Commercial agriculture in the Swartland: Investigating emerging trends towards more sustainable food production

by
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Thesis presented in partial fulfilment of the requirements for the degree Master of Philosophy in Sustainable Development, Planning and Management at the University of Stellenbosch

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March 2011

DECLARATION

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ABSTRACT

The aim of this thesis was to determine whether or not examples exist of commercial grain farmers in the Swartland region of South Africa moving away from high-external-input agricultural production systems towards production systems based on ecologically restorative partnerships with soils and other natural systems. The research also sought to understand why these farmers were changing their approach to farming, as well as investigating the specific technologies and practices they were implementing in order to achieve these changes. In addition, the thesis also considered the theoretical implications of these changes on food security in the Western Cape.

Three research approaches were employed: qualitative case studies of seven progressive farmers in the region; a literature review; and an analysis of secondary data. Throughout these three approaches, Swilling and Annecke's conceptualisation of a multifaceted global polycrisis was used as a conceptual reference point. This was done with the intention of providing an agricultural analysis which looks beyond the farm gate and takes cognisance of the broader socio-ecological issues which affect and are affected by agriculture.

The research identified seven farmers who are shifting towards lower-external-input production methods, which focus on enhancing beneficial partnerships with natural systems. The on-site interviews and observations revealed that the degree to which these seven farmers were altering their practices varied significantly. However, four key technologies and practices were identified as being common to all seven farmers: the use of legume rotations, reduced tillage, new styles of planters and increasing farm size.

With regard to food security, the research suggested that current changes in these farmers' agricultural practices could assist in keeping food prices and food production levels more stable in future, compared to production using high-external-input practices previously employed by the farmers. The potential improvement in production stability was shown to result mainly from improvements in soil health, as these improvements give crops increased resilience to unfavourable weather conditions, greater disease-resistance and improved vitality. The potential improvement in price stability stemmed predominantly from increased input-use efficiency and the utilisation of natural fertility and pest-management practices which were less susceptible to monopolistic input sales structures, international shortages and the increasing cost of fossil fuels.

Due to the small size of the case study sample and the fact that this research focussed specifically on farmers who were considered progressive, the findings presented in this thesis cannot be viewed as representative of the larger agricultural region. The intention was rather to establish the positive

changes currently underway, in order to provide useful pointers for similarly beneficial changes to be implemented elsewhere.

OPSOMMING

Die doel van hierdie tesis was om vas te stel of voorbeelde bestaan van kommersiële graanboere in die Swartlandgebied van Suid Afrika wat wegbeweeg van hoë-eksterne-inset produksie sisteme na sisteme wat gebasseer is op vennootskappe met grond en ander natuurlike sisteme. Die doel van dié vennootskappe isom ekologiese herstellingte bewerkstellig. Die navorsing het ook gepoog om te verstaan hoekom hierdie boere hulle boerderytegniekeverander; spesifieke tegnologieë en praktyke wat gebruik word om verandering mee te bringis ondersoek. Daarenbowe oorweeg hierdie tesis ook die teoretiese implikasies van die veranderings op voedselsekuriteit in die Wes-Kaap.

Drie navorsings benaderings is te werk gestel: kwalitatiewe gevallestudies van sewe vooruitstrewende boere in die area; 'n literatuurstudie; en 'n analise van sekondêre data. Swilling en Annecke se konsepsualisering van die veelvoudig-gefasetteerde globale polikrisis is deurlopend gebruik as 'n konsepsuele verwysingspunt. Dit is gedoen om'n boerdery analise daar te stel wat verby die plaashek kyk na wyer maatskaplike en ekologiese kwessies wat 'n wederkerige verhouding met boerdery het.

Die navorsing het sewe boere geidentifiseer wat na laer-eksterne-inset produksie metodes beweeg. Hierdie metodes fokus daarop om voordelige verhoudings met natuurlike sisteme te versterk. Onderhoude en waarnemings op die plase het vasgestel dat die graad van praktykverandering merkwaardig tussen die sewe boere verskil. Nietemin, vier gemeenskaplike sleuteltegnologieëen-praktyke is geidentifiseer: die rotasie van peulgewasse, verminderde grondbewerking, nuwe plantermodelle en die vergroting van plaasgroottes.

Met betrekking tot voedselsekuriteit vind die navorsing dat huidige veranderings in die wyse waarop geboer word, in vergelyking met die voorafgaande hoe-eksterne-inset produksie praktyke, kospryse en produksievlakke kan stabiliseer. Die navorsing wys daarop dat 'npotensiële verbetering in produksie stabiliteit 'n uitkoms van gesonder grond is. Gesonder grond verhoog gewasse se vermoëom effektief op ongunstige weerkondisies te reageer, bevorder hulle pes-afweringvermoë en verbeter die lewenskragtigheid van gewasse. Die potensiele verbetering in die stabiliteit van pryse is 'n nagevolg van meer effektiewe gebruik van insette en die gebruik van natuurlike vrugbaarheid en pesbestuurpraktyke wat minder vatbaar is vir monopolistiese inset-verkoopstrukture, internasionale tekorte en die prysverhoging van fossielbrandstowwe.

Na aanleiding van die klein skaal van die gevallestudies en die feit dat die navorsing spesifiek gefokus het op vooruitstrewende boere, verteenwoordig die bevindings in hierdie tesis nie die omliggende landbou area nie. Die veronderstelling was eerder om die positiewe veranderings wat tans

onderweg is vas te stel om sodoende bruikbare advies aan soortgelyke voordelige veranderings wat elders geimplementeer kan word te verskaf.

ACKNOWLEDGEMENTS

First and foremost I would like to thank the farmers for their time and patience with this thesis and acknowledge that much of the information herein is the product of an accumulation of many generations worth of knowledge and experience.

Secondly I would like to express my sincere gratitude to Candice Kelly, my supervisor, for her seemingly tireless dedication to improving the quality of this thesis through the review of, and feedback on, four drafts. I could not have asked for a better guide.

Thirdly, to my mother Penny, a huge 'thank you' for the many long hours you spent editing and reviewing my second draft. It was a task which spanned three countries and two departure lounges but your effort helped tremendously.

And finally I would also like to acknowledge and thank Stellenbosch University and in particular the Food Security Initiative, for the funding they provided for this research.

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LIST OF ACRONYMS

ARC	Agricultural Research Council
CEC	Crop Estimates Committee
DAFF	Department of Agriculture Forestry and Fisheries
EI	External Input
FAO	United Nations Food and Agriculture Organisation
FSI	Food Security Initiative
GHG	Green House Gas
GR	Green Revolution
GSA	Grain South Africa
HEI	High External Input
IAASTD	International Assessment of Agricultural Knowledge, Science and Technology for Development
LEI	Low External Input
MNC	Multinational Corporation
NAMC	National Agricultural Marketing Council
NS	Natural System
OA	Organic Agriculture
SDA	Secondary Data Analysis
SOC	Soil Organic Carbon
TFP	Total Factor Productivity
WEC	World Energy Council

CHAPTER ONE: INTRODUCTION

1.1 Background and motivation

There is currently a growing focus within the sustainability literature towards small-scale, localised, organic forms of agriculture (Sundkvist, Milestad, Jansson, 2005; Badgley *et al,* 2006; Magdoff, 2007; Pimbert, 2008). In the Global North these tend to be driven by a growing public demand for food which is healthier as well as less harmful to the environmental and social systems in which it is produced and consumed (Halweil, 2004; Taylor, Madrick and Collin, 2005; Pretty, 2006). In the South a similar trend exists within the developmental arena in which it is increasingly argued that agriculture be grounded in the principles of resilience and self reliance (Pretty, 2006; FAO, 2008). It is believed that this can be achieved through the use of localised low external input (LEI) forms of agriculture which work in closer partnerships with natural systems (Altieri, 1999; Pretty, 2006; FAO, 2008; Holt-Gimenez and Patel, 2009). These systems place the power of production in the hands of the farmers and local communities, encouraging them to form restorative partnerships with soils, animals and other living systems in order to reduce their dependence on credit providers and agro-chemical multinationals (Altieri, 1999; Pimbert, 2008; Holt-Gimenez and Patel, 2009).

However, the debate at an academic level appears to be polarised between those in agreement with the change towards LEI systems and those in favour of maintaining and expanding the high input Green Revolution (GR) methods[1], with very little meaningful dialogue taking place between the two camps (Pretty, 2006). During the coursework for my Honours degree in Sustainable Development, it seemed to me that the case against large-scale commercial GR agriculture was so strong that I found myself wondering how, given their supposedly fundamental unsustainability, the commercial farms I had grown up amongst still appeared to be functioning.

The literature to which I was exposed suggested that large-scale GR enterprises were simply operating on borrowed time, and remaining financially viable by externalising ever more of their costs and relying ever more on direct and indirect subsidisation (Altieri, 1999; Magdoff, 2007). To a large extent I accepted this explanation. Every year I saw spraying taking place, larger tractors appearing in fields, and the price of food steadily climbing. However, there was an image which kept coming to mind which prevented my full acceptance of this position: The image of a conventional farmer I had known while at school reacting with anger and frustration as we drove past a clayey field being deeply ploughed in the midst of a wet Cape winter. The picture stayed in my mind

[1] The Green Revolution refers to the application of modern agricultural technologies to agriculture, particularly in the developing world, in order to intensify production and raise yields. Technologies considered typical of the Green Revolution include synthetic fertiliser, pesticides, herbicides, high yielding modern seed varieties, tractors and other mechanical equipment, and increased irrigation (Jewitt and Baker, 2006).

because at the time I had never seen him angry and I was confused as to what he was upset about[2]. Now the memory returned because I realised that at least ten years before I had even heard the term 'minimum tillage', a large-scale commercial farmer was angered by the way that soil belonging to a person he had never even met was being mistreated. If this man cherished and valued the soil on which another farmer depended, then surely he was also concerned about protecting other aspects of his farming system. From my reading and coursework I had been exposed to a number of different narratives and perspectives about sustainable agriculture in South Africa, but none seemed to provide any insight into the type of large-scale commercial farmers I just described.

This led me to suspect that in between the often polarised debate regarding the pros and cons of large-scale GR agriculture and small-scale LEI farming there were local stories not being told, and that these stories could potentially be important at a time of multiple social, economic and environmental stresses. Swilling and Annecke refer to the convergence of these stresses as a 'global polycrisis' (Swilling and Annecke, Forthcoming), and join a growing number of individuals and institutions in highlighting the role agriculture has played in precipitating this polycrisis (Swilling and Annecke, Forthcoming; Bates and Hemenway,2010; Lal, 2010; FAO, 2009a; IPCC, 2007; Magdoff, 2007a; MA 2005). However, Swilling and others also demonstrate that not only is agriculture globally a significant driver of this polycrisis, it is also being adversely affected by the polycrisis. This suggests that in order to achieve long-term sustainability, agriculture needs to adapt to the impacts of the polycrisis while seeking to reverse the negative trends it helped to create. A reduction in non-renewable inputs facilitated by increased resource efficiency and a shift towards increasingly organic, self-produced inputs are important criteria for the restoration and adaptation of agriculture in the context of the global polycrisis (Lal, 2010; Pretty, 2006; Scherr, 1999; Altieri, 1999).

Given the likelihood of an emerging middle ground between large-scale GR agriculture and small-scale LEI farming, I wanted to understand if and how the commercial agricultural sector in the Western Cape was responding to the polycrisis of sustainability challenges facing agriculture globally, and in particular what this would mean for the poorest people in our society, who battle with chronic food insecurity on a daily basis.

Agriculture in the Western Cape serves as an interesting point of entry for this study, as this is a region of extreme cultural, economic and environmental convergence. The next three paragraphs attempt to briefly outline the situation in the region in the context of this research, and my motivation for undertaking it.

[2] In hindsight I assume that it was the destruction of soil structure which takes place when wet soil is ploughed that was upsetting him.

Of primary importance to this research is the fact that agriculture in the Western Cape is at an interesting juncture between developed and developing systems, and denies strict categorisation into either. On the one hand, farm sizes and levels of mechanisation are comparable to those of farms in Europe, Australia or the US, while on the other, farmers in the Western Cape receive none of the corresponding subsidies and only limited trade protection (Joubert, 2010). There is the potential that from this self-reliant position, internationally applicable lessons in more efficient, resilient farming can be drawn.

In terms of the region's cultural history, the agricultural sector in the Western Cape was historically closely aligned with the pre-1994 nationalist government, which has left it politically tarnished and stereotyped. Contentiously described by Patrick Noonan as 'the only white tribe in Africa' (Noonan, 2003), even the farmers themselves - who are predominantly white Afrikaners - are unique in the convergent cultural space they occupy between North and South. Despite the Western Cape being the most literate and generally best-resourced province in South Africa (Gbetibouo, 2009), racial segregation and socioeconomic inequalities remain critical issues. Against this backdrop of extreme socioeconomic inequality, food insecurity has emerged as a serious problem amongst the province's poor (Frayne *et al,* 2009).

Environmentally the Western Cape is unparalleled. With an entire floral kingdom, one of only six in the world, within its boundaries, the level of biodiversity found in the small region is trumped only by the Amazon (Conservation International, 2007). As the biggest land user in the region, agriculture in the Western Cape has a footprint on global biodiversity which is vastly disproportionate to its size (Conservation International, 2007). This situation brings agriculture up against strong local and international conservation movements. Small examples are beginning to emerge of alliances between conservationists and farmers, working together to conserve the region's ecological heritage and secure the future of their farms (Cape Nature, 2007; Goldblatt, 2010). This unique environment is an additional pressure on farmers to innovate so as to farm in ways which are more environmentally sensitive.

The unique positioning of agriculture in the Western Cape described above, together with the high levels of need for both social and environmental development are additional motivating factors for me in carrying out this research.

The funding provided for my Masters' thesis by Stellenbosch University's Food Security Initiative has also influenced the undertaking and focus of this research. The conditions of funding stipulate that this research focus on a topic which is of relevance to food security within the Stellenbosch

Municipal Area (SMA). This motivated me to focus on food crops produced within and adjacent to the SMA.

Finally, I am motivated by the encouragement of Eve Annecke[3], Mark Swilling[4] and Gareth Haysom[5] to research locally and to research towards understanding what *is* working rather than spending more time proving the unsustainability of current practices. I share their view that this is an important component for transforming the future and have tried to incorporate this philosophy into my research and methodology throughout my thesis.

1.2 Research objectives

The main objective of this research is to investigate whether or not examples exist of commercial GR farmers in the Swartland shifting towards LEI systems which are based on closer partnerships with natural systems. This is objective is in accordance with the assertions made in Section 1.1 by Altieri (1999), Scherr (1999), Pretty (2006), Pimbert (2008) and Lal (2010). These assertions state that in order to become sustainable, agriculture needs to shift towards much lower external input usage while forming restorative partnerships with other natural systems. Within this framework, the research aims to gain a better understanding of why farmers are choosing to shift their farming practices and how the transition to LEI systems is being achieved.

It is assumed that if significant changes in practice are taking place at farm level this will affect the long-term sustainability of food yields in the province and thus its long-term food security outlook. In To fulfil my commitments to the Food Security Initiative, understanding the effect of farm-level changes on the province's food security is the secondary objective of this research.

1.3 Research questions

The following set of questions serves to clarify the research objective and forms the foundation for this research:

I. Do examples exist of commercial farmers in the Swartland shifting towards lower-external-input practices which work in closer partnerships with natural systems?

If so:

II. What systems and technologies are these farmers using to achieve the above?

III. What are the motivating factors behind farmers' decisions to change the way they farm?

[3] Eve Anneke, director of the Sustainability Institute at Lynedoch.

[4] Prof. Mark Swilling is academic convener of Stellenbosch University's BPhil and MPhil in Sustainable Development Management and Planning.

[5] Gareth Haysom is the head of the Food Security Initiative at the Sustainability Institute and former Managing Director of Spier.

IV. What are the possible effects which the changes being made by farmers may have on long-term food production?

1.4 Value and relevance of study

This study is directly relevant to farmers, agricultural research institutions and policy-makers within the food security and agricultural sectors in the Western Cape. It is relevant to them because it aims to detail the practical changes being made at a farm level which could have positive long-term implications for agriculture and food security in the region. Indirectly the questions and findings within this paper are also of relevance to the same groups of people beyond the province, particularly in areas where large-scale commercial agriculture is practised.

By highlighting what certain farmers are doing to improve the way they farm and what prompted them to do so, it is hoped that the study will stimulate discussion about and consideration for the technologies and systems profiled in this paper. Indirectly the potential exists for all who rely on agriculture in the Western Cape for food or livelihoods to benefit from the increased use of what are arguably more resilient, cost-effective and sustainable agricultural practices.

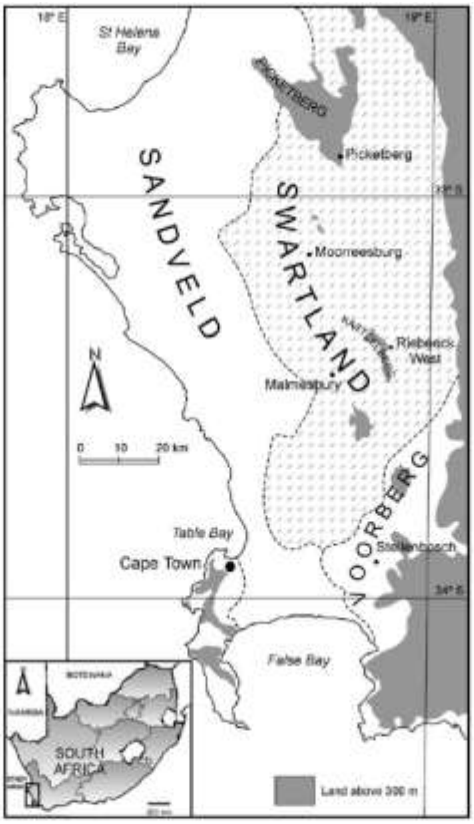
This study has chosen to focus on what can be considered a convergence point between those in opposition to the GR and those in favour of it. As such it is hoped that the study will contribute to the debate between the two paradigms by profiling a segment of agriculture which - in the struggle for its own long-term survival- appears to be evolving into a hybrid of the two.

1.5 Introduction to research design and methodology

The Swartland (see Figure 1.) was selected as the focus area for the study as it is one of the two major wheat-producing regions in the province and is considered an unforgiving farming environment in comparison to others in the country due to its climatic variability and shallow soils (Gregor, 2010; Rigter, 2010). The Swartland is therefore relevant to the region's food security as well as being a rigorous testing ground for potential future technologies. The harsh environment where risks are higher and profit margins slimmer could potentially push farmers to farm more efficiently and innovate to a greater degree in order to survive. From a practical research point of view, the region was within reasonable driving distance from Stellenbosch, which made time spent on field research more time efficient. I also had more connections amongst farmers in the Swartland than with those in the Overberg; this made the research process easier as it provided entry points for the 'snowball sampling'.

Furthermore, one of the conditions attached to the research funding I was allocated from the Food Security Initiative was that my research be of relevance to food security in Stellenbosch. As the most proximate wheat-producing region to Stellenbosch, the Swartland was the logical study area in this respect.

Figure 1: Swartland region in relation to Stellenbosch



Source: Conservation International. 2007

Within the study area the research focused specifically on case studies of farmers who have been progressive in lowering external inputs and overcoming sustainability challenges. The research aimed to generate a large amount of detailed data on each of the farmers selected, which necessitated a smaller sample size. The final sample size was also influenced by the number of farmers who were identified to be farming in ways which were relevant to the study.

Snowball sampling was used to source participants (Biernacki and Waldorf, 1981). Once potentially suitable farmers had been identified, farm visits and interviews with each farmer were conducted. These interviews used structured dialogue where standard questions and semiformal conversation are allocated equal weight in order to obtain a mix of qualitative and quantitative information (Ragin, 1994).

The structured section of the questionnaire aimed to gain general data such as farm size and range of crops, as well as detailed data on how much inputs have been reduced, how farm yields have changed and the state of general sustainability indicators. In order to get an idea of how these had changed, farmers were asked two sets of questions, one set relating to their farming in the 1980s and the other to their farming at present.

In addition to the research interviews, secondary data and a literature review were incorporated into the research design to augment the information gathered. The literature review involved a broad search of online academic journals in addition to a review of regionally specific agricultural research. This literature was used to frame the discussion on the region and to support and compare to the data gathered during the farmer interviews. Secondary data was also used to this end. The sources of secondary data included regional data released by Grain South Africa (GSA) on crop yield and input costs, the report of the Soil Carbon Research Project, which had conducted research into soil carbon on five of the farms I studied, and data released by Statistics South Africa in their Commercial Agricultural Censuses in 2003 and 2007. As the data from these sources were used predominantly to provide reference points and comparisons between the claims made by farmers and the regional averages, no data manipulation was undertaken during the analysis.

1.6 Key concepts

A number of the concepts and terms used consistently throughout this paper, and that form the basis of the discussions which take place within it, are ambiguous. This section aims to clarify by means of short definitions what is meant by each of these terms in the context of this paper.

Food security: A person is understood to be food secure when they have uninterrupted access to sufficient food to meet the nutritional requirements for a healthy lifestyle (World Food Summit, 1996). A region is understood to be food secure when all people within the region meet the above requirement, and food insecure when any component of the above is not met.

Low-external-input agriculture which works in closer partnerships with natural systems: This term denotes a system of farm management which improves the use of natural goods and services in order to reduce or eliminate the use of off-farm inputs (particularly those which are more toxic or widely contaminating). Examples of these natural goods and services include nitrogen fixation, soil nutrient cycling, the use of complementary crop and/or animal suites, pollination services, pest regulation, genetic and species biodiversity, and drought resistant soils. The definition also implies a more holistic consideration of the entire farm system but does not require that it be operated organically. The lowering of external inputs can also result from an increase in the efficiency with which external inputs used on condition that this does not counteract the improvement and restoration of agricultural ecosystems.

Green Revolution: The post-World War Two process of increasing the use of synthetic chemical inputs – predominantly fertilisers, herbicides and pesticides – in conjunction with high-yielding modern crop varieties, increased irrigation and increased mechanisation in order to maintain and increase agricultural production (Gliessman, 2005; Magdoff, 2007a).

1.7 Limitations and assumptions

This research is based on the following assumptions:

- Within the current crisis facing commercial agriculture globally, farmers in the Western Cape are being forced to adapt themselves and their practices in order to ensure their survival.
- The way that commercial agriculture in South Africa chooses to respond and adapt at this point will have a significant impact not only on the agricultural sector, but more importantly on the long-term food security and environmental wellbeing of the region.
- Commercial farmers are not a homogeneous entity; they vary significantly in their outlooks, approaches and practices. Therefore, while they may share similar problems, different coping strategies may emerge.

Due to time constraints, the number of farmers interviewed was a limitation to this study. Having time to locate and interview a greater number of farmers would have improved the depth of this research. Research into the practices of conventional farmers in the Swartland would also have been useful, as it would have allowed for improved comparison of the effects of the different management approaches.

Another limitation to this study was that the effects of the changes in farming practices on food security were not adequately explored. While regrettable, this was undertaken consciously in the understanding that sufficient and stable production are prerequisites for meeting two of the four pillars of food security which Web and Rogers (2003) as well as the World Food Summits of 1996 and 2002 identify: namely the existence of adequate quantities of food and the absence of risk that this availability will be disrupted.

1.8 Outline of chapters

This section outlines the six chapters as they appear in this paper, in order to provide an overview of the topics covered in each chapter and clarify the overall structure of the paper.

1. Chapter One introduces the focus of the paper and provides a background to the study so that the reader may better understand the context in which it is undertaken. This section also provides the motivation for undertaking this study from a personal and academic point of view. It also briefly outlines the limitations of the study and the assumptions on which it based.

2. Chapter Two provides a motivation for the selection of the research tools used. It then describes the design and the methodology of the research and research tools; namely the literature review, survey questionnaire and secondary data analysis.

3. Chapter Three extends the background and context which inform this study, via a review of the relevant literature. It begins with an introduction to international literature on the global polycrisis so as to provide a broad outline of the macro-context in which the study is situated and to which it responds. The chapter then samples texts from the debate on the global polycrisis and beyond which deal specifically with the challenges of agricultural development and food security. The focus of Chapter Three then moves on to a review of the solutions proposed by authors to the problems of agricultural development and food security – in particular the debate between those in favour of the expansion of GR technologies and those calling for a drastic departure from the practices put forward by the GR.

   The chapter then narrows to provide a picture of agriculture and food security in the Western Cape and how it is changing. This outline is primarily quantitative and relies heavily on existing statistical information from organisations such as Grain SA and Statistics South Africa. With this in place, the literature review shifts to providing possible explanations or drivers for the aforementioned changes which are taking place.

4. Chapter Four presents the results of the research and looks closely at the various changes taking place in the region, particularly the responses developed by farmers in response to the challenges they face. A large part of this chapter concerns the information captured in the interview process. The chapter concludes with an analysis of the effects of the responses which were implemented. These include the effects on farmers, the effects on farmlands and the effects on food security.

5. Chapter Five draws the paper to a close with a review of the research findings and a conclusion in response to the questions posed in Chapter One. It also relates these findings to the discussion on the global polycrisis found in section 3.2. In closing, recommendations for further study are made.

CHAPTER TWO: RESEARCH DESIGN AND METHODOLOGY

2.1 Introduction

The following section aims to outline the research process undertaken during this study and to justify the rationale behind the way in which the research was designed, conducted and interpreted. The section therefore begins by defining the questions which the research intended to answer. It then defines the way in which I set about obtaining the data needed, and concludes with a comparison between the desired and obtained data.

2.2 Research design

The research was designed to answer the research questions outlined in Chapter One 1. The objectives which it aims to achieve as follows:

I. Identify examples of commercial farmers in the Swartland who are shifting towards lower-external-input practices which work in closer partnerships with natural systems.
II. Come to a basic understanding of the systems and technologies these specific farmers are using to achieve the above.
III. Identify the drivers behind these farmers' decisions to change the ways in which they farm.
IV. Outline the effect which the changes being made by these farmers are having on long-term food production.

In order to achieve these four objectives, elements of three different research design types were employed. These were:

- Case studies based on a small sample of farmers in the region.
- A literature review of white and grey literature on agriculture in the region.
- The secondary analysis of existing industry data on agriculture in the Swartland.

The use of these three designs meant different sets of data were used to address complementary aspects of the same investigation. None of the four research objectives relied solely on one of the three research designs. For example, in determining the systems and technologies that farmers were adopting, data from all three research approaches were used. In this way, findings from one data set were validated by the findings from at least one of the other two data sets, which helped to improve the integrity of the findings. The availability of relevant data, particularly within the literature review and the secondary data, was a limiting factor in the study.

The cases studies based predominantly on farmer interviews formed the core of the research process. The findings and responses of the respondents were then used as a departure point for research into related industry and literary data which were used to provide quantitative reference points to their experiences as well as to cross-reference these experiences. Existing research into agriculture in the Swartland and Western Cape was used primarily to augment the interpretation of the interviewee responses.

Section 2.3, Section 2.4 and Section 2.5 describe the research methodology employed within the literature review, case studies and secondary data analysis respectively.

2.3 Literature review

This section describes the research methodology undertaken in the literature review and begins by defining a literature review as it is understood in this study. This is followed by a description of how the literature review intends to contribute to the achievement of the four research objectives and how the literature used was sourced and selected.

2.3.1 Introduction

Taylor and Proctor describe a literature review as "an account of what has been published on a topic by accredited scholars and researchers" (Taylor and Proctor, 2005: 1), while Mouton describes a literature review as an "overview of scholarship in a certain discipline through an analysis of trends and debates" (Mouton, 2001:179).

According to Taylor and Proctor a literature review must:

i. be organised around and related directly to the thesis or research question you are developing
ii. synthesise results into a summary of what is and is not known
iii. identify areas of controversy in the literature
iv. formulate questions that need further research

(Taylor and Proctor, 2005: 1)

Mouton goes on to say that a literature review can at best "only summarise and organise the existing scholarship" (Mouton, 2001:180). Although a literature review may lead to new theoretical insights, it cannot validate these insights or produce new empirical insights (Mouton, 2001).

2.3.2 Role of the literature review in meeting research objectives

This section will now explain how the literature review intends to contribute to the achievement of the four research objectives. Informed by the prerequisites laid out in Taylor and Proctor in 2.3.1 (particularly points (*b), (c)* and (*d)*) and the limitations described by Mouton, a literature review was deemed to be an appropriate means of contributing to the achievement of all four research objectives. The reasons for this are as follows:

RESEARCH OBJECTIVE I: Existing research into the region assisted in meeting research objective I by identifying examples of commercial farmers in the Swartland who have been shifting towards lower-external-input-practices which work in closer partnerships with natural systems. Existing literature about this was limited, which confirmed the need for my research into alternative farming practices in the region.

RESEARCH OBJECTIVE II: By reviewing recent and historical literature on agricultural practices in the region it was possible to gain information regarding the types of new technologies which had been adopted within the study region. This formed a useful point of comparison and validation for the data gathered during the farmer interviews. This literature also helped to elaborate on the descriptions given by farmers during the interviews. For example, Hardy (1998) and Smit (2004) had conducted extensive research into crop rotations in the Swartland, so their research was used to support claims made by farmers during the interviews that rotational cropping reduces their dependence on external inputs.

RESEARCH OBJECTIVE III: The extensive literature on the challenges facing agriculture internationally and a growing body of case studies focussing on change and adaptation within agriculture in the South was reviewed in order to understand what has driven change in agriculture in other regions. Where possible, local data were reviewed but this was limited in nature. These local and international data were used to support the drivers of change listed by farmers. The few Swartland specific studies that were available were particularly useful in terms of supporting the claims made by farmers during the interviews.

RESEARCH OBJECTIVE IV: One of the primary factors which the local and international case studies on changes in agricultural practice tend to focus on is the effect of new practices on crop yields. Where the changes in practice covered in the literature and the changes identified by farmers overlapped, this existing research assisted in providing insights into how food production might be influenced by the changes taking place.

2.3.3 Searching the literature

This section provides an explanation of how the literature used was sourced and selected.

A number of different channels were used in the process of searching for relevant literature: a search of relevant online academic journals, a reference list review of existing research, Google Scholar, a detailed search of the University of Stellenbosch's library catalogue and a number of relevant database search engines which encompassed all South African library catalogues and a complete list of current and completed South African research.

After a broad search of the internationally available literature pertaining to sustainability within the commercial agriculture sector I began to refine my search terms and focus more specifically on the literature directly relevant to the Swartland.

The subject librarian at Stellenbosch University suggested three particular South African databases which were likely to give me the best overall picture of available literature on my topic at a Swartland-specific level. These were *SACat*, which is a database of South African library catalogues; *Current and Completed Research* (within the *Sabinet* database), which as the name suggests is a database of current and completed research undertaken in South Africa; and *ISAP,* which is a database of articles in South African journals.

In searching these databases I defined a list of nine search terms which I felt were most likely to yield results relative to the study, based on prior reading. Because *biological farming, agroecology*[6] and *natuur boerdery*[7] are all established terms which focus on the use of natural systems in agriculture, I felt they were most suited to my search. I knew that in other areas where researchers had sought ways to improve agricultural sustainability a strong emphasis is often placed on the management of soils (IAASTD, 2009; Lal, 2006; Scherr, 1999) so I included a corresponding search term. I also included three open-ended search terms relating to both agriculture and sustainability in the Swartland in order to broaden the scope of the search, as a precautionary measure against missing outlying literature which the other more specific terms failed to identify. To this end I also added two generic search terms relating to agroecology and biological farming in South Africa. These terms were applied systematically across all three databases in turn. Table 1 lists these search terms and the results which each of the three recommended databases yielded.

[6] Agroecology is the "application of ecological concepts and principals to the design and management of sustainable agroecosystems" (Altieri, 1995)

[7] An Afrikaans term which translates to 'nature farming' and refers to a move towards more sustainable agriculture adopted by ZZ2 (Pty) Ltd. which is a large farming company in South Africa

Table 1: Search terms and data bases

	Search term	*SACat*	*Current and completed research*	*ISAP*
1	South Africa biological farming	5	8	65
2	South Africa agroecology	4	1	0
3	Swartland biological farming	0	0	1
4	Swartland agroecology	0	0	0
5	Swartland natuur boerdery	0	0	0
6	Swartland sustainab*	0	3	2
7	Swartland soil	11	10	32
8	Swartland agri*	18	10	42
9	Swartland production	4	9	79

While these results could not be considered to be a complete review of the available literature on the topic, the low level of responses in rows three to six in all three databases suggested a gap in the academic literature relating to alternative farming practices in the study region.

Despite the thin literature available on the study region a number of valuable texts were found, particularly those of Hardy, Meadows and Lanz, as well a number of masters theses originating from Stellenbosch University, University of Cape Town and University of the Freestate. The limitation to these masters theses, with the exception of the University of Cape Town research, was that they were all based on experimental trials conducted at the Langewens experimental farm near Malmesbury and focussed primarily on regional agronomy. In spite of their limitations these quantitative agronomic texts proved to be a valuable point of validation for the intuitive understandings which emerged from farmers during the interview process.

In addition to the academic material, literature was drawn from a number of other sources which included agricultural magazines such as *Farmer's Weekly* and *Landbou Weekblat*, and farmer information packs released by the Agricultural Research Council (ARC).

This concludes the description of the literature review, the following sub-section will now describe the case study methodology.

2.4 Case studies

As stated in Section 2.2, the farmer interviews formed the core of the research process. This section will therefore provide a detailed explanation of the case study process, including the process of participant selection and interviews, the design of the research questionnaire and the data capture.

2.4.1 Participant selection and questionnaire

I interviewed nine commercial farmers in the Swartland region. Two of them were interviewed twice - once during the preliminary stages of research in order to assist in the refining of the final questionnaire, and again after the final questionnaire had been compiled.

I began the interviewee selection process with a farmer to whom I had a prior connection and deemed relevant to the study. Following a discussion with this farmer he was able to recommend three other farmers in the region who might be of relevance to my research. He provided names and contact details for these farmers. I then followed up on the first of these farmers and repeated the process. This second interview also yielded three further contacts, two of whom were repeats of names given by the first farmer.

At this point I paused with the interviews and used the insights gained from these first two interviews to develop and expand the set of ten broad questions I had drafted into a more detailed questionnaire. The expanded product constituted the first draft of my final questionnaire. I approached Gareth Haysom, who is the Programme Manager for The Food Security Initiative at the Sustainability Institute in Stellenbosch for comment on this draft. Two comments were particularly influential. The first was that in his experience, particular sensitivity needed to be given to the differences in terms employed by different discourses to describe similar ideas, so as not to alienate oneself from those one is interviewing. In light of this I made some minor adjustments to the phrasing of my questions, such as changing my question on the loss of regional biodiversity as a result of agriculture to one which simply asked farmers about their sentiments towards regional biodiversity. His second comment was that because the research I was undertaking was ultimately exploratory in nature, I should take care to structure the questionnaires (and subsequently the interviews) in such a way that it would allow me to pick up on unexpected 'threads' as they emerged. This led me to increase the number of broad and open-ended questions in the questionnaire, such as "What do you see as the main challenges for your farm over the next ten to 20 years?" In hindsight this proved to be highly valuable, as these questions did indeed yield a number of unexpected but highly relevant answers.

I then piloted this second draft on Dougie Strachan, who is both a commercial dairy farmer and a fellow graduate of the BPhil in Sustainable Development. I reasoned that he would be able to provide practical feedback on the structure of my questions and the applicability of my use of language to commercial farmers, which he did. Two examples of this was the need to simplify the financially-orientated questions and the use of a one to five rating system to allow farmers to compare themselves against their neighbours in different categories.

During this period I had also met Amelia Genis, a longstanding agricultural journalist at *Landbou Weekblat* who is also particularly interested in the long-term sustainability of commercial agriculture in South Africa. Due to her longstanding reporting in the region and interest in alternative emerging approaches to agriculture within the commercial sector, Amelia was able to recommend six farmers in the Swartland who she thought would be relevant to my study. Once again three of these recommendations overlapped with the recommendations made by the two farmers to whom I had already spoken. This validated the relevance of the farmers whose names I already had, and their status as extra-ordinary farmers within the region. The overlapping of interviewee recommendations provided by three different sources also provided me with an initial justification for selecting the farmers with whom I would begin the second phase of interviews using my finalised questionnaire. I began my interviews with two farmers who had been highly recommended by all three sources.

At the end of the interview process with these two farmers I once again asked for further recommendations in the region, a practice which I repeated at the end of every interview. Biernacki and Waldorf describe this approach as ‘snowball sampling’ (Biernacki and Waldorf, 1981). This process of snowball sampling led me to a total of seven farmers in the Swartland, all of whom but one had been recommended to me by a minimum of two sources. At this point it appeared that although I had built up several recommendations of farmers in other regions such as the Overberg, I was no longer coming up with new names for the Swartland. As the remaining recommendations which I had gathered through Amelia and the local farmers were beyond my study area I decided not to follow these leads.

At this point I set out to confirm whether or not there were any further farmers within the boarders of the study region to whom I could put my questionnaire. My first step in doing this was to consult other academic research in the region.

I found two texts which I felt could help. These were a masters thesis titled *Soil nitrogen dynamics and spring wheat production in different cropping systems in the Swartland* by Wessels (2001) and a paper emanating from the Department of Agriculture Forestry and Fisheries’ (DAFF) LandCare

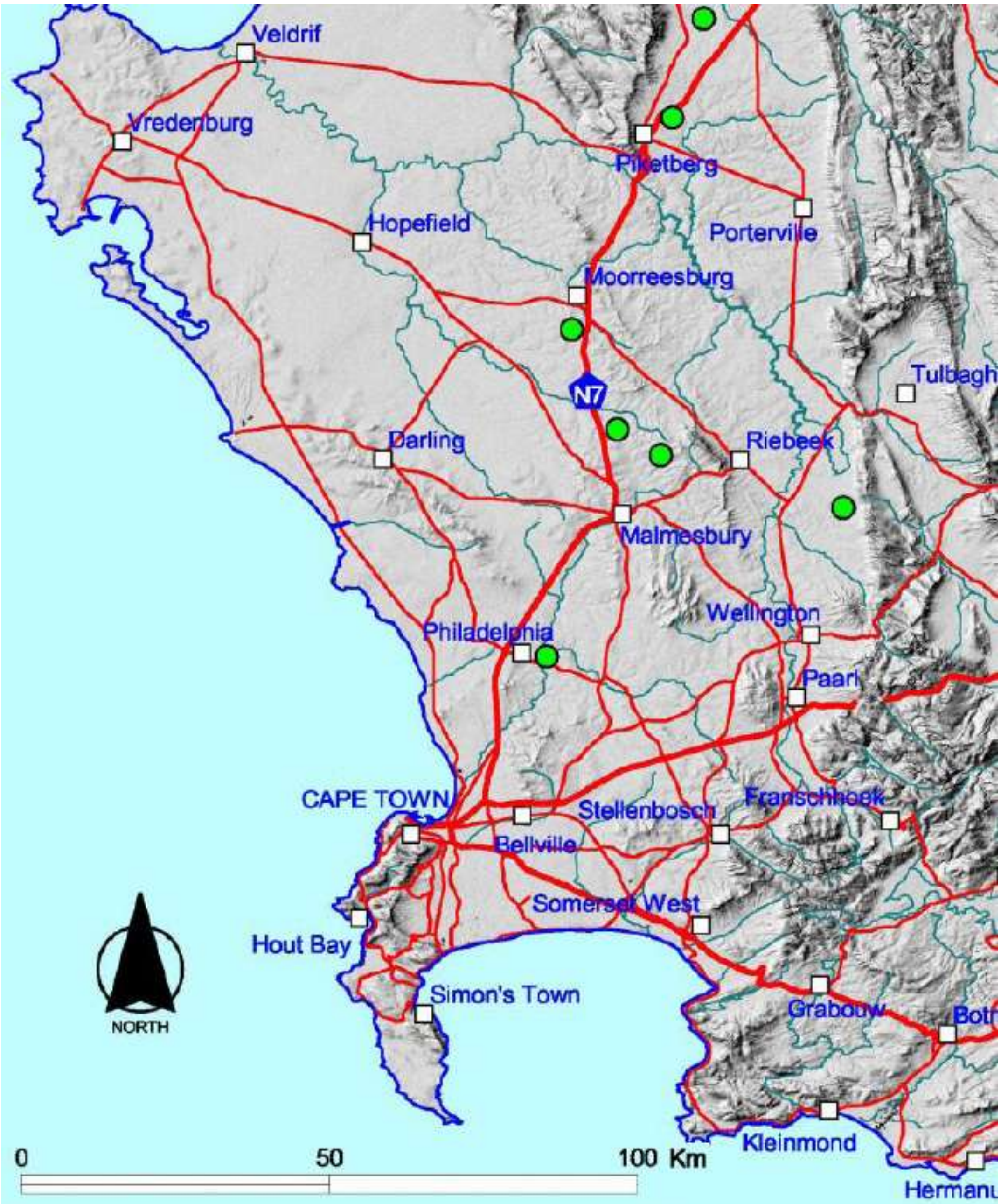
Program[8] titled the *Report of the Soil Carbon Research Project: Final Report* (Lanz, 2009). I hoped that as these papers had conducted recent research into alternative farming practices in the Swartland they would list the farms which they had investigated. It turned out, however, that neither would yield new farmers. Wessels's study had focussed solely on a number of 50 square metre test sites at the Langewens experimental farm run by the DAFF, and could thus provide me with no information about functioning farms in the region, and I had already visited all of the farms on which the Lanz study had focussed in the Swartland.

The fact that I had already covered all of the farms identified by Lanz added a third independent reference to the fact that my process of farmer selection was succeeding in identifying valuable case studies. The fact that the Lanz study, despite having operated independently of my own and in partnership with Landcare Programme, had not included any farmers other than those I had already interviewed suggested yet again that I was coming to the end of potential candidates in the area.

The geographical spacing of the farms (illustrated in Figure 2) also provided a fairly even spread across the region, both spatially and in terms of the proximity to mountain ranges a key geographical feature in the region which significantly affects rainfall (Morel, 1998). This spread also succeeded in capturing a wide variety of soil types, which also serves to broaden the potential applicability of the interview findings to other farms and regions.

[8] The Landcare Programme is a component of DAFF which seeks to improve agricultural land management by developing and promoting appropriate knowledge and technologies.

Figure 2: Map showing geographical location of interviewees' farms



Source: Lanz, 2009. Geographical locations added by myself.

2.4.2 Structure of the final questionnaire

The previous section described the participant selection process and the way in which the development of the questionnaire took place through this. This section aims to analyse and justify the final structure of the questionnaire. The full questionnaire can be found at the end of this section.

To begin with, it is important to note that the questionnaire was intended to contribute data to all four of the research objectives outlined in Section 1.3 through the creation of a set of broad but detailed cases studies. Mouton describes a case study as an empirical study which captures either text or numerical data in order to provide in-depth, qualitative information on a small number of subjects (Mouton, 2009). I accepted the limitation of this approach to be that the results would not be generalisable, but felt that this was not a problem as I was aiming to use the data obtained from the questionnaires in order to understand if and how an emerging trend was taking place, rather than proving the extent to which it occurred.

The questionnaire was divided into two distinguishable sections, the first aimed to create an understanding of each farm system in the past, while the second pertained primarily to the present status of the farm. This was done in order to gauge the nature and extent of change which had taken place on each farm. The 1980s were selected as the historic point of reference. Originally a fixed date was set at 1980, as this was deemed to be as far back as farmers were likely to be able to remember, while at the same time preceding most of the changes which began to take place in the 1990s and 2000s, particularly following agricultural deregulation. However, a number of the farmers had only begun farming on their farms later in the 1980s, so the questionnaire was conducted from the date from which they began farming, but no earlier than 1980.

Both the past and present sections began with a standard set of questions which were kept identical for both sections. As displayed in Figure 3a and 3e, these started off with a foundational set of 19 questions which aimed to capture broad social, environmental and economic facts about the farm system such as farm size, average rainfall and number of employees. This was followed by a review of the farm's products/outputs, in which the farmer was asked to list all crops and livestock raised as well as the yield per hectare and cost per unit of these outputs. As it could not be expected of farmers to recall these exact figures from as far back as 1980, they were asked to rate themselves in comparison to their neighbours at the time and to themselves in 2010. When combined with the same set of questions from 2010, this rating system allowed for a subjective analysis of changes in the productivity and cost of production. Comparison between the past and present components of this data also indicated how the farmers felt their systems were improving or declining in relation to their neighbours who had continued to farm largely as they had in the past. It also offered a good indication of the extent to which farmers had diversified their production systems over time. This section included a question on the soil productivity indicators which had been measured in the past. The question repeated the process of having the interviewees' rate themselves according to their neighbours at the time and themselves in 2010, in order to obtain similar comparative data regarding soil productivity.

Following this were 35 questions pertaining to input usage, copies of which can be found under Figure 3b and Figure3f. These 35 questions were posed twice, once in the past section and again in the present. This section on input usage was important for two reasons: firstly, it contextualised the preceding section on outputs as it enabled me to check if the changes in productivity were a result of changes in inputs. For example, if a farmer reported a drastic increase in yields over the last 20 years, it could be checked to see whether this had been achieved by simply shifting from a low–input/low-output system to a high-input/high-output system or vice versa. Secondly, the questions on input usage aimed to determine how the volume and nature of farm inputs has changed over the past 20 to 30 years. This information was important in determining whether or not farmers had shifted to LEI systems which worked in closer partnerships with natural systems. In terms of the nature of the farm inputs, I was looking for a shift away from synthetic external inputs (such as synthetic fertilisers and pesticides) towards increasingly natural self-produced inputs (such as composts and legume rotations). As was introduced in Section 1.1, and will be shown in Chapter Three, this shift towards increasingly natural and self-produced inputs is an important criterion for the restoration and adaptation of agriculture in the context of the global polycrisis. The motivation for the shift towards increasingly organic and self produced inputs is discussed further in Section 3.4, 3.5 and 3.6, in which it is argued that the economic viability of a farm is closely linked to its ecological integrity and that both of these are adversely affected by increasing reliance on and consumption of synthetic external inputs.

The last set of the standard questions which were posed in both the past and present sections pertained to the social networks and learning structures in which the farmers participated. This section consisted of 11 questions, some of which were open-ended, that aimed to determine how farmers were obtaining information about their farming practices and with whom they would likely to have shared their knowledge. This was undertaken largely in order to assist in answering why farmers were changing the way they farm and the role which information networks played in changing practices.

On each page within this standardised section I allowed space to record any additional information which the interviewee might offer during the process, and I included a prompting question to this end, which asked for any ‘general reflections or important events’ around the time.

Following the standardised section in both the past and present sections were an additional six and eleven questions respectively, copies of which can be seen under Figure 3c, 3d and 3g. These sections were designed to understand how and why farmers had changed in the past, as well as how and why they saw themselves changing in the future. The questions were open-ended and began with questions which aimed *not* to lead interviewees in their responses. These questions also aimed to open up a space for open conversation. Questions such as ‘Between 1980 and 2010 what new tools or systems have you adopted or experimented with?’ and ‘What do you see as the main challenges for your farm over the next 10 to 20 years?’ were posed.

Once these responses had been captured the final questions in the questionnaire sought to determine the degree to which the farmers in the case studies could be considered to be responding to the global polycrisis as defined by Swilling and Annecke (Forthcoming). These questions related to key global challenges such as energy demand, population growth, climate change and biodiversity loss, as discussed in Section 3.2. This was done not only to assist in determining the drivers of agricultural change in the region, but also to determine the relevance of the solutions farmers were developing to the resolution of the global polycrisis. A copy of this can be found under Figure 3h.

Figure 3a: Questionnaire page 1

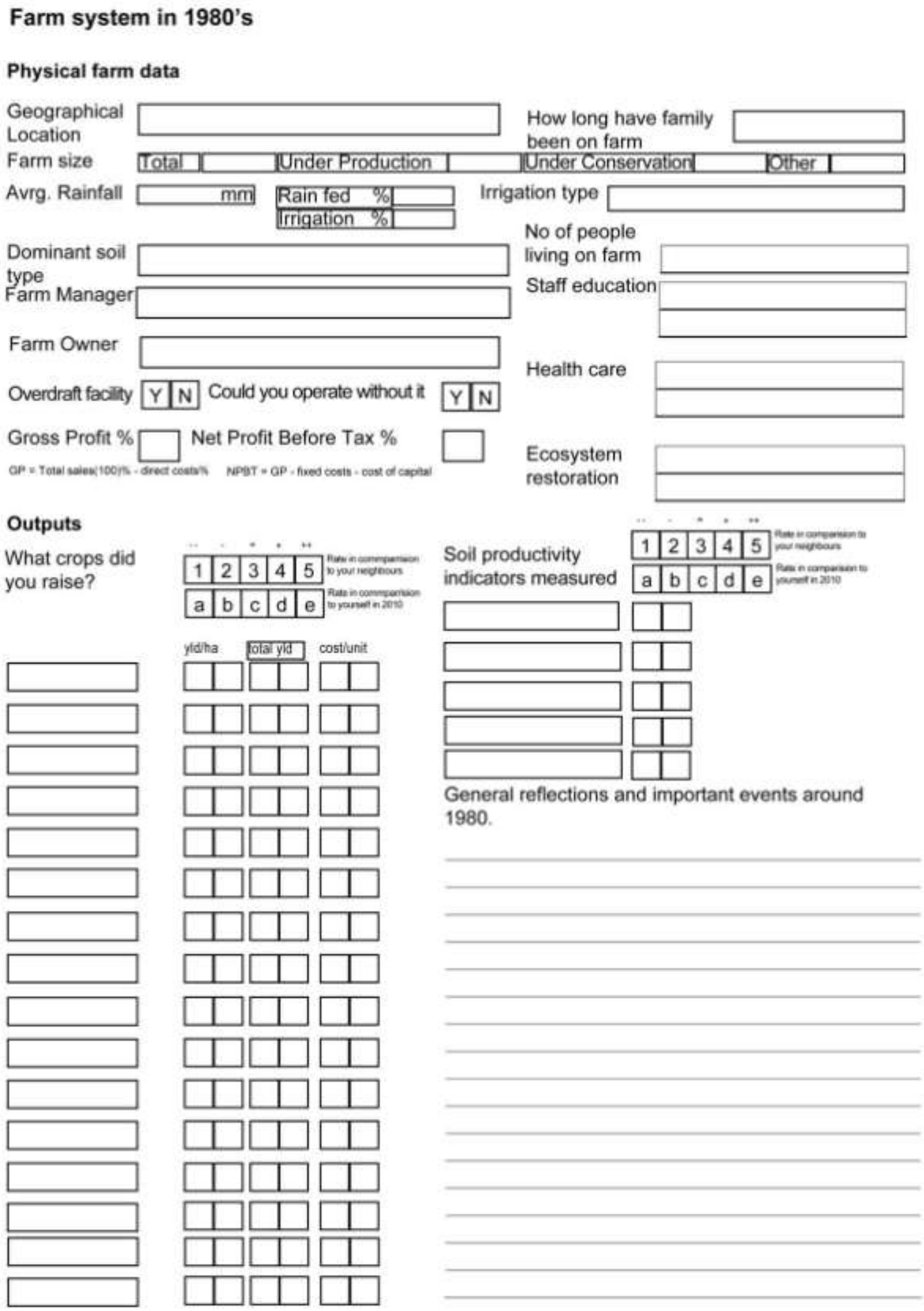


Figure 3b: Questionnaire page 2

Inputs:

What % of the of the following did you:	Buy in	Generate on farm
Nitrogen		
Potassium		
Phosphate		
Compost		
Manure		
Seed		
Animal feed		
Animal stocks		
Water		
Electricity		
Weed control		
Pest control		

What % of the herbicide you used was: Green ☐ Yellow ☐ Red ☐

What % of the pesticide you used was: Green ☐ Yellow ☐ Red ☐

Rate your usage of:

--	-	=	+	++	
1	2	3	4	5	Rate in comparison to your neighbours
a	b	c	d	e	Rate in comparison to yourself in 2010

N Fertiliser	☐☐☐	Lime	☐☐☐	Cover crops	☐☐☐	Water	☐☐☐
P Fertiliser	☐☐☐	Pesticide	☐☐☐	Green manure	☐☐☐	Agro-forestry	☐☐☐
K Fertiliser	☐☐☐	Herbicide	☐☐☐	Other rotations	☐☐☐	Wildlands belts	☐☐☐
Compost	☐☐☐	Diesel	☐☐☐	Mulches	☐☐☐	________	☐☐☐
Manure	☐☐☐	Electricity	☐☐☐	Microbial stimulants	☐☐☐	________	☐☐☐
Compost Tea	☐☐☐	Legumes	☐☐☐				

Social network and learning structure

What were the most important sources of information to you in this period?

Did you belong to:		How often did you		Agricultural texts read:
Boere Vereeniging	Y N	Speak to other farmers	☐	
Study group	Y N	SMS other farmers?	☐	
Other agricultural organisations	Y N	Write to farmers?	☐	
		Visit other farms?	☐	

How often did you attend talks or short courses related to farming? ☐

Educational background? ☐

Level of influence of the DoA on your farming practices? High | Med | Low | None ☐

Figure 3c: Questionnaire page 3

Discussion notes

Between 1980 and 2010 what new tools or system have you adopted or experimented with?

What was the single biggest element or practice which you changed between 19080 and 2010??

How did you first become aware of these new practices and what evidence did you use to determine thier applicability to your context?

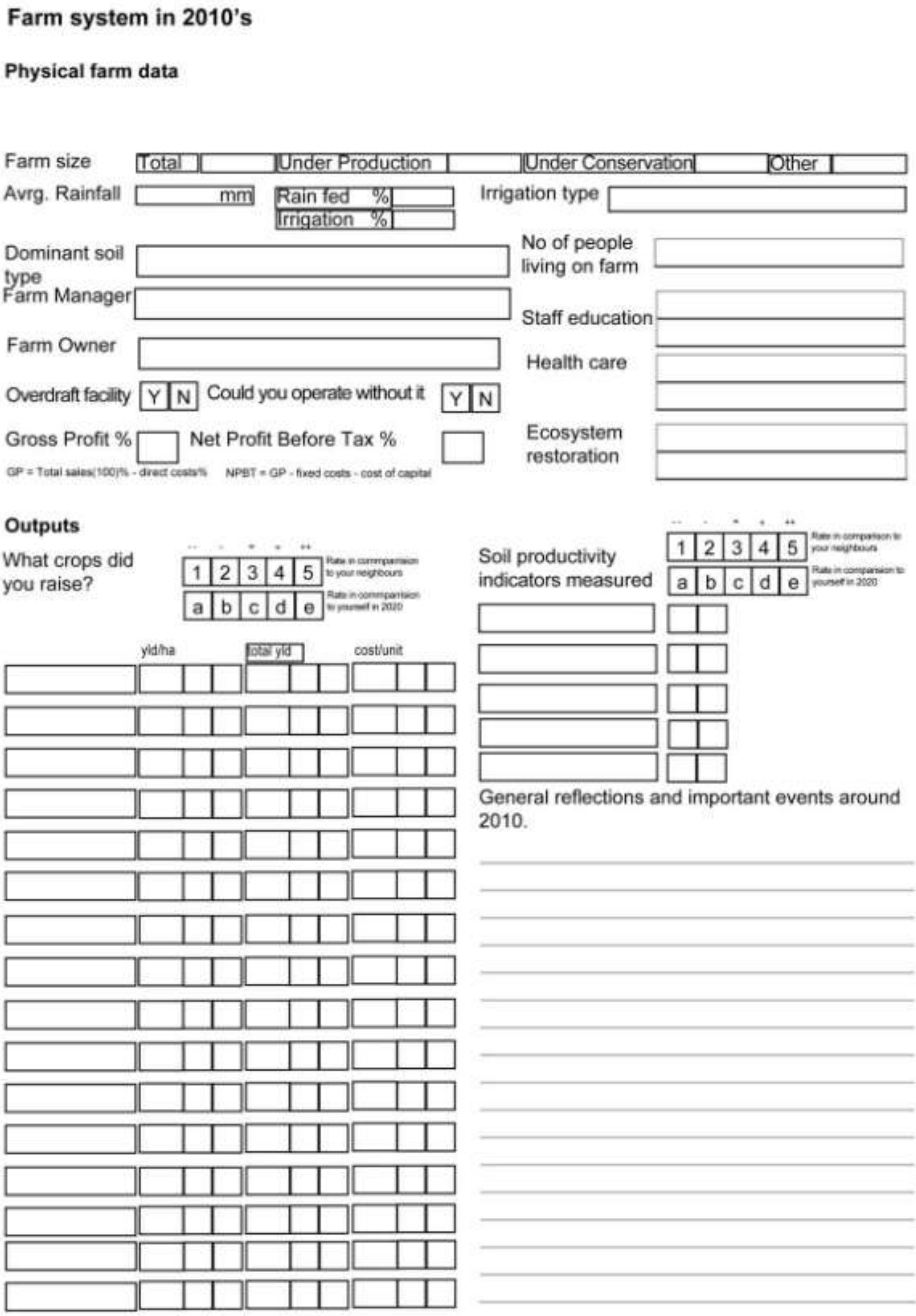
Figure 3d: Questionnaire page 4

What prompted you to undertake the changes you have just described?

Of the changes in practice you have undertaken, which were not adopted by most other farmers around you?

Why do you think they did not adopt these practices?

Figure 3e: Questionnaire page 5



Farm system in 2010's

Physical farm data

Farm size: Total | Under Production | Under Conservation | Other

Avrg. Rainfall ___ mm | Rain fed % | Irrigation % | Irrigation type

Dominant soil type

No of people living on farm

Farm Manager

Staff education

Farm Owner

Health care

Overdraft facility Y N | Could you operate without it Y N

Gross Profit % | Net Profit Before Tax %

GP = Total sales(100)% - direct costs% NPBT = GP - fixed costs - cost of capital

Ecosystem restoration

Outputs

What crops did you raise?

-- - + + ++

1 2 3 4 5 Rate in commparison to your neighbours

a b c d e Rate in commparison to yourself in 2020

yld/ha | total yld | cost/unit

Soil productivity indicators measured

-- - + + ++

1 2 3 4 5 Rate in comparison to your neighbours

a b c d e Rate in comparison to yourself in 2020

General reflections and important events around 2010.

Figure 3f: Questionnaire page 6

Inputs:

What % of the of the following did you:	Buy in	Generate on farm
Nitrogen		
Potassium		
Phosphate		
Compost		
Manure		
Seed		
Animal feed		
Animal stocks		
Water		
Electricity		
Weed control		
Pest control		

What % of the herbicide you used was: Green ☐ Yellow ☐ Red ☐

What % of the pesticide you used was: Green ☐ Yellow ☐ Red ☐

Rate your usage of: -- - ~ + ++ | 1 | 2 | 3 | 4 | 5 | Rate in commparison to your neighbours

| a | b | c | d | e | Rate in commparison to yourself in 2020

N Fertiliser	Lime	Cover crops	Water
P Fertiliser	Pesticide	Green manure	Agro-forestry
K Fertiliser	Herbicide	Other rotations	Wildlands belts
Compost	Diesel	Mulches	________
Manure	Electricity	Microbial stimulants	________
Compost Tea	Legumes		

Social network and learning structure

What were the most important sources of information to you in this period?

Did you belong to:		How often did you		Agricultural texts read:
Boere Vereeniging	Y N	Speak to other farmers		
Study group	Y N	SMS other farmers?		
Other agricultural organisations	Y N	Write to farmers?		
		Visit other farms?		

How often did you attend talks or short courses related to farming?

Educational background?

Level of influence of the DoA on your farming practices? High | Med | Low | None

Figure 3g: Questionnaire page 7

Discussion notes

Change and adaptation:

Who do you see taking over the ownership/management of this farm from you?

What do you see as the main challenges for your farm over the next 10 – 20 years?

What are you doing to overcome these challenges and how do you think the way you farm will change?

Figure 3h: Questionnaire page 8

Do you subscribe to the concept of peak oil? And how much do you think the oil price in the future will increase the cost of fuel and farm chemicals?

Do you consider the forecast changes in regional weather patterns as a result of global warming to be a threat to your business?

Is the security of your land tenure and the process of land redistribution and restitution a concern for you? If so does it affect the way you farm?

How will the rise in the electricity price affect your energy consumption?

How do you view regional indigenous biodiversity in relation to your farm?

If you irrigate how do you think the increasing competition for available water resources in the WC will affect the way you are able to farm?

In your view, what area of agriculture is in the biggest need of research and development?

In your view, what type/types of agriculture are best suited to reducing world hunger and feeding a growing world population?

2.4.3 The interview process

The interview process was fairly straightforward. The interviews were prearranged telephonically for a time and place which suited the farmer, generally on their farms (for summary see Table 2). Amelia Genis or the farmer who had recommended the next farmer I was intending to interview would generally phone ahead as a courtesy to notify the new farmer that I would be contacting them. I suspect that the fact that I had been introduced by a familiar party helped to increase the receptiveness of the new farmers to my questions. I chose to conduct the interviews myself, face-to-face with the farmers. Brace (2008) states that this method of interviewer-administered questionnaires has a number of benefits over self-administered questionnaires. These include being able to handle queries relating to the meaning of questions, correct misunderstandings and explore deeper into the responses to open-ended questions. This ability to explore open-ended or unexpected responses was particularly important to me considering the exploratory nature of the study.

Initially getting farmers to agree to interviews was not a problem, but as the final interviews were being conducted during the planting season, in which farmers have only a few weeks to prepare and plant their fields before the first of the winter rains, farmers became reluctant to take the time to be interviewed. The issue was easily overcome, however, by suggesting to farmers that I join them in their tractors while they worked. This worked particularly well as the tractor cabins were well insulated and the process of preparing large fields is a relatively monotonous and lengthily process. Tractor-cabin-interviews removed all sense of time pressure from the process and provided valuable insights I would not have gained had the interviews been conducted in the farmhouse living room. Interview times ranged between two and five hours, depending on the willingness of farmers to enter longer discussions and their enthusiasm to show me around their farms to see points of interest. On average the process took about three and a half hours.

The farm tours were an extremely valuable information-gathering process in that they often raised new material for discussions and allowed me to gauge the extent to which systems and technologies raised in the questionnaire had been implemented. During these tours, additional notes and photographs were collected.

Table 2: List of interviewees, farms, and interview dates

No.	Location	Farm name	Farmer name	Farm size	Date
1	Malmesbury	Silvermyn	Peter Steyn	1100 ha	04/05/2010
2	Bo Hermon	Elandsberg	Mike Gregor	6500 ha	09/03/2010 & 04/05/2010
3	Philadelphia	Uitkyk (1)	Junior Heroldt	1800 ha	05/05/2010
4	Morreesburg	Uitkyk (2)	Cobus Bester	2250 ha	12/05/2010
5	Picketberg	Partyskraal	Francious Ekstien	2486 ha	14/05/2010
6	Pools	n/a	Aubrie Rigter	1000 ha	14/05/2010
7	Malmesbury	Elim	Dirk Lesch	395 ha	14/03/2010 & 14/05/2010

2.4.4 Data capture and analysis

The questionnaire data for each farmer were transcribed from the paper forms into a digital format using a standardised template. The template was designed to allow easy comparison between time periods on a specific farm, as well as comparison between farmers[9]. As in the questionnaire, the data were categorised during capture into distinct sections; namely a Standardised and a Discursive section. As the same set of questions had been asked twice in the Standardised section, once for the past and once for the present, this section of the data capture sheet was divided into two columns on the same page to allow for easy comparison between the same subsections at different points in time.

In determining whether or not farmers had in fact shifted to LEI systems which worked in closer partnerships with natural systems a comparison between their inputs and practices in the past and present sections was made. In order to avoid misunderstandings and conflicting interpretations of terms, farmers where not asked directly whether or not they had shifted to LEI systems which worked in closer partnerships with natural systems. Instead a range of questions were asked which sought to determine whether or not their synthetic inputs had increased or decreased over time, whether their organic inputs had increased or decreased over time, and how these increases or decreases had been achieved.

[9] For examples of individual interview capture sheets with recorded data see Appendix A, B and C

2.5 Secondary data

2.5.1 Introduction

As only a small sample of farmers had been interviewed, secondary data were used to augment and broaden the findings from the farmer interviews and literature review. Mouton (2009) describes secondary data analysis (SDA) as an empirical study which reanalyses existing data in order to test a hypothesis or validate a model. The primary focus of the SDA was to achieve the following three points:

1. Support a better understanding of the drivers of agricultural change in the Swartland (research question III).
2. Support a better understanding of the nature of changes farmers were adopting in response to the challenges in the region (research question II).
3. To gauge the effects of the drivers of change and farmers' responses to them on the Swartland's food production (research question IV).

2.5.2 Ideal anticipated data versus obtained data

While it was the intention of the research into secondary data to provide accurate information to achieve the previous three points, this was limited by the available research into the topic. As such it is important to take cognisance of the discrepancies between the secondary data that were anticipated and the actual data which were obtained. Table 3 lays out the differences between anticipated and obtained data for each of the three SDA goals.

Table 3: Comparison between anticipated and obtained secondary data

Objectives	Anticipated data	Actual data obtained
Support a better understanding of the drivers of agricultural change in the Swartland	Financial: Crop-specific data on the cost of production inputs in the Swartland between 1980 and 2010	Financial: Data detailing the cost of wheat production in the Swartland between 1999 and 2007 (Grain South Africa, 2007
	Soil health: Indicators tracking general soil health for the Swartland between 1980 and 2010	Soil health: Comparison of soil carbon measurements on five of the case study farms (Lanz, 2009) Data tracking wind and water erosion in the Swartland between 1942 and 2003 (Meadows, 2003)
Support a better understanding of the nature of changes farmers were adopting in response to the challenges in the region	Inputs: Data tracking regional changes in fertiliser use	Inputs: No data available
	General agricultural indicators: General farm data for the Swartland such as farm sizes, labour levels and crops produced	General agricultural indicators: Commercial Agricultural Census data for the Western Cape between 2002 and 2007 (Statistics South Africa, 2002; Statistics South Africa, 2007)
Gauge the effects of the drivers of change and farmers' responses to them on the Swartland's food production	Changes in cost of production: Data reflecting the changes in the cost of the main agricultural outputs in the Swartland between 1980 and 2010	Changes in cost of production: Data detailing the cost of wheat production in the Swartland between 1999 and 2007 (Grain South Africa, 2007) Cost comparison between wheat grown in a monoculture system and wheat grown in a No Till and a Wheat to Medic system in the Swartland. (Grain SA, 2010)
	Changes in food volumes: Data reflecting the changes in the volume of the main agricultural outputs in the Swartland between 1980 and 2010	Changes in food volumes: Only broad data for winter cereals were available from the Crop Estimates Committee. This was not of use as it included a number of provinces.

The variances displayed in the Table 3 indicate that while a number of relevant sources of secondary data were obtained, particularly with regard to the changes in the cost of production and soil health in the Swartland, there were also areas where no applicable secondary data were available. Topics for which no secondary data were obtained included the tracking of regional changes in fertiliser use and the changes in the volume of primary food outputs. This lack of data in these fields limited the conclusions which could be reached with regard to research questions III and IV.

2.5.3 Analysis and interpretation

Despite the somewhat limited nature of applicable secondary data, a number of valuable data sets were identified and utilised. The sources of these data are outlined below in Table 4.

Table 4: Sources of secondary data

No.	Source	Title	Subject	Date generated
1	Grain SA	*Wheat Production Costs 1999-2007*	Wheat production in the Swartland	2007
2	Grain SA	*Kunsmis/Fertiliser*	Fertiliser price trends	September 2008
3	NAMC	*Update: Trends in selected input prices*	Agricultural input prices	November 2009
4	Stats SA	*Survey of Large-scale Agriculture 2002*	Trends in commercial agriculture	2003
5	Stats SA	*Survey of Large-scale Agriculture 2006*	Trends in commercial agriculture	2007
6	Lanz	*Report of the Soil Carbon Research Project*	Soil carbon changes	September 2009
7	Crop Estimates Committee (DAFF)	*The Final Area Planted and Crop Production Figures of Winter Cereals 2009 Season*	Winter cereals planting and production estimates	6 May 2010

As the data from these sources were used predominantly to provide reference points and comparisons between the claims made by farmers and the regional averages, no data manipulation was required. Figures for average wheat yields or soil organic carbon (SOC) levels were used as they were presented in the source text and were interpreted as guidelines rather than exact figures, while the data for primary wheat production costs were assembled from a spreadsheet spanning a number of years and represented in the form of a graph in order to illustrate the trends present in the data. This suited the exploratory nature of this research well, as primary data provided by farmers were interpreted in a similar manner.

This completes the explanation of the secondary data used in this study. The following section will draw Chapter Two to a close with a final review of the research objectives and the degree to which they were met through the use of the literature review, farmer case studies and secondary data.

2.6 Summary

The research design and methodology set out to answer four research questions. Table 5provides a preliminary summary of the degree to which the research succeeded in meeting these objectives.

Table 5: Comparison between desired and obtained objectives

Objective no.	Desired objective	Obtained objective
I	Identify examples of commercial farmers in the Swartland shifting towards lower–external-input practices which work in closer partnerships with natural systems.	Seven farmers were successfully identified.
II	Come to a basic understanding of the systems and technologies that these farmers are using to achieve the above.	A range of systems and technologies was identified though the interviews and literature review.
III	Identify the drivers behind farmers' decisions to change the way in which they farm.	A range of drivers was identified though the interviews, SDA and literature review.
IV	Outline the effects which the changes being made by farmers are having on food production.	Only limited success. Some information on the volume and diversity of food produced, but very little on the effect of the cost of food production.

This section set out to outline the research process undertaken during this study and to justify the rationale behind the way in which the research was designed, conducted and interpreted. A blend of case study research, secondary data analysis and a literature review was presented as the best way to answer the research questions within the framework of a masters thesis. This approach yielded successful results for the first three research objectives and limited results for the forth objective.

The first of the three research methodologies to be discussed in Chapter Two was the literature review, this literature review follows in Chapter Three.

CHAPTER THREE: LITERATURE REVIEW

3.1 Introduction

The literature review provides an overview of the global polycrisis, guided by the conceptualisation of seven key focus areas as expressed by Swilling and Annecke. This is done in order to better understand the challenges agriculture faces on a global level as well as agriculture's impacts and responsibilities. Swilling and Anneckes' conceptualisation of the polycrisis also serves as a conceptual grounding and reference point for the remainder of the literature review which follows, as well as the case studies and secondary data in later chapters[10].

Following the discussion on the global polycrisis the literature review focuses in on the challenges faced by agriculture and food security globally. As this research focuses on the production component of food security, more attention is paid to the production-related segment of this multi-faceted problem. In doing so this section helps to lay the framework for answering research questions III and IV. Within this section it will be argued that currently access to food is the key driver of food insecurity and that farmers globally are struggling to manage their enterprises due to sharply increasing production expenses. It is also suggested that there is a close connection between the cost of agricultural production and food security, and that both are negatively affected by the polycrisis.

This provides an entry point into a discussion on proposed solutions within the literature about the challenges faced by agriculture and food security, which helps to provide a framework for answering research questions I and II. The section is concluded with a motivation for focussing on changes within large-scale commercial agriculture.

From this point the focus becomes more regionally specific and focuses on the state of agriculture and food security in the Western Cape and Swartland.

3.2 Overview of the global polycrisis

It is becoming increasingly clear that the current patterns in human development are transforming the nature of the Earth in ways which will negatively affect life on Earth. A growing number of diverse indicators allude to this change and suggest that fundamental changes are required across all

[10] Swilling and Anneckes' conceptualisation of the polycrisis was favoured over a host of others because the authors are internationally recognised within the field of sustainable development while at the same time being grounded in the study region which this research addresses. It was therefore reasoned that their conceptualisation of the polycrisis would be both internationally applicable and reputable while also displaying an awareness for the context in which this study operates.

sectors of society if greater suffering and loss of life is to be averted. Swilling describes this situation as a global polycrisis (Swilling and Annecke, Forthcoming). Within the polycrisis he identifies seven primary sub-crises, namely: eco-system degradation, global warming, peak oil, inequality, urbanisation, growing slums and food insecurity (Swilling and Annecke, Forthcoming). In his conceptualisation of the global polycrisis Swilling argues that all seven factors are interrelated and manifest themselves in all other aspects of life, including agriculture. The structure of this paper adopts this perceptive of interconnectivity. The logical implication of this approach is that in order to understand agriculture's position in the polycrisis and the changes taking place within it, these seven sub-crises must be understood. The following section will offer a supporting review of these seven global indicators in order to contextualise the discussions, arguments and research relating to agriculture in the Swartland which take place later in this paper.

3.2.1 Urbanisation and the growth of slums

Over the last hundred years the world population has grown at a historically unprecedented pace, rising from 1.65 billion in 1900 to around to 6.9 billion today (UN, 2009). Each and every one of these 6.9 billion people needing food, water and shelter are dependent on the same finite resources as their ancestors 10 000 years ago. Even at high levels of efficiency and low levels of consumption, the impact of such a vast number of people taking their daily needs from the fabric of one planet has left its mark on just about every part of the Earth's surface, and as the human population continues to grow, so too will the demand for space to accommodate and feed it (WCED, 1987). The *Bruntland Report* identifies the major practical and ethical challenge for the current generation as not only adapting to adequately meet the needs of the 6.9 billion people already alive, but also to do so in a way that allows future generations to do the same (WCED, 1987). With an estimated future population of around 9 billion by 2050 this task will become ever more challenging (UN, 2009).

At the same time as the dramatic rise in population was taking place, a second demographic change was occurring in the form of an urban migration which resulted in the fact that, as of 2008, for the first time in history, the majority of people on the planet now live in cities and urban areas, as opposed to rural environments (UNPD, 2008). By 2050 this figure is likely to have climbed from 50.5 percent to 70 percent in favour of urban areas (UNPD, 2008). During this period the total number of people living in urban areas will almost double, climbing from 3.3 billion in 2008 to 6.4 billion in 2050 while the rural population declines to 2.8 billion (UNPD, 2008).

The majority of this shift from the countryside into urban areas is taking place in developing nations with previously low levels of urbanisation (UNPD, 2008). At least 130 cities internationally have experienced population growth rates of 5 percent and above over the last 50 years (UN, 2001); this is well above the baseline average population growth figure of 2.04 percent per year (UN, 1999). This massive influx of people into the urban centres of the developing world is putting significant strain on already failing and backlogged infrastructure in these centres (UNCHS, 2003). Already one third of the world's urban population live in slums. With very little money and limited capital, most new urban arrivals end up in the sprawling slums on the urban peripheries, where access to even the most basic services such as water and sanitation often does not exist (UNCHS, 2003). The absence of these basic services is in turn a major cause of illness and death within slums (Fewtrell, Prüss-Üstün, Bos, Gore and Bartram, 2007). Unable to cope under the huge increase in customers (and often battling with financial and skills shortages), public services such as health care and education facilities often fail in their mandates (Satterthwaite, 2003).

Every new addition to the population means additional food also needs to be produced in order to sustain that person, and as the population has urbanised the responsibility of producing this food has fallen on an ever-smaller proportion of the population (UNCHS, 2003). As people have urbanised they have tended to replace their rural knowledge and connection to agricultural production with more financially-orientated urban knowledge sets. Urbanisation has also led to changes in eating patterns, particularly an increase in meat consumption, which in turn affects what farmers are called upon to produce (Brown, 1996). These changes in population distribution and social behaviour effect the nature of agriculture; as fewer people take part in farming, meat consumption increases and price becomes an increasingly important driver of people's access to food. The effect of these changes on agriculture has knock-on effects for climate change, ecosystems and food security (Brown, 1996).

3.2.2 Peak Oil

Oil is a finite resource which currently accounts for 60 percent of the global economy's energy requirements (WEC, 2007). However, while transport energy may be the primary focus in the debate around oil, oil is used for an increasingly wide range of other applications such as the production of plastics, antibiotics, cement and a wide range of agricultural inputs such as fertilisers, herbicides and pesticides on which our food production now depends (Swilling and Annecke, Forthcoming). Despite oil demand steadily increasing, a growing number of commentators are beginning to raise serious questions about how long the increase in supply can last (Deffreys, 2001; Hienberg, 2003; Strahan 2007; Swilling and Annecke, Forthcoming). While global production has yet to peak, Atkinson claims that "Global oil discoveries peaked in the 1960s and the rate of global oil extraction today has reached twice that of new discoveries." (Atkinson, 2007: 11). This suggests that as existing oil reserves are depleted, a decline in oil production is inevitable as new discoveries fail to replace depleted wells. The timing of this event is contested (Swilling and Annecke, Forthcoming) and the

World Energy Council (WEC) predict that the remaining potential for conventional oil will succeed in sustaining moderate growth over the next ten to fifteen years (WEC, 2007). Beyond this the WEC state that insufficient supply is likely "owing to decreasing production when the depletion mid-point has been passed." (WEC, 2007).

While the predictions around the timing and nature of peak oil may be varied, there is a large body of literature which states that peak oil has already taken place or will do so in the near future (Hirsch, 2005; Atkinson, 2007; Hopkins and Holden, 2007; Wakeford, 2007; WEC, 2007). The impact of this is that oil will become an increasingly problematic resource on which to base global growth, particularly in sectors which are as critical to human survival as agriculture is (Heinberg, 2003; Swilling and Annecke, Forthcoming; Hopkins and Holden, 2007; Wakeford, 2007). Taking into consideration the reliance of the global food system on oil for everything from draft power and fertilisers to distribution, peak oil and its impacts pose a serious threat to global food security (Swilling and Annecke, Forthcoming).

In the short to medium term the most worrying implication of peak oil for agriculture and food security will be the effect which rapidly rising oil prices – resulting from growing scarcity – will have on the cost of producing food. If agriculture fails to reduce its dependence on oil, the end of cheap oil will also spell the end of cheap food, and for those who already struggle to afford food this is a life-threatening situation (IEA, 2008).

However, the problems associated with modern society's dependence on oil and other fossil fuels go beyond future food availability and food security, as there are much broader ecological, social and economic implications (IEA, 2008). Of primary concern in this regard is the effect of oil dependence on the world's climate. This is discussed further in the following section.

3.2.3 Climate change

The primary driver of the growing call for reform of the global energy system is the impact which greenhouse gases (GHGs) resulting from the burning of fossil fuels has been proven to have on the planet's climate. As the biggest GHG emitter, energy production is the main driver of climate change (UNEP and UNFCCC, 2002). The second greatest GHG emitter is agriculture and agriculture-related activities (UNEP and UNFCCC, 2002). Rice paddies and concentrated animal feedlots alone account for 50 percent of all anthropocentric nitrous oxide emissions (UNEP and UNFCCC, 2002).

The Stern Report reiterated what the Intergovernmental Panel on Climate Change (IPCC, 1990; IPCC, 1995; IPCC, 2007), had been warning since the early 1990s:climate change is happening and human actions over the next ten to 20 years "could create risks of major disruption to economic and social activity, later in this century and in the next, on a scale similar to those associated with the great wars … And it will be difficult or impossible to reverse these changes" (Stern, 2006:2). The report led to the simple conclusion: the benefits of strong, early action outweigh the costs (Stern, 2006).

However, Teske, Zervos and Schäfer argue that, far from being a problem which the world will have to face in the future, climate change is already affecting people and harming the environment (2007). In support of this they cite disintegrating polar ice, thawing permafrost, dying coral reefs, rising sea levels and fatal heat waves (Teske, Zervos and Schäfer, 2007). They go on to warn that "the greatest impacts will be on poorer countries in sub-Saharan Africa, South Asia, Southeast Asia, Andean South America, as well as small islands least able to protect themselves from increasing droughts, rising sea levels, the spread of disease and decline in agricultural production" (Teske, Zervos and Schäfer, 2007:11).

However, despite the mounting evidence which led most governments to acknowledge climate change and agree on the need for action, the 2010 Copenhagen negotiations, which intended to develop a collective plan to address climate change, failed (Heinberg, 2009). The failed negotiations at Copenhagen left the world with a number of non-binding agreements – presenting a bleak reality in which the GHG emitters will continue to increase their emissions into the foreseeable future, thus leaving the world with the prospect of rising sea levels, reduced water availability, land degradation, increasing food insecurity and loss of biodiversity (UNEP, 2008).

For farmers this will mean having to deal with increasing risk of crop failure as the severity and frequency of extreme weather events such as floods and droughts increase (Stern, 2006). This increasing instability of crop production will impact on food security and people's ability to provide food for themselves. Gbetibouo and Ringler (2009) point out that, of all farmers, poor subsistence farmers on marginal lands will be hardest hit by climate change as they are least able to mitigate agricultural damage or shift to other survival mechanisms. However, as the second largest GHG emitters, farmers also bear a large portion of the responsibility when it comes to reducing the effects of climate change by cutting down on their GHG emissions (UNEP and UNFCCC, 2002). This will not only be important for future generations of farmers but for all social and ecological systems which stand to be adversely affected by climate change.

3.2.4 Ecosystem degradation

While climate change may be a prominent focus in the public arena at the moment, Swilling and Annecke highlight the importance of the widespread degradation and loss of ecosystems currently taking place: "Even without global warming, the planet's ecosystems that we depend on are falling to pieces" (Swilling and Annecke, Forthcoming:5). This degradation is not only unfair to the non-human forms of life which it destroys, but it also compromises socioeconomic welfare benefits such as fresh water, arable soils, pollination services, ocean life, fibre, crucial minerals and breathable air (Heinberg, 2009).

Many of the key resources Heinberg speaks of such as fresh water, arable soils, ocean life, pollination services and breathable air, are ecosystem services historically provided free of charge by healthy, functioning ecosystems (MA, 2005). Regardless of where they live, all people depend on these and other services provided by the Earth's natural systems for their survival (MA, 2005; Hails, 2008). Agriculture on the whole relies particularly heavily on ecosystem services in order to function, and so too do all of us who depend on agriculture for our food (MA, 2005). Despite the dependence of all people – particularly the poorest 2 billion–on the life-giving services provided by the planet's ecosystems, almost all of the world's major ecosystems have either been irreparably damaged or are in a state of decline as a direct result of human activity (MA, 2005; UNEP, 2008). Furthermore, it has beenand will continue to be the poor who are affected most by ecological degradation, as they rely most heavily on the free services provided by functioning ecosystems. They poor are also least able to afford alternative coping strategies if and when alternative strategies are available (Swilling and Annecke, Forthcoming).

As agriculture uses about one quarter of the Earth's land surface and at least 20 percent of all water running off the land, the way in which humanity produces its food has a disproportionately large impact on ecosystem degradation (MA, 2005). This suggests that ecological reform in agricultural is imperative if current trends in ecosystem degradation are to be reversed (UNEP, 2008). Put simply, agriculture needs to shift from practices which degrade natural systems in favour of partnerships which restore and enhance them. Encouragingly a wide body of practical experience and scientific research already suggests that these partnerships would also be beneficial for farmers (Pretty, 2006; Holt-Gimenez and Patel, 2009; Goldblatt, 2010).

3.2.5 Poverty and inequality

Within the various elements of the polycrisis a reoccurring point emerges from the literature on peak oil, climate change, urbanisation and declining ecosystems; namely that it is the poor who will be worst effected by these problems, despite having contributed least to their creation. The fundamental injustice present in this point is highlighted by the already stark contrast between the global haves and have-nots. At the time of release in 1998 the *Human Development Report* stated that 20 percent of the global population in richest countries account for 86 percent of total private consumption expenditure, whereas the poorest 20 percent account for only 1.3 percent (UNDP, 1998). Swilling and Annecke argue that it is no longer possible, or ethical, to ignore the negative impacts of poverty and gross inequality. Poverty and social inequality affect all levels of society and the resolution of extreme inequality and poverty is fundamental to both social and ecological development (UNDP, 1998).

Furthermore there seems to be growing consensus that the world is not going to meet the Millennium Development Goal of halving extreme poverty and hunger by 2015 (FAO, 2005). The main reason behind this is that, despite significant progress being made in a number of East Asian countries, the total number of food insecure people has increased since the Millennium Goals were set despite rising affluence within certain sections of society (FAO, 2005; FAO, 2008; Swilling and Annecke, Forthcoming). This presents a close link between growing inequality and the last of Swilling and Annecke's sub-crises within the global polycrisis, namely food insecurity.

3.2.6 Summary of the global polycrisis

Section 3.2 has outlined six of the seven points within the global polycrisis. The overview of these six points was undertaken in order to provide a conceptual grounding and reference point for the remainder of the literature review which follows as well as the case studies and secondary data. It was argued that in order to avoid a worsening of current problems human activity, particularly agriculture, needs to adapt to take these factors into account. For example, by reducing GHG emissions, restoring natural systems and reducing oil dependence. This conceptualisation of the global polycrisis is returned to throughout the text and served as an important guideline in assessing and evaluating research findings.

The seventh and final element which Swilling and Annecke (Forthcoming) identify is the issue of food security. However as food security and agriculture are a more central focus of this research they are discussed in greater detail than the preceding six points in the following section.

3.3 The crisis of food security and agriculture

Section 3.3 will now briefly outline the current state of global food production and food security. This is done partially to complete the review of the seventh aspect of the polycrisis as well as to provide clarity on the connection of this paper (which focuses on the sustainability of agriculture in the Swartland) to long-term regional food security.

World hunger is on the rise and the Millennium Development Goals of reducing hunger by half between 1990 and 2015, to no more than 450 million people, will not be met (FAO, 2009b). This trend is not as a result of production failures or a growing world population (Brown, 1996; FAO, 2009b; Holt-Gimenez and Patel, 2009). Food production has been expanding by 2.2 percent per annum during the last decade, while the population growth has been less than 1.5 percent for the same period (FAO, 2009a; Holt-Gimenez and Patel, 2009). During the 2007/2008 food price crisis, in which riots took place in counties across the developing world due to skyrocketing food prices, agricultural production reached record highs (FAO, 2007; Holt-Gimenez and Patel, 2009).

The main reason people went hungry *before* the food crisis of 2007/2008, the main reason *for* the food crisis of 2007/2008, and the main reason the world will fail to meet the target of a 50 percent reduction in world hunger by 2015 is that people cannot afford to buy food (FAO, 2008; FAO, 2009b; Holt-Gimenez and Patel, 2009; Timmer,2009; IAASTD, 2009). Furthermore, the recent increases in food prices have not been a result of demand outpacing agriculture's ability to supply food, as was commonly argued in the past; excess production capacity is available (FAO, 2008; FAO, 2009b; Holt-Gimenez and Patel, 2009; Timmer,2009; IAASTD, 2009). Indicative of this underutilised production capacity is the fact that, in response to the high food prices in 2008, grain producers were able to increase global grain production by 3.9 percent within a single growing season in order to capitalise on high prices[11], thus demonstrating their ability to produce food when the price is right (FAO, 2009a).

While this situation of access-driven food insecurity in a context of relative food availability is by no means ideal, it is arguably better than a scenario in which absolute food scarcity exists. However, this may not continue to be the case if the effects of the polycrisis on agriculture are not adequately addressed. In 1996 the World Watch Institute published *Tough Choices* (Brown, 1996) which detailed the reasons for what it termed the "growing imbalance" (Brown, 1996:2) between the world's food haves and have-nots. In the book Brown predicted growing food insecurity which would be driven by food price increases resulting from increasing food scarcity. In support of this argument Brown cited slowing growth in farm productivity as a result of GR technologies eroding natural soil capital, coupled with growth in demand as a result of population growth and changing dietary preferences – particularly for grain-reared meat (Brown, 1996).

Brown also criticised the FAO and World Bank for expecting gains in agricultural production to match gains made during the earlier part of the century following the Green Revolution (Brown, 1996). He

11 Agricultural input producers followed suit both with production and in price, matching the price of their inputs to meet the rise in sales prices being received by farmers using their products (NAMC, 2009). Following the crisis these input prices have remained well above their pre 2007-levels (NAMC, 2009), this is one reason why food prices have displayed price 'stickiness' and failed to come down to old levels following the 2007/2008 food crisis.

stated: "Taking into account advances in technology, a shrinkage of new productive land to plough, the diminishing response to the use of additional fertiliser, the growing scarcity of fresh water, a heavy loss of cropland to non-farm uses in the rapidly industrialising countries of Asia, the cumulative effects of soil erosion on land productivity, and the increasing frequency of crop-damaging heat waves associated with rising global temperatures growth in output [will] slow, lagging behind the growth in demand" (Brown, 1996:118) He forecast that this lag would drive up food prices, which would affect the 120 grain-importing countries most, particularly the high-import/low-income countries, whose consumers would be the ultimate losers in the globalised bidding scramble to secure food (Brown, 1996). Brown relates a number of the key elements of the global polycrisis (such as declining ecological capital, rising social inequality and climate change) to future food insecurity.

According to recent reflections and analyses by Holt-Gimenez and Patel (2009), the IAASTD (2009), the FAO (2009b) and others, Brown appears to have been right on a number of accounts regarding the effects of the polycrisis on food security:

1. Large animal feedlots have boomed over the past decade as a result of growing numbers of people increasing the meat intensity of their diets (FAO, 2009a). As these feedlots rely on grain-based feed-stocks and require 7 kilograms of grain for every kilogram of beef produced, world grain demand has soared (FAO, 2009a; Holt-Gimenez and Patel, 2009).
2. Technological advances made during the early to middle 20th century have yet to be replicated, despite strong promises from gene scientists (Pretty, 2005).
3. Water-related issues have risen as water scarcity has become a limiting factor in some regions while over-irrigation has resulted in the deterioration of farm land in others (Pretty, 2005).
4. Adverse climatic events including severe cyclones, heat waves and droughts have increased in regularity over the past thirty years, in certain cases much as six times since the 1980s (Starke, 2006). These are not necessarily directly attributable to climate change; however there were a number of climatic disasters during the lead up to the 2007/2008 food crisis which caused poor harvests and helped to raise the price of food (Holt-Gimenez and Patel, 2009).
5. The world did see an increase in the total number of people living in hunger and high food prices were the driving force behind this (FAO, 2009a; Holt-Gimenez and Patel, 2009).

However, where Brown seems to have been wrong in his predictions is that food production has not yet failed to keep up with demand. It has grown by over 2 percent per annum over the last decade and has shown itself to be capable of expanding growth to almost 4 percent when prices are high enough as was the case in 2008 (FAO, 2009a).

In relation to global production food insecurity arises largely out of an inability of the poor to effectively signal their demand because the price they are able to pay for food no longer covers the costs of producing it, and thus their demand falls largely on deaf ears. Even farmers who might want to produce in response to the needs of the poor cannot, because the costs of doing so would exceed the price the poor are able to pay. Instead, in times of low prices farmers fallow their fields and wait (IAASTD, 2009).

This assertion that the rising costs associated with food production (in a context of increasingly weak purchasing power on behalf of the world's food poor) are a threat to food security does not deny the long-term threat of persistent food shortages resulting from an absolute collapse of agricultural systems. Indeed, if agriculture globally completely ignores the multiple threats posed by the polycrisis,it would seem likely that much of world's agricultural production would collapse (Brown, 1996; Lal, 2006; Roberts, 2008; Swilling and Annecke, Forthcoming). Examples of this could include oil production peaking before alternative sources of energy have been developed for draft power and transportation, degrading soils to the extent that they are no longer arable, and failing to adopt sufficient climate change adaptation and mitigation strategies. When the effects of these threats are combined and applied to agriculture across the world a widespread collapse in food production is plausible (Brown, 1996; Lal, 2006; Roberts, 2008).This collapse would have a devastatingly negative effect on food security.

As such, the polycrisis poses two threats to the production component of food security: raising production costs and threatening total availability. As agricultural production continues to outpace population growth, instead of the other way around (FAO, 2009a; UN, 2009), the more pressing of the two food security threats posed by the polycrisis is impact of increasing production costs.

In light of this the following section aims to address the issue of rising production costs in greater detail.

3.4 Why are production costs increasing?

Section 3.3 concluded with a reflection on the impact of rising agricultural production costs without dealing with the possible drivers of these cost increases. Section 3.4 reviews both local and international literature in order to explore the reasons behind production cost increases, looking first at effect of rising input costs, then considering the role of declining ecosystems and concluding with a short section on non-production-related pricing factors.

3.4.1 Rising input costs

The cost of agricultural inputs such as fertilisers, pesticides, diesel and farm machinery have been rising steeply over the past decade, but particularly in the last five years (GSA, 2009; NAMC, 2009). This has had a significant knock-on effect on the cost of producing food. A number of reasons are behind this trend, including the close connection between the price of oil and the cost of synthetic chemical inputs, corporate monopolisation of the input market, and supply shortages (Hopkins and Holden, 2007; Holt-Gimenez and Patel, 2009).

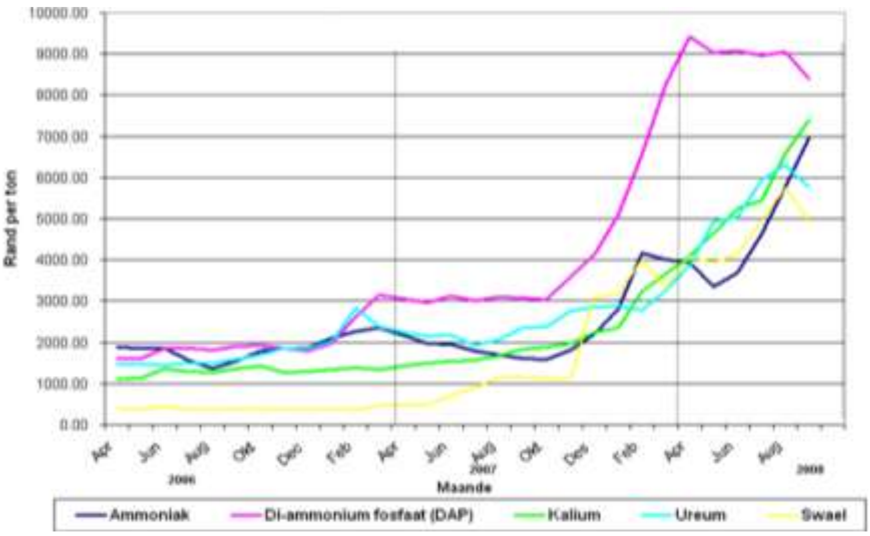
In adding to this debate, particularly the connection between oil based inputs and food production, Bartlett wrote "Modern agriculture is the use of land to convert petroleum into food"(Bartlett in Attarian 2002: 283). While this may be a radical viewpoint, it highlights the widely-cited dependence of modern agriculture on crude oil, and other fossil fuels such as natural gas. The past decade has seen a steep rise in the price of oil with all major energy forecasts predicting continued price inflation into the future's predominantly due to peak oil as discussed in Section 3.2.2 (Heinberg, 2003). This rise in the cost of oil has had a significant impact on the costs of agricultural production to date and will continue to do so in the future (FAO, 2009a). The FAO's 2009 *State of Food and Agriculture* report stated that "[Crude oil prices] remain high in real terms by historical standards. This will continue to translate into high input prices for chemicals and fertilisers as well as high transportation costs" (FAO, 2009a). This fact is raising alarm bells within a range of agriculture – and food security – related fields and is a key component of the argument for decreasing the dependence of farming systems on oil and other external inputs (Heinberg, 2003; Hopkins and Holden, 2007; Swilling and Annecke, Forthcoming).

In addition to the impact of oil and gas prices, Pearce notes that the bullish control of input markets by a small group of input producers has resulted in unbalanced power relationships between farmers and input retailers which also drives up the cost of inputs to farmers (Pearce, 2008; Holt-Gimenez and Patel, 2009). These power imbalances and the increasingly monopolistic structure of the large multinationals which supply agricultural inputs is covered in greater detail in section3.4.3.

Sharp increases in the price of food due to non-input-related factors can lead to farmers across the world wanting to increase their output for a season in order to capitalise on higher prices. As these production booms are achieved by increasing fertiliser applications in order to raise yields or by planting and fertilising fallow fields, these production booms can outpace input producers' ability to meet raised demand – as happened during the latter part of the 2007-2008 world food crisis (Grain

SA, 2009; Gregor, 2010). The effect of this scarcity in the past has been to push input prices up, as can be seen in Figure 4.

Figure 4: International change in primary synthetic fertiliser input price



Source: Grain SA, 2009

3.4.2 The role of declining agro-ecosystem health on the costs of production

Declining soil health also plays a big role in the cost of producing food, as degraded soils produce less relative to the inputs applied to them (Pretty, 1999; UNEP, 2009). Put another way, degraded soils require more inputs (and thus costs) in relation to their healthy counterparts in order to deliver equal yields, and ultimately they can fail to deliver yields altogether (Scherr, 1999; Lal, 2006). As a result of mismanagement by both traditional and GR farmers, one-third of all the world's agricultural land is either moderately or severely degraded (IAASTD, 2009) and this figure is growing at 0.2 percent per annum (UNEP, 2009). The main forms of degradation are the loss of topsoil from wind and water erosion, salination, acidification, nutrient depletion and declining soil structure leading to crusting and compaction (Lal, 2006).

The reasons for this are complex and vary greatly from one region to another. In developing countries, erosion, nutrient depletion and salination are the main drivers of soil degradation. These are largely economically driven, as farmers are pressured into over-grazing and struggle to afford the inputs required to replace nutrients extracted from their soils (Pretty, 1999; UNEP, 2009). In developed countries wind and water erosion are also prominent (IAASTD, 2009), as is eutrophication and soil acidification as a result of agricultural intensification and the disruption of mixed crop-livestock systems (FAO, 2009a). All of these also result in a loss of organic and living matter in agricultural soils which is increasingly being recognised as an important form of soil degradation (Scherr, 1999).

Beyond soils, a number of authors argue that there are other forms of natural agricultural capital that are being degraded by widely accepted agricultural practices which also result in the need to increasingly apply external inputs (Conway, 1997; Pretty, 1999; Magdoff, 2007a). By cultivating large areas of monocropped agriculture, farmers reduce the biological diversity on their farms. Conway (1997) states that this loss of biodiversity increases the need for external inputs to replace the ecosystem services which this biodiversity previously supported. Conway notes that increased loss of on-farm biodiversity and the increasing use of pesticides which has accompanied this loss are resulting in growing pest problems as pests adapt to external control measures while the natural pest control mechanisms are inadvertently removed from the system (Conway, 1997).

In his studies of South East Asian pest control Conway points to a direct correlation between the frequency and quantity of pesticide applications and the resurgence of pest populations. He attributes this to the fact that, due to their higher numbers, pests tend to develop resilience to pesticides faster than their natural predators do, and because of this the natural predators which play a vital role in keeping pest populations in check are affected more by pesticide applications than the pests (Conway, 1997).

The effect of this is that over time farmers are creating a more livable habitat for crop-damaging pests by removing their natural predators from the system. Conway (1997) also stresses that the more farmers tended towards the cultivation of a single crop over a diverse basket of crops, the more likely they were to be plagued by severe reoccurring pest and disease infestations. He states: “The move towards large areas of monoculture has been one of the reasons why pest and disease outbreaks have grown in the wake of the Green Revolution” (Conway, 1997: 115).

However, Jewitt and Baker argue that not all GR technologies have had negative effects on their surroundings, and that at times other factors are to blame for problems experienced in GR farming systems. To support this they compare social welfare and farming practices in three villages in India before and after the GR. Their findings suggest that that despite the draw backs of chemical inputs there has been a net gain in social benefit from inputs such as fertilisers and pesticides (Jewitt and Baker, 2006).

The authors do acknowledge however, that ecological declines are taking place in some spheres of the agricultural system, yet they do not attribute all of these declines to GR practices. They note, for example, that soil fertility is declining but suggest that the use of residual crop biomass for household combustion instead of fertility management is the primary cause for this. A key exception which they note has been the contamination of groundwater by agro-chemical applications directly connected to the introduction of GR technologies in the villages they studied (Jewitt and Baker, 2006).

With this in mind, it seems that despite differences of opinion surrounding the root causes of declining agro-ecosystem health, the literature suggests a consensus on the fact that some degree of decline is taking place, particularly with regards to soil. In addition, the majority of the literature considers the GRto play a significant role in this decline.

In summary, natural capital degradation is on the increase, and while it may not result in lower aggregate world food production in the next decade it will continue to reduce the total factor productivity (TFP)12 of the food system as more inputs are required to compensate for this loss of natural capital (Scherr, 1999, FAO, 2009a). It is likely to result in higher production costs per unit produced, lower farm incomes and higher consumer food prices (Scherr, 1999, FAO, 2009a). This will impact the poor the most, as farmers are forced to pass on the double burden of increased input requirements and input costs to those buying their products (Scherr, 1999; UNEP, 2009).

3.4.3 More than just production

Rising input costs and the increasing need for these inputs in order to maintain production represent a double burden for farmers and consumers alike. The literature presented suggests that these factors are an important component of the answer to why farmers are becoming increasingly unable to respond to the food demands of the world's poor, despite the fact that production capacity does exist. However, the global food system in which farmers and food-insecure consumers are a part extends beyond the relatively simple producer-consumer scenario portrayed thus far.

Of primary concern to Holt-Gimenez and Patel (2009) is the concentration of power along the agricultural input and value chain into the hands of an increasingly smaller number of large multinationals. Their concerns are echoed by Von Braun (2007), Roberts (2008), Pearce (2008) and Brown (1996), all of whom identify the increasing global consolidation of the agro-food system as a threat to health, livelihoods and food security.The 2007 *World Food Situation* released by the International Food Policy Research Institute (IFPRI) states: "The process of horizontal consolidation

[12]TFP is the total output from a farm in relation to the total inputs to the farm. It provides a more comprehensive measurement of the efficiency of agriculture as it captures change in inputs required to achieve reported yields.

in the agricultural-input industry continues on a global scale. The three leading agrochemical companies – Bayer Crop Science, Syngenta, and BASF – account for roughly half of the total market.

This increasing power wielded by an increasingly small number of input producers, merchants, processors and retailers allows these large conglomerates to mediate almost all interactions between farmers and consumers (Holt-Gimenez and Patel, 2009). This lack of competition allows them to force downward pressure on farm-gate prices as well as upward pressure on retail prices with neither farmer nor consumer able to control this process.

3.5 Summary

The literature reviewed from Section 3.3 onwards outlined in very broad terms the state of world hunger and the relation of agriculture, natural capital and agricultural inputs to this. While not denying the potential future issues regarding food availability, insufficient access to food is shown to be the primary cause of food insecurity at present. Within this it was argued that the price of food played an important role in determining food accessibility. From the farmers' perspective the costs of producing food were shown to be on the rise as a result of rising input costs as well as an increasing need for these inputs as a result of declining ecological capital. In this way a connection was drawn between external input dependence in farmers and food security by pointing out the role that pricing plays in determining access to food and the effect that agricultural inputs have in determining the cost of producing food.

As this thesis focuses on the production component of food security more attention was paid to the production-related segment of this multifaceted problem. The following section extends this literature review to a brief discussion of the solutions which have been proposed to the problem of the crisis facing agricultural production in relation to food security. This is done in order to elaborate on the decision to focus on changing practices within the commercial agriculture sector originally discussed in Section 1.1.

3.6 Proposed solutions

3.6.1 Introduction

With regards to the debate about the appropriate form agriculture should take going into the 21st century, a strong polarisation has developed between those in favour of HEI methods and those in favour of smaller-scale organic methods (Pretty, 2006). This part of Chapter Three seeks to chart a course between these two poles and proposes that the most appropriate course of action for the short to medium term is a hybridised middle ground.

3.6.2 The agricultural middle ground

Currently a large amount of the world's food is produced on large-scale farms using HEI farming methods. This situation has been made possible by the Green Revolution's success in dramatically raising food production during the past century while keeping food prices relatively low and stable (Pretty, 2005). However, based on the conceptualisation of the polycrisis as put forth in section 3.2 it has been argued that this approach is not a viable long-term solution to improving food insecurity, due to a number of key flaws. These flaws include the heavy reliance of HEI agriculture on oil and other non-renewable fossil fuels (Hopkins and Holden, 2007), the widespread degradation of natural capital as a result of current HEI farming practices – particularly with respect to soil and water capital – (UNEP, 2009c) and the growing power imbalances in the food system which have arisen out of a situation where farmers are dependent on large multinational corporations (MNCs) for their farm inputs (Holt-Gimenez and Patel, 2009). All of these flaws present a risk to food security in the future as they threaten both access and availability, as was demonstrated in section 3.4.

However, increasing the use of natural, on-farm 'tools' such as nitrogen-fixing crop rotations, mulching and reduced tillage offers a means by which the trend of increasing usage of non-renewable external inputs and declining ecological capital can be reversed (Altieri, 1999; Pretty, 2005; Genis, 2008).Similarly the vulnerable economic position of farmers in relation to MNCs can be improved for the farmer by developing ways in which to replace external inputs with on-farm alternatives such as the replacement of nitrogen fertilisers with nitrogen-fixing crops (Holt-Gimenez and Patel, 2009).

The aforementioned approaches offer an alternative to the dominant model of HEI farming. Encouragingly, there has been a growing resurgence of LEI agroecological farming techniques[13] which are less dependent on non-renewable inputs, able to restore degraded soils and water systems, and offer farmers a far greater degree of independence from potentially exploitative MNCs (Altieri, 1999; Pretty, 2006). These benefits make them far better suited to ensuring long-term food security, both in terms of food access and food availability without necessitating a trade off with profits (Altieri, 1999; Pretty, 2006; Magdoff, 2007a).

However, currently only a small percentage of farmers farm this way and consequently only a small fraction of the total food supply is produced this way. Furthermore, the majority of these existing

[13] At the far end of which is the pro-small-scale organic approach.

agroecological farms are radically different from the dominant HEI models in a range of respects including farm size, crop types and farmer knowledge sets. This makes it very difficult for the majority of existing farmers to relate to these approaches (Röling, 2000). It is also argued by some (Plunket, 1993; Badgley *et al* 2006) that the small-scale organic approach that is advocated by the likes of Norberg-Hodge, Goering and Page (2001) may be ideologically preferable but is ill-suited to certain types of production in reality. These facts make the possibility of a natural transition from the dominant large-scale HEI approach to the existing organic approach seem unlikely[14] and not necessarily beneficial.

This suggests that there is a need to encourage transitional forms of agriculture which adapt practices from the existing organic systems in a way which can provide benefits to existing HEI farmers so as to begin to shift the bulk of the world's food production away from the pitfalls of HEI agriculture. The preceding paragraphs also suggest that organic agriculture as it is currently practised may not be the best solution in all circumstances and that there are opportunities for hybridised middle grounds in which healthy agro-ecosytems provide the basis from which agri-science will achieve its best results (Lal, 2006; UNEP, 2009c). Pretty supports this proposition and states that "until recently, few had considered the potential for a regenerative or sustainable agriculture that is situated somewhere between organic and very-high-input agriculture" and adds that "in contrast to organic systems these methods of agriculture, if profitable, would be immediately available to all farmers" (Pretty, 2006:208).

In summary Section 3.6 extended the literature review in order to reiterate the relevance of the research objectives[15]to the broader global debate on sustainable agriculture. The chapter argued that focussing on ways to shift current HEI farmers – who currently produce a large portion of the global food supply – towards LEI practices will be important for ensuring improved food security in the future. It suggested that this be done by focussing on ways in which existing large-scale HEI farmers could adapt and adopt principals and techniques from existing LEI farming practices. The relevance and benefit of these changes were summed up by Pretty, who suggests that this would allow more sustainable forms of agriculture to be available to all farmers, not just those who were able to capitalise on organic premiums (Pretty, 2006).

[14] As it would constitute too dramatic a shift within the existing structures.

[15]To investigate whether or not examples exist of commercial GR farmers in the Swartland shifting towards LEI systems which are based on closer partnerships with natural systems and to gain a better understanding of why farmers are choosing to shift their farming practices and how the transition to LEI systems is being achieved.

3.7 Conclusion of the global review

This concludes the global review of the context in which agriculture operates. Seven key challenges facing the world as a whole were identified, based on the work of Swilling and Annecke (Forthcoming). These were: eco-system degradation, global warming, peak oil, inequality, urbanisation, growing slums and food insecurity. The culmination of these challenges was considered to constitute a global polycrisis which requires urgent attention. It was argued that agriculture needs to be understood not only as a means of food production but also as an actor within the global polycrisis which both drives and is driven by these seven key challenges.

Food insecurity was shown to be a problem that the world's governments were failing to address, despite commitments towards the Millennium Development Goal of halving hunger by 2015. The work of the Food and Agriculture Organisation (FAO) (2009b), the *International Assessment of Agricultural Knowledge, Science and Technology for Development* (IAASTD) (2009), Holt-Gimenez *et al* (2009)and others was used to show that access to available food, rather than a global shortage of food, has been the main driver of food insecurity in recent years. Significant attention was also paid to the potential impacts of the global polycrisis on future food security from a food production perspective. In line with this it was argued that failing to adapt the current methods of HEI agriculture will likely lead to increased food insecurity in the future as both food access and availability will be negatively affected. It was, however, also acknowledged that HEI farms currently supply the majority of the world's food and that there are potential problems with strictly advocating the other extreme – namely small scale organic agriculture– without taking into account the practical realities of the individual farm systems that need to be changed. This led to the conclusion that in light of the global polycrisis and the specific challenges facing agriculture, a middle road approach is best suited to transforming the agricultural sector and improving food security. This middle-road approach would seek to begin improving HEI farming practices by actively seeking ways in which larger farmers could incorporate LEI and organic principles on their farms.

With this in mind, the following section departs from the global context in order to focus more specifically on the study region and its immediate surroundings.

3.8 The local context

3.8.1 Food security and the state of agriculture in the Western Cape

In the same way as the polycrisis manifests itself within the challenges of agriculture and food security globally, as was discussed in the previous section, agricultural problems and food insecurity are also present within the Western Cape. This section draws on existing white and grey literature to provide an outline of agriculture and food security in the Western Cape in order to provide a grounding for a review of the challenges present in these fields. While the focus remains local, links will be drawn back to the global polycrisis where relevant.

3.8.1.1 Provincial food security

Historically the availability of food in the Western Cape has remained relatively stable and the availability of basic foodstuff at retail outlets has also been maintained. With a diverse and productive agricultural landscape, the province produces over 20 percent of the national agricultural produce, despite containing less than 10 percent of the population (Elsenberg, 2005). This production capacity is important to maintaining sufficient levels of food in the province and for the regions to which it exports. It also helps to ensure that at a provincial level the province is relatively food-secure.

3.8.1.2 Household food insecurity

Despite the macro-level availability of food, large portions of the province's population suffer from chronic food insecurity throughout the year, and more still face a cyclical hunger season during winter months of low employment (HSRC, 2000; Frayne *et al*, 2009; McLachlan and Thorne, 2009). Research conducted into food security in poor urban areas in the Western Cape found that 84 percent of respondents had gone without food at some point during the six months preceding the survey due to their inability to afford food, and of these, 11 percent went without food at some point every day (Frayne *et al*, 2009). This is alarmingly high, particularly when taking into consideration that food security in the province tends to be worse in rural areas than in urban areas (HSRC, 2000).

The limited research which has been conducted into food security in the province strongly suggests that issues of access to food are the primary driver of household food insecurity (HSRC, 2000; Frayne, *et al*, 2009; McLachlan and Thorne, 2009). Due to the fact that the bulk of the region's food is grown by commercial farmers and is then distributed and sold by a range of middle-men and retailers (Schulschenk, 2009), almost all transactions involving food are financial transactions. As such the key barrier to food access amongst the province's food-insecure households is the price of food (HSRC, 2000; Frayne *et al*, 2009; McLachlan and Thorne, 2009).

The aforementioned point needs to be interpreted in two ways: Firstly, that if the point-of-sale price for food was lower, the limited funds that households have would stretch further, thus allowing them to buy more for the same amount. Secondly, if the available funds that households have to spend on food are increased through methods such as increased employment, better wages and government support grants, then the price of food decreases relative to their available income.

These connections between food pricing and household food security are important as they demonstrate the negative effect which rising agricultural production costs (as a result of polycrisis issues such peak oil and declining ecosystems) can have on household food insecurity. Additionally, case study research covered in Chapter Four reveals that one of the main reasons why farmers were shifting their practices to LEI methods was to counteract rising production costs and minimise financial risk. In this way farmers are able to remain in business without raising their farm-gate prices, thus shielding poor consumers to some degree from the negative price impacts of the global polycrisis.

However, focussing on macroeconomic pricing factors as a response to food insecurity is critiqued by De Wet, who states that national income increases fuelled by economic growth "have not convincingly 'trickled down' to better nourishment" and that household-level interventions are necessary (De Wit, 2009:71). Strong criticism of existing market-based approaches also comes from Norberg-Hodge, Merrifield and Gorelick, (2002), La Via Campesina (2009) and Holt-Gimenez and Patel (2009), all of whom argue that maintaining people's dependence on external production over which they have no control and reinforcing their dependence on financial systems to ensure food security is not an effective or sustainable solution. This argument suggests that the means of food production must be placed in the hands of food-insecure people and communities, thus allowing them to gain food sovereignty which in turn leads to food security (Norberg-Hodge, Merrifield and Gorelick, 2002; La Via Campesina, 2009).

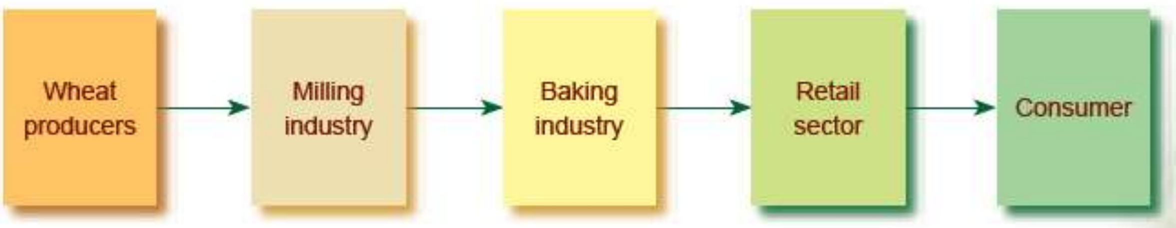
During research I conducted for the Food Security Initiative, I noticed a proliferation of both grass-roots and top-down initiatives in the Western Cape which worked towards enhancing food sovereignty These have largely been NGO-driven but there are also increasing partnerships with schools, municipalities, and local government departments taking place which effectively aim to promote food sovereignty. A partnership between low-income communities, NGOs and the Western Cape Department of Education is one such example which has resulted in a proliferation of school food gardens around the province in which food is grown at schools for and by learners. These help to feed both the schools at which they are based and the surrounding communities, while simultaneously fostering a culture of independent food production.

While very few disagree with the merits of increasing people's control over their food supply by placing the means of production within their control, the majority of people in the Western Province reside in urban areas where local food production is still very limited (Small, 2010). Where in-situ food production is taking place it tends to be on a part-time basis in which a person tends a small back yard plot in order to supplement their family's supermarket food basket. In these cases the focus tends to be on fresh vegetable production as this offers the most efficient use of limited land resources despite the fact that the staple diet in the province is based on wheat and corn. These facts suggest that even in a scenario in which urban and small-scale food production is up-scaled successfully, for the medium to long-term the bulk of the region's food, particularly staples such as wheat flour and maize meal, will come from commercial farms in the rural regions. This means that while small-scale localised production can and should be used as a powerful tool to help alleviate household food insecurity in the province, financial transactions are likely to remain the primary source of food for the region's population.

3.8.1.3 Understanding food prices

Focussing on ways to keep food prices low but stable, increasing incomes and empowering people to produce their own food will therefore all be part of the solution to addressing food insecurity (De Wit, 2009)[16]. As this thesis focuses on the potential that changing practices within the commercial agriculture sector could have on keeping the cost of food low and stable, it is important to recognise that there are a number of actors between the producer and consumer which also influence the shelf price – so as not to overstate the ability of farmers to keep prices down (DAFF, 2006; De Wit, 2009; Schulschenk, 2009).

Figure 5: Market chain in SA wheat industry



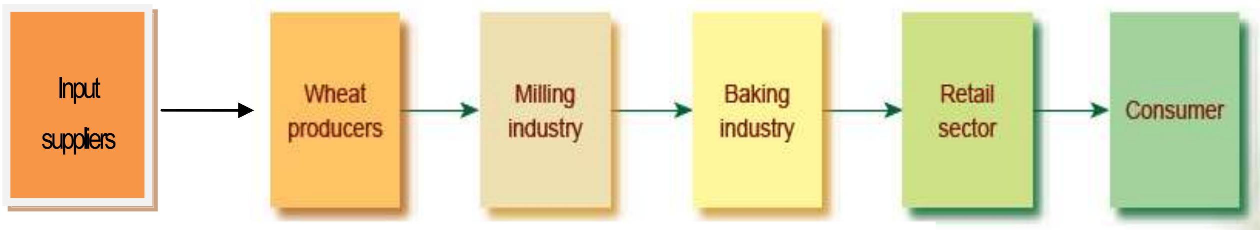
Source: DAFF, 2006

[16] Beyond these De Wit also highlights the importance of broader socioeconomic prosperity and stability due to its impact on family structures and their coping mechanisms (De Wit, 2009).

Figure 5depicts the value chain between wheat producers and consumers in South Africa (DAFF, 2006). De Wit points out that the management of agricultural supply chains has a potentially important role to play in improving food access amongst the food insecure (De Wit, 2009). Within this structure the retail sector plays a disproportionately large role in setting and defining prices (NAMC, 2008). However, ultimately the retail sector depends on the agriculture sector for its produce and therefore needs to purchase goods at a price which keeps enough farms in operation. This point is of particular relevance to food security as the minimum cost of production ultimately sets the foundation on which the ensuing price of food is built.

Figure 5omits a vital element in the value chain, namely the input materials required by farmers to grow food. This element has always existed but the Green Revolution has placed farmers in a position of far greater dependence on external parties to supply these inputs (Pretty, 2006; Holt-Gimenez and Patel, 2009). This holds true in the Western Cape and the impact of this on food security is that agricultural input producers, and not farmers, now form the foundation point which dictates the starting price for the agricultural value chain. This is a vital shift in relation to the access component of the food security web as it effectively adds a pre-production value-adding step in the value chain, thus incurring a cost to consumers. As inputs such as fertilisers, diesel and machinery become vital components in the production process, their suppliers gain significant power in determining food prices (Holt-Gimenez and Patel, 2009)[17]. This change is reflected in Figure 6.

Figure 6: Revised GR food market chain



Source: Adapted from DAFF, 2006

3.8.1.4 Overview of agriculture in the Western Cape

Agriculture in the Western Cape differs from the rest of South Africa in that it offers a mix of winter and year-round rainfall (Elsenberg, 2005). The region's relatively consistent rainfall and varied soils allow for stable production and a diverse crop mix (Elsenberg, 2005). The province contains about 10 percent of the national population, 12 percent of the country's agricultural land (11 million ha), and produces 20 percent of the nation's agricultural produce (Elsenberg, 2005). This makes it a disproportionately large contributor to the national agricultural economy (Elsenberg, 2005).

[17] As a case in point, there have been growing allegations of fertiliser price-fixing levelled against the major national suppliers by South African farmers and agricultural publications (Gregor, 2010).

Fruit; poultry and eggs; winter grains such as wheat, oats and barley; viticulture and vegetables make up for more than 75 percent of the province's agricultural production (Elsenberg. 2005). Barring viticulture, the region's agriculture is focussed almost entirely on food crops. In total the agricultural sector in the province had a gross financial income of around R 10 billion in 2007, the largest in the country (Stats SA. 2006). However, 45 percent of this income was generated from horticultural products such as fruits and wine, the majority of which are destined for export markets (Stats SA, 2007).

Unlike some other provinces in South Africa, where subsistence agriculture is widespread, there is almost no traditional subsistence agriculture taking place in the Western Cape (Elsenberg, 2005). However, in a move which is the first of its kind in South Africa, the City of Cape Town has implemented a policy on urban agriculture aiming to stimulate urban subsistence food production (Mc Lachlan and Thorne, 2009).

The total number of commercial farming units in the Western Cape stood at 7 185 in 2002 and had decreased by 7 percent in 2007 to6 682 units (Stats SA, 2002; Stats SA, 2007). This steady decline in the total number of farming units in production has resulted from the agglomeration of farms rather than a reduction in the total area under production (Stats SA, 2007).

Corresponding employment figures on large farms for the same period showed a 13.5 percent decline from 219 091 full-time and part-time employees in 2002 to 189 489 in 2007 (Stats SA, 2002; Stats SA, 2007)possibly due to merging farming units retrenching duplicate labour. In addition to the retrenching of duplicate labour, it is suggested by Vink and Van Rooyen (2009)that progressive regulation of the agricultural labour market may also have led to a decline in employment figures[18]. Either way, The resultant 29 000 part-time and full-time jobs lost across the province represent a significant failing in the region's struggle against unemployment[19].

[18]However, Vink and Van Rooyen do note that "While labour regulation appears to have negatively impacted on employment levels, there is evidence to suggest it has had a positive impact on the development status of those farm workers who continue to be employed" (2009: 25)

[19]Despite this, agriculture nationally remains a high-employment sector, employing 8.5 percent of the nation's work force despite only being directly responsible for about three percent of national GDP (Vink and Van Rooyen, 2009). This figure is likely to be even higher in the Western Cape, due to the labour intensity of its horticultural component.

3.9 Conclusion of Chapter Three

Chapter Three began by introducing the concept of the global polycrisis and outlined seven key elements of this crisis and their relation to agriculture. The seventh of these key elements was food security, and as this is a core focus of this paper it was reviewed in greater detail.

From this review of food security it was shown that currently insufficient access to available food is the primary driver of food insecurity globally, but that due to the nature of the polycrisis both access and availability are likely to deteriorate in future if a business-as-usual approach towards agriculture is maintained. In light of this it was proposed that for large-scale commercial agriculture the best polycrisis mitigation and adaptation strategy is that of a hybridised middle ground, where a shift towards LEI farming is initiated by finding ways to apply existing LEI or organic approaches to large-scale farms.

Having outlined the problems at a global level and established a proposed approach, the focus shifted towards the Western Cape in order to develop an understanding of the problems of food security and agriculture as they pertain to the area in which this study was conducted. As in the global context, the inability to access food due to financial limitations was shown to be an important driver of household food insecurity.

Chapter Four will now begin to address the title of this paper more directly. It aims to determine what drivers of change exist in the Swartland, how LEI technologies which work in closer partnership with natural systems are being used to respond to these drivers, and what the effects of this are likely to be on food insecurity – given the understanding of regional food security developed in section3.8.

CHAPTER FOUR: AGRICULTURE AND AGRICULTURAL CHANGE IN THE SWARTLAND

This chapter draws on the case study research, literature review and secondary data to present a picture of some of the drivers of agricultural change in the Swartland region as well as the way in which farmers are responding to these challenges, within the framework of the research objectives[20] . First the drivers are described, then examples of responses are provided, and the remainder of this chapter briefly outlines the effects of these responses on the volume of food produced as well as the cost of producing it.

4.1 Introduction

The Swartland climate is Mediterranean and the region receives between 250 and 700 millimetres of winter rainfall per year, depending on geographical locale (Morel, 1998). The main focus of Swartland agriculture is rain-fed winter cereals, predominantly wheat but also some oats and barley. The region also produces canola, horticultural products such as wine grapes and vegetables, sheep, cattle, poultry, eggs, dairy products and wool. Farm sizes are relatively large and generally range from 300 2000 hectares, with some exceptions.

The interviews and discussions held with farmers in the interview process did not provide any information which suggests that the Swartland does not fit into the broader set of trends taking place nationally – such as the trend of increasing farm sizes in South Africa that has been identified by Stats SA. None of the farmers contacted indicated that their farms had got smaller over the last 30 years, and five of the seven farmers interviewed indicated that their farms had grown in size, some by as much as 300 percent. Correspondingly the levels of large-scale mechanisation which become affordable at larger farm sizes are on the increase, resulting in higher labour productivity but lower total employment figures for the farms in question and probably the region as a whole. This suggests that a number of the trends taking place within the Swartland are reflections of a wider set of pressures and adaptation strategies taking place provincially, nationally and internationally.

[20] "To investigate whether or not examples exist of commercial GR farmers in the Swartland shifting towards LEI systems which operate in closer partnerships with natural systems."

4.2 Change in Swartland agriculture and its drivers (the local storm)

Using data collected from the farmer interviews, in conjunction with academic and industry research the following section seeks to identify agricultural changes taking place in Swartland agriculture as well as the drivers of this change.

4.2.2 Why is identifying the drivers of change important?

Identifying the drivers of change is important because understanding the challenges faced by farmers, and thus the reasons why they change is their farming methods is necessary for directing this and future research into how they are changing. Identifying the drivers of change also has the potential to yield information which can assist with anticipating future changes in the adoption patterns of the technologies identified here. More specifically, if the drivers of change in the study region are clearly connected to the global challenges identified by Swilling and others, then the intensity of these drivers in the Swartland can be expected to change in relation to future changes in the polycrisis. Should this be the case, the adaptation measures developed by the farmers who were studied could also be of relevance to the resolution of the polycrisis and the sustainability of future food supply elsewhere. This would suggest that further research into the field could be valuable.

If, however, the drivers of change in the study region have very little in common with the polycrisis identified in Chapter Three and the global challenges facing food security and agriculture, then the responses identified in this study could be deemed less important and only of local relevance.

4.2.3 Drivers of change

The farmer case studies were used as the primary means of determining drivers of change in the Swartland, together with supporting data from regional Swartland-specific literature by Hardy (1998), Genis (2008) and the Agricultural Research Council (ARC) (2010). In determining the drivers of change an effort was made not to lead farmers into their responses, by posing more open-ended questions such as, 'What prompted you to undertake the changes you have just described?' and, 'What do you see as the main challenges for your farm over the next 10 – 20 years?'. Farmers were also asked for their 'general reflections' at the end of the section which dealt with their farm in the past, as well as at the end of the section which dealt with their farm in the present. These spaces for general reflection encouraged all farmers to raise and discuss any points which they felt were important but which had not been addressed by the questionnaire. Finally, after all of this information had been captured, the closing section of the questionnaire raised specific questions relating more directly to the global polycrisis, such as, 'Do you subscribe to the concept of peak oil? And how much do you think the oil price in the future will increase the cost of fuel and farm chemicals?’ and, ‘Do you consider the forecast changes in regional weather patterns as a result of global warming to be a threat to your business?’.

Due to the largely open-ended nature of the questions a wide range of responses emerged relating to the drivers of change. Also the way that farmers articulated common drivers varied. For example, Farmer 1 cited that, “Many of the changes, particularly reducing inputs and building soils, arise from a desire to become more drought-resistant, both in terms of the ability of crops to survive through droughts and the financial loss which is suffered if crops do fail” (Steyn, 2010). While Farmer 3 stated, “Even though the low input low output system delivers lower yields than my neighbours get, it is just as profitable if not more profitable and more resilient to price fluctuations than they are” (Heroldt, 2010).While neither of these statements explicitly mentioned economic risk minimisation, it is implicit in both of the responses.

In order to determine the primary drivers of change, farmer’s responses from all potentially relevant sections of the questionnaire were analysed in order to establish what the most common and recurring drivers raised by the farmers were.

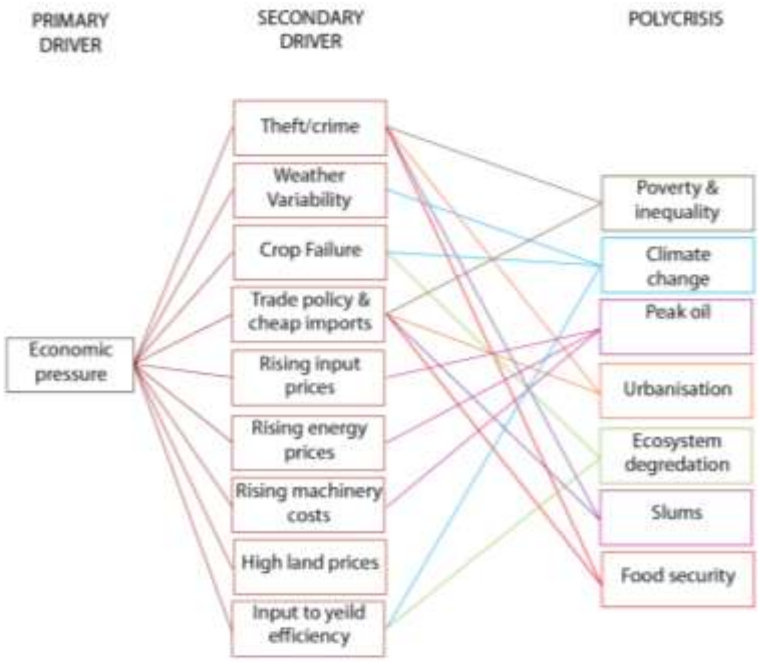
What emerged was that economic pressures, risk minimisation, the desire for intergenerational sustainability motivated by the tradition of the ‘family farm’, as well as the logical incentive to shift towards a system which appears to be more profitable and resilient were four main drivers of change listed by farmers during the interviews.

Economic pressures and risk minimisation were two drivers which were also identified as drivers by the literature on the region (Hardy, 1998; Genis, 2008). All four drivers are highly interdependent; economic viability is vital to intergenerational sustainability, as is the minimisation of risks associated with crop failure and drought. Similarly the practices in place on a profitable low-risk farm are likely to gain the attention of other farmers who are struggling to make ends meet and faced with the prospect of selling their farms.

As well as being interdependent, these drivers share a number of common root causes. These ‘drivers behind the drivers’ so to speak are as important, if not more important, to understand than the primary drivers, as they are the direct cause of the primary drivers. As such they are the first link in the chain which needs to be understood in order to determine effective responses to the four primary drivers. For example when farmers were asked what the primary driver behind their changes in practice was, most cited economic pressure. Predictably however, further questioning revealed that this economic pressure was not an event in itself, but rather the culmination of a range of other drivers such as changes in local and international trade policies (Phillips, 2010), rising input prices(Hardy, 1998), rising input requirements (Genis, 2008; Heroldt, 2010), rising machinery costs(Lesch, 2010), high land prices(Stats SA, 2007;Heroldt, 2010), crop failures(ARC, 2010), variable weather (Hardy, 1998), theft (Stats SA, 2007; Bester, 2010) and produce price fluctuation (Gregor, 2010).

Many of these secondary drivers can in turn be linked back to deeper causes within the global polycrisis. For example, crop failure, severe weather and rising input requirements can all be linked to ecosystem degradation and climate change (Conway, 1997; Meadows, 2003; UNEP, 2009c) Examples of these links are illustrated in Figure 7.

Figure 7: Indirect links between economic pressure on Swartland farms and the polycrisis



While the connections between the three columns in Figure 8 are simplistic and ignore many of the complexities and contradictions present, they serve to illustrate the chain of connections between farmers and the polycrisis. Being aware of this chain of connections, leading from the primary drivers which farmers state they need to overcome in order to be sustainable through to the polycrisis, is vital to ensuring that the responses put in place to address the primary drivers are positioned correctly and do not simply become short term solutions. Due to the importance of the secondary drivers the polycrisis drivers, a closer analysis of them is conducted in the following section. The focus on certain elements of the polycrisis within this section will not be a repeat of section 3.2, but rather a context specific analysis of climate change, peak oil and ecosystem degradation in direct relation to these farmers or as they were raised by the farmers themselves.

4.3 A closer look at the drivers of change

This section reviews eleven of the most prominent drivers of change in closer detail. The section is based primarily on data collected in the case study questionnaires. However, as the data provided by the farmers tended to be anecdotal, supporting literature and data were utilised to substantiate and broaden the farmers' claims in order to improve the understanding of the points they raised.

4.3.1 Trade policy and cheap imports

Following the deregulation of the agricultural marketing boards in 1996, farmers in the Swartland were forced into competition with other farmers from all over the world almost overnight (NAMC, 2008). However, the playing fields on which the Swartland farmers now compete are uneven as a number of the regions with which Swartland farmers compete receive government subsidisation which enables farmers in these regions to sell agricultural goods at prices which do not reflect the full cost of producing them (Wise, 2004). On average, farmers in OECD countries receive producer subsidy support equivalent to 44 percent of the total value of agricultural production (Pretty, 2006). Swartland farmers receive no subsidies and are granted relatively low levels of import protection by the South African government[21] (Joubert, 2010). This means that farmers are continually being driven to develop ways in which they can remain competitive in spite of the subsidisation of their competition.

These low prices are one driving force pushing farmers in the Swartland to develop alternative, more cost effective, competitive ways of farming. This in itself, however, does not determine whether the coping mechanisms which are adopted lead to improved or reduced sustainability of the sector.

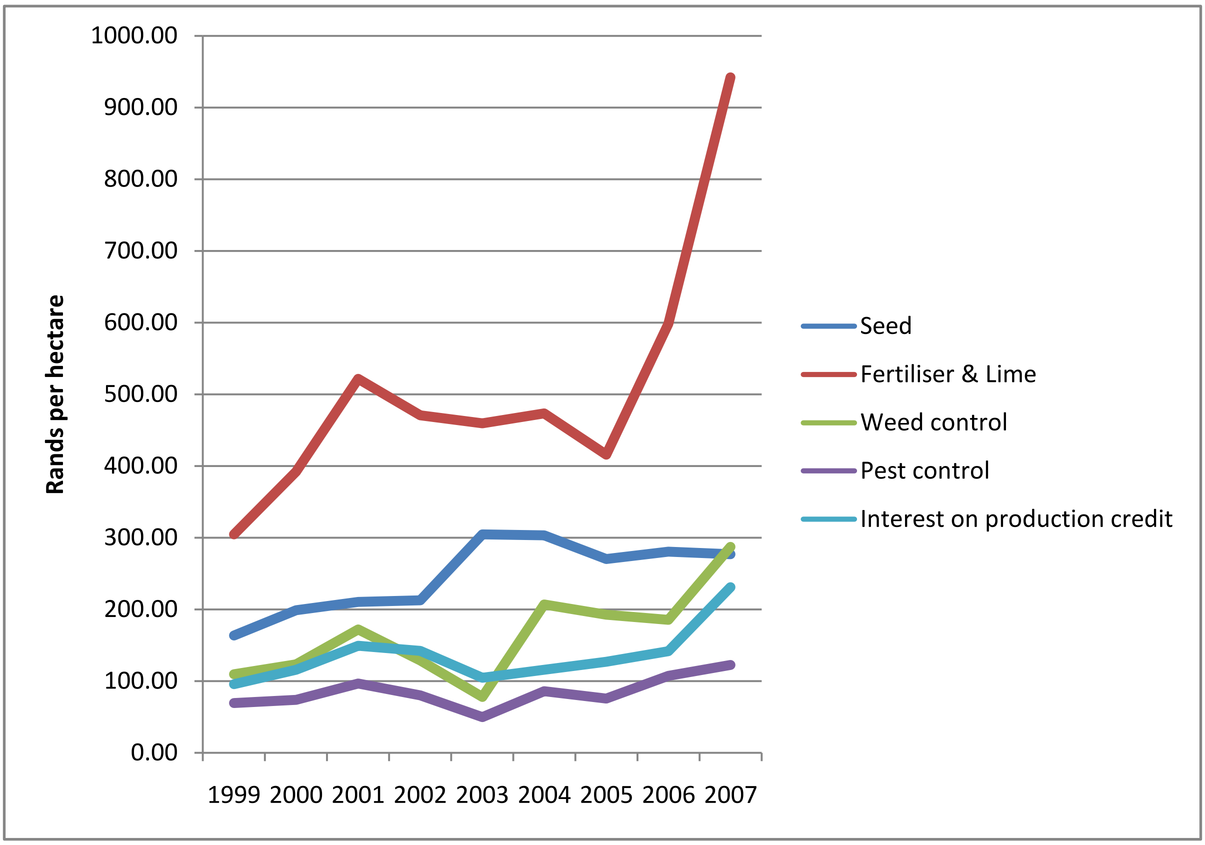
4.3.2 Rising input costs

Input costs have risen dramatically over the past decade (see Figure 8) and there have also been a number of allegations and concerns raised about price-fixing being committed by a number of large chemical suppliers, including the state owned petro-chemical company Sasol (Farmers' Weekly, 2010; Gregor, 2010). These allegations of price manipulation and unethical profiteering extend beyond the large-scale chemical producers to the chemical sales-people who act as middlemen between chemical retailers and farmers.

[21] Currently there is an import tariff in place for wheat which assists in protecting farmers from cheap imports. This import tariff was raised in May 2010 from R1170 per tonne to R1610 per tonne (Joubert, 2010).

Between January 2005 and September 2009 the domestic price of phosphate rose by58.4 percent, nitrogen by 59.7 percent and potassium by a staggering 239.1 percent (NAMC, 2009).

Figure 8: Selected input costs for Swartland wheat production



Source: Figures adapted from Grain SA (2007)

In the Swartland, the per hectare cost of production for wheat rose by 112 percent between 1999 and 2007 (Grain SA, 2007). This rise was largely due to increases in the following: seed rose by 39 percent; fertiliser and lime by 140 percent; weed control by 33 percent and pest control by 51 percent. In addition, the cost of borrowing the capital necessary to finance the increased input costs rose by 142 percent (Grain SA, 2007).

These per hectare figures can be misleading as they reflect the average cost of production per hectare and thus they do not reflect gains in productivity which potentially result from increased spending on inputs. In other words, at times of high wheat prices farmers may choose to increase the volume of seed and fertiliser they use (and thus spending per hectare) in order to increase their yields to capitalise on the high prices. However, the yield gains in terms of tonnes of wheat per hectare have remained modest in comparison to increases in the cost of inputs per hectare over the period reflected in Figure 8. The average wheat yield per hectare for the same period between 1999 and 2007 rose by only 7.4 percent, from 2.81 tonnes per hectare to 3.02 tonnes per hectare respectively (Grain SA, 2007).

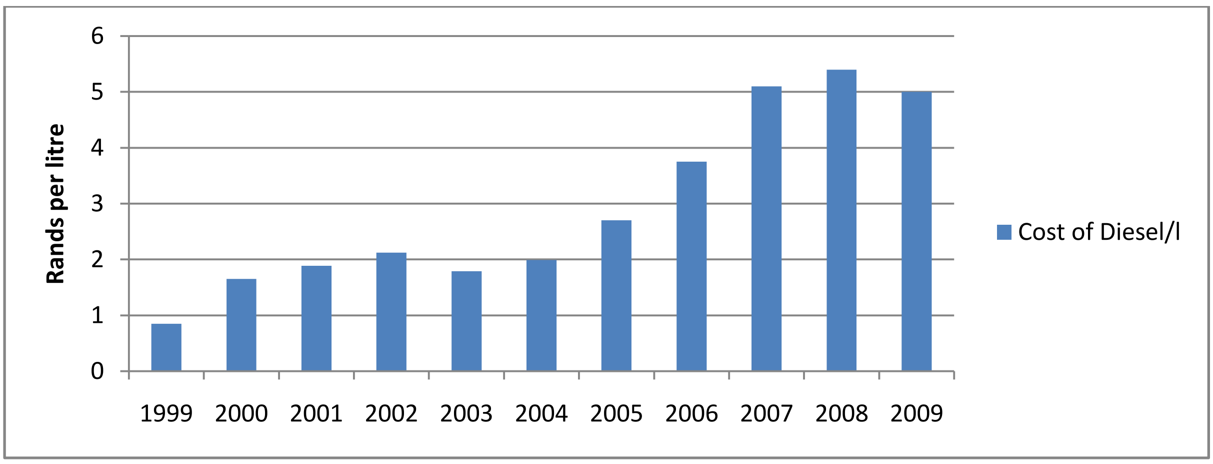
While the NAMC figures are for national input prices, the Grain SA figures do not necessarily reflect the retail price of inputs. As such the increased costs for production in the Swartland quoted above could be a result of cumulative factors. For example, the increased cost per hectare for fertiliser and lime might be a result of both increases in the price of these inputs and a decrease in the efficiency with which they are used.

Whatever the reasons for sharp rises in the cost of chemical inputs and the high price volatility, there is no question in the minds of Swartland farmers interviewed during this research that the growing proportion of their farm income being channelled into inputs as a result of price increases is something they would like to decouple themselves from. This drive to reduce the cost of production by reducing the need to purchase inputs is a significant driver of change in the Swartland.

4.3.3 The rising cost of energy

Although the diesel price has declined somewhat from record highs in 2008, it remains high by historical standards – as can be seen in Figure 9– and in the medium to long-term most forecasts warn that continued steep price increases are to be expected (WEC, 2007). This price increase is forcing farmers to look for ways to reduce their diesel consumption. Considering that one of the foundations of large-scale, rain-fed agriculture has been the power provided by diesel-driven machinery, which is used at every point in the production cycle, finding ways to significantly reduce diesel dependence is a daunting task.

Figure 9: Changes in the landed cost of diesel between 1999 and 2009



Source: DoE, 2010a

Similarly electricity, which has historically been cheap in South Africa (DoE, 2010b) is set to increase by 25 percent per annum for the next three years as the national energy provider seeks to raise capital to replace ageing power plants (DoE, 2010b). As Swartland farmers require almost no electrical energy in their crop production because they do not irrigate, the electricity price hikes will not have a large impact on their production costs. But, for those in the region who do irrigate and rely on electrical pumps in order to do so, this increase in the cost of electricity over the next three years will have a more serious effect.

However, on the point of energy as a driver of change, it must be noted that two of the seven farmers made statements which were contrary to the widely held belief that oil price increases will be bad for farmers. Farmers 3 and 6 felt that they stood to gain from rapidly rising oil prices, because this has stimulated demand for biofuels in the past and as more corn is diverted to biofuels, grain prices go up. These two anticipate the rises in grain price more than compensating for the increase in input costs which they will incur as a result of rising fuel prices.

4.3.4 Cost of machinery in relation to farm size

Just as fossil fuels have provided the necessary energy for the up-scaling of agriculture, a range of increasingly large machinery has provided the mechanisation to make this possible. As the size and technical sophistication of this machinery has increased, so too has the cost (Grain SA, 2009). This increase has been reflected in even the most fundamental machinery such as tractors, the prices of which have more then doubled over the last ten years (Grain SA, 2009). There is also the added cost of digital monitoring and control equipment and software which has entered the marketplace over the same period. In order to make these expensive purchases possible, farmers have to be operating on a scale which enables them to repay these investments (Lesch, 2010). The changing nature and cost of farm machinery used by farmers in the Swartland makes smaller farms less able to afford the investments necessary to replace old equipment or capitalise on improved technologies (Lesch, 2010). The advantage held by larger-scale farmers in this situation is a driver of change in the region and entrenches what one farmer referred to as a “get big or get out” mentality (Grobbler, 2010).

4.3.5 The cost of land

The above mentioned pressure on farmers to increase their farm sizes converges with the high cost of agricultural land in the Western Cape to create an unusually high level of farm debt for Swartland farmers. While figures for farm debt specific to the Swartland were unavailable, three of the farmers interviewed identified the high cost of land in the region as a problem, without being prompted by the questionnaire. Their comments tie in with Statistics South Africa’s provincial figures on agricultural debt in the commercial sector, which place agricultural debt and assets in the Western Cape at R9 billion and R44.6 billion respectively, compared to a provincial average of R3.5 billion and R16.8 billion respectively for the remaining eight provinces (Stats SA, 2007). This in turn means that farmers in the Western Cape pay R664 million rand in interest each year compared to the average of R270 million paid by farmers in the remaining eight provinces (Stats SA, 2007).

4.3.6 System in decline

Natural capital in the form of productive soils is vital to agriculture, and the Swartland is no exception. The importance of maintaining soils in the Swartland was acknowledged in the early 20th century, largely as a result of the raised public awareness of how badly soil management could go wrong following the 1930s Dust Bowl in the USA (Meadows, 2003). This came at a time when the Swartland was suffering from severe wind and water erosion following a century of agricultural expansion, misinformation and malpractice (Meadows, 2003). The culmination of the growing problem of soil erosion in the region and a heightened awareness of its effects led to active intervention by local authorities (Meadows, 2003). As a result, almost 70 years later only a small fraction of the erosion gullies present in mid 20th century are still visible in the Swartland (Meadows, 2003).

While this success is significant and encouraging, a number of other aspects of the region's soil health have not received the same attention and have continued to decline (Lanz, 2009; Heroldt, 2010; Gregor, 2010). Organic matter, measured by the amount of SOC present in the soil, has shown a steady decline over this period and is roughly estimated to be below 50 percent of the pre-agricultural levels (Lanz, 2009). There tends to be a close connection between SOC and soil structure, as well as soil fauna and flora (Reeves, 1997), so the claims made by all seven of the farmers who were interviewed, that the management practices which had been applied to their soils in the past had led to a significant deterioration in soil health, seem very plausible.

This decline in SOC, soil structure and soil biodiversity inhibits root growth, mineral uptake by crops and the resistance of crops to drought and pestilence (Lal, 2006). The loss of SOC also reduces the water use efficiency, water absorption and water storage capacity of the region's soils (Lal, 2006). These water absorption and storage losses are a significant disadvantage in terms of the region's resilience to climate change and rainfall variability.

According to the farmers who were interviewed, this decline in soil quality was caused by aggressive tillage practices, synthetic fertilisation and poor crop residue management practices such as burning and bailing. Smit (2002) also connects tillage practices and the burning and burning of crop residue to declining soil health in the Swartland. These findings are supported by Clapp, Allmaras, Layese, Linden, and Dowdy (2000) who found that tillage, fertilisation and residue management all had an effect on SOC. The detrimental effects of tillage are also supported by Lal (1991).

One reason for this decline in soil health is that crop residues are estimated to contain up to a quater of all nutrients applied to a crop (Magdoff, Lanyon and Liebhardt, 1997), therefore the burning or removal of this from the field represents the loss of potentially significant plant nutrition. Also, as plant litter is the food source for a range of agriculturally beneficial soil micro-organisms such as earthworms, the clearance of biological material from the field eliminates these organisms and the services they deliver (Mollison, 1998).

In addition to the degradation of regional soils, the extensive clearance of indigenous biodiversity, much of which is endemic and highly threatened, to make way for agricultural lands has severely degraded ecosystems in the Swartland (Conservation International, 2007). The use of remaining unploughable farm areas as rangeland for sheep and cattle has furthered this degradation (Conservation International, 2007). Currently less than 10 percent of the original Renosterveld in the region remains (Conservation International, 2007). According to Shiva (1995), this loss of total biodiversity within the system increases its vulnerability and reduces its overall resilience to shocks. As a case in point, the ARC's Small Grain Institute states that natural predators of aphids are important to their control and that ecological balance in the environments surrounding fields will help to limit aphid infestations and their associated financial costs (ARC, 2010). The ARC also warns that the use of pesticides can kill aphids' natural predators, which in turn increases aphid infestation in the future. The ARC therefore advocates cautious application of poison in dealing with aphids, and the maintenance of biodiversity surrounding fields (ARC, 2010).

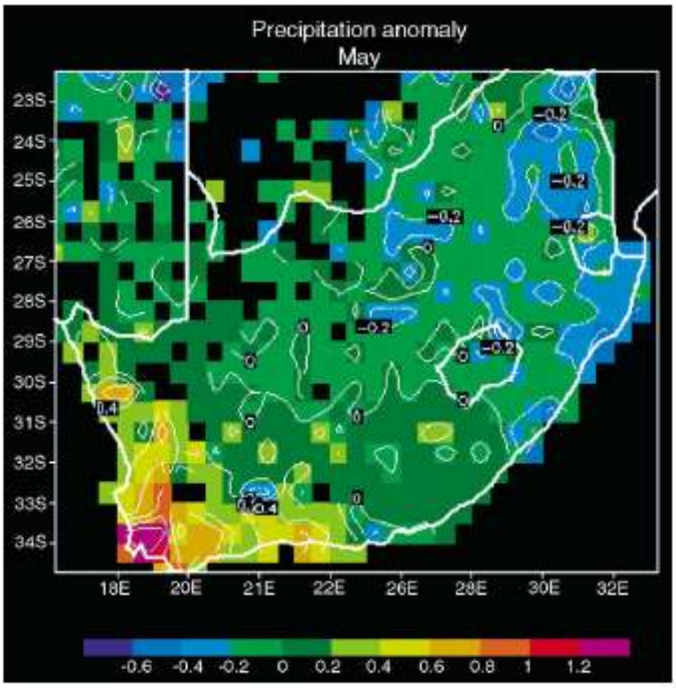
4.3.7 Climate change (local forecasts and impacts)

Temperature and rainfall patterns in the Swartland vary significantly, often by as much as 200 mm within the space of less than 10 kilometres. This phenomenon is a result of rain shadows cast by the mountain ranges which transect the region, as they run perpendicular to the westerly direction from which the region's rain originates. The effects of climate change are therefore likely to vary significantly within the region (Midgley *et al*, 2005).

Gbetibouo and Ringler (2009) identify the Western Cape as the province which will be most highly exposed to the effects of climate change in South Africa. Within the Western Cape, areas closer to the coastline will be the most affected (Gbetibouo and Ringler, 2009). Meadows (2003) confirms the high exposure of the Swartland to climate change and forecasts that the region will receive significantly more rain in certain months under a doubled carbon scenario as illustrated in Figure 10.

These increases would potentially be as much as 100 percent more in certain high rainfall months (Meadows, 2003). This is a dramatic increase which is unlikely to bode well for farmers in the Swartland. Meadows points out that while small increases in rainfall would benefit certain farmers, a doubling of rainfall in the month of May when farmers' fields are at their most vulnerable to erosion[22] could result in high increases in soil erosion (Meadows, 2003). Meadows' findings tie in

Figure 10: Rainfall forecast map of South Africa under a doubled carbon dioxide scenario



Source: Meadows, 2003

with those of Midgley *et al* who forecast an increase in summer rainfall combined with winter drying (Midgley *et al,* 2005).

In addition to changes in rainfall patterns, temperature variations are likely to change significantly too, with an overall increase in average temperature between 1.5 and 3 degrees Celsius by 2050 (Midgley *et al,* 2005). This will have an overall negative effect on the region as both consumers and producers will experience a decline in welfare (Erasmus, van Jaarsveld, van Zyl and Vink, 2000).

While climate change is unlikely to be as rapid or immediately visible an event as the increase in the price of fertiliser or soil erosion, its effects are likely to be far greater and its causes almost entirely beyond local or national control (Midgley *et al,* 2005). Farmers wishing to take an active stance on

[22] Shortly before and after the season's seeds have been sown, ground cover is at a minimum.

the threats posed by climate change will have to take a long-term pragmatic approach to adapting to its effects despite pressure to neglect adaptation measures in the face of pressing short-term challenges such as immediate economic pressures. However, as raised in section 3.2.3, agriculture is a significant GHG emitter so while agriculture in the Swartland may only be a very small part of a much larger problem, farmers in the Swartland, like all other emitters, have a role to play in climate change mitigation.

4.3.8 Water

Water forecasts for the Western Cape indicate a growing water scarcity as a growing population comes up against the fact that the majority of the province's water resources are already fully or over committed (Midgley *et al,* 2005). For the majority of farmers in the Swartland this increasing competition for water resources in the province will not be of great significance to their production potential as their farms are rain-fed. This sentiment was reflected in the interviews, during which none of the seven farmers indicated that the growing water scarcity in the province was a threat to their production.

This is not to say that water is not an issue for all Swartland farmers, or even that it was not highlighted as an issue during the research interviews. The volume, timing and reliability of rainfall was highlighted as an issue by six of the interviewees[23]. So while increasing water demand does not affect the bulk of production of field crops in the Swartland, changes in rainfall patterns do. Midgely *et al* (2005) indicate that the way in which rainfall patterns are likely to change in future will decrease the total amount of water available to rain-dependent farmers in the Swartland. However, because of significant variation in rainfall patterns in the region due to its topography (Morel, 1998), the effects of rainfall changes as a result of climate change are likely to vary significantly between farmers, making it very hard to make generalisations for the region (Gregor, 2010; Rigter, 2010). Despite this, five of the farmers indicated that they were concerned that climate change would have a negative impact on water supply.

4.3.9 Pests, weeds and disease

The rapid evolution of pests, weeds and diseases is a relatively new phenomenon to which farmers in the Swartland need to adapt and adjust their farming practices (ARC, 2010). Resistance to current chemical poisons is increasing throughout the small-grain producing areas of South Africa, meaning that weeds and pests are able to survive and reproduce in spite of exposure to chemicals that would previously have been lethal (ARC, 2010). The evolution of herbicide resistant strains of ryegrass and

[23] One of those who didn't cite decreased rainfall as a threat indicated that as he was up against a mountain range which caught the rain, he actually suffered from a problem of too much rain at present. He therefore felt that a reduction in total rainfall could be beneficial to him.

wild oats in the Swartland is of particular concern to the farmers who were interviewed (Steyn, 2010; Lesch, 2010; Gregor, 2010). This is consistent with a recent report released by the ARC (2010). The resistance of these species means that farmers are forced to find alternative ways of ensuring that these weeds do not overrun their fields. Many of the herbicide resistance problems have arisen out of changes in tillage practices: weeds that are no longer ploughed into the soil need to be chemically controlled (ARC, 2010). These changes in tillage are addressed in section4.4.

4.3.10 Crime

Stock theft, violent crime and equipment theft are arguably non-agricultural challenges faced by farmers in the Swartland. However, these forms of crime influence the way in which farmers are able to farm and the costs of farming in the region. In the agricultural sector in the Western Cape the financial losses as a result of crime amounted to R51 million in 2006, of which stock theft contributed 27 percent (Stats SA, 2007). Stock theft, in particular the theft of sheep and cattle, has an impact on the types of farm systems farmers are able to implement and could potentially pressurise farmers into maintaining less diverse forms of agriculture which exclude animals from the farm system. This has a potentially negative knock-on effect on the development of rotational cropping systems in the Swartland, as farmers wishing to introduce legume rotations into their production cycle tend to compensate for the loss of wheat revenue during the legume cycle by introducing sheep and cattle to graze on the legume pastures. These animals not only bring diversity back into the farm system and contribute to soil health through the contribution of their manure (Heroldt, 2010), but the meat, milk and wool which they provide are an important source of income for farmers trying to diversify their operations. If farmers are unable to stock these pastures, crop rotations become less profitable. According to farmers interviewed, the levels of stock theft from fields is linked to the size and proximity of urban settlements. Two farmers said that they were able to stock sheep on certain parts of their farms which were further from local towns but that the levels of theft from their land closer to Malmesbury and Moorreesburg made it unprofitable.

4.3.11 Peer influence

Even in sustainable systems that are run effectively, things can be tweaked and adjusted to improve the way they function. In light of the challenges that farmers face in the Swartland which have been outlined above, there is ample room for adjustments and innovation. In light of this the well developed inter-farmer knowledge sharing networks in the Swartland deserve attention as they have an influence on the way that new technologies and practices are developed and adopted.

All of the farmers interviewed belonged to the Farmers' Union. Within this structure most farmers choose to divide themselves up according to the sub-regions in which they farm and the crops they grow. These sub-regional, crop-specific groupings are referred to as 'study groups'. The study groups farmers meet on a monthly basis to share ideas as well as to plan collaborative test plots and review financial and farm management experiences (Lesch, 2010). The key concept being to create an open and mutually beneficial forum in which farmers can test ideas and learn from one another (Lesch, 2010).

In order to ensure that farmers in one sub-regional study group maximise the impact of their learning experience and benefit from the learning experiences of other study groups, each sub-regional study group holds an open day once a year which all other members of the Farmers' Union are encouraged to attend. In this way, if a farmer comes up with an improved solution to a problem it can be peer-reviewed by other farmers growing the same crops under similar conditions and if it is approved by this review it can be shared amongst the wider regional farming community through channels such as farmers' shows, farm visits and magazine articles. Through this process farmers share the risk associated with experimentation and there is a degree of quality control over the findings from on-farm experimentation which helps to reduce the risk of others to whom this information is passed.

This network acts in combination with more informal interpersonal and social networks to ensure a healthy regional awareness of agricultural developments taking place within the Swartland. This awareness does not necessarily translate into action or changed practices for farmers who receive information, but it does help to ensure that the knowledge is made available to allow farmers to make informed choices.

Furthermore, these study groups have many features in common with the innovation enhancing networks proposed by Reij and Walters-Bayer (2001). This supports the sentiments of interviewed farmers who see the study groups and informal personal networks as innovation enhancing structures.

Table 6: Sources of external agricultural information as listed by farmers

Information source	Farm1	Farm2	Farm3	Farm4	Farm5	Farm6	Farm7	Total
Study group	x	x		x	x	x	x	6
Local Farm Visits	x	x	x	x	x	x	x	7
International farm visits						x		1
Internet		x	x	x	x	x	x	6
Local agricultural magazines	x		x	x	x	x	x	6
USA and Australian publications	x		x	x	x			4
Grain SA		x	x	x		x	x	5
DAFF				x				1
Input salesmen	x	x						2
Agricultural consultants			x			x		2
Short courses	x		x	x	x		x	5

Besides other farmers, there are a number of diverse sources of information about new technologies which interviewed farmers tapped into, as is illustrated in Table 6. These included agricultural publications from South Africa, Australia and the USA, DAFF, input salespeople, local and international agricultural consultants, Grain SA and the internet. Furthermore, farm tours to other parts of South Africa as well as Australia seemed to have been important additional sources of information for those interviewed.

This extensive exposure to agricultural information and culture of knowledge-sharing means that farmers are continually prompted to reflect on their existing practices and weigh up alternatives.

4.3.12 Summary

It has been argued that farmers in the Swartland face a wide range of challenges and that these challenges act as drivers of change in the region. These were shown to be economic, ecological and social in nature. Of these drivers, the negative economic implications of the challenges was the reason that farmers cited most often for seeking alternative solutions. Farmers were predominantly financially motivated and tended to consider issues such as biodiversity loss or climate change as important only as far as they impacted on their farm businesses.

Due to the nature of many of these challenges faced by farmers, there was little doubt in the minds of the seven who were interviewed that failing to address these challenges would result in the collapse of their farms and livelihoods. In other words, maintaining a business as usual approach was not sustainable for them. This view is supported by a wide range of local and international literature which critiqued the prevailing approach to large scale HEI agriculture (as has been practiced in the Swartland) and highlighted the importance of change(Magdoff *et al.* 1997; Sherr, 1999;Smit, 2002; Meadows, 2003; Midgley *et al.* 2005; Lal, 2006; Pretty, 2006; ARC, 2010; Lal, 2010).

While the challenges outlined in this section and the unsustainability of maintaining a business as usual approach are arguably applicable to most farmers in the region, the first objective of this research was to identify farmers who were responding to these challenges by reducing their reliance on external inputs and building partnerships with natural systems. Therefore the responses to these challenges were not assessed for all farmers in the region, but only for farmers selected according to the process described in section2.4.1. The following section aims to address Research Objectives I and II by presenting the findings about the farmers' responses to the challenges raised thus far.

4.4 Farmer responses

As stated at the end of section4.3, this chapter aims to answer Research Questions I and II, namely: 'Do examples exist of commercial farmers in the Swartland shifting towards LEI practices which work in closer partnerships with natural systems?' and 'What systems and technologies are farmers using in order to reduce their external input usage and build partnerships with natural systems?'

Section4.4 is based on the data collected from farmers through the research questionnaire. Where applicable and possible these findings are supplemented or supported by existing literature or secondary data.

4.4.1 Introduction

Although farmers in the seven case studies varied significantly, all employed some practices which constituted a shift towards building partnerships with natural systems and all were reducing the extent to which they relied on external inputs (EI) – particularly synthetic ones.

External inputs were generally reduced in one of two ways:

- The need for EI was reduced or eliminated through the adoption of on-farm technologies or practices.

- Quantities of EI were reduced by increasing the efficiency with which EI were used or accepting declines in productivity.

A third practice is also worth noting, namely the replacement of synthetic EI with locally-sourced organic inputs such a chicken or cattle manure.

Enhanced partnerships with natural systems, such as the use of nitrogen fixing crop rotations and the restoration of soil biodiversity, were a common means by which the need for EI was reduced, eliminated or replaced.

In total 34new technologies or practices were identified by farmers during the case study interviews, of which 29 are considered to contribute towards a reduction in EIs or the enhancement of natural partnerships. Table 7 lists these 34 technologies and practices according to alphabetical order. Highlighted in grey are the six practices which are not considered to constitute or contribute directly towards a shift towards LEI systems which work in closer partnerships with natural systems.

Table 7: List of newly adopted technologies and practices

Newly adopted technology or practice
1. Albrecht system of soil balancing
2. Animal rotation
3. Bigger farms
4. Bigger machinery
5. Compost making
6. Compost tea
7. Reduced tillage
8. Crop Rotations
9. Developing own marketing channels
10. Foliar sprays over pelletised fertiliser
11. GPS technologies
12. Increasing herbicides
13. Leaving OM on soil surface (mulching)
14. Legume Rotation
15. Less labour
16. Microbial stimulants
17. More sheep and cattle/ha
18. New cultivars
19. New planters
20. New poisons
21. One pass planting
22. Organic fertiliser alternatives (eg rock phosphates)
23. Owl boxes
24. Precision planting
25. Reducing fungicides
26. Reducing pesticides
27. Reforestation
28. Removal of contour bunding
29. Stopped burning off crop residue
30. Trace element fertiliser application
31. Use of cow manure
32. Use of pelletised chicken manure
33. Virgin land conversion to farmland
34. Virgin land preservation

Many of these 34 technologies and practices were highly interdependent on one another and, of the 34, four were identified as being of foremost importance and key to the implementation of other technologies. This level of importance was determined by the ratings the farmers gave the technologies and practices, as well as the frequency with which the technologies and practices were mentioned by the farmers and in the literature.

The dependence of other technologies and practices on the four which were selected also supported their ranking as key technologies and practices.For example, the fact that farmers can only stop burning their crop residues once they introduce crop rotations[24] helped to promote legume rotations as one of the four most important technologies and practices

The four key technologies and practices were:

- Legume rotations
- Reduced tillage
- New planters
- Larger farms

Of these four, reduced tillage practices and legume rotations were identified as vital tools in their own right as well as enabling the adoption of a number of other important LEI or natural system (NS) practices. New planters and larger farms were considered key enabling prerequisites without which many other important LEI or NS practices could not be realised.

Due to the complex and highly interdependent nature of the elements within a farm, particularly those which work in closer partnership with natural systems, the systems and technologies adopted by farmers proved problematic to classify. This was largely because in resilient natural systems each element or practice fulfils a multitude of functions and can be interpreted from a number of different angles (Mollison, 1988). Legume rotations, for example, perform a number of important soil building functions and are most commonly classified accordingly. However, legume rotations also enable output diversification and the introduction of animals into the farm system, which in turn impacts on the type of management skills which are required by the farmer and the financial risk profile of the farm.

The following section aims to provide a description of the most common and important of the 35systems and technologies identified by the farmers during the case study interviews. Particular attention will be given to the four primary practices stated above, as well as justification for why the practices and technologies described can be considered to represent a shift towards LEI farming which works in closer partnerships with natural systems. This will be done in sections 4.4.2.1 – 4.4.2.4. Following this a wider review of the changes taking place on the farm is undertaken in

[24] Farmers farming on a straight monoculture system need to burn their crop residues in order to prevent the carry over and build of crop diseases to the next season.

sections 4.4.3 and 4.4.4. Section 4.4.3is largely centred around soils and the changes being made to their management while 4.4.4focuses more on a number of the other technologies and practices listed in Table 7.

4.4.2 Description of technologies

4.4.2.1 Legume rotations

A move away from wheat monocultures to rotational cropping systems[25] which include a strong legume component had taken place on all seven farms. According to the farmers this trend was the single most important change which had taken place on their farms. None of the seven farmers, still farmed on a wheat monoculture system. Six included a legume in their rotation cycle and the one farmer who didn't stated that he would like to but was unable to do so due to financial constraints related to the small size of his farm. Of these six, five considered the legume rotation to be the single most important difference between the way they had farmed in the past and how they were farming now, and all saw it as an important tool for the future of their farms. In terms of the research objectives of this thesis, the introduction of nitrogen-fixing plants and the range of benefits they deliver is relevant as it represents the use of a natural system to assist in the reduction of external inputs.

For the farmers who had adopted it, the legume rotation had a wide range of benefits, although the extent to which legumes were used differed between the six farmers.

The standard inclusion of legumes within the group was 50 percent, meaning that for each season 50 percent of their arable land would be planted with a leguminous crop. However, farmer 4 was experimenting with a one-third wheat to two-thirds legume ratio, and farmer 2 favoured a legume balance which was lower than 50 percent. For most of the farmers medics were the legume of choice, while some also included clovers and lupins into their rotation.

[25] These are systems which do not plant the same crop on one piece of ground year after year, but rather have two or more different crops which can be planted in succession.

Table 8: Summarised benefits of using a legume rotation, as listed by farmers

Listed benefit	Farm 1	Farm 2	Farm 3	Farm 4	Farm 5	Farm 6	Farm 7	Total
Soil improvement	x	x	x	x	x	x	N/A	6
Farm health[26]	x	x	x	x		x	N/A	5
Input reduction	x		x	x		x	N/A	4
Drought resilience	x		x	x	x	x	N/A	5
Financial risk reduction	x		x	x	x	x	N/A	5

Table 8 summarises farmers' accounts of the benefits of using a legume within their crop rotation scheme and gives an indication of which farmers listed which benefits[27]. The following list outlines these benefits in greater detail as they were described by the farmers. No order of importance was established with regard to these benefits, so the numerical order of the list does not imply a hierarchy of importance.

1. Soil improvement: Legumes improve soil structure and add nitrogen in a way which is not detrimental to soil humus and fauna. This was a point which was particularly important to the farmers who were interested in the benefits of enhanced soil biodiversity, such as farmers 3 and 7.
2. Farm health: The rotation has drastically improved the health of other crops such as wheat by breaking the disease and fungus cycles which develop in monocultures.
3. Input reduction:
    a. The nitrogen-fixing capacity of the legumes reduces the amount of nitrogen which needs to be added to the soil from external sources.
    b. This reduction in synthetic nitrogen also means that farmers require less lime to buffer soil acidity[28].

[26] The term farm health is used here to denote a lower prevalence of diseases and pests within crops and farm animals.

[27] The following is important to acknowledge: because the use of legume rotations was a finding in itself, the questionnaire had no structured questions designed to capture the benefits. So the benefits as they are listed in Table 7 and in the more detailed list that follows arose out of the semi-structured sections of the questionnaire. Because of this the fact that Farmer 2 didn't list financial risk reduction as a benefit does not necessarily mean that he does not see this as a benefit; it could simply mean that this point didn't come up during the semi-structured conversations.

[28] As lime is one of the highest external inputs by weight, even a small reduction in lime requirements can result in savings totalling hundreds of tonnes. Depending on the source of the lime, the overall impact of these

c. The shift from a predominantly grain system, to a mixed grain-and-pasture system means that farmers require less external animal feed to support their livestock.
d. The overall improvement to crop and animal health has drastically reduced, and in some cases eliminated, the use of pesticides and disease control chemicals.

4. Drought resilience:
   a. The soil quality improvements under the legume rotation (particularly when used in combination with conservation tillage practices) wereseen by farmers to significantly increase the water holding capacity of their soils. This was an important benefit to all but one of the farmers, as rainfall variability is a major risk factor for most of their farms.
   b. More pastures enabled farmers to increase the number of livestock which they were able to stock on their farms. As these animals are less susceptible to drought and climatic variation than rain-fed field crops, they provide a financial safety net for farmers in the event of adverse weather events.
5. Financial risk reduction:
   a. In comparison to wheat, meat and dairy prices are not as susceptible to price fluctuations. The increases in the livestock component therefore help to provide a more stable income for farmers.
   b. Reduced risks of financial losses resulting from severe or unexpected weather – see points 4a and 4b above.

Beyond their use in the yearly crop rotation cycle, leguminous plants, particularly lupins, are used as a tool for soil improvement and restoration on areas of land considered unsuitable for wheat production in their current condition. Both farmers 8 and 9 reported planting lupins on sections of newly purchased farms to restore degraded soils.

savings on agricultural fossil fuel consumption is significant when source-to-farm and farm-to-field transportation is considered.

4.4.2.2 Reduced tillage

Figure 11: An upside-down mouldboard plough marks the entrance to Farm 7, where conservation tillage has been practised for over 20 years.

Source: Luke Metelerkamp (own photograph)

All farmers interviewed reported a decrease in the depth and intensity of the tillage practices which they employed. Four out of the seven had adopted minimum tillage, while two of the remaining three had adopted a conservation tillage system and one had significantly reduced his tillage. These different tillage methods are described in the following paragraphs, but all generally employ the principles which one farmer described as "ploughing as little as possible, as shallow as possible, with as much cover as possible" (Lesch, 2010). The stated reasons for the adoption of reduced tillage are covered in Table 9, and included building SOC, improving soil structure, encouraging soil biodiversity, improving soil moisture content, minimising erosion and reducing diesel usage.

Table 9: Summarised benefits of reduced tillage practices as listed by farmers

Listed benefit	Farm 1	Farm 2	Farm 3	Farm 4	Farm 5	Farm 6	Farm 7	Total
Building SOC			x	x	x	x	x	5
Improving soil structure	x	x		x	x	x	x	6
Encouraging soil biodiversity			x	x		x		3
Improving soil moisture content (also drought resilience)		x		x	x	x		4
Minimising erosion				x			x	2
Input reduction (primarily diesel)	x		x	x		x	x	5

These benefits of minimum and conservation tillage are mirrored by Lithourgidis, Damalas and Eleftherohornios, who note that conservation tillage is "an attractive alternative to conventional tillage due to its potential to protect soils from erosion and compaction, to conserve soil moisture, and to reduce production costs" (Lithourgidis *et al,* 2009). In the Swartland these systems are also more economically and ecologically sustainable than conventional tillage (ARC, 2010).

Conservation tillage is defined as a tillage system in which soil disturbance is kept to a minimum, crop stubble is maintained and soil inversion almost never takes place (ARC, 2010). Because the soil is not inverted as it is with a mouldboard plough, or cleared by other means such as disking, the stalks and roots of each season's crops are left in place, as would occur in more natural situations. This lack of soil disturbance and retention of the crop stubble improves the production potential of the soil over time by altering the soil's physical, chemical and biological properties as well as improving water retention and controlling erosion (ARC, 2010). The achievement of these benefits by farmers in the case studies is explored in more detail in section 4.4.3.

While essentially a form of conservation tillage, the term 'minimum tillage' was used by farmers to denote a stricter interpretation of the principles of conservation tillage. The ARC differentiates between three different conservation tillage practices in the Swartland, namely no-till planting, direct seeding and zero till. These are detailed in Table10.

Table 10: Explanation of tillage practices

No-till planting (Minimum tillage)	Direct seeding (Conservation tillage)	Zero till
The planter is fitted with knife-point openers which to some extent cultivate the soil during planting. Soil disturbance takes place on less than 20 percent of the total field surface.	Similar to no-till, but ground openers can include disks or coulters which may disturb more than 20 percent of the soil surface.	No mechanical soil loosening takes place. A groove is cut in the soil with a disk, in which seed is placed and then closed over.
Planting takes place without prior soil cultivation.		
Stubble is generally retained.		
Weed control is predominantly done using pre-emergent herbicide and the use of pasture phases in the crop rotation.		

Source: Adapted from ARC (2010)

The Swartland farmers who referred to themselves as practising minimum tillage could generally be considered to be practising a no-till planting approach, while those using conservation tillage would employ practices more akin to direct seeding. However, there are no strict rules or classifications to which farmers adhere, and they generally modify their practices according to the potential and requirements of specific areas of their farms. Often soil chemical or structural problems have to be corrected through the use of deeper tillage before starting with any form of conservation tillage, because they can be very hard to rectify once the new system has been adopted (Lal, 1991; Gregor, 2010). One of the interviewees illustrated this point during the interview, in which he referred to the plough pan[29] which had existed across much of his farm as a result of many years of mouldboard tillage. In order to rectify this he had to use a deep ripper which went beyond the depth of previous mouldboard ploughing in order to break the plough pan. Following this he had spent a number of years loosening the residual hard clumps within the soil with a shallower ripper. Only after these soil

[29] A plough pan is a hardened layer of soil below the soil surface which is generally the result of compaction caused by the bottom of a mouldboard plough being repeatedly pulled over a field. This has negative effects on water filtration and root development.

structural problems at deeper levels had been rectified could he begin to focus on building the top 7 - 10 centimetres of soil through a conservation tillage approach.

For most farmers the high stone content of the soils in the Swartland prohibits a zero till approach, despite its benefits (ARC, 2010). Three of the farmers who were interviewed had experimented with zero till approaches but resorted back to minimum tillage after encountering problems during planting.

Figure 4: Example of conservation tillage and stubble retention on Farm 6.

Source: Luke Metelerkamp (own photograph)

Figure 12 shows an example of a field of winter wheat which had been planted using a minimum tillage approach. The stubble and decomposing crop residue from the previous year's canola crop is clearly visible on the soil surface as no soil inversion has taken place. The stubble can be seen all the way to the background of the image, and no soil has been left bare as winter approaches after a hot, dry and windy summer.

The difference between this and a system in which the soil is worked and cleared in preparation for planting can be seen by comparing Figure 10 to Figure 13, in which crop residue has been removed or burned before the soil is disked in preparation for planting.

Figure 13: Fields being cleared in preparation for planting on a farm in the Swartland

Source: Luke Metelerkamp (own image)

Beyond the soil improvement benefits which conservation tillage offers, it can also drastically reduce the diesel usage and labour time which go into producing a season's crop. Diesel use is reduced for two reasons:

- A large amount of energy is required to force a chisel or mouldboard plough through the Swartland's hard soils (Genis, 2008). The shallower the depth that a tillage implement is inserted into the ground, the less energy is required to move it through (Arvidsson, Keller and Gustafsson, 2004). Furthermore, the less soil a tillage implement displaces, the less energy it requires: a mouldboard plough with a wide below-ground surface area and high soil displacement requires far more energy than a knife-point implement inserted to the same depth (Arvidsson, Keller and Gustafsson, 2004).
- Under conservation tillage systems the potential exists to reduce the total number of tractor trips made over a single piece of land in any given season because no pre-planting soil preparation is required. When combined with the introduction of 'one pass' planters (discussed in section 4.4.2.3), farm traffic can be drastically reduced. This has the added benefit of reducing soil compaction.

Farmers reported diesel use reductions of between 40 and 75 percent in relative to the time at which they first started farming. For the farmer in case study 6, this translated to a diesel requirement of 20 litres per hectare in 2009. At an average yield of 3 tonnes of wheat per hectare he had a direct diesel requirement of 6.7 litres for every tonne of wheat produced, as opposed to around 32 litres per tonne in 1990. Changes in tillage practices contributed significantly to these savings.

These reductions in the power put into tillage and the number of tractor trips also cut down on mechanical wear and tear costs, thus extending the useful life of farm machinery.

While the shift to conservation tillage has resulted in a number of input reductions and made a significant contribution to the restoration of SOC, soil structure and soil biodiversity, it has a significant drawback which has yet to be fully overcome. This relates to additional herbicides being required in order to control weeds – a function which was previously fulfilled by the inversion of the soil during mouldboard ploughing. As soil inversion no longer takes place, more herbicides are now used to control weed growth in fields. Table 11 compares the changes in herbicide use amongst the seven case study farmers. Of the seven case studies, only one farmer reported using less herbicide than when he took over management of the farm, while five farmers reported using much more.

Table 11: Herbicide use relative to historical reference point

	Much less	Less	Equal amount	More	Much more
Number of farmers in category	0	1	1	1	5

4.4.2.3 New planters

Figure 5: Tractors with modern planters being prepared on Farm 1

Source: Luke Metelerkamp (own photograph)

The evolution and advancement in modern planters (see Figure 14) have had a large impact on farmers' input usage and their ability to adopt a number of related natural-system-enhancing technologies, including conservation tillage. As with all farm technologies, the precise nature of the new planters varies between farms, but the principal goal which they are designed to achieve remains fairly constant. The main goal which new planters have been designed to achieve is increased resource use efficiency. These resources include land, time and labour as well as inputs such as seed, fertiliser, herbicide and diesel. New planters largely facilitate this improved resource use efficiency by improving the degree to which the application of inputs such as seed and fertiliser can be managed.

With the new planter systems a range of tillage and planting systems are incorporated into a single trailer or series of trailers which are pulled behind a single tractor simultaneously. The processes which are combined in this manner include tillage, seed placement, fertilisation and other soil inputs, and weed control. Historically these processes would have been conducted largely on an individual basis, requiring a number of different passes over a single piece of ground in order to prepare it for the season. This required significantly more labour, fuel and machinery maintenance. The repeated traffic over fields also resulted in unnecessary soil compaction which adversely affected soil structure.

New planters which combine some, if not all, of these processes into a single trailer or connected series of trailers allow farmers to prepare and plant their fields with only a one tractor pass. This is referred to as 'one pass planting' and has had a significant effect on the farmers' planting and preparation-related expenses such as diesel usage and machinery maintenance.

This combined process of soil preparation and sowing also affords farmers a much higher level of control over the placement of seeds in relation to tillage and other soil inputs such as fertiliser and microbial stimulants. In a conservation or minimum tillage system a furrow or grove is made by a tine or disk as the planter moves forwards, into which seeds are placed straight into via a small pipe which sits directly behind the tillage implement. Depending on the desired spacing between crop rows and the width of the planter, between ten and 30 of these bands of seed are laid out simultaneously behind the tractor. Because the devices placing soil inputs are connected directly to the one placing the seeds, these inputs can be placed in controlled proximity to the seeds in order to ensure that they are neither too close nor too far from the seeds. This helps to ensure optimal nutritional uptake by plants, while reducing input wastage. The combined effect of this is to lower inputs relative to yields.

In the past these input applications were generally determined on a field by field basis. In this system the field within the farm was considered the smallest management unit and the inputs that one part of a field received were the same as those received by another, despite the possibility of significant differences in soil indicators within a single field. New monitoring and management technologies, such as global positioning system (GPS) soil and yield mapping, which are linked to new planters allow farmers to electronically control the application of seed and fertiliser to better match the specific soil and nutrient requirements of the particular part of the field over which they are passing. This has the potential to significantly improve yields by offering crops more customised nutrition and reducing the degree to which over application of inputs takes place. This has financial and ecological benefits, as inputs are used more efficiently and there is lower soil and water pollution results from fertiliser leaching.

In summary, new planters have enabled a significant increase in the efficiency with which inputs are used by the farmers who were studied. This helped farmers to reduce their spending on inputs relative to their production.

4.4.2.4 Larger farms

"All the bad farmers are gone, but it's not enough any more to just be a good farmer." (Steyn, 2010)

Of the seven farmers who were studied, only one farmer was still farming a land area of less than 1000 hectares. This farmer indicated that he was struggling to remain financially viable as a result.

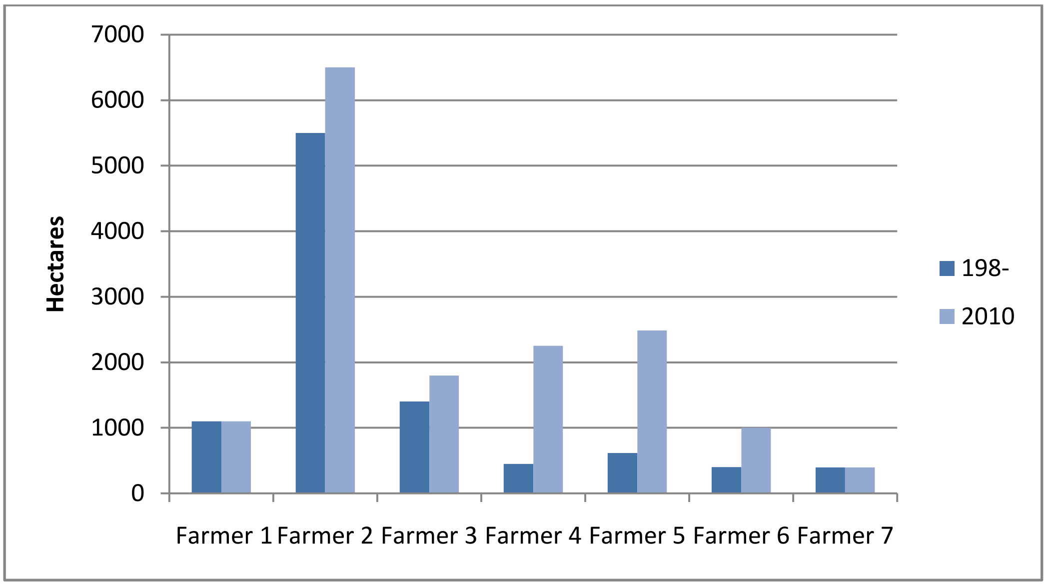
This farmer's land totals 395 hectares (small by regional standards) and his farm has not grown over the past 30 years. As such he does not have enough land available to make a wheat/medic rotation financially viable any longer, even though he would like to continue using this rotation. Instead he is forced to opt for a double cash-crop rotation of wheat and canola in order to keep his cash flow higher. He is unable to capitalise on the soil improvement and input reduction benefits of the legume crop, which increases his input costs and potentially reduces his soil health. It also deprives him of the opportunity to increase the farm's animal stocking capacity, so while all the other six farmers had increased the livestock component of their farms to provide financial stability, he had reduced the total number of sheep on his farm by 62 percent relative to 1980. So while he must maintain a double cash crop rotation in order to survive, he is placed in a position of low financial resilience – making him vulnerable to price fluctuations and crop failure.

The same farmer also cannot afford to purchase his own combine harvester, which further increases his risk profile as it means he has to rely on external contractors to do his harvesting. The risk in this is that he has to work according to their availability, and in cases where he needs to harvest urgently or at short notice he stands to lose his crop if he can't source a harvester in time.

This farmer had a number of trophies in his sitting room from farmers' shows and other competitions, which he has been awarded on the strength of his farming and quality of his wheat. He has also been working hard at improving the carbon content and biological quality of his soils for longer than most farmers in the region. Yet, as the costs of farming are outpacing the price he gets for his produce and he fails to grow his farm size, he has serious doubts about how long he will be able to continue farming. This year (2010), in light of the expected wheat price, he cannot afford the inputs required to plant a wheat crop. Instead he is renting his land out to a larger farmer who will take it over for the season and return it back to him once the crop has been harvested.

This example highlights the importance of achieving economies of scale in the Swartland region. This fact was reiterated by all seven of the farmers who saw increasing farm sizes as an important, if not vital factor, in their adaptation to economic and ecological pressures. For the five out of the seven who had grown their farms since taking over management, this growth had been realised either by purchasing new farms or by taking on new farmland on a tenant basis, as was being done in the afore-mentioned example. Figure 15 illustrates the change in total farm size for the seven farmers.

Figure 15: Changes in farm size within the seven case studies



While the questionnaire did not include any questions relating to the importance of increasing farm size, a number of drivers emerged in the course of the semi-structured dialogue during the interviews. The main benefits of lager-scale farms were considered to be the following:

- Lower profit margins were required to achieve a viable income level[30].
- Legume rotations become viable as enough crop land is available to produce an economically profitable wheat crop despite a significant portion of total land being converted to legumes.
- Investments into machinery replacement, cost-saving and risk-reducing technologies which are unaffordable on smaller farms become affordable at larger scales.

Table 12 indicates the distribution of these responses amongst the farmers.

Table 12: Summarised importance of increasing farm size as listed by farmers

Listed reasons	Farm 1	Farm 2	Farm 3	Farm 4	Farm 5	Farm 6	Farm 7	Total
Economies of scale				x			x	2
Viability of legume rotation						x	x	2
Ability to afford large machinery					x	x	x	3

[30] In other words a two percent profit margin on a turnover of R1000 000 is better than a three percent profit margin on a R500 000 turnover. Bigger farms achieve higher turnovers so can operate at lower profit margins.

Besides these listed reasons it seems logical to assume that growing business profits and personal wealth by increasing their land ownership and production base also motivated farmers to strive to increase the size of their farms.

4.4.3 Building soils

Healthy soils lead to healthy plants, and healthy plants are more resilient to damage by pests and disease (Rosenberg, 2006). Soils which are in good condition also deliver higher yields (Lal, 2006). Resilience to pests and disease means that farmers require fewer external inputs to protect their crops from these problems. This saves farmers money and improved yields help to boost incomes. Healthy soils, particularly those with a higher organic matter content, are also more resilient to variable weather because they are better at absorbing and storing water (Scialabba and Muller-Lindenlauf, 2010). This additional property is particularly important for the rain-fed farmers of the Swartland, where rainfall varies and cyclical droughts pose a very real risk to farmers. The ability of soils to absorb water also helps farmers in times of heavy rain as it reduces the amount of water flowing across the soil surface, thereby reducing erosion.

Due to the importance of healthy soils it is unsurprising that 21 of the 34 technologies and practices listed in Table 7,and all four of the key practices identified by farmers, related directly to soil management in some way. According to Sherr, soil rehabilitation and improvement goes well beyond simply applying fertiliser to replace chemical nutrients; it may involve restoring organic matter, improving soil structure and water-holding capacity, controlling the flow of water across fields, restoring soil flora and fauna, buffering acidity, and establishing vegetative cover (Scherr, 2000). Scherr's opinion is supported by Lal, who states that improving soil quality requires increasing SOC, improving soil structure, enhancing available water content, increasing water infiltration, controlling acidity and controlling erosion (Lal, 2010).

There is strong evidence from the interviews as well as associated research by Lanz (2009), Smit (2004) and Wessels (2001) that the farmers identified by this study are employing practices which address all seven of Scherr's suggestions.

4.4.3.1 Restoring and enhancing soil organic carbon

Soil organic carbon (SOC) content is an accepted measurement of the level of organic matter within soils. All seven of the case studies suggested that farmers were in the process of building their SOC levels. This increase in SOC is largely a result of the shift towards conservation/minimum tillage and the provision of increased organic matter to the soil (Lal, 1999; Bester, 2010; Ekstien 2010; Herlodt, 2010; Rigter, 2010; Lal 2010).As discussed in section 4.4.2.2 all farmers had adopted reduced tillage practices. However the provision of organic matter was undertaken in a range of different ways by the case study farmers. Table 13outlines the main ways in which organic matter was provided to the soil and indicates which farmers were employing these methods.

Table 13: Methods of increasing organic matter provided to farmed soils

Listed practice	Farm 1	Farm 2	Farm 3	Farm 4	Farm 5	Farm 6	Farm 7	Total
Stopping the practice of burning off crop residue after harvest	x	x	x	x	x	x	x	7
Leaving crop stubble in place to decompose naturally			x	x		x	x	4
Mulching by leaving crop residues such as wheat and canola stalks in the field instead of removing it and selling it as straw bails	x	x	x	x	x	x	x	7
Applying carbon-rich inputs such as chicken and cattle manure or compost	x		x	x		x		4
Minimising erosion	x	x	x	x	x	x	x	7

In order to confirm the increases in SOC levels, Lanz's parallel research into five of the seven farms which were selected for this research was analysed. According to Lanz, farms 1 (Steyn), 3 (Heroldt), 4 (Bester), 7 (Lesch) and 8 (Ekstien) had raised their SOC by an average of 0.5 percent above the level of their conventional neighbours, which equates to an increase of roughly 3.8 tonnes of carbon per hectare (Lanz, 2009).

In order to validate and contextualise the findings of the case studies Table14compares the differences between soil carbon levels reported by farmers at the time of first measurement and in 2010, to the statistical sampling conducted by Lanz. The 0.05 percent differentiation between the Lanz sampling figure in column two and the average of the farmers in column five could result from no data being given by farmer 1, or a slight differentiation in measurement.

In terms of contextualising the current SOC levels the figures suggest that a significant increase in SOC has been achieved by these five farmers and that a net increase in total SOC relative to pre-agricultural conditions[31] may have taken place.

Table 14: Comparison of SOC levels

Farm number	Lanz sampling Sept. 2009	Lanz estimate of natural SOC[32]	First farmer estimate or measurement	Farmer estimate in 2010	Farmer estimate for 2020
1.			-	-[33]	-
3.			0.6%	1.8%	2.2%
4.			0.6%	1%	1.5-2%
7.			0.5%	1.5%	1.5%
5.			0.4%	1.1%	2.0%
Average SOC	**1.3%**	**0.95%**	**0.52%**	**1.35%**	**1.9%**

Source: Adapted from Lanz (2009)

Also significant is the fact that when the averages for columns three, four and five are compared it seems possible that previous agricultural practices on the sites may have reduced the SOC by almost 50 percent in comparison to natural levels. The possibility that a negative trend in SOC levels has not only been slowed and halted but completely reversed and SOC levels even enhanced, suggests that the first of Scherr and Lal's criteria for soil rehabilitation and improvement is being met by these farmers.

4.4.3.2 Improving soil fauna and flora

Of the seven points listed by Scherr, the restoration of SOC is the most significant because it signals that a number of the other important soil restoration practices are already in place. As the decomposing organic material which constitutes SOC is the energy source for a host of soil micro-organisms, increasing SOC also enhances soil fauna and flora (Lal, 2006).

[31] This figure is for the top 150mm of soil from four of the five sites. Samples were not taken to be statistically analysed, but merely to give an idea of natural levels. (Lanz, 2009)

[32] This figure is for the top 150mm of soil from four of the five sites. Samples were not taken to be statistically analysed, but merely to give an idea of natural levels. (Lanz, 2009)

[33] As Steyn did not provide carbon estimates in the interview, an average of the remaining four was calculated.

The research indicated an awareness of this at farmer level, as the following points demonstrate.

- Five farmers valued the contribution which earthworms make to maintaining their soil fertility.
- Two of these also included earthworm sighting as an important gauge of their soil health.
- For one of these two farmers, doubling his earthworm population in the next ten years was an important target which he was actively working towards by continuing the practices which have improved his SOC thus far.
- Four out of the seven farmers also used or had experimented with products intended specifically to stimulate microbial activity within their soils. These included compost teas, molasses and fish hydrolysis mixture as well as pre-packaged microbial stimulants.
- A further two felt that additional products were not necessary due to the fact that the chicken manure which they applied to their fields already fulfilled this function.
- Four of the farmers expressed concern about the impact which their sprays and synthetic fertilisers had on soil life.
- All farmers had adopted reduced tillage practices. One effect of reducing tillage is that it improves soil fauna (Thorpe, 2006).

These observations and actions of the farmers combined with a significant increase in SOC support farmers' claims that soil biodiversity has improved under the systems they have adopted.

4.4.3.3 Enhancing water-holding capacity, increasing water infiltration and controlling erosion

Water infiltration, erosion control and water-holding capacity are closely linked. All three are also closely linked to SOC levels.

As wind and water erosion strip the top layers of soil in which SOC is built, erosion must be adequately controlled before long-term improvements to soil health can be realised. However, the poorer soil health becomes, the harder it is to control erosion. Conversely, as soil health improves so to does the ease with which erosion can be controlled (UNEP, 2009). This fact represents an effort bell-curve for farmers, which is largely a result of the fact that healthy soils with higher SOC and good structure are better at absorbing and retaining water (Lal, 2006). This means that in times of heavy rains when soils are most prone to erosion less water flows across the surface of the soil (leading to erosion) because a greater portion of it is infiltrating into the soil (Meadows, 2003).

Farmers 1, 4, 5 and 6 also reported that in times of drought the farmers who had implemented SOC and soil structure-building practices (such as medic rotations and conservation tillage) fared much better than those who had not. For farmer 6, whose farm has grown by over 400 percent since adopting soil restoration measures, his resilience to drought had enabled him to purchase a new farm during every dry year, due to losses suffered by other farmers.

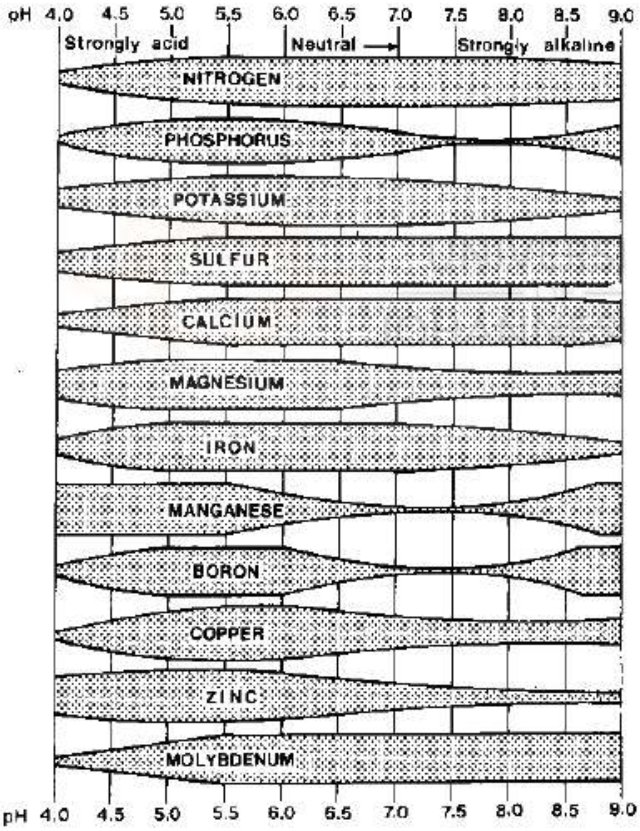
Farmer 6 noted the 2003 drought as a turning point in his approach to farming because it persuaded him of the benefits of alternative farming practices, particularly the use of medics and minimum tillage to increase drought resilience by raising soil moisture content. He believes that on his farm he obtained a 100 percent increase in rainfall use efficiency in a medic rotation system in comparison to a monoculture system: "in droughts the medics really perform. In the medic system I get 12 kg of wheat for every millimetre of rain, whereas in a monoculture I would only get 6 kg per millimetre" (Rigter, 2010). His farm has grown in size by 250 percent in the last ten years as he has been able to buy out monoculture farmers' land as they go out of business.

In addition, all farmers whose slopes were prone to erosion had contours in place to prevent water erosion. These contours assist in reducing water erosion, and also increase the amount of water infiltrating into the soil, by slowing the flow of water over and off farmlands. This helps to recharge groundwater reserves.

4.4.3.4 Buffering acidity

Soil acidity or alkalinity (pH) is a non-nutrient soil property which effects nutrient availability, soil microbial life and root development (Taiz and Zeiger, 1998). Figure14illustrates the impact of soil pH on nutrient availability and suggests that a pH of 5.5 – 6 is the general optimal range for plant growth. As such it is a key determining factor in crop development and yield. This makes it an important component to consider when addressing soil degradation (Scherr, 2000; Lal, 2010).

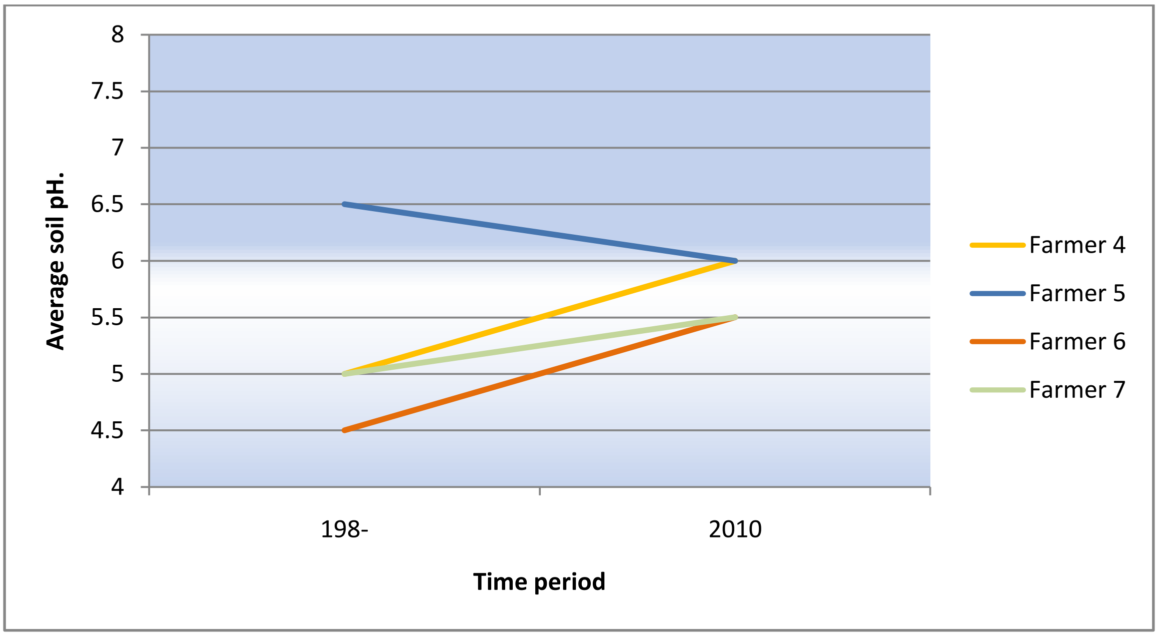
Figure 6: Influence of soil pH on the availability of macro and micro nutrient elements in organic soils



Source: Lucas and Davis, (1961), in Thrope (2006)

All five of the farmers who had measured their soil pH over time had brought their soil pH from outside the 5.5-6 bracket to within this optimal bracket, as shown in Figure16. These farmers felt that the combination of legume rotations, the reduction in applied nitrogen, and potentially the increased soil biodiversity as a result of increased SOC all assisted in regulating their pH. While these factors had helped to balance pH levels, lime was still bought in by all farmers to manage pH levels. Importantly, however, the quantity of lime used had been reduced, at times by over 50 percent since they began farming which indicates that the effort these farmers have put into balancing their soils is paying off as less pH regulation is now required. This decline in the need for lime coupled with evidence of increasingly well balanced soils (as shown in Figure 17) suggests that these farmers soils may be tending towards a point of healthy balance rather than declining into a state of ruin.

Figure 7: Change in pH trends between the past and present as stated by farmers 4, 5, 6 and 7



4.4.3.5 Summary of soil health

At the beginning of this section it was stated that in order to restore and improve agricultural soil farmers cannot simply rely on nutrient replacement; they have to work towards improving the soil's ecological capacity by restoring organic matter, improving soil structure and water-holding capacity, controlling the flow of water across fields, restoring soil flora and fauna, buffering acidity, and establishing vegetative cover (Scherr, 2000; Lal, 2010). The findings revealed in section 4.4.3 clearly indicate that widespread examples of all these practices exist within the studied farms, with the exception of Scherr's (2000) last point, namely establishing vegetative cover. This point was dealt with in section 4.4.2.2 in relation to tillage practices, where it was shown that a move towards maintaining some from of continuous organic matter cover on the soil was also taking place.

In light of this it seems reasonable to conclude that within the small group of farmers who were studied there are significant improvements being made with regard to the restoration and improvement of soil health.

4.4.4 Additional important changes

Beyond the four main responses identified in section 4.4.2 and the practices directly related to improving soil health that have been discussed in section 4.4.3, a number of other relevant changes were identified during the case study research. These were a potential shift towards more organicorientated fertilisation, a reduction in synthetic inputs, increasing output diversity, reforestation and changes in labour usage. These points are discussed in greater detail below.

4.4.4.1 Shifting to organic-based fertilisation

A number of the farmers had begun to replace some of their synthetic fertilisers with organic substitutes. The main example of this was the use of pelletised chicken manure as a means of adding nitrogen and phosphates to the soil. Of the three farmers who used chicken manure, all three felt that unlike synthetic fertilisers, the manure added a number of other benefits to the soil which included adding organic matter and encouraging microbial activity.

Two of the seven farmers were experimenting with compost at the time of the interviews and a further four were either using or had experimented with compost tea as a means of fertilisation and microbial stimulation. Thinking differed significantly among this group regarding the benefits of microbial stimulants. At one end of the spectrum, Farmer 2 felt that he wanted evidence of the effectiveness of the microbial stimulants before he would spend money applying it to his whole farm; he had therefore implemented a test plot on which he was testing the effects of microbial stimulants. Farmer 6, on the other hand, felt that although he had no hard evidence to support his decision to apply microbial stimulants, the theory surrounding them was solid enough and he was happy to apply microbial stimulants on the grounds that they improve soil health and will ultimately benefit his farm in the long run.

4.4.4.2 Reducing synthetic inputs

Despite significantly increasing their wheat yields per hectare between the past and present scenarios, there are indications of dramatic reductions in a number of key synthetic inputs used to grow these crops. The farmers who were interviewed indicated that, on average, they now use 38-58[34] percent less synthetic nitrogen fertiliser, 23 percent less phosphate fertiliser and 57 percent less diesel per hectare of wheat.

As these figures are based on a small number of farmer estimates, they cannot be considered conclusive or representative. However, these figures do serve as a potential indicator of a significant replacement of synthetic inputs with natural-system-based practices such as the use of chicken manure and nitrogen-fixing plants. In addition to the increased use of organic inputs, these

[34] This figure depends on whether or not farmer 7 is included in the calculations. The motivation for excluding him from the calculations regarding synthetic nitrogen is that he is the only farmer who has stopped using a legume rotation on his farm and as a result his nitrogen usage has increased significantly. The reasons behind his discontinuation of the legume rotation were covered in section 4.4.2.4.

reductions are also likely to be due to increased input use efficiency resulting from the deployment of new planters and related technologies.

4.4.4.3 Increasing output diversity

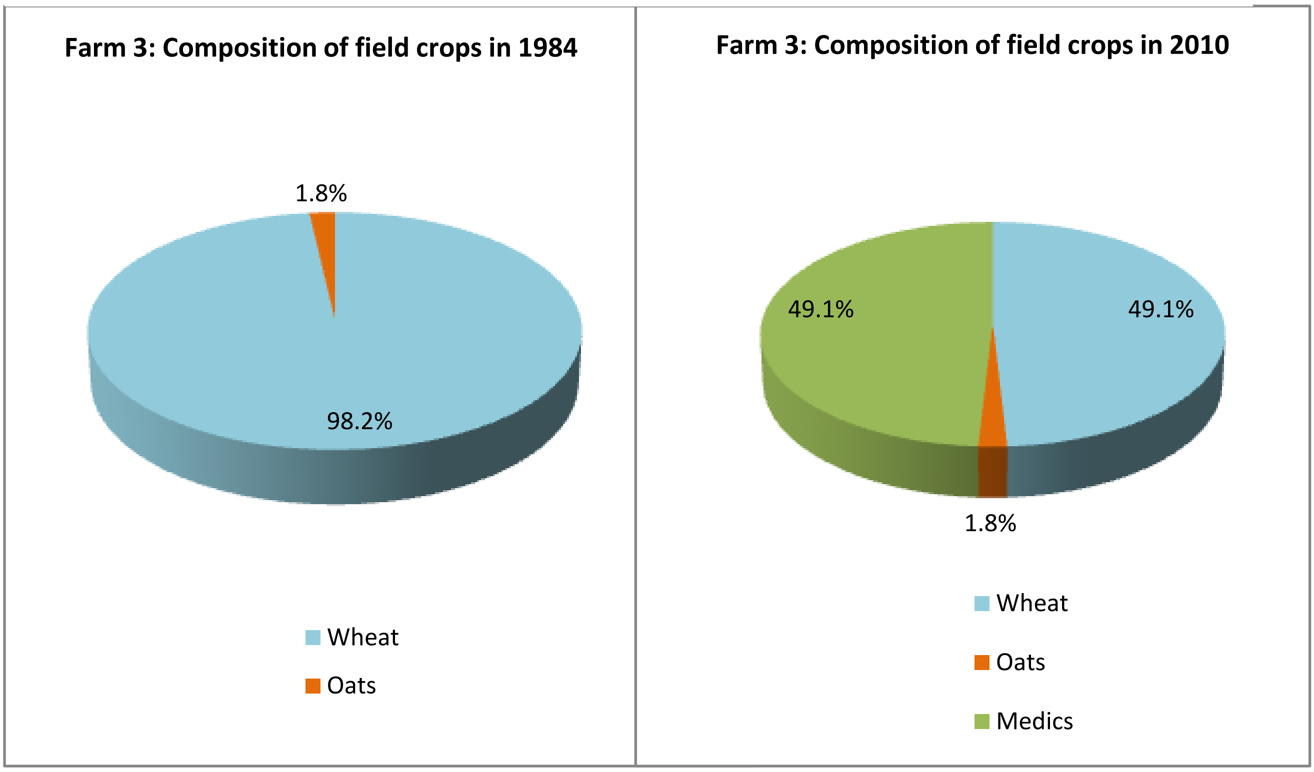
Farmers have also increased the level of crop diversity on their farms and the level of livestock integration into their systems. Mixing crops and livestock as well as mixing crops with legumes in a farm system can contribute significantly to agricultural sustainability (IAASTD, 2008). All farmers interviewed practised *both* mixed crop/livestock and crop/legume agriculture.

At the very least, farmers had planted wheat, a legume and had sheep and cattle on their farms. However, most had a number of other crops integrated into their farm systems. After wheat and legumes, the most common additional crops where canola and oats. These tended to be incorporated into the farmers' crop rotations. Three of the seven also practised some form of viticulture, and one also planted barley and triticale. Additional livestock included dairy cattle, kept by farmer 3, and a buffalo breeding project run by farmer 2.

The average change in on-farm diversity for the sample went from 4.3 to 6.6, with these numbers reflecting the average number of different crops and livestock which they stocked on their farms[35].

[35] This was calculated by adding up the total number of crops grown and livestock species kept by each farmer, once for the 'past' section of the questionnaire and once for the 'present' section, and dividing these by the total number of farmers.

Figure 8: Comparison of crop diversity under historic and present field crop scenarios for Farm 3.



More significant than the total number of outputs is the extent to which the ratio between these outputs has changed. In the past, farmers may have had four different outputs on their farm but still effectively practised a monoculture system. Figure18illustrates this point; farmer 3 had four outputs on his 1400 hectare farm in 1984: wheat, oats, sheep and cattle. However, only 25 hectares or 1.8 percent of the total farm was planted to oats; the remaining 98.2 percent of his arable land was used for a wheat monoculture system, on which sheep and cattle were allowed to graze once the harvest had been taken. For the rest of the year the livestock were fed a mix of oats-silage and imported feed. In 2010, despite having added only one new crop (medics) to his mix of field crops, the nature of his farm system had changed quite dramatically due to the type of new crop and extent to which it was planted. The impact of a 50 percent medic rotation was covered in section 4.4.2.1, but of particular significance to output diversification has been the increase in animals per hectare which has accompanied the shift to a legume rotation. Farmer 3 has almost doubled the number of sheep and diary cattle per hectare on his farm, in addition to adding 120 head of beef cattle to his system. This raised the total number of livestock from around 1850 in 1984 to around 3600 in 2010. Six of the seven farmers interviewed had increased the livestock component of their farms and at least four of these planned to increase this further in future, particularly with sheep. Among these six farmers the average stocking concentration was 1 sheep per hectare in addition to a combined average of 0.1 head of cattle per hectare.

4.4.4.4 Reforestation

As a result of the increasing number of livestock which farmers are stocking on their farms there is also a growing awareness of the need to provide an environment which is conducive to the good health of this livestock. In light of this, farmers one and six had both undertaken reforestation measures in order to provide cooler, shady refuges for their livestock during the very hot summer months. Figure 19 illustrates the progress being made by farmer one in this regard,in which some of the 2700 trees he has planted over the last ten years can be seen stretching out along the fence-lines into the distance. In addition to providing shade these trees also help to sequester carbon, bring deep nutrients up to the soil surface and encourage the return of birds and insects to the farm (Mollison, 1989).

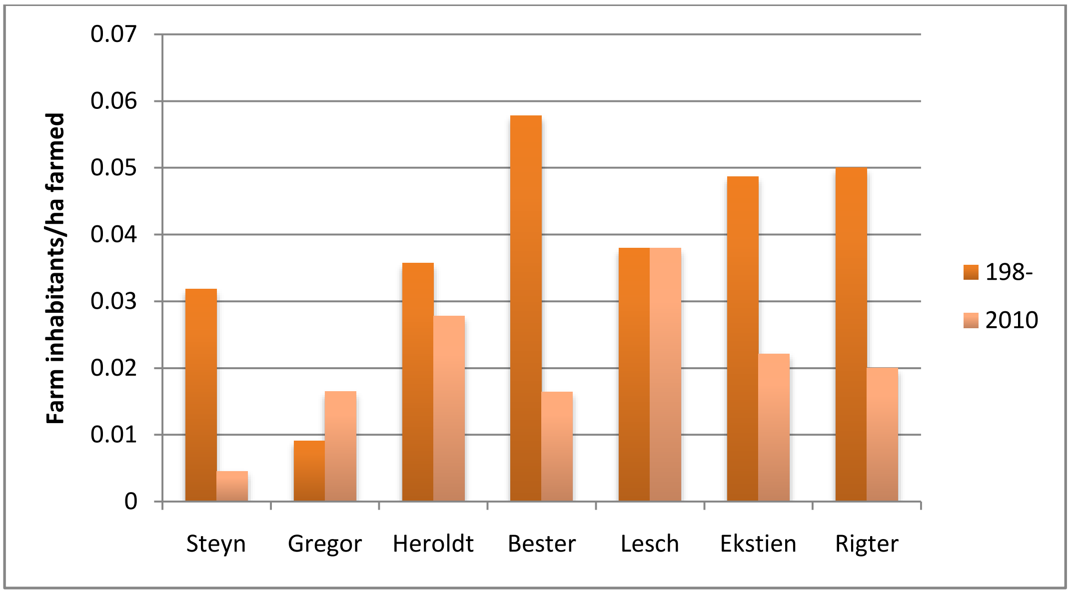
Figure 9: Evidence of reforestation on farm 1

Source: Luke Metelerkamp (own photograph)

4.4.4.5 Labour

While farmers had succeeded in reducing a number of their key inputs and capitalised on increased economies of scale in order to remain profitable, most had also shed labour during this period. This is displayed in a decrease in farm inhabitants per hectare farmed (see figure 20). From discussions with farmers it transpired that most of this labour-shedding tended to take place when new farms were acquired: On taking over a new farm, farmers tended to keep their existing workforce without expanding it in order to manage the increased land. This meant that the labour previously been employed on the farms that were being taken over were no longer required and were therefore evicted from the farms. While this may have helped to keep farmers in business, it is a disturbing trend from an employment and rural development perspective. The degree to which this trend stems from an economic necessity or desire to maximise profit was not established, but this is likely to differ significantly between farmers. It was also clear that farmers' attitudes towards labour varied significantly, with some aiming to retain labour on their farms while others aimed to shift labour off their farms and into nearby towns instead.

Figure 20: Comparison of farm inhabitants including labourers and family per hectare farmed



4.5 Effects

4.5.1. Introduction

The goals of Research Objectives I, II and III was to identify if, why and how farmers in the Swartland were shifting to LEI practices which work in closer partnership with natural systems. Chapters 3 and 4 have sought to address these questions and shown that examples do exist of farmers shifting to LEI practices which work in closer partnership with natural systems, as well as presenting research into how and why this is being done. As the final research question, Question IV seeks to understand what the effects of the changes identified in section 4.4 will be on long-term food production in the region. This is done in the understanding that the region's ability to produce sufficient food at affordable prices will be challenged by the global polycrisis, but that succeeding in these challenges is vital to achieving food security in the region. Furthermore it was argued that maintaining a business-as-usual approach to agriculture is likely to exacerbate the current problems and that this would be detrimental to both farmers and regional food security alike.

In assessing this from a farm perspective, both production costs and production volumes were considered, as both are important in ensuring adequate food access and availability.

4.5.2 Changes in yields

In order to gain a rough indication of how LEI systems yield in relation to the HEI systems traditionally employed in the Swartland, the current yields[36] achieved by the seven farmers were compared to the yields of other systems. This was done in three ways:

- The average given by the seven farmers was compared to average yield figures provided by Grain SA (GSA) and the Crop Estimates Committee (CEC).
- Farmers were asked to rate their yield compared to that of their neighbours.
- The current average yields for the seven farms were compared to average of the same seven farms 20 to 30 years ago (yields for both periods were provided by the farmers themselves). This provided an indication of how the farms had changed.

According to Grain SA the per hectare wheat yield in the Swartland was significantly reduced by heavy rains late in the 2008/2009 growing season. However, for 2007/2008 Grain SA indicate an average yield of 3.02 tonnes per hectare. This was similar to the average figure for winter wheat production in South Africa in 2009, which the CEC pinned at 3.04 tonnes per hectare (CEC, 2010). Combined, these two reports suggest an optimistic average wheat yield for the Swartland to be around 3.03 tonnes per hectare in a good year.

The average yield reported by the seven farmers was 3.43 tonnes per hectare. This indicates that their yield was potentially 13 percent higher than the average for the region.

This finding correlated with the findings of the second method, in which four of the farmers estimated their yields to be higher than their neighbours, while two estimated them to be equal and only one estimated his yields to be lower.

All farmers also reported their yields to be higher than in the past. Because the historic dates to which farmers compared themselves differed according to the dates on which the farmers took over

[36] This yield was taken from estimates given by farmers of the average yield on their farms in 2009. As yield per hectare is such a vital component of farm income it was expected that farmers had an accurate knowledge of their yield for the previous season.

management of their respective farms, averages could not be compared. Table15indicates the changes in yields estimated by the farmers between a personal reference point 20 to 30 years ago.

Table 15: Change in average wheat yield per hectare planted on the seven farms.

Farmer Number	198- Average yield per hectare	2009 Average yield per hectare	Percentage increase
1	-	4	-
2	0.9	3.5	289%
3	2.2	2.8	27%
4	2.3	4	74%
5	2.5	3.2	28%
6	2.5	3.5	40%
7	2	3	50%

All three indicators suggest that the LEI systems on the seven farms had managed to maintain and potentially improve wheat yields in relation to their HEI counterparts. It must be noted, however, that yield per hectare planted is a deceptive measurement when gauging the total yield per farm because although the yield per hectare may have kept up or even outpaced the traditional HEI systems, less total area is planted to wheat each year under a rotation system. In this way these systems can be expected to yield less wheat per hectare of available farmland at present.

However, there are two caveats to this, which are illustrated in the case study on the next page. Firstly, the rotational systems produced a greater volume of other products, such as oil, meat, wool and milk which compensate to varying degrees for lower wheat production. Badgley *et al.*(2006) highlight the difficulties of comparing yields from monoculture systems with rotational systems, but conclude that they found no evidence to suggest that rotational grain-based systems under an organic approach produced less when all produce were counted. A similar trend appeared to be true on the seven farms profiled in this study as is demonstrated in both Table15and the case study.

Case study of Farm 5

CASE STUDY

Cobus Bester shifted from an HEI wheat monoculture to a 50 percent wheat-medic rotation system. He has 2000 hectares under production. If he was farming under a wheat monoculture system and produced at the average regional yield of 3.03 tonnes per hectare his farm could be expected to yield 6060 tonnes of wheat under favourable weather conditions. Historically under his monoculture system he had stocked 0.22 ewes per hectare; on 2000 hectares this would amount to a total of 440 ewes.

Under his rotational system he gets a higher average wheat yield of 4 tonnes per hectare, but only half of the 2000 hectares are planted. This provides a theoretical yield of 4000 tonnes for his farm – 33 percent lower than the monoculture scenario (2000ha at 3.03t/ha = 6060). Under this system he also stocks sheep but at a rate of 0.63 ewes per hectare, more than double his monoculture system[37]. This puts his total ewe count at 1250, which is 280 percent higher than under the monoculture scenario. He also has 60 cattle in his rotational system.

	Monoculture	Rotation	Difference
Wheat (tonnes)	6060	4000	- 2060 (Grain)
Sheep (ewes)	440	1250	+ 810 (wool and meat)
Cattle (head)	0	60	+ 60 (hides and meat)

In summary Cobus' total wheat yield was only a third lower in his rotational system, despite only half the amount of land being planted, while his other outputs such as meat and wool were at least 300 percent higher.

He also considers his wheat harvest to be more resilient to adverse weather events under the rotational system. If this is correct, it means that over time, the difference in wheat yields between the two systems is likely to be less than a third, due to the fact that the monoculture system would perform worse in years of poor weather.

Secondly, the long-term sustainability of the higher wheat production in HEI monoculture systems has been shown to be questionable unless soil degradation and the use of non-renewable inputs can be curbed (Scherr, 1999; FAO, 2009a). What this suggests is that the potentially higher yields of a single crop will cease to be relevant in future as the cost of obtaining these yields becomes too great, or these yields cease to be possible altogether even with the use of HEIs. This ties in with the

[37] This is still relatively low in comparison to the other farmers interviewed, but Cobus plans to increase the number of ewes by 50 percent in the near future, bringing the total number of ewes to around 1875.

sentiments of farmers and the literature covered in section 4.3.12 regarding the unsustainability of HEI practices.

Of additional relevance when considering the volume of food produced is the fact that the improvement of natural soil functions which is taking place on these farms and the land under legume pastures represents an accumulation of natural capital. In the event of temporary food crises akin to those of 2007/2008, these ecological reserves could potentially be utilised to temporarily raise wheat production these farms by at least 100 percent for a few seasons at very little extra cost, in order to meet local or international demand.

4.5.3 Cost of production

Despite the inclusion of questions in the questionnaire aimed at determining a more accurate indication of the changes in cost of production as a result of LEI/NS approaches, these questions yielded a low level of responses from interviewees[38]. As a result, the indications of the effect of changes on the cost of production were limited to fairly subjective responses. Additionally, farmers could not be expected to have more than a very rough idea of what their conventional neighbours' production costs were. However, the data which were provided by the farmers does suggest that the systems they employed had succeeded in lowering the cost of production when compared to their own farms in the past and relative others farming in the Swartland. The following data support this:

1. Achieving financial sustainability through cost-cutting and risk reduction was listed by all seven farmers as one of the most important reasons for their adoption of LEI systems which work in closer partnerships with NS.
2. All the farmers felt that the measures they had put in place had assisted them in achieving greater financial security.
3. Four farmers provided responses to the questions comparing their cost of production to their estimates of their neighbours' production costs. Of these four farmers, three reported to have a lower cost of production per tonne of wheat in comparison to their neighbours, while one considered himself equal to his neighbours.
4. A number of key inputs had been reduced or eliminated. However, at times these had been replaced by other inputs, such as externally-sourced manure or increases in herbicides.

[38] Reasons for this low level of useful responses varied. They included: The fact that farmers did not calculate their costs in the same way (some would include labour in the cost per hectare while others wouldn't for example), because costs vary greatly year on year some felt they couldn't give an accurate estimate, some didn't know certain figures (such as net profit before and after tax) and others felt that this information was confidential.

These findings are supported by Grain SA's2010/2011 Swartland *Producer Price Framework,* in which cost-to-yield comparisons are made between different farming approaches including "conventional", "no till" and "wheat to medics" (2010). While Grain SA's model applies the same overhead and post-production costs to all three approaches, they provide a detailed break down of the direct variable costs under different yield scenarios[39]. This effectively tells farmers how much they should expect to spend in order to achieve a yield of 2.5 tonne per hectare compared to what they would have to spend in order to achieve a yield of 3 tonne per hectare, and so forth. These findings are summarised in Table 16.

Table 16: Direct variable costs for Swartland wheat production in the 2010/2011 production season

Estimated yield (t/ha)	Conventional (R/ha)	No till (R/ha)	Wheat to medic (R/ha)
2.5	4425	3945	4294
3	4889	4340	4572
3.5	-	-	4821

	Conventional (R/t)	No Till (R/t)	Wheat to Medic (R/t)
Lowest cost per tonne	1629	1446	1377

Source: Adapted from Grain South Africa, 2010

What emerges from Table 16 is that in all instances conventional production costs more per tonne than no till or wheat to medic production. Most significantly, the wheat to medic option is not only 16 percent cheaper per tonne, but it offers per hectare yields which are also around 16 percent higher. This provides a double financial benefit for farmers under this system.

However, most of the seven farmers who took part in the case study were practicing no till (or some form of conservation tillage) at the same time as the wheat to medic rotation. Unfortunately the Grain SA figures do not include a costing category which shows the cost benefits of combining no till farming with a wheat-to-medic rotation. However, given the explanations of the benefits of these two practices which were outlined in section 4.4.2 it would seem reasonable to assume that a number of the cost saving benefits within these two systems would be complementary and therefore relate to even lower costs per tonne relative to the conventional scenario than the current wheat to medic scenario does.

[39] Included in the direct variable cost calculations are seed, fertiliser, lime, fuel, repairs, herbicide, pesticide, input insurance, crop insurance and interest on production credit.

While this does not provide evidence relating to the cost of production of all farm outputs under these diversified systems, it does strongly suggest that these systems are at very least capable of producing wheat at significantly lower costs than conventional systems can.

In relation to the polycrisis, particularly the challenge of peak oil, it is significant to note that two of the biggest differences between the systems were the fossil-fuel-derived input costs. In relation to the conventional option, diesel usage was 22 percent lower under the no till scenario and fertiliser costs were 26 percent lower in the wheat to medic option. The relative importance of these differences in fossil-fuel-related costs is likely to increase if the steep oil price increases forecast by peak oil analyses such as Hopkins and Holden (2007) and Wakeford (2007) materialise.

4.5.4 Summary

Four main practices were identified namely: legume rotations, conservation tillage, new planters and increasing farm sizes. Aside from these a number of other practices were also identified which focussed on improving soil health and reducing risk within the farm system. These were undertaken in order to achieve increased economic efficiency through the reduction of input costs, the optimisation of outputs and the reduction in losses resulting from unfavourable natural factors. Most of the practices which farmers are implementing focus on improving soil health and it was shown that progress is being made in this regard – particularly with respect to improving SOC levels and water management. There is also evidence of increasingly efficient use of resources as well as a growing preference for natural inputs – both of which have resulted in a decline in the use of synthetic and external inputs.

As a result of economic pressures, and possibly bad farming practices by other farmers in the region, the farm sizes of five out of the seven farmers had increased, in one case by as much as 300 percent. While this allowed for improved economies of scale and a number of other benefits to the farmers, it has also resulted in a large number of farm labourer families being retrenched and evicted from farms, presumably resulting in forced urban migration.

The extent to which the effects of these changes on the volume and cost of food produced could be determined was limited. However, it would appear from the available data that no net loss in productivity had taken place and that the cost of producing this produce is significantly lower within these LEI/NS systems when compared to other farms within the Swartland using conventional methods.

CHAPTER FIVE: CONCLUSIONS

Chapter Five draws the paper to a close with a review of the research findings and a conclusion in response to the questions posed in Chapter One. It also relates these findings to the discussion on the global polycrisis found in section 3.2. In closing, recommendations for further study are made.

5.1 Conclusions

Section 5.1 summaries the discussions from chapters Three and Four and presents answers to all four research questions posed in Chapter One.

5.1.1 Introduction

In the opening section of the literature review in Chapter Three, it was argued that the world is currently facing a global polycrisis which affects and is affected by agriculture at a number of levels. Food insecurity was highlighted as one of the core elements within the polycrisis and also as a challenge in the Western Cape. It was argued that in order to address food insecurity and prevent future increases in the number of people suffering from food insecurity, agriculture needs to adapt in order to address the key elements of the polycrisis as laid out by Swilling and Annecke (Forthcoming). Through chapters Three and Four it was also shown that the continuation of a business-as-usual approach to large-scale commercial agriculture in the region is not sustainable as it will fail to maintain the farmers, farm employees, food consumers and ecosystems in the Swartland, and that therefore adaptation is necessary.

To adapt to the polycrisis it was argued that large-scale commercial agriculture in the region should adapt by looking at how EIs could be reduced, and productivity improved, by shifting toward LEI farm-systems which work in closer partnerships with natural systems – akin to those advocated by Altieri (1999), Pretty (2005), Magdoff (2007b), Sherr (1999) and Lal (2006).

5.1.2 Conclusions

In light of the above, this research aimed to investigate whether or not examples already exist of commercial farmers in the Swartland shifting towards LEI systems which operate in closer partnerships with natural systems. This was expressed in Research Question I. Within this framework the research aimed to gain a better understanding of how the transition to LEI systems which operate in closer partnerships with natural systems is being achieved (Research Question II) and why these Swartland farmers are choosing to shift to these systems (Research Question III).

Furthermore, the study assumed that if significant changes in practice were taking place that these changes would have an effect on what is produced in the region and the cost of producing it. These changes in production and the cost thereof are relevant to the region's food security. In fulfilment of commitments to the Food Security Initiative, understanding these changes was the secondary objective of this research, as was expressed in Research Question IV.

Sections 5.1.2.1 to 5.1.2.4 provide a breakdown of the answers to the four research questions.

5.1.2.1 Research Question I

Do examples exist of commercial farmers in the Swartland shifting towards lower-external-input practices which work in closer partnerships with natural systems?

Encouragingly, seven examples of large commercial farmers shifting to LEI systems which work in closer partnership with natural systems were identified in the Swartland region. Collectively these seven farmers managed over 15 000 hectares of land. The seven farmers were not a homogenous group; while they shared many common practices, the degree to which they had lowered their external inputs in favour of partnerships with natural systems varied significantly. In addition to partnerships with natural systems, technological innovation had also played an important role in lowering their external inputs.

5.1.2.2 Research Question II

What systems and technologies are these farmers using to achieve these shifts?

The seven farmers were shown to be achieving these goals largely by building the biological health and water-absorption capacity of their soils. In order to do this they were diversifying their crops, increasing the number of animals they stocked, including legume rotations in their crop rotations, reducing soil tillage, feeding the soil with organic matter (in the form of crop residue, manure and compost), applying microbial stimulants, buffering soil acidity, and where possible cutting down on chemical applications which adversely affect the biological soil functions.

These biological changes have led to reductions in a number of inputs. However, the farmers in the case studies also capitalised on modern technological developments to assist in the reduction of external inputs and improve yields. Of primary importance was the development of new planters and the associated technologies which followed them, such as GPS soil and yield mapping, larger tractors and chemical herbicides. These technological advances have enabled precision planting, band application of fertilisers, one-pass planting and reduced tillage; all of which have assisted in reducing external inputs.

5.1.2.3 Research Question III

What are the motivating factors behind farmers' decisions to change the way they farm?

The motivation behind these farmers' drive to reduce their external inputs was largely economic. Since agricultural deregulation in 1996, farmers have received low levels of trade protection while being forced to compete with subsidised imports from other countries. This placed significant pressure on this group of farmers to increase the economic efficiency of their farming operations. In addition to this the prices of key inputs such as nitrogen fertiliser and diesel have risen sharply in recent years, forcing farmers to seriously consider ways of reducing their usage of these inputs. This increase was causing farmers to seriously reconsider their consumption of these external inputs.

The reconsideration of these external inputs was also driven by a growing awareness of the negative effects which many of these synthetic external inputs are having on the health of their soils and the knock-on effect which this has the farms productivity and financial efficiency.

A growing aversion to high levels of debt and the need for financial risk reduction also played a role in pressurising these farmers into diversifying their sources of farm revenue while building their soils' inherent ability to store moisture. Income diversification and improved soil moisture retention were used to assist in financial risk reduction by mitigating the effects of farm-gate-price fluctuation for specific products as well as losses resulting from adverse weather conditions respectively.

Farmers also listed the desire for their farms to be improved for their children as a driver of their management practices.

5.1.2.4 Research Question IV

What are the possible effects which the changes being made by farmers may have on long-term food production?

The effect of these changes on the farms' food production has been to lower the total volume of grain produced, due to a lower percentage of the available land being planted to wheat. However, on a per hectare basis wheat yields were reported to be as high of not higher than the average for the region. Additionally there has been an increase in other food outputs – most notably sheep, but also cattle, canola, dairy products and potentially oats.

The findings regarding the cost of food production within the sample suggested that food can be produced at a lower cost using the methods employed by these farmers. This finding was supported by secondary data supplied by Grain SA. Findings also suggested that food supply under these systems is more stable and better equipped to mitigate the effects of food price shocks akin to those of 2007/2008 for three reasons: Firstly healthy soils with higher water absorption and storage capacity are better at delivering decent yields in times of drought, secondly significant soil reserves exist within a legume rotation system which can be planted to food crops in times of scarcity, and thirdly farmers are far less effected by input price spikes driven by sudden demand. All three of these point help assure adequate volumes of food at lower prices in times of need.

Summary

These findings indicate that although commercial farmers in the Swartland may not have conceptualised the challenges of sustainable development in the same terms as Swilling and Annecke, the pressures of the polycrisis are reflected in many of the challenges these farmers are facing. In response to these challenges the seven case study farmers demonstrated that a growing body of knowledge and practices are developing within the commercial agricultural sector in the Swartland. This body of knowledge addresses some of the key sustainability issues raised by Swilling and Annecke, including peak oil, ecosystem degradation, climate change and food insecurity. This knowledge of how more sustainable and restorative agricultural practices can be applied to larger-scale farm systems in the Global South is likely to become increasingly valuable asset in addressing these four elements of the polycrisis. The challenge which remains for Swartland farmers is how they respond to the threats posed by growing poverty and inequality, rapid urbanisation and slums.

5.2 Further study

This study was exploratory in nature and was intended to identify rather than substantiate potentially relevant practices and trends. More detailed, potentially quantitative research into the following could prove valuable to better understand the nature and effects of changes taking place in regional agriculture:

1. The reduction in external inputs: Only a small number of inputs were included in the questionnaire. These did not capture the full range of inputs used by farmers, and they tended to be hard to measure and compare. For example, 1ℓ of a pesticide A is not necessarily equivalent to 1ℓ of pesticide B, and neither are comparable to fertiliser usage or crop rotations, despite all four being linked to pest management. These difficulties in measuring and comparing led to a problem in determining the extent to which farmers had replaced their external inputs with natural systems. It also tends to encourage an all-or-nothing interpretation of chemical usage in agriculture. A consistent means of measuring and rating farms on this basis needs to be employed if the scale of changes taking place is to be accurately understood.
2. Changes in soil biology: What differences are occurring between LEI and HEI management approaches? This could be approached from a climate change adaptation angle.
3. Changes in an understanding around soil and the development of a more holistic understanding of what constitutes a balanced 'healthy' soil.
4. More detailed research into specific farmers: Particularly farmer 6 and farmer 4 because of their progressive, pro-organic, very LEI thinking. The following questions could be addressed:
    a. What are their visions for the future? How are they managing their systems towards these ends, and what are the major knowledge gaps they face?
    b. They appear to be improving economically and ecologically; but this needs to be proven more categorically with, detailed research and comparison with their more traditional HEI neighbours.
    c. How can they expand their vision of sustainability to include the enhancement of social justice within their farm systems? How necessary is this likely to be in light of the negative political attitude towards commercial agriculture, and can adopting progressive social development practices provide them with greater political resilience?
5. An in-depth study of farmer 7's farm could provide interesting insight into the pressures to increase farm size, and how to survive as a smaller farmer when those around you are coping largely through greater economies of scale.

6. What role do the structured learning networks (study groups within the Farmers' Union) play in assisting the survival and adaptation of large commercial farmers in the Swartland? And what lessons could be taken from these structures in order to improve learning amongst emerging farmers?

There is interest within academia, state agricultural departments and a number of developmental organisations in the application of concepts such as conservation agriculture and agroecology in Sub-Saharan Africa in order to raise productivity and improve food security. However, there is still a reliance on case studies from Brazil, the USA and South East Asia to support arguments for the application of these systems in Africa. This study has shown that examples of these systems already exist in Sub-Saharan Africa. Research into ways that these existing Sub-Saharan Africa systems could be applied or used as examples to for smaller scale farmers within Sub Saharan Africa could help to strengthen food security in the region.

An important social issue became apparent during the study, despite this not being the focus of my research. This was that a high level of (political) antagonism seems to exist between the predominantly white-owned commercial agriculture sector in South Africa and the dominant, largely black, political sphere. This suggests that in addition to the current attention being given to addressing the ecological challenges they are facing, it seems likely that farmers in the Swartland will also have to address major socio-political challenges in the future. In many ways these socio-political challenges can be interpreted as an embodiment of the unresolved components of the polycrisis within their systems –namely poverty and inequality, urbanisation and slums –emerging as direct challenges to agriculture in the region.

This study presented examples of positive adaptation which addressed climate change, peak oil and ecosystem degradation, but research into social restoration and innovation within the commercial agriculture sector is of equal if not greater importance than the LEI/NS technologies described in this paper, and should be granted due attention.

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6.2 Appendices

Appendix A: Interview write up: Farmer 3

Questionnaire No.		Page No.
3	J.Heroldt 05/05/2010	1

General Farm Data

	1984 Under production	1984 Conservation	1984 Other	1984 TOTAL	2010 Under production	2010 Conservation	2010 Other	2010 TOTAL
Farm size	1400	0	-	**1400**	1800	0	-	**1800**

	1984	2010
Average rainfall	400	400
Percent of farm rainfed	100%	95%
Percent of farm irrigated	-	5%
Irrigation type	-	Drip
Dominant soil type	Malmsbury Shale	Malmsbury Shale
Farm Manager	Self	Self
Farm Owner	Self and brother	Self and brother
No of people living on farm	50	50
Staff education	No	No
Health care	No	No
Ecosystem restoration	No	No
Overdraft facility	Yes	Yes
Could you operate without it	No	No
Gross Profit %	15%	30%
Net Profit Before Tax %	-	-

Outputs produced

1984

	Yield/total head	Yield relative to neighbours	Yield relative to self in 2010	Production cost per unit	R/unit relative to neighbours	R/unit relative to self in 2010
Wheat	2.2t/ha	lower	lower	-	much lower	much higher
Oats	(only 25ha)	equal	equal	-	equal	much higher
Dairy cows	250	much lower	much lower		-	-
Sheep	1600	-	-	-	-	-

2010

	Yield /total head	Yield relative to neighbours	Yield relative to self in 2020	Production cost per unit	R/unit relative to neighbours	R/unit relative to self in 2020
Wheat	2.8t/ha	lower (3.5t/ha)	lower (3.1t/ha)	R3200/ha	much lower (R2200/ha)	equal
Oats	-	equal	lower	-	-	equal
Medics	4t/ha	higher	equal	R250/ha	-	-
Vineyards	7t/ha	equal	lower (10t/ha)	R2000/ha	equal	equal
Sheep	3000	-	-	-	equal	equal
Dairy	480head 31L/h	-	-	R3/L	lower	equal
Beef	120head	-	-	-	equal	equal

Soil productivity indicators measured

1984

	Average Value	Indicator relative to neighbours	Indicator relative to self in 2010
Macro Nutrients	-	equal	much worse
PH.	-	equal	worse

2010

	Average Value	Indicator relative to neighbours	Indicator relative to self in 2020
Macro elements	-	-	-
Micro elements	-	much better	worse
Soil Carbon	1.8[1]	better	worse
Earthworms (by observation)	-	much higher	much lower

[1] Was 0.6% and aims for max of 2.2%

Inputs

	1984 Buy in	1984 Generate on farm	2010 Buy in	2010 Generate on farm
Nitrogen	100%	0%	2%[2]	98%
Potassium	100%	0%	0%	100%
Phosphate	100%	0%	0%	100%
Compost	0	0	100%	0
Manure	0	100%	0	100%
Seed	20%	80%	20%	80%
Animal feed	80%	20%	90%	10%
Animal stocks	0%	100%	0%	100%
Water	-	-	-	-
Electricity	100%	0%	100%	0%
Weed control	100%	0%	100%	-
Pest control	100%	0%	0	100%
Fungal control	-	-	0	100%

[2] Only bought nitrogen during 2 of the last 5 years and then only did 7gl/ha as foliar spray.

Questionnaire No.		Page No.
3	J.Heroldt 05/05/2010	2

1984

Inputs cont.

	Average Value	Usage relative to neighbours	Usage relative to self in 2010
N Fertiliser[2]	100kg/ha	equal	much more
P Fertiliser	18kg/ha	equal	much more
K Fertiliser	-	equal	much more
Lime [2]	2000kg/ha	equal	more
Compost	0	equal	much less
Manure	0	equal	more
Compost Tea	no	equal	much less
Microbial stimulants	-	equal	equal
Legumes/crop ratio	no	equal	much less
Other rotations	no	-	-
Green manure	-	equal	much less
Mulches	no	equal	much less
Pesticide [1]	yes	equal	much more
Herbicide	yes	equal	more
Diesel	-	equal	more
Electricity	-	equal	equal
Water	-	-	-
Agro Forrestry	no	equal	equal
Wildlands belts	non-cultivated grazing areas	equal	equal

Notes:

[1] *Stopped using pesticides and fungicides in 1990.*

[2] *Was not using Lime/Nitrogen balancing properly, which was a big issue. He claimed that for every kilogram of nitrogen which he applied he was loosing 250kg humus per hectare.*

2010

	Average Value	Usage relative to neighbours	Usage relative to self in 2020		Usage trend 1990-2010
N Fertiliser	7kg/ha	much less	more		down
P Fertiliser	7kg/ha	much less	equal		down
K Fertiliser	? [3]	much less	equal		down
Lime	1.5t/ha	more	equal		down
Compost	300kg/ha	much more	equal		up
Manure	6t/ha [4]	equal	equal		less
Compost Tea	no	equal	equal		up
Microbial stimulants	no	equal	equal		no change
Legumes/crop ratio	yes	more	equal		up
Other rotations	-	-	-		-
Green manure	yes	more	less		up
Mulches	yes	more	equal		up
Pesticide	-	equal	equal		down
Herbicide	-	equal	more		down
Diesel	-	equal	equal		no change
Electricity	-	more	equal		no change
Water	-	-	-		no change
Agro Forrestry	-	-	-		no change
Wildlands belts	non-cultivated grazing areas	equal	equal		no change

Notes:

[3] *With N, P & K he does not apply regularly so these figures are distorted.*

[4] *Does not apply every year, but applies 6t/ha when he does. Much of this is sourced from his dairy on farm.*

Poinson toxicity rating[5]	Green	Yellow	Red
Herbicide you used was	-	-	-
Pesticide you used was	-	-	-

[5] *Didn't know but guessed Red.*

2010	Green	Yellow	Red
Herbicide	-	-	-
Pesticide	-	-	-

Social Networks and learning structures.

Most important sources of information	1984	2010
	- Co-op consultants - University - Agricultural reps.	- Internet is most important - Workshops and short course - SA biofarm - Sends his soil samples to the USA where they are analysed in accordance to the Albrecht System. Says the results he gets are different from SA labs. - Feels Australian research is good but not as far ahead as USA because Austrialians still too keen on poinsons

Questionnaire No. 3	J.Heroldt 05/05/2010	Page No. 3

	1984	2010
Agricultural texts read	- Landbou Weekblat	- Acers USA - Landbou Weekblat - Farmers Weekly -Biological and Natural Farming
Group & organisation membership	-Boere Vereeniging - Study Group	-Boere Vereeniging -**No** Study Group
Interfarmer communication		
Talk to other farmers	Daily	3 a week
SMS other farmers	-	daily sms price updates
Write/email other farmers	no	-
Visit other farms	weekly	1 a month
Attend talks or short courses	2 a year	3 a year
Educational background	Elsenburg- grains and animals	
Level of influence of DAFF (DoA) on farming	low	None

General reflections

Was farming in almost straight monoculture till 1987, after which he began changing to legume rotations.

Stopped using pesticides and fungicides from 1990 onwards

There had been a trend on his farm of declining growth in yeild but rapidly increasing input requirements which he felt was unsustainable. So he shifted to a low input / low output system. He says that even though his yeilds are much lower than others around him he is just as, if not more, profitable and more resillent to price fluctuations. Believes that building his soils are the only way to sustainably increase yeilds.

"Working with nature, not against it...a healthy earthworm population will move 40t of soil per hectare..."

Trying to get away from what he calls a "rescue chemical" farming practice where chemicals are used to treat the symptoms of problems and not the causes.

Uses the Albrecht system of soil balancing now.

The compost he uses is Neutrog pelletised chicken manure which his brother runs as a business. Claims that he has no vested interest in that operation and that he prefers Neutrog over synthetic inputs because they are better for the soil. Much of the nitrogen requirements are met with this.

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Between 1984 and 2010

Between 1984 and 2010 what new tools or system have you adopted or experimented with?

Shifted to a lower input/lower output system.

Adopted minimum tillage.

Leaves as much organic matter in the soil surface as possible, leaves all wheat stubble, doesn't bail or burn anymore.

Thinks carefully before doing any tillage.

No fungicide or pesticide anymore.

Has adopted and subsiquently increased legume rotations.

(generally all these changes are designed to reduce financial pressure by building ecosystem services)

What was the signle biggest element or practice which you changed between 1990 and 2010?

The legume rotation

How did you first become aware of these new practices and what evidence did you use to determine thier applicability to your context?

In the late 1990's he read "The biological farmer" by Gary Zimmer, the book seemed to sum up the problems he had and showed good case studies on how people were doing things differently. The writing of Niel Kingsly also helped to make him aware of these new approaches.

What prompted you to undertake the changes you have just described?

Achieving financial viability - After deregulation farmers had to think a lot harder about how they farm.

Trying to get away from what he calls a "rescue chemical" farming practice where chemicals are used to treat the symptoms of problems and not the causes. This "rescue chemical" approach only makes the problems worse.

Felt that even with higher yeilds using chemical inputs, the nutritional quality of the food he was producing was lower.

Of the changes in practice you have undertaken, which were not adopted by most other farmers around you?

Says that only 50% of farmers do a proper legume rotation.

Most farmers still focus on feeding the plant and not the soil .

Why do you think they did not adopt these practices?

People don't do things differently because they were tought to think and percieve things in a certian way - they get stuck in this way of thinking.

The fact that so many people still rely on people who want to sell them inputs for advice also stops them from changing.

Between 1984 and 2010 cont.

Discussion notes

Spoke alot about ways of closing resource loops on his farm so as to lower external inputs. For example use of a lot of meddics in his farm system achieves the following:
1. Improves soil structure and adds nitrogen in a way which does not poison the soil
2. Drastically improves the health of his wheat crop by breaking the desease and fungus cycle which developes in monocultures
3. Provides feed for his dairy. The dairy in turn provides financial diversification as well as a steady supply of manure which he returns to his fields.
4. all of the above also save him money by reducing the ammount of external inputs he has to purchase

He also claimed that wheat produced on biologically diverse and healthy soil was healthier for the people who ate it too.

While he didnt seem very concerned about the above ground biodiversity in his area in terms of the threatened Ronesterveld he was quite passionate about soil biodiversity and soil micro-organisims.

Into the future

How long have your family been on this farm?

116 years

Who do you see taking over the ownership/management of this farm from you?

His son

What do you see as the main challenges for your farm over the next 10 – 20 years?

He sees his main challenge to be producing food for people which is of a higher nutritional quality.
If he is able to do this he aims to use the improved food to promote his farm and the farming system he believes in.

What are you doing to overcome these challenges and how do you think the way you farm will change?

He and his brother have started their own grain mill which they use to process 2000tonnes of their wheat per year into flour which they market as a niche product by selling the story of the farm with the flour.

Do you subscribe to the concept of peak oil? And how much do you think the oil price in the future will increase the cost of fuel and farm chemicals?

Doesnt really subscribe to the concept of peak oil. In terms of the cost of inputs going up he says he doesnt really use any fossil fuel based nitrogen anyway so thinks he will be fine (reading between the lines it would seem logical that he stands to benefit considerably if the nitrogen price goes up internationally because the knock on effect of this will push the wheat price up but his input costs will climb less than other farmers). He says the price of diesel is a concern (but again if higer oil prices stimulate corn demand for biofuels wheat farmers stand to benefit).

Do you consider the forecast changes in regional weather patterns as a result of global warming to be a threat to your business?

He thinks about it, but thinks he will be better prepaired for it with his style of farming than other farmers.

Into the future cont.

Is the security of your land tenure and the process of land redistribution and restitution a concern for you? If so does it affect the way you farm?

Not a big concern for him, mainly because of the fact that there are not really any land claims this far South.

How will the rise in the electricity price affect your energy consumption?

It wont really affect his consumption but it will push up his costs a bit, particularly in the dairy. Thinks it will also have an effect on the price of external inputs.

How do you view regional indigenous biodiversity in relation to your farm?

He doesn't really percieve any responsibility towards the overall regional biodiversity. He has areas on his farm that are either too steep or too wet to cultivate which has some indigenous species left but also uses these spaces as rangeland grazing for sheep and cattle.

If you irrigate how do you think the increasing commpetition for avaiable water resources in the WC will affect the way you are able to farm?

In your view, what area of agriculture is in the biggest need of research and development?

Changing the way agricultural problems are percieved and addressed so that farming can move towards adressing the "root of problems, instead of a patch up approach". He gave an example of a local formers meeting he had attended on weed control and eveyone was trying to work out how to kill the weeds, and not one of them asked why they were there.
Research into the farm as a complex, reactive system instead of more research into "rescue chemicals".

In your view, what type/types of agriculture are best suited to reducing world hunger and feeding a growing world population?

Firstly price is the biggest determining factor for the poor and farming with nature instead of against it is cheaper.
Secondly there is a need to look at nutritional density over just food quantity - if you produce twice as much food but it only has half the nutrients there is no gain.

Discussion notes

He was quite critical of people who worry and complain about the price of grain without seriosly looking at cutting their inputs.

He shares management and equipment with his two brothers on neighbouring farms.

Appendix B: Interview write up: Farmer 4

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1980

General Farm Data

	Under production	Conservation	Other	TOTAL
Farm size	425	0	25	**450**

Average rainfall	400
Percent of farm rainfed	100%
Percent of farm irrigated	-
Irrigation type	-
Dominant soil type	Hutton/Glenrosa
Farm Manager	Father
Farm Owner	Father
No of people living on farm	26
Staff education	No
Health care	No
Ecosystem restoration	No
Overdraft facility	Yes
Could you operate without it	Yes
Gross Profit %	50%
Net Profit Before Tax %	25%

Outputs produced

	Yeild/total head	Yeild relative to neighbours	Yeild relative to self in 2010	Production cost per unit	R/unit relative to neighbours	R/unit relative to self in 2010
Wheat	2.3t/ha	higher	much lower	-	equal	much lower
Sheep	300	-	-	-	-	-

Soil productivity indicators measured

	Average Value	Indicator relative to neighbours	Indicator relative to self in 2010
Phosphorus	35ppm	equal	equal
Potassium	70ppm	equal	equal
PH.	5	equal	worse
Soil Carbon	0.6%	equal	worse

Inputs

	Buy in	Generate on farm
Nitrogen	100%	0%
Potassium	0%	100%
Phosphate	0%	100%
Compost	0%	0%
Manure	0%	0%
Seed	25%	75%
Animal feed	0%	100%
Animal stocks	0%	100%
Water	-	-
Electricity	100%	0%
Weed control	25%	75%
Pest control	100%	0%
Fungal control	0%	0%

2010

General Farm Data

	Under production	Conservation	Other	TOTAL
Farm size	2000	0	250	**2250**

Average rainfall	450
Percent of farm rainfed	100%
Percent of farm irrigated	-
Irrigation type	-
Dominant soil type	Hutton/Glenrosa
Farm Manager	Self and brother
Farm Owner	Protion of land self owned potion rented
No of people living on farm	37
Staff education	No
Health care	No
Ecosystem restoration	No
Overdraft facility	Yes
Could you operate without it	No
Gross Profit %	40%
Net Profit Before Tax %	20%

Outputs produced

	Yeild /total head	Yeild relative to neighbours	Yeild relative to self in 2020	Production cost per unit	R/unit relative to neighbours	R/unit relative to self in 2020
Wheat	4t/ha	higher	higher	R2200/ha	equal	20% higer
Medics	2.5t/ha	equal	-	R3000/ha	higher	higher
Sheep	1250 ewes	less/ha	50% more in future	R300/head	-	equal
Cattle	60head	equal/ha	equal	R1000/head	-	equal

Soil productivity indicators measured

	Average Value	Indicator relative to neighbours	Indicator relative to self in 2020
Macro elements	-	better	worse
Micro elements	-	better	worse
Soil Carbon	1%	better	worse
Earthworms (aims to double)	-	much better	much lower
PH.	6	better	equal

Inputs

	Buy in	Generate on farm
Nitrogen	35%	65%
Potassium [1]	100%	0%
Phosphate	50%	50%
Compost [2]	0%	0
Manure	95%	5%
Seed	15%	85%
Animal feed	15%	85%
Animal stocks	0%	100%
Water	-	-
Electricity	100%	0%
Weed control	100%	-
Pest control [1]	50%	50%
Fungal control	-	-

1. Potassium is applied via manure as opposed to chemically
2. Doesn't use it across the farm but doing test trail on Shesfarms applying 2t per hectare
3. Doesn't actively do anything on the farm to combat pests but now uses 50% less than in the past

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1980

Inputs cont.

	Average Value	Usage relative to neighbours	Usage relative to self in 2010
N Fertiliser [1]	100kg/ha	more	more
P Fertiliser	18kg/ha	equal	less
K Fertiliser	-	equal	less
Lime	450kg/ha	more	more
Compost	0	equal	less
Manure	0	equal	much less
Compost Tea	no	equal	equal
Microbial stimulants	no	equal	equal
Legumes/crop ratio	no	equal	much less
Other rotations	no	-	-
Green manure	-	-	-
Mulches	no	equal	much less
Pesticide	no	equal	much more
Herbicide	yes	equal	less
Diesel [2]	20 000L/farm	equal	much more
Electricity	-	equal	less
Water	-	-	-
Agro Forrestry	no	equal	equal
Wildlands belts	same	-	-
	-		

Notes:

1. *Nitrogen application peaked in 1990 when he was doing 120kg/ha*
2. *In 1980's used 20 000L per year for their 400ha farm, now they use only 5000L per year on the same farm but get much higher yeilds.*

2010

	Average Value	Usage relative to neighbours	Usage relative to self in 2020		Usage trend 1990-2010
N Fertiliser	50kg/ha	much less	much more		down
P Fertiliser	15kg/ha	much less	equal		down
K Fertiliser	5kg/ha	much less	equal		down
Lime	250kg/ha	more	more		down
Compost	10t (test)	more	equal		up
Manure	100 kg/ha	much more	equal		up
Compost Tea	no	equal	equal		up
Microbial stimulants	no	equal	unsure		no change
Legumes/crop ratio	50/50	more	less		up
Other rotations	no	-	-		-
Green manure	no	-	-		-
Mulches	yes	much more	equal		up
Pesticide	-	much less	more		down
Herbicide	-	equal	more		up
Diesel [2]	5000L	equal	more		down
Electricity	-	-	-		up
Water	-	-	-		-
Agro Forrestry	-	equal	less		no change
Wildlands belts	-	-	-		no change
Gypsm	500t/yr	much more	equal		up
Rock phosphate [3]	yes	-	-		up

Notes:

3. *Has begun using organic rock phosphates as he sees them as better for his soil than the synthetic equivalents*

Poinson toxicity rating [5]	1980 Green	1980 Yellow	1980 Red	2010 Green	2010 Yellow	2010 Red
Herbicide you used was	-	100%	-	-	80%	20%
Pesticide you used was	-	-	100%	-	-	100%

5. *Didn't know but guessed Red.*

Social Networks and learning structures.

	1980	2010
Most important sources of information	- Department of Agriculture - Father (who was also the chair-man of the boere vereeniging at that stage)	- Department of Agriculture [4] - Internet - Farming Ahead magazine (Aus)
Agricultural texts read	- Landbou Weekblat	- Farming Ahead (Aus) - Landbou Weekblat - SA Grain Magazine

4. *The Department of Agriculture research facility at Langewens does has test sites on his farm*

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	1980	2010
Group & organisation membership	-Boere Vereeniging - Study Group -Wheat board	-Boere Vereeniging -Study Group - Grain SA
Interfarmer communication		
Talk to other farmers	Monthly	4 a week
SMS other farmers	-	1a week
Write/email other farmers	no	1 a week
Visit other farms	1 a month	1 a week
Attend talks or short courses	-	1 a year (only short ones)
Educational background	Matric	Cost and accounting course at Cape Techicon
Level of influence of DAFF (DoA) on farming	High	Medium

General reflections

1980

The family were financially very well off under the one channel fixed price system.

They had been farming straight monoculture for over 25 years between 1970 and 1995.

There was no stock theft.

2010

Believes increasing the number of sheep on his farm will good for the phosphate returns to his soils.

Also very interested in building the earthworm population in his soil and sees increasing the number of sheep and cattle on the farm as one way of encouraging them. His tillage and mulching practices are also working towards this.

Cobus seeks to acheive equally low external input requirements to Junior Heroldt (see Question paper 3) in future but unlike Junior he does not see this resulting in a lower output farm. This is potentially a very interesting case study conparrision for future study. "How does this very successfull farmer believe he can acheive a Low Input - High Output system?"

Stock theft is now a bigger issue. Especially closer to Morreess-burg. Other theft from sheds and storerooms is also becomming a bigger problem.

Using Gypsm instead of synthetic sulphers.

Makes hay from meddics for his livestock.

Owns two farms and leases a further three from people who no longer wish or are able to farm them.

Says there is a resentment amoung the more conventional farm-ers towards the way that he is trying to farm. They don't want him to succeed. To the extent that when thier farms come up for sale they will try not to sell to farmers who follow his way of farming

Between 1980 and 2010

Between 1980 and 2010 what new tools or system have you adopted or experimented with?

Stopped spraying via plane, back to tractors. Generally much bigger tractors.

Adopted a 50%/50% wheat meddic rotation. Currently engaged on a 6 year test on two of his farms of his envisioned 2020 rotation scenarion for his whole farm under which he plans impliment a 33%/66% wheat medic ration across his farm.

Adopted minimum tillage and 1 pass planting system.

GPS feild analysis during harvest to determine not only how much wheat is coming out of each part on his fields but also the protein content differences in the wheat accross different sections of the same field.

He is now taking GPS soil maps to determine more detailed soil requirements within single fields. He hopes this will improve the uniformity of his yeilds and cut down in fertiliser usage.

Leaves as much organic matter in the soil surface as possible, leaves all wheat stubble, doesn't bail or burn anymore.

Tried adopting cash crops like canola but sees them as too risky financially so stopped.

He has shifted back to using older more intense herbicides in order to deal with the rye grass problems.

Stopped using insecticides on meddics and cut down by 50% on wheat.

Albrecht system of soil balancing

What was the signle biggest element or practice which you changed between 1990 and 2010?

The legume rotation and its implications. (no more burning, more sheep, nitrogen fixing, wheat health...)

How did you first become aware of these new practices and what evidence did you use to determine thier applicability to your context?

Rotations came from watching others in the region begin adopting it as well as the Department of Agriculture at the time. Knowledge about new planters came from books.

What prompted you to undertake the changes you have just described?

Economics! - says he is an accountant by training and keeps a close eye on the long term financial prospects of the farm which led him to believe that they needed to change significantly if they were going to survive. Deregulation in 1997 really brought this about. But also the fact that diesel and other input prices were going up fast

Stopped burning to build soil carbon and moisture retention.

Rotations to lower costs and prevent harm to soils from constant fertilisation.

Of the changes in practice you have undertaken, which were not adopted by most other farmers around you?

He estimates that only 5-10% of farmers around Moorreesburg are farming like he is

Most do not use chicken manure, and use chemical fertiliser instead.

Most are still using a lot more insecticide than he does.

Many are not using the Albrecht system of soil balancing which he uses (particularly to level his soil PH)

Why do you think they did not adopt these practices?

They either dont understand what he is doing or they dont believe in it.

Fertiliser reps are also very against it and will try and discredit the systems he is using.

Between 1990 and 2010 cont.

Discussion notes

Spoke alot about ways of closing resource loops on his farm so as to lower external inputs. For example use of a lot of meddics in his farm system achieves the following:
1. Improves soil structure and adds nitrogen in a way which does not poison the soil
2. Drastically improves the health of his wheat crop by breaking the desease and fungus cycle which developes in monocultures
3. Provides feed for his dairy. The dairy in turn provides financial diversification as well as a steady supply of manure which he returns to his fields.
4. all of the above also save him money by reducing the ammount of external inputs he has to purchase

He also claimed that wheat produced on biologically diverse and healthy soil was healthier for the people who ate it too.

While he didnt seem very concerned about the above ground biodiversity in his area in terms of the threatened Ronesterveld he was quite passionate about soil biodiversity and soil micro-organisims.

Into the future

How long have your family been on this farm?

120 years

Who do you see taking over the ownership/management of this farm from you?

His children

What do you see as the main challenges for your farm over the next 10 – 20 years?

Economic success: The wheat price is steadily dropping in relation to input costs.
Biologically the farm must also be improving year on year in terms of the legumes, soil carbon, earth worms, Albrecht indicators- aims for a 1% overall increase in these overall per year.

What are you doing to overcome these challenges and how do you think the way you farm will change?

If wheat price stays the same farm will become 1/3 wheat 2/3 meddics and much more sheep.

Less chemicals in total to support soil and budget
Less pesticides in total to support soil and budget

Healthy lands = healthy sheep = less money spent keeping them healthy and better product.

Do you subscribe to the concept of peak oil? And how much do you think the oil price in the future will increase the cost of fuel and farm chemicals?

Ja, it is a problem, but the changes he is making in terms of cutting his fuel consumption and fertiliser imputs should help him and the environment.

Do you consider the forecast changes in regional weather patterns as a result of global warming to be a threat to your business?

Rain decrease of 10% over the next 20 years is forecast but if his soil improves its increased water retention capacity should ensure that he is ok. He also thinks that his farms will be able to handle more exteme weather events such as rain and drought better too as the water absorbtion and retention are both better under his sytem. Less bare soil also means less erosion damage during freak heavy rains. Expects other farmers who are not building soils will suffer as thaey don't have the same resilience.

Temparature peaks will also be hotter in summer which means he will be planting more trees as protection for his sheep.

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Into the future cont.

Is the security of your land tenure and the process of land redistribution and restitution a concern for you? If so does it affect the way you farm?

Nationwide it is a problem but doesn't concern him for his farms.

How will the rise in the electricity price affect your energy consumption?

It wont really affect his consumption but it will push up his costs a bit, particularly in the dairy. Thinks it will also have an effect on the price of external inputs.

How do you view regional indigenous biodiversity in relation to your farm?

Has some indigenous veld on unsable areas which he expects will remain unchanged. Not much regard for the greater impact of his farming on the ecological region.

If you irrigate how do you think the increasing commpetition for avaiable water resources in the WC will affect the way you are able to farm?

In your view, what area of agriculture is in the biggest need of research and development?

Research into the practical of biological farming. Organics is the next step after farmers have mastered biological farming, but this progression will happen naturally. Biological is a nessicary bridge which first has to be built. But because of the vested interest into research by private companies selling inputs they can not be counted on to do it. It will have to be farmers or governments.

In your view, what type/types of agriculture are best suited to reducing world hunger and feeding a growing world population?

Biological is the only way at present as the food is both healthier and cheaper.

Discussion notes

He was very keen to talk about the details of his future vision for the farm in 2020 which is what he referred to as "the exciting part". This is summarised on the following page.

His wife noted health issues with their family at times of the year when spraying is done on the farm. Particularly the flaring up of allergies in their young daugher.

She also raised a point about the connection between nutrient deficciencies in the soils and the animals gazing on the soils. Sheep in the region tended to have a zink deficiency according to the vet, the soils in their farm also tend to lack zink. Thus she suggested a possible connection between the health of soils and the life they support.

Vision for 2020

In 2020 he plans to have doubled his farm size again, to a total of 4500ha. He plans to own about a third of this and rent the other two thirds. On this land he envisages sticking to a wheat/meddic rotation with sheep and cattle. Although this is the same mix as at present the ratios will change.
He will shift to planting only one third of his available land in wheat each year instead of half, allowing the extra land to be placed under meddics. This one third –two thirds wheat/meddic rotation will be important for three main reasons.

1. His wheat will require no additional nitrogen fertilisation as the 2 years worth of meddic growth prior to the wheat crop would have fixed enough.
2. It will allow him to achieve a high wheat yield/ha , in the region of 4.5t/ha (currently 3.5t/ha is considered a high regional yield.) [1]
3. He will be able to increase the number of sheep per hectare by at least 35%.

Through this system he hopes to be able to cut down on other inputs significantly too. This includes the total elimination of pesticide and a further 50% reduction in herbicide use from 2010 levels. He envisages that his diesel usage will drop by over a 25% to a total of about 3500L per farm (compared to 5000L in 2010 and 20 000L in 1980).

Beyond the nitrogen fixing rotation, he expects his primary means of maintaining soil nutrient levels to be pelletised chicken manure, gypsum and rock phosphates. The use of these instead of synthetic inputs will help to boost his soil health and thus his overall system's health and yield. He would also like to double his soil carbon content and the farms earthworm population.

Due to the anticipation of declining wheat price relative to the costs of inputs, land and labour he expects his Net Profit Before Tax to drop down from 20% at present to around 15%. This will be compensated for to a degree by the economies of scale afforded by the increase in total farm size which he sees as being vital to maintaining financial viability.

Can be summed up as a farmer who hopes to remain financially viable by working more with natural systems and expanding to achieve greater economies of scale. This will result in a system which produces a wider range of food at a lower financial and ecological cost.

[1] It is important to note that while 4.5t/ha is a very high yield, especially on a lower imput system, only a third of the total farm area is used for wheat production at any one point. Whereas a high input monoculture system could deliver 3.5t/ha this yield is achieved across the whole of the farm. So from a total wheat production point of view every three hectares of farm under the rotation would yield 4.5t of wheat where as 3 hectares under high input monoculture would yield 10.5t.

Appendix C: Interview write up: Farmer 6

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1990

General Farm Data

	Under production	Conservation	Other	TOTAL
Farm size	350	0	50	**400**

Average rainfall	400
Percent of farm rainfed	100%
Percent of farm irrigated	0%
Irrigation type	N/A
Dominant soil type	Loamy clay
Farm Manager	Self
Farm Owner	Family Trust
No of people living on farm	20
Staff education	No
Health care	No
Ecosystem restoration	No
Overdraft facility	Yes
Could you operate without it	No
Gross Profit %	-
Net Profit Before Tax %	-

Outputs produced	Yeild/total head	Yeild relative to neighbours	Yeild relative to self in 2010	Production cost per unit	R/unit relative to neighbours	R/unit relative to self in 2010
Wheat	2t/ha	higher	lower	-	higher	lower
Oats	2t/ha	higher	lower	-	higher	lower
Sheep	300	-	-	-	higher	lower

Soil productivity indicators measured	Average Value	Indicator relative to neighbours	Indicator relative to self in 2010
Macro Nutirents	-	equal	poorer
PH.	4.5	equal	poorer

Inputs

	Buy in	Generate on farm
Nitrogen	100%	0%
Potassium	-	-
Phosphate	100%	0%
Compost	-	-
Manure	-	-
Seed	10%	90%
Animal feed	20%	80%
Animal stocks	0%	100%
Water	-	-
Electricity	100%	0%
Weed control	80%	20%
Pest control	-	-
Fungal control	-	-

2010

	Under production	Conservation	Other	TOTAL
Farm size	900	0	100	**1000**

Average rainfall	400
Percent of farm rainfed	100%
Percent of farm irrigated	0%
Irrigation type	N/A
Dominant soil type	Loamy clay
Farm Manager	Self
Farm Owner	Family Trust
No of people living on farm	20
Staff education	No
Health care	No
Ecosystem restoration	No
Overdraft facility	Yes
Could you operate without it	No
Gross Profit %	-
Net Profit Before Tax %	-

	Yeild	Yeild relative to neighbours	Yeild relative to self in 2020	Production cost per unit	R/unit relative to neighbours	R/unit relative to self in 2020
Wheat	3t/ha	higher	lower(3.8t/ha)	-	-	-
Meddics	N/A	N/A	much lower	-	-	-
Canola	1.5t/ha	higher	lower	-	-	-
Lupins	N/A	much higher	much lower	-	-	-
Oats	3t/ha	higher	higher	-	-	-
Sheep	900	higher	lower	-	-	-
Cattle	40	lower	equal	-	-	-

	Average Value	Indicator relative to neighbours	Indicator relative to self in 2020
Macro Nutirents	-	better	poorer
Trace elements	-	equal	poorer
PH.	5.5	better	poorer
Soil Carbon	1-1.8	better	much poorer

	Buy in	Generate on farm
Nitrogen	60%	40%
Potassium	90	10
Phosphate	90%	10%
Compost	-	-
Manure	100	0
Seed	10%	90%
Animal feed	20%	80%
Animal stocks	50%	50%
Water	-	-
Electricity	100%	0%
Weed control	100%	0%
Pest control	100%	0%
Fungal control	100%	0%

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1990 | 2010

Inputs cont.

	1990 Average Value	1990 Usage relative to neighbours	1990 Usage relative to self in 2010	2010 Average Value	2010 Usage relative to neighbours	2010 Usage relative to self in 2020	Usage trend 1990-2010
N Fertiliser	100kg/ha	equal	poorer	55kg/ha	much less	much more	down
P Fertiliser	13kg/ha	equal	poorer	17kg/ha	much more	less	up
K Fertiliser	0/ha	equal	equal	0/ha	-	-	no change
Lime	500kg/ha	equal	much more	200kg/ha	less	equal	down
Compost	0/ha	equal	equal	0/ha	equal	-	no change
Manure	"a bit" 3.	slightly more	much less	250kg/ha 4.	-	-	up
Compost Tea	0	equal	much more	yes 5.	-	-	up
Microbial stimulants	0	equal	slightly less	"a bit"	slightly more	equal	up
Legumes/crop ratio 6.	20/80	equal	much less	50/50	much more	equal	up
Other rotations	yes	-	-	yes	-	-	up
Green manure	no	equal	equal	no	equal	equal	no change
Mulches	no	equal	much less	yes	much more	equal	up
Pesticide	-	equal	equal	-	equal	equal	no change
Herbicide	-	equal	equal	-	less	equal	down
Diesel	-	much less 1.	much more	-	less 2.	much more	down
Electricity	-	-	-	-	-	-	-
Water	-	-	-	-	-	-	-
Agro Forrestry	no	equal	less	yes 7.	-	less	up
Wildlands belts	yes	equal	equal	yes	equal	equal	no change
Gypsm	-	equal	less	60t/yr	much more	equal	up
Dolomite	-	equal	less	80t/yr	much more	equal	up

Notes: (1990)

1. Adopting a new planter meant they only used 10 liters of diesel/ ha to plant as opposed to the 22 liters/ha which their neighbours required.

3. Small test patches of gauno

Notes: (2010)

2. They now do everything (planting , spraying, fertilising & harvesting) with 20 liters of diesel/ha

4. Does manure now when he can afford it. Prefers to use Neutrog organic pellitised chicken manure, but cant afford it this year as the price has gone up and expects wheat price to be lower.

5. Compost tea of mollasses and compost mix. He has no hard evidence that it works but belives it does.

6. Sowing meddics is expensive, costing R1000/ha. The seeds are particularly costly but they are self seeding once sowed the first time.

7. Planting three trees per paddock as shade for his sheep during the hot summer months. These trees require a lot of attention to get going.

Poinson toxicity rating	1990 Green	1990 Yellow	1990 Red	2010 Green	2010 Yellow	2010 Red
Herbicide you used was	-	-	-	0%	0%	100%
Pesticide you used was	-	-	-	50%	50%	0%

Social Networks and learning structures.

Most important sources of information	1990	2010
	- No internet - Farmers days with competitions and farm visits - No Till tours to other regions - Father	- Local study groups with like minded farmers - Internet

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	1990	2010
Agricultural texts read	- Landbou Weekblat - Condin Group magazines from Australia ("Very very good")	- Landbou Weekblat
Group & organisation membership	-Boere Vereeniging -Study Group - Grain South Africa	-Boere Vereeniging -Study Group - Grain South Africa
Interfarmer communication		
Talk to other farmers	Weekly	Daily
SMS other farmers	-	No
Write/email other farmers	no	1 a month
Visit other farms	1 a month	1 a week
Attend talks or short courses	Never	"A few"
Educational background	Elsenberg Landbou course (failed)	
Level of influence of DAFF (DoA) on farming	High (Financially and farm services)	None

General reflections

1990	2010
He had just taken over the farm from his father	"I only have 30 years left to improve this farm for my children"
His father had been shifting away from heavy tillage to minimum tillage: Mouldboard > Disks > Tines > Minimum	Farm size has a big impact on the way farmers are able to farm -particularly in terms of the affordability of meddic rotations
He tried Meddics at this stage but stopped because of weed problems (picked it up again at a later stage)	Wants to maximis the number of sheep on the farm as they are a fixed income and financial safety net.
In the 1980's his father could afford tobuy a new tractor and combine harvester on a 400ha farm. This is no longer possible on a farm of theis size even though his inputs are lower and yeilds are higher.	Planting trees across the farm as shade for sheep, 3 per paddock

Between 1990 and 2010

Between 1980 and 2010 what new tools or system have you adopted or experimented with?

New planters which allowed for one pass planting (ground preparation, fertilisation, sowing and spraying is alll done at once). These in turn allowed for band planting, prcicion application of inputs and reduced tillage.
In the band planting he leaves 270mm spaces between rows of wheat, he refers to these uncultivated strips as his "soil rese-viors".

Instead of burning, ploughing it in or bailing the crop stubble and residue he now leaves them on the surface.

Looking more into soil micro-organisims: To do this he is conducting test trials with compost tea and chicken manure in order to compare root development.

Increased the number of sheep/ha a lot because sheep prices keep up with inflation

Increased his crop rotations and overall diversity - now has canola, lupins, meddics and cattle in addition to wheat, sheep and oats.

Significantly increased his meddic rotations

What was the signle biggest element or practice which you changed between 1990 and 2010?

Adopting a 50/50 meddic rotations scheme

How did you first become aware of these new practices and what evidence did you use to determine thier applicability to your context?

Mainly via his neighbour the Francious Ekstien (see questionnaire 8) who always has the best yeilds and finances out of all the farmers in the region. "I am very lucky to have them as nighbours."

What prompted you to undertake the changes you have just described?

"Risk!" During times of drougt the benefits of the meddic rotation in the system really delivers. Both in terms of the way it improves the resillience of the soil to drought and the income it allows him to generate via the sheep.

With rotations everything is healthier: less disease, less funguses, better soil

Saw that a different system was working better and wanted to shift towards it to improve his farm.

Of the changes in practice you have undertaken, which were not adopted by most other farmers around you?

Many of them don't do the meddic rotation at all and others not to the same extent.

Some done use the same type of planter that he does.

They don't have as many sheep per hectare

(He describes himself as operating in the middle ground between very progressive successful farmers such as the Ekstiens and the "stupid" farmers who stick to the old ways. Says the only thing holding him back from being very progressive is finances.)

Between 1990 and 2010 cont.

Why do you think they did not adopt these practices?

Some are just "stubborn and stupid". They don't attend the show days or farm visits.

Their social circles also affect the way they farm, because all their friends are still farming in the old ways they don't change either.

Some can't do meddics because the PH of their soils is too low and the meddics won't grow (they haven't adjusted the PH with inputs such as Lime in order to make it possible)

(he noted earlier that farm sizes also effect the viability of meddic rotations - if a farm is too small the farmer cant afford it)

Discussion notes

His soils have improved on previously bad areas because of changes towards minimum tillage.

He is also using lupins to repair very degraded soils on parts of recently purchased farms. By doing this he converts soil which is not currently fit for production of other crops to productive land in the future.

The droughts in 2003 and the hardships it brought changed his outlook on farming . The droughts really influenced his decision to increase the portion of land under meddics and the number of sheep he had.

He has been able to buy 2 new farms in the last ten years from farmers who were in trouble due to monoculture farming methods. This has more than doubled his total farm size.

Into the future

How long have your family been on this farm?

80 years

Who do you see taking over the ownership/management of this farm from you?

His son

What do you see as the main challenges for your farm over the next 10 – 20 years?

Get away from bank financing
Build soils
Reducing risk through rotations and good management
Skillful financial management will be of utmost importance

What are you doing to overcome these challenges and how do you think the way you farm will change?

Trying to improve financial management
Working in more rotations
Working to get as many sheep per hectare as possible

Do you subscribe to the concept of peak oil? And how much do you think the oil price in the future will increase the cost of fuel and farm chemicals?

Yes, he believes it will be an important factor in the future. Particularly for nitrogen costs

Do you consider the forecast changes in regional weather patterns as a result of global warming to be a threat to your business?

Yes, he sees soil improvement, crop rotations and sheep as the best way to protect himself and survive.
He claimed that wheat grown in a meddic rotation system yeilds 12kg/ha/mm of rain. Whereas a wheat grown in a non-meddic system only yeilds 6kg/ha/mm of rain. (if there is other evidence of this it is a potentially valuable area of climate adaptation research)

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Into the future cont.

Is the security of your land tenure and the process of land redistribution and restitution a concern for you? If so does it affect the way you farm?

Yes, trys not to read the papers. Either a farmer must farm all out and go big, or stop farming. He has chosen to farm.

How will the rise in the electricity price affect your energy consumption?

Yes

How do you view regional indigenous biodiversity in relation to your farm?

He says he will not remove ANY of the existing fynbos from his farm in order to increase the size of farmland. "I have enough, I feel something for the fynbos."

If you irrigate how do you think the increasing commpetition for avaiable water resources in the WC will affect the way you are able to farm?

N/A

In your view, what area of agriculture is in the biggest need of research and development?

Not rotations, there is enough info on rotations, now farmers just need to do it.
Drought resistant wheat varieties would be very valuable.
Some way to change the goverment outlook on wheat price protection.

In your view, what type/types of agriculture are best suited to reducing world hunger and feeding a growing world population?

Farming which uses rotations instead of exteral inputs.
Forget about small scale farming, lots of opportunities for impoving and expanding largescale production in Africa.

Discussion notes

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