Continuous cash crop rotation systems under full CA principles for the Riversdale winter cereal production area

By

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Declaration

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Date: March 2020

Summary

The challenge for South African and world agriculture in general, is to produce food for more people with less arable land. The negative impact of global warming is undeniable and competition for limited natural resources has increased dramatically. It is therefore necessary to replace conventional farming practises with sustainable agricultural practises. Conservation Agriculture (CA) is a holistic approach to sustainable agriculture based on three related principles namely: minimum soil disturbance, maximum soil cover, and crop rotation. After the deregulation of the South African agricultural sector in the 1990s, South African farmers began practising crop rotation to counter the risk associated with the liberalised market. The benefits of CA are site-specific and vary from soil to soil. Thus trial data from the Riversdale experimental farm was used to evaluate the financial implication of different crop rotation systems under full CA practises over the long run.

To ensure that both institutional and economic environments that drive whole farm profitability are accommodated, research into mixed crop-livestock systems are region and country-specific and no universal fact exists. One of the specific objectives of this study was to determine how the continuous cash crop systems under full CA principles compare financially with traditional crop-pasture systems for the Riversdale area on a whole farm level.

The multi-faceted, complex, interconnected synergies of the farm system were incorporated in the present study through the systems approach, specifically a typical farm approach. Approximately nine stakeholders in the Riversdale production region were engaged through a multidisciplinary focus group discussion. Disciplines represented during the group discussion were agronomy, agricultural economics, soil sciences, and producers. Each stakeholder contributed to the group discussion with unique, intricate information about their specific fields. Typical whole farm budgets for alternative crop rotation systems for the Riversdale production area were constructed using Microsoft excel spreadsheet programmes. Whole farm modelling in excel spreadsheets enabled the modeller to integrate the knowledge of multidisciplinary experts within the multi-period budgets. The components of the whole farm budgets are interconnected and changes in one component impacts the profit of the whole farm system.

The whole farm profitability for different crop rotation systems in the Riversdale area was measured based on the Internal Rate of Return (IRR) and the Net Present Value (NPV). The traditional crop-pasture rotation system (LLLLLWBCWB) is the most profitable rotation system for the Riversdale area over a random 20 year period with an expected IRR of 5.39 per cent. The continuous cash crop rotation systems, specifically the WBC and WC rotation systems, are more profitable than the traditional crop-pasture rotation system when wheat prices are R3590/ton or more. The traditional crop-pasture rotation system is also more resilient to changes in output and input prices, while the continuous cash crop rotation systems are highly volatile to fluctuating external elements.

Opsomming

Die grootste uitdaging vir Suid-Afrikaanse-, sowel as wêreldlandbou vandag, is om vir meer mense met minder bewerkbare grond, genoeg voedsel te produseer. Die negatiewe impak van aardverwarming is onbetwisbaar en die kompetisie vir beperkte natuurlike hulpbronne het toegeneem. Vir die rede word daar aanbeveel dat volhoubare landboupraktyke, konvensionele boerderypraktyke vervang. Bewaringslandbou is 'n holistiese benadering tot volhoubare landbou en is gebaseer op drie geïntegreerde beginsels nl.: minimum grondversteuring, maksimum grondbedekking en wisselbou. Na die deregulering van die Suid-Afrikaanse landbousektor in die 1990s, het Suid-Afrikaanse boere begin om wisselbou te beoefen as 'n teenmaatreël om die risiko's van 'n geliberaliseerde mark te oorleef. Die voordele van bewaringslandbou is terreinspesifiek en verskil van grondsoort tot grondsoort. Gevolglik word daar in die studie gebruik gemaak van data vanaf die Riversdal-proefplaas, om sodoende die finansiële gevolge van verskillende wisselboustelsels onder die volle bewaringslandboupraktyke op die langtermyn, te evalueer.

Om te verseker dat die institusionele en ekonomiese omgewings wat die winsgewendheid van die hele plaas bevorder, geakkommodeer word, is navorsing oor gemengde gewasweidingstelsels streek- en landspesifiek ondersoek, aangesien daar geen universele feite bestaan nie. Die hoofdoel van hierdie studie was om te bepaal hoe die deurlopende kontantgewasstelsels onder volle bewaringslandboubeginsels finansieël vergelyk met die tradisionele gewasweidingstelsels vir die Riversdal-omgewing op 'n hele plaas vlak.

Die multi-fasette, komplekse, geïntegreerde sinergieë van die plaasstelsel is in die huidige studie geakkommodeer deur van 'n stelsels raamwerk gebruik te maak. Verskillende rolspelers in die Riversdal produksiestreek was betrokke in 'n multidissiplinêre groepbespreking. Die dissiplines wat betrek is in die groepbespreking, was agronomie, landbou-ekonomie, grondwetenskappe en produsente. Elke belanghebbende het die groepbesprekings gestimuleer met unieke inligting rakende hul spesifieke velde. Tipiese hele-boerderybegrotings vir alternatiewe wisselboustelsels vir die Riversdal-produksiegebied is opgestel met die hulp van Excel-programme. Die modellering van volledige boerdery modelle in Excel het die navorser in staat gestel om die kennis van multidissiplinêre kundiges binne die meerjarige begrotings te integreer. Die komponente van die hele boerderybegroting is geïntegreer en veranderinge in een komponent beïnvloed die winste van die hele plaasstelsel.

Die hele-plaas winsgewendheid van verskillende wisselboustelsels vir die Riversdal omgewing word gemeet op grond van die IOK (Interne Opbrengskoers) en die NHW (Netto Huidige Waarde). Die tradisionele gewas-weidingstelsel (LLLLLWBCWB) is die winsgewendste rotasiestelsel vir die Riversdal gebied oor 'n ewekansige 20 jaar periode met 'n verwagte IOK van 5.39 persent. Die deurlopende kontantgewas wisselboustelsels, spesifiek die WBC en WC rotasiestelsels is meer winsgewend as die tradisionele gewas-weiding rotasiestelsel wanneer die koringpryse R3590/ton of meer is. Die tradisionele wisselweidingstelsel is ook meer stabiel wanneer veranderinge in uitset- en insetpryse voorkom, terwyl die deurlopende kontantgewas wisselboustelsels wisselvallig is wanneer wisselende eksterne elemente voorkom.

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List of Abbreviations

BFAP: Bureau for Food and Agricultural Policy

CA: Conservation Agriculture

DAFF: Department of Agriculture, Forestry and Fisheries

EU: European Union

FAO: Food and Agriculture Organisation

GM: Genetically modified

IRR: Internal Rate of Return

NPV: Net Present Value

N: Nitrogen

NH_3: Ammonia

N_2O: Nitrous Oxide

SARB: South African Reserve Bank

REOSA: Regional Emergency Office for Southern Africa

USA: United States of America

Crop Rotation Systems:

WC: Wheat - Canola

LWCW: Lupines – Wheat – Canola – Wheat

WWGma: Wheat – Wheat – Cover Crop

GmaWC: Cover crop – Wheat – Canola

WBC: Wheat – Barley – Canola

CBLWW: Canola – Barley – Lupines – Wheat – Wheat

LLLLLWBCWB: Lucerne – Wheat – Barley – Canola

Chapter 1: Introduction

1.1. Background

The world population is growing at an alarming rate. Estimates showed that the world population will increase to 9 billion people within the next 30 years, with 90 per cent of the growth expected in sub-Saharan Africa and Asia (Conway, 2012 and FAO, 2018). World food production should therefore increase by at least 70 per cent to achieve global food security by 2050 (FAO, 2018). There is global concern over achieving food security, given that the agricultural sector has to compete with urbanization and industries for limited land and water resources (Conway, 2012). The challenge for world agriculture is to produce more food with less arable land, due to environmental degradation over the past number of decades. Increased food production can only be achieved through intensified and/or the expansion of agricultural activity on the available land (Baudron *et al*., 2012). The latter is near impossible due to strong competition for land and water resources which is limited. Increased agricultural activity on current agricultural land is the only means of increasing world food production (Baudron et al., 2012 and FAO, 2018). Food security, therefore, depends on the responsible and sustainable use of natural resources by farmers.

Sustainable agriculture is proposed by agricultural scientist as a substitute for traditional farming systems. The core focus of sustainable agriculture is to enhance productivity through the sustainable management of natural resources (Blignaut *et al.*, 2014). CA is a holistic approach towards sustainable agriculture (Basson, 2017 and Thierfelder *et al.*, 2014). The main principles of CA are: minimum soil disturbance (zero tillage/minimum tillage), maximum soil cover (retention of mulch) and crop rotation. For best results, the three principles should be applied simultaneously (Baudron *et al*., 2012; Hobbs, 2007 and Pittelkow *et al.*, 2014). There is no standard approach for the implementation of CA so that it can be applied everywhere. The application of the principles of conservation farming is site and time-specific and thus there are no specific set of rules that can be applied in every situation. The applicability of CA techniques vary from country to country, region to region and farm to farm (Baudron *et al*., 2012; Knowler & Bradshaw, 2007 and Swanepoel *et al.*, 2018). South African ecological and climate regions range from semi-desert to Mediterranean to subtropical. CA has been implemented vigorously in some regions and feebly in others. In South Africa the commercial rain fed cereal farmers of the Western Cape Province, takes the lead in adopting CA, with a 90 per cent rate (Mudavanhu, 2015). Some farmers in the Western

Cape practise crop-pasture farming systems, while others practise continuous cash cropping, depending on the preference of the specific farmer and/or the specific production area.

The farm environment in South Africa is volatile due to multiple factors influencing the production of agricultural products. Farmers are actively seeking methods to limit risk and enhance the profitability of their farm businesses. South African farmers are averse to risk and reluctant to practise untested crop rotation systems[1] even if it might enhance farm profitability (Hoffmann, 2010).

Cash crop rotation trials are continuously conducted on a commercial farm in the Riversdale[2] area. This is to assess the potential of various cash crop rotation systems within a conservation farming framework as alternative to prevailing crop-pasture rotation systems.

The previous study investigating practises to enhance the profitability of farms in the Southern Cape, exclusively focused on strategies to improve established production systems and ignored the possibility of switching to alternative production systems based on CA principles. Hoffmann (2010) investigated the profitability of prevailing production systems in different homogenous production areas in the Western Cape. However, the scope of the study undertaken by Hoffmann (2010) did not focus on comparing whole-farm profitability between alternative production systems in a specific homogenous production district. Furthermore, Hoffmann (2010) did not include the Riversdale plains as an explicit homogenous production region in the Southern Cape. This study attempts to fill this gap with a whole-farm economic evaluation of continuous cash crop rotation systems under full CA principles for the Riversdale winter cereal production area as an alternative to prevailing rotation systems to increase profitability. The ongoing 12-year (2012-2024) experimental trials in the Riversdale area provided technical data for the present project.

1.2. Problem statement and research question

The Riverdale experimental farm is a case-specific research initiative into CA. The aim of research and development is to increase knowledge (Hall, 2002). The second phase of the Riverdale experimental farm trials commenced in 2012. Summary reports exist for the first phase of the Riversdale experimental farm which included a lucerne pasture as part of a crop rotation system. Currently there is no study specifically focusing on the economics of the

[1] For purposes of this project a crop rotation system refers to a production system.
[2] Riversdale area refers to a production zone in the Southern Cape production region of the Western Cape Province in South Africa. Riversdale production area and Southern Cape are used interchangeable through the project.

continuous cash crop rotation systems under full CA principles conducted at the Riversdale trial farm. The main question is what the financial implications of the continuous cash crop rotation systems on a whole-farm level are, with reference to the current systems that include pastures and sheep grazing.

Literature indicates that no-till continuous cash cropping systems pertaining to one specialised production system would bring about higher profitability than a crop-pasture production system. For example, Millar & Badgery (2009) used trial data in Southern Australia and found that continuous no-till production systems achieved higher average gross margins over three years when compared to crop-pasture and continuous pasture systems. Morrison *et al.* (1986) also showed that net farm income in Western Australia, increases as more land is allocated toward continuous cropping instead of crop-pasture. Literature also indicates that diversification into crop-pasture systems would result in income stability and sustainability (Doole & Weetman, 2009; Kingwell & Fuchsbichler, 2011; Morrison *et al.*, 1986 and Poole *et al.*, 2002). This project is necessary as results acquired from literature are region and country-specific and therefore cannot be conveyed as a universal norm. Different countries and production regions have different institutional environments and climate conditions which might influence whole-farm profitability. Thus it is important to determine how a potential shift from traditional crop-pasture systems to continuous cash cropping under full CA principles for the Riversdale area, might compare financially on the whole-farm level.

Adopting all three CA principles are expensive and require significant capital injections. The benefits of implementing CA principles are case-specific, hence highly debated in the literature. A financial evaluation of the Riversdale experimental trial farm could bridge the knowledge gap and alter the perception of a few farmers in the Riverdale plains, reluctant to adopt CA.

1.3. Objectives

The main objective of the study is to evaluate the expected financial implications of continuous crop rotation systems under full CA principles for the Riversdale area on the whole-farm level.

The specific goals of the project are:

- ❖ To determine the profitability of the six crop rotation systems, under full CA principles at the Riversdale experimental farm, on gross margin level.

- To evaluate the profitability of continuous cropping versus crop-pasture production systems on the whole-farm level for a typical farm in the Riversdale area.

1.4. Materials and method of study

To fully understand the origins of CA in the Western Cape, a comprehensive literature review of sustainable agricultural development was conducted. The literature review of CA history, adoption and constraints to adoption was supplemented by a multidisciplinary group discussion where advocates of adopting CA principles in winter cereal farming in the Western Cape participated.

The distinction between disciplines remains vague because producing wheat requires systematic knowledge integration across disciplines. The narrow reductionist approach that prevailed in agriculture prior to the 1960s was replaced by a more positive systems approach. The farming environment is characterised as complex and multifaceted. A systems approach, as opposed to the reductionist approach, enhances the understanding of complex synergies within the farming environment (Jones *et al.*, 2016). Therefore, the financial evaluation of continuous crop rotation systems under full CA principles at the Riverdale trial farm was done through a systems approach.

To financially analyse the continuous crop rotation systems under full CA principles as investigated by the Riversdale trials, a whole-farm model for a 'typical farm' with multi-period budgets were used. Industry experts and farmers in the Riversdale area were engaged through a sequence of focus group discussion to determine the parameters of a typical farm in this area. The farm that served as basis for the model was therefore viewed as typical for the Riversdale area. Hence the assumption is made that the outcomes can serve as a guide in decision-making for winter cereal production on the Riversdale plains. Multiple whole-farm budget models were constructed to mimic the implementation of the various systems on the typical farm. These included continuous cash crop budgets with alternative crop rotation systems and a crop-pasture budget. The data used in the continuous cash crop budgets were derived from the Riversdale trial site. Each of the six crop rotation systems researched at the Riversdale trial farm served as a separate production system for the Riversdale area. Traditionally farmers in the Southern Cape practise crop-pasture systems. Therefore, the crop pasture rotation system served as the control. The crop-pasture rotation system consists of five years of lucerne followed by five years of cash crops. Lucerne is under sown in the final year of the cash crop phase. The data used to construct the lucerne enterprise budget in the crop-pasture model was implemented from the Tygerhoek[3] trial farm because the Riversdale trial farm does not include pastures and sheep. The data was verified by producers through the multidisciplinary focus group discussion.

1.5. Expected outcome and significance of the study

The project should illustrate which production system, continuous cash cropping or conventional crop-pasture, is more profitable for the Riversdale area over the medium to long term. Capital requirements to convert from a crop-pasture production system to a continuous cash crop production system under full CA principles will be presented in the project. The project would thus present economic and financial knowledge to prospective CA adopters in the Riverdale area. The expected outcomes from this project are;

- ❖ Continuous cash crop production systems under full CA principles in the Riversdale area will be more profitable than conventional crop-pasture production systems in the long term.
- ❖ The conventional crop-pasture production systems will be more resilient to external shocks, compared to continuous cash crop production systems under full CA principles. Though the latter might potentially reduce yield losses over the short term, the current upward trend in livestock prices would enhance the stability of the crop-pasture system.

The dynamics operating a farm with continuous cash crops under full CA principles are different from that of a crop-pasture farm. Continuous cash crop production systems are single enterprise farms and would be less complex than a crop-pasture production system. However, continuous cash crop systems integrated with CA principles require added inputs (seeds, fertilisers, pesticides, etc.), closer site management, better agronomic knowledge, and suffer from higher susceptibility to climate change. Adopting CA principles is a knowledge-intensive process which requires precision during the application of inputs, a lack of knowledge could be financially adverse. The results of the study would provide key insights for the use of fertilisers, chemicals and management differences between the crop-pasture production system and continuous cash crop production system. Farmers will also be provided with knowledge on common CA challenges, benefits and adaptability. Results from the

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[3] Tygerhoek is a trial farm managed by the Department of Agriculture Western Cape and is situated about 100km west of Riversdale. Only data for the pasture component was implemented from the Tygerhoek trials, therefore, the trial farm is not discussed during the latter parts of the project when the Riversdale trial site is discussed in detail.

project can serve as a beginners guide for prospective CA adopters in the Riversdale winter cereal production area.

1.6. Outline of chapters

The first part of Chapter 2 is a comprehensive literature review of sustainable agricultural development, tracing its origin and development. In the second part CA is presented as the most holistic approach to sustainable agricultural development, its origin, benefits, progression, applicability and constraints to adoption among farmers worldwide, is discussed.

The first part of Chapter 3 focuses on the complexity of the farming environment. The genesis and progression of the systems approach over time is reviewed. Approaches to modelling are also presented in Chapter 3, particularly the whole-farm budget model. Typical farm models are used as the evaluation tool of choice in this study, hence a thorough review of its concepts are presented in the last part of Chapter 3.

Chapter 4 describes the Riversdale experimental farm in detail, its objectives, progression, the rotation systems researched and the financial performances of each rotation system. A description of the parameters of the whole-farm model forms the first part of Chapter 5. The last part of Chapter 5 shows the results of the scenarios run through the model. In Chapter 6 the conclusions, summary and recommendations of the project are given.

Chapter 2: Literature Review

2.1. Introduction

Due to worldwide population growth food production should rapidly increase to feed 9 billion people by 2050. The demand for land and water resources has intensified. Therefore, yield increase rather than the expansion of cultivated land is necessary (FAO, 2018). However, on average the annual global yields of maize, rice and wheat have increased at a subdued rate since the 1990s (FAO, 2018). Natural resource conservation practises, such as CA, Climate-Smart Agriculture, Agroforestry, and Agroecology should become the norm. The use of natural resource conservation agricultural practises can stabilise or boost food production in the medium to long term. The implementation of case-specific resource conservation practises, depends on research and development (Conway, 2012).

The main aim of this research project is to evaluate the financial implications for implementing various cash-crop rotation systems on the whole-farm level in the Riversdale area. In the first section of this chapter, an overview of sustainable agriculture is provided. The need for sustainable agriculture is emphasized and prominent philosophical approaches toward sustainable agriculture will be discussed. Secondly the focus will fall on CA, its origin, principles and the worldwide adoption thereof. The chapter concludes with a look at the adoption of CA in South Africa and more specifically in the Western Cape Province.

2.2. Overview of sustainable agriculture

World agriculture was at a crossroads during the 1960s. Rapid population growth triggered the demand for food to surpass the supply of food (Conway, 2012). The green revolution emerged with new crop selections such as dwarf varieties, greater inputs of fertiliser and pesticides. The technological advances of the green revolution which helped to meet the world demand for food came at a cost. The continuously high application of fertilisers and pesticides to produce sufficient food for the ever-increasing population can cause great stress to the natural environment and ecosystem. Today the green revolution is a story of the past, but world food security again is of great concern (Schiere et al., 2012).

The complexity of sustainable agriculture makes it hard to define, especially since it is viewed differently by different individuals. To some agricultural scientist, sustainability entails resilience and the capability to bounce back after difficulties. To others it indicates perseverance and the ability to endure something for a long time (Pretty, 2008). Often included in the definitions is respect for the natural environment and not damaging or degrading natural resources. It may be viewed as a concept that refers to developmental activities that consider the natural environment, or agricultural sustainability could simply mean continuing to produce at a similar rate (Pretty, 1995).

Pretty (2008) summarized the main principles of sustainability to include the following:

- integrating biological and ecological processes such as nutrient cycling, nitrogen fixation, soil regeneration, allelopathy, competition, predation and parasitism into food production processes,
- reducing the use of non-renewable inputs that cause damage to the natural environment or to the health of humans,
- making use of the knowledge and conventional experience of farmers, thus improving their independence and substituting human capital for costly external inputs,
- using of people's joint capabilities to work collectively solving agricultural and natural resource problems such as pest, watershed, irrigation and credit management.

Sustainable agriculture, according to the definition provided by the United States Department of Agriculture in their Farm Bill cited in (Knott, 2015) should fulfill human needs, enrich the environmental quality and natural resource base and most importantly sustain economic feasibility.

Sustainable agriculture by definition originated in the USA during the early 1980s (Gomiero *et al.*, 2011). Despite the term being defined in the 1980s, sustainable agricultural practises were first adopted by early cultural groups who saw the benefit of resting soils as evidenced by this distinguished verse.

> "Six years thou shalt sow thy field, and six years thou shalt prune thy vineyard, and gather in the fruit thereof; but in the seventh year shall be a Sabbath of rest unto the land, a Sabbath for the Lord: thou shalt neither sow thy field nor prune thy vineyard. That which groweth of its own accord of thy harvest thou shalt not reap, neither gather the grapes of thy vine undressed: for it is a year of rest unto the land." Leviticus 25: 3-5, cited in (Reeves, 1997: 132).

Environmental concern was not prevalent in early agriculture, however, after the eye-opening Millennium Ecosystem Assessment Report in 2005, concerns regarding the environment escalated (Conway, 2012). To achieve sustainable agricultural growth, properties of the agroecosystem which are productivity, stability, resilience and equitability should simultaneously be enhanced by agriculturists. Productivity is measured by yields, stability by the consistency of yields, resilience by the ability of the agroecosystem to withstand natural shocks and lastly by how fair products of the agroecosystem are distributed among beneficiaries (Conway, 2012). For example, the green revolution focused on productivity at the expense of the other three properties, thus the sustainability of the green revolution was restricted. Gordon Conway proposes a "doubly green revolution" that is more "productive", more "green" and more "effective in reducing hunger and poverty" compared to the first green revolution (Conway, 2012).

2.3. The need for sustainable agriculture

In 1960 when the green revolution made its mark, little thought was given to the environment. The impact on the environment was deemed either insignificant or capable of being redressed easily in the future, once the main objective of feeding the world was met (Schiere et al., 2012). Cordon Conway repeated to infer about the sustainability of the green revolution when visiting the Ford Foundation (pioneer of the green revolution in India) in New Delhi. Their answer was; "we are not interested in saving birds but in feeding people" (Conway, 2012). This neglect of the environmental impact resulted in negative consequences. The main environmental costs with regards to modern agriculture are discussed below.

2.3.1. Soil degradation

Conventional crop harvesting methods have a negative impact on the quality of soil, severely degrading it (Knott, 2015). Soil degradation refers to the depletion of soil quality over time and therefore, productivity as well. Soil degradation is intensified by soil erosion. Erosion is the physical removal of soil from its original place thus the manifestation of soil degradation (Lal, 2001). Soil erosion happens in three phases: detachment, transport and decomposition. According to Lal (2001), soil detachment manifests in the following ways: slacking (the breakdown of soil aggregates), compaction (increase in bulk density) and crusting (formation of thin, dense, and laminated and quite an impermeable layer on the soil surface).

If detached, surface soil is vulnerable to erosion by wind, rain and gravity. Conventional agricultural practises such as ploughing, mono-cropping and lack of ground cover are the root causes of the detachment phase. Soil organic carbon (SOC), soil organic matter and soil nutrients are fundamental to crop growth. These are found in the top layers of soil that is the first 25cm (Du Toit, 2018). Soil detached by erosion is 1.3–5.0 times richer in organic matter compared to the soil left behind (Gomiero *et al.*, 2011). South African soils have low levels of SOC. It is estimated that local topsoil contains 0.5 per cent or less carbon (Swanepoel *et* *al*., 2018). As of 1990, about 300 million hectares, or 5 per cent of formerly arable land in developing countries have been lost due to severe land degradation. There was a net loss in cultivated land due to soil degradation (Conway, 2012). Fortunately, soil erodibility is a dynamic property that can be changed and restored by sustainable soil management (Lal, 2001).

2.3.2. Water resources

When natural land adjacent to streams, rivers and basins are converted to other land uses such as agriculture, urbanisation and industrialisation, the quality and availability of water is often compromised (Cullis *et al*., 2018). Agricultural crops need water to grow, cool and retain turgor pressure. Poor water supply and/or quality, either from underground or rainfall can have adverse effects on the yields and consequently on food security (Conway, 2012). Irrigation for food production is maintained through the unsustainable extraction of underground water. In China for instance, overpumping of underground water via subsidized electricity is predominant, while water is mined through tube wells in India. Groundwater overdrafts exceed 25 per cent in China and 56 per cent in parts of India (Conway, 2012).

Conventional agriculture leaves soil uncovered which leads to faster evaporation of water and poor infiltration of rainwater. The water holding capacity of the soil is compromised under conventional agricultural practises and therefore, yields and productivity are compromised, which entails food insecurity (Thierfelder & Wall, 2009). Globally the agricultural sector uses about 70 per cent of freshwater (Gomiero *et al*., 2011 and Motoshita *et al.*, 2018). In South Africa, it is estimated that freshwater demand will exceed supply by 2025 (Van der Laan *et al*., 2017). Groundwater levels are declining, rivers are drying up and water pollution is increasing, hence the call for efficient water use production systems are crucial. Sub-Saharan Africa has an untapped potential of underground water (Conway, 2012).

2.3.3. Biodiversity loss

Agricultural growth directly affects biodiversity through landscape changes, which displaces local populations of species. The displacement of native traditional seed varieties with modern genetically uniform, high yielding crops are threatening both wild and domesticated biodiversity (Gomiero *et al.*, 2011). There is a strong interplay between aboveground and underground organisms within the ecosystem, though the two are often treated in isolation. For example, insects and parasitoids spend most of their lifecycle underground before being active aboveground on the crops (Gomiero *et al*., 2011).

The synthetic inputs of the green revolution, such as fertilisers and pesticides have a negative impact on the fauna and flora. Fertilisers can cause excessive growth in wild plants, but cannot affect wildlife directly. Fertiliser runoff from agricultural land causes eutrophication of nearby rivers and lakes (Gomiero et al., 2011). Phosphate and nitrate leaching can cause dense blooms of surface plants and algae. Excessive growth of algae and surface plants can shade out essential aquatic plants. If aquatic plants die and decompose, oxygen would be removed from rivers, which would cause fish to be killed, thus having an indirect influence on wildlife (Conway, 2012).

Between 1961 and 1999 pesticide use as a means of pest control increased by more than 700 per cent globally (Reinecke & Reinecke, 2007 and Stehle & Schulz, 2015). The assumption among conservationists was that pesticide-related biodiversity concerns were solved by the ban of most organochloride and organophosphate insecticides. Yet the application of neonicotinoid pesticides is among the key threats to pollinator's existence. The impact of pollinators on crop quality is crucial because pollination directly affects the quality of crops and subsequently the value of the crop (Dudley et al., 2017). Ironically, despite numerous intentions to conserve pollinators, 40 per cent of invertebrate pollinators are faced with extinction. The negative impact of pesticides goes beyond pollinators (Stehle & Schulz, 2015). Like other terrestrial and aquatic invertebrates, amphibians are also threatened by the continued application of pesticides (Dudley *et al.*, 2017). For instance, if pesticides are applied on arable land it inevitably reaches unintended land as droplets also reach these areas through rain or wind. The biodiversity in the non-targeted area is thus also affected by pesticide spraying (Reinecke & Reinecke, 2007). According to Stehle and Schulz (2015) surface water contamination is a hazard to aquatic biodiversity. Pesticide/fertiliser concentration levels in the water, often exceeds the regulatory threshold. Strong opposition exists against pesticide regulation because the global pest industry is worth U$ 50 billion (Stehle & Schulz, 2015).

2.3.4. The role of animal production

Livestock production plays an important role in the provision of food, employment, nutrients and risk insurance to humankind worldwide (Conway, 2012). Globally livestock production systems occupy 30 per cent of the planet's surface area and accounts for 70 per cent of all agricultural land (Gomiero *et al.*, 2011). Livestock production causes deforestation mainly by two methods. Firstly it is done through the direct clearing of forest for livestock ranching. For example, extensive cattle ranching are responsible for up to 80 per cent loss of the Amazon forest. Secondly, the forest is cleared and used as cropland to grow crops such as soybeans which is used as pig and chicken feed in industrial systems (Herrero *et al.*, 2009). Water use by livestock production systems accounts for 31 per cent of the total water used by the agricultural sector. In order to meet the long term demand for livestock products, water use by the agricultural sector should virtually double (Herrero *et al.*, 2009). A typical western diet consists of roughly 80kg of meat per person per year. Rapid income growth in developing countries implies that a western diet will be a norm in developing countries in the near future. The land required to provide such a global diet suggests that land currently devoted to livestock production should expand by at least two thirds (Gomiero *et al.*, 2011).

Livestock production is one of the main contributors to GHGs (Greenhouse Gas) emissions by the agricultural sector globally. Approximately 6.5 billion carbon dioxide equivalent GHGs is released along the entire livestock commodity chain (Gomiero *et al.*, 2011). Livestock production accounts for 18 per cent of GHGs emissions globally (Herrero *et al.*, 2009). Greenhouse gases cause extreme changes in the weather. It is often responsible for erratic rainfall patterns which negatively affect food production in rain fed production zones.

2.3.5. Agrochemicals

Biological systems such as crop production, needs reactive nitrogen which has historically been in short supply. Nitrogen (N) can be divided into two classes; unreactive N_2 and reactive nitrogen (element in fertilisers) which include nitrogen oxides, ammonia and nitrates. Prior to the 20th-century, the scarcity of reactive nitrogen was mitigated by planting legumes and recycling nitrogen in manure (Conway, 2012). Limited reactive N gained from legumes and growth in the manuring, meant population outpaced food supply. In 1908 the Haber-Bosch process was discovered and allowed for cheap Ammonia (NH_3) to be made from unreactive nitrogen (Sutton *et al.*, 2011). The application of reactive nitrogen to cultivated land increased crop yields per ha. Production of fertilisers intensified during the green revolution. In the mid-1980s subsidies accounted for 68 per cent of the world price of fertilisers and 40 per cent of the world price of pesticides (Conway, 2012). The increased use of fertilisers in crop production is widely recognised as the main reason for increased food supply during the green revolution (Gomiero *et al.*, 2011). In order to meet the world food demand the high application of fertilisers continued. This caused the efficient use of fertiliser to drop from approximately 80 per cent in 1960 to about 30 per cent in 2000.

The majority of nitrogen applied as fertiliser on crops is lost to the environment through runoff, leaching, or volatilization (Gomiero *et al*., 2011 and Erisman *et al*., 2007). The emission of ammonia in nitrogen-deficient areas might be good for crop production. In areas where the optimal amount of nitrogen is surpassed, the emissions might directly or indirectly cause environmental distress to the natural biogeochemical cycle of N (Erisman *et al*., 2007). Heavy application of fertilisers produces nitrate levels in drinking water which might later exceed medically permitted levels (Conway, 2012). The call for increased food production worldwide implies a greater application of fertiliser and consequently more unwanted nitrogen emission into the atmosphere will occur. Pan *et al* (2016) stated that globally, up to 64 per cent of applied N was lost as NH_3, hence mitigating strategies are necessary. The indirect connection between NH_3 and Nitrous Oxide (N_2O) emissions is often neglected and therefore, the indirect effect of NH_3 on carbon emission and global warming is not accounted for in most countries.

2.4. Possible actions towards more sustainable agriculture

The greatest challenge of feeding 9 billion people, is managing the socio-economic, political, environmental, scientific and biological synergies worldwide, ensuring that representatives of these synergies agree on a global scale on the most holistic approach to achieve sustainable agriculture. If no universal agreement is reached, nature will take its course and only the fittest will survive. In the past few decades, different philosophical approaches have been proposed and implemented to move toward agricultural practises that are more sustainable. In the following section a brief discussion on some of the philosophical approaches is provided.

2.4.1. Organic Farming

The organic farming movement emerged around the 1920s and 1940s in Europe and the USA respectively. It represented citizens and farmers who refused to use agrochemicals and were keen to continue traditional farming practises. The increased use of synthetic fertilisers and pesticides to produce food compelled people to demand organic food. For instance, the poorest of poor and undernourished households in Pakistan and India refused to consume red grain products made from the then-new crop varieties of the green revolution (Conway, 2012). Organic agriculture is defined in Edwards-Jones & Howells (2001: 33) as:

> "…..both a philosophy and a system of farming, grounded in values that reflect an awareness of ecological and social realities and the ability of the individual to take effective action…."

Organic farming practices are well defined and regulated by law in many countries. Seufert *et al.* (2017) analysed different organic farming regulations worldwide and concluded that the codification of organic farming focused on the avoidance of synthetic inputs rather than sustainability. Seufert *et al*, (2017) further stated that important components of sustainable agriculture such as permanent soil cover are not clearly defined in organic farming regulations worldwide. Edwards-Jones & Howells (2001) also claimed that organic farming is not absolutely sustainable because regulated inputs used in organic farming systems are derived from non-renewable sources and the use of crop protection in organic systems causes harm to the environment. Conway (2012) further argued that natural pesticides used in organic farming are not necessarily environmentally friendly, on the contrary, natural pesticides can have higher environmental impacts than synthetic pesticides. Organic farming, though heavily regulated and represented on national and international fronts, is lacking the holistic prerequisite needed to achieve sustainable agriculture.

2.4.2. Precision farming

The basic principle of precision agriculture (PA) is to apply the right treatment (fertilisers, pesticides, irrigation, seeding densities and planting depth) at the right time, rate and at the right place (Gomiero et al., 2011). This principle is the foundation of agriculture itself. PA includes all site-specific management (SSM) practises that use information technology to tailor input use to obtain preferred results or monitor results [e.g. remote sensing, yield monitors and variable rate applications (VRA)]. Precision farming provides a set of technologies that can be used to reduce the incidence of fertiliser and pesticide spraying on non-target areas, thus reducing the net environment loss caused by fertilisers and pesticides (Bongiovanni & Lowenberg-Deboer, 2004). The accuracy of PA depends on highly sophisticated technologies that are either very costly or not readily available (Aune *et al.*, 2017). Aune *et al.*, (2017) found that water harvesting, seed priming, seed treatment, micro-dosing and manuring could provide cost-efficient methods for practicing PA to increase the yields of producers in semi-arid West Africa. Aune *et al.*, (2017) further state that cost-efficient, precision farming practises, guided by conventional ecological knowledge, could be the starting point for sustainable agriculture among smallholder farmers in semi-arid regions of West Africa. PA requires highly sophisticated technology which needs to go through an experimental phase before adoption, thus precision farming would not be easily adopted as a way of achieving sustainable agriculture.

2.4.3. Permaculture

The permaculture movement originated in the 1970s and is defined in Ferguson & Lovell (2014: 252) as;

> "Consciously designed landscapes which mimic the patterns and relationships found in nature, while yielding an abundance of food, fiber, and energy for provision of local needs".

Permaculture originated from the word permanent agriculture and was often used analogously with sustainable agriculture (Ferguson & Lovell, 2014). The conceptual framework for evaluating permaculture practises is based on ecosystem mimicry and systems optimization. The core principle of permaculture is to adapt to the environment by designing eco-like, holistically integrated production systems with minimum alteration to nature as it is (Ferguson & Lovell, 2014). The potential role that permaculture could play in the ecological transition is restricted by the general isolation of permaculture from science in terms of scholarly research. Advocates of permaculture make oversimplified claims about permaculture techniques, though the systematic site-specific assessments of the potential benefits are non-existent (Ferguson & Lovell, 2014). Gomiero *et al.* (2011) state that permaculture techniques deplete resources in surrounding areas because biomass from surrounding areas is used to fertilise permaculture areas, thus it's not as environmentally friendly as portrayed by supporters.

2.4.4. Perennial crops

Conventional tillage has harmful effects on soil biomass, which can decrease crop yields per hectare and ultimately compromise long term food security (Knott, 2015). Usually the cultivation of annual crops necessitates fields to be ploughed every season thus accelerating negative impact on soil (Gomiero *et al.*, 2011). Perennial crops are said to reduce the negative impact of tillage and agrochemicals on the environment. These are crops that can be harvested more than once while annual crops live for one season only. Perennial crops have roots more than two meters deep and can therefore improve nitrogen cycling, carbon sequestration and water conservation (Gomiero et al., 2011). Perennials are less susceptible to pests and so it needs fewer pesticide treatments, compared to annuals, thus reducing side effects of pesticide application (Glover, 2004 and Fernando *et al.*, 2018).

Glover *et al.* (2010) argued that annual wheat is grown on more cropland than maize, despite lower yields per hectare because wheat can be grown on marginal areas not suitable for maize. Henceforth low yielding perennials could also be grown on marginal land where high yielding annuals fail to reach their full yield potential. In doing so more food will be produced in the semi-arid and arid regions of the world which would enhance global food security.

2.4.5. Transgenic crops

Plant breeding is an ancient art. Early farmers domesticated wild grass to cereals such as barley, maize, and wheat. The wheat presently used in bread for instance, is a result of crossbreeding emmer wheat and wild goat grass (Conway, 2012). Improved technology, mean human ability to experiment with cellular and biological features of plants are advanced. In recent years there has been an increase in GM (genetically modified) products. GM food technology enables the development of new crop varieties that can supplement the biological deficiencies in specific soils. For instance, GM technology can engineer crop genes that are highly productive, stable and resilient. Crops are engineered to be pest-resilient, drought-tolerant and self N-fixing. Biotechnology can be the answer towards achieving food security and nature conservation simultaneously in developing countries. This can enable the availability of food to the poor at a reasonable cost (Conway, 2012). The fear exists that the potential benefits of biotechnology might not trickle down to the poorest of the poor. Opponents of GM products have raised concerns about human health, secondary pests and gene spreading to non-targeted areas and therefore they still call for alternative sustainable means to increase food production. Those opposed to GM further argue that the detrimental environmental effects of the past green revolution are evident. By virtue of past experiences, thorough research into the sustainability of GM technology is a necessity (Azadi & Ho, 2010 and Gomiero *et al*., 2011). The contributions of biotechnology are promising in some aspects such as plant mutations, less so in others and unproven in many. Therefore, research and experimentation are crucial towards the complete utilisation of biotechnology.

The above mentioned philosophical approaches fail to solve the environmental costs discussed in Section 2.3 because negative trade-offs exist. The following section focuses on CA and it emphasises how CA attempts to solve the environmental cost mentioned in Section 2.3 in a holistic manner.

2.5. Concept of Conservation Agriculture

Prior to the 20th century farmers would till land before planting crops and leave land once the soil is degraded. In the quest for fertile soils, farmers in the USA started to till the deep fertile soils of the Midwest. The excessive tillage of deep soils in the Great Plains of the Midwest meant topsoil was left exposed to erosion by the wind. The infamous dust bowls of the 1930s in the Great Plains was a result of loose topsoil caused by tillage. Farmers responded in two ways towards the 'dust bowls'. They either applied conservation tillage or no-tillage. This was the origin of CA. According to Kassam *et al.* (2019) CA is based on three interlinked practical principles which are:

- Principle 1: continuous no mechanical soil disturbance (no-till seeding of crop seeds, directly planting seeds into uncultivated soil and causing minimal soil disturbance from conventional set-ups such as tractors, etc.).
- Principle 2: permanent or semi-permanent biomass soil mulch (retaining crop biomass, such as mulch and/or growing cover crops).
- Principle 3: diversification of crop species (implementing crop rotation systems, and/or associations involving annual and perennial crops, often including a mix of legume and non-legume crops).

The central idea behind CA is farming for future generations while attaining short term profit objectives. Minimum tillage, mulch tillage, zero tillage and no-tillage have all been incorporated in CA experiments. Some contradictory results of CA experiments are evident from the literature (Elsevier, 2014). It is important to note that conservation tillage does not imply CA. Conservation tillage was a set of practises used in conventional agriculture to counter the drastic impact of soil erosion. Henceforth, conservation tillage still used tillage as a soil structure-forming element, while CA attempts to keep permanent or semi-permanent soil cover and refrain from tillage (Hobbs, 2007 and Knott, 2015). The worldwide use of CA has been on an upward trajectory. Implementing CA is driven by an intrinsic change of mind by farmers, rather than a drastic upward shift in yields under full CA principles. For example, in some agro-ecological regions within South Africa, yields under conventional systems are higher than yields under CA systems and vice versa (Swanepoel *et al*., 2018).

2.6. Advantages of CA in reducing environmental costs

2.6.1. Reduced Soil Degradation

A major cause of soil degradation is conventional tillage which disrupts the stability of soil aggregates. This leaves topsoil loose and exposed to wind and/or rain erosion. Continuous ploughing under conventional agricultural practises accelerates soil degradation (Conway, 2012). In a CA production system no-till practises are applied, aided by reduced and lighter mechanical farm traffic on cropland. This improves the structural stability of soil aggregates. Stable soil aggregates mean reduced loose soil that is susceptible to erosion (Knott, 2015). This minimises soil degradation in the medium to long term. Crop residue retention on the topsoils under CA production systems also protects the soil from raindrop impact and direct solar radiation of the sun, whereas soil is left exposed under conventional tillage (Jat *et al.*, 2012 and Jat *et al.*, 2014).

2.6.2. Water retention

Rainwater retention is normally measured by the level of water evaporation, water holding capacity of the soil and water infiltration rate in the soil (Jat et al., 2012). Crop residues left on the surface of the soil under CA practises acts as a barrier which gives rainwater time to infiltrate the soil. Water infiltration under CA is further improved by better soil stability and improved soil cohesion (Knott, 2015). Rainwater is captured in CA systems by crop residues on the soil surface and will gradually release it into the soil later, which ensures higher moisture levels in the soil. This characteristic prolongs water supply to crops (Jat *et al.*, 2012). According to Jat *et al.* (2014) a one per cent increase in the soil's organic mass induced by residue retention, increases the water holding capacity of soil by at least three per cent.

The impact of CA on the "soil water balance" in rain fed agricultural production areas such as the Western Cape is critical. Soil water balance means inputs of water into the soil should equal outputs of water from the soil, plus changes in soil water storage rates. Soil water output can be in the form of evaporation, runoff and drainage. If one of the components in the equation changes, another should also change to maintain the balance. For example, if crop residues are used to protect evaporation from the soil, zero-till is necessary to support the soil in storing water and thus maintain the "soil water balance". Since CA contributes to this "soil water balance" adopting integrated principles will realise the benefits of conserving water under CA practises in dryland agriculture.

2.6.3. Reduced use of Agrochemicals

Deep-rooted cover crops used in rotation systems with cash crops can release nutrients from deeper soils that would be absorbed by subsequent cash crops. Integrating N-rich legume crops in CA rotation systems also increase soil organic matter retention. This reduces the need for chemical fertiliser (Jat *et al.*, 2014). The prevalence of nitrogen leaching is reduced under CA systems because cover crops slowly release nutrients (Kassam *et al.*, 2012). Microorganisms hold mineral nutrients in the initial stages of implementing CA practises, however over time nutrients become readily available due to enhanced microbiological activity. In the long run this reduces the application rates of chemical nitrogen. After years of practicing CA the soil is rich in organic nitrogen, thus releasing greater amounts of N compared to conventionally tilled soils. Reduced dependence on mechanical traffic (tractors) on crop fields under CA systems also implies less carbon emission from the tractor. Organic soil cover in CA systems improves biological diversity and enhances the potential prevalence of natural pest predators. Additionally, crop rotation systems can break pest life cycles and/or pathogen build-up. CA systems help to diminish the dependence on synthetic pesticides and reduce the environmental effects of chemical pesticides (Kassam *et al.*, 2012).

Weed management is a major problem for CA producers. CA proponents propose effective residue management, crop rotations with green manure crops and/or crop-livestock integration as methods of controlling weeds (Kassam *et al*., 2012). For example, MacLaren *et al.* (2019) found that grazed crop rotations with high crop diversity tend to have lower weed abundance and greater weed diversity than un-grazed crop rotations with low crop diversity on the Langgewens research farm. The grazed system also had fewer herbicides applied as opposed to un-grazed fields.

2.6.4. Reduce the effects of animal production

The gradual increase in the per capita income of households in less developed countries implies that the demand for meat products would more than double by 2050 (FAO, 2018). Livestock production is the main source of animal protein. However, livestock production results in severe environmental consequences such as deforestation, soil erosion and high use of nitrogen and phosphorus (Lemaire *et al.,* 2014 and Gomiero *et al.*, 2011). Crop and livestock integration, though not a CA principle, can be used in CA production systems to increase animal production. Harnessing the biological, ecological and economic benefits and/or synergies accrued by the animal component are beneficial in crop rotation systems (Basson, 2017). Crop-livestock integration reduces the incidence of deforestation to grow animal feed in some regions of the world, and simultaneously attempts to meet the increasing demand for meat products in a sustainable manner. The same area of land is used to grow cash crops and raise livestock. This reduces the necessity of vast land expansion required to raise livestock (Gomiero *et al.*, 2011). However, crop-livestock integration might increase the incidence of soil compaction by livestock, consequently reducing the yields of cash crops. Therefore, sophisticated, on-site grazing management strategies (e.g. let animals graze on dry soil instead of moist soil) are critical to managing trade-offs between livestock grazing and animal hoof compaction (Basson, 2017 and Sanderson *et al.*, 2013).

2.6.5. Increased Biodiversity

CA production systems can almost mimic natural conditions that are ideal for diversity of above and below ground fauna and flora. No-till minimises the disturbance of biological activities of organisms living within the soil (Jat et al., 2014). Retention of residues creates an eco-friendly environment in which bacteria, fungi, earthworms, arthropods and other microorganisms can thrive. The biomass retention is food for organisms and cover crops keep soil temperature moderate thus supporting the microbe's lifecycle. CA production systems also support above-ground biodiversity by providing food for insects, reptiles, birds and mammals (Jat *et al.*, 2014). Meyer & Erasmus (2017) found that within three cultivation seasons morphospecies' numbers were greater in CA fields compared to ploughed fields in the Ottosdal, Hartbeesfontein, Sannieshof, Vredefort and Kroonstad areas of South Africa.

The aforementioned advantages of CA production systems focused on the environmental benefits that a CA production system offers. To achieve food security in a sustainably all-inclusive manner by 2050, yields under CA production should also be considered. For this reason, the next part will emphasise productivity under CA systems.

2.6.6. Productivity

Implementing CA production systems makes timelier planting possible because there is no need to wait on ideal weather conditions to plough land before planting (Hobbs, 2007). Larger areas can be cultivated with no-till compared to conventional tillage (Jat *et al.*, 2012). The immediate impact of CA on yields might be positive, constant or even negative, depending on the initial state of the soil, climate or rainfall. In the medium to long term, improvement in the physical, biological and chemical state of the soil occurs because of continued residue retention, crop rotation and minimum soil disturbance. The result is higher and more stable yields. For instance, using N fixing crops (legumes) followed by N adsorbing crops (wheat) in a rotation system would enhance the performance of crops on the CA fields (Jat *et al.*, 2014).

In the dry Mediterranean climates of different continents, yield differences of up to 100 per cent have been noted between CA systems and conventional tillage systems (Kassam *et al.*, 2012). In rain fed areas improved soil porosity under CA systems leads to better water infiltration and improved water holding capacity of the soil and so the impact of rainless periods after planting are minimised (Jat *et al.*, 2014). The plant is able to continue growing until harvest time. In the Swartland, crop rotation systems have higher yields compared to monoculture systems (Hoffmann, 2001). No-tillage with crop rotation returns higher yields than mono-cropping under conventional tillage (Knott, 2015).

Empirically it is evident that CA supports the environment without compromising yields. The philosophical approaches discussed in Section 2.4 can be incorporated within CA production systems. CA has numerous social and private benefits including better aqua life and increased yields. The cost to implement CA is exclusively borne by the farmer which has hindered the widespread uptake of CA globally. Some of the constraints of adopting CA are discussed in the next section.

2.7. Constraints to adopting CA

2.7.1. Uses of crop residues

Retention of crop residue is a core principle of CA. Crop residues are not readily available in all crop growing parts of the globe. Legume and cereal residues are highly valued as fodder for feeding livestock. Using residue as feed often takes precedence over mulching for soil cover as required by CA. Conventionally livestock has cultural (wealth indicator, green manure) and economic (investment, risk insurance) value (Jat *et al*., 2012 and FAO-REOSA, 2010). The projected increase in demand for animal protein (FAO, 2018), entails that animal populations will increase. Consequently residue retention for soil protection would decrease. Different management strategies to integrate livestock with CA have been proposed. An animal component poses serious challenges to the success of CA. Livestock causes soil compaction and animals often overgraze the residues left on the soil if not closely monitored (Basson, 2017).

2.7.2. Weed infestation

Weeds are present and difficult to manage in all crop production systems. In CA production systems weed increases in the initial stages, which require the application of herbicides. Herbicides are not widely available in resource-poor, developing countries. Poor functioning markets in these countries result in the high cost of herbicides, which reduces the ability of farmers to acquire herbicides (Mutua *et al.,* 2014). Under CA production systems there is a shift in labour use profiles from ploughing and/or planting to weed control. During the initial phase of adopting CA, the labour requirements of weeding might outweigh the labour savings gained from converting to a CA production system. Ploughing is the most cost-effective strategy to control weeds in the short term, especially for smallholder farmers. Investment in extra labour and inputs are only necessary for the first few years of adopting CA as advocates argue that after the transition phase, weed is expected to decrease due to continuous early weeding (Jat *et al*., 2012).

2.7.3. Lower crop yields

Nutrient immobilisation, higher insect-pest attacks, higher weed infestation and inadequate skills when initially adopting CA are some of the contributing factors to lower yields in the transition phase when implementing CA (Jat *et al*., 2014). To overcome these detrimental factors, experts need to be hired. The additional input requirements are necessary to keep yields stable. In the widespread poor clay soils of sub-Saharan Africa, the benefit of mulching will not be visible in the initial years of implementing CA. CA being a knowledge-intensive often uncertain process and the possibility of lower yields, reduces the likelihood of risk-averse farmers to adopt CA practises (Jat *et al.*, 2012 and Jat *et al.*, 2014).

2.7.4. Land tenure systems

Farmers are reluctant to invest time and money into improving soils for which they do not hold title deeds. The traditional land tenure systems that are often practised in smallholder agriculture, limits the willingness of small scale farmers adopting CA practises (FAO-REOSA, 2010). Irrespective of who cultivated the land, mulch is often regarded as a public good in traditional land tenure systems, and so it is grazed by free-roaming livestock in the fallow season. Farmers burn crop residues or store it away in the fallow season to keep livestock off fields. Adopting CA practises is often daunting in traditional land tenure systems even though some farmers might be willing to try-out CA practises (FAO-REOSA, 2010 and Jat *et al.*, 2014).

2.7.5. Investment, skill requirement and tillage mind-set of farmers

The more sophisticated farming equipment (disc, direct seed drill, harvesters, fertilizer and manure spreaders and sprayers) necessary to successfully adopt CA principles, require new capital investments. During the preliminary phase additional inputs such as labour, pesticides and fertilisers are needed to obtain the same yields as with conventional tillage systems (FAO-REOSA, 2010 and Mutua *et al*., 2014). To mitigate the risk of converting to CA, farmers often only adopt one or two principles of CA, depending on the needs of specific soils. CA requires farmers to make an basic mind-set change. Conventionally tillage is synonymous with growing crops, so to make the shift requires time, evidence and extensive work. Older farmers are often reluctant to change, while younger farmers are modernised, risk seeking and often less reluctant to change farming practises (Jat *et al.*, 2012). Adopting all three CA principles is a complex, knowledge-intensive process which requires self-taught skills. It takes many years of trial and error to obtain the required skills, knowledge and wisdom to understand and operate a conventional farm, which would mostly become redundant after converting to CA. How many more years will it take to understand the more complex CA production systems? The "no size fits all" site-specific nature of adopting CA principles, which entails even long term experimental research into CA would find it difficult to answer the question appropriately. The basis of CA is that it is not only site specific, but also season specific and practises are adapted according to the weather conditions between seasons (Knott). It is not a recipe based decision making environment.

Although adopting CA means dealing with many obstacles, implementation has been widespread in certain regions of the world such as Australia, and America (Kassam *et al.*, 2019). The following section focuses on the global progress of CA.

2.8. CA adoption globally

The global uptake of CA practises has been rapid in recent years. Cropland under CA production systems was approximately 7.5 per cent of global cropland in 2008/09, 11 per cent in 2013/14 and 12.5 per cent in 2015/16. During the nine-year period (2008/09-2015/16), CA production practises have expanded to 180 M ha in 2015/16 globally from 106 M Ha in 2008/09, a significant growth rate of about 69 per cent (Kassam *et al*., 2019).

Table 2.1. Cropland under CA (million hectares) by continent in 2015/16; CA area as percentage of global cropland and CA area as a percentage of cropland in each region.

Region	CA Cropland area (M ha)	% of global CA cropland area	% of Cropland area in the region
South America	69.90	38.7	63.2
North America	63.18	35	28.1
Australia & NZ	22.67	12.6	45.5
Asia	13.93	7.7	4.1
Russia & Ukraine	5.70	3.2	3.6
Europe	3.56	2	5
Africa	1.51	0.8	1.1
Global total	180.44	100	12.5

Source: Kassam, *et al.*, 2019

South and North America are the global pioneers of CA adoption. Table 2.1 indicates that 69.9 M ha, about 38.7 per cent of total global cropland under CA is in South America and some 63.2 M ha roughly 35.0 per cent is in North America. Approximately 22.7 M ha (12.6 per cent) is in Australia & New Zealand. Europe and Africa are the regions with the lowest cropland under CA production systems. In Europe, 3.6 M ha is under CA which is about 2 per cent globally, while Africa has approximately 1.5 M ha (0.8 per cent).

2.8.1. CA adoption in North America

Historically crop production in the USA had little impact on the natural environment. Crop production was practised on soft soils along rivers and streams, with long fallow periods, intercropping and conventional zero-till practises. European colonisation imposed mono-cropping by intensive tillage on American farmers (Duiker & Thomason, 2014). During the 1930s farmers saw the effect of excessive tillage with the occurrence of the infamous "Dust Bowls" in the US. The tillage left topsoil loose and exposed to wind erosion. This was an eye-opener for the government to which the government responded by establishing the soil erosion service in 1933. Weed infestation limited the widespread adoption of no-till production systems after the "Dust Bowls" (Jat *et al.*, 2014). The widespread adoption of CA was triggered by the synthetic inputs of the green revolution in the 1960s, which limited weed infestation (Knott, 2015).

The Canadian Prairie is the central crop producing area in Canada. In 1886 Canada established experimental farms to measure the soil organic matter (SOM) of the Canadian Prairies. Scientists could take detailed accurate measurements of SOM when tills started to invert the Canadian Prairie fields. By 1980 Canadian Prairie soils had lost approximately 40 per cent of initial organic N content. The report on the state of Prairie Soil N content levels released by the Standing Committee on Agriculture, Fisheries and Forestry in 1984 was crucial to CA progress in Canada (Lafond et al., 2014).. CA practises were only rapidly adopted during the 1990s in the Canadian Prairies (Lafond *et al*., 2014). CA is mainly adopted in the north western parts of North America, with approximately 50 per cent adoption rates. CA adoption in North America increased to 63.2 M ha in 2015/16 from 40 M ha in 2008/9 (Table 2.2). During the 9-year period (2008/9-2015/16) cropland under CA production increased by approximately 16 M ha in the US, 6 M ha in Canada and 18 thousand ha in Mexico (Table 2.2). The US is the frontrunner of CA adoption in North America followed by Canada and Mexico.

Table 2.2. The progress of CA ('000 ha) within North America.

Country	Cropland under CA (2008/09)	Cropland under CA (20013/14)	Cropland under CA (2015/16)
USA	26 500	35 613	43 204
Canada	13 481	18 313	19 936
Mexico	22.80	41	41.#
Total	***40 003.80***	***53 967***	***63 181***
Percentage difference		***34.9 since 2008/09***	***57.9 since 2008/09*** ***17.1 since 2015/16***

Source: Kassam, *et al*., 2019 #from 2013/14.

The USA has a conducive, institutional environment for adopting CA principles. Policy instruments such as land retirements, educational and technical assistance, financial support and conservation compliance requirements, are used to encourage farmers to adopt CA principles. For example, farmers are supported by the state to purchase capital requirements to switch to CA production systems. If CA systems are less profitable than conventional systems, farmers are compensated to continue producing using CA systems (Mudavanhu, 2015). The Canadian government also has policy instruments such as National Soil

Conservation Programs (NSCP) and Save Our Soil (SOS) to persuade farmers to adopt CA (Lafond *et al*., 2014).

2.8.2. CA adoption in South America

During the 1800s, European immigrants arrived in Brazil and subsequently imported tillage equipment from Europe to plant crops. To mitigate severe soil erosion associated with tillage, farmers implemented shift farming techniques. As soil erosion was still a big concern, agricultural stakeholders started to ponder scientific solutions to fight soil degradation (Calegari *et al.*, 2014). CA adoption rates are fast approaching 100% in southern Brazil, Argentina, Paraguay and Uruguay. Brazil and Argentina are the frontrunners in this process. Brazil had approximately 32M ha of cropland under CA in 2015/16, while Argentina had around 31M ha (Table 2.3). The quality of CA practises in South America is unfortunately questionable. Some farmers often practised soya mono-cropping with no cover crops (Kassam *et al.*, 2019).

Table 2.3. The progress of CA ('000 ha) within South America

Country	*Cropland under CA (2008/09)*	*Cropland under CA (20013/14)*	*Cropland under CA (2015/16)*
Brazil	25 502	31 811	32 000
Argentina	19 719	29 181	31 028
Paraguay	2400	3000	3000
Uruguay	655.10	1072	1260
Bolivia	706	706*	2000
Venezuela	300	300*	300#
Chile	180	180*	180#
Colombia	102	127	127#
Total	49 564.10	66 377	69 895
Percentage difference		33.9 since 2008/09	41.0 since 2008/09 5.3 since 2015/16

Source: Kassam, *et al.*, 2019 *from 2008/09 #from 2013/14.

The pioneers of the widespread adoption of CA in Brazil, and subsequently South America are the research service provider IAPAR (Agronomic Institute of Paraná), together with agricultural input manufacturers seeking to expand their markets (Calegari *et al.*, 2014). APRESID (Argentinian Association of No-till Farmers) was and is the pillar of CA adoption in Argentina. Only after its foundation in 1986 was CA widely adopted through Argentina (Kassam *et al.*, 2012).

2.8.3. CA adoption in Europe

According to Friedrich *et al.*, (2014), research on conservation tillage has an extended history in Europe. However, CA is not widely adopted across Europe, and Africa is the only continent with a lower implementation rate than Europe, in terms of cropland under CA practises globally. In 2015/16 cropland under CA was approximately 3.56 M ha in Europe and 1.51M ha in Africa. The adoption of CA principles is slow in Europe, but significant headway was evident in the past decade. In the nine-year period (2008/09-2015/16), croplands under CA in Europe increased by more than 100 per cent (Table 2.4.). Spain with a distinctly Mediterranean climate is the pioneer of CA in Europe by some margin, with 900 000 ha (2015/16) of cropland under CA. Unexpectedly, the cropland under CA has decreased in European superpower Germany. In Germany the area under CA receded from 354 000 ha in 2008/09 to 146 000 ha in 2015/16, see Table 2.4.

Table 2.4. The progress of CA (‘000 ha) in Europe

Country	Cropland under CA (2008/09)	Cropland under CA (20013/14)	Cropland under CA (2015/16)
Spain	650	792	900
Italy	80	380	283.92
Finland	200	200	200
France	200	200*	300
Germany	354	200	146
United Kingdom	25	150	362
Slovakia	10	35	35#
Portugal	28	32	32#
Switzerland	9	17	17#
Hungary	8	5	5
Ireland	0.10	0.20	0.20
Other	-	64.77	1277.08
	1564.10	**2035.97**	**3557.20**
Percentage difference		**30.1 since 2008/09**	**127.4 since 2008/09** **74.7 since 2015/16**

Source: Kassam, *et al.*, 2019 *from 2008/09 #from 2013/14

The ECAF (European Conservation Agriculture Foundation) is the promoter of CA production systems in Europe. ECAF successfully brought CA practises to the attention of the European Commission (EU). Support from European farmers to incorporate CA practises with CAP (Common Agricultural Policy) is slow (Kassam *et al.*, 2019). Friedrich *et al.* (2014) argued that CAP cannot serve as a stimulus to adopt CA since the standard method for which CAP was formulated is conventional agriculture. Switzerland is one of the few European countries that have policies to support the adoption of CA at national level. The adoption of CA principles is farmer-driven. Farmers in Europe prioritise compliance with EU regulations more than good farming practises because large portions of European farm income is derived from EU subsidies (Friedrich *et al*., 2014).

2.8.4. CA adoption in Australia and New Zealand

The arrival of European settlers in the 18th century in the Oceania region was the starting point of traditional tillage farming practises in Australia and New Zealand. These settlers imported farming techniques proven to be unsustainable for the new found conditions (Ward & Siddique, 2014). The vast availability of land meant farmers continued using unsustainable European techniques, with shift farming approaches. The development of the stump-jump plough and the Ridley stripper of the 1800s, shows that the Oceania farmers solved early agricultural problems in an innovative manner. To minimise the significance of long fallow periods in combating soil erosion during the 1930s pushed Australian farmers toward adopting CA (Ward & Siddique, 2014 and Kassam *et al.*, 2019). Approximately 45 per cent of total cropland in Oceania is under CA production systems (Table 2.1). This occurs mainly in Western and Southern Australia with its Mediterranean climate. In the western region, 90 per cent of farmers use no-till systems to harvest crops (Ward & Siddique, 2014). Derpsch, cited in Ward & Siddique (2014), claimed that Australian no-till systems have reached a peak, incapable of being improved to a much higher level. In New Zealand CA is not widespread because of the higher soil potential than that of Australia. Benefitting from adopting CA practises are thus less evident in New Zealand compared to Australia (Ward & Siddique, 2014).

Established farmer groups such as WANTFA (West Australia No-Till Farmers Association), and NZNTA (New Zealand No-Till Farmers Association), play a critical role, encouraging farmers to try and tailor CA practises to suit specific soils. "Land Care" programs in Australia provided funding for localised studies on CA implementation to create awareness and ensure relevance to Australian conditions (Brown *et al.*, 2018).

2.8.5. CA adoption in Asia

In China experimental research on CA started around the 1970s and the results were positive. As suitable power driven no-till planters for the Chinese land tenure systems were unattainable, it meant the uptake of CA was non-existent between 1970 and 2000. The development of no-till planters suitable for double cropping systems in northern China ignited the uptake of CA in China (Hongwen *et al.*, 2014).

In SEA (South-Eastern Asia) the expansion of cropland under CA is small and mainly limited to research trials (Jat *et al.*, 2014). In central Asia, CA is widely adopted in the rain fed agricultural areas of Kazakhstan. In the attempt to integrate CA with irrigation systems, experiments are done in the irrigated areas of central Asia (Aziz *et al.*, 2014). In Asia, China is the largest user of CA with approximately 9 M ha of cropland in 2015/16, followed by Kazakhstan with 2.5 M ha in 2015/16. In 2008/09 CA was only reported in two countries across Asia, compared to 18 countries in 2015/16. In recent years the area under CA has grown significantly in India, with no CA recorded during 2008/09 compared to 1.5 M ha in 2015/16. The cropland under CA has increased by more than 400 per cent in Asia from 2.6 M ha in 2008/09 to 13.9 M ha in 2015/16 (Kassam, *et al.*, 2019).

Asian countries, particularly China, Kazakhstan and Laos, are committed to implementing CA principles. China has developed no-till equipment suitable for small and medium-size Chinese farms. Researchers at the Kustanay Research Institute of Agriculture (Kazakhstan) have successfully eliminated conservation tillage in experiments and adopted all three CA principles. The Laos governmental decree "No 554 dated 21/4/2005" promotes CA as a favourable agroecological technique (Lienhard *et al.*, 2014 and Aziz *et al.*, 2014).

2.8.6. CA adoption in Southern Africa

Ploughing has been used to prepare soil since the start of colonialization in Southern Africa. The mouldboard plough was commonly used by farmers in Southern African since the 1920s. Intensive tillage to cultivate land caused land degradation in the region, which required farmers to look for alternative sustainable production systems (Thierfelder *et al.*, 2014). CA was introduced in southern African countries such as South Africa, Zambia, Zimbabwe and Malawi, during the late 1900s and early 2000s (Nyamangara *et al.*, 2014). The implementation of CA on southern African farms is often debated. The main argument is that

CA was adopted on mechanised large scale farms overseas, thus experience from overseas cannot be used as a learning curve for more complex Southern African smallholder farms (Thierfelder *et al.*, 2014). Southern Africa has seen robust growth in CA adoption. For instance, CA is mainly practised on large commercial farms since the deregulation of South African agriculture in the 1990s (Knott, 2015).

The cropland under CA practises in Southern Africa increased by 224 per cent from 2008/09 (432 000 ha) to 2015/16 (1.4 M ha). South Africa is the pioneer for CA in Southern African with 439 000 ha of cropland under CA during 2015/16, followed by Zambia and Mozambique with 316 000 ha and 283 000 ha respectively in the same period, see Table 2.5 for details.

Table 2.5. The progress of CA in Southern Africa

Country	CA Area 2008/09	CA Area 2013/14	CA Area 2015/16
South Africa	368	368*	439
Zambia	40	200	316
Zimbabwe	15	90	100
Mozambique	9	152	289
Lesotho	0,13	2	2
Malawi	0	65	211
Tanzania	0	25	32,6
Madagascar	0	6	9
Namibia	0	0,34	0,34#
Swaziland	0	0	1,3
Total	432,13	908,34	1400,24
Percentage difference		Since 2008/09 110	Since 2008/09 224 Since 2013/14 54

Adopted from Kassam, *et al.* 2019 edited by author *from 2008/09 #from 2013/14.

The unfavourable environment in sub-Saharan Africa has hindered the widespread adoption of CA. Missing and/or distorted markets for agricultural inputs and outputs in Southern Africa serve as deterrent for farmers to adopt CA (Brown *et al.*, 2018). CA benefits are accrued over time, whilst smallholder farmers are concerned with immediate food security and survival (Nyamangara *et al.*, 2014). Only a fragment of government policies in Southern African countries are integrating CA principles with government policies. Consultation is ongoing about integrating CA in the agricultural development policies of South Africa. Agricultural development based on CA principles in the Guinea savanna zone is promoted by (AfDB) African Development Bank. The adoption of CA practises in Africa would result in the development of context-specific, localised technology, which would boost the uptake of CA (Kassam *et al.*, 2019).

2.8.7. Adoption of CA in South Africa

Research trials led by the Small Grains Institute of the Agricultural Research Council of South Africa, concerning CA, were initiated around 1976 (Mudavanhu, 2015). According to Knott (2015) widespread adoption of CA throughout South Africa was hindered by the following factors during the 1970s:

- Lower yields and poor quality crops caused by disease infestation
- The high cost of herbicides
- Unwillingness among farmers
- Unsatisfactory results from no-tillage tested in poor soils
- Farmers lacked economic incentive to intensify crop production
- Regulated agricultural sector

A decline in wheat and maize prices beyond export parity levels, after the deregulation of the South African agricultural sector, necessitated farmers to reduce input cost to remain competitive globally. Input cost was the only variable controlled by farmers. Experiments on CA in other regions of the world indicated that CA reduces input costs significantly. CA was thus an economically and ecologically viable option for South African farmers (Knott, 2015).

South Africa is the leader in terms of cereal cropland under CA across Africa. The area under CA in South Africa was 368 000 ha and 439 000 ha in 2008/09 and 2015/16 respectively (Kassam *et al.*, 2019). CA is mainly adopted by commercial winter cereal farmers in the Western Cape, inspired by their Australian counterparts. Commercial farmers in the Free State and KwaZulu-Natal have also widely adopted CA principles. The establishment of no-till clubs in the Western Cape and KwaZulu-Natal are critical parts for gathering knowledge on CA.

According to Mudavanhu (2015), all regions in South Africa have the potential to implement CA, except those that are part of the Namib and Kalahari Deserts. The North West province of South Africa is a special case where a phobia regarding CA exists. This is due to a no-till experiment in the 1980's on a maize farm in the province that was a catastrophic failure. The news quickly spread to grain farmers in the region, after which a stigma towards no-till in favour of tillage was established (BFAP, 2007). According to Knott (2015), conventional tillage is only practised on approximately 20 per cent of arable agricultural land throughout South Africa, whilst 80 per cent of arable land is under practises ranging between conventional till and zero-till.

2.8.7.1. CA adoption in Western Cape

The Western Cape Province of South Africa is the leader in the implementation of CA in the country. CA is mainly implemented on large commercial farms harvesting winter grains such as wheat and barley. Wheat is the major winter cereal crop cultivated in South Africa, where wheat products are deemed a staple food (DAFF, 2017). South Africa is a net importer of wheat, as local consumption exceeds local supply (BFAP, 2018). Wheat production will remain a key determining factor for national food security in the country. The Western Cape Province produced approximately 66 per cent of the total amount of commercially produced wheat in South Africa during the 2017 planting season (DAFF, 2017). Approximately 87 per cent of all wheat produced in the province comes from the Swartland and Southern Cape areas (Hoffmann & Kleynhans, 2011).

Traditionally wheat producers in the Western Cape planted wheat in a monoculture system. Mono-cropping compromises the quality of soils and negatively influences crop yields. The ARC (Agricultural Research Council) and the Department of Agriculture Western Cape recognised the need to assist farmers to move away from conventional mono-cropping practises. The ARC, in co-operation with the department, implemented strategies to generate awareness among farmers on CA. Initially the adoption of CA was slow. The benefits of CA were evident on experimental farms led by ARC and the Provincial Department of Agriculture and the results inspired farmers to adopt CA. ARC's development of no-till planters suitable for the stony terrain of the Western Capes made conversion easier. ARC in collaboration with the department of agriculture provides assistance to farmers adopting CA, by providing information about seed densities, row width and fertiliser placement under CA. According to Strauss cited in (Madavanhu, 2015), about 90 per cent of farmers in the Western Cape have adopted CA principles. Approximately 49 per cent of the 51 farmers surveyed by ARC and Department of Agriculture Western Cape use all three CA principles while the majority adopted one or two of the three CA principles. See Figure 2.1 for details (Modiselle, *et al.*, 2015).

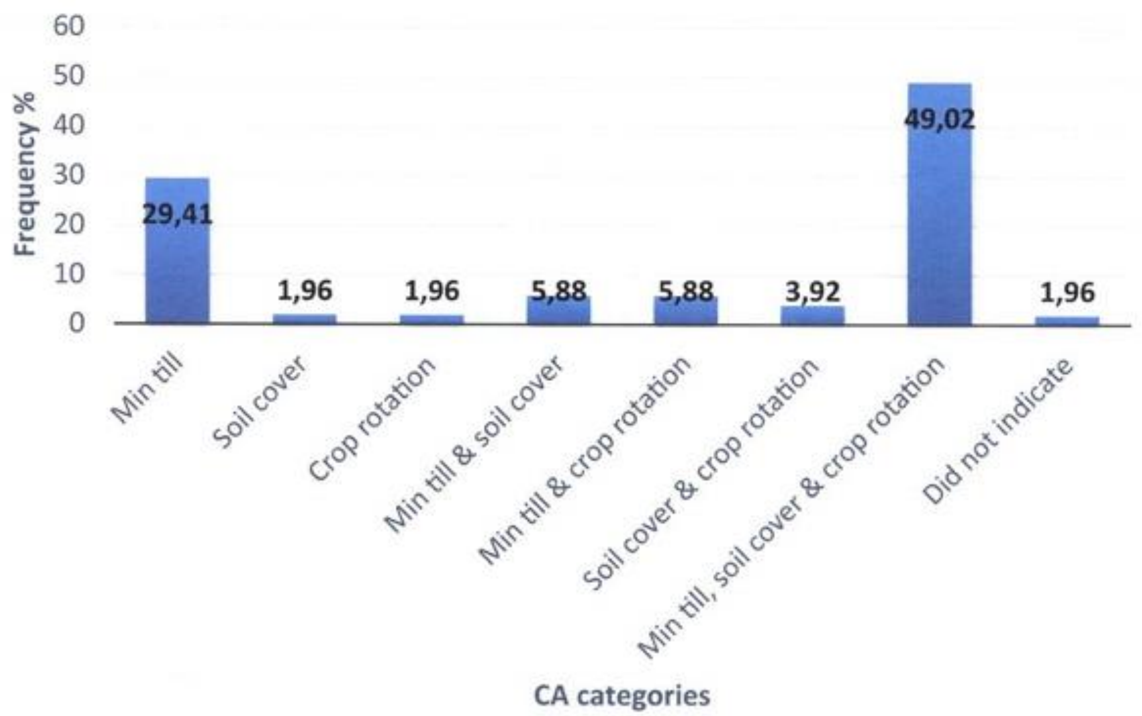

Figure 2.1. Categories of CA adopters in the Western Cape.

Source: Modiselle *et al.*, 2015

According to Modiselle *et al.* (2015), the majority of famers in the survey reported the following:

- CA increased total production, income and yield per hectare (Advantage)
- CA decreased labour requirement and cost (Advantage)
- CA improved soil quality, moisture and microorganism (Advantage)
- CA improved water quality due to reduced fertiliser use (Advantage)
- CA increased weed & pest control (short term disadvantage)
- CA increased equipment cost (initial Cost)
- CA increased insect attacks on crops (short term disadvantage)

A general lack of expertise and risk aversion among farmers is the reason for the low and slow uptake of CA in the other provinces. The traditional land tenure systems, communal grazing and other socio-economic constraints hinder the adoption of CA by smallholder farmers. The increasing HIV and AIDS pandemic implies labour would become a scarce resource, therefore CA adoption might be crucial for the long term livelihood and sustainability of smallholder farmers.

2.8. Conclusion

The first section of this chapter provided background information on sustainable agriculture and briefly discussed proposed philosophies to attain sustainable agriculture. The second part focused on CA as a way of achieving sustainable agriculture.

Practically environmental degradation is an ancient concern. Sustainable agriculture emerged around the 1980s in literature, amid concern regarding the green revolution's synthetic agricultural inputs. Sustainable agriculture is viewed differently by individuals. Therefore, different philosophical approaches such as organic farming and permaculture have been proposed to achieve sustainable agriculture. The proposed philosophical approaches often fail to achieve the common aim of food security and sustainability simultaneously. CA is proposed as a holistic approach to sustainable agriculture, with its origin from the infamous Dust Bowls in the USA. CA is a site-specific, knowledge-intensive practise, which achieves environmental improvements without compromising short term profitability. Weed infestation hindered the initial uptake of CA whereas herbicide developments in the 1960s ignited the global uptake of CA. Presently CA is widely adopted across all continents, with Brazil and the USA among the frontrunners. Europe and Africa are the continents with the least cropland under CA production globally. European farmers lack the incentive to adopt CA, while their African counterparts face resource constraints. South Africa is the pioneer in CA in Southern Africa where it is mainly practised by commercial farmers in the Western Cape, Free State and KwaZulu-Natal. The smallholder farm communities in South-Eastern Asia and Southern Africa are constrained by financial, socioeconomic and institutional problems, which hinder the uptake of CA technology.

Chapter 3: Methodology

3.1. Introduction

In the struggle to produce sufficient food and fibre, mankind is attempting to control biological systems in an uncertain environment. Farming systems emerged over centuries, disappeared and reappeared in differing circumstances (Schiere *et al.*, 2012). A farm can be considered as a bio-economic system controlled by humans to achieve their economic goals. To meet food demand for the increasing population, farm production is becoming more intensive and subsequently more biologically unstable. Mankind's ability to directly manipulate the food-producing environment by the use of synthetic agricultural inputs is advanced but unsustainable (Dent & Anderson, 1971 and Ikerd, 1993). For instance, the green revolution only temporarily increased food production in certain parts of the world as global food security is once again a concern (FAO, 2018). The failure of the green revolution to sustainably provide food and fibre to all mankind, indicates that we failed to design food systems capable of feeding the world continuously (Schiere *et al.*, 2012).

A system entails complex factors that are interconnected, and therefore a conceptual boundary can be established around the system as a limit to its organisational independence (Dent & Anderson, 1971). There are multi-facets to the same problem within a system, though not all are visible and tangible.

The first section of this chapter will focus on the systems approach, what it is, how it emerged and its usefulness in agricultural systems research. Then the methodologies used in systems research with its advantages and disadvantages will be discussed.

3.2. Overview of the agricultural systems approach

In the past, complex problems arising in an agricultural system were solved using an analytical approach. The objective of the analytical approach is to deconstruct complex problems into simpler, smaller components, to be solved individually. Multiple specialised disciplines emerged as a result of complex problems being deconstructed. Universal application of the reductionist analytical approach necessitates linearity and zero interrelationships between components of a system (equilibrium, *ceteris paribus*) (Hirooka, 2010). The reductionist view which is associated with the analytical approach is typically portrayed in the "war against famine" paradigm of the 1900s when "once and for all" solutions were pursued. The "once and for all" predator-prey models that emerged with the ancient Mesopotamian agriculture boom, or the more recent green revolution, have instrumental value for agricultural development, but not a permanent value (Schiere, *et al.*, 2012).

The flaws of the one-sided reductionist approach became apparent when systems continued to display unexpected and unexplainable dynamics (Schiere *et al.*, 2012 and Schiere *et al.*, 2004). The development of computers made it possible for researchers to collect and store information. The widespread availability of information led to greater recognition of the interconnectedness of the deconstructed parts of a system under the reductionist approach. Around 1960 researchers started adopting a systems mentality when investigating agricultural phenomena.

The basic principle of the systems approach is to study the relationships between objects as a whole (Jones *et al.*, 2016). A collection of parts, where the general goal is the production of crops and/or raising livestock to produce food from natural resources, is known as an agricultural system. Agricultural systems science is a multidisciplinary field that studies complex behaviours in agricultural systems. The systems approach allow for agricultural systems to be studied as a whole rather than each discipline focusing on solving the puzzle according to their limited specialty (Jones *et al.*, 2016). For instance, an agricultural economist can actively seek the expertise of agronomists, ecologists, or soil scientists to understand the complex unpredictable changes in yields per hectare, instead of using economic models to explain every problem in the farm environment. Whole systems have qualities and features not existing in some of their essential parts; therefore, one must seek to understand the greater whole in order to understand its parts, and not seek to understand the small parts to explain the whole. The application of systems thinking in agriculture takes on many forms, one of which is that of modelling. Agricultural models are required to understand and forecast the general sensitivity of agricultural production systems to assist agriculturists in making informed decisions (Jones *et al.*, 2016). The next section focuses on modelling and simulation.

3.3. Modelling and simulation

Simulation is a technique that involves setting up a duplicate model of a real system, then performing tests regarding the real system on the duplicate system (Dent & Anderson, 1971). Alternatively, Hardaker *et al.* (2015) defined simulations as an analogue used to study the features of the real systems. The analogue can be in the form of statistical, mathematical and econometric models. Models can be defined as a simple but ideal demonstration of reality based on observations and assumptions (Hirooka, 2010). Simulation and modelling techniques are cost and time-efficient ways to investigate large systems as compared to real-life experiments. For instance, in simulation techniques the external environment can be controlled by exclusively changing the model parameters and exogenous variables, thereby reporting insights that cannot be cost-efficiently captured by real-life experiments (Hoffmann, 2010). There are specific steps involved in the simulation process under the systems approach. These steps are outlined in Figure 3.1 as illustrated in (Strauss, 2005).

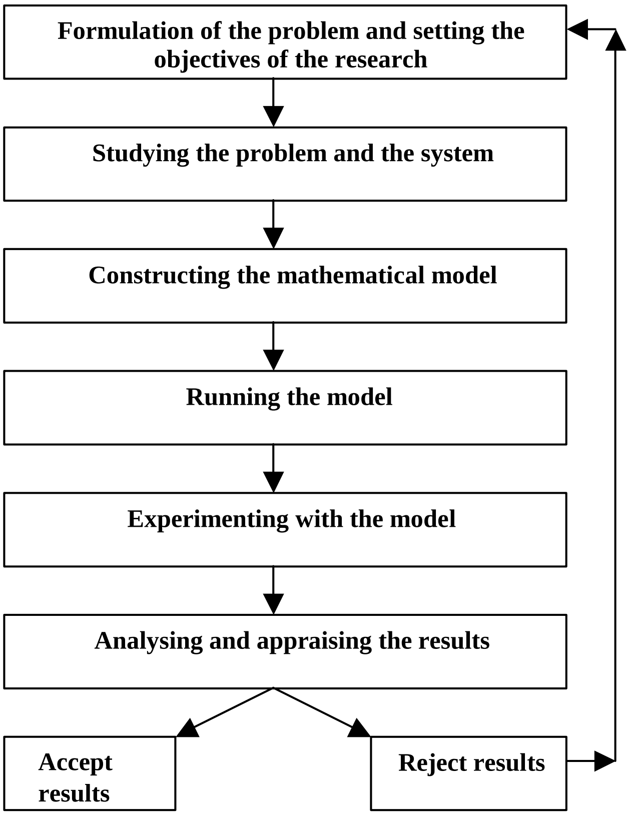

Figure 3.1.The order of implementation of simulating economic problems.

Source: Strauss, 2005

The main drawback of developing a simulation model for an agri-ecosystem is the inability to accurately incorporate human behaviour in the model. Human beings are integral to the operation of agricultural systems; therefore, understanding human behaviour in terms of decision making is critical for modellers (Strauss, 2005). In economics the assumption is made that humans are rational, hence their goal is profit maximisation. The complexity and volatility of the farm environment requires that the farm managers act differently from humans in other disciplines. Farm managers are not wholly rational but distinctly risk-averse (Hardaker *et al.*, 2015). Data deficiencies in the subsystems (biological data) can be amended using mathematical and statistical procedures. However, human behaviour is uniquely uncertain and therefore not modifiable (Strauss, 2015). Multidisciplinary and expert group discussion techniques are useful to help incorporate human behaviour in models, but such techniques also have limits to their usefulness (Hoffmann, 2010).

3.3.1. Stochastic vs deterministic models

The different types of models are stochastic and deterministic. Deterministic models have constant probabilities for different model variables. Therefore, deterministic models can make definite predictions about output variables without probability distributions. Deterministic models are unable to incorporate risk, due to the constant relationships between model variables (Hirooka, 2010 and Strauss, 2005).

Stochastic models on the other hand have random variables, thus contain probability distributions. Unlike deterministic models, stochastic models can incorporate risk by assigning density functions to certain exogenous and endogenous input/output variables (Hirooka, 2010 and Strauss, 2005).

3.3.2. Approaches to modelling

A normative approach looks at what “ought to be”. Generally, normative statements depend on value judgments, which are determined by cultural, social and religious believes. Therefore, the “what ought to be” statements and questions cannot be answered exclusively by facts. Conventional knowledge about the system being modelled is sufficient in constructing normative models and historical data is not necessary. Mathematical programming, input-output analysis and mathematical statistics are examples of normative models (Hoffmann, 2010). Normative models are useful in prescribing solutions, predicting consequences and demonstrating sensitivities within a system. However, normative models are constrained by rigidness and the availability of data, thus stochastic and dynamic elements within systems are not incorporated clearly (Strauss, 2005).

A positive approach looks at “what is”, “what was”, and/or “what will be”. Positive models are descriptive and non-optimising models. The positive models attempt to mimic the real system by describing historically proven interrelationships statistically. Therefore, a positive approach can illustrate how real systems will respond to external factors, caused by decision-makers (Hoffmann, 2010). The realism in positive models implies that a lot of time should be dedicated to thoroughly understanding the real system. This has advantages as well as disadvantages. For instance, positive models are realistic but costly and time-consuming.

Modellers spend a lot of time validating and verifying the model before it can be applied (Strauss, 2005).

The main objective of this project is to evaluate the financial performance of continuous crop rotation systems under full CA principles for the Riversdale area on the whole farm level. A positive approach is well suited in this regard.

3.4. Agricultural systems modelling

The increased need for the systems approach as a method of research to understand interrelationships within the agricultural system drove scientists from multiple disciplines to develop agricultural systems models. The first agricultural system models were built by Earl Heady and his students in 1958 at Iowa State University. The early work of Heady inspired the development of agricultural system models. See Table 3.1 for important events in agricultural systems modelling.

Agricultural systems are developed for two main purposes, decision support and better scientific understanding. Agricultural system models can easily capture complex interactions within the agroecosystem. Scientists across disciplines can validate and compare experiments from laboratories with specific models. The farming environment is complex and extremely volatile. Agricultural system models can also accurately mimic how farm systems might respond to different external shocks (Jones *et al.*, 2016). The information would assist decision makers to make informed, risky decisions. Disciplines within agronomy, soil and environmental sciences use agricultural system models to improve their understanding of the agroecosystem as a whole. Farm managers and agricultural economists, on the other hand, utilise the ability of models to mimic real systems to make better decisions at the farm and policy level. The differing roles that agricultural system models play in specialised fields have led to the development of sophisticated models. However, neither complex financial nor scientific models can be used effectively by politicians or farmers to make better decisions (Schiere *et al.*, 2012).

Table 3.1. Key events in agricultural systems modelling

Time	Event	Effects
1940–1950	Development of nutrition prerequisite guidelines for cattle (NRC, 1945); Van Bavel (1953) and De Wit (1958) develop initial computational analyses of soil and plant processes.	Established a foundation for modelling livestock responses to nutrients and applying simulation and operations research optimization in soil-plant systems research.
1960–1970	Pioneers for soil water balance modelling (WATBAL) [(Slatyer, 1960, 1964, Keig and McAlpine, 1969; Ritchie, 1972 and McCown, 1973)].	Water balance models were useful in the evaluation of climatic restrictions on agricultural development. Established foundations for linking soil-plant models.
1965–70	Early crop modelling pioneers develop photosynthesis and growth models.	Caught imagination of crop and soil scientists. Encouraged many to follow in their footsteps.
1969–75	S-69 Cotton Systems Analysis Project (Bowen et al., 1973; Stapleton et al., 1973; Jones et al., 1974, 1980 and Baker et al., 1983).	Prompted development of several cotton models (W. G. Duncan, J. D. Hesketh, D. Baker, J. Jones and J. McKinion).
1971	Creation of the Biological System Simulation Group (BSSG).	Resulted in self-supported, annual workshops aimed at advancing the cropping system and other biological system models, continuing through 2014.
The 1970s	Gordon Conway develops the concept of IPM in Malaysia. Huffaker Integrated Pest Management (IPM) Project begins in the USA, evolves into the Consortium for IPM, ending in 1985. Universal importance on decreasing pesticide application, due to increases in pesticide application and resistance in principle pest populations.	Insect and disease models established and used to support the formation of economic thresholds and predicting the time of threshold exceedance; some pest models were linked with crop models.
1970/80s	Development of early herd dynamics simulation models (Freer et al., 1970; IADB, 1975; Davis et al., 1976; ILCA, 1978; Sanders and Cartwright, 1979, Konandreas and Anderson, 1982).	Established in developed countries but some early examples in developing countries. Essential toward the progress of whole-farm livestock modelling and for demonstrating disease and reproductive effects.

Source: Jones *et al.*, 2016

The state of agricultural systems is frequently influenced by uncontrollable elements, so the future outcomes of an agricultural system cannot be predicted with certainty. Whole farm budgeting models are used in this project to investigate the profitability of different rotation systems. Budgeting techniques are discussed in the next section.

3.5. Budgeting Models

The budgeting process involves projecting expected revenues and expenditures for a certain period of time. Budgeting is a non-optimising method that can be used to evaluate expected future plans in financial and physical terms (Boehlje & Eidman, 1984). The simplest budgets are based on a two-column income and expense technique, where the difference represents profit or loss. The simplicity of constructing budgets entails budgeting as a financial planning tool is widely adopted among literate and illiterate users (Hoffmann, 2010). Advancements in computer technologies permitted budgeting to be used as a dynamic planning tool. Computer programmes allow modellers with sufficient knowledge about a farm system to mimic real farms with whole farm budgeting. Budgeting can therefore be viewed as a simulation model. Whole farm budgets are constructed using spreadsheet programmes; therefore, complex sophisticated calculations can be accommodated by exclusively using accounting principles. Budgets are typically used for benchmarking and planning purposes. The popularity of budgets among farmers and farm system researchers is due to the ability to permit for great detail, adaptability and user-friendliness (Hoffmann, 2010). Some other advantages of budgeting according to Hoffmann (2010) are:

- Simplicity,
- Adaptability (incorporate multi-period farm budgets to assist in long term planning),
- Budgets can accommodate large input-output variable relationships, the more relationships the better, the accuracy of budgets are only limited by the modeller's knowledge of the system,
- Whole farm budgets can be used to calculate potential returns of farm investments,
- Whole farm budgets are useful tools for comparing and choosing appropriate production plans.

Budgeting methods are often criticised for:

- Lack of optimisation objective (Boehlje & Eidman, 1984),
- Inability to easily deal with large complex problems (Boehlje & Eidman, 1984),
- The modeller should have a thorough knowledge of the system being modelled and,
- Validation and verification of whole farm budgets can often lead to long philosophical debates between experts rather than solving the problem (Hoffmann, 2010).

With reference to the current project, whole farm multi-period budgets are useful to integrate the insights of multidisciplinary experts, in order to better mimic the real farm system.

Furthermore, whole farm budget tools are useful to determine the capital investment required when converting crop-pasture to continuous cash crop production systems in the Riversdale area. The long term financial viability of converting to continuous cropping is indicated by the NPV (net present value) and IRR (internal rate of return) adopted from whole farm multi-period budgets. Whole farm budgets were critical when evaluating how continuous cash crop rotation systems compare financially with traditional systems that include pastures and sheep on a whole farm level in the Riversdale area. Whole farm budgets attempt to solve whole farm problems incompletely, rather than solve parts of the whole farm problem accurately. Budgets are thus repeatedly used as farm decision-making tools, in spite of apparent shortcomings (Hoffmann, 2010).

3.6. Multidisciplinary group discussion techniques

It was established in Section 2.3 that the whole farm system contain qualities not present in some of its essential parts; therefore, one must seek to understand the whole system in order to understand its parts and not vice versa. Multidisciplinary group discussions can accommodate research that is based on the systems approach. Multidisciplinary research is defined as a research method where scientists from different fields, work side by side, contributing expertise from within their specialised fields to solve a collective problem (Young, 1995).

The challenges and problems of everyday life motivate mankind to seek knowledge. Knowledge is divided into three levels, which are lay knowledge, scientific knowledge and metaknowledge. Lay knowledge is knowledge that people gain from day to day experiences through introspection and is a necessity in everyday life. For example, a farmer's conventional wisdom might be regarded as lay knowledge. The second level of knowledge is science, which requires the search for the truth about everyday problems. The development of models and theories that attempt to explain the worldly phenomena is the central objective of science. For instance, Newton's law of gravity was a human inquiry into why apples fall downwards instead of upwards. Metascience is about reflecting on the "nature of scientific enquiry", and is the third level of knowledge (Hoffmann, 2010).

Enquiries about truthful knowledge have led to the formation of discrete but wholly similar disciplines. Agricultural research in South Africa is further deconstructed by commodity experts, for example wheat industry experts, wool industry experts and wine industry experts. Disciplinary or specialised research often results in the break-up of knowledge that might already exist. Multidisciplinary group discussion techniques can bridge knowledge gaps between disciplines (Hoffmann, 2010). Farm oriented research is multifaceted, and use insight from experts across different disciplines. Experts from different fields use different vocabulary and methodological paradigms, which are different from conventional economic paradigms. The advantages of multidisciplinary group discussions are:

- Stimulate creative thinking by introducing divergent new viewpoints (Hoffmann, 2010),
- Easier and cheaper method to understand the whole farm system,
- Higher social value, the research work from most agricultural consultants are used practically but are not published (Young, 1995), and
- Create intellectual synergies.

Getting scientist with different lay knowledge backgrounds on the same agenda and keeping them on the same agenda might be a daunting task for any coordinator of multidisciplinary group discussions. Other challenges of multidisciplinary group discussions according to Hoffmann, (2010) are:

- The influential figure might dictate the opinions of other experts,
- Philosophical battle on model verification and validation might be time-consuming,
- Disciplinary politics, for example, lack of respect for social scientist (agricultural economist) from other scientists (agronomist, crop scientist, plant biologist, etc.) and,
- Disciplinary chauvinism, multidisciplinary researchers use methods and materials from different fields, thus reducing the chances of publishing in traditional disciplinary journals (Young 1995).

Hoffmann (2010) claimed that facilitators of multidisciplinary group discussion can reduce the drawbacks by creating a favourable environment where all experts can participate.

The main objective of this study is to evaluate the financial implications of continuous crop rotation systems under full CA principles for the Riversdale area on the whole farm level. Therefore, participants involved in the group discussions had to be from the Riversdale area. Group discussions were done online via WhatsApp messenger. WhatsApp messenger is a cost and time efficient way for collecting information from stakeholders that often have busy schedules. The main issues discussed during the group discussions were the physical and financial extent of a typical farm for the Riversdale area. The group discussions occurred over 10 days from 7th October until 17th October 2019. The following stakeholders were involved in the group discussions:

- ❖ Dr. Strauss J. Plant scientist at the Department of Agriculture: Western Cape and leader of the crop rotation trial at Riversdale.
- ❖ Dr. Hoffmann W. Agricultural Economist at the Stellenbosch University
- ❖ Blom, P. Agricultural Expert. SSK Riversdale.
- ❖ Bruwer, J. Area manager Bayer Crop Sciences Western Cape.
- ❖ De Wet, N. Agricultural Economist. SSK Riversdale.
- ❖ De Jager, P. Producer. Riversdale.
- ❖ Hendrik, J. Producer. Riversdale.
- ❖ Hopkins, D. Producer Riversdale.

3.7. Typical farm as basis for comparison

According to Carter (1963) and Feuz & Skold (1990) the representative firm or typical farm ideology was first used by Alfred Marshall and F. W Taussig in their respective textbooks on the principles of economics. They saw representative firms, as firms that were stable, with a "fairly long life" and made sufficient economic profit. Taussig and Marshall used the theoretical and conceptual framework of representative firms to explain economic phenomena of price and supply shifts (Feuz & Skold, 1990).

The typical farm concept as an empirical tool for agricultural research and extension was first used by Elliot in 1928. He defined a typical farm as a simulation farm with "frequency distributions" of farms in the same homogenous area. The main difference between a representative farm and a typical farm is that typical farms are free from the effects of outliers, while parameters of representative farms are influenced by outliers. Elliot argued that the complex interplay of socio-economic and biological factors influencing net farm income is numerous. There are no two farms with identical factors that determine net farm profitability. Each farm has unique characteristics; therefore, blanket policy recommendations based on the average farm approach cannot be applicable to all farms in a given homogenous region (Carter, 1963 and Feuz & Skold, 1990).

A typical farm simulation is a hypothetical model that can roughly mimic a real farm in a homogeneous region. The hypothetical farm can serve as an experimental tool. For example, investment decisions or government policy decisions can be tested on the hypothetical farm model before real implementation. If the hypothetical farm model reacts negatively towards investments or state policies, decisions can be taken with greater caution. Furthermore, typical farm research techniques can provide reliable data cheaply, compared to farm surveys (Knott, 2015). The major challenges of adopting a typical farm approach are adequately defining a typical farm for a region and formulating the criteria to classify a typical farm. Typical farm models, complemented by systems research techniques are crucial towards attaining the objectives of the present project.

3.8. Conclusion

This chapter focused on the systems approach, what it is, how it emerged and its usefulness in agricultural systems research. The chapter concluded by discussing methodologies used in systems research with their respective advantages and disadvantages.

The farming environment is uncertain and volatile. The reductionist approach used in the past to solve complex problems is an inappropriate method to fully understand the agroecosystem. In recent decades the systems approach has been increasingly used to study farm-level problems. The whole farm system has qualities not evident in some of its essential parts; therefore, understanding the whole system through a systems approach is important, instead of understanding its parts. Roughly modelling and simulating the real system has been central to the widespread adoption of the systems approach as a research method. Simulation and modelling can be powerful tools in assisting academics and farm managers to understand uncertain synergies within the farm environment. However, the development of sophisticated disciplinary agricultural system models has limited the usefulness of models for decision-makers (farmers and politicians). Simplicity, user-friendliness and the adaptability of whole farm budgeting has increased the use of budgets as financial and physical planning tools among illiterates and literates. Although whole farm budgeting requires a thorough knowledge of systems being modelled by the modeller, multidisciplinary group discussions, supplemented by typical farming research techniques have improved the usefulness of whole farm budgeting when conducting farm-level research.

Chapter 4: Crop rotation systems at gross margin level for the Riversdale trial site

4.1. Introduction

One of the specific objectives of the current project was to investigate the profitability of the six crop rotation systems, under full CA principles at the Riversdale experimental farm on gross margin level. This chapter focuses on achieving this objective and is a key component for the development of whole farm models.

Firstly the chapter provides a detailed introduction to the Riversdale experimental farm. The physical dimension of the site, the crop rotation systems, management of the farm and data collection at the site is discussed. Secondly the financial performance of the six crop rotation systems under full CA principles is examined on the gross margin level. The last part of this chapter argues the limitations of analysing trial data at only the gross margin level. The need for whole farm financial analysis is presented and complemented by the theoretical context of constructing a whole farm multi-period budget model.

4.2. Description of Riversdale experimental trial farm

A key feature of this research project is that the information regarding the functioning of the systems is generated in a scientifically, sound manner. This not only strengthens the validity of the data sets, but also the trustworthiness amongst producers. The various facets of the trial layout and management are briefly discussed.

4.2.1. Description of research trial site

The Riversdale experimental farm investigates the agronomic, scientific and economic performance of six different crop rotation systems under full CA principles. The experimental farm is located in the Southern Cape homogenous production zone approximately 12km outside of Riversdale, in the Western Cape Province (-34° 16′ 35.173″ S, 21° 9′ 7.664″ E; Figure 4.l). The farm on average, receives 350mm rainfall yearly. Precipitation is dispersed equally across winter and summer months. The Riversdale trial began in 2002. Initially the trial involved a crop-pasture rotation system up until 2011. Since 2012 the performance of continuous cash crop systems are investigated. The main objective is to evaluate the short and long-term performance of six of the most promising crop rotation systems identified for the high potential soil of the Riversdale area. The performance measure, *inter alia* crop yields, disease suppression and profitability.

The management of the trial is adjusted to mimic the practical farm environment as closely as possible. To achieve this goal a technical advisory committee has been appointed by the Department of Agriculture Western Cape, Elsenburg. The committee is responsible for management decisions regarding the trial and associated farming practises. The committee meets several times during and before the production season and is responsible for all practical farm-level decisions. These decisions include: seeding rates, fertiliser application rates and spray application rates for herbicides, pesticides and fungicides. For the purposes of this project data from the Riverdale trial farm is used to comprehensively investigate the economic feasibility of continuous cash crop production systems for the Riversdale winter cereal production area in the medium and long term.

Figure 4.1. Represents the location of the Riversdale trial site in the Western Cape Province of South Africa

Source; Google maps, 2019

4.2.2. Description of the six crop rotation systems

The experimental design of the trial includes six crop rotation systems, fully represented each year and replicated three times in a randomized block design (See schematic presentation of experimental layout in Annexure A). The entire experimental farm is operated under full CA principles and crops are planted with a no-till disc planter. The total experimental area of 9ha is divided into 60 camps, each camp covering a size of 0.15ha. Each year wheat is the most used crop on the trial farm, grown on 27 camps, followed by canola and others (barley, lupines, cover crops), which are grown on 15 and 6 camps respectively. The systems that the trials are done on include the following:

- ❖ System 1. Canola – Wheat – Canola – Wheat (2-year repeating system) – 50% small grain, 50 % canola
- ❖ System 2. Legume crop – Wheat – Canola – Wheat (4-year system as control) – 50% small grain, 25 % canola, 25% legume crop
- ❖ System 3. Wheat – Wheat – Oats (3-year grain system) – 100% grain (oats can be used as smother crop/green manure if needed)
- ❖ System 4. Coriander – Wheat – Canola (3-year system with an alternative broadleaf cash crop – 33% grain, 67% broadleaf
- ❖ System 5.Wheat – Barley – Canola (3-year repeating system) – 67% small grain, 33 % canola
- ❖ System 6. Canola – Barley – Legume crop – Wheat – Wheat (5-year system) – 60% small grain, 20% canola, 20% legume crop

4.2.3. Data compilation

The research team monitors, maintains and collects detailed data from the Riversdale trial farm (Strauss, 2019). Data collected from the trial include physical/biological information such as camp number, crop rotation systems, year of cultivation and crop cultivated. Data related to planting activities such as land preparation, input application rates and cost of activities for each camp, year and crop are also accurately captured. Refer to Annexure B for an example of how data is captured for each crop. The trial farm is a mixed farm with pastures for sheep and winter cereal crops. The trials are agronomic of nature and collected data cannot be used for economic purposes in its raw form. The data collected from the trial site is sorted and transformed into financial information up to gross margin level for each camp. Yields, inputs and other economically important data are analysed and reported in annual progress reports. The data used in this research project was obtained from the progress reports between 2013 and 2018 in the gross margin per camp format. The challenge was to integrate the yearly data per camp, to enable the evaluation of each system on its own merit. The system is made up of a specific sequence of crops and for each system there is a 'phase' in the crop rotation system simulated every year. To evaluate the system the camps that form part of each simulated system needs to be pooled together. Then these camps must be integrated over the sequence of years that the trials have been running. This is required to determine the financial performance of each simulated system at gross margin level for six years. Gross margin data for the different camps and systems were integrated into a single excel spreadsheet, see Annexure B.

4.3. Different crops used in crop rotation on the Riversdale trial farm

The Riversdale trial farm is based on CA principles. The benefits of CA were extensively discussed in Chapter 2. Crop rotation as a principle of CA is particularly important to organically control pests and enhance whole farm profitability by improving the stability and resilience of the system. According to Hoffmann (2010), climate, terrain, soils and a lack of a well-established market for alternative crops limits the successful inclusion of crops in a crop rotation system. The Western Cape has a distinctly Mediterranean climate. The combination of these factors inherently restricts the alternative crops available to be successfully incorporated into crop rotation systems. Crops that are included in the crop rotation systems on the Riversdale trial are discussed below.

4.3.1. Wheat

According to Hoffmann (2010), the majority of typical farms in the Western Cape produce wheat. Wheat products such as bread, pasta and confectioneries are staples in South Africa. The Southern Cape and Swartland produces about 87 per cent of the wheat produced in the province and more than half of South African's production. According to De Wet & Liebenberg (2018), after the deregulation of the South African agricultural sector in the 1900s the average profit from wheat production decreased throughout wheat-producing regions in South Africa, except in the Southern Cape. Therefore, it is feasible to actively seek ways to improve wheat yields and profitability, as the distinct Mediterranean climate of the Western Cape is perfectly suitable for wheat cultivation.

4.3.2. Canola

Canola is an oilseed crop that originates from the "*Brassica* family". Canola is suitable as a rotation crop since the extensive root system improves the soil structure, and also improves water infiltration and soil aeration (Knott, 2015). Therefore, canola as a rotation crop causes yield increases for the following crop in the rotation system. A 22 per cent increase can be expected on subsequent wheat yields compared to wheat following wheat (Hoffmann, 2010). Weed infestation is one of the disadvantages of CA production systems since weed, especially ryegrass, tends to build up resistance to herbicides. Canola is a broadleaf crop, thus different chemicals can be applied for grassy weed control during the canola phase compared to the cereal phase. This limits the build-up of the weeds resistance to particular groups of chemicals. Canola has a well-established market in South Africa, with the oil consumed by humans and also used in the animal feed industry. Canola can only be grown every third or fourth year in a rotation system due to the occurrence of black stem disease.

4.3.3. Barley

Barley is the second most important small grain crop in South Africa (DAFF, 2017). It is mainly used in malt production, which is used to brew beer. Only poor-quality barley is used for animal feed because of the well-established beer industry in South Africa. Barley is a winter cereal crop; therefore, it is limited to particular production zones across South Africa (DAFF, 2017). The barley produced in the Southern Cape is particularly sought after by the malting companies due to its unique, intrinsic quality regarding starch and protein content (Strauss, 2019). The Western Cape Province, specifically the Southern Cape production area is the largest producer of barley in South Africa. Barley serves two purposes for farmers, improving the stability and resilience of a farming system (DAFF, 2017).

4.3.4. Lupines

Lupine is a nitrogen-fixing broad-leaf legume crop that has the same impact on subsequent crop yields in rotation as canola (Knott, 2015). Due to the protein content of lupines, it is considered a high quality animal feed.

4.3.5. Cover Crops

A mixture of cover crops is used on the farm, depending on the specific objective determined by the committee in a given season. Oats and pea cover crops have been used interchangeably in the rotation systems. The project leader closely monitor the yields of cash crops following cover crops to determine the precise consequence of cover crops on the yields of a particular cash crop. Wheat planted after pea cover crops indicated higher yields compared to wheat planted after oats (Strauss, 2019).

4.4. The profitability of continuous cash crop production under full CA principles at the Riversdale trial site

4.4.1. Yields

An analysis of yields harvested from the Riversdale trials during the period 2013 to 2018, indicates wheat yields are worst in the rotation systems where wheat is planted consecutively. It shows that yields are the highest in rotation systems where wheat is planted in rotation with other crops. Over the six-year period, wheat yields are the highest (3.18 tons/ha) in the short wheat-canola rotation system and lowest (2.77 tons/ha) in the wheat-wheat-cover crop system. Figure 4.2 indicates average yields of different crops in different rotation systems.

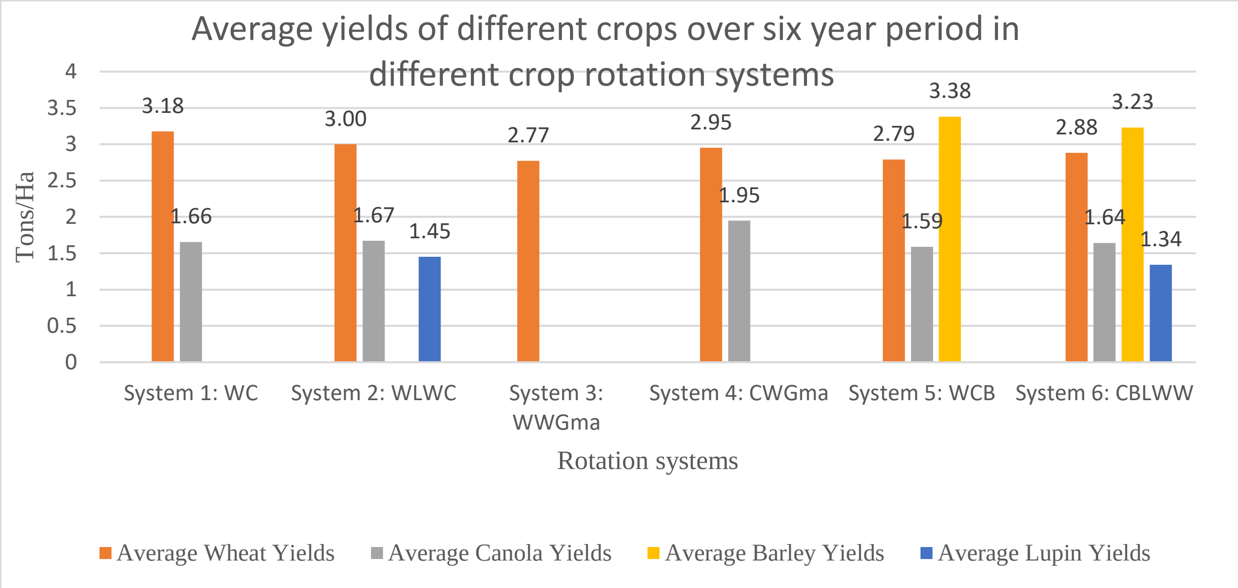

Figure 4.2. Average yields of different crops in different crop rotation systems included in the Riversdale crop rotation trials

The CWGma rotation system shows the highest average canola yields over the six-year period with 1.95tons/ha. This is followed by the WLWC rotation system with canola yield at 1.67tons/ha. The WCB rotation system shows the lowest average canola yields over the six-year period. Due to disease, canola is typically cultivated after every three or four years. Despite this issue, the short WC rotation system averaged higher canola yields than longer rotation systems over six years. Further scrutiny of the canola yield data indicates that canola yields in the short WC rotation system have been decreasing relative to the canola yields in the longer rotation system. Barley yields have averaged above 3 tons/ha in both rotation systems where it is represented. Lupines have performed indifferently on the Riversdale trial, as yields averaged above 2 tons/ha in 2013 and 2016, while yields were below 1 ton/ha in the 2014 and 2015 production seasons. Lupines cultivated during the 2017 and 2018 production seasons had to be destroyed for agronomic reasons. There are also some inconsistencies with seed supply regarding quality and consistency.

4.4.2. Gross margin analysis of Riversdale trial data from 2013-2018

Figure 4.3 presents the average gross margin and variable cost of the six crop rotation systems under full CA principles at the Riversdale trial farm from 2013-2018. The rotation system with the highest average gross margin per ha across the six years from 2013 to 2018 is the wheat-barley-canola rotation system with R5152/ha. This system is closely followed by the wheat-canola short rotation system with a gross margin of R5089/ha. Over the six-year period Systems Three and Four, where cover crops are present, had the lowest average gross margins with R2647/ha and R3153/ha. Wheat following wheat (see Figure 4.2) in rotation produces lower yields, thus System Three returns the lowest gross margin. Only 66 per cent of both systems produce a marketable crop. That means that 33 per cent of the land area under this crop rotation system represents a crop that does not yield revenue. No producer is likely to follow these two systems. Farmers will only follow System Three and Four if the returns from the subsequent crops can offset the losses from the cover crops. However, a conclusion on the feasibility of the cover crops can only be determined at the end of the trial when there is sufficient data. The potential benefit of cover crops would only show over the long run.

Over the six-year period System Three and Four return the lowest average variable cost with R2863/ha and R3058/ha respectively. According to the literature discussed in Chapter 2, cover crops are used in rotation systems because of the agronomic benefits. These benefits accrue on the subsequent crop in a rotation system which diminishes the required fertiliser application over the long run. The short two-year wheat-canola rotation system shows the highest allocatable variable cost over the six-year period. The reason for this is that the canola year in the rotation system, is used as a weed control year, whereby expensive chemicals are sprayed to remove grass weeds.

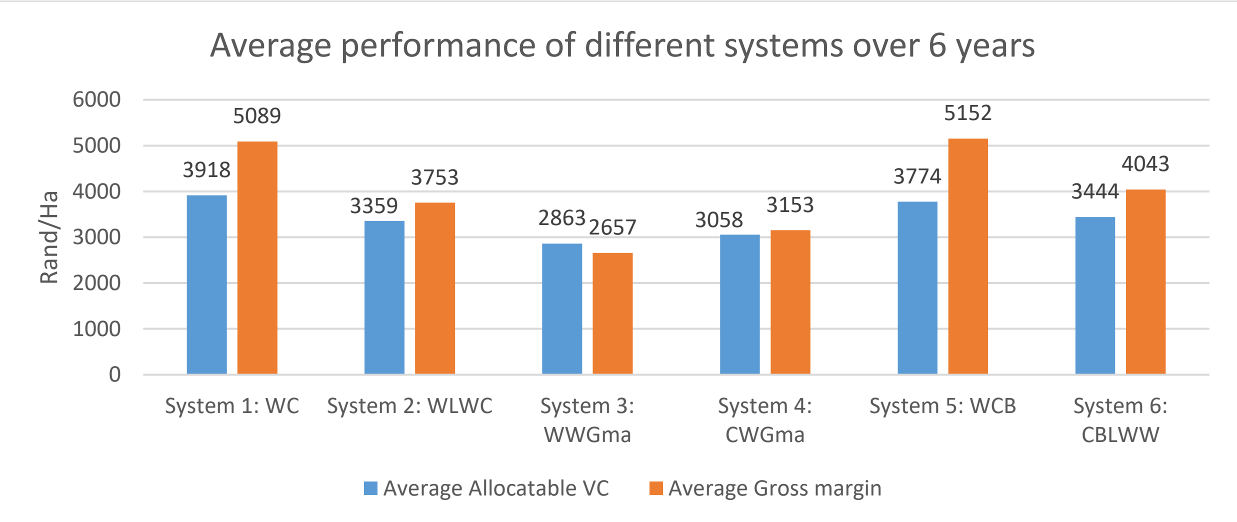

Figure 4.3. Average GM and AVC across different crop rotation systems in the Riversdale crop rotation trials

Barley proves to be a significant cash crop used in rotation with other winter cereals in the Western Cape Province. Over the six-year period, from 2013 to 2018 at the Riversdale trial site, barley production showed the highest average gross margin with R6382.53/ha. This is followed by wheat and canola production with R5185.53/ha and R4404.56/ha respectively.

The demand for barley is mainly driven by the beer brewing market, which is an established industry in South Africa. It is important to note that barley cultivated at the Riversdale trial site is of high quality and produced for malting purposes. Poor quality barley has to be sold to the livestock feed market and might produce volatile gross margins per hectare. The camps at the trial site are relatively small, thus quality barley for malting purposes can be produced with certainty. In practise, producing barley of sufficient quality on 500 hectares of land for malting purposes, with certainty, might be more challenging. The risk might be too high when considering the contrasting prices of barley for malting and barley for livestock feed. Livestock feed prices will be based on alternative sources of starch such as oats and maize.

4.4.3. Average wheat yields following different crops in rotation

Figure 4.4 illustrates the average yield range of wheat following different crops over the six-year period from 2013 to 2018, at the Riversdale trial site. Over the six-year period under investigation average wheat yields have been the highest when wheat is planted after lupines with 3.16ton/ha. This is followed by wheat planted after a cover crop with 3.06ton/ha. Lupines are a high nitrogen-fixing broad-leaf legume crop that increases the yields of the subsequent crop. This is illustrated by the excellent wheat yields following lupines at the Riversdale trial site. The relatively high wheat yields after a cover crop cannot be attributed to a specific cover crop in this analysis. Data was aggregated and cover crops were used interchangeably over the six-year period at the trial site. Wheat planted after wheat, indicated the poorest yields on average over the six-year period which is consistent with previous findings (Hoffmann, 2001 and Knott, 2015).

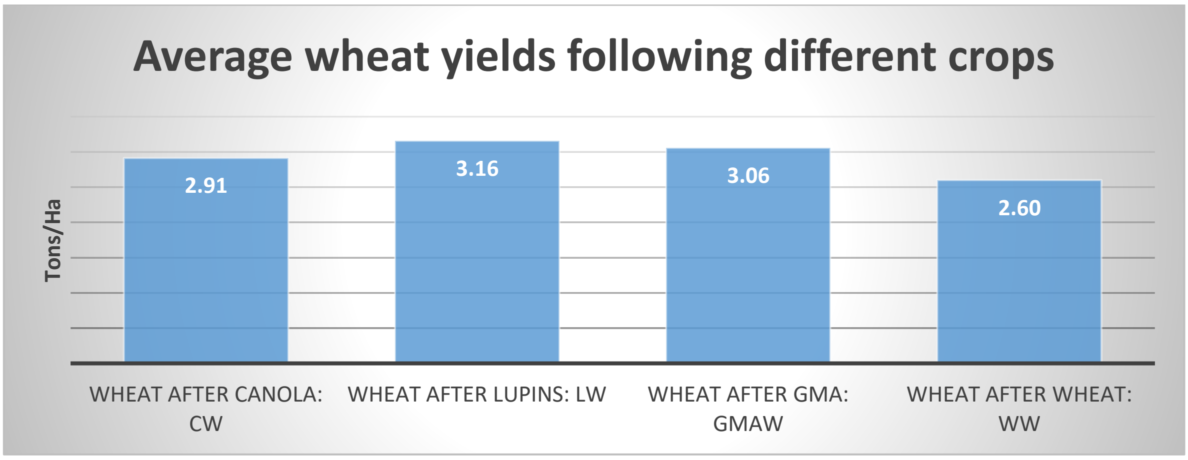

Figure 4.4. Average wheat yields after specific different crops as obtained from the Riversdale crop rotation trials (2013 – 2018)

Wheat planted after lupines indicated the highest gross margins per hectare and the lowest allocatable variable cost per hectare on average, with R 6128/Ha and R 3579/ha respectively. See Annexure F for more detail regarding the average GM and AVC performance of wheat following the different crops over six years.

The conclusions drawn from the gross margin analysis of trial data is of limited use to farmers, as the experiments are carried out on a small scale over a restricted time. Farm setbacks and/or gains on a larger farm would result in greater losses and/or rewards compared to what might be portrayed by gross margin per ha data. For instance, the adverse impact of factors such as drought on the cash flow of farmers cannot be deduced from gross margin analysis. Fixed cost is a major component of farm profitability and it is excluded in the gross margin analysis. This is because the gross margin is silent on capital requirements and fixed costs structures required to support the specific income and production cost structure. The gross margins might be positive while net margins are negative, which would avert the sustainability of the farm business. Therefore, the whole farm analysis is compelled by the limited usefulness of gross margin analysis due to the arguments above. The subsequent section concentrates on the theoretical aspects of constructing a whole farm budget model using excel spreadsheet programmes.

4.5. Construction of the Whole Farm Budget Model

The key research question for the current project refers to how continuous cash crop production systems for the Riversdale area compare financially to the traditional crop-pasture systems. In order to answer the question multiple whole farm budget models were constructed for the Riversdale area. The models were constructed to simulate the typical farm under continuous cash crop rotation systems and a crop-pasture budget.

The financial position of a typical farm can be determined by different interconnected factors. Factors within the internal environment can be managed to a certain extent, but factors in the external or macro-environment are beyond the control of farmers. For instance, crop yield, input and output prices are key determinants of farm profitability but are beyond the control of farmers. The potential impact of these interconnected variables was determined by the construction of whole farm multi-period budgets for the Riversdale winter cereal production area. The whole farm budgets facilitate the incorporation of many variables. This permits a modeller to capture and gain insight into the interrelatedness of factors that influence farm profitability. The "guide to machinery costs" according to Overberg Agri was a point of departure and the initial physical dimensions of the typical farm were based on existing assumptions (Hoffmann, 2010). Machinery costs applicable to the Western Cape are more accurately reflected by the model developed by Kaap Agri, Overberg Agri and SSK. This is compared to the *Guide to machinery cost*, released by the National Department of Agriculture Forestry and Fisheries (DAFF). The models are based on standard accounting principles and include a standardised format of calculating income, cost and margin concepts. This is applied in a range of interconnected data sets and calculations in different excel spreadsheets. The spreadsheet programme permits numerous alterations to the whole farm budget models. Alterations can be done in terms of farm size, inventory replacement periods, input and output prices, different production systems and structural farm parameters. Excel spreadsheet programmes have functions that allow a modeller to include a wide range of interrelated variables. Whole farm budgeting requires and challenges the modeller to have a thorough knowledge of the system being modelled. The model in a excel spreadsheet programme is only constrained by the expertise and knowledge of the modeller. Whole farm budget models have three components that follow in a certain practical order. These components are: the input component, the calculation component and the output component. In the next section each component and key variables within the different components will be discussed.

4.5.1. Input component

The input component consists of the physical description of the farm, crop rotation systems and assumptions about yields, land utilization patterns and output/input prices. The variables in the input component can be altered and manipulated according to the needs of the user. Alterations in the input component variables will cause immediate changes in the output component.

4.5.1.1. Physical description of the typical farm

The main objective of a typical farm approach in this project is to simulate a farm in the Riversdale area with physical parameters to which farmers can relate. Physical parameters of a typical farm for the Southern Cape production area were reported by Hoffmann (2010). These parameters served as point of departure upon which the initial description of a typical farm for the Riversdale area was based. These physical dimensions of the typical farm for the Riversdale area necessitated validation because of out-datedness. Hoffmann’s model was not based on the Riversdale area but on the Heidelberg Vlakte. Although these are neighbouring areas, deviations often occur, which was indeed found. Typical farm parameters were presented to a multidisciplinary discussion, where final parameters of a typical farm for the Riversdale area were decided upon through consensus. Parameters included farm size, land ownership structures, land utilization patterns, livestock carrying capacity and livestock replacement policies.

4.5.1.2. Farm physical dimensions

The total farm size is a key assumption within the whole farm model because total farm size determines numerous other factors such as the number of livestock, number of permanent employees, mechanical requirements and fixed cost. For example, a larger farm will have more labourers and mechanical assets as opposed to a smaller farm. Land use indicates the percentage of area of the total farm that is not suitable for cultivation. These areas are due to poor soil (sandy or brackish), steep gradients, riverbeds, roads, housing or protected areas. These areas affect profitability in that it forms part of land and its capital requirement, but do not contribute to the productive area. It thus contributes only to investment requirement but not income generation. Another important factor influencing farm profitability is land ownership. The whole farm budget is parameterised to be able to include owned land in various combinations with rented land. Rented land impacts the factor cost component in the model. The own-borrowed capital ratio would have an impact on the expected profitability of the farm business.

Land utilization limits the total hectares allocated to each crop/pasture. Functions were integrated into the models to instantly adapt the number of hectares allocated to each product as required by crop rotation systems.

4.5.1.3. Financial description of the farm

The physical extent of a typical farm for Riversdale is expressed in financial terms and is presented in the format of an asset register. The total of the land values in the asset register is the investment required to acquire the farm assets. The inventory contains all values for assets, such as land, fixed improvements, machinery and livestock. Sizes and numbers of assets in the whole farm budget model are determined by the size of the farm. The assumptions about the dependency of livestock numbers and movable assets on land were determined by field capacities of engines and the sheep carrying capacity of pastures. Participants of the multidisciplinary group discussion verified and agreed upon the assumptions. The multidisciplinary group also distinguished between the difference in requirements between continuous cash crop and crop-pasture production systems regarding movable assets.

4.5.1.4. Data on input and output prices

The model extracts data from a data table containing a list of input and output prices and typical application rates for all inputs. The data table forms the basis from which calculations within enterprise budgets are done. Sales units of products, unit prices and typical yields per hectare are translated into values per hectare in enterprise budgets. Spreadsheet functions in excel can easily be used to adapt the table according to the objective of the user.

Input cost (quantities and prices) and output prices for the continuous cash crop systems simulated in the model, were directly obtained from trial data at the Riversdale farm. Refer to Section 4.3.3 and Annexure B regarding procedures of data capturing at the trial farm. The inputs and costs associated with expanding pasture for livestock were adopted from the Tygerhoek trial farm. In principle this was suggested and verified by participants of the multidisciplinary group discussion. Three years (2015-2017) average input and output prices for each crop were used as a proxy throughout the model. The three-year average method was taken as the norm for crops represented in both crop-pasture and continuous cropping budget models.

4.5.2. Calculation component

The calculation component includes a sequence of interconnected equations. The calculation component is the key element that links the input component to the output component. Assumptions made about the parameters of a typical farm for the Riversdale area are integrated with standard accounting principles through a sequence of excel functions to determine enterprise budgets for different farm products.

4.5.2.1. Farm inventory

The main objective of the inventory is to calculate the capital requirements for the whole farm. Capital requirements to enable successful farming are the sum of the groups of assets in the inventory. Typical capital items for a farm to operate successfully include land, fixed improvements, movable assets and livestock. Land is the largest contributor to capital requirements. In capital budgeting current assets such as cash, inputs, fuel and debtors are included as inputs as these items are by definition consumed in the normal production process. The key question for the current project is how the identified continuous cash crop production systems compare financially with the traditional crop pasture systems for the Riversdale area. The two systems require somewhat different movable capital items, therefore the sum of the inventories registered for continuous cropping compared to crop-pasture systems would differ. The investment requirements influence the profitability of both systems which is shown in the output component. The participants of the multidisciplinary group discussion agreed on the inventories for both continuous cropping and crop-pasture production systems.

Prices of farm equipment and implements were acquired from the Western Cape *Guide to machinery cost*. The size, current value and list of inventories required for a typical farm in the Riverdale area were suggested by the participants of the multidisciplinary discussion. Machinery is replaced every 12 years, provided that the annual usage of machines is a 1000 hours according to the *'Guide to machinery cost'*. Producers in the Western Cape typically replace machinery every 15 years because farm machinery is used for about 350 hours per year and farmers are often constrained by cash flow problems.

Livestock investment requirements are based on the herd composition and grazing capacity. The models are constructed to automatically calculate herd size using the carrying capacity and land allocated for pasture. Assumptions are made about the ram-ewe ratios and the ewe replacement norms, which determine herd composition. These assumptions and values of livestock were adopted from previous studies. Values and assumptions were updated and validated during the multidisciplinary group discussion. See Annexure C for asset registers.

4.5.2.2. Calculation of gross profit

Multiple whole farm budget models were constructed in a spreadsheet programme, a simulated farm with a crop-pasture system and simulations with continuous cash crop systems. The continuous cash crop system budget model is based on the six crop rotation systems that are investigated at the Riversdale trial farm. The traditional crop-pasture system is used in the Riversdale area and serves as the *status quo* system. Refer to Section 4.3.2 regarding the details of the crop rotation systems.

For each production system, a set of enterprise budgets was constructed for all crops represented in the rotation systems. The data tables mentioned in Section 4.5.1.4 includes the appropriate prices which are incorporated in the enterprise budgets. Input details for each camp within each system are captured in the enterprise budgets. Only the total values for each input component were incorporated in the whole farm models. For instance, in the enterprise budgets the input cost of fertilisers, seeds and chemicals are separated, and is detailed to individual products. Only the total allocatable variable cost in the enterprise budget is drawn into the whole farm model. This means that even if the details of the production costs are not in the whole farm model, it is still directly linked to the enterprise budgets, which is the direct result of the trials.

When considering a longer term production cycle, provision for yield risk is relatively important. This is also a key consideration in the cereal system design, as it is generally believed that high yield years offer real profitability benefits to the cereal producer. Livestock is seen as a more stable income generator and is believed to buffer the effect of a low rainfall and subsequently low yield years for cash crops. Three separate budgets were constructed for each crop. These budgets each pertained a year with good, average and poor yields. The rainfall in the Western Cape is relatively unpredictable. This is inherent to Mediterranean climate zones with no identifiable rainfall patterns. The most certain part is the prevalence of good, average or poor years in a 20 year period, although the sequence is completely unpredictable. This was confirmed by meteorologists that research the weather in the Western Cape. The participants of the multidisciplinary group discussions gave advice on the prevalence of good, poor or average years in a ten-year period. A good year is when rainfall is sufficient in quantity and falls exactly at the right time for plant growth. The opposite is true for a poor year and an average year would entail sufficient total annual rainfall, but poor dispersion over the growing season (Hoffmann, 2010). In the 20-year multi-period budget, it is indicated whether a specific year is good, poor or average. The model would select the gross margin for the whole farm budget based on the type of year. This gross margin is then multiplied with the hectares under that specific crop. It was achieved through the inclusion of a series of ‘If-statements’.

The sequence of good, poor or average years over the next 20 years is completely unpredictable. Any sequence with the indicated number of good, poor and average years are all equal possibilities. Therefore, trial data from the Riversdale trial site was combined with insights gained from participants of the multidisciplinary discussion group to determine the sequence. The sequence was kept constant in all multi-period budget models throughout the entire analysis.

4.5.2.3. Overhead and fixed cost

Fixed cost refers to the cost that does not vary with scale or intensity for production over the short run. Overhead and fixed cost in the initial model presented to the multidisciplinary group for discussion was obtained from study group results in the area. These were validated and updated and the final values of overhead and fixed cost included in the whole farm multi-period budgets. Fixed cost generally include: insurance, salaries of permanent labourers, maintenance, electricity and other transaction cost associated with the farm business.

4.5.3. Output component

The output component of the models expresses whole farm profitability in terms of the IRR (internal rate of return on invested capital) and NPV (Net present value). The output component also incorporates multi-period cash flow budgets that determine the sensitivity of farm cash flow to different rotation systems.

4.5.3.1. Profitability

The whole farm budget models are based on 20 year planning periods. The 20 year period is suitable to capture the nature of extended rotation systems and to permit replacement of farm inventory. It is important to note that the 20 year period is completely random and does not pertain to any specific period in the total "life" of a typical farm for the Riversdale area. The 20 year period allows for full evaluation of alternative crop rotation systems, replacement schedules and yield sequences due to rainfall dispersion when evaluating the profitability of different production systems. The calculations used in the models are based on three years (2015, 2016 and 2017) of average prices for most inputs and outputs.

A central objective of the multi-period whole farm models used in the present project is to determine the current financial performance of a typical farm in the Riversdale production area. It is also to observe the financial impact of various risky input and/or output factors on the profitability of the farm. Real interest rates are used in the models to calculate the profitability and cash flow of the farm. Nominal interest rates are converted to real interest rates through the following formula; Real interest rate = {[(1+nominal interest rate) / (1+inflation rate)]-1}*100. The models are therefore based on constant prices instead of nominal prices. Constant prices were used to curb the potential impact of inflation on the profitability and cash flow calculations throughout the 20 year planning period. The aim is to evaluate the various systems.

The total gross margin for each crop within the whole farm budget models were calculated by multiplying gross margin (according to good, poor and average yields) per hectare with total hectares allocated to a specific crop. The hectares per crop were determined by farm size, land use and the system being simulated. A series of excel functions combined with information on crop rotation systems were used to determine the total area allocated to a specific crop. The summations of all gross margins for each product serve as the whole farm gross margin. Overhead and fixed costs in the multi-period models remain constant over the 20 year planning period. These costs were determined through consensus during the multidisciplinary discussions. The physical description of a typical farm for the Riversdale winter cereal production area, combined with the asset register of such a farm, is used to calculate the capital expenditure. Replacing farm inventory depends on the expected lifespan and current age of specific items. The Western Cape *Guide to machinery cost* was used to determine depreciation and salvage values of farm equipment.

The multi-period cash flow budget used in the models, basically calculates the annual net flow of funds. The net flow of funds equals gross profit minus fixed and overhead cost and capital expenditure. The profitability of a typical farm for the Riversdale area is measured based on the IRR and NPV. IRR and NPV were calculated from the yearly net flow of funds for the farm over 20 years. IRR measures the return on capital investment, therefore IRR should be greater or equal to the cost of an investment expressed as a percentage. The NPV measures the present value of all anticipated future farm cash flows. The NPV and IRR both attempt to establish whether an investment would add value to the farm business. Therefore, if the IRR is smaller than the real interest rate, the NPV is expected to be negative. IRR and NPV are ideal profitability measures when comparing two different projects which started off at different times and required different capital outlays. See Annexure E for the multi-period budget models for each of the different production systems.

4.5.3.2. Cash flow

The multi-period cash flow budgets are used to determine the affordability of the investment. Yearly cash flow analysis is used to establish the impact of different rotation systems on the cash flow of the farm. Cash flow budgets incorporate cash payments exclusively and can therefore show the potential effect and magnitude of interest payments or receipts on the closing bank balance of the farm. The breakeven year and years with positive or negative cash flows are calculated in the cash flow budget. Affordability of borrowed capital and the ability of the farm's bank balance to replace machinery are observable in the multi-period cash flow budgets.

4.6. Conclusion

The first part of this chapter described the Riversdale experimental farm in detail. Physical information about the site, the crop rotation systems, management of the farm and data collection at the site is presented. The rest of the chapter focused on the method of analysing trial data on gross margin level and the usefulness of gross margin analysis for farmers.

At the Riversdale experimental trial farm the agronomic, scientific and economic performance of six different crop rotation systems under full CA principles are investigated. The main cash crops cultivated at the trial farm are wheat, canola, barley and lupines. The management of the trial is adjusted to mimic the practical farm environment as closely as possible. To achieve this goal a technical team was compiled by the Department of Agriculture Western Cape, Elsenburg. Data is collected and sorted by the main researcher.

Analysis of the six crop rotation systems under full CA principles at the Riversdale trial farm indicates that the WBC rotation system has the highest average gross margin over a period of six years. The short wheat-canola rotation system has performed excellent with an average gross margin of more than R5000/ha. This is despite the disease challenges faced during the canola phase. The system with the cover crops had the lowest average allocatable variable cost. The short WC rotation system indicated the highest average allocatable variable cost over six years.

Conclusions drawn from the gross margin analysis of trial data is limited in its usefulness to farmers because the experiments are carried out on a small scale and over a restricted timespan. A need for whole farm analysis arises. A typical whole-farm model specifically multi-period budgets were discussed extensively as potential tools to carry out whole farm analysis of the continuous cash crop rotation systems under full CA principles on the Riverdale trial farm. Industry experts and farmers in the Riversdale area were engaged to validate the parameters of a typical farm to be used in the whole farm models. A whole farm model makes use of standard accounting principles to mimic the interconnectedness of factors that influences farm profitability.

Chapter 5: The financial analysis of different crop rotation systems at the whole farm level for the Riversdale winter cereal production district

5.1. Introduction

Typical farm information is not a direct guiding tool for farm managers, but once the typical farm information is converted to a whole farm model, alternative internal farm management decisions can be evaluated and compared (Hoffmann, 2010).

The last part of Chapter 4 focused on describing the theoretical framework for constructing a whole farm budget model. This chapter concentrates on describing the whole farm model with the inclusion of values as pertained in the final models. Chapter 5 starts with the description of the validated assumptions regarding a typical farm for the Riversdale area. This is followed by discussions on the investment requirements, product variable cost and whole farm gross margin. The final section of Chapter 5 investigates the profitability of the different crop rotation systems conducted at the Riversdale trial on the whole farm level in terms of the IRR and NPV. This is concluded with an assessment of the effect of changes to certain key parameters with the support of different scenarios.

It is important to note that the two crop rotation systems that include cover crops were part of the gross margin analysis of the Riversdale trial data presented in Section 4.4, but excluded from the whole farm analysis in this chapter. In the trial the crop rotation systems that include cover crops would require farmers to plant half the farm under cover crops that yield no cash returns, which is not practical.

5.2. Assumptions regarding the physical farm description

The context and structure of the main components that the whole farm model consists of were discussed thoroughly in Section 4.5. The participants of the multidisciplinary discussion agreed on a typical farm size of 1400 ha for the Riversdale area. Only 56 per cent of the land is arable. The remaining 44 per cent of the land include roads, wet areas, riverbeds, sandy soils that are too marginal for profitable production, livestock handling facilities and buildings. Section 4.5.1 shows the total cultivated area and crop rotation system that determines the area on which each crop is planted yearly. To simplify the modelling exercise, it was assumed that the typical farm for the Riversdale area could be divided into camps of equal size. This assumption is necessary to simulate the crop rotation system practised within the crop rotation trials. For instance, when the crop-pasture production system was modelled half the arable land would automatically be allocated to pasture. The remaining half is divided equally among the other crops (wheat, barley and canola) represented in the system. It is important to note that these assumptions are for comparison purposes and in reality, farmers might not allocate land equally among crops. Table 5.1 provides validated details of the assumptions concerning a typical farm for the Riversdale area.

Table 5.1 Typical farm description for the Riversdale winter cereal production area

Homogeneous Area	**Riversdale**
Typical farm size (ha)	1400
% Arable Land	56%
Ha Arable Land	718
Ratio pasture : crop	50%
Animal	Dual Purpose Delhi Merino sheep
Land Price R/ha	27790

Other important parameters that influence the profitability of the typical farm in the Riversdale plains include lambing rates, slaughter weight and age of ewes and lambs, ewe replacement policies and kilograms wool sheared per sheep. Lambing percentage was assumed to be 180 per cent and the replacement of ewes assumed to be 20 per cent. Slaughter weight for ewe and lambs was assumed to be 55kg and 23kg respectively. Wool sheared was assumed to be about 4.5kg per ewe, 5.5kg per ram and 3.4kg per weaner. These values were multiplied with the ewe (2.5), ram (0.13) and weaner (3.825) carrying capacities per hectare to determine expected wool yield per hectare in kilograms.

The climate conditions in the Western Cape are unpredictable. The multi-period budget models were modelled over a 20 year period. The rainfall dispersion over time greatly influences the expected profitability and cash flow of the farm. The multidisciplinary group agreed on the rainfall prevalence norm expected over a 10 year period. The group allocated typical yields for each crop according to good, average and poor years, see Table 5.2. The participants pointed out that the sequence of good, average or poor years cannot be predicted with certainty. Refer to Section 4.5.2.2 for a discussion on good, average and poor years and what it entails in the budget models. Table 5.2 represents the frequencies and typical yields associated with each crop represented in a crop rotation system.

Table 5.2. Validated expected yields and associated prevalence of good, average and poor yield years for wheat, barley, canola and lupines for the Riversdale area

	Wheat		Barley		Canola		Lupines	
	Yield (ton/ha)	Across 10years	Yield (ton/ha)	Across 10years	Yield (ton/ha)	Across 10years	Yield (ton/ha)	Across 10years
Good	3.5	4	3.3	4	1.6	3	1.5	3
Average	2.9	5	2.7	5	1.3	4	1.2	4
Poor	2.3	1	2.1	1	1.0	3	0.8	3

5.3. Farm inventory

The farm inventory represents the capital investment requirement for a typical farm in the Riversdale plains. The total value of the inventory is basically the investment requirement as discussed in Section 4.5.2.1. Participants of the multidisciplinary group agreed on the land price for farmland in the Riversdale plains to be R27 790 per hectare. The assumed stocking rate and ewe to ram ratio is 2.5 ewes per hectare and 20 ewes: 1 ram respectively. The key question of the study is how continuous cash cropping under full CA principles for the Riversdale area compares financially with traditional crop-pasture systems at the whole farm level. The sizes of mechanical equipment requirement in a crop pasture and continuous crop rotation system are different. In continuous cash crop systems under full CA principles farm machinery with bigger engine sizes are required compared to crop-pasture production systems. The farm inventory subsequently strongly influences the profitability and cash flow of a particular rotation system. The participants of the multidisciplinary discussion decided on a typical inventory list for a continuous crop production system under full CA principles and a crop pasture production system. The capital requirement for a typical farm in the Riversdale area under continuous cash crop production and full CA principles, is about R18 466 150. A typical farm under a crop-pasture rotation system has an investment requirement in machinery of approximately R11 015 150. Refer to Annexure C for a detailed list of farm machinery and equipment differences between a continuous cash cropping and crop pasture production system.

5.4. Gross production value

The gross production value in this regard refers to the number of hectares allocated to a product/crop multiplied by the yield, multiplied by the price of that product/crop per hectare. In other words, the cross production value is the revenue associated with a product before any cost is subtracted. The summation of all the individual gross production values for each enterprise is equal to the gross production value of the whole farm. Table 5.3 represents the three-year average product prices as incorporated in the whole farm budget models.

Table 5.3. Product prices for crops and livestock products (average: 2015-2017)

Product	Unit	Price per unit (R)
Wheat	Ton	R 3 265
Barley	Ton	R 3 520
Canola	Ton	R 5 386
Lupines	Ton	R 2 283
Meat (lamb)	Kg	R 62,61
Meat (ewes)	Kg	R 43,88
Wool	Kg	R 81,33

Source; Strauss, 2019

❖ Average wheat prices across different quality measures B2, B3 and B4. Wheat at the Riversdale trial predominantly graded B2, B3 and B4 over six years.

A series of "DSUM" excel functions combined with crop rotation systems were used to determine the total area allocated to a specific product. The probable crop yields are presented in Table 5.2 and were validated by the participants of the multidisciplinary discussion. Table 5.4 shows the whole farm gross production values per rotation system for a typical farm in the Riversdale plains according to associated yields as represented in Table 5.2.

Table 5.4. Gross production value per rotation system for a typical farm in the Riversdale plains for good, average and poor years as determined by rainfall

Rotation System	Total income for the whole farm and per hectare					
	Good Year		Average Year		Poor Year	
	R/farm	R/ha	R/farm	R/ha	R/farm	R/ha
WC	7857470	5612	6456188	4612	5054905	3611
WLWC	6839825	4886	5620960	4015	4357341	3112
WBC	8273674	5910	6787602	4848	5301530	3787
CBLWW	7293076	5209	5986854	4276	4644829	3318
LLLLLWBC	7612914	5438	6847941	4891	6082969	4345

Source; Own calculations

5.5. Variable Cost

Variable cost is defined as a cost that varies with production scale or intensity. On a farm, variable cost would be determined by the hectares planted to a specific product. Variable cost generally includes items such as fertilisers, chemicals, contract work, transport, insurance, seed and other consumables. Input cost prices used in the continuous cash crop model were obtained from trial data captured at the Riversdale farm. Section 4.3.3 and Annexure B describe the scientific and systematic process of data captured at the trial farm. The inputs and costs associated with growing pasture for livestock were adopted from trial data captured at the Tygerhoek Experimental Farm. These costs were validated by the participants of the multidisciplinary group discussion. Only the total values for each cost item were incorporated in the whole farm models. In the trials, fertilizer cost would be a function of the sum of each type of fertiliser, e.g. LAN or UREA, times the application rate times the price. Instead of including the input cost of fertilisers, seeds and chemicals, only the total allocated variable cost from the enterprise budgets was captured from the relevant data into the whole farm model. These totals were directly obtained from the experimental data and thus served as the basis for the budgets. Table 5.5 represents the average total variable cost over three years (2015-2017) for each crop represented in different rotation systems at the Riversdale trial site.

Table 5.5. The variable cost of products represented in crop rotations of the Riversdale crop rotation trials

Crop	Total yearly variable cost per ha (R/ha)
Wheat	R 3 947
Barley	R4 001
Canola	R4 581
Lupines	R2 135
Cover crops	R1 435
Pastures	R4 000

- Marketing cost such as storage cost and transportation differential cost are also captured in the Riversdale trial data.

5.6. Gross margin

Total farm gross margin refers to total farm revenue minus cost of producing the farm products, in other words the variable cost. The gross margin of each crop is a function of yields (good, average, poor) per hectare and the price of products, minus variable cost per hectare. Total hectares allocated to each crop as determined by the rotation system and farm cultivated area is multiplied with applicable gross margins of specific crops and added to return whole farm gross margin. Annexure D serves as example of the gross margin calculations for barley with good, average and poor yields as determined by rainfall and rainfall dispersion. Table 5.6 shows whole farm gross margins for the alternative rotation systems evaluated in the crop rotation trials at the Riversdale experimental farm.

Table 5.6. Total whole farm gross margin per system for a typical farm in the Riversdale plains for good, average and poor years as determined by rainfall and rainfall dispersion

Rotation System	Gross margins for the whole farm and per hectare					
	Good Year		Average Year		Poor Year	
	R/farm	R/ha	R/farm	R/ha	R/farm	R/ha
WC	5913027	4224	4317273	3084	2721520	1944
WLWC	4675530	3340	3359429	2400	1998575	1428
WBC	5929122	4235	4313402	3081	2697683	1927
CBLWW	4932686	3523	3548675	2535	2128862	1521
LLLLLWBC	4717629	3370	3913763	2796	3109896	2221

Source; Own calculations

5.7. Fixed & Overhead cost

Fixed cost refers to the cost that does not alter with the scale or intensity of production. The typical fixed cost on a farm would include, insurance cost for permanent improvements (fences, buildings) salaries of permanent workers, licenses, water levies, consultancy fees, banking cost, maintenance cost on fixed improvements and vehicles for general farm use, communication cost and administration cost. Farms rarely share identical fixed costs, however farmers that participated in the multidisciplinary discussion agreed on the total annual fixed cost for a typical farm in the Riversdale area. The fixed and overhead cost was assumed to be the same for all rotation systems however, trivial differences might be possible in reality due to varying perceptions of different farmers. Unforeseen expenses were also accounted for in the model, calculated at four percent of the agreed total fixed cost of R1 211 949. Over the 20 year planning period, the fixed cost was assumed to remain constant.

5.8. Profitability

Making profit is the main objective of any business. In farming sustained profitability is the aim and challenge of all farm managers. A whole farm multi-period capital budget was used to calculate the expected profitability, expressed in IRR and NPV of a typical farm in the Riversdale area. Components of whole farm budgets were presented in detail in Section 4.5. The IRR and NPV were used as principal profitability indicators of alternative crop rotation systems for the Riversdale winter cereal production area over a 20 year period. Multi-period capital budgets for alternative rotation systems are shown in Annexure E. The expected IRR and NPV are calculated on annual net flow of funds for a typical farm over a 20 year period. The three-year average (2015-2017) nominal interest rate was 10 per cent while the inflation rate stood at 5.5 per cent. This brings the real interest rate to 4.3 per cent (SARB, 2019 and Stats SA, 2019). Table 5.7 indicates the expected IRR and NPV with different crop rotation systems for a typical farm in the Riversdale winter cereal production area.

Table 5.7. Expected IRR and NPV for alternative rotation systems on a typical farm in the Riversdale winter cereal production area

Rotation System	IRR (Internal rate of return) %	NPV (Net Present Value) Rand
WC	5,13%	R3 872 661
WLWC	2,41%	-R9 028 944
WBC	5,29%	R4 602 899
CBLWW	3,04%	-R6 010 480
LLLLLWBCWB	5,39%	R5 117 631

Source; Own calculations

A rotation system with an expected IRR of less than 4.30 (real interest rate), returns a negative NPV. This suggests that the project is not profitable and the farmer would receive a higher return by banking the money. The continuous cash crop rotation systems where lupines are present are not profitable, while the short WC and WBC continuous cash crop rotation systems are profitable. The profitability of the WLWC and WBLWW rotation systems are negatively influenced by the presence of lupines. Regardless of the positive impact of lupines on wheat yields following lupines in a rotation system, the lack of an established market accompanied by erratic lupine yields decreases the whole farm profitability of farms practising rotation systems involving lupines in the Riversdale area.

The traditional crop-pasture rotation system (LLLLLWBCWB) is the most profitable rotation system for the Riversdale area over a 20 year period with a projected IRR of 5.39 per cent. Generally, continuous cash crop rotation systems are more profitable than crop-pasture rotation systems. This is because the producer can take full advantage of a good year as cash crops generate high gross margins in good years. This is not the case in a crop-pasture rotation system because half the farm is under pastures and farmers are unable to reap the reward of a good year. The Riversdale homogenous region is a special case because typical farms in the Riversdale area only contain 56 per cent arable land, while the 44 per cent is not cultivatable. The 44 per cent of uncultivatable land provides a natural buffer against continuous cash cropping in favour of livestock production. Hence the crop-pasture rotation system is more profitable at a whole farm level than the continuous cash crop rotation systems for the Riversdale area. The livestock component has the added advantage of buffering the low profitability of poor yield years as determined by rainfall and rainfall dispersion.

5.9. Cash Flow and Liquidity

The sustainability of a farm enterprise cannot entirely be determined by the IRR. The IRR is exacerbated by escalating farmland prices in South Africa which does not change the bank balance of the farm. For instance, most farming enterprises, especially grain farms, only receive income once a year but expenses required to keep the farm operational are incurred monthly. This leads to cash flow shortages during the course of the year. Therefore, the liquidity measured in expected cash flow of the farm enterprise in this case, is a critical determinant of sustainability. The liquidity of a production system measures the ability of such a production system to repay its liabilities without adversely influencing day to day operations of the farm (Hoffmann, 2001).

The cash flow budget only includes cash items, thus focuses exclusively on factors that directly affect the farm's bank balance. Part of the farm equipment that makes up the asset register for a typical farm in the Riversdale area was assumed to be financed externally. The borrowed money requires an annual payment that influences the expected bank balance of the farm. A 20 year cash flow budget was constructed for each rotation system. The budget started with a zero balance for year one and incorporate yearly inflows and outflows of the farm enterprise, determined by the specific crop rotation system. The cash flow budget also accounted for interest earned from the bank in cases where the closing bank balance was positive. The closing balance of one year becomes the opening balance for the following year in the 20 year cash flow budget.

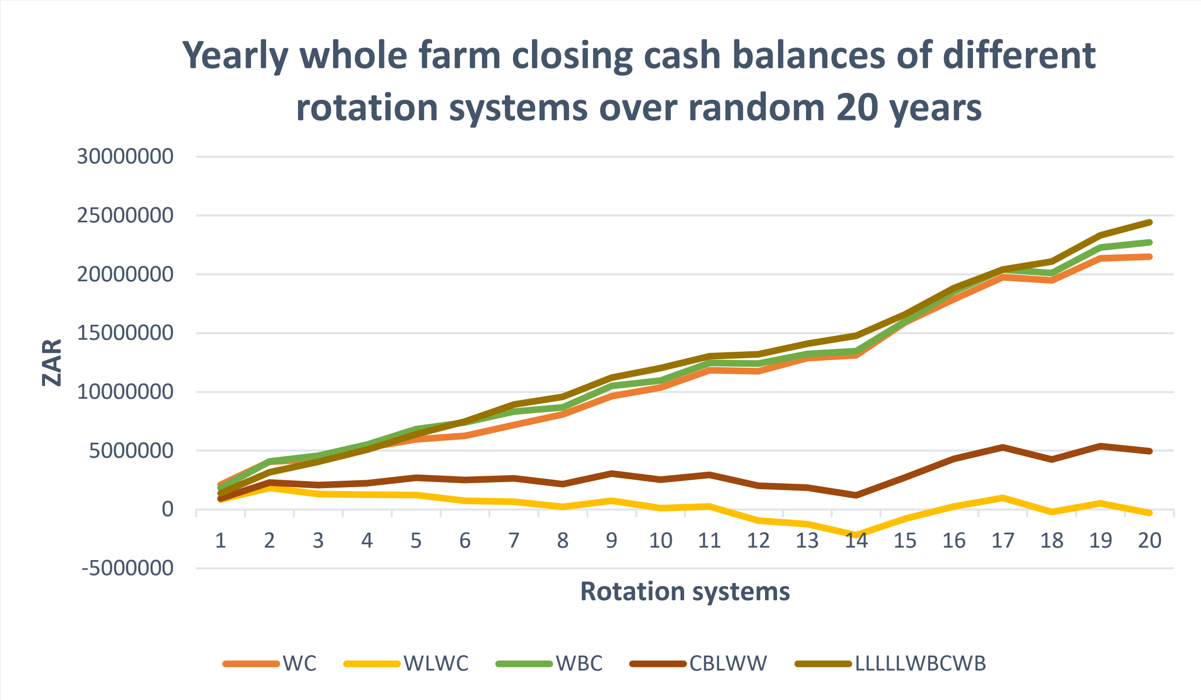

Figure 5.1. The expected closing cash balances on a whole farm over 20 years for different simulated crop rotation systems on a typical farm for the Riversdale area

Figure 5.1 shows that the expected cash balance of continuous cash crop rotation systems start to decrease after the sixth year. The continuous cash crop rotation systems refer to the WC, WLWC, WBC, and WBLWW systems, while system LLLLLWBCWB is the traditional crop-pasture system. The expected cash flow balance of the traditional crop pasture systems remains steady. The downward trend in the expected cash flow balance of the continuous cash crop rotation systems can be attributed to the need to replace machinery since the continuous cash crop systems are more machine dependent, compared to crop pasture systems.

5.10. The expected impact of key variables

The next section concentrates on the sensitivity of whole farm profitability relating to changes in product and input prices through different scenarios. A scenario refers to a description of potential outcomes (Knott, 2015). Scenarios are used as tools to explore possible outcomes to prepare strategies to overcome probable obstacles. Agriculture in particular, is characterised by an unpredictable business environment. This is caused by the many sequential factors that are involved in producing a single product. Scenario analysis can assist farmers to successfully explore the impact of possible future outcomes. The WLWC and CBLWW rotation systems are not profitable on a whole farm level for a typical farm in the Riversdale area. The expected impact of different scenarios on these two systems would only be discussed if necessary. All the scenarios in the next section are implemented under *ceteris paribus* conditions.

5.10.1. Scenario 1: Wheat price change

Before the abolishment of the marketing boards in 1996 South African wheat producers were protected against foreign competition, and received stable, cost-plus basic prices for wheat. The wheat board was particularly powerful compared to those of other crops, which meant wheat producers were better protected. Farmers grew accustomed to the process of cultivating wheat. Wheat remains the major crop in most winter cereal, rain fed rotation systems throughout the Western Cape Province. Variations in the prices of wheat are an important factor that determines the whole farm profitability of a typical farm for the Riversdale area. The wheat price that farmers receive in the Riversdale area is influenced by various external factors. These include the SAFEX price, silo cost, wheat quality and the transportation differential costs between Randfontein and Riversdale. Furthermore, the SAFEX wheat price is influenced by world demand and supply of wheat, world stock rates, exchange rates, logistics cost and the applicable tariffs and import and export duties for different countries. Therefore measuring the sensitivity of whole farm profitability toward changes in wheat prices can assist to investigate potential future scenarios. The current profitability of a typical farm in the Riversdale area is depicted under the "whole farm model" on the left column of Table 5.8. The columns on the right titled "increasing wheat price scenario", represent the new IRR after percentage increases in wheat prices. The difference between the new IRR and the current IRR is measured as a relative change. Table 5.8 below represents the sensitivity of whole farm profitability to possible increasing wheat prices per ton.

Table 5.8. Percentage change in IRR due to increasing wheat prices per ton

Whole farm model Wheat R 3265/ton (2015-2107 average)		Increasing wheat price scenario					
		10% ⬆ R3591.5	Relative Change in IRR	20% ⬆ R3918	Relative Change in IRR	30% ⬆ R4244.5	Relative Change in IRR
Rotation system	IRR	IRR		IRR		IRR	
WC	5,13%	6,24 %	22%	7,37 %	43 %	8,52 %	66%
WLWC	2,41%	3,48 %	44%	4,56 %	89 %	5,67 %	135%
WBC	5,29%	6,03 %	14%	6,78 %	28 %	7,54 %	43%
CBLWW	3,04%	3,90 %	28%	4,77 %	57 %	5,65 %	86%
LLLLLWBCWB	5,39%	5,83 %	8%	6,27 %	16 %	6,71 %	25%

Source; Own calculations

An increase in the wheat price results in higher relative changes in the IRR's of the 'unprofitable' WLWC and CBLWW rotation systems. The actual IRR, generated as a result of the increased wheat price, remains lower than the three profitable rotation systems. Table 5.8 indicates that the WC rotation system is the most sensitive rotation system regarding profitability to increases in wheat prices on a typical farm in the Riversdale area. The traditional crop pasture (LLLLLWBCWB) rotation system is the least sensitive. A 10 per cent increase in the price of wheat would expectedly generate a relative increase in the IRR of the WC rotation system of 22 per cent. This is compared to a mere eight per cent expected relative increase in the IRR of the traditional crop-pasture rotation system. The reason why the IRR of the WC rotation system is more sensitive to increases in the price of wheat is, because wheat is cultivated on half of the farm in the WC rotation system, while wheat is only cultivated on 20 per cent of the farm in the traditional LLLLLWBCWB rotation system.

Table 5.9 shows the percentage changes in the IRR of different rotation systems due to decreasing wheat prices per ton. The buffering effect of planting half the farm under wheat is reversed in this scenario. Table 5.9 indicates that a 10 per cent decrease in the price of wheat would expectedly generate a relative decrease in the IRR of the WC rotation system of 21 per cent. This is compared to a mere eight per cent expected relative decrease in the IRR of the traditional crop pasture rotation system. The WBC and the traditional LLLLLWBCWB rotation systems are the only systems that generate a positive IRR after a 10 per cent decrease in the price of wheat. The traditional crop-pasture rotation system remains profitable after a 20 per cent decrease in the price of wheat. This could be attributed to the stabilisation of income due to the impact of the livestock component in the rotation system. A decline in the wheat price beyond 20 per cent, render all rotation systems unprofitable for a typical farm in the Riversdale area.

Table 5.9. The impact on IRR for the different crop rotations on the typical farm in the Riversdale area due to possible decreasing wheat prices per ton

Whole farm model Wheat R 3265/ton		Decreasing wheat price scenario					
		10% ⬇ R2938.50	Relative Change in IRR	20% ⬇ R2612.0	Relative Change in IRR	30% ⬇ R2285.50	Relative Change in IRR
Rotation system	IRR	IRR		IRR		IRR	
WC	5,13%	4,04 %	21 %	2,96 %	42%	1,90 %	63%
WLWC	2,41%	1,36 %	44 %	0,32 %	87%	-0,71 %	129%
WBC	5,29%	**4,56 %**	14 %	3,83 %	28%	3,11 %	41%
CBLWW	3,04%	2,19 %	28 %	1,35 %	56%	0,51 %	83%
LLLLLWBCWB	5,39%	**4,95 %**	8 %	**4,52 %**	16%	4.09 %	24%

Source; Own calculations

5.10.2. Scenario 2: Increasing input cost

Fertilizers, chemicals and fuel prices are the main contributors to the input cost portfolio of rain fed winter cereal farmers in the Western Cape (Hoffmann, 2010). The main objective of the current project is a whole farm economic evaluation of continuous cash cropping under full CA principles for the Riversdale winter cereal production area. According to the literature reviewed in Chapter 2, CA production systems depend on chemical use to control weed in the early years of adopting CA. Weed suppression provided by tillage is lost when shifting to CA. South Africa is a net importer of agricultural chemicals and fertilizers. According to DAFF (2015), the South African fertilizer and chemical industries are completely open to international market forces. These industries operate in a liberalized environment with zero government subsidies or import protection. Fertilizer and chemical prices are directly subject to international prices, currency exchange rates (R/US$) and shipping cost. Similarly, world crude oil prices are completely unpredictable and determine the domestic fuel price that farmers will pay. The input cost scenario is necessary as any changes in the prices of externally determined input costs, directly influences the expected whole farm profitability of farms in the Riversdale area drastically. This scenario focuses on increases in the cost of all variable inputs uniformly because the scenario is applied to the total allocated variable cost and not on the variable cost of individual inputs. Table 5.10 represents the sensitivities of different rotation systems to rising allocated variable costs.

Table 5.10. Expected change in IRR for the typical farm in the Riversdale area due to increasing input costs

Whole farm model		Increasing input cost scenario					
		5 % ⬆	Relative change in IRR	10 % ⬆	Relatively change in IRR	15 % ⬆	Relative Change in IRR
Rotation system	IRR	IRR		IRR		IRR	
WC	5,13%	**4,69 %**	6 %	4,25 %	17 %	3,81 %	26 %
WLWC	2,41%	2,04 %	15 %	1,66 %	31 %	1,29 %	46 %
WBC	5,29%	**4,84 %**	6 %	**4,40 %**	17 %	3,96 %	25 %
CBLWW	3,04%	2,65 %	13 %	2,26 %	26 %	1,88 %	38 %
LLLLLWBCWB	5,39%	**4,95 %**	8 %	**4,51 %**	16 %	4,07 %	25 %

Source; Own calculations

Table 5.10 shows that the most susceptible rotation systems as a result of an increase in the variable input cost are the unprofitable WLWC and CBLWW rotation systems. The allocated variable costs are a critical part of any farm business regardless of the rotation systems practised. This is proven by the fact that the profitable WC, WBC, and the traditional LLLLLWBCWB rotation systems are equally vulnerable to increasing variable costs. A 20 per cent increase in the price of variable input cost would decrease the IRR of WC and WBC rotation systems by 17 per cent, while the same scenario would decrease the IRR of the LLLLLWBCWB rotation system by relatively 16 per cent.

5.10.3. Scenario 3: Wool price change

South African wool prices are influenced by demand and supply and are closely related to the world price of apparel wool, which is mainly driven by the Australian market. Therefore wool prices are susceptible to international shocks and subsequently relatively volatile. The profitability of the rotation system which includes the livestock component can thus vary with changes in, often unstable, wool prices. The income from the sheep component in the whole farm budget is determined by meat prices as well as wool prices. Sheep prices are relatively stable compared to wool prices (BFAP, 2018). Table 5.11 indicates the sensitivity of whole farm profitability towards escalating wool prices. The four continuous cash crop rotation systems are not influenced by wool prices because continuous cash crop systems do not incorporate the livestock component; therefore, they are excluded in Tables 5.11 and 5.12.

Table 5.11. Percentage change in IRR for the typical farm in the Riversdale area due to increasing wool prices per kg

Whole farm model Wool R 81.33/kg (2015-2017 average)		Increasing wool price scenario					
		50% ↑ R122.00	Change in IRR	100% ↑ R162.67	Change in IRR	150% ↑ R203.33	Change in IRR
Rotation system	IRR	IRR		IRR		IRR	
LLLLLWBCWB	5,39%	6,56 %	22 %	7,76 %	44 %	8,98 %	67 %

Source; Own calculations

When using the LLLLLLWBCWB rotation system, half the cultivated area of the farm is allocated to pastures and therefore wool prices strongly influence the profitability of a typical farm in the Riversdale area. Table 5.11 indicates that a 50 per cent increase in the price of wool would increase the IRR of the LLLLLWBCWB rotation system by relatively 22 per cent.

Table 5.12 represents the sensitivity of whole farm profitability toward decreasing wool prices.

Table 5.12. The expected percentage change in IRR for the typical farm in the Riversdale area due to decreasing wool prices per kg

Whole farm model Wool R 81.33/kg (2015-2017 average)		decreasing wool price scenario					
		10% ↓ R73.20	Change in IRR	30% ↓ R56.93	Change in IRR	50% ↓ R40.67	Change in IRR
Rotation system	IRR	IRR		IRR		IRR	
LLLLLWBCWB	5,39%	5,15	4 %	4,69 %	13 %	4,23 %	21 %

Source; Own calculations

The significance of the livestock component in the traditional LLLLLWBCWB rotation system practised in the Riversdale area is highlighted in Table 5.12. It is evident from this information that a 30 per cent decrease in the price of wool would decrease the IRR of the LLLLLWBCWB rotation system by almost 13 per cent. The stability and resilience of the traditional crop-pasture rotation system is the result of three different income streams. Typical farms in the Riversdale area receive income from wool, meat and cash crops which stabilise the farm revenue in variable economic downturns. The farm sector is generally characterised by low returns; therefore, the more income streams a farm has the better the chances of sustainability.

5.11. Conclusion

One of the specific objectives of this project was to investigate the profitability of continuous cash cropping under full CA principles and standard crop-pasture rotation systems for the Riversdale area. Typical whole farm multi-period budget models were constructed for alternative rotation systems that could be implemented on typical farms in the Riversdale area. Typical farm information is not a direct guiding tool for farm managers, but once the typical farm information is converted to a whole farm model, alternative rotation systems can be evaluated and compared. The physical parameters of the typical farm model were provided by experts in the Riversdale area and presented to a multidisciplinary group of experts for validation. These parameters included farm size, land ownership structure, land utilisation patterns, mechanisation requirement, revenue and costs. Using these parameters within standard accounting principles the expected return on investment for each crop rotation system on the typical farm was calculated and conveyed in terms of cash flow, NPV and IRR. The role of the budget models was to measure and compare alternative crop rotation systems for a typical farm in the Riversdale area.

The traditional crop-pasture rotation system (LLLLLWBCWB) is the most profitable and resilient rotation system over a period of 20 years for a typical farm in the Riversdale area. Typical farms in the Riversdale area have 56 per cent arable land while 44 per cent is not arable. A natural buffer exists against the continuous cash crop systems in favour of crop-pasture rotation system, because the sheep component in the crop-pasture rotation system can utilise the uncultivatable land.

Three scenarios were simulated within the whole farm multi-period budgets for a typical farm in the Riversdale area. These scenarios were based on the observed market trends in the South African agricultural sector and included an upward and downward shift in the prices of wheat and wool. One scenario also assumed increasing allocated variable input costs. Based on the simulated scenarios the traditional crop-pasture rotation system is the most resilient and financially stable rotation system for typical farms in the Riversdale area. The product mixture in the traditional LLLLLWBCWB rotation system stabilises the profitability of farms using this rotation system. The continuous cash crop rotation systems have a buffer effect when wheat prices increase and outperform the traditional crop-pasture rotation system when wheat prices increase with 10 per cent or more.

Chapter 6: Conclusion, Summary and Recommendations

6.1. Conclusions

The world population is growing at an alarming rate and is expected to increase to 9 billion people within the next 30 years. World food production should increase by at least 70 per cent to achieve global food security by 2050. Natural resources are by definition limited, but the uses and demands for the resources are limitless. The agricultural sector has to compete with urbanization and industries for these limited land and water resources, which challenges world agriculture to produce more food with less arable land. To achieve this task, sustainable agriculture is proposed as a substitute for conventional farming systems worldwide.

Conservation Agriculture (CA) is a holistic approach to sustainable agriculture. It is based on three integrated principles namely: minimum soil disturbance (zero till/min till), maximum soil cover (retention of mulch) and crop rotation. CA principles are based on optimising yields and profits, as opposed to maximising yields, which is key to sustainable agriculture. This is the classical challenge of “best” rather than “most” production. Farmers across South Africa were forced to diversify as a countermeasure to risk after the deregulation of the South African agricultural sector in 1996. South African farmers started to adopt CA principles as a strategy of diversification, particularly crop rotations, which was the starting point of CA in South Africa.

The Southern Cape homogenous production zone is one of the main cereal production areas in the Western Cape and South Africa. The Southern Cape is mainly characterised by its Mediterranean climate. However the area does receive summer and winter rainfall that is distributed almost evenly. Traditionally farmers in the Southern Cape practise mixed crop-pasture rotation systems. Literature indicates that continuous cash cropping is more profitable than crop-pasture rotation systems, though the latter ensures a stable income. Research results obtained from literature are often region and country-specific; therefore, they cannot be conveyed as the universal norm. Crop rotation trials are carried out on a commercial farm in the Riversdale area in order to investigate the feasibility of continuous cash cropping, as an alternative rotation systems to the traditional crop-pasture system, in the Southern Cape within a CA framework.

A research method that can accommodate complexity is needed to determine the expected performance of alternative continuous cash cropping, and crop-pasture systems in financial terms for the Southern Cape production area. The research method and tool should accommodate the multi-faceted, complex, interconnected, biophysical and socio-economic synergies of the farm environment. The interconnected farm system requires a multidisciplinary research technique that would permit active participation from stakeholders within the farm environment.

The complexity of the farm system is accommodated through the use of the systems approach. Stakeholders in the Southern Cape production region were engaged through a series of interviews and a multidisciplinary group discussion. Disciplines involved in the group discussion were agronomy, agricultural economics, crop sciences, crop protection and producers. Each stakeholder stimulated the discussions with unique intricate information within their specific fields. Grain producers in the Southern Cape provided the practical insight regarding application of aspects in the farm system. Simulation modelling, specifically a typical whole farm budget model, was used as the tool to accommodate the multi-faceted farm system in this research project. Whole farm multi-period budgets for alternative crop rotation systems for the Riversdale production area were constructed using spreadsheet programmes. Complex, sophisticated and interlinked calculations were executed within standard accounting principles to enable the measurement of the impact the physical system has on the financial outcome. Whole farm modelling in spreadsheets enabled the integration of knowledge from the multidisciplinary experts into the multi-period budgets. The components of the whole farm budgets are interconnected and changes in one component will instantly affect the profit of the whole farm system.

The main research question of the current project was to explain how continuous cash crop rotation systems financially fare on a whole farm level in the Riversdale area. Multi-period, whole farm budget models supplemented with a multidisciplinary group discussion amongst various stakeholders was successfully adopted to assess these systems financially. Traditionally continuous cash cropping under full CA principles is more profitable than the crop-pasture rotation system over the long term. The crop-pasture production system is also expected to be more resilient to external shocks. However, the traditional crop-pasture rotation system proved more profitable than the continuous cash crop rotation systems on a typical farm in the Riversdale area.

The following three important conclusions were made:

- ❖ Typical farms in the Riversdale area only have 56 per cent arable land while 44 per cent is not arable; therefore, a natural buffer exists against the continuous cash crop rotation systems in favour of the crop-pasture rotation system. The traditional crop-pasture rotation system that includes five years of lucerne followed by five years of cash crops (LLLLLWBCWB) is the most profitable and stable rotation system for a typical farm in the Riversdale area.

- ❖ The WC and WBC continuous cash crop rotation systems are the only profitable continuous cash crop rotation system from the six crop rotation trials conducted at the Riversdale trial site. Additionally, the WC and WBC continuous cash crop rotation systems became more profitable than the traditional crop-pasture rotation system if wheat prices are more than or R3590/ton.
- ❖ Wheat following lupines indicated the highest yields at the Riversdale trial site, but the lack of an established market accompanied by erratic lupine yields decreases the whole farm profitability of farms practising rotation systems involving lupines in the Riversdale area.

6.2. Summary

The challenges faced by world agriculture due to the rapidly increasing population growth, is real. The need for sustainable agriculture is emphasised and CA is discussed as the most holistic approach towards sustainable agriculture. CA is based on three interlinked principles which are: minimum soil disturbance, permanent soil cover and crop rotations. After the deregulation of the South African agricultural sector, South African farmers started to adopt crop rotation as a risk mitigation strategy, which was the genesis of CA in the country. Benefits of CA are context specific. Therefore, it is necessary to assess the potential of continuous cropping within a conservation farming framework by carrying out crop rotation trials on a commercial farm in the Riversdale area. Traditionally crop-pasture rotation systems are predominant in the Riversdale area or Southern Cape production zone. Therefore, the main research objective was to financially compare continuous cash crop rotation systems to the traditional systems that include pastures and sheep, on a whole farm level.

The first part of Chapter 2 provided a historical background of sustainable agriculture and reaffirmed the urgent need for sustainable agriculture. People have different interpretations of sustainable agriculture, although the endeavour to practise sustainable agriculture originates from ancient times. Widespread physiological approaches towards sustainable agriculture such as organic farming, permaculture, trans-genetic farming and perennial farming were presented as options to solve the challenges faced by world agriculture. It was concluded that physiological approaches often lack holistic solutions to ensure sustainable farming. The last part of Chapter 2 focused on CA as the most holistic approach towards achieving sustainable agriculture. The origins, benefits, challenges and adoption rates of CA globally and specifically in South Africa, were discussed thoroughly in the latter parts of Chapter 2. South Africa, specifically the Western Cape Province is the leader in adopting CA in southern Africa. CA implementation is mainly driven by an intrinsic mind-set shift of farmers. Vigorously adopting all three principles of CA has been a problem particularly for resource constraint smaller farmers.

The first section of Chapter 3 emphasises the fact that farm systems have qualities and features not existing in some of their individual components; therefore, one must seek to understand the greater whole in order to understand its parts, and not seek to understand the small parts to explain the whole. The evolution of systems research was highlighted. Systems modelling were discussed as a research tool to undertake systems research. In the last part of Chapter 3, a typical farm approach was introduced as a systems research method with reference to the present project. A typical farm is almost identical to an average farm for a production area. The key difference is that a typical farm cannot be affected by outliers while an average farm can be.

In Chapter 4 the experimental design, management and crop rotation systems of the Riversdale trial farm were discussed extensively. The trials involve six crop rotation systems which are based on CA principles: LWCW (Legume crop – Wheat – Canola – Wheat), CWCW (Canola – Wheat – Canola – Wheat), CBLWW (Canola – Barley – Legume crop – Wheat – Wheat), WBC (Wheat – Barley – Canola), WWO (Wheat – Wheat – Oats), and CWC (Coriander – Wheat – Canola). The importance of crops selected in the rotation systems was also discussed. Wheat is the most represented crop in the rotation systems followed by canola and barley. The financial performance of each crop in a rotation system was discussed on the gross margin level. The system with the highest average gross margin per ha across the six years from 2013 to 2018 was the wheat-barley-canola rotation system with an expected gross margin of R5152/ha, closely followed by the wheat-canola short system with R5089/ha. However, gross margin analysis can be restricted and the need for whole farm analysis was argued. The latter part of Chapter 4 focused on the components of a whole farm budget model and how these components were constructed in the budget model. The input component includes the physical description of the farm, crop rotation systems, assumptions about yields, land utilization patterns and output/input prices, while the calculation component includes a sequence of interconnected calculations. The calculation is a key element that links the input component to the output component. The output component of the models mainly expresses whole farm profitability in terms of the NPV and IRR. Assumptions made about the parameters of a typical farm for the Riversdale area were combined with standard accounting principles through a series of excel functions to determine enterprise budgets for different farm products.

Chapter 5 expands the theoretical background of constructing a whole farm budget as discussed in Chapter 4 with values as pertained in the final models. The first part of Chapter 5 focused on the description of the validated assumptions regarding a typical farm for the Riversdale area. The investment requirements, product variable cost and whole farm gross margin are important components. In the last part of Chapter 5 the profitability of different crop rotation systems at the whole farm level in terms of the IRR and NPV are investigated, with the support of different scenarios. The traditional LLLLLWBCWB crop-pasture rotation system is the most profitable rotation system on the whole farm level for a typical farm in the Riversdale production area with the highest expected IRR and NPV. Scenarios are good tools in exploring possible future outcomes. The first scenario investigated how the IRR of each rotation system reacted to changes in wheat prices, while the second scenario altered the allocated variable cost and the third scenario focused on changes in wool prices. It was evident from the three scenarios that all continuous cash crop rotation systems are highly susceptible to changes in the prices of wheat, while the crop-pasture rotation system is more stable. For instance, the IRR of the wheat-barley-canola rotation system decreased by 0.73 percentage points from 6.29 per cent to 4.56 per cent with a 10 per cent decrease in the price of wheat, while the IRR of the crop-pasture system decreased by only 0.44 percentage points from 5.39 per cent to 4.95 per cent.

6.3. Recommendations

The principal objective of the current project was a whole farm economic evaluation of continuous cash cropping under full CA principles for the Riversdale area. The question thus asked is, how continuous cash crop rotation systems and traditional systems that include pastures and sheep, on a whole farm level, compare financially. Whole farm budget models supplemented by multidisciplinary group discussions were used to answer the research question.

Whole farm budget models used in the current study indicate that the traditional LLLLLWBCWB crop-pasture rotation system is the most profitable rotation system for a typical farm in the Riversdale area over the long term. It is commendable that farmers in the

Riversdale area continue practising their traditional crop-pasture rotation system although the buffer effect is lost when wheat prices increase. The value of sheep appreciates over time and sheep are replaced from sheep, while the mechanical requirements of continuous cash cropping systems depreciates over time and should be replaced after a certain period of time with new capital injections. Sheep are unique in a production system because each farmer breeds his/her sheep to achieve certain qualities. To embed, certain traits in a sheep breed necessitates trial and error often through generational farming. Henceforth, sheep are passed from generation to generation and generational experimentation is priceless in this regard. Therefore, the decision to convert from traditional crop-pasture production systems should not solely be fuelled by profitability. If sheep are sold, the action would be difficult to reverse. Farmers should proactively incorporate all CA principles with the traditional crop-pasture system to reap the soil-related rewards of having CA oriented systems, by practising continuous cash cropping under full CA principles on the parts of the farm allocated to cropping.

The biggest limitation of the whole farm budget models used in the current study is that the models lack an optimisation narrative. Therefore, it is recommended that future studies investigate how the arable land of farms might be allocated optimally between cash crops and pastures in order to maximise farm revenue for a typical farm in the Riversdale plains. The technical committee which is in charge of the Southern Cape crop rotation trials should investigate the possibility of introducing new crop varieties in rotation systems with predominant crops in the Southern Cape to maximise the use of summer rainfall. Secondly, to investigate the viability of regenerative farming as a means of achieving sustainable agriculture in the Southern Cape would increase understanding of its unique challenges. Thirdly, the possibility of incorporating cover crops with the livestock component under full CA principles to ensure that the cover crops serve a dual purpose, first as grazing for sheep and second as a soil nutrient stimulating crop. If this is not done, farmers are not going to cultivate cover crops that yield no returns.

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Annexure A: Location and experimental Design of the Riversdale Trials

Riversdal proef - 2019.

Jaar 8

31	32	33	34	35	36	37	38	39	40	41	42	43	44	45
		JL				JL		JL						
2,3	3,2	1,2	5,2	3,3	4,3	2,1	3,1	5,3	4,1	4,1	5,3	1,2	5,2	2,2
L	Er	K	C	K	C	C	K	K	K	K	K	K	C	K

46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
												JL		
6,1	1,1	2,1	6,5	4,2	1,2	5,1	2,4	5,3	2,3	6,5	3,1	6,4	3,3	6,1
L	C	C	G	S	K	G	K	K	L	G	K	C	K	L

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
4,2	6,5	6,3	5,1	2,2	6,1	6,4	1,1	6,2	2,4	2,4	6,2	6,3	5,1	4,3
S	G	K	G	K	L	C	C	K	K	K	K	K	G	C
1		2		3		4		5		6		7		8

16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
								JL				JL		
3,3	6,4	3,1	2,3	3,2	5,2	6,3	6,2	4,1	3,2	4,2	2,1	1,1	2,2	4,3
K	C	K	L	Er	C	K	K	K	Er	S	C	C	K	C
	9		10		11		12		13		14		15	

Vliegveld

Stelsels

1,1	WC
1,2	CW
2,1	WLWC
2,2	LWCW
2,3	WCWL
2,4	CWLW
3,1	WWGm (Gm = saia)Gebruik Ertjies in 2019
3,2	WGmW (Gm=saia)
3,3	GmWW (Gm= Saia)
4,1	CWGm(Gm = Wieke)Plant Saia in 2019
4,2	WGmC (Gm = Wieke)
4,3	GmCW (Gm = Wieke)
5,1	WBC
5,2	BCW
5,3	CWB
6,1	CBLWW
6,2	BLWWC
6,3	LWWCB
6,4	WWCBL
6,5	WCBLW

Annexure B: An example of how data are captured at the Riversdale trial site

GROSS MARGIN & MARGIN ABOVE SPECIFIED COSTS:							
Crop:	**Wheat**			**Date:**	**19-Jan-18**		
				YEAR	**2017**		
Counrty:	**SA**						
Province:	**Western Cape**						
Location:	**Riversdale**						
Comment:	**Southern Cape crop rotation trials**						
Camp:	2	**System:**	**6,5**	**Canola-Barley-Lupin-Wheat-Wheat**			
			Price/unit				
		Unit	**Rand**	**Quantity**	**R per ha**	**R/yield unit**	
							Code:
Gross Income							
Product income:							
Wheat							
Wheat: B3		ton	3391,00	1,740	5900,34	3391,00	102
Marketing cost:							
Gross income minus marketing cost					**5900,34**	**3391,00**	
ALLOCATABLE VARIABLE COSTS:					**3606,31**	**2072,59**	
Directly Allocatable Variable Costs:					**3101,77**	**1782,63**	
Pre Harvest Cost:					**2984,08**	**1714,99**	
Plant material:							
Seed							
SST 0127		kg	6,90	79,000	545,10	313,28	200
Fertilizer:							
U - Plant 31 S		t	6219,00	0,100	621,90	357,41	300
1.0.0 (33.5)		t	4893,00	0,090	440,37	253,09	301
#N/A		#N/A	#N/A		0,00	0,00	
#N/A		#N/A	#N/A		0,00	0,00	
#N/A		#N/A	#N/A		0,00	0,00	
#N/A		#N/A	#N/A		0,00	0,00	
#N/A		#N/A	#N/A		0,00	0,00	
#N/A		#N/A	#N/A		0,00	0,00	
#N/A		#N/A	#N/A		0,00	0,00	
#N/A		#N/A	#N/A		0,00	0,00	
Lime & manure:							
#N/A		#N/A	#N/A		0,00	0,00	
Weed Control:							
Erase 360 3L + Bladbuff.125L		per Ha	134,25	1,000	134,25	77,16	405
Aurora25glmiboost1LErase(360)3LBladbu		per Ha	255,30	1,000	255,30	146,72	400
Sakura		g	4,40	125,000	550,00	316,09	401
Bladbuff.125L Wetcit.2LAurora25gBrushc		per Ha	179,06	1,000	179,06	102,91	404
#N/A		#N/A	#N/A		0,00	0,00	
#N/A		#N/A	#N/A		0,00	0,00	
#N/A		#N/A	#N/A		0,00	0,00	
#N/A		#N/A	#N/A		0,00	0,00	
Pest Control:							
Mospilan		gram	0,65	50,000	32,25	18,53	426
Mospilan		gram	0,65	50,000	32,25	18,53	426
#N/A		#N/A	#N/A		0,00	0,00	
#N/A		#N/A	#N/A		0,00	0,00	
#N/A		#N/A	#N/A		0,00	0,00	
#N/A		#N/A	#N/A		0,00	0,00	
#N/A		#N/A	#N/A		0,00	0,00	
Fungicide control:							
Duett Ultra		liter	352,00	0,550	193,60	111,26	424
#N/A		#N/A	#N/A		0,00	0,00	
#N/A		#N/A	#N/A		0,00	0,00	
#N/A		#N/A	#N/A		0,00	0,00	
#N/A		#N/A	#N/A		0,00	0,00	
Contractors:							
#N/A		#N/A	#N/A		0,00	0,00	
#N/A		#N/A	#N/A		0,00	0,00	
#N/A		#N/A	#N/A		0,00	0,00	
Lime spread:							
#N/A		#N/A	#N/A		0,00	0,00	
Harvest cost:					117,69	67,64	
Grain							
Transport		ton	67,64	1,740	117,69	67,64	
MARGIN ABOVE DIRECTLY ALLOCATABLE COSTS:					**2798,57**	**1608,37**	
In Directly Allocatable costs:					**504,54**	**289,96**	
PRE HARVEST COST:					**357,39**	**205,40**	
Energy					190,05	109,22	
Repairs and Maintenance					163,40	93,91	
Tyres					3,94	2,27	
HARVEST COST:					**147,15**	**84,57**	
Energy					77,05	44,28	
Repairs and maintenance					69,32	39,84	
Tyres					0,77	0,44	
TOTAL PRE HARVEST COSTS					**3341,47**	**1920,39**	
TOTAL HARVEST COSTS					**264,84**	**152,21**	
GROSS MARGIN ABOVE ALL ALLOCATABLE COSTS:					**2294,03**	**1318,41**	

Crop: **Wheat** **Date:** **19-Jan-18**
YEAR **2017**
Location: **Riversdale**
Southern Cape crop rotation trials

Monthly Machinery Usage per Activity: **Camp:** **2**

Activity Code	**Month**	**Activity**	**Power source**	**Implement**	**Time/km**	**Usage per Year Implement**	**Power source**	**Labour**	**Cost per Year Implement Repair**	**Energy**	**Power Repair**	**Casuals labour costs Oper.**	**Other**	**Total Variable Costs**	**Regular Labour cost Oper.**	**Other**	**Tyre c**
1	JAN	Spray weed control	67	101	1	0,14	0,14	0,17	1,00	16,52	10,08	0,00	0,00	27,61	25,21	0,00	0
1	MAR	Spray weed control	67	101	1	0,14	0,14	0,17	1,00	16,52	10,08	0,00	0,00	27,61	25,21	0,00	0
3	**APR**	Plant	67	104	1	0,55	0,55	0,66	34,25	64,89	39,60	0,00	0,00	138,74	99,00	0,00	1
1	**APR**	Spray weed control	67	101	1	0,14	0,14	0,17	1,00	16,52	10,08	0,00	0,00	27,61	25,21	0,00	0
2	**JUL**	Spread fertiliser	67	102	1	0,14	0,14	0,17	2,45	16,52	10,08	0,00	0,00	29,06	25,21	0,00	0
11	**JUL**	Spray herb & insect	67	101	1	0,14	0,14	0,17	1,00	16,52	10,08	0,00	0,00	27,61	25,21	0,00	0
12	**SEP**	Spray fungi & insec	67	101	1	0,14	0,14	0,17	1,00	16,52	10,08	0,00	0,00	27,61	25,21	0,00	0
		#N/A	#N/A	#N/A	1	#N/A	#N/A	#N/A	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0
		#N/A	#N/A	#N/A	1	#N/A	#N/A	#N/A	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0
9	**OCT**	Swath	67	103	1	0,22	0,22	0,26	5,71	26,02	15,88	0,00	0,00	47,61	39,70	0,00	0
10	**NOV**	Harvest	124	0	1	0,31	0,31	0,37	0,00	77,05	69,32	0,00	0,00	146,38	55,58	0,00	0
Totals:									**47,41**	**267,10**	**185,31**			**499,82**	**345,54**		4

Source; Riversdale Trial data

Aggregated trial data from which gross margin analysis over six years for the Riversdale trial were determined

System 1 = WC						
Camp No	8	33	47	43	28	51
Crop:	Canola	Wheat	Canola	Wheat	Canola	Wheat
Yields(ton)	2,11	3,08	2,48	3,49	2,25	3,37
Gross income:	9797,55	8202,87	11532,00	8829,70	10481,10	8531,16
Allocatable variabl	3223,27	3496,23	3241,06	3515,88	3230,28	3510,25
Margin above direc	6990,77	5123,13	8707,42	5730,31	7667,30	5437,40
Indirect allocatable	416,49	416,49	416,49	416,49	416,49	416,49
Gross margin abov	6574,28	4706,64	8290,94	5313,82	7250,82	5020,91
				3369,49	2,80	6192,90

System 2 = WLWC												
Camp No	37	5	31	10	48	45	19	11	27	29	55	53
Crop:	Lupin	Wheat	Canola	Wheat	Lupin	Wheat	Canola	Wheat	Lupin	Wheat	Canola	Wheat
Yields(ton)	2,09	3,28	2,20	2,67	2,12	4,41	2,16	2,67	1,82	3,94	2,12	3,54
Gross income:	6608,52	8751,86	10211,4	6744,98	6700,305	11755,32	10025,4	6744,98	5769,795	10502,765	9844,05	9431,435
Allocatable variabl	3010,354	3506,052	3227,515	3476,574	3011,737	3559,81	3225,607	3476,574	2494,956	3349,4054	3223,746	3518,216
Margin above direc	4013,966	5662,293	7400,371	3684,892	4104,368	8611,99	7216,279	3684,892	3274,839	7569,845	7036,789	6329,705
Indirect allocatable	415,8005	416,4854	416,4854	416,4854	415,8005	416,4854	416,4854	416,4854	415,8005	416,48535	416,4854	416,4854
Gross margin abov	3598,166	5245,808	6983,885	3268,406	3688,568	8195,505	6799,793	3268,406	2859,039	7153,3596	6620,304	5913,219
							3256,712	2,75	5299,538			

System 3 = WWGma									
Camp No	38	32	35	18	20	16	57	25	59
Crop:	Wheat	Gma	Wheat	Wheat	Gma	Wheat	Wheat	Gma	Wheat
Yields(ton)	3,88	0,00	3,70	3,96	0,00	4,02	3,75	0,00	3,32
Gross income:	10345,53	0	9350,88	10553,4	0	10710,64	10004,41	0	8855,795
Allocatable variabl	3534,577	664,8033	3525,705	3538,297	579,9887	3541,112	3528,471	579,9887	3507,912
Margin above direc	7227,439	-442,5	6241,661	7431,588	-442,5	7586,009	6892,424	-442,5	5764,368
Indirect allocatable	416,4854	222,3033	416,4854	416,4854	137,4887	416,4854	416,4854	137,4887	416,4854
Gross margin abov	6810,953	-664,803	5825,175	7015,103	-579,989	7169,523	6475,939	-579,989	5347,883
							2555,651	2,51	4091,088

System 4 = CWGma									
Camp No	40	1	36	41	50	15	24	26	30
Crop:	Wheat	Gma	Canola	Wheat	Gma	Canola	Wheat	Gma	Canola
Yields(ton)	3,73	0,00	2,84	3,76	0,00	2,60	3,07	0,00	2,87
Gross income:	9927,125	0	13219,95	10031,06	0	12080,7	7762,04	0	13354,8
Allocatable variabl	3527,088	886,5534	3258,376	3528,948	751,8595	3246,69	3495,749	751,8595	3259,76
Margin above direc	6816,523	-705,35	10378,06	6918,597	-592,35	9250,495	4682,776	-592,35	10511,53
Indirect allocatable	416,4854	181,2034	416,4854	416,4854	159,5095	416,4854	416,4854	159,5095	416,4854
Gross margin abov	6400,037	-886,553	9961,574	6502,112	-751,859	8834,01	4266,291	-751,859	10095,04
							2522,987	2,10	4852,088

System 5 = WBC									
Camp No	4	34	39	14	44	42	52	21	54
Crop:	Barley	Canola	Wheat	Barley	Canola	Wheat	Barley	Canola	Wheat
Yields(ton)	5,50	2,44	3,47	4,93	2,36	3,55	3,90	2,08	3,68
Gross income:	11008	11350,65	9247,55	9866	10983,3	9458,085	7804	9662,7	9796,54
Allocatable variabl	3120,946	3239,201	3514,924	2867,709	3235,433	3518,693	3044,53	3221,886	3524,751
Margin above direc	8280,834	8527,934	6149,111	7392,071	8164,353	6355,878	5153,25	6857,299	6688,275
Indirect allocatable	393,7797	416,4854	416,4854	393,7797	416,4854	0	393,7797	416,4854	416,4854
Gross margin abov	7887,054	8111,449	5732,626	6998,291	7747,867	5939,392	4759,47	6440,814	6271,789
							3254,23	3,55	6654,306

System 6 = CBLWW															
Camp No	6	9	3	7	2	46	12	13	17	49	60	23	22	58	56
Crop:	Barley	Lupin	Wheat	Wheat	Canola	Barley	Lupin	Wheat	Wheat	Canola	Barley	Lupin	Wheat	Wheat	Canola
Yields(ton)	4,68	2,53	3,46	3,24	1,74	5,12	2,12	3,25	3,90	2,42	3,89	1,75	3,77	3,10	2,27
Gross income:	9364,000	8004,285	9220,900	8184,550	8067,750	10232	6700,305	8647,925	10398,83	11257,65	7784	5551,41	10057,71	8256,17	10574,1
Allocatable variabl	3081,736	3031,390	3514,447	3503,715	3205,525	3102,438	3011,737	3278,192	3535,531	3238,2471	3044,053	2994,422	3529,425	3497,18	3231,235
Margin above direc	6676,044	5388,696	6122,938	5097,321	5278,711	7523,342	4104,368	5786,219	7279,785	8435,8883	5133,727	2972,788	6944,77	5175,475	7759,35
Indirect allocatable	393,780	415,800	416,485	416,485	416,485	393,7797	415,8005	416,4854	416,4854	416,48535	393,7797	415,8005	416,4854	416,4854	416,4854
Gross margin abov	6282,264	4972,895	5706,453	4680,835	4862,225	7129,562	3688,568	5369,733	6863,299	8019,4029	4739,947	2556,988	6528,285	4758,99	7342,865
									5566,821			3253,285		3,15	

2013 averages				
	wheat	canola	barley	lupins
Yields	3,52	2,33	4,67	2,07
Allocatable VC	3501,99	3233,855	3043,569	2925,766
Gross margin	5768,54	7595,685	6299,431	3560,704

Yields

	2013	2014	2015	2016	2017	2018
Wheat	3,52	2,60	3,60	4,39	1,44	1,88
Canola	2,33	1,39	1,41	2,26	1,16	1,66
Barley	4,67	3,77	3,61	4,14	1,12	2,51
Lupins	2,07	0,97	0,27	2,27	0,00	0,00

Allocatable VC

	2013	2014	2015	2016	2017	2018
Wheat	3501,989	3574,074	4208,834	4036,625	3579,484	2687,151
Canola	3233,855	4985,875	4403,696	5750,581	3589,691	3291,064
Barley	3043,569	3289,998	4010,845	4480,807	3541,908	2765,596
Lupins	2925,766	2287,297	2928,477	2230,587	1246,073	1653,746

Gross margin

	2013	2014	2015	2016	2017	2018
Wheat	5768,537	3313,171	8604,075	7962,727	1529,669	3752,839
Canola	7595,685	996,5721	2616	7270,002	2631,779	5317,34
Barley	6299,431	6898,836	8618,321	9643,816	547,9166	6285,404
Lupins	3560,704	-2287,3	-2928,48	3098,43	-1283,41	-1653,75

Annexure C: Inventory list for farm practising continuous cash cropping under full CA principles versus traditional crop-pasture rotation system

Traditional crop-pasture rotation system inventory list for the Riversdale area

Inventaris							
Item	**Beskrywing**	**Aantal**	**R/item**	**Waarde**			
Grond & Vaste verbeterings:							
Grond (a)	Waarde sluit alle verebet	1120	27790	31124800			
Vaste verebeterings:							
Woonhuis	Plaasopstal	1	900000	900000			
Arbeiders huise	1 Per arbeider	8	900000	7200000			
Buite geboue	2 Kantore & pakkamers	2	60000	120000			
Skuure	1 Groot skuur vir trekkers	1	300000	300000			
Skeerhokke	1 Vir skeer aksies	1	120000	120000			
Watervoorsiening	Stelsel vir veesuipings	1	300000	300000			
Omheining	Kampe vir vee	1	480000	480000			
Totaal vir vaste verbeterings (b)	(Is ingesluit by R8000/ha vir grond)			9420000			
Meganisasie:							
Item	**Beskrywing**	**R/nuut**	**Ouderdo**	**Depresiasie**	**Waarde**	**Leeftyd**	**Jaarliks**
Stropers/Havestors	kW						
1	220	3 700 000	3	925000	2775000	12	282638,9
Platsnyers	Kode						
1	30vt	350 000	3	87500	262500	12	26736,11
Trekkers	kW						
1	120	1 662 500	5	692708,333	969792	12	126996,5
2	75	901 500	5	375625	525875	12	68864,58
3	75	592 000	8	394666,667	197333	12	45222,22
4	50	385000	12	308000	77000	15	23955,56
Baler	5070	341 000	8	227333	113667	12	26048,61
Waterkar/brandbestryding	5000L WK	203 250	4	67750	135500	12	15526,04
Planters							
15 tand		1 104 000	3	276000	828000	12	84333,33
Diepbewerkings implement (chisel	9 tand super	156 000	8	104000	52000	12	11916,67
Vragmotor(ton)	5 ton	821 000	11	752583	68417	12	62715,28
Bakkies							
1	5013	254500	2	42417	212083	12	19440,97
2	5010	424400	8	282933	141467	12	32419,44
		10 895 150					
Losgoed en gereedskap:	Gereedskap, veehanterings apparaat ens.				120000		826814,2
Totaal meganisasie & toerusting (c)					6478633		
Vee:			Aantal	R/kve	Waarde		
Ramme			49	5000	247058		
Ooie			988	2500	2470580		
Vervangingsooie			198	2000	395293		
Lammers			1581	400	632468		
Hamels							
Totaal kleinvee: (d)					3745399		
Totale bates: (a+b+c+d)		11 015 150			**41348833**		

Continuous cash crop rotation systems under full CA principles inventory list for the Riversdale area

Inventaris							
Item	**Beskrywing**	**Aantal**	**R/item**	**Waarde**			
Grond & Vaste verbeterings:							
Grond (a)	Waarde sluit alle verebetringe i	1120	27790	31124800			
Vaste verebeterings:							
Woonhuis	Plaasopstal	1	900000	900000			
Arbeiders huise	1 Per arbeider	8	900000	7200000			
Buite geboue	2 Kantore & pakkamers	2	60000	120000			
Skuure	1 Groot skuur vir trekkers ens	1	300000	300000			
Skeerhokke	1 Vir skeer aksies	1	120000	120000			
Watervoorsiening	Stelsel vir veesuipings	1	300000	300000			
Omheining	Kampe vir vee	1	480000	480000			
Totaal vir vaste verbeterings (b)	(Is ingesluit by R27790/ha vir grond)			9420000			
Meganisasie:							
Item	**Beskrywing**	**R/nuut**	**Ouderdom**	**Depresiasie**	**Waarde**	**Leeftyd**	**Jaarlikse depres**
Stropers/Havestors	kW						
1	220,00	3 700 000	3	925000	2775000	12	282638,8889
	220,00	3 700 000	7	2158333	1541667	12	282638,8889
Platsnyers	Kode						
1	30vt	350 000	3	87500	262500	12	26736,11111
2	30vt	350 000	6	175000	175000	12	26736,11111
Trekkers	kW						
1	241	2 775 000	3	693750	2081250	12	211979,1667
2	120	1 662 500	5	692708,333	969792	12	126996,5278
4	100	789 500	8	526333,333	263167	12	60309,02778
5	80	631 500	10	526250	105250	12	48239,58333
6	50	385 000	12	308000	77000	15	23955,55556
Waterkar/brandbestryding	5000L	203 250	4	67750	135500	12	15526,04167
Planters							
12.3 m planter	7124	2 299 500	3	574875	1724625	12	175656,25
Laaiers			3	0	0	12	0
Vragmotor	5ton	821 000	11	752583	68417	12	62715,27778
Bakkies							
1		254500	2	42417	212083	12	19440,97222
2		424400	8	282933	141467	12	32419,44444
		18 346 150					
Losgoed en gereedskap:	Gereedskap, veehanterings apparaat ens.				120000		1395987,847
Totaal meganisasie & toerusting (c)		18 466 150			10652717		
Vee:			Aantal	R/kve	Waarde		
Ramme			0	5000	0		
Ooie			0	1200	0		
Vervangingsooie			0	850	0		
Lammers			0	200	0		
Hamels							
Totaal kleinvee: (d)					0		
Totale bates: (a+b+c+d)					**41777517**		

Annexure D: Example of gross profit calculations for good, average and poor year for barley.

Gars						
Inligting:						
Opbrengs potensiaal gegrond op reënvalverspreiding		**t/ha**				
1	**Goed**	3,3				
2	**Gemiddeld**	2,7				
3	**Swak**	2,1				
Prys R/t	3520					
1	Goed					
Buro marge beraming:						
Item	**Beskrywing**	**Eenheid**	**R/eenheid**	**Eenheid/ha**	**Herhalings**	**Waarde**
Bruto Inkomste:(a)						
Gars	Verkope	t	3520	3,3		11614,90
Versekering ontvang						
Eie gebruik						
Arbeidverbruik						
Voorraadaanpassing						
Totale bruto inkomste						**11614,90**
Toedeelbare veranderlike koste: (b)						4011,19
Kotrakwerk						
Oesversekering	SASRIA&Brand, wind-, oesversekering					0,00
Bemarkingskoste	Silokoste,droogkoste,heffings					0,00
Vervoer gehuur						
Totale toedeelbare veranderlike koste:						**4011,19**
Bruto Marge: (= a-b)						**7603,71**
Jaar						
2	Gemiddeld					
Buro marge beraming:						
Item	**Beskrywing**	**Eenheid**	**R/eenheid**	**Eenheid/ha**	**Herhalings**	**Waarde**
Bruto Inkomste:(a)						
Gars	Verkope	t	3520	2,7	0	9503,10
Versekering ontvang			0			
Eie gebruik			0			
Arbeidverbruik			0			
Voorraadaanpassing			0			
Totale bruto inkomste						9503,10
Toedeelbare veranderlike koste: (b)						4011,19
Kotrakwerk						
Oesversekering	SASRIA&Brand					0,00
Bemarkingskoste	Silokoste,droogkoste,heffings					0,00
Totale toedeelbare veranderlike koste:						**4011,19**
Bruto Marge: (= a-b)						**5491,91**
Jaar						
3	Swak					
Buro marge beraming:						
Item	**Beskrywing**	**Eenheid**	**R/eenheid**	**Eenheid/ha**	**Herhalings**	**Waarde**
Bruto Inkomste:(a)						
Gars	Verkope	t	3520	2,1		7391,30
Versekering ontvang						
Eie gebruik						
Arbeidverbruik						
Voorraadaanpassing						
Totale bruto inkomste						**7391,30**
Toedeelbare veranderlike koste: (b)						4011,19
Kontrakwerk						
Oesversekering	SASRIA&Brand					0,00
Bemarkingskoste	Silokoste,droogkoste,heffings					0,00
Totale toedeelbare veranderlike koste:						**4011,19**
Bruto Marge: (= a-b)						**3380,11**

Annexure E: Whole farm multi-period budgets for different rotation systems

Geheelplaas multi-periode

Opbrengs potensiaal gegrond op reënvalverspreiding

1	**Goed**
2	**Gemiddeld**
3	**Swak**

Jaar		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	
Koring & Gars: Jaar indeling (goed, gemiddeld, swak)		2	1	2	2	1	2	2	3	1	2	1	2	2	2	2	1	2	3	1	2	
Canola & Lupiene: Jaar indeling (goed, gemiddeld, sw		1	2	3	2	3	3	2	1	2	1	1	2	1	2	1	3	2	3	2	3	
Bruto marge:																						
			Good	Average	Bad																	
BPW			7612914	6847941,233	6082968,913																	
		Farm production v	5437,795395	4891,386595	4344,977795																	
Gewas	Hektaar																					
Koring/Wheat	156,80	R 865 777	R 1 172 949	R 865 777	R 865 777	R 1 172 949	R 865 777	R 865 777	R 558 606	R 1 172 949	R 865 777	R 1 172 949	R 865 777	R 865 777	R 865 777	R 865 777	R 1 172 949	R 865 777	R 558 606	R 1 172 949	R 865 777	
Gars/Barley	156,80	R 861 132	R 1 192 262	R 861 132	R 861 132	R 1 192 262	R 861 132	R 861 132	R 530 002	R 1 192 262	R 861 132	R 1 192 262	R 861 132	R 861 132	R 861 132	R 861 132	R 1 192 262	R 861 132	R 530 002	R 1 192 262	R 861 132	
Canola	78,40	R 596 131	R 430 566	R 265 001	R 430 566	R 265 001	R 265 001	R 430 566	R 596 131	R 430 566	R 596 131	R 596 131	R 430 566	R 596 131	R 430 566	R 596 131	R 265 001	R 430 566	R 265 001	R 430 566	R 265 001	
Lusern	392,00	R 1 756 287	R 1 756 287	R 1 756 287	R 1 756 287	R 1 756 287	R 1 756 287	R 1 756 287	R 1 756 287	R 1 756 287	R 1 756 287	R 1 756 287	R 1 756 287	R 1 756 287	R 1 756 287	R 1 756 287	R 1 756 287	R 1 756 287	R 1 756 287	R 1 756 287	R 1 756 287	
Kapitaal verkope		R 0	R 68 417	R 0	R 32 083	R 126 117	R 0	R 0	R 213 667	R 16 938	R 429 500	R 21 208	R 0	R 0	R 68 417	R 0	R 0	R 126 117	R 0	R 32 083	R 213 667	
Bruto marge: totale boerdery	**784,00**	**4079327,62**	**4620480,61**	**3748197,38**	**3945845,84**	**4512615,49**	**3748197,38**	**3913762,50**	**3654692,85**	**4569001,44**	**4508827,62**	**4738837,40**	**3913762,50**	**4079327,62**	**3982179,17**	**4079327,62**	**4386498,82**	**4039879,17**	**3109895,94**	**4584147,28**	**3961864,05**	
			4552063,94	3748197,38	3913762,50																	
		Gross margin per	3251,474245	2677,283845	2795,544645																	
			59,79%	54,73%	64,34%																	
Oorhoofse jaarlikse kostes																						
totale vaste koste		1211949,28	1211949,28	1211949,28	1211949,28	1211949,28	1211949,28	1211949,28	1211949,28	1211949,28	1211949,28	1211949,28	1211949,28	1211949,28	1211949,28	1211949,28	1211949,28	1211949,28	1211949,28	1211949,28	1211949,28	
Diverse koste (4%)		48477,9712	48477,9712	48477,9712	48477,9712	48477,9712	48477,9712	48477,9712	48477,9712	48477,9712	48477,9712	48477,9712	48477,9712	48477,9712	48477,9712	48477,9712	48477,9712	48477,9712	48477,9712	48477,9712	48477,9712	
Totaal:		**1260427,251**	**1260427,251**	**1260427,251**	**1260427,251**	**1260427,251**	**1260427,251**	**1260427,251**	**1260427,251**	**1260427,251**	**1260427,251**	**1260427,251**	**1260427,251**	**1260427,251**	**1260427,25**	**1260427,251**	**1260427,251**	**1260427,251**	**1260427,251**	**1260427,251**	**1260427,251**	
Marge na vaste en oorhoofse koste:		**2818900,37**	**3360053,36**	**2487770,13**	**2685418,59**	**3252188,24**	**2487770,13**	**2653335,25**	**2394265,60**	**3308574,19**	**3248400,37**	**3478410,15**	**2653335,25**	**2818900,37**	**2721751,92**	**2818900,37**	**3126071,57**	**2779451,92**	**1849468,69**	**3323720,03**	**2701436,80**	
Kapitaal uitleg:																						Herverkoopwaard
Langtermyn:																						
Grond & vaste verbeterings		31124800	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	31124800
Intermediêre kapitaal:	Ouderdom																					
Stropers/Havestors																						
1	3	2775000	0	0	0	0	0	0	0	0	3700000	0	0	0	0	0	0	0	0	0	0	616667
Platsnyers																						
1	3	262500	0	0	0	0	0	0	0	0	350000	0	0	0	0	0	0	0	0	0	0	58333
Trekkers																						
1	5	969792	0	0	0	0	0	0	1662500	0	0	0	0	0	0	0	0	0	0	0	1662500	1523958
2	5	525875	0	0	0	0	0	0	901500	0	0	0	0	0	0	0	0	0	0	0	901500	826375
3	8	197333	0	0	0	592000	0	0	0	0	0	0	0	0	0	0	0	592000	0	0	0	444000
4	12	77000	0	0	385000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	385000	0	359333
Baler	8	113667	0	0	0	341000	0	0	0	0	0	0	0	0	0	0	0	341000	0	0	0	255750
Waterkar/brandbestryding	4	135500	0	0	0	0	0	0	0	203250	0	0	0	0	0	0	0	0	0	0	0	16938
Planters																						
15 tand	3	828000	0	0	0	0	0	0	0	0	1104000	0	0	0	0	0	0	0	0	0	0	184000
Diepbewerkings implement	8	52000	0	0	0	156000	0	0	0	0	0	0	0	0	0	0	0	156000	0	0	0	117000
Vragmotor	11	68417	821000	0	0	0	0	0	0	0	0	0	0	0	821000	0	0	0	0	0	0	410500
Bakkies																						
1	2	212083	0	0	0	0	0	0	0	0	0	254500	0	0	0	0	0	0	0	0	0	63625
2	8	141467	0	0	0	424400	0	0	0	0	0	0	0	0	0	0	0	424400	0	0	0	318300
Gereedskap en toerusting		120000																				
Totaal intermediêre kapitaal:		6478633	821000	0	385000	1513400	0	0	2564000	203250	5154000	254500	0	0	821000	0	0	1513400	0	385000	2564000	5194779
Vee:		3745399																				3745399
Totale Kapitaal uitleg:		41348833	821000	0	385000	1513400	0	0	2564000	203250	5154000	254500	0	0	821000	0	0	1513400	0	385000	2564000	40064978
Netto jaarlikse vloei:		-38529932,24	2539053,36	2487770,13	2300418,59	1738788,24	2487770,13	2653335,25	-169734,40	3105324,19	-1905599,63	3223910,15	2653335,25	2818900,37	1900751,92	2818900,37	3126071,57	1266051,92	1849468,69	2938720,03	40202415,25	
IRR	5,39%																					
NPV	R 5 117 631																					

Kontantvloei ontledings by verskillende eie:vreemde kapitaal verhoudings:

Rentekoers	Nominaal	Breuk	Reëel
Uitleen	10,04%	0,10	4,30%
Verdienste	7%	0,07	0,99%
Inflasie koers	5,50%	0,06	
	Eie	Vreemde	
Kapitaal bydra verhouding	60,00%	40,00%	

Geheelplaas multi-periode (CBLWW)																						
Opbrengs potensiaal gegrond op reënvalverspreiding																						
1	**Goed**																					
2	**Gemiddeld**																					
3	**Swak**																					
Jaar		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	
Koring & Gars: Jaar indeling (goed, gemiddeld, swak)		2	1	2	2	1	2	2	3	1	2	1	2	2	2	2	1	2	3	1	2	
Canola & Lupiene: Jaar indeling (goed, gemiddeld, swak		1	2	3	2	3	3	2	1	2	1	1	2	1	2	1	3	2	3	2	3	
Bruto marge:																						
			Good	Average	Bad																	
BPW			7293076	5986853,973	4644828,91																	
		Farm productio	5209,340267	4276,324267	3317,73493																	
Gewas	Hektaar																					
Koring/Wheat	313,60	R 1 731 555	R 2 345 897	R 1 731 555	R 1 731 555	R 2 345 897	R 1 731 555	R 1 731 555	R 1 117 212	R 2 345 897	R 1 731 555	R 2 345 897	R 1 731 555	R 1 731 555	R 1 731 555	R 1 731 555	R 2 345 897	R 1 731 555	R 1 117 212	R 2 345 897	R 1 731 555	
Gars/Barley	156,80	R 861 132	R 1 192 262	R 861 132	R 861 132	R 1 192 262	R 861 132	R 861 132	R 530 002	R 1 192 262	R 861 132	R 1 192 262	R 861 132	R 861 132	R 861 132	R 861 132	R 1 192 262	R 861 132	R 530 002	R 1 192 262	R 861 132	
Canola	156,80	R 1 192 262	R 861 132	R 530 002	R 861 132	R 530 002	R 530 002	R 861 132	R 1 192 262	R 861 132	R 1 192 262	R 1 192 262	R 861 132	R 1 192 262	R 861 132	R 1 192 262	R 530 002	R 861 132	R 530 002	R 861 132	R 530 002	
Lupien	156,80	R 202 265	R 94 857	-R 48 354	R 94 857	-R 48 354	-R 48 354	R 94 857	R 202 265	R 94 857	R 202 265	R 202 265	R 94 857	R 202 265	R 94 857	R 202 265	-R 48 354	R 94 857	-R 48 354	R 94 857	-R 48 354	
Gma/covers	0,00	R 0	R 0	R 0	R 0	R 0	R 0	R 0	R 0	R 0	R 0	R 0	R 0	R 0	R 0	R 0	R 0	R 0	R 0	R 0	R 0	
Kapitaal verkope		R 0	R 68 417	R 52 625	R 32 083	R 101 158	R 308 333	R 29 167	R 138 542	R 16 938	R 760 375	R 21 208	R 0	R 0	R 68 417	R 52 625	R 0	R 101 158	R 308 333	R 61 250	R 138 542	
Bruto marge: totale boerdery	**784,00**	**R 3 987 214**	**R 4 562 565**	**R 3 126 960**	**R 3 580 759**	**R 4 120 966**	**R 3 382 668**	**R 3 577 842**	**R 3 180 283**	**R 4 511 086**	**R 4 747 589**	**R 4 953 895**	**R 3 548 675**	**R 3 987 214**	**R 3 617 092**	**R 4 039 839**	**R 4 019 807**	**R 3 649 834**	**R 2 437 195**	**R 4 555 398**	**R 3 212 876**	
			4494148,11	3074334,57	3548675,47																	
		Gross margin p	3210,105796	2195,953263	2534,7682																	
			61,62%	51,35%	76,40%																	
Oorhoofse jaarlikse kostes																						
totale vaste koste		1211949	1211949	1211949	1211949	1211949	1211949	1211949	1211949	1211949	1211949	1211949	1211949	1211949	1211949	1211949	1211949	1211949	1211949	1211949	1211949	
Diverse koste (4%)		48478	48478	48478	48478	48478	48478	48478	48478	48478	48478	48478	48478	48478	48478	48478	48478	48478	48478	48478	48478	
Totaal:		**1260427**	**1260427**	**1260427**	**1260427**	**1260427**	**1260427**	**1260427**	**1260427**	**1260427**	**1260427**	**1260427**	**1260427**	**1260427**	**1260427**	**1260427**	**1260427**	**1260427**	**1260427**	**1260427**	**1260427**	
Marge na vaste en oorhoofse koste:		**2726786,46**	**3302137,53**	**1866532,32**	**2320331,56**	**2860538,29**	**2122240,65**	**2317414,89**	**1919855,49**	**3250658,36**	**3487161,46**	**3693467,44**	**2288248,22**	**2726786,46**	**2356664,89**	**2779411,46**	**2759379,96**	**2389406,56**	**1176768,01**	**3294970,86**	**1952448,98**	
Kapitaal uitleg:																						Herverkoopwaa
Langtermyn:																						
Grond & vaste verbeterings		31124800	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	31124800
Intermediêre kapitaal:	Ouderdom																					
Stropers/Havestors																						
1	3	2775000	0	0	0	0	0	0	0	0	3700000	0	0	0	0	0	0	0	0	0	0	616667
	7	1541667	0	0	0	0	3700000	0	0	0	0	0	0	0	0	0	0	0	3700000	0	0	3083333
Platsnyers																						
1	3	262500	0	0	0	0	0	0	0	0	350000	0	0	0	0	0	0	0	0	0	0	58333
2	6	175000	0	0	0	0	0	350000	0	0	0	0	0	0	0	0	0	0	0	350000	0	320833
Trekkers																						
1	3	2081250	0	0	0	0	0	0	0	0	2775000	0	0	0	0	0	0	0	0	0	0	462500
2	5	969792	0	0	0	0	0	0	1662500	0	0	0	0	0	0	0	0	0	0	0	1662500	1523958
4	8	263167	0	0	0	789500	0	0	0	0	0	0	0	0	0	0	0	789500	0	0	0	592125
5	10	105250	0	631500	0	0	0	0	0	0	0	0	0	0	0	631500	0	0	0	0	0	368375
6	12	77000	0	0	385000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	385000	0	359333
Waterkar/brandbestryding	4	135500	0	0	0	0	0	0	0	203250	0	0	0	0	0	0	0	0	0	0	0	16938
Planters																						
12.3 m planter	3	1724625	0	0	0	0	0	0	0	0	2299500	0	0	0	0	0	0	0	0	0	0	383250
Laaiers	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Vragmotor	11	68417	821000	0	0	0	0	0	0	0	0	0	0	0	821000	0	0	0	0	0	0	410500
Bakkies																						
1	2	212083	0	0	0	0	0	0	0	0	0	254500	0	0	0	0	0	0	0	0	0	63625
2	8	141467	0	0	0	424400	0	0	0	0	0	0	0	0	0	0	0	424400	0	0	0	318300
Gereedskap en toerusting		120000																				
Totaal intermediêre kapitaal:		10652717	821000	631500	385000	1213900	3700000	350000	1662500	203250	9124500	254500	0	0	821000	631500	0	1213900	3700000	735000	1662500	8578071
Vee:		0																				0
Totale Kapitaal uitleg:		41777517	821000	631500	385000	1213900	3700000	350000	1662500	203250	9124500	254500	0	0	821000	631500	0	1213900	3700000	735000	1662500	39702871
Netto jaarlikse vloei:		-39050730	2481138	1235032	1935332	1646638	-1577759	1967415	257355	3047408	-5637339	3438967	2288248	2726786	1535665	2147911	2759380	1175507	-2523232	2559971	39992820	
IRR	3,04%																					
NPV	R -6 010 480,82																					
Kontantvloei ontledings by verskillende eie:vreemde kapitaal verhoudings:																						
Rentekoers	Nominaal	Breuk	Reëel																			
Uitleen	10,04%	0,10	4,30%																			
Verdienste	7%	0,07	0,99%																			
Inflasie koers	5,50%	0,06																				

Geheelplaas multi-periode (WBC)																					
Opbrengs potensiaal gegrond op reënvalverspreiding																					
1	**Goed**																				
2	**Gemiddeld**																				
3	**Swak**																				
Jaar		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
Koring & Gars: Jaar indeling (goed, gemiddeld, swak)		2	1	2	2	1	2	2	3	1	2	1	2	2	2	2	1	2	3	1	2
Canola & Lupiene: Jaar indeling (goed, gemiddeld, swak		1	2	3	2	3	3	2	1	2	1	1	2	1	2	1	3	2	3	2	3
Bruto marge:																					
			Good	Average	Bad																
BPW			8273674	6787601,956	5301529,96																
		Farm productio	5909,767111	4848,287111	3786,80711																
Gewas	Hektaar																				
Koring/Wheat	261,33	R 1 442 962	R 1 954 914	R 1 442 962	R 1 442 962	R 1 954 914	R 1 442 962	R 1 442 962	R 931 010	R 1 954 914	R 1 442 962	R 1 954 914	R 1 442 962	R 1 442 962	R 1 442 962	R 1 442 962	R 1 954 914	R 1 442 962	R 931 010	R 1 954 914	R 1 442 962
Gars/Barley	261,33	R 1 435 220	R 1 987 104	R 1 435 220	R 1 435 220	R 1 987 104	R 1 435 220	R 1 435 220	R 883 336	R 1 987 104	R 1 435 220	R 1 987 104	R 1 435 220	R 1 435 220	R 1 435 220	R 1 435 220	R 1 987 104	R 1 435 220	R 883 336	R 1 987 104	R 1 435 220
Canola	261,33	R 1 987 104	R 1 435 220	R 883 336	R 1 435 220	R 883 336	R 883 336	R 1 435 220	R 1 987 104	R 1 435 220	R 1 987 104	R 1 987 104	R 1 435 220	R 1 987 104	R 1 435 220	R 1 987 104	R 883 336	R 1 435 220	R 883 336	R 1 435 220	R 883 336
Lupien	0,00	R 0	R 0	R 0	R 0	R 0	R 0	R 0	R 0	R 0	R 0	R 0	R 0	R 0	R 0	R 0	R 0	R 0	R 0	R 0	R 0
Gma/covers	0,00	R 0	R 0	R 0	R 0	R 0	R 0	R 0	R 0	R 0	R 0	R 0	R 0	R 0	R 0	R 0	R 0	R 0	R 0	R 0	R 0
Kapitaal verkope		R 0	R 68 417	R 52 625	R 32 083	R 101 158	R 308 333	R 29 167	R 138 542	R 16 938	R 760 375	R 21 208	R 0	R 0	R 68 417	R 52 625	R 0	R 101 158	R 308 333	R 61 250	R 138 542
Bruto marge: totale boerdery	**784,00**	**R 4 865 286**	**R 5 445 655**	**R 3 814 143**	**R 4 345 485**	**R 4 926 512**	**R 4 069 852**	**R 4 342 569**	**R 3 939 992**	**R 5 394 175**	**R 5 625 661**	**R 5 950 330**	**R 4 313 402**	**R 4 865 286**	**R 4 381 819**	**R 4 917 911**	**R 4 825 354**	**R 4 414 560**	**R 3 006 016**	**R 5 438 488**	**R 3 900 060**
			5377237,87	3761518,40	4313402,14																
		Gross margin p	3840,884193	2686,79886	3081,00153																
			64,99%	55,42%	81,36%																
Oorhoofse jaarlikse kostes																					
totale vaste koste		1211949	1211949	1211949	1211949	1211949	1211949	1211949	1211949	1211949	1211949	1211949	1211949	1211949	1211949	1211949	1211949	1211949	1211949	1211949	1211949
Diverse koste (4%)		48478	48478	48478	48478	48478	48478	48478	48478	48478	48478	48478	48478	48478	48478	48478	48478	48478	48478	48478	48478
Totaal:		**1260427**	**1260427**	**1260427**	**1260427**	**1260427**	**1260427**	**1260427**	**1260427**	**1260427**	**1260427**	**1260427**	**1260427**	**1260427**	**1260427**	**1260427**	**1260427**	**1260427**	**1260427**	**1260427**	**1260427**
Marge na vaste en oorhoofse koste:		**3604858,62**	**4185227,29**	**2553716,15**	**3085058,22**	**3666085,22**	**2809424,49**	**3082141,55**	**2679564,55**	**4133748,12**	**4365233,62**	**4689902,69**	**3052974,89**	**3604858,62**	**3121391,55**	**3657483,62**	**3564926,89**	**3154133,22**	**1745588,75**	**4178060,62**	**2639632,82**
Kapitaal uitleg:																					
Langtermyn:																					
Grond & vaste verbeterings		31124800	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Intermediêre kapitaal:	Ouderdom																				
Stropers/Havestors																					
1	3	2775000	0	0	0	0	0	0	0	0	3700000	0	0	0	0	0	0	0	0	0	0
	7	1541667	0	0	0	0	3700000	0	0	0	0	0	0	0	0	0	0	0	3700000	0	0
Platsnyers																					
1	3	262500	0	0	0	0	0	0	0	0	350000	0	0	0	0	0	0	0	0	0	0
2	6	175000	0	0	0	0	0	350000	0	0	0	0	0	0	0	0	0	0	0	350000	0
Trekkers																					
1	3	2081250	0	0	0	0	0	0	0	0	2775000	0	0	0	0	0	0	0	0	0	0
2	5	969792	0	0	0	0	0	0	1662500	0	0	0	0	0	0	0	0	0	0	0	1662500
4	8	263167	0	0	0	789500	0	0	0	0	0	0	0	0	0	0	0	789500	0	0	0
5	10	105250	0	631500	0	0	0	0	0	0	0	0	0	0	0	631500	0	0	0	0	0
6	12	77000	0	0	385000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	385000	0
Waterkar/brandbestryding	4	135500	0	0	0	0	0	0	0	203250	0	0	0	0	0	0	0	0	0	0	0
Planters																					
12.3 m planter	3	1724625	0	0	0	0	0	0	0	0	2299500	0	0	0	0	0	0	0	0	0	0
Laaiers	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Vragmotor	11	68417	821000	0	0	0	0	0	0	0	0	0	0	0	821000	0	0	0	0	0	0
Bakkies																					
1	2	212083	0	0	0	0	0	0	0	0	0	254500	0	0	0	0	0	0	0	0	0
2	8	141467	0	0	0	424400	0	0	0	0	0	0	0	0	0	0	0	424400	0	0	0
Gereedskap en toerusting		120000																			
Totaal intermediêre kapitaal:		10652717	821000	631500	385000	1213900	3700000	350000	1662500	203250	9124500	254500	0	0	821000	631500	0	1213900	3700000	735000	1662500
Vee:		0																			
Totale Kapitaal uitleg:		41777517	821000	631500	385000	1213900	3700000	350000	1662500	203250	9124500	254500	0	0	821000	631500	0	1213900	3700000	735000	1662500
Netto jaarlikse vloei:		-38172658	3364227	1922216	2700058	2452185	-890576	2732142	1017065	3930498	-4759266	4435403	3052975	3604859	2300392	3025984	3564927	1940233	-1954411	3443061	40680004
IRR	5,29%																				
NPV	R 4 602 899,13																				
Kontantvloei ontledings by verskillende eie:vreemde kapitaal verhoudings:																					
Rentekoers	Nominaal	Breuk	Reëel																		
Uitleen	10,04%	0,10	4,30%																		
Verdienste	7%	0,07	0,99%																		
Inflasie koers	5,50%	0,06																			

Geheelplaas multi-periode (WLWC)																						
Opbrengs potensiaal gegrond op reënvalverspreiding																						
1	**Goed**																					
2	**Gemiddeld**																					
3	**Swak**																					
Jaar		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	
Koring & Gars: Jaar indeling (goed, gemiddeld, swak)		2	1	2	2	1	2	2	3	1	2	1	2	2	2	2	1	2	3	1	2	
Canola & Lupiene: Jaar indeling (goed, gemiddeld, swak		1	2	3	2	3	3	2	1	2	1	1	2	1	2	1	3	2	3	2	3	
Bruto marge:																						
			Good	Average	Bad																	
BPW			6839825	5620959,867	4357341,33																	
		Farm productio	4885,589333	4014,971333	3112,38667																	
Gewas	Hektaar																					
Koring/Wheat	392,00	R 2 164 443	R 2 932 371	R 2 164 443	R 2 164 443	R 2 932 371	R 2 164 443	R 2 164 443	R 1 396 515	R 2 932 371	R 2 164 443	R 2 932 371	R 2 164 443	R 2 164 443	R 2 164 443	R 2 164 443	R 2 932 371	R 2 164 443	R 1 396 515	R 2 932 371	R 2 164 443	
Gars/Barley	0,00	R 0	R 0	R 0	R 0	R 0	R 0	R 0	R 0	R 0	R 0	R 0	R 0	R 0	R 0	R 0	R 0	R 0	R 0	R 0	R 0	
Canola	196,00	R 1 490 328	R 1 076 415	R 662 502	R 1 076 415	R 662 502	R 662 502	R 1 076 415	R 1 490 328	R 1 076 415	R 1 490 328	R 1 490 328	R 1 076 415	R 1 490 328	R 1 076 415	R 1 490 328	R 662 502	R 1 076 415	R 662 502	R 1 076 415	R 662 502	
Lupien	196,00	R 252 831	R 118 571	-R 60 442	R 118 571	-R 60 442	-R 60 442	R 118 571	R 252 831	R 118 571	R 252 831	R 252 831	R 118 571	R 252 831	R 118 571	R 252 831	-R 60 442	R 118 571	-R 60 442	R 118 571	-R 60 442	
Gma/covers	0,00	R 0	R 0	R 0	R 0	R 0	R 0	R 0	R 0	R 0	R 0	R 0	R 0	R 0	R 0	R 0	R 0	R 0	R 0	R 0	R 0	
Kapitaal verkope		R 0	R 68 417	R 52 625	R 32 083	R 101 158	R 308 333	R 29 167	R 138 542	R 16 938	R 760 375	R 21 208	R 0	R 0	R 68 417	R 52 625	R 0	R 101 158	R 308 333	R 61 250	R 138 542	
Bruto marge: totale boerdery	**784,00**	**R 3 907 602**	**R 4 195 774**	**R 2 819 128**	**R 3 391 513**	**R 3 635 590**	**R 3 074 837**	**R 3 388 596**	**R 3 278 216**	**R 4 144 295**	**R 4 667 977**	**R 4 696 739**	**R 3 359 429**	**R 3 907 602**	**R 3 427 846**	**R 3 960 227**	**R 3 534 431**	**R 3 460 588**	**R 2 306 909**	**R 4 188 607**	**R 2 905 045**	
			4127357,38	2766503,25	3359429,38																	
		Gross margin p	2948,112413	1976,073747	2399,59241																	
			60,34%	49,22%	77,10%																	
Oorhoofse jaarlikse kostes																						
totale vaste koste		1211949	1211949	1211949	1211949	1211949	1211949	1211949	1211949	1211949	1211949	1211949	1211949	1211949	1211949	1211949	1211949	1211949	1211949	1211949	1211949	
Diverse koste (4%)		48478	48478	48478	48478	48478	48478	48478	48478	48478	48478	48478	48478	48478	48478	48478	48478	48478	48478	48478	48478	
Totaal:		**1260427**	**1260427**	**1260427**	**1260427**	**1260427**	**1260427**	**1260427**	**1260427**	**1260427**	**1260427**	**1260427**	**1260427**	**1260427**	**1260427**	**1260427**	**1260427**	**1260427**	**1260427**	**1260427**	**1260427**	
Marge na vaste en oorhoofse koste:		**2647174,93**	**2935346,79**	**1558700,99**	**2131085,46**	**2375162,33**	**1814409,33**	**2128168,79**	**2017788,59**	**2883867,63**	**3407549,93**	**3436311,26**	**2099002,13**	**2647174,93**	**2167418,79**	**2699799,93**	**2274003,99**	**2200160,46**	**1046481,33**	**2928180,13**	**1644617,66**	
Kapitaal uitleg:																						Herverkoopwaa
Langtermyn:																						
Grond & vaste verbeterings		31124800	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	31124800
Intermediêre kapitaal:	Ouderdom																					
Stropers/Havestors																						
1	3	2775000	0	0	0	0	0	0	0	0	3700000	0	0	0	0	0	0	0	0	0	0	616667
	7	1541667	0	0	0	0	3700000	0	0	0	0	0	0	0	0	0	0	0	3700000	0	0	3083333
Platsnyers																						
1	3	262500	0	0	0	0	0	0	0	0	350000	0	0	0	0	0	0	0	0	0	0	58333
2	6	175000	0	0	0	0	0	350000	0	0	0	0	0	0	0	0	0	0	0	350000	0	320833
Trekkers																						
1	3	2081250	0	0	0	0	0	0	0	0	2775000	0	0	0	0	0	0	0	0	0	0	462500
2	5	969792	0	0	0	0	0	0	1662500	0	0	0	0	0	0	0	0	0	0	0	1662500	1523958
4	8	263167	0	0	0	789500	0	0	0	0	0	0	0	0	0	0	0	789500	0	0	0	592125
5	10	105250	0	631500	0	0	0	0	0	0	0	0	0	0	0	631500	0	0	0	0	0	368375
6	12	77000	0	0	385000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	385000	0	359333
Waterkar/brandbestryding	4	135500	0	0	0	0	0	0	0	203250	0	0	0	0	0	0	0	0	0	0	0	16938
Planters																						
12.3 m planter	3	1724625	0	0	0	0	0	0	0	0	2299500	0	0	0	0	0	0	0	0	0	0	383250
Laaiers	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Vragmotor	11	68417	821000	0	0	0	0	0	0	0	0	0	0	0	821000	0	0	0	0	0	0	410500
Bakkies																						
1	2	212083	0	0	0	0	0	0	0	0	0	254500	0	0	0	0	0	0	0	0	0	63625
2	8	141467	0	0	0	424400	0	0	0	0	0	0	0	0	0	0	0	424400	0	0	0	318300
Gereedskap en toerusting		120000																				
Totaal intermediêre kapitaal:		10652717	821000	631500	385000	1213900	3700000	350000	1662500	203250	9124500	254500	0	0	821000	631500	0	1213900	3700000	735000	1662500	8578071
Vee:		0																				0
Totale Kapitaal uitleg:		41777517	821000	631500	385000	1213900	3700000	350000	1662500	203250	9124500	254500	0	0	821000	631500	0	1213900	3700000	735000	1662500	39702871
Netto jaarlikse vloei:		-39130342	2114347	927201	1746085	1161262	-1885591	1778169	355289	2680618	-5716950	3181811	2099002	2647175	1346419	2068300	2274004	986260	-2653519	2193180	39684988	
IRR	2,41%																					
NPV	R -9 028 944,40																					
Kontantvloei ontledings by verskillende eie:vreemde kapitaal verhoudings:																						
Rentekoers	Nominaal	Breuk	Reëel																			
Uitleen	10,04%	0,10	4,30%																			
Verdienste	7%	0,07	0,99%																			
Inflasie koers	5,50%	0,06																				

Geheelplaas multi-periode (WC)

Opbrengs potensiaal gegrond op reënvalverspreiding

1 **Goed**
2 **Gemiddeld**
3 **Swak**

Jaar	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
Koring & Gars: Jaar indeling (goed, gemiddeld, swak)	2	1	2	2	1	2	2	3	1	2	1	2	2	2	2	1	2	3	1	2
Canola & Lupiene: Jaar indeling (goed, gemiddeld, swak	1	2	3	2	3	3	2	1	2	1	1	2	1	2	1	3	2	3	2	3

Bruto marge:

			Good	Average	Bad																
BPW			7857470	6456187,733	5054905,33																
		Farm productio	5612,478667	4611,562667	3610,64667																
Gewas	Hektaar																				
Koring/Wheat	392,00	R 2 164 443	R 2 932 371	R 2 164 443	R 2 164 443	R 2 932 371	R 2 164 443	R 2 164 443	R 1 396 515	R 2 932 371	R 2 164 443	R 2 932 371	R 2 164 443	R 2 164 443	R 2 164 443	R 2 164 443	R 2 932 371	R 2 164 443	R 1 396 515	R 2 932 371	R 2 164 443
Gars/Barley	0,00	R 0	R 0	R 0	R 0	R 0	R 0	R 0	R 0	R 0	R 0	R 0	R 0	R 0	R 0	R 0	R 0	R 0	R 0	R 0	R 0
Canola	392,00	R 2 980 656	R 2 152 830	R 1 325 004	R 2 152 830	R 1 325 004	R 1 325 004	R 2 152 830	R 2 980 656	R 2 152 830	R 2 980 656	R 2 980 656	R 2 152 830	R 2 980 656	R 2 152 830	R 2 980 656	R 1 325 004	R 2 152 830	R 1 325 004	R 2 152 830	R 1 325 004
Lupien	0,00	R 0	R 0	R 0	R 0	R 0	R 0	R 0	R 0	R 0	R 0	R 0	R 0	R 0	R 0	R 0	R 0	R 0	R 0	R 0	R 0
Gma/covers	0,00	R 0	R 0	R 0	R 0	R 0	R 0	R 0	R 0	R 0	R 0	R 0	R 0	R 0	R 0	R 0	R 0	R 0	R 0	R 0	R 0
Kapitaal verkope		R 0	R 68 417	R 52 625	R 32 083	R 101 158	R 308 333	R 29 167	R 138 542	R 16 938	R 760 375	R 21 208	R 0	R 0	R 68 417	R 52 625	R 0	R 101 158	R 308 333	R 61 250	R 138 542
Bruto marge: totale boerdery	**784,00**	**R 5 145 099**	**R 5 153 618**	**R 3 542 073**	**R 4 349 357**	**R 4 358 534**	**R 3 797 781**	**R 4 346 440**	**R 4 515 713**	**R 5 102 139**	**R 5 905 474**	**R 5 934 235**	**R 4 317 273**	**R 5 145 099**	**R 4 385 690**	**R 5 197 724**	**R 4 257 376**	**R 4 418 432**	**R 3 029 853**	**R 5 146 451**	**R 3 627 989**
			5085201,28	3489447,68	4317273,28																
		Gross margin p	3632,286627	2492,462627	3083,76663																
			64,72%	54,05%	85,41%																
Oorhoofse jaarlikse kostes																					
totale vaste koste		1211949	1211949	1211949	1211949	1211949	1211949	1211949	1211949	1211949	1211949	1211949	1211949	1211949	1211949	1211949	1211949	1211949	1211949	1211949	1211949
Diverse koste (4%)		48478	48478	48478	48478	48478	48478	48478	48478	48478	48478	48478	48478	48478	48478	48478	48478	48478	48478	48478	48478
Totaal:		**1260427**	**1260427**	**1260427**	**1260427**	**1260427**	**1260427**	**1260427**	**1260427**	**1260427**	**1260427**	**1260427**	**1260427**	**1260427**	**1260427**	**1260427**	**1260427**	**1260427**	**1260427**	**1260427**	**1260427**
Marge na vaste en oorhoofse koste:		**3884671,63**	**3893190,69**	**2281645,43**	**3088929,36**	**3098106,76**	**2537353,76**	**3086012,69**	**3255285,29**	**3841711,53**	**4645046,63**	**4673807,96**	**3056846,03**	**3884671,63**	**3125262,69**	**3937296,63**	**2996948,43**	**3158004,36**	**1769425,76**	**3886024,03**	**2367562,09**

Kapitaal uitleg:

																						Herverkoopwaa
Langtermyn:																						
Grond & vaste verbeterings			31124800	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	31124800
Intermediêre kapitaal:		Ouderdom																					
Stropers/Havestors																							
	1	3	2775000	0	0	0	0	0	0	0	0	3700000	0	0	0	0	0	0	0	0	0	0	616667
		7	1541667	0	0	0	0	3700000	0	0	0	0	0	0	0	0	0	0	0	3700000	0	0	3083333
Platsnyers																							
	1	3	262500	0	0	0	0	0	0	0	0	350000	0	0	0	0	0	0	0	0	0	0	58333
	2	6	175000	0	0	0	0	0	350000	0	0	0	0	0	0	0	0	0	0	0	350000	0	320833
Trekkers																							
	1	3	2081250	0	0	0	0	0	0	0	0	2775000	0	0	0	0	0	0	0	0	0	0	462500
	2	5	969792	0	0	0	0	0	0	1662500	0	0	0	0	0	0	0	0	0	0	0	1662500	1523958
	4	8	263167	0	0	0	789500	0	0	0	0	0	0	0	0	0	0	0	789500	0	0	0	592125
	5	10	105250	0	631500	0	0	0	0	0	0	0	0	0	0	0	631500	0	0	0	0	0	368375
	6	12	77000	0	0	385000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	385000	0	359333
Waterkar/brandbestryding		4	135500	0	0	0	0	0	0	0	203250	0	0	0	0	0	0	0	0	0	0	0	16938
Planters																							
12.3 m planter		3	1724625	0	0	0	0	0	0	0	0	2299500	0	0	0	0	0	0	0	0	0	0	383250
Laaiers		3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Vragmotor		11	68417	821000	0	0	0	0	0	0	0	0	0	0	0	821000	0	0	0	0	0	0	410500
Bakkies																							
	1	2	212083	0	0	0	0	0	0	0	0	0	254500	0	0	0	0	0	0	0	0	0	63625
	2	8	141467	0	0	0	424400	0	0	0	0	0	0	0	0	0	0	0	424400	0	0	0	318300
Gereedskap en toerusting			120000																				
Totaal intermediêre kapitaal:			10652717	821000	631500	385000	1213900	3700000	350000	1662500	203250	9124500	254500	0	0	821000	631500	0	1213900	3700000	735000	1662500	8578071
Vee:			0																				0
Totale Kapitaal uitleg:			41777517	821000	631500	385000	1213900	3700000	350000	1662500	203250	9124500	254500	0	0	821000	631500	0	1213900	3700000	735000	1662500	39702871
Netto jaarlikse vloei:			-37892845	3072191	1650145	2703929	1884207	-1162646	2736013	1592785	3638462	-4479453	4419308	3056846	3884672	2304263	3305797	2996948	1944104	-1930574	3151024	40407933	

IRR 5,13%
NPV R 3 872 661,94

Kontantvloei ontledings by verskillende eie:vreemde kapitaal verhoudings:

Rentekoers	Nominaal	Breuk	Reëel
Uitleen	10,04%	0,10	4,30%
Verdienste	7%	0,07	0,99%
Inflasie koers	5,50%	0,06	

Annexure F: GM and AVC of wheat following different crops