance, root strength, moderate/early maturation and breeding larger grain. Greyling and Pardey (2018) suggested that, in the early years of hybrid maize research in South Africa, the development of varieties that produced larger yields was slow. Rather, priority was given to drought tolerance over yield potential and yield only grew by 0.7 percent between 1920 and 1949. The focus on drought tolerance was also to expand maize production areas into lower rainfall areas, which would boost the country's overall maize production. In comparison with the US, South Africa's transition to hybrids was relatively slow (Greyling, 2019). One of the main reasons for this was government control over seed development, making conditions unfavourable for private seed companies (Parley, 2019).

A turning point came in 1937 with the promulgation of the Marketing Act of 1937 (initially the Marketing Act of 1931) as well as the establishment of the Maize Control Board (MCB), one of several agricultural boards, designed to implement the Act. The function of the MCB primarily was to manage the marketing of maize (Greyling & Pardey, 2018). The Act prescribed that the government was the sole buyer and seller of various agricultural commodities including maize (Bernstein, 1996; Greyling, 2019; Stanwix, 2012). The Act boosted the development of co-operatives of white farmers only, who were guaranteed that the state would buy their produce. White farmers were provided with finance at negative, real interest rates. This system "increased the use of mechanization", "the development and adoption of improved maize varieties and heavy application of chemical fertilizers", the "expansion of maize planting (including on marginal soils)", the "construction of modern silos and bulk handling facilities" by cooperatives with easy access to finance, and the "disposal of surplus maize (subsidised by the state) in good harvest years" (Bernstein, 1996: 16). Thus, since white farmers were supported by the state, maize agriculture became a function of the state and secured the political loyalty of these farmers (Bernstein, 1996).

In 1947, the MCB initiated a Hybrid Maize scheme with the Department of Agriculture. It was at this point that maize seed began to become a profitable commodity. This transition, in turn, shaped the focus of agricultural R&D on maize which, from this point, from being predominantly in the public arena, was progressively taken over by private seed companies. This shift came at the time when apartheid was formalised in 1948. During the apartheid era, maize continued to be the focus of state supported agriculture and was used as an agronomic instrument of power. A minority of white farmers were supported by the state in this industry, while black, small-scale farmers were excluded. A dual agricultural system was established in which a relatively small number of white commercial farmers expanded their farms and intensive systems, while thousands of small-scale, black farmers were confined to farming in the homelands without government support.

The then University of Natal (now the University of KwaZulu-Natal) became a key site for the development of maize hybrids. Rabie Saunders became the first Dean of the Faculty of Agriculture and Professor of Genetics at the University of Natal. He initiated the Natal seed programme to develop maize hybrids in 1947. Saunders wrote *Statistical Methods with Special Reference to Field Experiments*, published in 1951, which became a valuable resource for plant researchers who were carrying out field trials (UKZN, 2018).

In 1950, a 500-acre farm which constituted part of Shortt's Retreat, just outside Pietermaritzburg, was purchased by the state. It was named *Ukulinga* (meaning "to test" or "to endeavour" in *isiZulu*). Adjoining land was purchased later, increasing the farm to 356 ha. In 1973, it was transferred to the University of Natal. *Ukulinga* became a site for developing and testing hybrid maize seed before release (UKZN, 2017)

In 1949, the first bags of hybrid maize seed (a cross between Potchefstroom Pearl and Kansas) were sold (Ruskie, 1995). From the 1950s, on the advice of the American seed developer, Jenkins, the hybrid maize seed scheme increased the price of hybrids to attract private investment (Beyerlee, 2018; Greyling, 2019). By the mid-1950s, seed multiplication and distribution was being carried out by farmers, farmer co-operatives and seed merchants (Greyling, 2019).

Pannar, the first private seed company in South Africa, was established in 1958. However, the seed market was only formalised in 1963 through the promulgation of the Seed Foundations Act of 1963. This Act was integral to the growth of the private seed sector because it regulated the registration of new varieties (which would be added to the SA varietal list), established standards for trials and certification, regulated the process of seed merchant registration and legislated control of imports and exports (Greyling, 2019). The seed inspection service was instated under this Act. It was outlined in the Act that, in order for new varieties to be registered on the varietal list, they had to pass through government trials to ensure “uniformity”, “agricultural value" and “genetic stability” (Greyling, 2019:55). This was part of a global trend in standardisation and homogenisation among plant researchers and was vital to ensure the success of commercial seed development (Kloppenberg, 2005).

Another key development towards attracting private investment in the seed industry and R&D was the promulgation of the Plant Breeders Rights Act of 1963 (Greyling, 2019). This secured the intellectual property of plant developers. This Act was similar to legislation in the US and attracted the attention of private, US-based, seed companies who formed partnerships with South African seed companies, notably Sensako and Delkab Genetics International, and Pannar and Pioneer Hi-bred International.

The first proprietary maize seed was registered with Pannar in 1965 and another four varieties were registered in 1968 (Rusike, 1995). While the government continued to produce seed varieties during the 1960s and 1970s, private seed development overtook government’s efforts by the 1970s and private hybrids were out-yielding government varieties (Kuhn & Gevers, 1980; Greyling, 2019). The process of public seed varieties being replaced by private varieties took approximately15 years from the time the first hybrid seed was registered (Greyling, 2019). By the early 1980s, most of the seeds sold were developed privately. Rusike (1999) suggested that the maize seed industry reached maturity at this time, consolidated by Pannar, Sensako, Asgrow, Ciba-Geigy, Saffola and Cargill Hybrid Seeds.

However, the government continued to be involved in developing maize seed as well as other, related areas of research, including weed science and crop protection. Cronje (2007) questioned whether state involvement was sustainable, given the changing research environment at the time, and what the traditional role of state research should be in a climate where private companies were dominant.

In 1981, the Grain Crops Division (GCD) of the Department of Agriculture (DoA) was established in Potchefstroom to focus solely on grain research, of which maize was a big component. Potchefstroom was a key maize growing location in the heart of the maize triangle and maize research was carried out also at Potchefstroom University (now North West University). In 1991, the GCD fell under the Agricultural Research Council (ARC), which was a statutory, parastatal body established in terms of the Agricultural Research Act, 1990 (Act 86 of 1990).

The GCD was one of three divisions within Field Crops, including Industrial Crops in Rustenburg, and Small Grains in Bethlehem. The separation between these departments was geographical, according to where these crops grew, but also signified the industrial agricultural approach that separated the research of different types of crops such as Tropical and Subtropical Crops and Deciduous Fruit, Vines and Wine.

Many scientists and technicians were employed at the maize research unit of the GCD, including "agronomists, soils scientists, entomologists, weed scientists, breeders", dedicated to maize research and improving the success of the commercial maize industry (Entomologist 7, Potchefstroom, 2016). The GCD was funded fully by the government but supported only a racial minority of white commercial farmers. This function changed considerably after the transition to democracy in 1994 when GCD became part of the Agricultural Research Council. Under the new dispensation, structures were adjusted to expand mandates to accommodate the needs of thousands of smallholder farmers who did have access to state support. The department had to be adjusted also to accommodate the neo-liberal market, as South Africa was opened to global market forces. Subsequently, research areas at the GCD included cultivar evaluation, plant breeding, improvement of crop quality, weed control, tillage, plant nutrition, water utilisation, plant pathology, entomology and nematology (ARC, 2018).

During the apartheid era, the DoA, which comprised 12 research units, was responsible for the majority of agricultural research in South Africa. Research was carried out also in faculties of agriculture at universities linked to the DoA. Marketing councils, agricultural co-operatives, private researchers and the Department of Development Aid collaborated on research. The DoA had a large "manpower component for agricultural research" with approximately 5600 staff members, including 950 researchers, 58 agricultural economists and 46 agricultural engineers (GrainSA, 2016). The DoA also had well-equipped research laboratories and 74 experimental farms, across climatic regions, on which controlled field trials were carried out. The experimental farms were sites for research, training, demonstrations, and the development of new cultivars. During the apartheid era, facilities was geared towards serving white commercial farmers.

In 1992, after the ARC had been established in terms of the Agricultural Research Act 86 of 1990, changes were made to ensure that research benefited not only white commercial farmers, but also supported small-scale farmers and previously disadvantaged farmers, termed "developing farmers", in establishing commercial agriculture enterprises (GrainSA, 2016). Some of the former DoA research institutes closed and, as deregulation occurred over time, private companies, such as seed and chemical companies began to set up research facilities, specialising in research that had been done formerly by the DoA. The privatisation of research was not unique to South Africa but was part of a growing global trend (Buhler *et al.*, 2002). Thus, in the period before South Africa made the transition to pluralist democracy, the maize R&D system had undergone a major shift from being largely a public project to comprising a range of private stakeholders. While Cronje (2007) argued that little changed at the ARC, much had changed in the broader research environment. In addition to the role of private companies in research, a key development was the introduction of GMOs to the South African maize system.

6.2.3. A shift to GMOs during the transition to democracy in South Africa

During the transition to democracy in 1994, agrarian reform was a vital part of the new dispensation in South Africa. Maize continued to be regarded as a vital crop and one to which state aspirations of transforming the economy and agrarian politics were attached. Successful maize agriculture was envisioned as a means to bring small-scale farmers into the commercial sector.

The transition to the commercial release of GMOs coincided with the transition to democracy. However, as in the case of hybrids, the shift to GMOs in South Africa was a process that involved political will and support. While GMOs were first released for commercial use in the late 1990s, the foundations for the transition to biotechnology were laid during the apartheid era. In 1979, the government established SAGENE (South African Committee for Genetic Experimentation). SAGENE was made up of a group of South African scientists who were eager to see biotechnology grow in the country (Wynberg & Fig, 2013; Whittingham & Wynberg, 2021). SAGENE was responsible for permitting and supervising the first open field trials in the country before any GMO legislation had been passed. During the 1989-1999 period, 178 permits were granted for open field trials using GMOs (Mayet, 2007). In 1994, SAGENE continued to operate during the transition to democracy and were made advisors to the government on pending legislation related to GMOs. When legislation did come into being in the form of the GMO Act of 1997, it was strongly informed by scientists affiliated with SAGENE. SAGENE continued as a key advisory board until 1999, when the GMO Act was promulgated (Prince & Black 2010). The GMO Act replaced SAGENE with an Executive Council comprising government departments. Thereafter, SAGENE transformed into an Advisory Committee tasked with providing expert advice (Thomson, 2014).

GMOs were first released commercially in 1997 with Monsanto's MON810 Yield Guard, insect resistant maize being the first seed to be approved. Once GMOs became part of the South African agricultural sector, research and development institutions had to be set up or adjusted to accommodate this new addition. GMOs posed new challenges, concerns and risks and required a new set of research. Not only did they require development and testing, but also their risks had to be researched and managed. The kinds of shifts that occurred within R&D as a result, specifically in relation to ecologically-based knowledge, are described in depth in Chapter Seven. In the following section, the changes that came about as a result of GMOs being introduced into the maize R&D system are recorded.

6.2.4. Institutions promoting GM crops in South Africa

In the late 1990s, the "industry-funded pro-GM organization" AfricaBio was established (Scoones, 2008:321). Scoones (2008: 321) suggests that this organisation attempted to "occupy the scientific highground" using the legitimacy of science to create space for the acceptance of GMOs. AfricaBio aimed to create a smooth process for the adoption of biotechnology in South Africa and as their website currently states: "to build confidence in biotechnology's potential in Africa" (AfricaBio, 2020). In the early years of GM adoption, AfricaBio made statements to undermine anti-GMO activists as 'thoughtless', providing 'misleading' information to the public (Scoones, 2008:322). AfricaBio today is self described as:

> an independent non-profit stakeholders' association [who] represent the interests of all stakeholders involved in the biotechnology sector throughout Africa, and promote the use of biotechnology as a means to upliftment. AfricaBio focuses on agriculture, health, industrial, environmental and marine biotech (AfricaBio, 2020).

They describe their work as promot[ing] safe, responsible and ethical use of biotechnology and its products by providing a knowledge and communications platform for all involved. According to the organisation, this vision is to be achieved through: workshops, conferences, seminars, newsletters and demonstration projects, advocacy and position papers, business partnerships and partnering sessions, stimulating the development of biotechnology products and companies and engagement with decision-makers and governments. AfricaBio works closely with policy-makers and policy-regulators at all levels of government to ensure that legislation does not impede the biotech industry. As explained on the organisation's website, "Some of these laws and regulations can have profound effects on our ability to effectively meet the needs of the millions of people who rely on our products every day" (AfricaBio, 2020) AfricaBio has been involved in various demonstrations and trial projects, working with small-scale farmers to encourage the uptake of GM technologies including Bt and RoundUp ready crops. The aim of these trials has been to introduce small-scale farmers to the technology as well as increase the understanding and acceptance of AgBiotech products by the general public, farming communities, policymakers, and the media

Another organisation that came into being was Biosafety South Africa, an initiative of the Department of Science and Technology (now the Department of Science and Innovation) that was publicly funded. Biosafety South Africa is described as:

a national technology platform in service of the country's biotech regulators, researchers, technology developers and public (Biosafety South Africa, 2019).

Biosafety South Africa has assisted and advised all stakeholders in the country on matters of regulatory compliance, biosafety, best practice, risk analysis and sustainable biotechnology innovation through the creation of an enabling environment for investment in biotech. The organisation promotes biosafety research and development in line with national policy and to "ensure effective risk management" and analysis. Finally, the organisation has been involved in communicating "the science behind biosafety to all stakeholders" (Biosafety South Africa, 2019).

6.3. The current maize R&D system in South Africa

The technification of seed through hybridization in the 1930s and most notably genetic modification in the 1990s has transformed agricultural seed into a highly profitable commodity and has spurred corporate investment and the global consolidation of seed companies (Howard, 2009). The location of research and development and sources of funding in South Africa have shifted over the years according to national and international trends (Chaminuka et al., 2019). In recent decades, private companies and international research agencies have taken on greater portions of R&D globally while public investment in research has decreased in many countries (Buhler et al. 2002; ACB, 2017). Since 1994, South Africa's agricultural sector has been through a number of shifts within the national policy environment. Many of these policy changes have sought to address discriminatory legislation from the previous dispensation. Other major policy shifts have included the deregulation agricultural product marketing and the liberalisation of trade (Kirsten, Stander, and Haankuku, 2011). These reforms have attracted increasing foreign investment by multinational companies. In South Africa, privately funded research has increased significantly in the seed industry as seed companies have consolidated and institutional changes have occurred (Kirsten, Stander, and Haankuku, 2011). The process of this shifting R&D landscape is outlined in the following section.

6.3.1. Public maize R&D

Since 1994, public R&D in South Africa has been carried out largely by the parastatal Agricultural Research Council (ARC) as well as by provincial agricultural departments, government agencies and universities (Chaminuka et al., 2019). A small amount of R&D is carried out by non-profit organisations. In South Africa maize industry stakeholder organisations, including the Maize Trust and GrainSA, have also undertaken and supported agricultural research since the transition to democracy.

The ARC was funded mainly though a parliamentary grant until 1997 when this source of funding decreased and the funding of the ARC became the responsibility of DAFF (Liebenberg, 2013; Chaminuka et al., 2019). At this point provision was made for additional funding from the Department of Science and Technology through centres for excellence or line departments seeking contract R&D services (Chaminuka et al., 2019). Portions of commodity levies are also allocated for public R&D. The funding available for agricultural R&D has fluctuated significantly over the years as a result of the various structural changes and economic influences (Chaminuka et al., 2019). Chaminuka et al. (2019:9) explain that while public R&D grew into the 1970s, it then showed periods of "upward and downward spiralling" until the present. After a period of slow growth in the 1980s and 1990s it declined from 1998 until the early 2000s due to the shift away from dedicated funding streams to a parliamentary grant system (Chaminuka et al., 2019). The periods between 2001 to 2005 and 2010 to 2013, however, saw some increase in spending on public R&D. Figures beyond this are not available. In addition to public research, the capacity for agricultural research in universities has increased over the years funded by various sources.

In 1998, the Maize Trust was founded. It was formed after the closure of the Maize Board and inherited the remaining assets of that Board. The Trust's annual income is derived from interest on donations that were transferred from the Maize Board when it was closed (Maize Trust Website, 2019). The Maize Trust aims to promote the South African maize industry by providing financial support for institutions and organisations with programmes aimed at market and production-related research (Maize Trust Website, 2017). The Trust funds the dissemination of market-related information though print and other media, such as through the SA Grain Guide. Since its establishment, the Maize Trust has granted a large amount of money to a variety of organisations and institutions involved in research, development and information programmes in the South African maize industry. The trust has also funded transformation projects through GrainSA's farmer development programme run by the Grain Farmer Development Association (GFADA). In addition the Maize Trust has provided Masters and Doctorate level bursaries for maize industry research topics (Maize Trust Website, 2017).

In 1999, GrainSA was established out four former commodity organisations NAMPO (maize), NOPO (soybeans, sunflower and groundnuts), the WPO (wheat, barley and oats) and the SPO (sorghum). GrainSA is considered to be a voluntary association of grain farmers. It aims to represent the interests of its members and serve the wellbeing of the industry (GrainSA website, 2019). GrainSA has played a coordinating role for maize and other grain research, and identifying research priorities and synergies between existing research, locally and globally. The organisation also facilitates links between the ARC and universities to increase research capacity based on the belief that the ARC did not have enough capacity to carry out all the necessary research within the grain industry. The organisation also locates funds from the government for research (GrainSA, 2016).

6.3.2. Private maize R&D

Since the late 1990s, private agricultural firms have expanded their investment and involvement in R&D in South Africa (Kirsten, Stander, and Haankuku, 2011; ACB, 2013, 2015). The number of scientists employed within private R&D has grown alongside this (Kirsten, Stander, and Haankuku, 2011). Multinational companies have formed partnerships with local companies and the increasing consolidation of the global seed industry has had a large impact on South Africa's seed industry. Kirsten, Stander, and Haankuku (2011) found a significant increase in private R&D between 2001 and 2008 due to an increase in multinational partnerships. This trend is reflected in the maize R&D system by the growing presence of multinational seed companies, the number of mergers with local companies and the expansion of privately funded R&D facilities in the country.

In 2016, the multinational company Bayer, purchased the multinational company Monsanto. Monsanto had acquired the American seed company DeKalb in 1998. In South Africa, DeKalb had already had a relationship with South African seed company Sensako since the 1960s (ACB, 2013). Monsanto had been also present in South Africa since the 1960s and has licensed their genetic technologies to domestic seed companies (ACB, 2017). At the end of the 1990s Monsanto purchased Sensako and Carnia, two of South Africa's largest seed companies, thus significantly extending their influence over the local seed industry. The purchasing of Sensako afforded Monsanto approximately 45% of the agrochemical market for field crops incuding maize (ACB, 2017). In 2016 Monsanto launched their newly renovated breeding centre in Petit South Africa where they would be able to establish new breeding programs with both imported and local germplasm (ACB, 2017). Monsanto also established a partnership with Water Efficient Maize for Africa (WEMA) project, a public-private partnership which is linked to the ARC. This project is funded by the Bill and Melinda Gates foundation, the United States Agency for International Development (USAID) and the Howard Buffet Foundation. Given the noted inaccessibility of commercial seed for smallholders, WEMA focuses on producing improved seed varieties (hybrids and GMOs) for smallholder farmers (ACB, 2017). WEMA has a partnership with the ARC in South Africa.

In 2019, DuPont Crop Protection, DuPont Pioneer, Pannar Seed and Dow AgroSciences merged to form Corteva Agriscience. Corteva Agriscience has headquarters in the United States with sites in Casablanca (Morocco), Cairo (Egypt), Pretoria (South Africa), and Nairobi (Kenya). In South Africa, many of these companies still function under their own brand names, including Pannar, Du Pont Pioneer, Du Pont Crop protection, Delkab. The acquisition of Pannar was a major resource for multinational companies. In operation since the 1950s, Pannar was the first private company in South Africa to produce its own hybrids and has decades of experience in maize R&D. They also own an extensive library of proprietary maize seed adapted to South African growing conditions (Pannar website, 2020). They have both summer and winter research stations in five loactions in South Africa and operate in eight African countries. Unlike most South African seed companies, Pannar is also involved in biotechnology R&D (Johann Kirsten, Stander, and Haankuku, 2011). Smaller seed companies involved in GM research include Agricol, Klein Karoo and Vuna Seeds and some others and focus mostly on hybrid and open pollinated variety seed development.

Mergers between agrochemical companies have reportedly increased the capacity of local South African seed companies for R&D (Kirsten, Stander, and Haankuku, 2011). This has largely taken the form of carrying out trials and testing the suitability of new technologies developed by multinationals (Kirsten, Stander, and Haankuku, 2011). Today private companies guard most of the genetic material for breeding maize within private collections and hold intellectual property rights over most of these commercial varieties (ACB, 2017). In South Africa the main repositories for germplasm are the ARC, the National Plant and Genetic Resource Centre (mainly storing indigenous crops and does not keep improved varieties) and privately owned collections. A central rationale for multinational seed companies to merge with local companies has been to obtain access to local germplasm for breeding new varieties (ACB, 2017). Increasingly, therefore, the development of local varieties is by multinational companies and their domestic subsidiaries (ACB, 2017). Within the maize industry this includes DuPont Pioneer and Pannar (now Corteva Agriscience), Monsanto (now Bayer) and Syngenta. Domestic companies involved in breeding include Capstone Seeds, Klein Karoo and Sensako (ACB, 2017). The ARC is still involved in some breeding, however this has decreased over the years. Some breeding work is also carried out within universities. Seed production is carried out by both multinational and local companies. Multinational companies who are involved include DuPont Pioneer (and Pannar), MonsantoSA (now under Bayer) and Syngenta. Domestically this is carried out by Klein Karoo and Vuna Seeds (ACB, 2017). Chemical research associated with the maize industry is mainly carried out by multinational companies including BASF, Bayer and Corteva (Dow, Dupont). Domestic companies are involved more widely in the production under licence to multinational companies as well as distribution (ACB, 2017).

Smaller seed companies involved in GM research include Agricol, Klein Karoo and Vuna Seeds and focus mostly on hybrid and open pollinated seed development. Klein Karoo Seed Marketing has been engaged in commercial seed since the 1990s with their development programme initiated in 2012, and is one of South Africa's last independent seed companies (ACB, 2013). The organisation is engaged in developing, selecting and selling hybrid, open pollinated varieties and GM Roundup Ready and Bt cultivars. Agricol, who owns 49% of Klein Karoo, are also involved in the development of Hybrids and OPVs. Vuna Seeds is a non-GMO and hybrid seed producer, which focuses purely on OPVs for smallholder farmers (ACB, 2013).

Sensako, while being part of Monsanto, supplies seed for smallholders aware that most, larger, private companies target large-scale commercial markets (Agronomist 4, 2019). Sensako's seed development programmes are serviced operationally from two sites in Bethlehem (Marnè Research Farm) where the analytics laboratory, tunnel complex, irrigation and winter wheat and summer crop programmes are based.

1. ARC Plant Protection Unit (RoodePlaat)
2. ARC Grain Crops Institute & North West University (Potchefstroom)
3. Monsanto Research Station (Petit)
4. Klein Karoo Research Station (Bapsfontein)
5. Du Pont Pioneer Hi Bred international
6. Pannar (Greytown)
7. Sensako (Bethlehem)
8. CEDARA Agricultural College (Hilton) + University of KwaZulu Natal (Pietermaritzburg)

FIGURE 6.5: Map showing a number of the main locations of maize field R&D sites in South Africa. Source: Map created by Maya Marshak from Google Map images.

6.4 Conclusion

This chapter has traced the historical development and evolution of maize R&D system in South Africa. It showed that the history of seed development can be divided into three periods that coincided with key political periods. In the colonial period, maize R&D was started with a focus on the scientific development of OPVs. While hybrid research began during the colonial period, it was only during the apartheid era that hybrids became proprietary seed. Similarly, while the foundations for maize biotech research were laid during the apartheid era, it was only after the transition to a democracy that GMOs were released into South African fields. The purpose of this chapter was to map the R&D system, to provide the background for the thesis and to illustrate how the focus of maize R&D has shifted greatly over the past 100 years. As has been demonstrated, the system has gone from being closely associated with the colonial state to becoming deeply embedded within the global powers and structures of multinational companies. The next chapter focuses on how the technification of maize seed has affected ecological-based knowledge within maize research and development (R&D) in South Africa.

FIGURE 7.1: Specimens from a collection of insects related to maize agriculture held at the Agricultural Research Council (ARC). These armyworm specimens were collected in 1973. Source: Maya Marshak, 2017.

7. CHAPTER SEVEN: Seed Technologies and Ecological Deskilling in Research and Development

7.1 Introduction

Like farmers, agricultural scientists and researchers are makers, keepers and transmitters of agricultural knowledge. This knowledge and the ways in which it is generated is always shifting in relation to economic, political, technological, ideological and biophysical factors. Technologies bring change to the systems they enter (Herrero & Wickson, 2017; Green, 2017). This chapter focuses specifically on how the addition of GM maize seed has affected ecological-based knowledge within maize research and development (R&D) in South Africa.

Data gathering for this chapter began with a systematic literature review of scientific maize research in South Africa from 1900 to present. This informed an understanding of the various aspects of maize research in South Africa and how its focuses have shifted over time. This, as well as desktop research, informed a map of the various sites and stakeholders involved in maize R&D, which provided a basis for setting up in-depth interviews with key informants working within maize R&D across the country. As on the farms, this fieldwork adopted a multispecies lens as a way of tuning into changing socio-ecological knowledge in the R&D space over time. Maize research has involved a plethora of 'non-humans', including fungi, bacteria, rodents, insects, birds and viruses. Like farmers, who are engaged relationally with ecological systems on farms, scientists and technicians are engaged in another set of ecological relations through their work in laboratories, on test plots, on farms and, increasingly, through technology. Within this context, and for the purposes of this research, the concept of 'laboratory ecologies' was developed to refer to the kinds of ecologies scientists, technicians and other actors in the R&D space are attuned to and engaged with through their research.

While all of these socio-ecological entanglements were of interest in the early parts of this study, the study of insects and weeds came to occupy a specific focus. This is because pests and weeds are considered as two great challenges that need to be combatted within the industrial-agricultural paradigm, and have been the focus of extensive R&D. The development of GM maize seed specifically has focused on traits that tackle insects and weeds. GM Bt maize targets stem borer insects and GM herbicide-tolerant (HT) maize creates tolerance in the maize plant of the herbicide glyphosate. Stacked maize combines these two traits to create insect-resistant and herbicide-resistant maize. Both weeds and pests are categories of a dualist industrial-agricultural paradigm geared towards efficient production of monocrops in which all other species become unwanted and problematic. Insects are a particularly prominent group of protagonists in the unfolding story of maize R&D. Wherever there is maize, these tiny beings have played an important part in the evolution of farming practices and knowledge development. Our relationships with them can reveal much about our ways of engaging in the world (Biesel, Kelly & Toussant, 2013). As Biesel et al (2013) explain, insects have been entwined in scientific research for as long as it has existed. They note that "the history of science is teeming with ants, bees, moths, beetles, cockroaches and fleas revolutionizing the terms of empirical inquiry" (Biesel et al, 2013:4). Biesel et al (2013) tell us how insects are "good to think with" and "being attentive to ways of knowing with, about and through insects can shed considerable light on changing understandings of the natural world and on promises of technocratic order involved in its control" (Biesel et al, 2013:3). They show how "focusing on the creatures that trouble coexistence" (for example in agriculture, or human and animal health) allows us to look at human-non human interactions (Biesel et al, 2013:8). Insects become a "foci for understanding how humans inhabit specific spaces and moments in history." (Biesel et al, 2013:10). Studies that use insects as a lens have become useful ways of "illuminating scientific territories and colonial pasts" (Biesel et al, 2013:8).

One of the key insect threats in commercial maize fields globally is the stem borer. There are a number of species of these insects in South Africa. The most notorious species in South African maize fields are *Busseola fusca* and *Chilo partellus*, relatives of the European and the American stem borers. Looking at the socio-ecological entanglements of insects within the R&D space over time provided a lens through which to look at a wider picture of the culture of agricultural science. This multispecies journey into the research space tells a story about unravelling and remaking relationships between scientists and ecological systems, within the bounds of global and national economic and political shifts.

Like chapter five, this chapter draws on the concept of ecological deskilling in agriculture. This concept was introduced in chapter five as a means to draw attention to the unravelling of ecological-based knowledge and practices in agriculture, as well as to a subsequent loss of the ecological agency of farmers. To date, while agricultural deskilling has been examined in relation to the work of farmers and the introduction of new seed technologies (Fitzgerald, 1993; Vandeman, 1995; Stone, 2004; Stone et al., 2007), little research focuses explicitly on the concept of deskilling in relation to agricultural R&D. This chapter traces how the continued modernisation of maize seed technologies, and most notably the introduction of GM seed, has affected socio-ecological relationships and knowledge in maize R&D. However, it argues that this is not merely a linear story of unravelling or loss of knowledge, but a more dialectical process. It suggests that GM seeds and what we have come to know about their widespread socio-ecological impacts have become both agents and portents of loss, warning of the dangers of losing practical, manual, visceral relations with ecological systems.

7.2. Conceptual starting points

As in chapter five, the literature on agricultural deskilling provided a conceptual starting point for exploring the loss of agricultural knowledge related to newly introduced seed technologies. This literature aided the understanding of how the introduction of GM maize might have contributed to shifting knowledge within maize R&D spaces. The term 'ecological deskilling in agriculture' was suggested as conceptually useful for understanding and describing how the introduction of new technologies has contributed to farmers' loss of relationships with and knowledge of their immediate agricultural environment. This chapter carries through the concept of ecological deskilling, this time to articulate the growing disconnect between scientists and agroecological systems that became visible during the research process.

In the context of their role in developing technologies for private companies and furthering the transfer of new technologies to farmers, scientists are often blamed for deskilling, as farmers resultantly become the mere recipients of technologies developed elsewhere based on the advice of experts (Fitzgerald, 1993). Fitzgerald (1993), for example, argues that the adoption of hybrids led to the deskilling of American farmers, turning them into passive customers of seed firms. As shown in chapter five, this dynamic also plays out in smallholder farming environments in South Africa. However, to focus exclusively on how agricultural science has deskilled farmers potentially obscures a similar process that is experienced by scientists. This chapter illustrates how the knowledge of scientists working in maize agriculture has also been significantly affected by the introduction of GM seed technologies.

In the process of conducting interviews with scientists involved in maize R&D, two distinct narratives emerged among respondents in the R&D and scientific community. On one hand, some felt that GM seed technologies promoted a process of skilling within R&D. These respondents saw GM seed technologies as broadening the field of R&D in maize farming, and expanding the tools available for farming in more ecologically sensitive ways. On the other hand, however, some respondents were of the opinion that GM seed had contributed significantly to the deskilling of scientists, leading to a loss of skills, knowledge, capacity and agency within the sector. Each of these narratives reflects much about the world views or ontological standpoints from which the scientists being interviewed assert these opinions, rather than an account of reality.

This chapter expands on both of these narratives by presenting a full exploration of each scenario, taking care to avoid reducing this complex landscape into the binary of either skilling or deskilling scientists. Despite the persistence of this binary discourse in existing research, the findings of this study highlight the complexity and nuance of both positions. The use of a multispecies lens assisted with finding ways to move beyond this binary narrative; by looking in detail at scientists' relationships with these species over time, it became possible to track various disruptions and continuities in research related to these species. This approach also revealed a third process concerned with skilling, articulated here as ecological reskilling. This term is used to describe the addition or re-addition of more contextual, relational research placed in real time and space, and which is moving away from control over nature in favour of working with it.

The theme of ecological reskilling became more prominent in a series of follow-up interviews in the last year of fieldwork between 2019 and 2020, as well as in an additional set of interviews. In many of these interviews, scientists spoke about the challenges brought about by GM maize, such as the threat of insect and weed resistance. Set against the realities of the global environmental crisis, the severe drought that South Africa recently experienced, and the threat of the new, invasive fall armyworm (*Spodoptera frugiperda*) that emerged in 2017, these interviews revealed that agricultural scientists were becoming increasingly concerned with dualist industrial approaches to agriculture. These interviews revealed respondents' growing interest in the need to repair socio-ecological relationships, something that necessitates long-term, more contextually specific research.

7.2.1. What constitutes ecological-based research within the context of agricultural research and development?

Before presenting the findings of this chapter it is important to discuss the way the term 'ecological' is conceptualised in this study in relation to the research of scientists and ecological deskilling in agricultural R&D in South Africa. From its inception in South Africa, maize R&D was based on anthropocentric and dualist conceptions of agroecosystems. During the colonial period and into apartheid, as traced in chapter six, maize R&D functioned to support white commercial farmers by promoting ideals of efficiency and productivity through finding ways of "putting nature to work", and controlling agroecosystems to extract as much profit as possible (Moore, 2015b:2). A significant number of scientists were employed to efficiently understand these agroecosystems, including soil scientists, plant pathologists, entomologists, weed scientists, breeders and agronomists. These scientists worked alongside commercial farmers in an attempt to solve particular and contextually specific problems on farms. This presented an irony: despite the fact that this research was taking place with and within actual agroecosystems (and was thus substantially informed by this context), this was not done with the intention of being ecologically sensitive.

In this context, detailed ecological-based research was not necessarily done with the intent to bolster ecological relationships or find more environmentally sensitive methods of farming. Instead, it was more often motivated by finding ways to better understand ecological environments, in order to control farming systems in ever more efficient ways. In the late 1960s Integrated pest management (IPM) and with the use of biocontrol became a globally recognised approach to pest management when the

FAO put the concept into operation (Kogan, 1998; Peshin et al. 2009). These approaches began to ecologise approaches to pest management, by seeking to reduce the use of pesticides that were expensive and increasingly seen as harmful to people and the environment (Peshin et al. 2009). While these techniques rely on ecologically based research and gathering relational information within particular agroecosystems, one would be hard pressed to say that their motivations and ontological underpinnings were purely ecologically motivated. While the aim was to reduce the use of chemicals, chemicals are still incorporated as part of this integrated approach. The motivations here are pragmatic: within an industrial-agricultural paradigm, these management approaches – considered in line with sustainability – have modernist, industrial motivations.

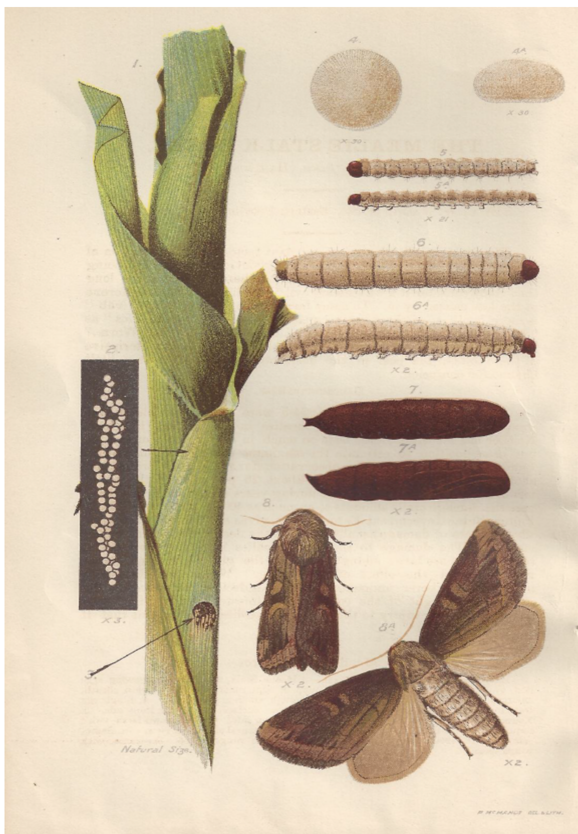


FIGURE 7.2: The image above is taken from the book The Maize Stalk Borer: *Busseola Fusca*. It contains the first scientific research done on stem borers in South Africa classifying *Busseola Fusca* and exploring cultural methods for controlling it. In the opening paragraph, the author explains how this borer is known as 'a necessary evil' in South African maize fields where people have become 'indifferent to the losses it causes' (Mally, 1920:3).

The motivations within capitalist industrial agriculture can be summarised using Latour's conceptions of the modernist "Gods of Reason", namely Scientific Objectivity, Technical Efficiency and Economic Profitability (Green, 2012, 2015, 2020). Latour (2007) refers to the priorities as the "Gods of Reason" because achieving them is put before any other matters of concern (such as social and ecological well-being) within the capitalist system. These priorities underpin the development of industrial agriculture. For example, while using less pesticides is potentially better for the environment and humans, what is perhaps equally, if not more, important for industrial agriculture is the fact that it reduces the cost of production, as well as the potential for weed or pest resistance. The concept of 'protecting [a] technology' (for example, the longevity of pesticide application) by using it correctly was emphasised by three of the scientists interviewed. It was often suggested that it was not these technologies, but rather the incorrect use thereof that could lead to problems such as insect resiatance. Therefore the technologies need to be protected from misuse. Within this dominant industrial paradigm, GM seeds if used responsibly are often considered as offering a sustainable and ecologically sensitive solution to other agricultural challenges like addressing pests (Entomologist 7, 2020: Zoom).

This managerial and pragmatic approach to sustainability, in which new technologies or techniques are considered more sustainable than conventional systems, is common within the maize R&D spaces explored in this research. It is this kind of thinking that Herrero, Wickson & Binimelis (2015:11326) explain leads to the ecological benefits of GM crops being compared to 'conventional agriculture', rather than alternative farming practices. They argue that this dualistic comparison has the potential to "encourage[e] development that is no worse than the unsustainable systems we already have", instead of drawing out more complex dialogues about whether other, more socially-ecologically desirable possibilities that do not include GMOs might exist (Herrero, Wickson & Binimelis, 2015: 11327).

However, while much ecological-based research within industrial agriculture is arguably anthropocentric and capitalist in its motivations, this does not mean that this research is without ecological value. In many ways, it does offer more sustainable solutions. Furthermore, some of the research being done by scientists within this paradigm could be extremely valuable for agroecological approaches and suitable for smallholders, if more consideration of the relationship between these spaces and the ontological standpoints of both these lineages of knowledge are given. The next section reviews the kinds of ecological-based research that have potentially been displaced by GMOs. The following sections use the term 'ecological' to denote research that involves the study of the more-than-human world by scientists.

7.3. GMOs and ecological deskilling in maize research and development

This section explores the narrative of ecological deskilling that emerged during the interviews in R&D institutions. It suggests that the introduction of GM maize effected significant change within the R&D system, and that it contributed to a disruption of important ecological-based research. The section outlines two dimensions of ecological deskilling that became visible through the research: 1) the displacement of relational and ecological-based research and knowledge, and 2) the loss of agency to do ecological-based research.

7.3.1. The displacement of relational, ecological-based research and knowledge

> The day that GM was announced it all stopped, because there was an answer to everything. So all the resources were channelled towards doing contract work for multinational companies, screening their GM events to tell them which one was best, and after that the best one was identified. Farmers were told, this is your silver bullet to control your most important pest with… and IPM died within a matter of a few years and that was bad... In my opinion, there was a huge change in maize and cotton research because now the pest was gone (Entomologist 7, 2016: Potchefstroom).

The above quote emerged from an early interview with an agricultural entomologist who has worked in maize research in South Africa since the 1980s. They recounted how, at the time of GM maize coming into the country, there had been "a huge team of agronomists, pathologists, entomologists" working in IPM research and maize at the Agricultural Research Council (ARC) (Entomologist 1, 2017: Potchefstroom) According to this scientist, some of the topics investigated at the time included crop rotation, the role of wild host plants on pest management, when to apply pesticides to reduce the amount used, and which insecticides were less harsh on the environment. A scan of the literature reveals the breadth of this kind of work, which was underway in South Africa from the 1980s until the early 2000s. This research was conducted by scientists at the ARC, within South African universities, and regionally. Figure 7.3 is a graph derived from a systematic literature review of all the research done concerning stem borers from 1900 to 2019. It illustrates a decrease in IPM studies concerning stem borers at the time in which GM maize was becoming a focus of research in the late 1990s and early 2000s.

In the opinion of the entomologist interviewed above, the introduction of Bt maize into the research environment significantly affected the progression of more integrated pest research. They explained that while IPM research related to maize did not stop altogether, it was deprioritised for some time, and a number of projects were sidelined as a result. Importantly, these were long-term, systematic projects that involved collecting observations over multiple consecutive seasons and years. The view that IPM research had become less important was echoed in two more interviews conducted with scientists who had seen shifts in their immediate research environments when GM maize was introduced.

Reflecting on his past experience, a now retired agricultural entomologist who worked for many years at the ARC, expressed how, in the 1970s and 1980s, they experienced 'a very good set up in terms of agricultural research' (Entomologist 1, 2017: Potchefstroom). In the ARC-Grain Crops Institute (ARC-GCI) where they were based, researchers worked on "all the possible pests" of maize. However, they explained that "most of these people had disappeared" (Former ARC entomologist 1 2017:Potchefstroom).

The agricultural entomologist mentioned above had also worked in public-funded maize breeding since the 1970s, and explained how the introduction of Bt maize directly affected a breeding program they had been working on for ten years. During the 1980s, they had identified a population of Caribbean maize, bred by a breeder in Mississippi who had developed lines resistant to multiple kinds of stem borers – a novelty, given that scientists had previously targeted only singular species of the insect.

They managed to obtain the maize seed, tested it and found that "it worked like a charm against the local stem borer" (Entomologist, 1, 2018: Potchefstroom). However, the seed was not adapted to local conditions, and so they began working on it to integrate the resistance into locally adapted varieties. This took about ten years, as breeding is a long-term process that requires years of commitment. Unfortunately, as they explained:

> Just as I was finished and I reported that we have resistant lines available with good yield potential, the Bt entered the scene, so it was all for nothing, wasted…(Entomologist, 1, 2018: Potchefstroom).

Another example of a project that was directly disrupted by the introduction of GMOs was a long-term project designed to better understand the spread, lifecycle and behaviours of stem borers in South African maize fields. This project was referred to in three separate interviews with scientists as an example of a project that had unfortunately come to an end.

The retired agricultural entomologist whose breeding program was disrupted also did a great deal of work on understanding the life cycles of stem borers. They were very passionate about this, and had spent approximately ten years working on a stem borer moth tracking project in an attempt to better understand the life cycles of this insect. It involved the very time consuming, hands-on work of traveling daily to field sites, gathering moths in light traps overnight in five different localities, and tracking their life cycles. As explained:

> I started working with stem borer, and do you know, it was amazing, every year there was a lot of new information. I started off with light traps in various localities, let them go round the clock all year round, every day – even on Christmas day they had to be emptied and all those moths identified and counted… What happened next, we realised that the moth numbers go up over a period of ten years and down over a period of ten years with the rainfall cycle. We had an epidemic in the late 70s and that showed up nicely, and actually the next epidemic I could predict; I told the farmers, be ready, here it comes, and it was spot on (Entomologist, 1, 2018: Potchefstroom).

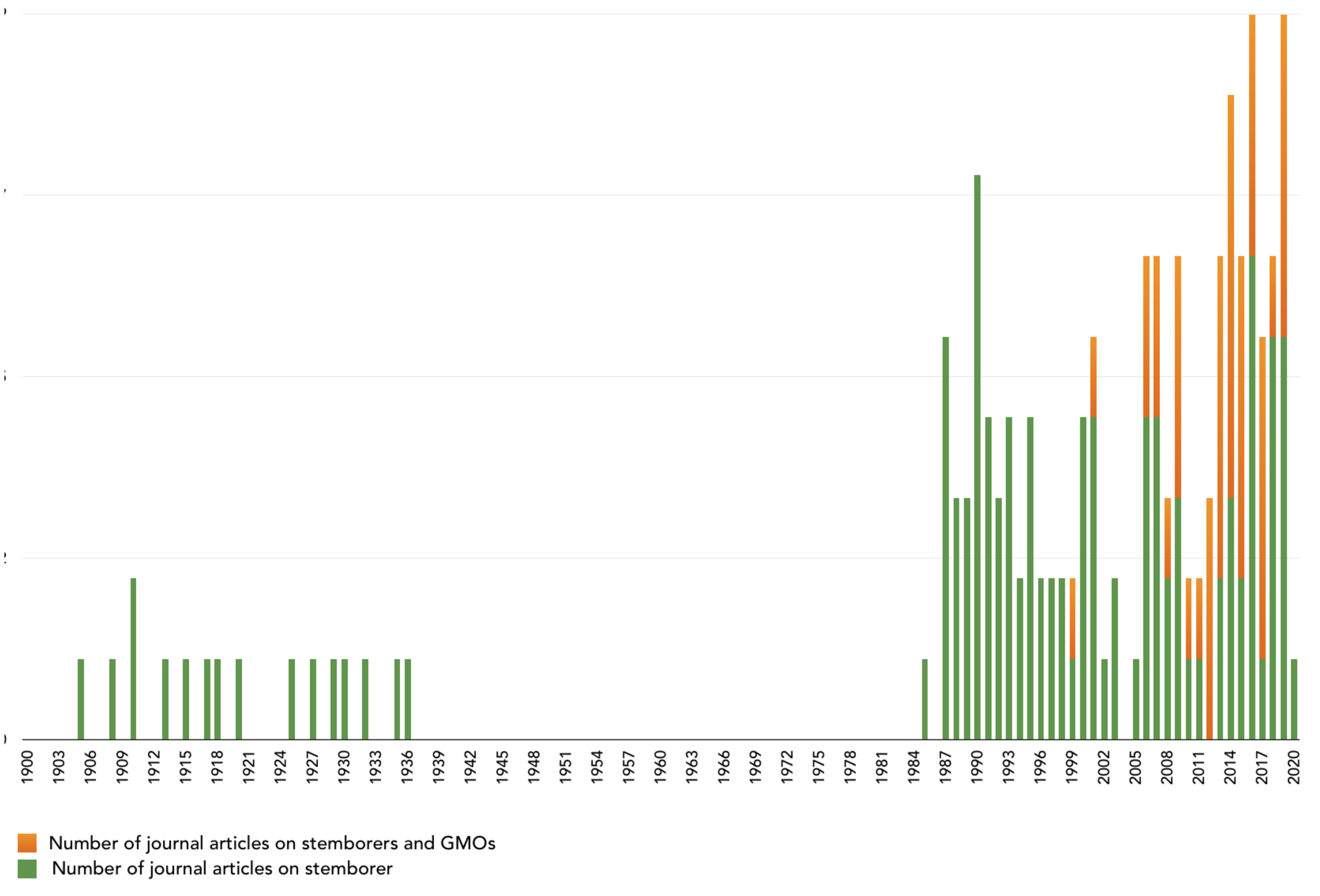


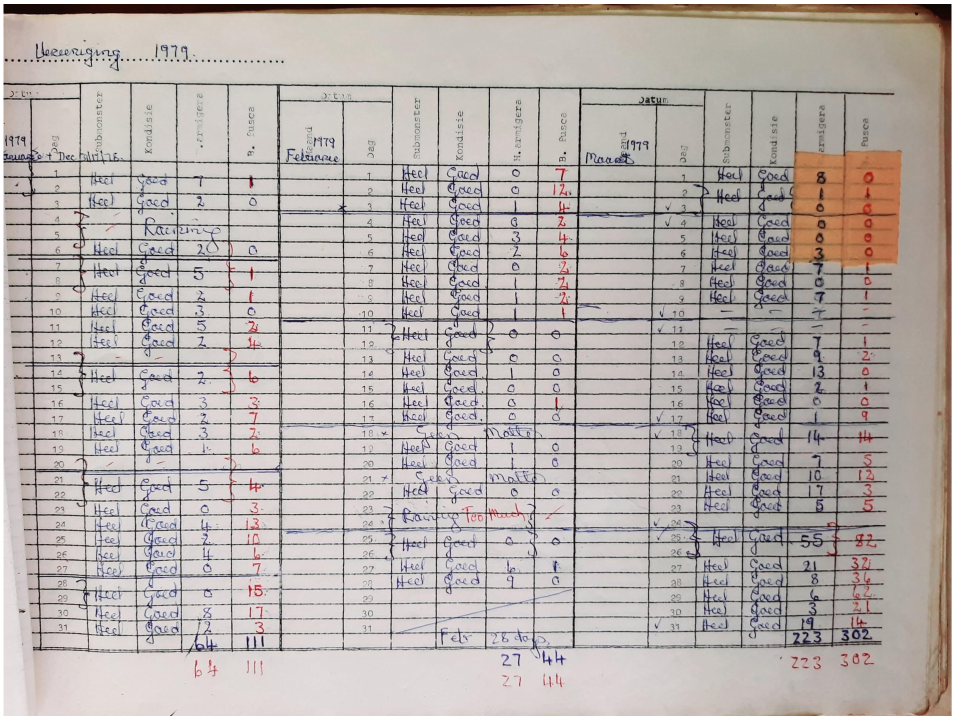
FIGURE 7.3: Graph showing results of a systematic review of articles on stem borers from 1900 to 2020. The green bars show scientific articles published in journals on topics related to stem borers and maize. The orange bars show articles related to stem borers and GM maize. One can see a significant number of the articles on stem borers from 2006 onwards involved research on GMOs. Source: Review carried out by Maya Marshak, 2019.

At the ARC, one is able to look through the handwritten journals in which these results were recorded (7.4(a) and (b)). Through detailed research and understanding of stem borers, including of their lifecycles and their relation to biophysical landscapes, scientists, extension officers and commercial farmers worked together in teams to reduce pest damage and the use of chemicals (Entomologist, 1, 2018: Potchefstroom). These studies were used to help develop an IPM approach to farming maize. In this way, farmers, with the help of the government extension service, came to understand the behaviour of this pest in relation to the exact context in which their farm was located, including the seasons, weather patterns and other factors. In being able to track stem borer lifecycles and behaviour, scientists, along with commercial farmers, could work out how to plant in ways that would avoid key lifecycle stages of stem borer and avoid spraying in years when they were not widespread. An entomology professor who worked in maize research for 30 years explained that there was a time when this kind of knowledge was used by farmers to significantly reduce pesticide sprays, but today there are very few farmers who understand the pests enough to attempt this. These studies stopped over two decades ago, and there was no longer much interest from commercial farmers to understand these patterns, with most now relying on GM seed (Entomologist 7, 2020: Zoom). In a later interview, they explained:

> When GMOs as a product came along, because it was very effective there was no need to know anymore...you may come across a light trap now but its rusted…today I get messages from farmers and even chemical experts trying to understand what moth they found… (Entomologist 7, 2020: Zoom).

This points to a growing divide between R&D and farmers, a concern that was raised by a number of researchers during interviews. Their frustration was that available research was not making its way to farmers so that they could integrate it into their systems. According to one entomologist, in the past there was a stronger connection between researchers and farmers;

> [In the past], government departments were monitoring the annual flight patterns of maize pests and we used that to tell farmers when to apply insecticides. You got on the radio and informed farmers, and that is the management in IPM; you make a decision and give advice… it's a long-term thing, and everyone has to have the general knowledge of this pest, and farmer could plan ahead and even in November they know they may have to spray in January so they are ready (Entomologist 7, 2020: Zoom)



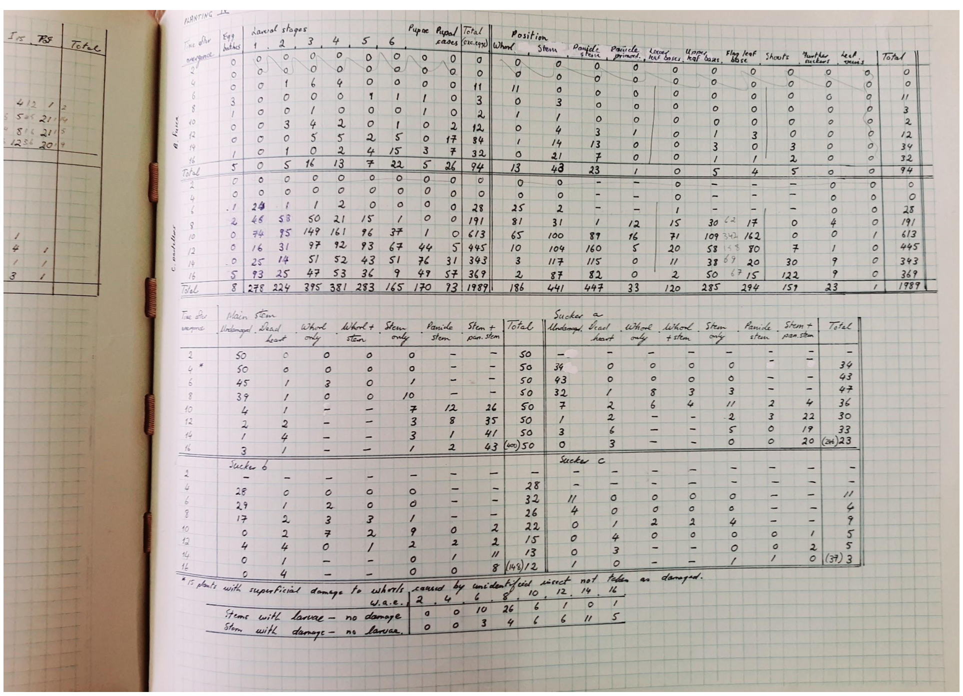


FIGURE 7.4(a) and (b): These pages are taken from a fieldwork data logbook that was kept by a now retired agricultural entomologist employed at the ARC-GCI. These pages show an exercise undertaken by scientists over a 20-year period from the 1970s to the 1990s to track flight patterns of stemborer in farmers' fields. This long-term method helped researchers understand a great deal about the life cycles of stem borer and their relationships with weather cycles over time.

In an earlier interview, this same entomologist explained that they believed a process of "deskilling" within research and development was underway. As explained:

> People have used the word deskilling… for me this is serious; well, depending on where you come from… meaning you don't have the skills you had or your father had… for example, with traditional seed, your grandfather had seed and you don't have it anymore… or in a commercial farming context it means that old *oom* [uncle] out here in Bothaville, he knew his pests. He knew what to spray and then he started planting Bt maize. Now 15 years down the line he doesn't remember anymore, because he hasn't seen those small worms he saw before in ten years, or his son took over the farm and he doesn't know if this is a beetle or a worm. It happens. I get a call a week and get asked questions of a primary school kid and the decision we make requires a million rand of pesticides to be applied or not, and that is why this thing about deskilling concerns me… people have really forgotten (Entomologist 7, 2016: Potchefstroom).

Here, they point to the way that many farmers are losing touch with the pests in their fields. There is an increasing reliance on generic solutions, such as broad spectrum herbicides and in-built pest resistance, which are designed to work across different agricultural contexts, thereby removing the need for place-based knowledge. It was his opinion that GM maize deepens this disconnect, in that the mechanism for dealing with the pest is built into the seed and is thus invisible. The farmer is able to buy a technology to deal with the pest absolutely; in this way, there is no need for the knowledge that would previously have been needed to understand how to use the maize seed within the wider agroecological system (Entomologist 7, 2020: Zoom). The relationships between farmers and the R&D system thus decreases, further widening a growing disconnect between knowledge and agroecosystems. In this case, this entomologist refers to commercial farmers, but in an interview with an agronomist working in smallholder development, the respondent explained the frustration of not being able to convey research that could be useful for smallholders. A reason given for this was that the current governmental extension service was not trained in these more integrated methods, but rather that the system relied on the transfer of generic solutions, including GMOs (Agronomist 2, 2019:Potchefstroom).

The same entomologist suggested that GMOs could have also contributed to a process of deskilling in the area of chemical insecticide development. They explained:

> There was a total stop of activities around development around new chemical insecticides. You could say that it's good but today if a farmer has a problem they may go back to chemicals from 80s and 90s. That's terrible stuff… so for ten or 15 years there was a slow-down of development and thinking around more environmentally friendly products (Entomologist 7, 2020: Zoom)

As the entomologist explained, Integrated Weed Management (IWM)[14] focuses on the complex interactions between crops and the plants surrounding them in an agroecosystem, and how they compete for light, nutrients and water, while simultaneously benefiting each other. It involves conducting detailed experiments to try to understand competition between certain weeds, and crops and from this basis make decisions about how and when to apply chemicals in different stages of crop development (Entomologist 7, 2020: Zoom). In the past in South Africa, scientists worked with farmers to better understand their weeds and how to spray them. However, when HT maize was introduced along with glyphosate, it removed the need for those skills; the in-built resistance of maize and the broad-spectrum nature of the herbicide to remove all weeds at once rendered the knowledge of different weeds redundant. A knock-on effect of this was a reduced focus on lessening pesticides, something that usually came about through an understanding of the environmental interactions between species, trying to find chemicals that were more environmentally friendly, and learning to apply as little pesticides as possible as a result. This became extremely problematic when weeds started developing a resistance to herbicides (Entomologist 7, 2020: Zoom). As one weed scientist explained, farmers no longer know how to identify weeds; in fact, if a new weed species enters the system, farmers will likely be unaware of it (Weed scientist 1, 2017:Pretoria). This same weed scientist offered an example of a new weed that had found its way into maize fields some years ago, and only after a long while had it been identified as a new weed variety, because farmers mistakenly thought it was simply another, similar-looking weed to one they were already familiar with (Weed scientist 1, 2017:Pretoria).

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[14] For more on IWM see: Harker and O'Donovan. 2013. Weed Control, Weed Management, and Integrated Weed ManagementK. Weed Technology. 27:1–11

A related theme that surfaced in interviews was the loss of institutional memory. This theme refers to the displacement of older methods of research, due to the change in focus and pace of research. Three respondents (an entomologist, a taxonomist and a maize breeder) referred to biotechnology as a "sexy" choice for many students and young scientists who were choosing to focus on biotechnology research rather than what was perceived as the "slow-paced" work that they had experienced as young scientists.

The taxonomist explained:

> The problem in all scientific endeavours, not this field only, is that you build up this knowledge and expertise and then you retire (Taxonomist 1, 2017:Roodeplaat).

This excerpt came from an interview that took place at the beginning of the fall armyworm (FAW) crisis that emerged in 2017. This Lepidopteran species is native to eastern and central North America and South America and had not been seen in South Africa until early 2017, when it was spotted in the Limpopo province. The first sighting on the African continent was in 2016 when it was reported in Nigeria. It then moved south, voraciously devouring maize crops in its path. It has a rapid life cycle and can quickly multiply if not halted (Harrison et al., 2019). Since it was first sighted in South Africa, the FAW has been found in Limpopo and Mpumalanga and parts of Northwest, Gauteng, Free State, the Northern Cape and KwaZulu-Natal provinces (Harrison et al., 2019).

In order to map the spread of the insect, specimens have to be properly identified, which requires taxonomic expertise. When the FAW suddenly became a problem, identifying it correctly posed a significant challenge; very few taxonomists in the country had the expertise necessary to identify the insect, which is done using a microscope, in order to identify the genitalia, which differs from that of indigenous species. At the time, the taxonomist interviewed was the only person in the ARC who was able to do the identification; they had a pile of specimens and were overwhelmed by the flood of new ones that kept arriving. Not only was her workload more than she could manage – as there was no longer a system in place to receive, send and store specimens – the samples being recieved were often damaged and badly presented.

Farmers and others wishing to have them identified were unaware of the science of taxonomy, thus sending specimens that sometimes made the work of identification impossible. The crisis that emerged in 2017 acted as a lesson on the importance of scientists who still have basic skills in taxonomy, and the importance of systematic and detailed record-keeping.

There has yet to be an in-depth process of inquiry into how the introduction of GMOs has affected the nature and focus of ongoing research in R&D institutions. The experiences of maize scientists point to the fact that the impact of GMOs on their daily work has gone largely undocumented. Talking to these scientists about their experiences suggests that since the introduction of GMOs – but not exclusively because of them – there has been a shift away from long-term, place-specific research. For many of these scientists, their concerns about shifting research agendas has just been accepted as a part of a process of technological advancement over time. However, reflecting on their experiences, many articulated ways in which valuable research has been displaced; while GMOs promised more direct, 'silver bullet' solutions, they reduced the immediate need for certain long-term studies, which in some cases got halted. The example of the loss of the moth flight pattern tracking programme is a key example. The reduction of work on integrated herbicide use is another.

7.3.2 Loss of agency to do ecological-based research

The interviews with scientists revealed a number of ways in which the introduction of GMOs had indirectly altered their ability to carry out more ecological-based studies. The first was the decrease in availability of funding for long-term ecological-focused studies. The second was the pull towards GMO-focused research, as there was increasing funding available for it. A third theme related to the loss of agency to do ecological-based research concerned the personal relationships scientists have had with their work over time and how this relates to the requirements of agricultural research within a capitalist-industrial paradigm.

7.3.2.1. Decreased funding for long-term research projects

Three of the agricultural entomologists and the one taxonomist interviewed expressed a deep respect for long-term projects that had become less common overtime, such as the use of light traps to determine stem borer life cycles, behaviour and potential threats in a given year. Another example of a long-term project was the breeding of stem borer-resistant, hybrid varieties of maize suitable for local climatic conditions. These kinds of projects are, however, expensive and time-consuming to undertake. As noted in the previous section, while such research was of great value in the days before GMOs, Bt maize effectively 'dealt' with existing stem borers and acted as insurance against future infestations. This in some ways removed the immediate need to really understand the behaviour of these insects, thereby rendering this kind of research irrelevant and invisible. In one interview, an entomologist explained their frustration with short funding cycles in which they were often requested to do long-term research in unrealistic time frames. They recounted a recent experience in which they had been asked to write a proposal for a field trial-based research project, which they were required to complete in four months, something they felt required at least six years to do well (Entomologist 2, 2019:Potchefstroom). Limitations on funding available for long-term research thus impact the kind of work that can be carried out, as ecological-based studies often require longer-term experimentation and cumulative research that spans decades.

These studies often do not yield high economic benefits for those involved; for example, developing a hybrid that is resistant to stem borer would be less profitable than developing a patented GMO with a Bt gene in it. Chaminuka et al. (2019:8) explain that "private sector investment in agricultural research can, amongst other factors, be stifled by the public good nature of research outputs and the long-time frame between investment and realisation of returns in agricultural research". Alston et al., (2009) explain that returns on investment in agricultural R&D can often take decades to be realised, yet this will often pay off in the long term. However technological advances such as in biotechnology have sought to significantly reduce the lag time between investment in R&D and the realisation of outputs (Chaminuka et al, 2019).

In their study on spending in the agricultural R&D sector of South Africa, Chaminuka et al. (2019) assert that investment in R&D is key to "bringing about technological change that stimulates development". The prioritisation of technological and technocratic solutions towards development and poverty alleviation is one that can be seen in the space of maize R&D. For example, one of the breeding projects of the Water Efficient Maize for Africa (WEMA) project is based at the ARC. Initiated in 2008, this project targeted the development of drought tolerant and insect pest-resistant maize varieties, especially for smallholder farmers, through conventional, molecular, and genetic engineering breeding approaches (WEMA, 2020). A key selling point of the project was to make biotechnologies more accessible to smallholders by marketing them royalty-free in sub-Saharan Africa through African seed companies (WEMA, 2020). Fischer and Hajdu (2015) argue that while there has been increased focus on developing technological solutions for smallholders over the last decade, this may not be the most appropriate approach; they argue that research into hybrids and OPVs would offer more benefits to smallholders in the long term.

The investment in shorter-term research, boosted by technological inputs and with technological motivations, is a trend that is growing globally. In a recent report, IPES (2020) outlined the limited research funding globally for agroecological-based research, where most funding goes into supporting industrial agriculture 'and/or increasing its efficiency via targeted approaches such as improved pesticide practices' (IPES, 2020:4). There is thus a growing need to explore where research is being driven by the market, rather than what research would be most appropriate given the needs of farmers and long-term sustainability. As the IPES (2020:5) report states, "the huge potential of systemic, agroecological research for development has barely been tapped. A series of steps are required to overcome "lock-ins", change the way priorities are set and accelerate the development and dissemination of agroecological knowledge".

7.3.2.2. The pull of biotech-focused research and the displacement of 'slower' science

While Bt maize traits may have narrowed the scope of research needed to protect maize plants from stem borers, the unexpected nature of how GMOs behave outside of the laboratory in South African landscapes has created new avenues of research that need to be explored. This includes research into the resistance of stem borers to the Bt trait. Ongoing work is necessary to ensure that resistance will not contribute to the creation of 'superbugs' that cannot be managed with GM traits or accepted levels of insecticides (Kruger, van Rensburg & van den Berg, 2009; Hilbeck & Bøhn, 2013). Also necessary is research on the potential ecological impacts of Bt toxins. In South Africa, there has been a growing body of literature from between 2007 and 2019 concerning the potential ecological impacts of Bt toxins on non-target insects and other species in maize agroecosystems (van Wyk, van den Berg & van Hamburg, 2007; van der Merwe *et al*., 2012; Truter et al., 2014; Erasmus et al., 2014; Petersen et al., 2017; van den Berg et al., 2017) and soil and water bodies (Du Pesani et al., 2018; Venter, 2016).

One scientist expressed how the complexity of research required to understand the impacts of GMOs was often far beyond the available capacity of scientists who had previously worked in other fields. Yet this was often where the funding was available, pressing scientists into new fields and away from their original specialisations. As they explained:

> I am a trained taxonomist and not an ecologist, and taxonomy does not get good funding, because people aren't prepared to fund long projects… so we are being coerced into getting involved in ecological projects like risk assessments and we are not trained for it… We work as part of an interdisciplinary team, and I resist that because I feel out of my depth… if you are a brain surgeon you shouldn't do heart surgery. I can give you the information you have on those specimens if I have it but I cannot give you information on target species and all these things they [risk assessment studies] are looking for. I can't tell you how big a field must be to be statistically viable for a refuge – I can't do that because I'm not trained in that. I think its criminal to make those decisions if you are not trained for it (Taxonomist 1, 2017:Roodeplaat)

At least three respondents mentioned a change in the pace of work over the years. This was linked to the idea that skills were being lost, because the R&D system didn't have time for slow, methodical, long-term projects anymore. Solutions were expected to be delivered faster than they had been in the "old days". Biotechnology is often touted as a quicker way of developing cultivars, most recently with clustered regularly interspaced short palindromic repeats (CRISPR) promising even quicker gene editing techniques. As mentioned earlier in the chapter, a number of scientists explained that young scientists coming into the field were attracted to faster, 'sexy' sciences, such as biotechnology. A seed company representative who worked in maize breeding explained how students today "are not willing to work long hours in the field" (Agronomonomist 4, 2019: Skype). In his experience, being a student and breeder meant he had to spend long hours outdoors, sometimes in 40 degree temperatures. He felt that students were no longer attracted to those working conditions and preferred to do more laboratory-based work. Drawing on his attempts over the years to hire experienced breeders, he felt that plant breeding is "becoming a scarce commodity" internationally, and that "practical plant breeders who understand the dynamics of plant breeding are getting scarce" (Agronomist, 2019:Skype). In another interview, a representative from GrainSA also raised the issue of "certain skills diminishing over time" (Scientist/ researcher 2, 2019: Pretoria). They felt that "agronomists are getting scarce", and that breeding as a field was no longer "seen as a sexy science". They also raised the notion that "the outdoor nature of the work was increasingly seen as less appealing" (Scientist/ researcher 2, 2019: Pretoria). They felt this was leading to a growing lack of capacity of scientists that have practical outdoor skills, as these skills can only be developed over time and through practical experience. She felt this was causing a "loss of institutional memory" and in their experience more seed companies were now no longer hiring breeders but rather buying in material from elsewhere (Scientsits/ researcher 1, 2019: Pretoria).

Similarly, a taxonomist felt that the work in their field was "not a sexy science" (Taxonomist 1, 2017:Roodeplaat), because it also requires long hours and is low-tech in nature. This is despite the fact that the work of taxonomy is mostly indoors, sitting at a microscope. While the nature of taxonomic work is different to that of breeding, for example, these concerns mirror the idea that slow, 'low-tech' work has been regarded less over time. They felt that the fields of biotechnology are more appealing to students these days as they are "high-tech and flashy" (Taxonomist 1, 2017:Roodeplaat), in contrast to taxonomic work. They explain:

> Taxonomy requires you to sit on your bottom behind your microscope and you study your specimens, and it has this connotation of "fuddy duddies" sitting in a dusty corner somewhere looking through a microscope and it doesn't have mass appeal. That is why there are so few of us and also you have to have a certain temperament to do it. You can't be a jumpy person; you have to be able to apply yourself for hours on end and

> maybe at the end of the day not be much further than you were when you started. So we always say you can't train a taxonomist – they are born. It's a temperament that you have to have… and we've seen it here; people come in and they are eager but they don't last because they can't deal with that slow pace of work (Taxonomist 1, 2017:Roodeplaat).

7.3.2.3. GMOs, dualism, scientists, and the pragmatic distance from ecological systems

In one of the corridors of the ARC-GCI, there is a glass cabinet filled with models of maize insects. They are beautifully detailed, depicting even the fine hairs on the insects' bodies (See Figures 7.5(a) and (b)). I had been eager to find their maker and after some time I did meet him. They had retired some years before. When I asked them about these 'artworks', they expressed how they enjoyed the very precise work but did not necessarily see them as artworks.

My interest in collecting visual data opened up a series of interesting conversations with many of the scientists interviewed. I met a number of agricultural entomologists who also had creative interests. In the zoology hallway, I met an entomology student who was playing a 300-year-old violin. I also spoke to a professor of agronomy who had been a passionate concert pianist. One PhD student in entomology told me how they decided to stop collecting insects, "throwing them in the freezer" and pinning them, in favour of photographing them, as a new creative exercise (Entomologist 4, 2016:Potchefstroom). There was also a professor who spent his time carefully pinning insects as a kind of meditative or relaxing practice, away from the busy-ness of the world, after everyone had gone home for the night. When I told the agronomist who played the concert piano and had an interest in entomology that I had met a number of entomologists who were interested in art, they explained:

> I think if you know ecology, you must be absolutely stimulated by the wonders of it. If you look at nature it is fantastic… all the small natural enemies, and there is such an intricate system. You must be artistic to find how fantastic ecology is… if you are an environmentalist and a biologist you must be artistic as well… entomology is fantastic – you must see the art of it (Agronomist 1, 2016: Potchefstroom).

Through conversations about art, entomology and nature it became clear that a fascination with insects and the generative nature of life seemed to be what had drawn so many of these scientists to their discipline. Yet the reality of working in agricultural entomology within an industrial agricultural system was quite different from this. In this world killing insects with toxins was an everyday reality and a necessity if the industrial-scale production of food and food security were to be realistically achieved. The contradictions are embedded in this world in which agricultural entomologists display a sense of wonder about nature, but at the same time make a living in a field whereby they are required to find the best, most efficient ways to manage, control and eradicate it. These realities operate on different scales and levels of meaning.

FIGURE 7.5: These images show a series of models made by a former agricultural entomologist, who specialised in maize pests at the ARC in Potchefstroom. Source: Maya Marshak.

One day I was invited to assist with an experiment on the effectiveness of Bt maize. It involved using a fine paintbrush to paint newly-hatched borer caterpillars onto samples of Bt maize stems (see Figures 7.6(a) and 7.6(b)). While we sat, carefully painting the tiny borers onto the stems, one of the scientists referred to the little caterpillars as their "babies", showing an affection for these little creatures that were being led to an almost certain death. This kind of contradiction is one that is embedded within agricultural research environments – a complex engagement with necropolitics, a negotiation about life and death (Green, 2015). While it would require a longer, more in-depth study to be able to generalise about these observations, the experience of interviewing scientists about their relationships with the non-humans they work with opened up questions about the socio-ecological relationships at play, and how they shift within agricultural R&D.

a b

FIGURE 7.6: Photographs taken at the ARC showing (a) hatched stem borer larvae, and (b) stem borer larvae feeding on Bt maize stems as part of an experiment. Source: Maya Marshak.

7.4. GMOs and ecological skilling in maize research and development

> When GM products are developed within a framework that ensures their sustainability, they can effectively address social, environmental and technical challenges associated with biological systems… The unique potential benefits of GM technology [are]

> especially important in the face of climate change and the challenge of feeding a growing population using limited natural resources (Biosafety South Africa, 2019)

As the above excerpt reveals, biotechnology is generally presented by its proponents in the R&D community in South Africa as an innovative technology that has great potential for improving the management of ecological systems, especially in the face of climate uncertainties and population growth. As Stone (2007) illustrates, biotechnology companies emphasise the skilling component associated with biotechnologies – that they provide new methods of farming that farmers will eagerly adopt to improve the performance of their crops.

This section takes a deeper look at the skilling narrative that emerged during interviews with actors within the maize R&D system. This so-called 'skilling' suggests that GMOs have in fact contributed to building the available skills and knowledge, by adding a new branch to maize R&D.

At the outset of this research I was interested in exploring how the commonly used GM traits in South Africa (Bt – stem borer resistant, and HT – herbicide-tolerant) had shifted the focus of researchers who, before the introduction of GM crops, had been working in a range of other ways to manage stem borers and weeds. A number of respondents found this idea to be overly simplistic. The idea that all branches of research may have been affected by GM seemed far-fetched for them, and in some cases offensive. As one scientist explained:

> In the science community, there is always a spectrum; there is never a straight yes or no to GMOs. I think that for a long time people in the science community have realised that those Bt genes are not going to last forever. They are going to break down sometime; even chemicals aren't going to be effective forever. So I think there is an understanding that IPM is the best way forward (Scientist/ researcher 1, 2019:Pretoria).

This scientist made the argument that agricultural science is not a homogenous system, and within it exists different opinions and therefore different research interests. Those scientists that understand that GM is not a quick fix have continued to investigate and develop alternative research and strategies all along. A weed scientist working at Plant Protection at the ARC, who described themself as 'pro GM', explained that while

GMOs were welcomed as an "environmentally friendly" tool, their group never saw them in "isolation" (Plant protection scientist 1, 2019: Potchefstroom). While attention had to be paid to this new technology, other research could not simply be abandoned:

> When GMOs came in, there was only another aspect added to the research. We have always looked for more environmentally friendly kinds of management systems and at the beginning it was for us another management tool that can be used. I think researchers as such didn't see it in isolation, we didn't change totally to GMO research; that was never our aim, so the normal things were still important, such as threshold values, economic and environmental aspects (Biocontrol scientist 1, 2017: Roodeplaat).

Interestingly, of all of the scientists interviewed, many of whom were not opposed to GMOs, most did not see GMOs as a holistic solution, rather making reference to them as a useful 'tool' within a wider approach:

> The truth is Bt maize cannot stand alone to control insect pests, and why I am saying that is first you have your target insects that you can control but what about the rest of the species that are not being controlled? So, if I'm a farmer, I still have to think about the insects that may harm the plants when they are seedlings that are not stem borers. There is always a need to do research not thinking about GM, so there will always be other research because there are other insects (Entomologist 2, 2019: Potchefstroom).

Some respondents spoke of how, while GMOs have been popular in South Africa, there has been and will always be a need for non-GM products. One seed company representative spoke of there being a need for non-GM maize to export to the European Union countries for the production of baby food, or for companies such as SA Breweries who do not use GM maize in their products (Agronomist 5, 2019: Skype; Entomologist 2, 2019: Potchefstroom).

Respondents also noted that since the development of Bt resistance by stem borers (first reported by van Rensburg [2007]), and by weeds to glyphosate, there was widespread recognition that it would not make economic sense to rely solely on GM traits:

> If resistance happens for Bt maize then you have to fall back on other research to keep the resistant insect below economic threshold levels. So when I talk to anyone I will always say IPM is the answer, and GM crops fit into that. You cannot rely only on one product to have the answer to everything. So yes, I think GM has driven research but it is research that is needed. The rest of the research didn't stand still because of GM – both are needed for food security. We cannot say GM, GM, GM and there are other non-target insects. There will always be other problems and it is just a matter of time. You can use a GM crop like Bt maize or if you don't want to use GM you can spray insecticide, but with both resistance can happen. Insects can develop resistance to insecticides as well, and if you have a problem with an insect developing resistance to an insecticide you could plant Bt maize to overcome that problem or the other way around too (Entomologist 2, 2019: Potchefstroom).

This scientist went on to explain that it is short-sighted to rely only on one option such as GM seed and "think that it's going to last forever" (Entomologist 2, 2019: Potchefstroom). They reiterated that in order to "look after the technology", more research must be conducted, in order to understand if resistance is developing and, if so, what can be done about it to prevent its spread and keep it localised (Entomologist 2, 2019: Potchefstroom) The idea that the only problem with GMOs was human error was also a common theme in the interviews, often linked to the idea that it is a valuable tool that needs to be safeguarded:

> I think it is unnecessary that so many people are so worried about GM. It's another IPM tool in an integrated system. It's a very valuable tool and we don't want to lose it, so it has to be managed well or we could lose it (Biocontrol scientist 1, 2017: Roodeplaat).

As described above, the introduction of GMOs into South African research systems certainly added weight to the amount of research that needed to be carried out. There was now the need for capacity to do the necessary studies to ensure the management of this technology in real agricultural systems. This involved doing trials, conducting impact assessments and studying questions such as how to curb the inevitable resistance to GM traits. One might assume that this reduced capacity for other kinds of research, making funding scarce, given government and corporate interest in this new technology. However, several respondents did not believe this to be the case. One even felt that more funding was available for research but then pointed out that this was due to the interest in this new technology. In their opinion, while some scientists broke away to study GMOs, others continued in their original research interests:

> I didn't find that there was less funding available. There were more funding opportunities because everyone was curious about if GM was a new solution, and if it could be a cure for all our problems. In the beginning of such a new technology there is always scepticism. I mean, I think we were very positive from the beginning but you must demand that you must be very objective in your research, not to be 'pro' a thing before you really have studied it. So we did a lot of studies for private companies, impact assessments and testing the GM technologies. I don't think this took current capacity and refocused it, but added capacity. Some people broke away from the normal, old threshold studies and focused more on GMs, but I think all over it was a new aspect, like any new technology such as a new chemicals, it won't take all the focus of your research (Plant protection specialist 1, 2019: Potchfestroom).

This section has presented the argument of some scientists and agricultural researchers that GM seed technologies have not contributed significantly to a process of ecological deskilling within the R&D system, but rather added a set of new skills. While some of these scientists acknowledged that there may have been a time in which GMOs off-set more ecological-based research, most argued that scientists have always been aware of the dangers of relying solely on one technology. For this reason they argue that research was not lost and that in fact GMOs added a new set of skills to the field. This view was strongly opposed by one entomologist, arguing that while GMOs are another tool that can be used to deal with stem borer pests, they do not necessarily add skills as "one does not need to know new skills" to use GM maize (a product bought ready to use); rather, one needs less of the skills they had relied on before (Entomologist, 7, 2020: Zoom).

In the context of this study, these contrasting narratives are important. They point to the diversity of viewpoints within the maize R&D space, beyond the commonly held notion that scientists and practitioners hold a dichotomous, pro- versus anti-GMO stance. While the research presented thus far shows that Bt maize has not destroyed more integrated research altogether, it has had a significant impact on the R&D system. The following section presents a third narrative, that of ecological reskilling. This third narrative emerged in the last two years of fieldwork in which a renewed interest or changing orientation towards more ecologically focused research in maize R&D was noticed. The FAW has shown up as a protagonist in this story, illustrating the importance of deep, slow studies grounded in real time and space.

7.5. GMOs and reskilling in maize R&D

7.5.1 The FAW: a harbinger of the consequences of a loss of ecological-based research

In early 2017 I walked into the ARC-GCI in Potchefstroom. I was greeted by piles of decaying maize leaves on the usually clean surfaces of the laboratory benches in the maize research unit. Here, scientists and technicians were working on the latest biosecurity threat that had emerged in the world of maize agriculture – the fall armyworm (FAW) (See Figures 7.7(a) and 7.7(b)).

Bt maize was shown to be resistant to the FAW, and while this was a great relief for many, there was also a consensus among respondents that there was no room for complacency. Resistance to Bt traits had already developed in South America (the native habitat of the FAW) (Storer et al., 2012; Huang et al., 2014; Omoto et al., 2016) and it was understood that it would be only a matter of time before this insect developed resistance in Africa (assuming the resistance trait had not already crossed the ocean with the stowaway insect). There was thus a growing sentiment that a great deal of effort would need to go into IPM-type studies geared towards understanding the spread and behaviour of this new pest.

In 2017 Cropwatch Africa, along with the ARC, the former Department of Agriculture, Forestry and Fisheries (DAFF)[15] and North West University (NWU), set up moth traps for the first time in decades to help better detect and understand the distribution and behaviour of the FAW. This time, pheromone instead of light traps were used, as this was more cost effective, but the aim of the study was to do exactly what had been

[15] This department was reconfigured. The agriculture function of DAFF became part of the new Department of Agriculture, Land Reform and Rural Development, while the forestry and fisheries functions became part of the Department of Environment, Forestry and Fisheries (confirm dates.

done years before with stem borers – to try to understand their distribution, behaviour and lifecycle in relation to the South African environment.

a b

FIGURE 7.7(a): Detritus left by fall armyworm having eaten maize stalks as part of an experiment. Source: Maya Marshak, 2017. FIGURE 7.6(b): The fall armyworm. Source: South African National Biodiversity Institute.

A 2019 study by Harrison et al. warned against purely promoting the use of chemical inputs and relying on Bt traits to combat the threat of the FAW, both of which could lead to resistance developing in the pest. Instead, they suggested the use of agroecological approaches together with crop breeding for resistance, classical biological control, and the selective use of pesticides. This study points to a shift in what was happening within the R&D space; there was a growing acknowledgement from stakeholders in the R&D sector that more integrated methods needed to be developed as opposed to generic solutions to growing maize, such as a pure reliance on GMOs. One agronomist now working for a private seed company suggested that there might have been a time when GMOs had absorbed the research capacity, but that had changed because people began to realise that GMOs did not have all the answers. They explained that in the early 2000s, there had been a shift in public plant protection research because of the influence of private seed companies who were beginning to "take over" (Agronomist 5, 2019:Skype); scientists at the ARC at that time took on research related to GMOs for private seed companies (Agronomist 5, 2019). In their opinion, the problems associated with GMOs and the fact that consumers were not receiving GMOs as well as was hoped meant that there was a growing recognition that they could not be solely relied upon. They explained:

> I have been working with GMOs for 19 years and I am a proponent of GMOs but recently, especially this year in 2019, I don't see their future. It's my feeling, looking at [weed and pest] resistance that it is winning… we cannot force the consumers to consume what they don't want. We understand from the farmers' side that it is beneficial for the management of your crop and to produce good yields and feed humankind, but at the same time when you look at the resistance to GMOs… companies are going to withdraw from GMOs… Remember, GMOs have been in SA for the past 20 years or so, but our neighbours still don't want it… If tomorrow we said 'no GMOs', then what would happen? We would need other methods (Agronomist, 2019:Pretoria).

Interviews pointed to a growing realisation of the need to fill the "void" of more integrated knowledge and research that had formed over the last few decades (Entomologist 7, 2020:Zoom). One entomologist, who expressed the opinion that GMOs had slowed down the development of more eco-friendly pesticides, explained how they had witnessed 'a shift' (Entomologist 7, 2020:Zoom) towards finding alternative solutions over the last two years, due to a growing recognition of pest resistance to GMOs internationally. They felt that there was a renewed interest in more integrated maize research in recent years. Furthermore, they explained how, over the last few years, they had realised "the size of the gap" in research, and that before he hadn't been as aware of just how large a "vacuum had formed over the last two decades and the amount of reskilling that is needed" as a result (Entomologist 7, 2020:Zoom). They explained:

> It is going to take a lot of work to get back to what I think they [scientists and farmers] knew about ecology and pests and weeds and maize 20 or 30 years ago (Entomologist, 7, 2020: Zoom).

In addition to the lost knowledge from the reliance on GMOs, there was also a recognition that climates are changing and agroecological systems, including plants, soil qualities, microbiota and insect populations, have changed drastically, due to industrial farming methods. There is therefore a need for not just a reconnection with more relational research methods that have been displaced but for research to be "rebuilt", and that requires time and careful study with the cooperation of both scientists and farmers (Entomologist 7, 2020:Zoom).

7.6. Conclusion

Through the use of a multispecies lens alongside the concepts of ecological skilling, deskilling and reskilling in agriculture this chapter explored how the introduction of GMOs has shifted agroecological knowledge within maize R&D institutions in South Africa. Based on interviews with stakeholders within the R&D system and maize scientists working in various areas of maize research, specifically those with a focus on stem borer and weed management, alongside the use of in-depth literature reviews on maize research in South Africa, this chapter presented a diversity of views and varying narratives. The different narratives that emerged in the research have been given their own space inspired by the theoretical traditions that work to offset dualist approaches. Discussions of modern vs traditional, large-scale vs small-scale, scientist vs farmer, and pro-GMO vs anti GMO views tend to remove the space for finding unanticipated overlaps and disjunctures between narratives.

The chapter has shown that although GMOs may not have diverted ecologically focused research altogether, they have had significant impacts on drawing attention away from important, long-term research projects that had previously been a vital part of scientists coming to understand and work with agroecological systems. Some scientists have argued that GMOs in fact contribute to a skilling process, as they provide a new tool for controlling stem borers and weeds. Viewing these narratives side by side rather than dismissing one or the other allows new questions to emerge about how these complex modified organisms influence the world of research and mediate social-ecological relationships and knowledge making.

It could be argued that by their very 'nature', GMOs do not foster agroecological knowledge; instead, their invisible traits foster a tendency to disconnect from knowledge related to agroecosystems, as this knowledge becomes less relevant. Having said this, there has been a renewed interest in a process of ecological reskilling within maize R&D in recent years, precipitated by a complex interaction of factors, including the growing awareness of the global environmental crisis, a realisation that GMOs cannot offer a silver bullet solution, an awareness of GMOs' many accompanying risks (such as weed and pest resistance), and the recent FAW crisis. In this way GMOs can perhaps be seen as protagonists for rethinking dualism.

The maize R&D system in South Africa is still very much cemented within a dualist industrial paradigm. Even scientists who wish to approach their work with ecological awareness find themselves having to work towards the 'reason' of industrial agriculture, thereby always having to put profitability and production first. However, as the interviews indicate, there is a sense that change is afoot and a search for multiple ways of knowing and multiple truths can be useful in looking for pathways forward.

FIGURE 8.1: A composite image of pinned stem borer moths photographed at the ARC Grain Crops Institute by the author and a found image of brown veined butterflies. Source: Get Local.africa. Available from: https://getlocal.co.za/blog/wonder-of-migrating-butterflies.

8. CHAPTER EIGHT: Discussion - Modern Seed Technologies, the Unravelling of Place-based Knowledge, and the Need for Decolonial Approaches to Nurture Relational Knowledge in Agriculture

It's an autumn day in KwaZulu Natal on a smallholder farm where a diversity of crops are grown, including traditional maize for subsistence use and for local sale. There are strings of white butterflies flying overhead and these have been present on all our days here. When we asked some of the farmers about them, we were told that they signaled a "bad crop to come". These butterflies indicated the possible onset of a stem borer infestation (Field note entry, KwaZulu Natal, April 2016).

On returning from KZN, I mentioned to an entomologist specialising in maize how farmers had explained a connection between the white butterflies and the inset of stemborer. entomologist who had worked on maize about the white butterflies and how the farmers associated them with the onset of stem borer. He thought about it and then suggested that to link the white butterflies with the arrival of the stem borer was perhaps a "half-truth". He said that it was not the butterflies that laid the eggs that developed into the stem borers but rather a small brown moth. However, these two species, the butterfly and the moth, hatched at about the same time of year and as such the butterfly in a sense signaled the time of year and conditions that sustained the borer. He suggested that while the butterflies fly by day and the moths by night, farmers often see the butterflies while less frequently encounter the moths who come out under the cover of darkness. This experience got me thinking about matters of "truth" and hierarchies of knowledge (Field note entry, Cape Town, May 2016).

8.1. Introduction

Social-ecological systems can be understood as coming into being through 'coevolution between their social and ecological components' (Gual and Norgaard, 2008:1). As Gual and Norgaard (2008:1) explain, the social and natural sciences "have ignored the existence of interlinked/interdependent evolutionary processes between cultural and biotic systems", embedded in the biophysical environment. Until recently in research, the impacts of modern maize seed technologies on diverse social-ecological knowledges have not been widely explored, with social and environmental concerns commonly studied separately. This reflects a human versus nature dualism embedded within the dominant industrial agricultural paradigm (Norgard, 1984; Goodman, 2001). To contribute to broadening this discussion, this thesis has focused on the ways in which modern maize seed (GMOs, conventional hybrids and their co-technologies) have affected social-ecological knowledge and relationships in two sites in South Africa: smallholder maize farms in northern KwaZulu-Natal and research and development (R&D) institutions.

Smallholder farming and R&D, which in South Africa have a history of tension due to their polarisation, are rarely researched simultaneously. While Chapters 5 and 7 present the findings on smallholder farms and in R&D spaces separately, the broader intention of this thesis is to move beyond this dualism to explore the changing relationships around seed technologies within and also between these sites. This is important firstly because these spaces cannot be seen as static and bounded spaces of knowledge creation; and secondly because of historic polarisations in the way knowledge has come to be understood. Working between these spaces enables more dialogue and supports the dismantling of these dualisms.

The first section of this chapter brings the findings in Chapters 5 and 7 together, to discuss changes relating to ecologically based knowledge in both spaces, as well as the relationships concerning the politics of knowledge between these two sites. Drawing on Science and Technology Studies (STS), this thesis regards seeds not as inert objects but as powerful political actors fashioned within a particular world view (Asdal, Brenna & Ingunn Moser, 2007; Harding, 2009). These entities have the power to shift socio-ecological realities into which they enter, bringing with them the power to shape reality (Asdal, Brenna & Moser, 2007; Harding, 2008). This chapter suggests that modern maize seed technologies perpetuate a dualistic ontology rooted in modernism and enforced through colonialism and capitalism that has contributed to a loss of relational knowledge and skills among farmers, and which has also increasingly narrowed the social-ecological work of agricultural scientists. Furthermore, modern seed technologies can perpetuate a dualistic relationship of coloniality between smallholder farming and R&D that has historically marginalised Indigenous knowledge and continues to treat smallholders as passive recipients of knowledge rather than as co-creators of place-based knowledge.

Drawing on decolonial literature, the second section of this discussion considers how to restore and foster relational knowledge by de-centering the hegemony of modernist agricultural science (from which modern seed comes) and bringing in knowledge from the margins (both that of farmers and of scientists working relationally). It considers how this theory could inform efforts to work beyond binary thinking, in order to rebuild and foster fractured relational knowledge so as to create more resilient and socially and ecologically just pathways in agriculture. Given the growing presence and consolidation of modern seed corporations and the expansion of the use of GM seed in the Global South, it is argued that it is important to focus on how the technification of seed can deeply impact agroecological knowledge and socio-ecological relationships. This can be an important consideration towards fostering agricultural resilience and offering alternative pathways to the current dominant model based on limitless growth.

8.2. Ecological deskilling and reskilling on farms and in R&D: parallels and contrasts

Stone (2007) refers to the process of ongoing cumulative skill development in relation to changing context as 'agricultural skilling'. As ecological environments are not static, place-based knowledge requires constant learning and engagement over time. Within this process, humans and ecological systems coevolve and ecological knowledge becomes embedded in practice and place (Gual and Norgaard, 2008).

Contrastingly, conventional hybrid seeds have brought about a significant disruption of farmers' own skill development. This has been described as a process of "agricultural deskilling" (Fizgerald, 1993). GMO seed technologies essentially add the genetically modified trait to a hybrid-bred seed. In this way, GMOs bring a new set of characteristics to that hybrid, thereby opening up new avenues for agricultural change. By exploring the relationship between GM cotton seed and farmer deskilling in India, Stone (2007, 2011) suggests that GMOs, in their addition of a new set of complexity and traits to the seeds available, have exacerbated the deskilling process set in motion by commercial hybrids (Stone, 2007). The scientific breeding of hybrid seed transfers the process of knowledge generation from farmers to scientists. GM manipulation has allowed scientific control over seed to an even greater extent. With technological traits being embedded in the seed itself, this seed acts even more independently, in a sense diminishing the need for people to understand the relationships between the seed and the environment.

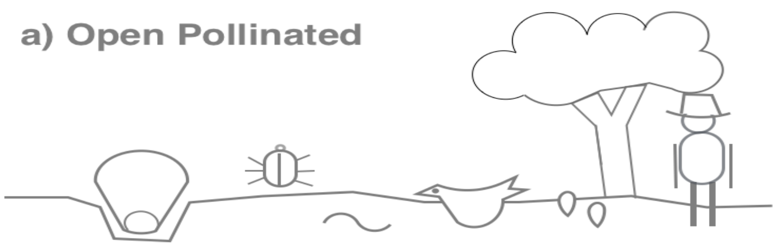
The term 'agricultural ecological deskilling' is used in this thesis to denote the disruption of the coevolutionary generation of knowledge and practice between humans (farmers and scientists) and agroecosystems. This concept incorporates a coevolutionary approach with the concept of deskilling to bring in a posthumanist lens in which human action is not central but rather part of a dialogue with the more-than-human world (Fitzgerald, 1993; Stone, 2007; Gual and Norgaard, 2008).

The research on smallholder farms and in R&D both reveal themes of ecological deskilling in relation to the ongoing modernisation of seed. On smallholder farms where farmers have grown open pollinated maize for hundreds of years, the modernisation of or changes in seed includes the introduction of conventional hybrids and, more recently, GMOs. Scientific maize breeding began with the breeding of open pollinated seed but developed and changed significantly due to the breeding of conventional hybrids. Furthermore, GMOs have since the 1990s offered the latest technological shift in seed breeding and research. While the experiences of farmers and scientists are very different, examining their experiences side by side reveals a wider and more collective process of ecological deskilling in maize agriculture associated with the modernisation of seed and changes in the generation of knowledge surrounding it.

Chapter 5 described the process of ecological deskilling on farms through three interrelated dimensions: 1) the loss of ecologically based practices; 2) the disruption of relational knowledge; and, 3) the loss of socio-ecological agency. In R&D sites, ecological deskilling was seen in: 1) the displacement of relational and ecologically based research and knowledge, and 2) the loss of agency to be able to do ecologically based research. Figure 8.2 (a, b and c) provide a summary of the processes of ecological deskilling in both sites.

The following section discusses similarities in the processes of agricultural deskilling on farms and in R&D under the following two themes: 1) the loss and disruption of ecological place-based knowledge and practices, and 2) the loss of ecological agency. In addition, a parallel yet less obvious theme of 'ecological reskilling', whereby farmers or scientists are working to reclaim relational knowledge, was noted in both sites and is discussed later in this chapter.

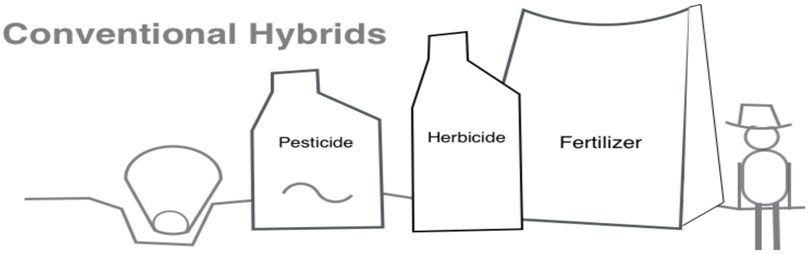
TABLE 8.1 (a), (b), (c): These tables illustrate the processes of ecological deskilling on smallholder farms and in maize R&D alongside the introduction of open pollinated, hybrid and GM seed respectively over time.



Smallholder Farmers	**R&D Institutions**
OPV maize varieties are adopted by farmers before the colonial settlement and integrated into agroecological smallholder farming systems in SA. Seed adapted to context over time as farmers choose favorable traits and it evolves in relation to the more than human ecology The growth of seed is reliant on the relationship of that seed to the argoecosystem and farmers ' relational knowledge of it Seed is embedded in social-cultural practices, it is more than a commodity, it is valued for its taste and nutrient density and cultural value Seeds such as maize are often grown intercropped with other complimentary crops - these compliment growth and provide a balanced diet as well as security against harvest loss of any particular crop. They also provide food at different times Farmers have agency to plant and grow their own seed	During the late 1800s, maize was recognised by colonial farmers and scientists as having the potential to be a crop of great commercial success in South Africa. There was an interest in boosting yields as American farmers were doing. Farmers and scientists were interested in developing genetically homogenous (open pollinated varieties that were high yielding and standard in appearance for easy milling. In the early 1900s seed breeding began with OPVs. Using varieties from around the world, including SA, they tested a wide variety of seed for the South African context. In the early 1900s commercial farmers partook in government breeding competitions where certain favored traits such especially yield and uniformity. Farmers were assisted in learning breeding techniques, a relationship existed between commercial farmers and scientists

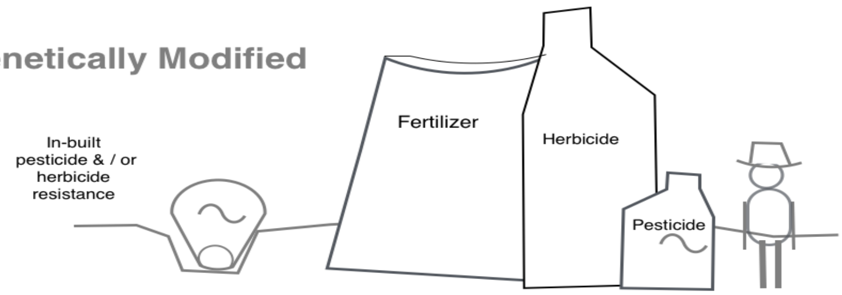
and are not reliant on outside inputs or knowledge Knowledge is passed down generationally and adapted overtime to social-ecological context that is ever changing	Research and development, including breeding was carried out predominantly by government scientists at dedicated research stations. Some small seed companies emerged

b) Conventional Hybrids



Smallholder Farmers	R&D Institutions
Smallholders growing hybrid seed over time may no longer save traditional or open pollinated varieties this may lead to loss of seed saving skills and loss of farmers varieties that were adapted to their context. As farmers adopt co-technologies of hybrid seed including pesticides, fertilizers and herbicides, former methods for dealings with weeds, pests and soil fertility may be lost. As farmers adopt hybrids, specific knowledge related to their own saved varieties is displaced With the use of hybrids and associated inputs some place based practices fall away and mono cropping becomes more common, there is a breakdown in the relationality of Indigenous farming systems. Intergenerational agroecological knowledge is passed down less and less leading to loss of generational agricultural memory While IPM can be used alongside hybrid seed, most often smallholders are treated as recipients of knowledge rather than co-creators which is important for the development of IPM. The technology transfer process is often done through industrially motivated extension programs, via seed companies themselves, or agri dealers and the information on the packaging - these favor high input solutions, and do not value traditional methods which become displaced.	In 1925 the first hybrid seed breeding program is started in SA. Hybrid seed breeding and research is undertaken by government scientist. Farmers are not involved in hybrid breeding. 1937 - Marketing Act and Maize control Board subsidized and supported white cooperative farmers and increased the use of mechanization and inputs 1947 - MCB establish Hybrid Breeding program and maize seed becomes seen as a commodity. The commodification of seed is made possible through hybridization and this paves the way for the increasing privatization of research and influence of seed companies over research agendas Natal seed programme to develop maize hybrids initiated in 1947 1958 Pannar became the first private seed breeding company established. Over time private seed companies have taken over most of the breeding and less was done by government breeding programs. Hybrid seed is bred to be used alongside external inputs (fertilizers, pesticides and herbicides) yet place-based research is also considered vital for developing integrated approaches such as IPM and IWM are regarded as important as they can help reduce the amount of expensive chemicals.

c) Genetically Modified



Smallholder Farmers	R&D Institutions
Farmers receive seed from development programs or can purchase them when affordable from agridealers. This can lead to ad hoc procurement of seed over time, breaking down relationships with specific varieties It is not legal to recycle seed nor effective adding another level of disconnect from seed Embedded insect/ weed resistance further removes need to understand insect / weed behaviour and how to manage them using alternative methods. Farmers are often unaware of the difference between GM & Hybrid seed - further alienating farmers from their seed choices and making seed choice more complex The use of GM can interfere with relational place-based practices notably the use of intercropping and collection of wild edibles in fields as herbicides do not allow for this insect / weed resistance can change ecological systems potentially making IPM/ IWM less effective Farmers are treated as passive recipients of technological knowledge concerning the use of GMOs rather than co-creators of agroecological knowledge Smallholders have little access to alternative knowledge as extension services focus on technological solutions	When GM crops were approved for commercial release in 1998, GM traits developed outside of SA are added to hybrids broad geographical applicability and tested for efficacy in field trials locally. Government breeding has become very limited, most breeding is done by private seed companies and GM traits developed outside SA are added to hybrids and then tested. Conventional breeding becoming a rare skill & many young scientists choosing to focus on biotech, a loss of institutional memory. R&D capacity must go into studying the environmental risks such as on non target organisms and water bodies. Availability of funding for GM focused research and the necessity of conducting studies on heir impacts and efficacy means there is less funding for ecologically focused / place-based research$. Scientists find work funded by seed companies and related to GM research Long-term ecologically or place based research has in some cases stopped or is more difficult to fund given increasing reliance on quicker more generic options provided by GMOs and co-technologies. There may be a lock-in to industrial/ technology first research pathways Private seed companies are increasingly consolidated with agrochemical companies deepening relationships between seed and chemicals and the impetus for knowledge generation that supports this financially.

8.2.1. The loss and disruption of ecological place-based skills and knowledge and practices

Within smallholder farming systems, agricultural knowledge and skills have historically been generated through observations and coevolutionary interactions within ecosystems (Alitieri, 1984; Gual and Norgaard, 2008; van Dooren, 2012). This cumulative, living, place-based knowledge has been passed down via cultural practices through generations and adapted over time. This knowledge is not static; rather, it is an adaptive and responsive relationship affected by ecological, social, cultural, political, economic, ecological and technological changes. This knowledge is a relational system, always in motion and guided by the limitations and possibilities of context and more-than-human actors (Norgaard, 1984; Muir; 2010). Contrastingly, as smallholder farmers began to adopt modern seed varieties, they came to rely increasingly on the prescribed knowledge associated with growing that seed. This prescribed knowledge is communicated through extension services, agri dealers, and on the product packaging of seed. It is designed to be as generic and widely applicable as possible; consequently, it is not grounded in biocultural context (Kloppenberg, 1988). Over time, the development of scientifically bred seed has resulted in the generation of seed and the knowledge thereof beyond the context of agroecosystems and the place-based knowledge of farmers through which agricultural practice has traditionally come into being.

Within the R&D environment, as within smallholder farming, the generation of agricultural skills and knowledge has historically relied on cumulative observation and skill development through long-term studies and learnings passed on by researchers and institutions over time. Agricultural science is like any knowledge system – ever changing, in relation to social, cultural, political, economic, ecological and technological changes. The research in this thesis showed how, during the colonial and apartheid period in South Africa, a large amount of R&D capacity was dedicated to what may be termed place-based or ecologically engaged research. This research involved pathologists, soil scientists, agronomists and other scientists who worked together to find patterns in ecological systems that could help boost maize yields and better control agroecosystems. Scientists actively engaged with commercial farmers to transfer the skills and knowledge developed through research. The development of hybrid seed was therefore accompanied by the concurrent development of place-based agroecological knowledge.

Due to the development of hybrid seed and its co-technologies, and the concurrent shifts in the agenda and location of R&D (increasingly within laboratories), the necessity for scientists to understand specific, local agroecosystems has decreased. Breeding, which is increasingly being undertaken by private companies, has focused on designing seed that can be utilised across wide geographical contexts rather than on locally adapted traits (Tripp & Derek Byerlee, 2000). This approach is commercially favourable, as seed can therefore be produced on a mass scale for a wide market (Tripp and Byerlee, 2000). Commercial seed is reliant on a web of external inputs, such as fertilisers and chemical inputs, for its survival, rather than on agroecological relationships. Fertilisers help to adjust the soil to suit the needs of the seed, while chemical inputs are designed to target specific, widely problematic pests, or to function as broad-spectrum technologies that can work for multiple species and thus locations. This not only supports the growth of that seed in a wider range of environments, as the inputs mould the environment to the seed; it also has commercial value. It ensures that seed companies are not only able to sell seed but also the package of inputs associated with it, thus increasing their profits and market base. The ability of these technologies to control environmental factors is significant in terms of its impacts on socio-ecological knowledge. The findings suggest that the increasing modernist tendency to control the environment for the survival of one type of seed and monocrop, and the growing efficiency of technologies in doing this, has reduced the urgency or need for place-based, long-term, cumulative research. In this way, the ongoing modernisation of seed and its co-technologies has crucially shifted the relationship between agricultural research and agroecosystems over time. As seed and its inputs have become more generic and widely applicable, there is less need for scientists to test those seeds or adapt them to specific agroecosystems. Research and knowledge production can thus be carried out in a way that is removed entirely from the contexts in which it will be used or in partnership with those that will use it. It becomes disseminated in a unidirectional way to farmers.

The technification of seed has also greatly altered knowledge generation by facilitating a shift in the location of knowledge generation, not only from actual agricultural environments but from the realm of public research to the private arena. Developments in seed technology such as hybridisation and genetic modification have resulted in seed becoming commodifiable in ways that they were not previously. GM seed technologies are hybrid seed technologies with the addition of a genetically modified trait to a hybrid-bred seed. The shift from hybrids to GM seed marks a significant shift in the technification of seed and the politics of knowledge production surrounding it.

While public breeding and the associated research was initially carried out in the public sector, the ability to commercialise seed through patents and property rights has increasingly attracted attention from the private sector (Tripp and Byerlee, 2000). As seed becomes increasingly commercial and more research is carried out by private companies, less agricultural research is done within public research institutions (Tripp and Byerlee, 2000; Buhler et al. 2002). Historically public research in South Africa and beyond had stronger relationships with farmers and was directed primarily by their needs. However, as seed has become more of a commodity, research is increasingly guided by economic incentives (Buhler et al. 2002; Tripp and Byerlee, 2000). The growing monopoly of private companies over seed has had implications for the politics of knowledge production.

Looking at smallholder maize farming and maize R&D collectively, one is able to see commonalities in how both farmers and scientists are losing relational knowledge and practices based on long-term, place-based observations and work in specific agroecosystems. In both spaces, the growing reliance on increasingly generic seed and chemical applications and inputs means that direct understanding of ecological systems becomes less important for the success of maize yields and, as a result, this place-based knowledge is being displaced.

8.2.2. A loss of ecological agency

The findings revealed a theme of loss of agency in both spaces associated with the use of commercial seeds and their co-technologies. For thousands of years, agroecological knowledge and relationships have allowed smallholder farmers around the world to grow food autonomously by seed-saving and using locally and cyclically available inputs (Kloppenberg, 1988; Mascarenhas and Busch, 2006). However, as farmers became more reliant on generic seed and its co-technologies, they have become dependent on the knowledge associated with it, leading to farmers becoming 'locked in' to buying corporate seed and farming using industrial methods (Mascarenhas and Busch, 2006; Hu and Rahman, 2016).

In their study on pesticide dependence in rural China, Hu and Rahman (2016) argue that agricultural technologies, including hybrid seed (rice) and its associated modern farming techniques, work together to create dependence on pesticides. Here they draw attention to how the use of one technology causes farmers to become locked in to using associated technologies and agricultural techniques or methods, unable to use methods they had once used. In the case of pesticides, once they are used by a farmer or in a specific region, it is difficult for farmers to stop using them, because they cause ecological imbalances in insect populations and diversity. This is particularly the case where neighbouring farmers use pesticides, leaving those farmers who are not use pesticides vulnerable to infestations (Wyckhuys, 2007). This can also occur from the use of broad-spectrum herbicides, such as glyphosate alongside hybrid and GM seed, which can lead to weeds becoming unmanageable without herbicide use (Powles, 2008; Pieterse, 2010) In this way modern agricultural technologies become built into ways of farming.

Hu and Rahman (2016) explain how pesticides can become built into farming systems as social structures change. In the area of rural China in which they worked, they noted that mainly women and the elderly work in agriculture, due to rural–urban migration and changing livelihoods. This has required the use of less labour intensive methods and crops supporting the use of monocrops and their associated chemical inputs. Similar evidence was found in this study's field research in Pongola, where today mainly women and the elderly are left to farm, while other family members seek to diversify their livelihoods through other types of work. The lack of assistance on farms with tasks such as weeding makes the use of modern seed and associated herbicides attractive to smallholders; those using them remarked that to not use them now seems difficult. In this way, these technologies become embedded in modern livelihoods, making the use of alternatives difficult to do or imagine.

As Cowan and Gunby (1996) show, the success of the rollout of agrochemicals and the relative lack of evidence for the success of alternatives makes it difficult for farmers to imagine taking a different route, even if they desire to or understand the drawbacks of using chemicals. Alternatives such as integrated pest management (IPM), which can reduce chemical use and integrate local knowledge, can be extremely valuable for smallholders, yet smallholders are rarely able to access them as the extension service tends towards the transfer of industrial methodologies (Cowan and Gunby, 1996; Wyckhuys, 2007). The research revealed that in South Africa, IPM became a flourishing field of public research from the 1970s to 1990s (see Chapters 6 and 7) when scientists worked with commercial farmers to significantly reduce the use of pesticides. However, after the transition to democracy the capacity of this research was greatly reduced, due to the trend towards privatising research and the concurrent focus on using chemical inputs rather than knowledge inputs. As a result, when smallholders finally became recipients of extension support in the democratic transition, they received information on how to grow hybrid and GM seed with the use of chemical inputs rather than knowledge concerning more integrated methods.

Within current development approaches, chemical solutions are often put forward as more effective and efficient for boosting crop yield. While integrated methods may in the long term be more sustainable, their development is context-specific; they are research and "knowledge intensive" and require the involvement of scientists and farmers to develop skills (Cowan and Gunby, 1996:524). As a result, many smallholders come to rely on chemical use and less on methods they may have once used, thus contributing to a process of ecological deskilling. The findings suggested that, as farmers experience ecological deskilling, there is a risk that they are not only less able to remember traditional practices or pass them on to the next generation but are also less likely to believe in their own ability to develop alternative strategies within their own unique context. This can lead to a lock-in of chemically and technologically intensive solutions based on industrial models of production (Cowan and Gunby, 1996; Hu and Rahman, 2015). If sustained through time, this is likely to close the door to alternative pathways for agricultural crop production that support biological diversity, and which are adapted to local conditions and needs.

Additionally, the findings suggest that, as farmers become reliant or locked-in to the use of industrial farming methods that support modern seed, that there might be a process of ontological lock-in at play. This could refer to a process in which farmers might come to view their 'old' ways as irrelevant or inefficient as seed company representatives, agricultural suppliers and extension services sell the newer technologies as better, and more efficient and productive. This was apparent in the interviews with smallholder farmers in which they claimed that their 'old' seed was less productive than commercial seed. They described commercial seed as 'better' because it produced bigger yields. Farmers often cited yield as the most important measure of value when choosing commercial seed, rather than a more ecological view of the value of various traits, such as taste of the variety, its tolerance to drought and ability to adapt to specific environmental and social contexts. Other studies with smallholder farmers in South Africa also show that farmers "considered grain yield as the most important trait for maize cultivar selection" (Abekmal, et al. 2013:159) with other factors such as maturation period and resistance to insects being ranked below this (Assefa & van den Berg, 2010).

As demonstrated by Assefa and van Den Berg (2010), farmers' reasons for adopting new seed technologies (GM, in the case of their study) are due to a variety of factors. They found that the factors stated by farmers for the choice of certain varieties are often not accurate concerning the actual traits of those varieties, or not unique to the stated variety (Assefa and van Den Berg, 2009). Seed companies encourage adoption through the dissemination of information supporting that technology, alongside other incentives (Assefa and van Den Berg, 2010). Perceptions of seed technologies are not always based on reliable information and are open to influence from expert advice. It was only when asked what the favourable qualities of traditional seed were that farmers began to recall them, pointing out their ability to withstand extreme heat or their superior taste and nutritious qualities (van Niekerk and Wynberg, 2017). Seed technologies are in no way neutral; they go into the world and perpetuate the dualist legacy and power systems in which they are fashioned, thus enforcing what Mignolo (2002) and other decolonial theorists refer to as 'coloniality', in which the legacies of the past are perpetuated in the systems of the present. The focus of modern agricultural science on yield and not on other priorities such as taste or local environmental adaptations means that a modernist way of ordering the world becomes embedded in the receiving agricultural systems.

The findings suggest that R&D institutions also experience a loss of agency through similar processes of lock-in to certain research and knowledge pathways in relation to the technification of seed. As discussed in Chapter 6, the technification of seed, through the development of hybrids and then GMOs, has shifted the research environment and its focus significantly. Since the 1990s there has been an increased pressure to restructure and reform agricultural research in developing countries, and privatisation is an "increasingly prominent feature of the policy advice directed at agricultural research in developing countries" (Tripp and Byerlee, 2000:1). This is true of the agricultural research system in South Africa which has over the last two decades been restructured significantly as public research budgets have been reduced and private seed and chemical companies have taken up greater amounts of research (Cronje, 2007). Within maize breeding and other maize research, this has been significant (Tripp and Byerlee, 2000). Given the reduced funding for public research, public institutions need to increasingly take on research that is profitable and makes commercial sense, often by selling products and research services to private companies or through public-private partnerships with seed agrochemical companies (Tripp and Derek Byerlee, 2000). This means that research is less likely to be independent of the commercial needs and interests of private companies.

As corporations influence the focus of research agendas, scientists can become locked into working on research related to corporate seed; as a result, there is a lower probability of finding work or funding for alternative research or research that is less obviously profitable and more experimental. The commercial framing of research can mean that research projects are expected to fit into shorter time frames, with less funding for longer-term research and less directly profitable outcomes.

Corporate research agendas are primarily guided by the pursuit of ever-increasing yield and profit. This is justified by the need to produce more and more food to improve food security and feed growing global populations. However, in the pursuit of this agenda, other priorities such as finding alternative, less chemical intensive farming methods are in danger of being sidelined. This can be seen in the introduction of agrochemicals after World War II that began to rapidly replace previous farming methods and knowledge (Cowan and Gunby, 1996). Consequently, scientists became involved in research related to the use of chemicals. In 1937, according to Cowan and Gunby (1996:254) "33% of the articles in the Journal of Economic Entomology dealt with the general biology of insects; 58% were devoted to testing pesticides. By 1947 these proportions were 17% and 76% respectively". This example demonstrates how a new agricultural technology can in a very short period completely shift research priorities and agendas.

Moreover, Cowan and Gunby (1996) illustrate how, while IPM research has the potential to be more sustainable in the long run, and thus more profitable for farmers as it reduces chemical inputs, the chemical approach pushed by agrochemical companies and encouraged through policy has overshadowed IPM research. IPM research requires a thorough process of "information gathering and processing" and "sources of inexpensive localised information can be crucial", requiring collaboration between farmers and scientists (Cowan and Gunby, 1996:527). Unfortunately, if funding does not allow, alternative technologies and research cannot be developed and the prioritised technology and research path can become entrenched over time (Cowan and Gunby, 1996).

The interviews conducted with scientists for this study suggested that the introduction of GM seed technologies similarly created a shift towards research concerned with GMOs and, consequently, a shift away from the important research concerned with alternative or integrated methods that had been undertaken before. The findings from these interviews suggest that it is becoming increasingly difficult to acquire funding for longer-term, place-based research in the current funding system within R&D. Current research focuses on the Hr and Bt traits of GM seed, given their arguable effectiveness, rendering other research less important and therefore less visible. As a result, important long-term cumulative public research has been sidelined and could be in danger of potentially being lost.

More often, several scientists find themselves working in shorter-term research projects often related to biotechnology, because that is where funding is available. Findings from this research point to the fact that less technology-centred skills, such as breeding and taxonomy, are becoming lost as fewer students choose to focus on these career pathways, instead of focusing on the potentials of biotechnology, which is also an area of research for which they are more likely to find funding. The lack of young scientists able to find work or funding in alternative, longer-term place-based research might over time lead to a process of institutional memory loss as researchers retire and new researchers fail to take their place. In this way, there is a lock-in process visible in R&D, too, where older knowledge becomes abandoned in place of newer research trends.

Similar to the ontological lock-in process visible on farms, there is also evidence within the R&D space that some scientists feel locked into the current dominant paradigm of doing research. As shown in Chapter 7, a number of scientists expressed disillusionment with how difficult it has become for them – almost impossible - to work in a sustainable way within the current industrial system that pushes for big yields, such as without the use of herbicides and inputs. While scientists may feel they are locked into industrial pathways, there is also an ontological lock-in process where a different future seems unimaginable, both because of a growing loss of institutional knowledge and because environments are changing at the same time. Cowen and Gunby (1996) noted a similar process whereby farmers felt "uncertain" about following alternative pathways as embodied by IPM, because of a perception that their effectiveness has not been widely proven, with most farmers choosing the certainty granted to them by the use of pesticides (529). As time goes on and alternative research is deprioritised, relationships of knowledge between scientists and agroecosystems are lost. This is furthered by the constant change of agroecosystems, due to technological impacts and climate change.

As scientists and farmers lose relational knowledge about agroecosystems, there is a growing reliance on technologies that transform the environment, making the agency to restore relational knowledge more and more improbable over time. In both spaces, over time there has been a growing tendency to work against nature, to control it and put it to work rather than to work relationally with it (Moore, 2015a). The histories and experiences of smallholder farmers and those of scientists are vastly different; however, if we look at these sites side by side, there is a common thread, one of a growing rift or unravelling of place-based knowledge, and a replacement of seed by generic ways of knowing and growing maize (Green; 2015; Moore, 2000, 2015a).

8.2.3. Ecological reskilling: towards a reclamation of relational knowledge on farms and in research and development

While the findings suggest that a process of ecological deskilling is unfolding both on farms and in R&D institutions in various ways, it also suggests that the technification of maize is not the sole contributor to ecological deskilling. To infer as much would be to tell a one-sided story that removes some agency from all the human and non-human actors involved. Furthermore, this line of thinking risks falling into the trap of telling a dualist account in which scientists and farmers and their knowledges are considered within static categories. This discussion suggests that modern seed technologies, and especially their most recent incarnation – GM seed have not only further disconnected people from agroecosystems, but have also ironically acted as protagonists for change in unexpected ways.

While relational knowledge and research continues to be marginalised in both sites, smallholder farmers and scientists are working towards more sustainable methods of farming by focusing on developing more relational knowledge and practices. This process is referred to in this thesis as ecological reskilling. It involves farmers, NGOs and scientists who recognise that ecological interconnections and human relationships with ecological systems are intrinsically valuable for the future of agricultural resilience and sustainability, but that this is being lost rapidly. These actors are therefore actively engaged in finding ways to reconnect and rebuild relational knowledge. For scientists, this manifests as a reclamation of integrated research and methodologies that have received less attention in recent decades, due to a reliance on generic approaches. It also includes a growing interest in ecological farming methods such as agroecology (Zuma-Netshiukhwi, Stigter & Walker, 2013; Harrison et al. 2019). At the University of KwaZulu-Natal researchers interviewed were working to incorporate a focus on traditional, relational methods of farming.

During the three years of field research for this study, scientists interviewed and some of those interviewed in follow up interviews within the R&D system demonstrated a growing interest in reclaiming relational ways of working. This was notable surrounding the fall armyworm invasion first detected in 2016. There was a concern among respondents about the potential of governments promoting the "indiscriminate use of chemical pesticides" as a response and the effects this could have on humans and ecosystem health. As a response Harrison et al, (2019) suggested the use of agro-ecological approaches and IPM strategies as a more sustainable way of tackling the outbreak (Harrison et al. 2019).

In Pongola, a growing number of smallholders are now involved with Biowatch South Africa, an NGO dedicated to reclaiming relationships with traditional seed and the lost knowledge of how to interact with place and the more-than human world. In the late 1990s, Biowatch began to mobilise against the release of GMOs in South Africa, and while they continue with this work, they now focus more on supporting alternative agricultural pathways through working to restore seed and knowledge systems disrupted by modern agricultural interventions. In this way, the fight against GM seed has mobilised a reclamation of relational knowledge.

Yet while the currents of reskilling are growing and there is an expanding awareness of what has been lost, along with an increasing effort to create research alternatives and alternatives to industrial farming, governmental and financial support for these pathways are still marginal in comparison to the scale of industrial farming and the resources being directed towards it, including research and knowledge generation. Modernist science and industrial pathways continue to be prioritised, resulting in the relegation of smallholder knowledge as 'non-scientific'. If this continues, in South Africa (and countries where similar trends are occurring), smallholder farmers' relational knowledge, as well as relational scientific work, risks becoming completely displaced. This is especially the case as agroecosystems become more degraded and out of balance, and socio-ecological relationships become undone.

The previous section argued that modern seed technologies have deeply affected relational knowledge in agriculture, as well as the agency of farmers and scientists to develop relational knowledge. The following section focuses on the importance of rethinking knowledge creation within maize agriculture by challenging modernist ontology through the recognition of its violent history and the marginalisation of other ways of knowing. Drawing on Boaventura de Sousa Santos (2016:70), this discussion suggests that to restore social and ecological wellbeing, "cognitive justice" must be restored. This requires a de-centring of modernist ontology in agricultural science and a reclaiming of knowledge from the margins (Mignolo, 2011; Rojas, 2015; Rosenow, 2019).

8.3. Maize R&D and the undermining of Indigenous relational farming knowledge in the past and the present

Since its emergence at the turn of the 20th century, maize R&D in South Africa has been entangled with the racist, segregationist ideology that underpinned colonial and, later, apartheid-era agriculture and land use (Greenberg, 2010). Within this ideology, and more widely colonial systems black smallholder agriculture has been labelled "backwards, inefficient, and unproductive" and compared to supposedly rational, Western, modernist agricultural science (Schnuur, 2019). This hierarchy of knowledge is common in colonial discourse throughout the Global South, and paints indigenous agricultural seed and farming practices as inferior, irrational, and disorderly (Eddens, 2019; Schnuur, 2019).

Postcolonial Science and Technology (PCSTS) scholars have shown how agricultural science (among other sciences), played a significant part in shaping colonial power and control over people and landscapes (Fanon, 1952; Harding 2001; Anderson, 2002; Raj, 2006; Tilley 2011; Biesel et al, 2013; Myers, 2017). When Europeans settled in South Africa, maize was already being grown by Indigenous farmers as part of diverse and flourishing cropping systems (Jeffreys 1954; Bundy, 1979; van Onselen, 1996). European settlers learned from Indigenous farmers how to grow food successfully, as they knew nothing of farming in the South African context (van Onselen, 1996). For this reason, they relied initially on sharecropping arrangements for the successful production of food (Bundy, 1979; Van Onselen, 1996). However, in time agricultural R&D and the development of agricultural technologies were used as instruments of power through which colonists came to control production and undermine the very Indigenous agricultural systems they once relied on (van Onselen, 1996).

Maize is a crop that found itself (or planted itself as McCann [2007] describes it, acknowledging the agency of maize itself) in the middle of this relationship of power. During apartheid, maize was central in maintaining white power and wealth, and maize

R&D received ample government funding as a result (Greenberg, 2015). Within this system, white commercial farmers became the sole recipients of the fruits of this R&D system, while black smallholder farmers, displaced from fertile agricultural land and confined to homeland areas where they were restricted from selling their produce, struggled to regain their former farming systems and success (McKinnon, 1999).

During the colonial period and into apartheid, scientists worked hands-on with white commercial farmers to find integrated ways of tackling challenges, such as pests and weeds, in their research within specific agroecosystems. Over time, and with the ongoing assistance of agricultural scientists, these commercial maize farmers developed a set of cumulative skills and understandings about the land on which they farmed. While this was informed by ideals of profit and "mastery over nature" (Moore, 2015a), achieving growing yields required hands-on, place-based research and a robust relationship between farmers, scientists and agroecosystems.

While historically the field of agricultural science around the world was closely linked to the work of commercial farmers, this began to change as agricultural corporations became more powerful within the R&D system, and inputs including seed and chemicals became more generic and package-based (Fitzgerald, 1993; Buhler et al, 2002). GM seed has furthered the corporatisation of knowledge by embedding the technology in the seed itself, making seed less reliant on the skills of those growing it and more on a formula. In this way, farmers – both commercial and smallholder – have increasingly become clients who buy both inputs and the knowledge associated with them from corporations and their own endemic and place-based knowledge has become less relevant within R&D as a consequence (Fitzgerald,1993; Vandeman, 1995).

In South Africa, the onset of democracy and the reopening of international trade coincided with the rise in power of the corporate seed industry and the subsequent reduction in public research funding (Liebenberg, 2013; Chaminuka et al., 2019). Public research, which formerly only served a minority of white farmers, now also needed to take into account and prioritise the needs of approximately four million black smallholder farmers (Aliber and Hart 2009; Greenberg, 2013). Smallholder farmers thus became connected to the R&D system that was opening up to neoliberal markets and increasing its ties with the global corporate seed industry. The support farmers received was thus embedded in the politics of neoliberalism and modernisation (Fitzgerald, 2003 Stone, 2017).

After South Africa's transition to democracy in 1994, maize continued to be a vital economic crop, and commercial maize agriculture was promoted as a tool through which to help reduce the inequality between white commercial agriculture and black smallholder agriculture Gouse, 2005; Fischer and Hajdu, 2015). South Africa became the first country in the world to approve GM seed as a staple crop to be grown by smallholder farmers when GM maize seed was introduced into South Africa just four years after the transition to democracy (Gouse, 2005). Development projects such as the Massive Food Production Program (MFPP) sought to disseminate modern maize seed, its co-technologies and modern farming knowledge to smallholders (Fischer and Hajdu, 2015). This seed was put forward as a way to boost smallholder production and access to markets with a view towards reducing poverty and inequality (Fischer and Hajdu, 2015). Smallholders in the democratic period have thus become the receivers of a unidirectional and often inappropriate transfer of knowledge by seed companies and governmental development projects (often public-private partnerships between governments and seed companies) (Fischer and Hadju, 2015).

The transfer of seed technologies often occurred in an ad-hoc manner whereby government-initiated projects and partnerships with seed companies came and went, leaving farmers unsure of exactly how to use these technologies or integrate them into their farming systems. The findings of this study confirmed accounts by other researchers that smallholder farmers are often unsure about the traits of new seed varieties, assuming they are better than those that came before but also unsure of how to differentiate between or use them (Fischer and Hajdu, 2015; Mahlase, 2017). Farmers were also often unsure about how to use the seed alongside chemical inputs or about the hazards of certain chemicals and how to use these according to the guidelines for their use. This process reflects what Stone (2007) saw happening in India where the constant turnover of cotton seed left farmers unsure about what varieties they were planting and how to use them appropriately.

Farmer development projects aim to bring smallholders into the commercial market by means of boosting yields with modern seed technologies and inputs. These projects tend to maintain a modernist approach, underpinning Green Revolution-type interventions. Their reliance on modern seed technologies and intensive inputs assumes the need to modernise smallholder systems in which smallholders are often treated as lacking in agricultural knowledge and experience merely because they are not producing high yields and generating large profits. In the process, the skills smallholders have used to keep farming throughout these challenges and with barely any financial or other support in the former dispensation are disregarded. This approach dismisses the knowledge and practices of farmers themselves, treating them instead as if their knowledge is outdated, if they have prior knowledge at all. In this way the modernist dualism embedded in the former colonial and apartheid dispensations persists into the current system through the use of modern seed technologies and the technology transfer process.

PCSTS theorists have worked to de-centre the objectivity of Eurocentric, modernist, science-based knowledge creation and its universal applicability (Harding, 2009; Bhambra, 2014). These theorists show how, if not questioned, technologies can contribute to perpetuating colonial relationships into present social and ecological landscapes (Bhambra, 2014, Seth, 2017). The findings of this research suggest the introduction of modern maize seed technologies has done just this, because these technologies are not neutral, but embedded in systems of power. These technologies effectively displace smallholder farming knowledge in favour of modernist approaches to farming based on dualism. While political systems and R&D have transformed in South Africa since the colonial period and apartheid, the history and hegemony of modernist agricultural science and its technologies remains largely unquestioned.

Where Indigenous agricultural knowledge is recognised, it is often approached as a potentially useful addition to current commercially driven farming systems, rather than acknowledged as a different system of knowledge that has the power to usefully question the ontological foundations of scientific practice itself (Rosenow, 2019; Muir, 2010). This can be seen in the growing interest in adding indigenous crops to industrial farming systems for climate change adaptation or the growing interest in genetically modifying these indigenous crops (Bosibori Bett, *et al*. 2017; Ndimba et al, 2017). Such approaches fail to decolonise knowledge and relationships of power; they keep a dualist ontology intact, treating Indigenous knowledge as a "static archive" or resource to be exploited rather than an alternative ontological approach (Muir, 2010: 259). As Green (2012:1) argues, the "bifurcation" of the way science and traditional knowledge are understood "does not facilitate the important discussions needed on intellectual heritage, or on the relationship between sciences and coloniality". This bifurcation impedes the dialogue needed to broaden our understandings of the world and future possibilities (Green, 2012; Rojas, 2016; Rosenow, 2019).

The modernist assumptions and systems of coloniality embedded in this transfer of seed, and its implications for knowledge and agriculture going forward, has not been widely investigated in South Africa. Within development discourses, smallholders are most often not treated as knowledge holders and makers themselves, but rather as passive recipients of knowledge. The effects of this transfer of technology on smallholder agricultural knowledge and practice is rarely questioned, as smallholder agriculture remains treated as inefficient and in need of being modernised within the current industrial paradigm supporting development projects in South Africa. Dualist relationships between the knowledge of science and farmers are embedded, while dualist relationships between humans and nature are enforced. As long as the relationships between seed and knowledge remain unquestioned, it is likely that the relational knowledge of farmers and scientists will continue to unravel in South Africa and throughout the continent, especially as the Green Revolution for Africa (often termed the Gene Revolution for Africa) continues to gather momentum (Schnuur, 2019). While South Africa was at the forefront of GM crop adoption, recently there has been an increased interest from other African countries in adopting GM crops, including indigenous crops such as cowpeas and sorghum (Bosibori Bett, *el al*. 2017; Ndimba et al, 2017). In light of this, questions concerning the impacts of GMO crops on agricultural knowledge are vital for other African countries, as to date impacts on agricultural knowledge have not been widely explored.

Decolonial theory can offer important insights into how it is possible to build more resilient pathways to agriculture in South Africa (and beyond), by building on the marginalised relational knowledge of both farmers and scientists working on the fringes of modernist science in a way that recognises past knowledge and power relationships, epistemicide and injustice. This theoretical work offers pathways to thinking beyond more reductionist approaches which have in recent decades merely added Indigenous knowledge to the "pot" of solutions, because it recognises the unique ontological standpoints of smallholder farmers and the importance of decolonising agricultural science and knowledge production (Muir, 2010; Green, 2012). This will require what Muir et al. (2010:263) describe as moving beyond the "knowledge frontier". While synergies between different knowledge systems can be found, their differences also need to be acknowledged. This is demonstrated by Muir (2010:259) who says that "indigenous knowledge and Western science belong to different world views". Within the practices of modern agricultural science there is a need for an ontological turn that recognises that modernist science is just one way of knowing and operating in the world, one that has deeply fractured relations with nature, and which has contributed to the current ecological crisis and marginalised other ways of knowing and being in the world (Muir, 2010).

Globally, through the industrialisation of agriculture and the increasing reliance on commercial technologies, the importance of farmers' knowledge has been diminished. Much of this knowledge has been lost because of the influence of 'productivist logic and standardized solutions' (Šūmane et al, 2018:1). In recent years there has been increased global awareness of the need to rebuild relational, place-based knowledge in order to work towards more resilient futures of agriculture and to restore ecological well being and sovereignty within the food system (Šūmane et al., 2018; IPES; FAO). Smallholder farming systems and knowledge are finally being acknowledged as vital in moving towards this objective (FAO, 2013; IPES, 2020). Kloppenburg (1993) argues that working towards alternative, more sustainable agricultural futures requires firstly a "deconstructive" process whereby a total reliance on modernist science is questioned and power imbalances are acknowledged, making way for other ways of knowing. He suggests that a 'reconstructive' phase will need to bring in 'other ways of knowing', towards creating a different kind of science. Decolonial theorists suggest that an ontological shift is needed to move beyond the oppressive effects of modernity and rationality and that this must involve the "re-construction and restitution of silenced histories, repressed subjectivities, subalternized knowledges" (Mignolo, 2007(b):451). Drawing on PCSTS and decolonial literature, the following section considers how relationships between smallholder knowledge and science can be reconsidered by prioritising relational knowledge in favour of dualist, hierarchical science, thus opening up possibilities for more just and less damaging agricultural futures.

8.4. Butterflies in the daytime; moths at night: towards a decolonial approach to nurturing relational agricultural knowledge

> In this post-truth world order, where alternative facts threaten to unravel even the most stably constructed scientific claims, it may seem utterly blasphemous to question whether more science or even better science are what we need in order to respond to the dire circumstances unfurling all around us. But we also need to invest our efforts in generating robust forms of knowing (and not knowing) that can stand both alongside and thwart science.
>
> Myers, 2017:2

> The decolonization of knowledge, [Mignolo] suggests, occurs in acknowledging the sources and geo-political locations of knowledge while at the same time affirming those modes and practices of knowledge that have been denied by the dominance of particular forms.
>
> Bhambra, 2014:118

As Harding (2016:1064) explains, "sciences and societies co-produce and co-constitute each other at particular times and places". Technologies fashioned in a world guided by the logic of modernist science and its principles – efficiency, profitability and progress – therefore both simultaneously reflect that world and create it (Latour, 2007; Harding, 2016). Modern science is a construct; it came into being within a particular culture and is imbued with the interests of power and capital (Harding, 2016). To move modernist scientific practice beyond this, there needs to be a fundamental ontological shift towards fostering relationality, sustainability and care. Harding's (1991) conceptualisation of (s)cience with a lowercase 's' (science that is for the good of humanity and all life) as opposed to (S)cience with capital a 'S' (science that is captured by the desires of capitalism and priority of profit), along with what Kloppenberg (1991) envisioned as the possibility of building an 'alternative science', offers the idea that modernist science does not have to be and is not the only way of doing science (Kloppenberg,1991). This awareness and vision for a different kind of science is useful for rethinking the possibilities of agricultural science beyond a discipline that in its dominant form has come to enforce dualism and perpetuate coloniality.

Decolonial theory and postcolonial STS, have in different ways brought to this thesis theoretical tools for reimagining how the field of modernist agricultural science in its current form may be de-centred, by considering other ways of knowing and being human in relation to all other life in the world. This work has brought to the fore important conceptual tools for thinking through how to reintroduce relational knowledge in agriculture, by encouraging reconnections between smallholders and ecosystems, between scientists and ecosystems, and a collective relationship with ecosystems in agriculture. Decolonial theory can help to think through critical relationships between history, knowledge and seed, as well as relationships between smallholder farming and R&D. This requires consideration of how to bring different ways of knowing into the same conversation to move beyond a colonial, hierarchical and relativist approach in which all knowledge is compared to a benchmark of modernist 'scientific truth' (Muir, 2010).

Decolonial theory suggests that there are multiple 'worlds', rather than a relativist approach in which there are multiple perspectives on 'the one world world' (Law, 2015). This idea requires not just a decolonisation of knowledge but a decolonisation of being, a move beyond Western dualist conceptualisations of reality, and an opening up of what Christina Rojas calls "the politics of pluriversity" which is 'premised on deep rational ontologies between humans, and humans and nature' (Rojas 2016; Rosenow, 2019).

Smallholder farmers and agricultural scientists both work with agroecological systems, yet the way in which they do this is historically and ontologically different. The knowledge of smallholders today cannot be idealised as separate from scientific and modernist knowledge; nor can the work of scientists be regarded as separate from that of farmers. Beyond the influence of agricultural technologies, the knowledge of smallholder farmers has changed vastly, due to social, ecological, and political tensions over the last five hundred years. So, too, have the ecological systems they have been working in and in South Africa as a whole; populations have increased and socio-cultural structures have shifted, too. Many smallholders no longer have the desire to use traditional farming methods, instead favouring the use of industrial farming methods and technologies. Others wish to use a combination of methods. One cannot put smallholders or agricultural scientists into a box, because while it might be useful for some level of analysis, there are always hybridities within knowledge, practice and identity (Anderson, 2002; Coole 2013; Schulz, 2017).

Some of the smallholder farmers interviewed for this study desired to revive and carry on the farming practices of their parents and grandparents while others wished only to use industrial methods. Some incorporated elements of traditional farming knowledge into their practice; however, they also utilised industrial seed. Similarly, the agricultural scientists interviewed were not a homogenous group; some advocated for only modernist agricultural methods while others recognised the value of Indigenous knowledge and building deeper understandings and engagements with agroecosystems, and have tried to incorporate this into their work (Modi & Henricks, 2006; Zuma-Netshiukhwi, Stigter & Walker, 2013).

This research revealed that more than one narrative can exist at a time. On the one hand, there is a deep disconnection with agroecological environments and a loss of relational knowledge evolving within both R&D and smallholder farming environments. On the other hand, there are both farmers and scientists working to rebuild relational knowledge and hold on to that which still exists. While both narratives may exist at one time, however, it is likely that the relational work at the margins will become lost over time if attention is not given to the importance of relational knowledge in agriculture. There is a need to consciously create space for multiple ways of knowing so as to not shut down future possibilities in agriculture and confine farming and research to a narrow industrial trajectory. Space needs to be created by recognising and prioritising the importance of socio-ecological connections and knowledge in agriculture underestimating and how new technologies including seed can undermine this. If space is created for a relational ontology to exist alongside the dominant dualist approach – thus allowing for a pluriversal approach to knowledge – it may become possible to find more integrated solutions to the problems created by a dominance of modernist knowledge production (Rojas, 2016).

The two excerpts at the start of this chapter speak to a scenario encountered in the research that made visible the ways in which smallholder ontologies are often read through or measured by the lens of modernist science as a benchmark of the 'truth'. In the second excerpt, the scientist refers to the farmer's observation as a "half-truth": here he is gauging 'truth' through a modernist scientific lens. Since the early 1900s, scientists have studied the behaviour of stem borers and have traced the lifecycle of this insect in detail (Kfir, 1993). However, the knowledge of the connection between stem borers and the white butterflies reveals a different 'way of knowing', a relational knowledge that extends beyond a focus on the behaviour of that individual 'pest' species. In this relational ontology it is not so important if the moths or butterflies lay the eggs that become caterpillars; instead, the butterflies are a sign to farmers of the conditions in which stem borers hatch – they are connected to the wider agroecosystem. By focusing on a modernist idea of facts and 'truth' or 'reality', farmers' more relational, place-based ways of knowing can easily be disregarded and lost over time.

The layering of knowledge described above could offer a way of offsetting dualist knowledge. With some reflection on the research process and the gathering of these excerpts a methodological learning could be ascertained. The excerpts reflect an experience that emerged organically whereby I had been speaking to farmers and then had spoken to an entomologist who I had met with right after meeting with farmers. However this process of bringing what farmers had explained into the awareness of the entomologist and then witnessing their response is in hindsight a methodological choice. For this methodology to move further towards breaking down hierarchies of knowledge it would be important to go back to talk to farmers about what scientsist are saying; asking farmers' opinions on certain topics could help provide a more nuanced layering of knowing.

Given that both smallholders and farmers have experienced a deepening disconnect between their work and the agroecological systems in which they work, this thesis suggests that finding ways to support the reclamation of relational knowledge may require the support of both knowledge systems in order to reclaim relational knowledge and redirect scientific research towards a relational approach.

Decolonial theory as explored above offers a way to reshape this hierarchical relationship of knowledge and being, thereby helping to move towards the co-production of relevant contextual and more socially and ecologically just agricultural systems. As decolonial theorist Boaventura de Sousa Santos argues, we need to think differently to think of alternatives as dominant modernist thought cannot help out of the problems it has instilled (De Sousa Santos, 2016). For De Sousa Santos (2015) fostering socio-ecological wellbeing, which he refersto as 'buen vivir', requires an ontological shift towards more relational understandings of socio-ecological wellbeing. Therefore, socio-ecological justice requires an interrogation of coloniality for cognitive justice to be restored (De Sousa Santos, 2016). Chapter 9, the conclusion to this thesis, thinks through some suggestions for how this might be possible in South Africa and beyond.

8.5. Conclusion

The relationship between smallholder farming and agricultural R&D is one imbued with injustice and a hierarchy of knowledge. Smallholder knowledge and the relational ontology in which it is historically embedded in South Africa has been deeply disrupted by the dominance of modernist agricultural science. Modern seed technologies, fashioned within modernist ontology, perpetuate this bifurcation of knowledge and contribute significantly to the unravelling of place-based knowledge and disconnection with ecological systems. However, within this, there remains on the margins hybridities as well as both farmers and scientists who understand the importance of relational knowledge.

Smallholder farmers and scientists have unique vantage points concerning agriculture; they hold different standpoints and each knows different things about agroecosystems. This thesis suggests that, historically, smallholder farmers have understood agroecosystems in a more relational sense than agricultural scientists working within the power structure of a modernist ontological frame of reference. While scientists have studied and mapped elements of ecological systems, their work and methods have been shaped by colonial and modernist agendas and ontology. However, this thesis goes on to argue that, given the influence of new seed technologies alongside other social, political and economic influences, both scientists and farmers are increasingly disconnected from agroecosystems and place-based knowledge. Given the scale of environmental degradation and the changing global climate, agroecosystems are in flux. There is a pressing need to build agricultural resilience in the face of escalating uncertainty. Increasingly, it is being recognised that rather than relying on technological fixes, agricultural resilience will come from a diversity of both knowledge and practices in agriculture (IPES, 2020; Šūmane, 2020).

There is thus an urgent need to move beyond the limited dualist paradigm that has fashioned so much of the dilemma we find ourselves in today. Drawing on decolonial theory, this discussion has suggested that there is a need to not only incorporate elements of traditional knowledge into agricultural science but to shift towards an ontology of relationality in agricultural science, in order to repair fragmented relationships with agroecosystems, and build alternative relationships between scientific research and smallholder farmers.

FIGURE 9.1: Image of maize in agroecological farmer's fields in Pongola alongside pumpkins and beans; these crops are traditionally grown together and support each other. Source: Maya Marshak, 2019.

9. CHAPTER NINE: Conclusion

9.1. Introduction

There has been an increased exploration into the impacts of modern maize seed technologies since the introduction of GM seed, due to its controversial nature. However, studies have tended to look at these impacts in a dualist way, focusing on either social or ecological impacts (Wickson, 2014; Herrero, Wickson & Binimelis, 2015). Given that agricultural seed is a socio-ecological entity, this thesis has sought to contribute to an understanding of how the ongoing technification of maize seed affects socio-ecological relationships and knowledge in agriculture. In order to do this, this thesis drew on theoretical literature that grapples with how to move beyond the nature/culture divide that is prevalent in modernist science, including the way it is studied within academia (Maffi, 2007; Norgaard, 2008).

Maize is a key industrial crop both globally and in South Africa. Due to its genetic malleability, maize seed has been the subject of significant amounts of R&D over the past century through which scientists have developed open-pollinated, hybrid and GM varieties (McCann, 2007). For this reason, the aim of this thesis was to examine the socio-ecological effects of the technification of maize over time on agricultural knowledge and practice in South Africa. Research was undertaken in two nodes of agricultural knowledge generation and practice: on smallholder maize farms and within maize R&D institutions. Through an exploration of the interactions between humans and agroecosystems, the second aim of this thesis was to contribute to broadening the understanding of the impacts of maize seed technification, and the implications for agricultural sustainability in South Africa and beyond.

Five objectives were outlined for this thesis. The first was to find and incorporate novel conceptual and methodological modes of examining the effects of modern seed technologies on socio-ecological knowledge and relationships within agroecosystems. This involved drawing on a range of conceptual and methodological literature stemming from the posthumanist turn, in which scholars across disciplines have sought to decentre an anthropocentric focus in research (van Dooren et al., 2016).

Through the use of a posthumanist conceptual framework and methodology, the second and third objectives sought to investigate the effects of maize seed technification on socio-ecological knowledge and practice within smallholder maize agriculture and maize R&D respectively over time.

The fourth objective was to explore how the technification of maize seed has affected, and may continue to affect, the often-polarised relationships of knowledge between smallholder farming and R&D. This exploration was informed by scholarship and activism from the Global South which stems from the ontological turn that questions the centrality of modernist thought, and therefore the hegemony of modernist science in the production of knowledge. A secondary part of this fourth objective was to utilise these findings to consider ways of working beyond the modernist and colonial bifurcation of scientific knowledge versus farmers knowledge. In doing so, the intention was to ask questions concerning the importance for future agricultural resilience and the restoration of more relational agricultural practices.

The final objective was to use the research to reflect on how an improved understanding of the socio-ecological implications of the modernisation of seed may inform thinking around future agricultural pathways and resilience in South Africa and beyond.

9.2. Summary of findings

9.2.1. A posthumanist lens in coversation with decolonial theory provides a novel way to study the impacts of the technification of seed

The first objective of this thesis was applied using a posthumanist conceptual framework and methodology which tried through interviews and observation to understand and capture the nature of changing socio-ecological entanglements in the respective field sites. This approach drew inspiration from Science and Technology Studies (STS), which brings attention to the agency of all living and non-living parts of a system. Multispecies ethnography informed the method, in terms of how it encouraged a focus beyond humans as the sole protagonists, and incorporated this into the field of vision humans' relations with other beings. This approach helped focus the research towards the meeting points between humans and all other lifeforms they are involved with through their lives and work in maize agriculture.

On farms, this approach meant that interviews investigated how farmers interacted with the more-than-human world around them and how these interactions have shifted and changed over time in relation to new seed technologies. Within R&D institutions, this approach meant that interviews explored scientists' interests, focus and interactions with the more-than-human beings they encountered (or did not) in their work in maize research, and how these interactions shifted over time. The focus on the meeting points or relations between humans and other beings was a useful way of moving beyond a study of the impacts of modern seed technologies according to the nature/culture divide so prevalent in the study of the impacts of seed technologies. Insects emerged within this area of research as lively protagonists. By focusing on human-insect relations, it became possible to gain insight into the ways in which the technification of seed and its co-technologies (such as pesticides and embedded genetic traits targeting insects) has wider implications for the unravelling of socio-ecological relationships and knowledge.

9.2.2. Exploring the effects of the technification of maize seed within and between smallholder farming and R&D

The second and third objectives sought to investigate the effects of maize seed technification on social-ecological knowledge and practice within smallholder maize agriculture and maize R&D respectively over time. These findings were presented separately in Chapters 5 and 7. The fourth objective was to examine the effects of seed technification on these sites collectively and on the relationships of knowledge between them. This was explored in Chapter 8. The following sections present key findings and themes that emerged from studying the effects of modern seed on these sites in their own right, but also in relation to each other.

9.2.2.1. Ecological deskilling

The research suggested that the technification of seed contributes to a growing disconnect between farmers and scientists and agroecosystems. Traditionally, on farms, ecological, place-based skills and knowledge were generated through cumulative observations and interactions within the agroecosystems and with its more-than-human inhabitants over generations of farming. In this context, agricultural seed comes into being in a coevolutionary way involving interactions between biodiversity and cultural practice (Maffi, 2007). Agroecological skills arise from the complex environmental and social learning processes that form part of a continuous "agricultural skilling" (Stone, 2007), and often lead to culturally situated and sustainable practices (DeWalt, 1994).

A posthumanist approach, in combination with literature on agricultural deskilling and coevolutionary theory, has led this thesis to suggest that the concept of 'ecological deskilling' in agriculture be considered, as it can be useful for drawing attention specifically to the displacement or loss of skills between people and agroecosystems. While the concept of agricultural deskilling provides a basis for understanding the impacts of new technologies on the skills of farmers, this thesis suggests that the addition of the term 'ecological' to agricultural deskilling helps to bridge the concept of agricultural deskilling with a socio-ecological and posthumanist focus. The term ecological deskilling implies a move beyond an anthropocentric lens towards one that considers the relationships between farmers and the agroecosystems within which they work. While the concept of agricultural deskilling has in the literature focused mainly on farmers, the concept of ecological deskilling has also been used in this thesis to describe a growing disconnect between scientists and agroecosystems alongside the technification of seed. The thesis suggests that using the same concept to explore changing skills across farming and R&D allows for a wider view of the impacts of seed technologies beyond isolated impacts and, more broadly, their impacts on agricultural knowledge, practice, and the impacts of agricultural change on our relationships with the earth.

The concept of ecological deskilling was articulated using themes of loss or displacement, which related to both farmers and scientists in varying degrees. On farms these dimensions included, 1) the loss of ecologically based practices; 2) the disruption of relational knowledge; and, 3) the loss of socio-ecological agency. In R&D

sites, ecological deskilling was presented as, 1) the displacement of relational and ecologically based research and knowledge, and 2) the loss of agency to do ecologically based research.

Chapter 5 showed that, for smallholder farmers, the introduction of hybrid seed has meant that traditional place-based skilling and knowledge has been interrupted in various ways over time. An example is the use of pesticides and, more recently, Bt maize, which has increasingly removed the need for farmers to draw on relational knowledge and ecologically based solutions for pest management. In the smallholder farming space where GM seed has not yet been widely adopted, GMOs present another development that threatens to undermine cumulative, relational knowledge. While hybrids have long contributed to this process, the research pointed to the fact that GMOs can further disrupt and break down relationships between farmers, seed, and agroecosystems. The adoption of commercial seed has disrupted farmer seed systems, making farmers increasingly reliant on outside actors for agricultural knowledge and inputs, thereby undermining the ecological agency associated with the relationships between farmers and their own seed.

With regards to the maize R&D system, which initially took root around open-pollinated seed but was bolstered around the development of hybrid maize, Chapter 7 suggested that the technification of seed and, most recently, the introduction of GMOs has prompted significant shifts in the generation of ecologically based research. Hybrids, developed within a lineage of modernist agricultural science, prioritise higher yields and profit by achieving "mastery over nature" (Moore, 2015a). Over time, hybrids were fashioned to be grown as a package alongside co-technologies such as pesticides and herbicides, which provide generic, reliable solutions to the production of high yields. However, while the requirements for their growth became increasingly generic, resting heavily on external inputs, in South Africa the public maize R&D system also invested in conducting more ecological and place-based research alongside the development of hybrids. This research was needed to support the growth of hybrids and ensure growing yields and profits. As a result, scientists worked together to develop approaches such as integrated pest management (IPM), biocontrol or integrated weed management. These approaches aimed to limit the use of expensive chemical applications and thus reduce the cost of farming, rather than support their limitless use.

Interviews with maize scientists revealed that the introduction of GM seed had in some ways led to the displacement of the long-term, place-based research they had once been engaged in. This was attributed to various factors: the first is an increase in corporate funding for research and a decrease in public funding. This means that research is increasingly focused on corporate agendas which prioritise profit generation, thus resulting in the prioritisation of GM seed over the last several decades. A decrease in public funding has also resulted in a decreased availability of funding for longer-term research projects typically funded by public funding rather than corporate funding, which focuses on shorter-term gains. This has affected ecologically based studies that tend to be carried out over longer periods of time. A final reason for this suggested by the research is that the introduction of GM crops required the development of a new set of research focused on understanding the behaviour, risks and complexities associated with these newly introduced organisms in the South African context. A number of scientists who had previously been engaged in more integrated, systemic, place-based research found themselves studying ecological impacts or the performance of GM maize in the context of South Africa, for example on water bodies and non-target insects. Less funding became available for their former projects, such as flight pattern research. In this way the abundant research needs of integrating GM maize into the agricultural system overshadowed other areas of important research. While some scientists regarded this as a skilling process in which new skills related to biotechnology grew within the R&D sector, others saw it instead as disruptive for the skilling process that had developed around hybrids.

Chapter 8 suggested that in both spaces, together with the technification of seed and the adoption of co-technologies, there has been a growing tendency over time to work against 'nature', to control it and 'put it to work', rather than work relationally with it (Moore, 2015a). The research suggests that the specification and generalisability of seed and the application of its co-technology means that both farmers and scientists are losing touch with knowledge related to specific contexts and ecological systems, as this knowledge is needed less and less to produce a high yielding crop. As scientists and farmers lose relational knowledge about agroecosystems, there is an ever-growing reliance on technologies that transform the environment to produce successful crops. As such, there is a resultant loss in agency that makes the probability of restoring this relational knowledge over time less likely, as knowledge is lost and technologies become locked in (Cowen & Gunby, 1996). The histories and experiences of smallholder farmers and those of scientists are vastly different; however, if one looks at these sites side by side it is possible to see a common thread – one of a growing rift or unravelling of place-based knowledge, and a replacement around seed of generic ways of knowing and growing maize (Green, 2015; Moore, 2000, 2015a). In both cases, farmers and scientists are experiencing less agency over the creation of agricultural knowledge; instead, they are influenced by corporate interests and research agendas that prioritise the generation of profit above other matters.

While the technification of seed cannot be blamed solely for the deep shifts in agricultural practice and knowledge generation, research on smallholder farms and in R&D institutions has pointed to tangible ways in which these technologies contribute to widening disconnections between human actors and agroecological systems. Relational place-based knowledge is being replaced by the continued modernisation of seed based on dualist principles of "mastery over nature" (Harding, 2008).

9.2.2.1. Ecological reskilling

While the research suggested a process of ecological deskilling on farms and in R&D, it also revealed a parallel, less prominent process referred to in this thesis as 'ecological reskilling'. This refers to a process whereby both scientists and farmers are beginning to build the capacity to reclaim relational knowledge and ecological-, place-based practices within agroecosystems. A group of smallholders alongside Biowatch, an NGO operating in the area, were beginning to work towards incorporating more agroecological methods to reclaim the place-based knowledge they had learned as children from their parents. They were working towards saving their own seed, as well as teaming up with farmers across the region to revive local seed and knowledge networks. Within R&D and to varying degrees, scientists appeared to be acutely aware that relying solely on technological solutions, such as is embodied by GMOs, was risky and that there is a subsequent need to diversify agricultural practices. During the recent FAW outbreak, many scientists hesitated to advocate for technology-heavy, chemical-intense controls, recognising instead the need to find more integrated solutions (Harrison et al., 2019).

While these currents of reclamation exist, they are still marginalised and under supported by the wider industrial approach to agricultural development in South Africa. The thesis suggested that if this is not addressed the loss of relational knowledge might be irreparable, and we might become locked into pathways in which relational knowledge becomes increasingly un-placed and difficult to regenerate (Cowen & Gunby, 1996). This lock-in can be both material and ideological, as agricultural landscapes change and balance is lost. Outbreaks of pests and weeds, for example, are likely to increase and this makes it more inconceivable for human actors to imagine farming without external inputs by which to control nature. Given that there is a growing recognition globally of the need for diversity and diverse knowledge and reconnections with nature for the resilience of farming (Pretty, 1994; UN, 2013; IPES, 2020), this thesis suggests that it is necessary to consider how the ongoing technification of seed can perpetuate the disconnect between humans and agroecological systems, and thus the decreased possibility of rebuilding them in the future. Rebuilding relationships with seed can create space for reconnection and renewal of socio-ecological connections and knowledge that have been relegated to the margins (Gundidza, 2018). The final part of Chapter 8 drew on decolonial theory to consider how this might be possible.

9.2.3. Ecological reskilling requires an ontological shift that dismantles the hegemony of modernist agricultural science and brings in knowledge from the margins

Part of the fourth objective of this thesis was to explore the relationships of knowledge between smallholder farming and R&D around the technification of seed. Historically, a bifurcation developed between these spaces, resulting in the imposition of a hierarchy of scientific knowledge and farmers' knowledge, with smallholder, local and Indigenous knowledge being treated as inferior and less productive. Modern seed technologies (alongside their co-technologies) and technological methods for growing them are presented as better, more efficient, and more productive than farmers' seed and practices. Over time, smallholder farmers in much of the Global South have been treated increasingly as passive recipients needing the assistance of modern science to improve their skills and knowledge. This has been the project of developmental assistance programmes and, most recently, the push for the Green Revolution and Gene Revolution in Africa (Schnuur, 2019; Parayil, 2003; Schnurr, 2019). Central to these approaches has been the dissemination of modern seed and knowledge associated with it.

Seeds, like all socio-technical 'objects,' are not neutral but are enmeshed in the knowledge system in which they are fashioned (Harding, 2008). Since its beginnings in the late 1800s, modern seed development has been shaped by a dualist ontology rooted in modernist and colonial histories. Implicit in the making of modern seed technologies is the idea that nature can be controlled by humans through rational, positivist science-based methodologies for the benefit of human beings (Pretty, 1994). Industrial capitalism (underpinned by and fashioned through dualist ideas of humans versus nature) prioritises profit, progress and efficiency (Latour, 2007; Pretty, 1994). In doing so, other concerns beyond these fall away (de Bella Casa; Moore, 2015a; Green 2011, 2015). As Asdal, Brenna and Moser (2007) point out, modernist science does not merely describe and discover reality in a neutral way; rather, science and technology are seen as "ordering activities" that generate a reality rather than discover it (Asdal, Brenna & Moser, 2007:9). Particular versions of reality thus emerge from the introduction of technologies, which can enforce the ideas and systems of power that generated them. Therefore, the introduction of modern seed technologies encourages dualistic modes of engaging with agroecological environments and disregards relational ways of knowing, thereby continuing to enforce modern ways of engaging with the world, and thus modernity/coloniality (Mignolo, 2011, 2012). As both farmers and scientists come to rely on more generic seed and the ways of farming associated with it, relational knowledge built up within particular place-based contexts can become devalued and lost and modernity/coloniality carried forward (Werner, 2008; Mignolo, 2011, 2012).

Postcolonial STS and decolonial theory in varying ways have been important in this thesis for providing a lens through which to consider the effects of dualist, modernist science and seed in South Africa and beyond. This theoretical work, stemming from different contexts and theoretical traditions, provides a critique of modernist approaches to science and development and acknowledge the violence and epistemicide that has resulted from the dominance of agricultural science over other ways of knowing and being in the. Modern seed brings with it the dualist ontology through which it was fashioned and has the power to shape agricultural realities and marginalise other more relational ways of knowing. The hegemony of modernist scientific knowledge that underpins modern seed production and dissemination needs to be investigated (Muir et al., 2010; Rosenow, 2019).

Decolonial theory considers how relational ontology may be reclaimed and fostered. By drawing on decolonial theory, this thesis therefore suggests that there is a need to recognise the ontological implications of the introduction of modern seed, so as to encourage more sustainable and just socio-ecological pathways. Importantly, decolonial theory understands that ecological reskilling in maize agriculture cannot merely be about adding in ecologically based knowledge – such as that borrowed from Indigenous knowledge – to dominant industrial modes of knowledge generation (Muir et al., 2010). Instead, there needs to be a recognition of the need for an ontological shift to offset the hegemony of modernist dualist ontology altogether (Muir et al., 2010; Green, 2012; Rosenow, 2019). There needs to be a reframing whereby modernist science is understood as only one way of knowing – and one that has caused great socio-ecological damage (Escobar, 2011). This could make more space for a shift away from dualistic agricultural science (which has dominated the Indigenous knowledge of smallholders and created a R&D system that is increasingly displaced from context) towards more relational knowledge creation.

This thesis suggests that decolonial theory offers a way to consider what it might look like to undertake a process of ecological reskilling in agriculture around seed. An ontological shift requires making space for more relational knowledges and modes of enquiry and practice that have been relegated to the margins. This includes the knowledge of both smallholder farmers and scientists, who work outside of the dominant methods which prioritises the pursuit of capital above more socially and ecologically just solutions. This could help to move towards building a different kind of agricultural 'science' – as Harding (2008) suggests, 'science' with a lower-case 's' rather than a capital 'S' needs to be fostered. Harding's (2008) conceptualisation of 'science' as that which serves the greater wellbeing of people and ecological systems, rather than 'Science', which predominantly serves capital and the gains of a few, as well as Kloppenberg's (1991) framing of an 'alternative science', provides a way of reimagining the project of agricultural science. This will require practical steps towards rethinking the hierarchies of industrial agricultural knowledge production through the generation of participatory, anti- and non-hierarchical, collaborative knowledge. Part of this will include a growing understanding of how the categories of scientist or farmer, which are often seen as separate, are in fact not static categories. As postcolonial STS theorists have argued, science through history has incorporated Indigenous sciences and philosophies while not always acknowledging this (Seth, 2017).

Around the world, farmers and communities are working towards reclaiming marginalised knowledge and relationships with nature. This process of ecological reskilling is happening on a community scale in many countries; on a regional scale, as can be seen in regions of India, Ethiopia, California and other places; and even on a country scale, as seen in Cuba, where a countrywide industrial agricultural system has since the 1990s and the collapse of the Socialist Bloc been refashioned into an agroecological model admired worldwide (Ngcoya, forthcoming; Mier y Terán Giménez Cacho et al., 2018). The reclamation of relational knowledge and practice is vital for working towards more socially-ecologically just futures and social-ecological wellbeing.

9.2.4. Creating space for relational knowledge in maize agriculture and beyond in South Africa: recommendations for fostering more sustainable agricultural futures

The final objective of this thesis was to use the research to reflect on how a better understanding of the socio-ecological implications of the modernisation of seed can inform thinking around future agricultural pathways and resilience in South Africa and beyond. This thesis suggests that, while studies in South Africa or globally have yet to focus deeply on the socio-ecological impacts of the technification of seed on relational knowledge and skills, this is important. It is likely that if this is not done, the knowledge holders – both farmers and scientists who still have some relational understanding of maize agriculture – will not transmit this knowledge to younger generations. Furthermore, these relationships could become irreparable, as relational knowledge requires sustained relationships with agroecosystems and an ongoing skilling process; however, this is disrupted by the increasing need for generic seed and their co-technologies. Therefore, this thesis suggests that in South Africa and other countries facing increasing agricultural modernisation, a focus on the socio-ecology of newly introduced seed can be an opportunity to think through what kind of relationships that country wishes to have with agroecosystems and, in so doing, what agricultural futures are being created. Furthermore, this can be an opportunity to question the systems of coloniality embedded in the adoption of corporate seed and industrial agricultural science based on a modernist disconnect between humans and 'nature'.

There is a need to move beyond the "expert/lay" system and set of power relations in which smallholder farmers are treated as "users" of technologies and scientifically generated knowledge instead of as co-creators of agricultural knowledge (Warner, 2008:2). This requires a shift in the generation of agricultural knowledge. Moreover, it requires a shift in the motivation for doing science away from a focus on yield and profit at the expense of socio-ecological wellbeing towards more sustainable and relational approaches (Pretty, 1994).

The interdisciplinary practice of agroecology offers an alternative relational approach to regenerating socio-ecological relationships and skills, as well as challenges hierarchies of modernist approaches to generating agricultural knowledge with a move towards restoring cognitive justice (Scoones and Thompson, 1994; Warner, 2008; De Sousa Santos, 2016). Proponents of agroecology have long suggested that agroecology as a science, practice and social movement is based on participatory and place-based, locally relevant knowledge creation (Altieri, 1989; Gliessman, 2016; Werner, 2008). Agroecology can be distinguished epistemologically and ontologically from reductionist science because it is "grounded in ecology" (Warner, 2008:3) and place-based, relational, socio-culturally relevant farmer-led knowledge creation (Altieri, 1989).

Cuba offers an example of a restorative national agricultural system whereby a highly industrialised, resource intensive system has been transformed since the 1990s into a participatory agroecological farming model, whereby agricultural knowledge and technology production is done in collaboration between farmers and scientists (Ngcoya, forthcoming; Mier y Terán Giménez Cacho et al., 2018). Participatory breeding of seed is an integral part of this process. Given South Africa's highly industrialised agricultural system and the current dominant model of expert-led technology transfer, Cuba's transition demonstrates the possibilities for developing a more relational system. This will require a reinvestment and reorientation towards public funding for farmer-led research in which smallholder farmers are recognised as key participants in research. Moreover, this will require the adoption of new methodologies for participatory research that look towards dissolving hierarchies of knowledge and finding ways to bring multiple knowledges together into learning platforms (Chambers, Pacey & Thrupp 1989; Pretty, 1996; Uphoff, 2002). It will require a rethinking of current extension systems and expert/lay power relations that have privileged the role of scientists at the expense of poor farmers and their Indigenous knowledge (Werner, 2008:4). It will also require a shift in the anthropocentric nature of industrial agriculture and an increased engagement of both farmers and scientists with the more-than-human world. As smallholder farmers in South Africa have not fully embraced industrial agriculture, smallholders are among the few farmers who still maintain agroecological relationships and knowledge.

9.3. Conclusion

Agricultural seeds are not static; they are bio-cultural entities that coevolve with their human collaborators, their priorities and with the more-than-human world. Over time seeds, have been co-opted by imperial and capitalist projects and their natures moulded to fit these. Seeds that were once an exchangeable and fluid entity that evolved in relation to agroecosystems and human interactions with them have become commodities fashioned within the realm and control of modern science. The commodification of seed has deeply altered power and knowledge systems, threatening to undermine centuries of farmer-seed development grounded in deep socio-ecological relatedness. The corporate, science-based control over seed has been opposed globally by smallholder farmers and activists fighting for the right to retain their own relationships with seed. While hybrid seed presented a drastic departure from the coevolutionary nature of farmer seed production, the commercial release of GMOs in the late 1990s has intensified the global debate about the modernisation of seed. In many ways, the controversy of genetic modification has raised new questions about the ethical boundaries of scientific control over life and drawn attention to the importance of studying the impacts of the technification of seed from a diversity of perspectives. It has encouraged the emergence of more nuanced conversations.

This thesis sought to contribute to the understanding around how seed might be impacting not just humans or the environment but our relationship with and understanding of the ecological and planetary systems on which all human existence ultimately depends. It argues that understanding socio-ecological implications of the modernisation of seed is vital for restoring cognitive justice and fostering more resilient agricultural futures.

9.4. Recommendations and reflections for future research

Given the wide scope and multi-sited nature of this project, a recommendation for research going forward would be to conduct further in-depth studies - in the research sites and beyond - to expand on the themes of ecological deskilling and reskilling uncovered in this research. Within smallholder farming sites it would be important for further research to be carried out by a researcher who is fluent in local languages and cultures and who could spend a longer period understanding more deeply biocultural knowledge that requires a deep understanding of cultural systems in the area. This deeper knowledge could build further on the understanding of the impacts of seed technification on biocultural relationships and knowledge. Further it may offer ways of documenting a knowledge that is being lost over time. This is important if farmers' knowledge is to be prioritised and understood so that it is not marginalised by the hegemony of scientific knowledge. Along with the research presented here, more in-depth research of the relationships between farmers, extension services and knowledge may offer valuable material to inform future research priorities, particularly concerning how to design a more participatory R&D system between farmers and scientists around seed.

Most of the interviews accessed for this thesis focused on public research, with fewer interviews in the private R&D arena, as it is more accessible to access interviews within the public sphere and this is where the research process began. Further research would be useful in both private R&D and the public sector to further deepen understanding of the history and practice of agricultural research over time. It could also be useful in future research to widen the scope of "scientists" to include social scientists.

Research into the changing nature of private R&D could be particularly useful to explore in more depth. As companies grow and increase their R&D capacity they have a growing influence on the direction of research. Increasingly, precision agriculture and the incorporation of information and technology systems are being put forward as potential solutions for agricultural sustainability. This growing area of research has important implications for the future of social-ecological relationships and knowledge in agriculture. A multispecies approach into the nature of this research could be useful in understanding how companies are mediating relationships between humans and agro-ecosystems in their research and technology development going forward.

9.4.1 Conceptual and methodological reflections – scope for further research

On reflection the term "skill" as embedded in the word ecological deskilling or ecological reskilling is perhaps a slippery word that brings both benefits and challenges. The word "ecological" was added in this work to the deskilling language to attempt to bring attention to the meeting points and relations between humans and all other forms of life in agricultural contexts.

This word "skill" also operated in this work to draw validity to the skills of farmers and scientists alike and to break down colonial, dualist hierarchies that have come to be associated with this word.

However, on reflection "skill" reveals an anthropocentric bias in the work - as I have attributed this word only to humans. A question that arises is whether "non-humans" also have skills which are affected by different technological interventions. Further work could grapple more with this term and its merits and setbacks. Perhaps this is space for collaborative work, which is where I hope this work will lead.

Examination of the word "skill" also draws attention to how the multispecies work could be deepened. This thesis has pragmatically tried to balance a focus on people and all other life through qualitative interview methodologies, alongside observational work and visual and sensory data gathering. The aim was to place humans in a web of life without placing them at the centre, yet in not specifically trying to tell the story from the vantage point of other life forms perhaps the human remains close to the centre. The research has revealed much about the shifting relationships between people, seed and the more-than-human actors within agroecological systems. However, further work could delve deeper into multispecies methodologies. Working on the margins of the lives of humans and other species has pointed to is that a rich world of multispecies conversations just beyond the scope of this thesis. For example a study that starts from a curiosity purely about the vantage points of insects.

9.4.2. Interdisciplinary theory, margins and friction

It is also worth reflecting more deeply on not just the merits of using posthumanism and decolonial theory in the same work, but also on what the possible drawbacks of using them together due to the possible frictions between these bodies of work (Wynter, 2003; Schulz, 2017;Zembaylas, 2018). This is an important reflection for this thesis and for work stemming from it. As decolonial theorists have pointed out, posthumanism stems largely from western academic tradition and experience. As such, it doesn't always go far enough to challenge modernist/colonial mindsets and thinking, including in its call to move towards the post-human without deeply interrogating the category of human itself and how this has been used oppressively throughout colonial history (Schultz, 2017; Zembaylas, 2018). Furthermore, as Wynter (2003) has pointed out, not to interrogate if it is being human or rather the western version of being human that is in fact the problem. Does this render posthumanist work static and incapable of assisting in asking how to better inhabit the world? While this has been suggested by some scholars (Oliveira and Lopez, 2016), others have argued that the tension between these bodies work has the ability to spark learning (Schulz, 2017; Zembaylas, 2018). Drawing on Rojas' work on the Pluriverse, Zembaylas (2018) suggests that postcolonial and decolonial perspectives used together can "pluriversalize" learning. Schultz (2016) suggests that a "reapproachement" between these bodies of work could open up new understandings. In this thesis, posthumanist theory has offered a conceptual but also methological approach of finding a way to study the meeting points between humans and all other life in a world of research so dominated by humanist approaches. Decolonial theory has been used in a conceptual way to try and widen the map of thinking – but it would be interesting and important to explore the frictions between these theoretical traditions more deeply in on-going work and ask what a decolonial approach to method would look like.

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APPENDICES

Appendix 1: Ethical clearance form

UNIVERSITY OF CAPE TOWN

IYUNIVESITHI YASEKAPA • UNIVERSITEIT VAN KAAPSTAD

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18 March 2016

Maya Marshak
Department of Environmental and Geographical Sciences

The spaces around seeds: a creative ethnography of small-scale agri-cultural systems

Dear Maya Marshak

I am pleased to inform you that the Faculty of Science Research Ethics Committee has approved the above-named application for research ethics clearance, subject to the conditions listed below. You are required to:

- Implement the measures described in your application to ensure that the process of your research is ethically sound; and
- Uphold ethical principles throughout all stages of the research, responding appropriately to unanticipated issues: please contact me if you need advice on ethical issues that arise.

Your approval code is: **FSREC 09 – 2016**

I wish you success in your research.

Yours sincerely

Prof Timm Hoffman
Chair: Faculty of Science Research Ethics Committee

Cc: Rachel Wynberg - Supervisor

Appendix 2: Consent form sample

Informed Voluntary Consent to Participate in Research Study

Title of research project: Exploring changes to maize agriculture systems and the effects on farmers that come about by the introduction of new types of seed.
Names of principal researcher: Maya Marshak
Department/research group address: Environmental and Geographical Science
Telephone: 072 6250 367
Email: mayamarshak@gmail.com

Nature of the research: This research is interested in understanding better how new varieties of Hybrid and GM maize seed are affecting farmers and farming systems.

Participant's involvement: You are invited to participate in a research study conducted with a range of stakeholders involved in maize agriculture, processing and distribution such as farmers, millers, government employees, scientists, researchers, food and agriculture companies. I will be doing interviews and taking photographs with farmers and scientists involved in maize agriculture. The study aim is to develop an understanding of how new maize seed varieties affect farmers and farming systems. I believe that your experience would be a valuable source of information, and hope that you may find participation in this study useful too.

What's involved: During this study, you will be asked questions about your personal experience with how maize farming has changed since you have been a farmer. If possible and if you agree I would like to ask to be shown around your farm, and to take pictures if you are comfortable. I would like to take photographs of soil, insects, tools and other things that help me understand how the farm works and what is different on different farms. I also want to use the pictures to help me speak with farmers about the different insects and weeds and farming methods.

Costs: there should be no costs involved. Participants will not be given money in exchange but will receive a gift.

I agree to participate in this research project.
Y / N

I have read this consent form and the information it contains and had the
opportunity to ask questions about them.
Y / N

I agree to my answers being used for education and research on condition that my privacy is respected and my name/identity and personal information will not be used. Y / N

I understand that I can say I don't want to be part of this study. Y / N

I understand I have the right to withdraw from this project at any stage. Y / N

Name of Participant / Guardian if willing: ____

Signature of Participant / Guardian (if under 18): ___________________________

Name and Signature of researcher who sought consent: __________________________________

Date: ______________________________