The cost implications of technology options for winter cereal production systems in the Swartland

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Declaration

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Abstract

Global population growth has placed pressure on commercial agriculture to increase food supply, in an environmentally manner. While producers are faced with an increasing cost-price squeeze.

Precision agriculture (PA), is emerging as one of the most sustainable agricultural production practices. Revolutionary technological developments have allowed producers to intensify agricultural mechanisation and increase field sizes, by responding to spatial and temporal variations that exist within fields. PA offers a practical, economic and environmental solutions. Increased yields, reduced input costs and more efficient operation times, result in higher profitability. PA has been adopted by a number of commercial grain producers in the Western Cape, to varying degrees and for a number of reasons. Adoption has taken place despite the absence of any policy support framework directed at PA, therefore, has been market driven.

Benefits of PA are well documented, while, the financial implications that these benefits have on the farming operation are not. The study utilises primary, trial, and secondary data to analyse the financial implications of various production methods over an extended period.

Farm systems are complex, consisting of numerous interrelated components. A whole-farm budget model is developed within a systems approach to measure the impact that improved technologies have on a production system. A trustworthy whole-farm model providing an accurate representation of a real-life farm requires insight across many scientific disciplines. Multidisciplinary approach is used to bridge the gap between practical, on farm, and scientific knowledge. To serve as a basis for comparison, the whole-farm model was based on a conventional typical farm within the Middle Swartland, relative homogeneous farming area. Trial data on systems from Langgewens experimental farm served as starting point for the research. The data was fitted for use in financial analysis and as input to the typical farm model. A key role of the inter-disciplinary approach was to ensure that data and the model design accurately reflect a PA system with its key underlying processes.

The financial evaluation of the various production systems showed that conventional agricultural practices, soil tillage and uniform input application, are financially constrained. Conventional practices have high mechanical costs per hectare and are vulnerable to input price fluctuations. PA reduced the mechanical costs of production per hectare, resulting in a more resilient farm operation. Modern production systems, in the long-run, were more resilient to the cost-price squeeze than conventional systems.

Opsomming

Wêreldwye populasie groei plaas druk op landbou om voedsel aanbod te verhoog op ŉ omgewingsvriendelike manier. Terselfdertyd konfronteer ŉ toenemende koste-prys druk produsente.

Presisie boerdery (PB), ontluik as een van die mees volhoubare landbouproduksiestelsels. Revolusionêre tegnologiese ontwikkelinge het produsente toegelaat om landbou-meganisasie te intensiveer op groter oppervlaktes deur te reageer op ruimtelike en temporele variasie wat binne landerye voorkom. PB bied ŉ praktiese, ekonomiese en omgewingsvriendelike oplossing. Verhoogde opbrengs, verlaagde insetkoste, meer doeltreffende bewerkingsperiodes veroorsaak beter winsgewendheid. PB is aangeneem deur ŉ aantal kommersiële graanprodusente in die Wes-Kaap. Hierdie aanname het plaasgevind ten spyte van die afwesigheid van beleidsondersteuning.

Die voordele van PB is goed geboekstaaf, maar die finansiële betekenis van die voordele is tans steeds redelik onduidelik. Hierdie studie gebruik proefdata as basis om die finansiële implikasies van verskillende produksie praktyke te evalueer oor ŉ langer termyn.

Boerdery stelsels is kompleks en bestaan uit verkillende komponente en gepaardgaande interverwantskappe. ŉ Geheelplaas begrotingsmodel is binne ŉ stelselsbenadering ontwikkel om die impak van verbeterde tegnologie te bepaal. ŉ Geloofwaardige geheelplaas model wat ŉ akkurate refleksie van ŉ werklike plaas verskaf vereis insig vanuit verskillende wetenskaplike dissiplines. ŉ Multidissiplinêre benadering is gebruik om die gaping te oorbrug tussen wetenskaplike kennis. Om as basis vir vergelyking te dien is die tipiese plaas baseer op ŉ konvensionele plaas vir die Middel Swartland. Proefdata van stelsels van die Langgewens Proefplaas het gedien as vertrekpunt vir die navorsing. Die data is pasgemaak vir gebruik in die finansiële analise en as inset in die geheel plaas model. ŉ Kern rol van ŉ multidissiplinêre benadering was om te verseker dat die data en die model die onderliggende konsep van presisie boerdery akkuraat reflekteer.

Die finansiële evaluasie van die verskillende produksiestelsels het gewys dat konvensionele produksiepraktyke, grondbewerking en uniforme bemesting finansiële beperking meebring. Konvensionele praktyke se meganiesekoste per hektaar is hoog

en is blootgestel aan insetkoste fluktuasies. Presisieboerdery verminder die meganisasiekoste per hektaar wat 'n meer lewenskragtige stelsel tot gevolg het. Moderne produksiestelsel is oor die langtermyn meer bestand teen die koste-prys knyptang in vergelyking met konvensionele stelsels.

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Chapter 1: Introduction and problem statement

1.1. Introduction

Technological advances from several industries contribute significantly to various agricultural production systems (Zhang, Wang & Wang, 2002). The industrial age provided agriculture with mechanisation and synthetic fertilisers, while the technological age presented genetic engineering and automation. More recently, the information age has allowed technological advances to be combined with precision agriculture (Hendriks, 2011).

The aim of precision agriculture (PA), namely responding to spatial and temporal variations that exist within fields, has for the past few decades been gaining momentum in research. Prior to the implementation of agricultural mechanisation, very small field sizes allowed farmers to manually adapt treatments. However, due to increasing field area's and further intensification of agricultural mechanisation, it has become progressively difficult to measure and respond to field variability without revolutionary technological developments (Stafford, 2000).

The concept of PA developed towards a systems approach which seeks to reorganise the total farming system to achieve low-inputs, high efficiency and sustainable agricultural production (Blackmore, 2003). This new approach is advanced, and challenges conventional production strategies. It is based on the emergence and convergence of several technologies, e.g. geographic information system (GIS), global positioning system (GPS), miniature computer components, automatic control, in-field and remote sensing, mobile computing, advanced information processing and telecommunications (Berry, Delgado, Pierce & Khosla, 2005; Batte & Ehsani, 2006).

Modern commercial producers are constantly faced with an ever increasing cost-price squeeze. The basic features of the supply-demand model for agricultural products can be put forward as follows; (i) the demand is very inelastic (ii) the supply is very inelastic (iii) the demand increases slowly over time and (iv) the supply increases notably quicker. An implication is that farm product prices decline over time in real terms. Importantly, it requires technological progress sufficient to generate only a slightly larger rate of increase in supply compared to demand to cause prices to fall substantially, or small demand shocks to cause price fluctuations (Gardner, 1992).

The agricultural sectors unique phenomenon, the cost price squeeze, is distinctly heterogeneous aggregate, as it includes both raw materials such as corn and soybeans and the products made from them i.e. pork and chicken. Producers then have important investment decisions to consider. Taking into account the financial, societal and environmental factors, the investment decision soon becomes an arduous task.

PA offers practical, economic and environmental solutions. Increased yields, reduced input costs and more productive operation times, will result in higher profits. Factors such as farm size, cropping cycles, soil profile variations and consequently yield variations all effect the economics of farming. Benefits of PA stem largely from a reduction in operator and human factors, as well as a reduction in waste (Knight et al, 2003).

The focus of PA has two applications; (i) developing a comprehensive database as a result of monitoring production variability in both space and time components, and (ii) improving the intended response (Whelan et al, 1997). Generally, the emergence of new technologies has been a result of ‘developer push’ rather than ‘user pull’. Unfortunately, insufficient attention is paid to well-known adoption paradigms and consequently, the adoption process of PA leaves a lot of room for improvement. There is often a knowledge gap between developers and users of PA-technologies, and often very little effort is made to bridge this gap. Developers can exert a stronger, more positive influence on the rate and breadth of adoption by focusing on the development of protocols and realistic performance criteria (Lamb, Frazier & Adams, 2008).

In view of the world population, crossing the seven billion mark, and expected to increase by a further three billion in the next three decades, world food security has become a major concern. Arable land resources are finite, therefore providing, a limited amount of resources, causing pressures on arable land to continually increase production. Based on projections; arable land, per capita, will decline from about 0.23 hectares (2000) to about 0.15 hectares in 2050. On the other hand, global food demand is projected to increase by 1.5 – 2 times. Increased demand can be associated to a growing population as well as demand for richer diets by those climbing the economic ladder. One of the major concerns is the increased volatility in the cost of agricultural inputs and the income generated from farm products that contribute to the instability of the farm economy. To alleviate such pressures lies in the introduction of new technologies to; improve crop yields, provide more information for better in-field management; reduce chemical and fertiliser input costs through more efficient application, increase traceability through more accurate farm records, increase profit margins and reduce the overall farm environmental footprint. This can be translated to improving operational efficiencies in order to optimise inputs and outputs. It is important to note that although technological innovations have the potential to alleviate various problems faced by current and future generations, an integrated approach to implementation will prove vital to strategical success (Seelan, Laguette, Casady & Seielstad, 2003; Hendriks, 2011).

The South African agricultural market faces similar challenges. Increasing input costs notably with regards to labour, low and fluctuating commodity prices and a degree of political uncertainty are common issues. These factors will necessitate local producers to monitor and manage their farming operations more effectively. The implementation of PA-technologies has the ability to reduce a number of issues, currently faced by society, and more specifically the South African agricultural sector, to enhance sustainability in the local agricultural sector (Hendriks, 2011).

1.2. Background and problem statement

The South African agricultural landscape is evolving at a rapid rate. External factors, for example; increasing oil prices, fluctuations of the exchange rate against other major currencies and increasing minimum wages are a few factors which contribute to ever increasing input costs and exacerbate the ‘farm problem’. Fluctuations of commodity prices, together with constantly increasing input costs place added pressure on local producers. South African agriculture is following the trend of more developed countries, in the sense that small less efficient producers are pushed out of the sector, giving more efficient large scale producers the opportunity to expand. This has resulted in a ‘grow or go’ situation. This has left the sector having fewer producers with larger commercial operations. Two factors have played a significant role in the declining number of local farmers. Firstly, uncertainty, driven by political interference in the form of new policies and trade agreements. Secondly, as the South African economy develops and the local markets begin to saturate mainly the most efficient producers will survive. These two factors along with changing rainfall patterns, have placed significant pressure on the South African farmer.

The Swartland area was named after the renosterbos (rhinoceros bush) that turns black after the rain. The Swartland is a farming region within the Western Cape region of South Africa and typically characterized as a Mediterranean climate. It receives winter rainfall averaging 400mm from March to mid-October and hot dry summers. The Swartland differs from the rest of the Western Cape in that the summer months are extremely hot and dry with a complete absence of rainfall. Other wheat producing areas of the Southern Cape receive up to 40 percent of annual rainfall in the summer. The soils are dominated by what's known as Malmesbury shale, shallow sandy-loam soils, with low clay content, and are generally rocky (Wiese, 2013). As a result, there are no summer rain fed crops grown in the Swartland. The Swartland is most similar to the cereal production areas of Western Australia and North Africa (Knott, 2015).

Taking the factors above into consideration, it becomes clear that certain strategies used over the previous decade will not ensure sustainable and profitable production for future generations. Strategies that promote reduced inputs, environmental protection and yield improvements will be central to profitable farming operations in the current and future environments. It seems that the concepts and strategies of precision agriculture and its technologies have the potential to provide farmers with the ability to produce at a more efficient capacity than was previously achievable.

There are however some uncertainty regarding the trade-off between different levels of technology and the cost. The research question for this project is what are the implications on profitability of improved technologies on selected crop systems in the Swartland?

1.3. Objectives of the study

The main aim of the study is to determine the profitability implications of improved technologies on selected crop systems that producers implement to improve productivity of grain production in the Southern Cape.

The primary objectives of the study are;

1. To identify and evaluate the financial feasibility of the available strategies that farmers can implement to improve productivity, namely precision agriculture.
2. Evaluate the financial and economic aspects of the strategies.

The study will investigate further the definition of precision agriculture and the alternate strategies which farmers have available to improve productivity, as well as the various financial benefits and costs associated with the implementation of PA.

Secondary Objectives

After achieving the primary objectives above, the following will represent the secondary objectives:

- Assess the adoption of precision agriculture, and the barriers that producers face when adoption PA.
- Identify the most efficient tractor planter combination for farmers i.e. conventional / minimum-tillage / no-tillage.

1.4. Proposed method

In essence this is an exploratory research approach tha will apply operational management principles to analyse the effectiveness of PA-technologies in improving the efficiency of grain production in the Southern Cape. The aim of the study is to analyse the financial feasibility of improved technologies, (Precision Agriculture-technologies), of selected strategies, used by farmers to achieve more profitable and efficient production. This will be achieved by identification of various precision technologies as well as their result on farming operations, by measuring the mechanical cost implications of these strategies. The study will focus on winter grain production in the Swartland area of the Western Cape A typical wheat / canola farm will be modelled to identify and measure the financial implications of selected strategies.

The information with regards to the range of PA technologies as well as their potential on farm performance will be obtained from relevant literature and various online databases as well as personal communications involved in the agricultural sector in the production area in focus.

To fully understand the origins and potential of PA within the Western Cape, an overview of the relevant literature will be conducted, outlining key concepts, benefits and challenges that precision technologies can offer producers. The exploratory nature of the research means a comprehensive literature must be conducted to fully understand the implications of PA. A whole-farm multi-period budget model is the preferred method used to evaluate the financial implications, on a farm level, of a change of production method on a typical farm. This method is inexpensive and can accurately model the possible financial implications, of changing input combinations, using mathematical and accounting formulas in excel spreadsheets (Microsoft Office).

Observations made from the literature will be used in developing a whole-farm multi-period budget model. Conventional production methods will form a base model, adapting observations from the literature, by consulting with experts in the Western Cape agricultural sector, will allow a model of both PA and CA to be developed in conjunction with the base. Using parameters put forward by previous studies, a 'typical farm' in the Swartland could be developed, see (Knott, 2015). The study focus is regarding the financial implications that machinery have on a whole farm, for specific production methods, for this reason the directly allocable costs, gross margin (GM) calculation, are assumed constant for all systems and the directly allocable costs section will be the main focus of the study. It is important to note that CA and PA systems both have implications on directly allocable costs in terms of yield, quality and input requirements, due to differentiation of managerial practices. Note will be made in terms of the effect on yield for each system and how this will affect enterprise GM, however not all directly allocable cost implications will be discussed.

1.5 Layout of the rest of the thesis

The thesis is comprised of five chapters. Chapter 1 is an introductory chapter which puts forward the problem statement with a small background to highlight thhe importance of the study.

Chapter 2 is comprised of a comprehensive literature review. Which focuses on relevant studies which have been completed and observations made about the topic. Using these observations, assumptions can be established and utilised in the construction of the whole-farm multi-period budget model.

Chapter 3 focuses on the methods and materials utilised in the research project. The chapter highlights the complexities that exist in agricultural systems, as well as how the budget model was constructed, and assumptions adapted to a South African context. The concept of model simulation is outlined with particular focus of budget modelling, the method of evaluation in this study. Chapter 4 elaborates on the findings of the model constructed in Chapter 3.

Chapter 5 contains the conclusions of the study, summary, and ends with recommendation for future study.

Chapter 2: Literature Review

2.1 Introduction

The introduction of the farm problem, discussed in Chapter One, has placed many commercial farmers in a financial conundrum. The definition of precision agriculture, need to be established firstly. This will add scope to the study, and relate the concept to the Western Cape.

Understanding adoption rates of precision technologies, in developed countries, and the factors which influence the adoption of the technology, will assist in creating a greater understanding of the current adoption rates of PA within South Africa.

Precision technologies offer an opportunity to improve productive efficiencies, by reducing input costs. It also has broader applications in terms of environmental conservation. These applications will be mentioned and discussed. Although not a pivotal component of the study, due too current environmental and societal pressures on agricultural production practices, awareness of the sustainability implications of PA-technologies is important. The proceeding section will discuss the financial benefits of implementing a PA approach to production. Financial costs of adopting PA and the implications there after will be discussed, while mentioning the financing options available to small scale producers. Finally, a discussion of the various budgeting techniques will provide perspective of how the financial implications of PA will be determined.

2.2 Precision agriculture definition

Precision agriculture (PA), site specific management, has been receiving an increasing amount of attention (over the past decade) from a number of stakeholders within the agricultural sector. These include agribusinesses, consultants, producers, traders and politicians. All of whom have over the past decade been primed for new developments. Development requirements are the outcome of profitability constraints, environmental concerns over current production practices and the improvement of technologies that have numerous applications in the agricultural sector (Schepers & Francis, 1998).

The fundamentals of PA have been appreciated for many centuries. Before the advent of agricultural mechanisation, small field sizes allowed farmers to vary production treatments manually. Increasing field sizes have made it difficult to manage in-filed variability without significant technological improvements.

PA can be defined as a conceptualised systems approach. This approach seeks to reorganise the total farm system towards a low input, high efficiency, sustainable system. This system benefits from the emergence of a number of technologies including; Geographic Information System (GIS), Global Positioning System (GPS), miniaturised computer components, automatic control, in-field and remote sensing, remote computing, advanced information processing and telecommunications. The agricultural industry is capable of gathering comprehensive data in both spatial and temporal production variability (Zhang *et al.*, 2002). The goal of PA is now to respond to the variability that is measured on a small scale. The spatial variability that exists within field boundaries, i.e. changes in crop response to soil type, is the basis for the emphasis of PA research and variable rate technology applications (Tozer, 2009).

The applications of site-specific management of agricultural inputs, is achieved by dividing a field into smaller management zones, which are more homogenous in properties of interest than the field as a whole. Thus, management zones within a field can vary for different inputs. In this instance, a single rate for each specific input within a zone is applied. The number of distinctive management zones within a field is a function of the natural variability within the field, field size, and certain management factors. The size of the zone is limited by the ability of the farmer to differentiate management for regions within a field, GPS systems, have allowed producers to control application of inputs by implements limiting size and shape restrictions of management zones (Zhang *et al.*, 2002).

PA can be defined as a, 'management strategy that uses information technologies to bring data from multiple sources to bear on decisions associated with crop production'. This definition is used by the National Research council (Adrian, Norwood & Mask, 2005; National Research Council, 1997). It is important to note that the definition of precision agriculture is still evolving as technology changes / advances and our understanding of what is achievable still constantly increases. A generic interpretation of PA would be 'the kind of agriculture that increases the number of correct decisions per unit of land, and per unit of time, with net benefits ' (McBratney, Whelan, Ancev & Bouma, 2005).

There is much more to agriculture than crop management, which forms one aspect of the term. Similarly, the term precision agriculture should be applied more generally to the use of information technology in all aspects of agriculture, in which Site Specific Management (SSM) forms one aspect (Plant, 2001). Mechanical operations of the production process will be the focus of this study.

2.2.1 Precision technologies

Technological developments are the driving force behind precision agriculture efficiency benefits. For the effective and efficient implementation of a PA system, requires technology (Zhang *et al.*, 2002; Hendriks, 2011). **Error! Reference source not found.**, gives a graphic representation of the variety, as well as the percentage adoption of the precision technologies and agricultural data management tools. (2016, August 2)

The data was collected from surveys distributed to farmers, at extension sponsored events in Nebraska county (United States) in early 2015. Which provide a good indication of the preferred technologies.

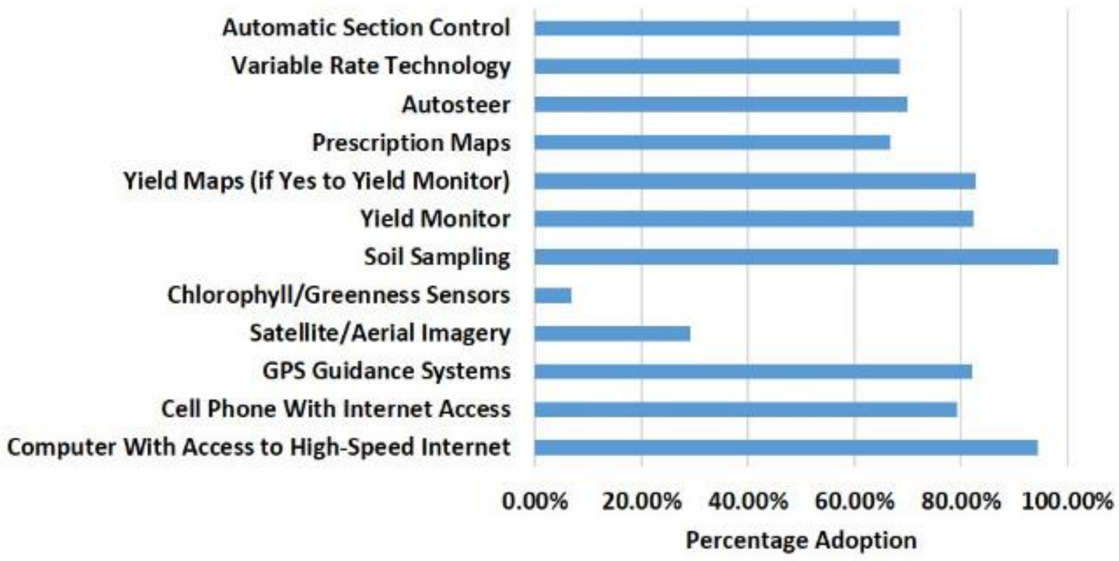

Figure 2.1: Precision agriculture technology usage: (2016, August 2).

Precision agriculture is not a single technology, but rather a set of various component technologies from which farmers can select to form a system that meets their unique needs and management style. By individual farmers customising precision systems to best suite individual operations, better results can be obtained while saving costs on irrelevant technologies (Batte & Ehsani, 2006). The generally significant technologies include; sensors, controls and remote sensing, and will be discussed in more detail.

2.2.1.1 Sensors: Yield, field, soil and anomaly.

Robust, low cost and preferably real-time sensing systems are needed for implementing various PA technologies.

Yield sensors: grain yields are measured using four types of yield sensors, impact or mass flow sensors, weight-based sensors, optical yield sensors and x-ray sensors. Most agricultural equipment companies provide optional yield mapping systems for combine harvesters.

Field sensors: comprise of a range of commercial sensors which receive and process GPS signals. These are essential for guiding and maintaining vehicle movements and position.

Soil sensors: a near infrared (NIR) soil sensor measures soil reflectance within the waveband of 1600 – 2600 mm to predict soil organic matter and moisture contents of surface and subsurface soils. Other soil sensing equipment, such as a soil electrical-conductivity (EC) sensor, has proven effective at detecting several yield-limiting factors in non-saline soils (Lund *et al*., 2000).

Anomaly sensors: include several commercially available weed sensors. An intelligent sensing and spraying system which is able to detect weed-infested zones with a high accuracy level.

2.2.1.2 Controls: VRT agro-chemical applicators, Automatic guidance systems.

VRT agro-chemical applicators: a number of equipment manufacturers are now producing controllers, sprayers, air-spreaders and herbicide applicators for variable rate technological applications. Optical sensors, which are able to measure flow rates of granular fertilisers etc. provide important feedback of a variable rate spreader.

Automated guidance systems: are able to position a moving vehicle within 30cm or less using high precision DGPS. In years to come AGS systems may replace conventional equipment markers for spraying or planting, as well as providing a valuable field scouting tool.

2.2.1.3 Remote sensing, (RS).

Precision farming requires information on crop condition frequently throughout the growing season, and at a high spatial resolution. Until recently, satellite sensors were inadequate to provide frequent coverage at required resolutions (Seelan *et al.*, 2003). Remote sensing has a broad number of applications in agriculture, particularly with the detection and classification of anomalies, which occur within field boundaries. These include predictions of nitrogen requirements of crops, assess insect damage in wheat, assist in insecticide application, detection of weeds, quantify hail or wind damage in crops and finally detecting and classifying other various anomalies which may occur (Zhang *et al.*, 2002; Thorp & Tian, 2004).

Satellite remote sensing hold much promise for within-field monitoring, but there are issues associated with the adoption of RS. Problems include timeliness, cloud cover, cost, poor spatial resolution and a lack of processing produce image data which is of use to crop managers (Zhang *et al.*, 2002; Ge, Thomasson & Sui, 2011).

2.2.2 The precision agriculture cycle

Precision agriculture can be explained with more ease by using a cycle. The system, which comprises of several components are imperative to the effective and efficient functionality of the system. The components are dependent on one another. Subsequently management is the key component, because miss-management of a single component will eventually influence other components and ultimately the system as a whole (Grisso *et al.*, 2004).

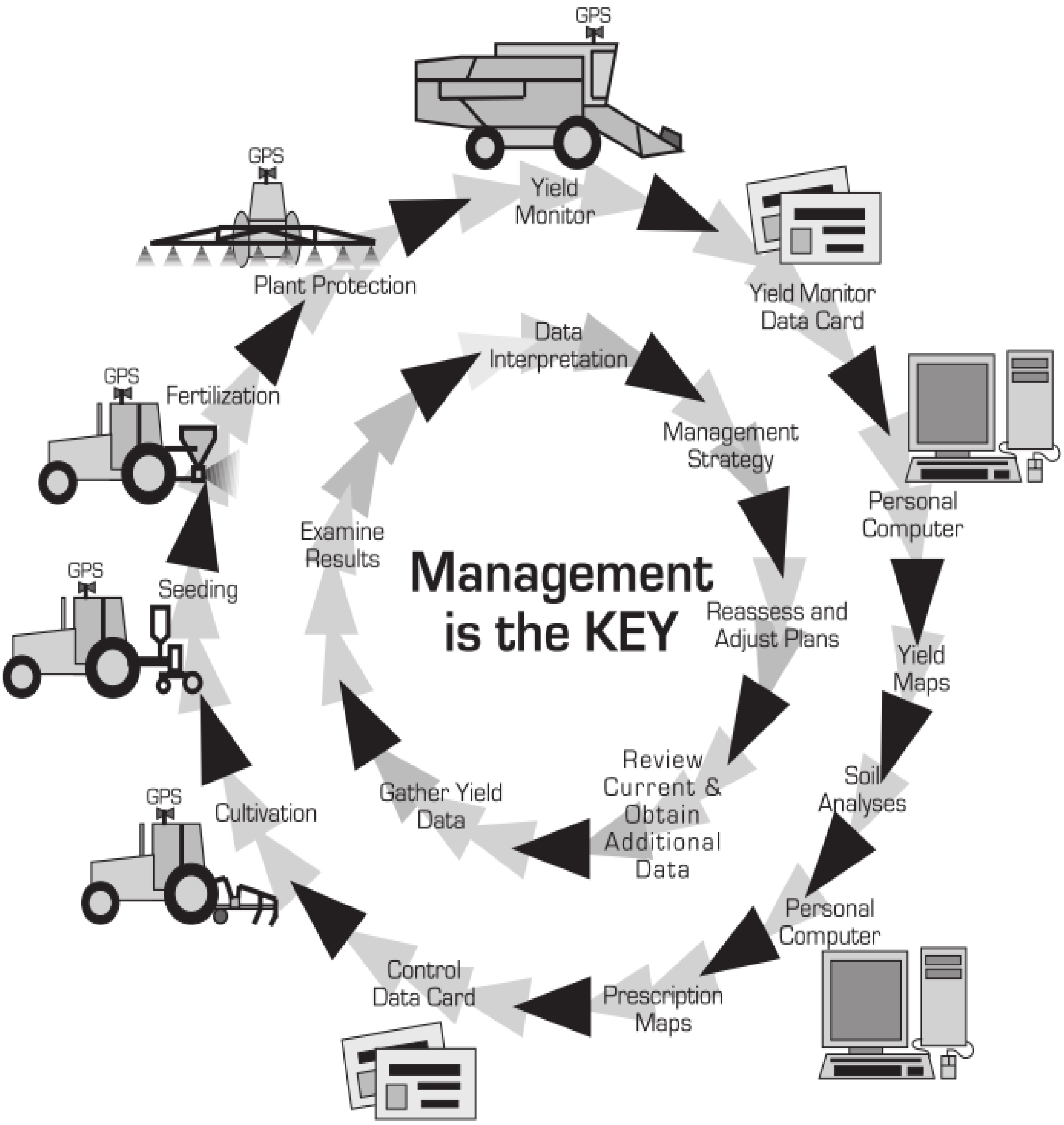

Figure 2.2*:* Schematic representation of the components of the precision agriculture cycle illustrating their interdependence, with equipment use and technology overlaid (Grisso *et al.*, 2004).

2.2.2.1 Elements of PA

Precision agriculture relies on the following three main elements

- **Information** – timely and accurate information is the modern farmer's most valuable resource. Data should include crop characteristics, soil properties, hybrid responses, soil properties, fertility requirements, weather predictions, weed and pest populations, plant growth responses, harvest yield, post-harvest processing and lastly marketing projections. Farmers must locate, analyse and utilise the available information (Inner circle of Figure.2), at each stage of the cropping system.
- **Technology** – each individual producer must assess how new technologies can be adapted to their operations, to improve efficiency. For example, farmers can utilise personal computers (PC's) to effectively organise, analyse, and manage data. By doing so, records can easily be accessed and used for current strategy development. Personal computers offer a wide variety of software such as GIS, GPS, spreadsheets and various other data manipulation packages. By linking PC's with vehicle mounted sensors and controls, producers are able to gain access to real time information that can then be used to adjust or control operations.
- **Decision support systems (DSS)** – is an essential component to the PA cycle. Decision support combines traditional management skills with PA-technologies and tools to assist farmers make the best management choices for their production system, Figure. Unfortunately, decision support systems have either been unreliable or difficult to understand. Establishing and building databases based on relationships between input and potential yields, refining analytical tools while increasing agronomic knowledge at a local level can prove difficult tasks for farmers. DSS remain the least developed aspect of PA. Diagnostic and database development, in the long-run, is expected to prove more beneficial that the actual technologies used (Grisso *et al.*, 2004).

2.2.3 Logical steps in establishing a PA system:

Precision farming is not applicable to every field. In order to determine if site specific management will benefit a field, and to explain further the steps involved in the PA cycle, the following steps are suggested:

2.2.3.1: Review current data

Reviewing existing information such as soil survey maps, cropping management records, historical characteristics, additional information regarding weeds and disease information, wet areas and any other field characteristics (Grisso *et al.*, 2004)

2.2.3.2: Obtain additional data

At present most efforts for the collection of additional information is centred on the collection of yield maps. Apart from soil samples, it is generally not worth the effort to collect data which is not collected automatically. Government agencies may be able to provide additional data, from surveys completed previously regarding digitised soil surveys and topography analysis. This information can be acquired at little to no cost, and can assist farmers in establishing fields, contours as well as the various soil types within each field (Rüsch, 2001; Grisso *et al.*, 2004)

2.2.3.3: Gather yield data

By determining the yield variations that exist within each field using yield monitors, farmers are then able to, with the assistance of a range of technologies, develop informative yield maps.

2.2.3.4: Examine results

A collection of data sets in combination with geo-referencing provides valuable information for map construction. Possible data sets include

- Yield (cash and forage crops)
- Vigorousness of growth (either by satellite or during plant protection measures)
- Soil type
- Soil nutrient status for a variety of macro and micro nutrients
- Disease status of the soil (i.e. nematodes)
- Soil resistance to cultivation

- Heat uptake of soil (soil temperature)

The ideal situation would be to utilize every trip over a field to collect meaningful data that can add value to the map. The aim of the evaluation stage is to assess whether data is consistent. If not, possible errors in the system which may have caused the inconsistencies (should be located). For this reason, it is generally thought that three yield maps are necessary to start implementing a PA system in South Africa (Rüsch, 2001; Hendriks, 2011). The reason for this is that South Africa, where inter-seasonal variability is greater than Europe or certain parts of North America, more yield-maps are required to find long-term trends.

2.2.3.5: Data interpretation

Patterns of uniform and non-uniform variability throughout the field can be noticed when interpreting yield maps. Table 5.1 provides a guide to interpreting variability within a yield map. This information can, in addition, be used to evaluate management techniques and other factors influencing crop production.

Developing a systematic approach to information storage while collecting data is key. Safely storing this information, will ensure ease of access when retrieving past information for analysis,improving PA system efficiencies (Grisso *et al.*, 2004).

2.2.3.6: Management strategy

Once a problem has been identified, the necessary managerial adjustments can be made. As each farm is unique, adjusting management practices can prove difficult as no set approach may be available. In these instances farmers are recommended to seek assistance from agricultural extension agents to evaluate management strategy alternatives (Grisso *et al.*, 2004)

Table 2.4: Guide to interpreting / detecting variability within a yield map(or field) (Grisso *et al.*, 2004)

Pattern Description/Explanation			
Uniform Patterns		Irregular Patterns	
With Direction of Application	Against Direction of Application	Irregular Line	Irregular Area/Patch
• change in planting date	• drain tile patterns	• topography changes	• change in soil type
• change in hybrid/variety	• historically different fields	• herbicide drift	• drainage patterns
• change in chemical application	• old traffic patterns	• border shading effects	• weed infestations
• selected rescue treatment	• manure applications	• insect infestation from bordering lands	• soil fertility changes
• chemical skips and misapplications	• pipelines/phone lines underground	• improper manure application	• previous crop activity
• equipment errors	• previous compaction	• waterways	• disease infestations
• poor straw/chaff distribution			• herbicide carryover
• compaction			• historic occurrences
			• insect infestations
			• changes in organic matter
			• animal damage
			• wet areas

It is apparent that the integration of agricultural production techniques and information technologies, can have synergistic effects. One which has far reaching implications, both on a farm and national level.

2.3 Producer production strategy alternatives

The development of precision farming technologies has opened up new ways of thinking about the agricultural management, production and crop protection (Kroulik, Kviz, Masek & Misiewicz, 2012). There are a number of production strategies or approaches that farmers are able to follow. The discussion to follow will discuss conventional production methods and move on to the three alternative strategies which will be the focus of the study, namely;

i. Conventional
ii. Technological
iii. Conservation

Commercial producers have the option in reality to make the necessary technological investments in any chosen production strategy, to realise the benefits of a site-specific management. For the purpose of the study, the three production strategies in focus are treated as distinct strategies. In order to accurately ascertain the degree to which precision technologies benefit producers.

2.3.1 Conventional cropping system

Conventional cropping systems rely mainly on inorganic fertilizers and are characterised by short-term fertility management practices, one of which is intensive soil cultivation (Chirinda, Carter, Albert, Ambus, Olesen, Porter & Petersen, 2010). Uniform rate technology (URT) are utilised, where the goal is to maintain a constant application rate across the entire field. By not taking into account the spatial variability that may exist within a given field, inefficiency of input use can occur (Mooney, Roberts, Larson & English, 2009). This approach will be used as a base, in the whole-farm budget model, from which alternative strategies can be measured against.

2.3.2 Technological system

The first of the alternative strategies is the technological approach to agricultural production. More specifically PA, which although not new, has brought about a shift in the thinking and management of the inherent variability that exists within field boundaries. The utilisation of precision equipment (GPS and satellite guidance systems) represents a great benefit concerning precise production inputs, minimizing machine errors in field, and ultimately lower costs for agricultural production (Kroulik *et al.*, 2012; Shockley *et al.*, 2012).

2.3.3 Conservation agriculture

The practice of Conservation Agriculture (CA), is defined by a combination of three fundamental principles. These components are minimum soil disturbance (no-tillage), maximum soil cover and crop rotation systems. Further discussion is presented in Section 2.6. It is important to note that in order for the full potential of CA to be reached the system has to be implemented in its entirety, as the costs of partially implementing CA in conjunction with another production system can lead to additional costs as well as sub-optimal results due to components not being implemented (Hobbs, 2007; Knowler & Bradshaw, 2007).

2.4 Precision agriculture adoption

World population growth has placed pressure on the agricultural sector to provide a sustainable source of food. In addition, a number of societal and environmental needs have to be met. It may seem a simple task to achieve approximately half the food production growth rates achieved over the past 40 years. The exhaustion of some past sources of growth, however makes future yield expansions as much of a challenge as it was in the past (Huang, Pray & Rozelle, 2002).

Cultivation is defined as ‘tilling the land, the raising of a crop by tillage’ or ‘to loosen or break up soil’. Other terms describe the process as an improvement or increase in soil fertility. It is obvious that the cultivation of crops is synonymous with tillage or ploughing (Hobbs, Sayre & Gupta, 2008). The statement above represents traditional cultivation practices, which are being challenged by new innovative production practices such as precision agriculture. Advancements in information technology and the application thereof in agriculture, is creating the opportunity for sustainable change in agricultural management and decision making (National Research Council, 1997). If there is an alternative to conventional production practices available, it remains uncertain why commercial producers not implementing these new methods. The answer to this question will be discussed in this section.

2.4.1 Factors influencing the adoption of new technology

The adoption of any new technique, or technology requires much support, nurture and most importantly, explanation (McBratney *et al.*, 2005).

A number of emotional factors such as, fascination with or aversion to new technologies, can influence an individual's adoption patterns. For the general and sustained use of technology, economic advantage provided to the user is a key factor. Farmers will only invest in new technology, as well as making the effort to learn how to use the equipment, once they are convinced that the time and money spent will be justified by increased yields, reduced costs or reduced risk (Plant, 2001). Farmers view agricultural technology as a means to achieve various production objectives. At the same time farmers have a number of other objectives to take into consideration, such as; risk mitigation, environmental stewardship and quality of life. These considerations place pressure on producers whom rely entirely on agricultural income to stay in business. This highlights the importance of making farmers aware of the potential of improved technologies (Swinton & Lowenberg-Deboer, 2001).

In order for the use of precision agriculture, or site-specific management, to be justified three criteria must be satisfied. These are;

- That there are significant in-field spatial variability exists in factors that influence crop yield.
- Causes of variability can be identified and measured, and
- The information from these measurements can then be used to modify crop production practices to increase profits or decrease environmental impacts (Plant, 2001).

2.4.1.1 Farmer objectives and constraints.

Producers, in the attempt to produce profitably, are constrained by limited access to production resources such as land, labour, capital, fixed improvements and management information.

The profitability appeal for PA, comes through the variable rate of application (VRA), or input control, which has the potential to tailor input use site- specifically. Increasing inputs where justified, by expected yield gains, or reducing inputs where the costs exceed the potential benefits.

2.4.1.2 Factor scarcity and the theory of induced innovation.

The principle of profitable farming is to balance inputs so that no reallocation of inputs will reduce the costs of production. For example, where land is more expensive than capital, producers will capitalise enough to plant and harvest at the correct times, to maximise returns of land. By contrast where capital is the more expensive resource, farmers will extend planting and harvesting dates in order to economise on equipment, the result being lower yields and returns. This principle also implies that new technologies tend to be developed and adopted in order to optimise the use of the scarcest or most expensive inputs.

There are two factor scarcity characteristics that are likely to drive adoption of PA technologies. Firstly, precision technology improves the efficiency of input use in mechanised agriculture. This means that the technology will be adopted first in places where input use is already relatively efficient. Secondly, as the technology uses high cost capital to automate human information processing, they will be most attractive initially where capital is more abundant relative to labour.

2.4.1.3 Capital replacement and adoption of technology embodied in costly equipment:

Technology that requires equipment tend to be large units that are not easily subdivided. The units may be a system that includes, not only the equipment itself, but also specialised inputs, services and knowledge that make the technology effective. Examples include yield mapping that requires the hardware of a yield monitor, the appropriate software, a computer with the necessary PCMCIA drive, as well as the necessary skills to operate the hardware and software, to build and interpret maps (Swinton & Lowenberg-Deboer, 2001). This point highlights a major barrier to the adoption of PA, which is a lack of Decision Support Systems (DSS). Farmers are engaged in highly variable and unpredictable environments, and no farm or farmer is the same (McBratney *et al.*, 2005; Zhang & Kovacs, 2012). These DSS systems is essential for a larger uptake of PA within South Africa. Realistic strategies can be developed for specific aspects that fit into an overall management plan that assists farmers, and promotes the adoption of precision technologies.

In many industrialised countries farmers have found measures to smooth the adoption of these high cost equipment. These measures include various cost sharing schemes where a number of producers share a piece of equipment. In other instances entrepreneurs may offer special services which reduce the need for a farmer to purchase the equipment.

In the instance where the decision has been made to adopt PA, the timing of the adoption can be delayed. This is due to the capital replacement cycle of the machines which will include the GPS, sensors and other electronics. A number of producers install the equipment on existing machinery, however many farmers are reluctant to do so. This can be due to a lack of experience with electronics, cost of instillation services, and lack of standardisation of equipment. This can reduce the effectiveness of the instillation on existing equipment.

Farmers reliant on agricultural income, whom are not interested in purchasing the new technologies first, generally prefer to purchase precision equipment pre-installed on new capital purchases. However, this exposes producers to larger financial risk and additional challenges (Swinton & Lowenberg-Deboer, 2001).

2.4.2 Barriers to adoption of new technologies

After establishing the considerations that commercial farmers face when investing in new technologies, it is evident that there are a significant number of factors influencing adoption rates. The most important barriers will be discussed below:

2.4.2.1 Socio-economic factors:

These factors are concerned with the background of the farms main decision maker. Because information technologies require a high level of relatively high skilled human capital, a farmer’s capacities and abilities clearly influence the decision to utilise precision technology.

Age has a negative relationship with the adoption of high technologically intensive systems, i.e. computer systems. Older farmers have shorter planning horizons, diminished incentives to change, and less exposure to precision technology. While younger producers are seen to have longer planning horizons and are more technologically orientated.

The farm decision maker's formal education can be measured by the number of years of formal education. Precision technology requires significant information and technologically driven analytical skills. The more educated farmers are, the more likely they are to meet the human capital requirements to operate information technologies. Therefore, hypothetically, formally educated farmers are expected to be positively related to the adoption of precision technology.

Farming experience is used to quantify the number of years a farmer has been involved in agricultural production activities. Greater experience can lead to better knowledge of spatial variability within the field, and operational efficiency. More experienced farmers may feel less need for the supplementary information provided by PA-technologies, therefore, eschew adoption (Tey & Brindal, 2012).

Presently and until the new computer educated generation arrives on the farm, only more innovative, progressives will adopt PA. Only a limited number of experienced farmers have, or are willing to acquire, the new skills required to operate a PA system (Robert, 2002)

2.4.2.2 Agro-ecological factors:

Are known as farm biophysical factors, which embodies both the on-farm natural endowments, (biotic) as well as the operational factors, (abiotic).

Yield is an important indicator of soil health / quality, and identified as one of the most significant yield determining factors. A blanket rate of fertiliser application over a field that results in suboptimal yields, means that poorer quality soils are less responsive. When taking note that more productive soil are offset by unproductive ones, the knowledge of spatial variability is more probable to induce adoption (Tey & Brindal, 2012).

Agro-ecological location factors such as soil quality and climate can, in the case of PA, affect profitability through the variability in soil productivity. Heterogeneity of the soil resource has been shown to influence profitability and adoption of new technologies (Daberkow & McBride, 2003). Knowledge of in field spatial variabilities of soil varieties, combined with precision technologies, can improve yields. As various management zones within a specific field are identified, plant populations can be altered to better suite soil type. Although the cost, of determining optimal plant population per soil variety, would probably exceed the potential yield increase benefits (Bullock, Lowenberg-DeBoer & Swinton, 2002).

Land tenure, which differentiates between self-owned land and rented land. A farmer is more likely to manage self-owned land in a more favourable manner than rented land. Such ownership allows the land owner to reap the benefits accruing from farm management styles, which increases the incentive to adopt more efficient production methods. Tenants have less incentive, due to the short term nature of lease agreements, as benefits are perceived to move to the land owner (Daberkow & McBride, 2003).

Farm size refers to the total land available for production activities. This factor can be seen as a proxy for economies of scale, which is an important consideration in any attempt to acquire high level technologies. As investment, administrative costs and uncertainty increase, the critical farm size which could adopt PA technologies will increase. This is a result of larger farming units having a larger capacity to absorb costs and risks, while allowing those factors to be spread over a larger productive base.

Financial status is a continuous factor used to represent sales, production value, profitability, and debt-to-asset ratio. Investments in innovative products such as precision technology, require high entry or start-up costs and carry greater risk, than investments in mature, well tested products. For producers with financial limitations, high risk investments will present significant difficulties in raising external capital to fund new equipment. Farmers with greater financial capabilities, have a larger capacity to adopt PA technologies, and develop the necessary human capital to operate the system. For example sending children to university (Tey & Brindal, 2012). PA clearly fits the requirements to be classified as a capital intensive technology, especially when education and training costs are considered. Consequently, a financial or credit constraint will reduce PA adoption (Daberkow & McBride, 2003).

2.4.2.3 Institutional factors:

Are indicators which either enable or disable a farmer’s inclination towards behavioural change. First, farm location, which differentiates on-farm biophysical factors as discussed previously has a significant impact of PA technology adoption. Many developing countries have expanded agricultural production and efficiency with the aid of institutional factors, by creating incentives to stimulate growth of PA technologies. Visa-versa, institutional factors are able to have the opposite effect on production. Without incentives and institutional assistance measures agricultural innovation / production can stagnate and hinder new, more efficient methods to enter the sector (Fan, 1991).

2.4.2.4 Information Factors:

The diffusion of innovations, requires information. Information regarding agricultural practices is typically sourced from extension service providers or consultants. These services are intended for mass consumption, which limits an extension service provider’s ability to assist an individual farm. The complexity of the precision technology limits the service provider’s availability to provide a comprehensive product that a producer may implement into a production based system.

A lack of extension service providers and consultants will create a barrier to farmers adopting information technologies, as those that adopt PA technologies are more likely to be those whom have access to consultants.

2.4.2.5 Farmer perception:

Refers to a farmers’ subjective evaluation of the innovative attributes of a new technology. Among these perceived attributes, perceived relative advantage is primary in assessing potential benefits, in excess of the equipment that is to be replaced. In any capital-intensive agricultural scenario, a famer’s profitability is a major concern, which requires in-depth consideration.

2.4.2.6 Behavioural factors:

Are used to portray a producer’s psychology. These factors are of particular importance in the decision making process where an innovative technology does not offer direct benefits. Precision technologies provide a number of economic and environmental benefits. Taking this into consideration, intention, has been positioned as an antecedent to the adoptive decision making process.

Motivational factors which influence a decision makers choices are complex and subjective. Quantified, this factor can be represented by an individuals' willingness to pay for PA technologies. Individuals' adoptive decisions emerge from intentionality, of the subject. The lack of providing incentives (subsidies) to alter famers' behavioural and motivational factors, will result in slower adoption of PA (Tey & Brindal, 2012).

2.4.2.7 Physical factors:

Represented by the physical barriers that are present and unique to each farming operation. In order to compute its location in three-dimensional space, a GPS receiver must be able to lock onto signals from at least four different satellites. Moreover, the receiver must maintain its lock on each satellite's signal for a period of time that is long enough to receive the information encoded in the transmission. Achieving this lock-on for four satellite signals can easily be impeded. This is because each signal is transmitted at a frequency (1.575 GHz) which is too high to bend around or pass through solid objects in the signals path. It is for this reason that GPS receivers cannot be used indoors, around tall buildings, dense foliage or terrain that stands between a GPS receiver and satellite, as this will block the satellites signal (Abbott & Powell, 1999). Therefore, producers in close proximity to mountains, steep slopes or large timber plantations face unique challenges when adopting precision technologies.

The adoption of technology can be examined across time and space. The adoption of PA technologies has been relatively uneven. Despite the rapid growth in global commerce and the widespread availability of VRA technologies and yield monitors, adoption rates appear to differ considerably in various regions (Swinton & Lowenberg-Deboer, 2001). The intent of making the barriers, to adoption of PA equipment, known, is in order to smooth and ensure more consistency when producers adopt new PA systems.

2.5 Current uptake levels of precision technologies in South Africa

Table 5.2 gives a break down of the key South African, agricultural, statistics. The study focus on the arable land available, currently commercially utilised and the financial implications of selected technological strategies in tillage systems.

Table 5.2: Key South African Statistics (Smith, 2016)

Arable Land	12.9m Ha	Economic operating framework	Open Market, with supported access to Emerging farmers
Arable Land Utilised Commercially	6.1m Ha	Legislative restrictions	25% Import Tariff on Wheat Foreign land ownership restrictions. Full GMO access
Commercial Farmers	8800 registered	Storage & Handling Infrastructure	360 Silo's 12m ton capacity
Tractor Fleet	20 – 30 000	Processing Infrastructure	18m tons annual capacity
Log PI	3.46	Mechanisation Infrastructure	All Major and Most Minor OEM's: Case 48, New H 84, JD 49, MF 32. Points of sale

The number of commercial grain producers currently registered in the country is 8800. The South African agricultural sector is comprised of a significant number of, small scale, unregistered producers who are actively involved in the sector. South Africa contains 12.9 million hectares of arable land available for production, of which 6.1 million hectares are utilised commercially. This indicates that more than half, 6.8 million hectares, of arable land is utilised relatively inefectively.

Figure 2.4:The effects of inappropriate tillage practices (Hobbs, 2007). provides a breakdown of the various commodities produced in the country. It also show commercially utilised land, and the percentage of the commercially utilised land occupied, as well as the number of hectares represented by the commodity. The selected strategies will focus on commodities which occupy large quantities of land

i.e. majority staple crops. These farmers are effected by spatial and temporal variability on a larger scale, PA-technologies will have more significant financial implications.

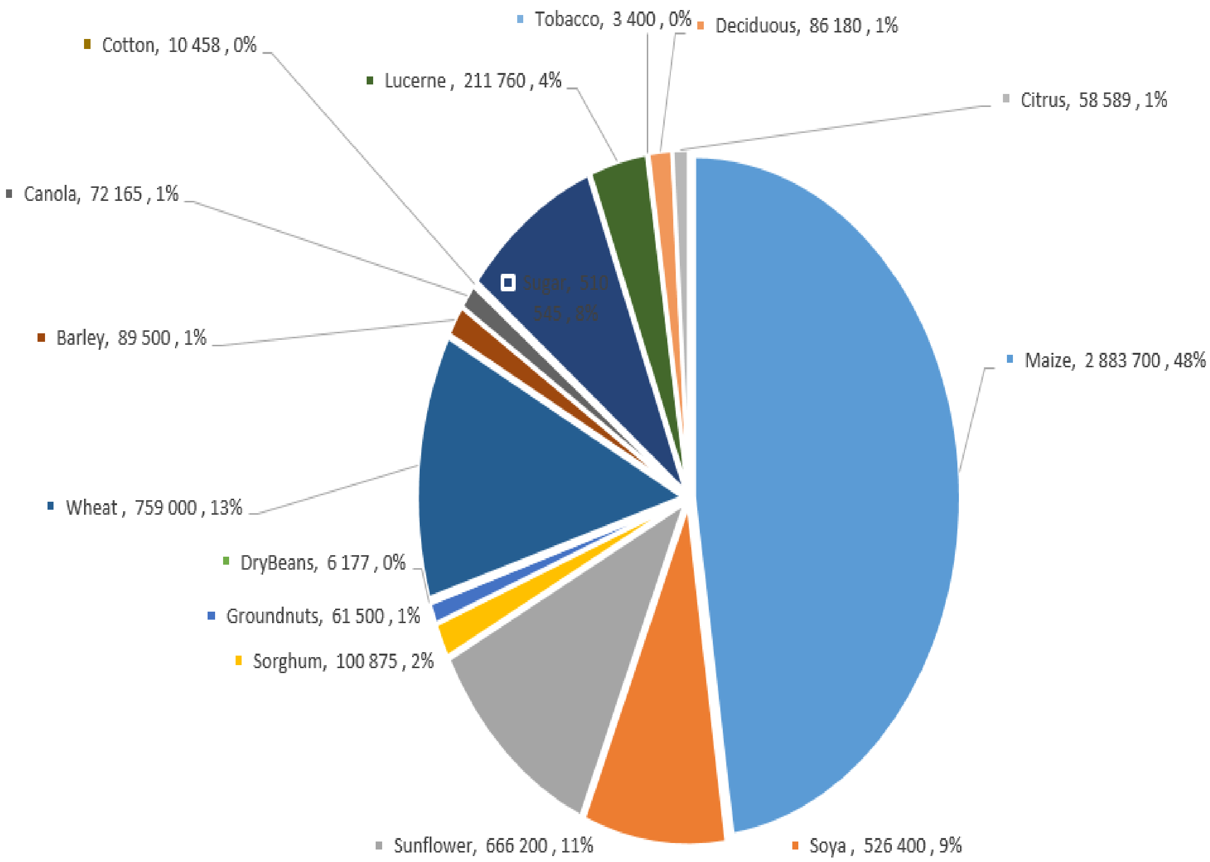

Figure 2.3: South African Commodity, Hectares, Percentage (Smith, 2016)

2.6 Applications of precision agriculture in conservation agriculture

Many years after the Green Revolution the challenge of producing enough food to meet food security needs of an ever-increasing population, is growing. These increases in production in today’s world must be accomplished sustainably, by minimising negative environmental effects as well as providing income to help improve the livelihoods of those employed in agricultural production (Hobbs, 2007).

The practice of Conservation Agriculture (CA), is defined by a combination of three fundamental principles. These three components are minimum soil disturbance (no tillage), maximum soil cover and crop rotation systems.

Minimum soil disturbance, otherwise known as 'no-till', is a relatively new concept. It involves planting seeds directly into left over plant residue from the previous year's crop. The scientific term for this practice is known as Conservation Tillage, which can be defined as; collective umbrella term commonly given to no-tillage, direct-drilling, minimum tillage / ridge tillage. The principle denotes that the specific practice has a conservation goal of some nature (Hobbs, 2007). Soil organic matter (SOM), content, in the soil is an important determinant of fertility, productivity and sustainability. The dynamics of SOM are directly influenced by various agricultural management practices, such as tillage, mulching, removal of crop residues and application of organic and mineral fertilizers. Removal of crop residue is known to reduce soil organic carbon (SOC) especially combined with conventional tillage practices (Chivenge, Murwira, Giller, Mapfumo & Six, 2007). SOM is oxidised when it is exposed to air by significant tillage, which results in a reduction of organic matter in the soil. The consequence is that SOM must be replaced by additional plant residue or composts. Due to tillage practices having a large impact on factors that affect productivity, fertility etc. the result will be a direct impact on potential yield and subsequently profitability of the agricultural enterprise. Tillage, costs both the environment and the farmer in a number of ways. Firstly fuel, tractor, equipment wear and tear as well as operator costs require significant monetary investment in order to perform. Secondly the greenhouse gas emissions contribute towards global warming, as well as soil erosion that can occur as land is left bare (Hobbs, 2007).

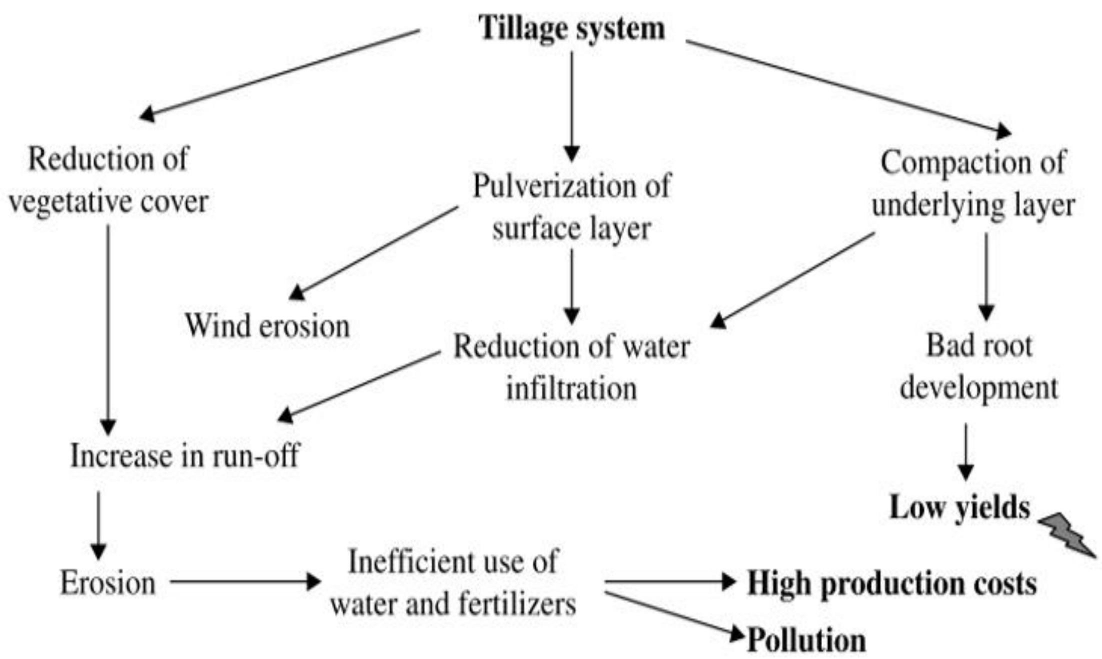

Figure 2.4:The effects of inappropriate tillage practices (Hobbs, 2007).

Figure, illustrates the issues associated with conventional / inappropriate tillage practices, in a graphic form. An important point to take note of is that inefficient or bad production / tillage practices, lead not only to high production costs due to inefficient use of fertilisers and pesticides, but also to a reduction of yields. Where yields are traditionally an important factor contributing to farm profitability.

Conventional agricultural practices go along with unacceptably high economic, environmental and social costs. Conventional practices also do not answer to the promise of continued sustainable output growth. CA is being promoted, with an increasing intensity, as being a system that constitutes a set of principles and management practices that can make a significant contribution towards sustainable production, but also intensification of production. It addresses the missing components of the intensive tillage-based standardised seed-fertiliser-pesticide approach to agricultural intensification (Kassam, Friedrich, Shaxson & Pretty, 2009).

As society advances, new challenges arise, and consequently new solutions need to be developed and implemented. New production techniques such as CA can be seen as a possible solution / alternative to more conventional production systems. The combination of plant material and soil micro-organism, building up over a number of cropping seasons, has the ability to replace some of the nutrients extracted from the soil from various crops. The result, which is not uncommon, is that producers implementing the system, have the ability to reduce fertilizer and pesticide costs by as much as 10 – 15 percent. However these savings are largely associated with better placement of fertilisers and pesticides by modern technology, offered by PA technologies. Increasingly a major requirement of conservation agriculture is that it relies heavily on the development and availability of modern equipment. Such technology ensures enhanced germination of crops drilled into soil that is not tilled, and where larger amounts of plant material covers the soil surface. Equipment should be able to place fertilizer bands and spray precisely for increased efficiency. Again, this is where precision and conservation agriculture are combined (Hobbs, 2007).

2.6.1 Precision Conservation

Producers primarily justify implementing a PA system through the improvement of crop yields. While the public sectors primary interest in precision production systems, are the environmental improvements achievable (Lerch & Kitchen, 2005). The combination of an information based, and an environmental approach, towards agricultural production can be called Precision Conservation, PC. Logically conservation farming practices are highly dependent on some form of precision farming technology adoption. This term is defined as a set of spatial technologies and procedures linked to mapped variables, directed to implement conservation management practices that take into account spatial and temporal variances across natural and agricultural systems. This is a relatively new concept put forward (Berry, Detgado, Khosla & Pierce, 2003). This definition is purely technologically oriented, and requires the integration of a number of spatial technologies, GPS, GIS, remote sensing and the ability to analyse spatial relationships within and among mapped data. Mapped data represented by, surface modelling, data mining and map analysis are three broad approaches that can be used to analyse layered information. Management practices that contribute towards soil and water conservation are developed and implemented (Berry *et al.*, 2005).

Conservation practices must be compatible with profitability, otherwise it will not be adopted or sustainable in a free market system. The free market system means resources are owned by individual decision makers, who make rational resource allocation decisions. In order to achieve a sustainable production system, precision agriculture technologies and practices, need to be integrated with conservation planning. This allows for the ability to deal with the complex spatial variabilities that naturally exist in farming (Lerch & Kitchen, 2005). Precision conservation has a number of broad applications. Although a comprehensive PC management system has not been formalised, producers are beginning to take advantage of the applications of PA within other systems such as CA. Potential improvements in environmental quality are often cited as a reason for implementing PA. Reduced agro-chemical use, higher nutrient use efficiencies, increased efficacy of managed inputs, and increased protection of soils from degradation (erosion) are the most frequently cited (Pierce & Nowak, 1999) (Godwin *et al.*, 2003; Shockley *et al.*, 2012).

After establishing a brief insight into the potential environmental and financial benefits of a precision farming approach to agricultural production, the next question to be answered is the financial feasibility of implementing such a system.

2.7 Benefits and costs of precision farming

Variable rate technologies applied in agriculture have been around for more than a decade. However current adoption rates in many instances, have been low, much lower than initial projections. Bullock et al (2002) attributes the low adoption rates of precision technologies, to non-profitability, caused by a lack of information of crop yield responses to managed inputs. An interesting aspect of PA is that a single technology is not used to improve the efficiency of a single practice. PA is emerging as the convergence of several technologies with applications in a variety of management practices (Cox, 2002; Godwin *et al.*, 2003; National Research Council, 1997).

The section to follow will discuss the benefits, highlighting financial and non-financial benefits, and the costs associated with precision technology adoption.

2.7.1 Benefits

Vehicle and implement monitoring and control has advanced rapidly over the past decade. On-board sensors monitor a range of factors; engine and transmission, implement draught and position, ground speed, wheel slip, spray rates, seed and fertiliser delivery. Farmers now have the ability to generate and measure a variety of data, such as; work rates, areas covered, fuel consumption and materials applied (Cox, 2002).

Automatic section control (ASC), is a VRA technology that is gaining popularity. This technology selectively manages input application by controlling sections, nozzles and rows on agricultural implements. With the assistance of GPS, automatic section control, can locate the position of the machine in the field and record the size of the area covered. If the machine traverses an area previously covered, it can automatically turn the appropriate section / nozzle / row off, thereby eliminating over application. Complimenting automatic section control with navigational aid i.e. auto steer, increases the scope of the technology as well as the number of benefits that can be realised from it. The most significant benefit associated with automatic section control is the reduction in overlapped areas sprayed. In large or irregular shaped fields the potential for over application of chemicals is high, therefore the technology has the ability to reduce input costs and ultimately increase profits (Shockley *et al.*, 2012).

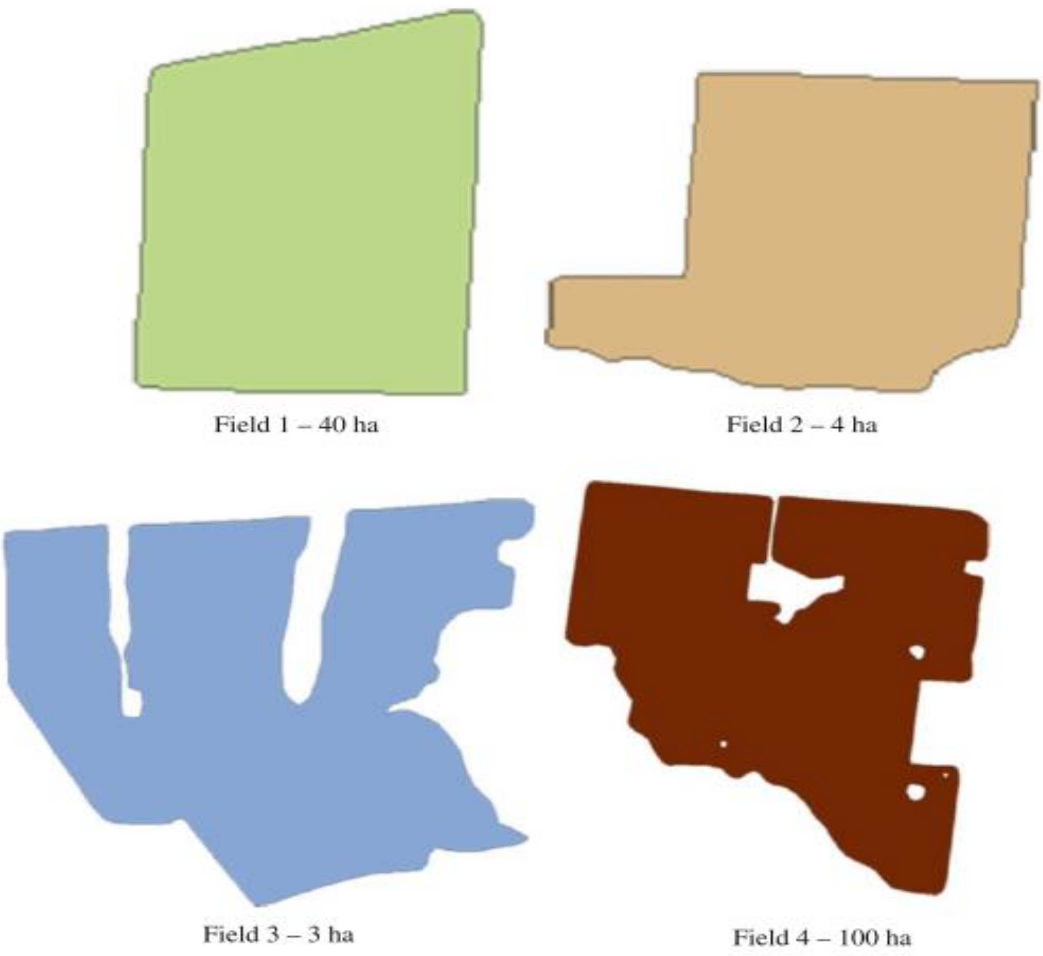

Figure 2.5: Four different field shapes, representing the base overlap scenarios used to investigate the economic potential of automatic section control (Shockley *et al.*, 2012).

Figure represents four fields, which give a figural representation of the broad spectrum of size, shape and the various obstacles that exist within typical field boundaries.

The reductions in overlap were determined using the Field Coverage Analysis Tool (FieldCAT) (Stombaugh et al. 2009). FieldCAT estimated the overlapped area in a particular field by utilizing field boundary shape files, implement width and number of sections controlled. The program generated field coverage using straight parallel paths, in which overlaps occurred due to encroachment in headland and point row areas and when avoiding obstacles within the field boundary. The profitability of automatic section control is dependent on the difference between the percentage of the field overlapped before (zero sections controlled) and after utilizing the technology (positive number of sections controlled).

Two implement widths were modelled, a 24m self-propelled sprayer and a 12m, 16-row planter. Table .3, shows the resulting overlaps with and without section control. The results can be interpreted as follows, field one shows a 2.16% reduction in seed costs. The average reduction in overlap across the given fields using the technology was 9% when utilised on the sprayer and 6% when utilised on the planter. Other literature indicates that by simply controlling individual sprayer sections, reduction of applied inputs (pre- and post- emergent chemicals) of 10.5% are achievable, while reducing fuel requirements by 15.6%. (Shockley *et al.*, 2012; Schieffer & Dillon, 2014). Also important to note is, as implement width decreases, so too does the potential for section control to reduce overlaps.

Table 2.3: Percentage overlap, calculated for each machine, with and without section control in each field (Shockley *et al.*, 2012).

	Field 1	Field 2	Field 3	Field 4
Spraying				
No section control (%)	4.43	12.62	16.96	4.77
10 section control (%)	0.56	1.30	1.73	0.49
Planting				
No section control (%)	2.31	7.27	12.83	2.44
Individual row control (%)	0.15	0.47	0.80	0.15

Automated guidance systems, either a GPS-based guidance system or a fully automated / hands free system that guides the tractor through the field with the driver merely supervising it, has brought a new dimension to precision agriculture. The guidance systems can be used in any field or operation, such as planting, spraying and fertilising, and soil cultivation. The technology is able to reduce operator fatigue, as modern equipment have many controls, and improve machinery performance by reducing overlaps or 'skips' during field operations.

Positional information gained from GPS signals can be used not only for guidance but seed mapping, controlled traffic and controlled tillage. By retrofitting a planter with a range of optical sensors and an on board computer, accurate seed maps can be developed and later used for weed control purposes. (Batte & Ehsani, 2006). Studies have indicated that equipment equipped with auto guidance technology can be used to cultivate or spray extremely close to the plant line, within the range of 5cm accuracy using real-time kinematic (RTK) GPS receivers. While traveling at a ground speed of up to 11km p/h (Abidine et al. 2002). The time savings potential, of equipment which is able to operate quickly and effectively while applying inputs in an efficient manner, has potential financial benefits which a farmer can realise.

Potential payback variables of a variable rate technology system include input savings, yield gains and reduced application costs. The cost saving of precision technology (VRT) relative to conventional, uniform rate technology (URT), will be greater only in fields with greater spatial variability, as the optimal application rate will also vary more (Mooney *et al.*, 2009). An important point to take note of is, that many studies have been conducted on the financial benefits of a VRT system in comparison to a URT system, in which only a single input in focused on. Unless inputs are independent of one another, a change in the quantity of one input affects the marginal productivity of other inputs as they interact in producing output. Therefore, the multiple-input VRT decision, optimal quantities of inputs must be determined jointly. An example of a multiple-input production system would be; seed, in-furrow fungicide, insecticide and a growth regulator (Roberts, English & Larson, 2006). This point highlights that precision technology is optimally efficient and effective when used in conjunction with other technologies, which creates a synergism effect within the system.

It is important to recognise PA as a systems approach (Blackmore 2003; Shibusawa, 1998), while the value of the increased information flow as a benefit to overall farm management efficiencies (Auernhammer, 2001). It is evident that the largest benefit / impact associated with PA-technologies, will be on the decision making process of asset management and resource allocation (Fountas, Blackmore, Ess, Hawkins, Blumhoff, Lowenberg-Deboer & Sorensen, 2005). It has been suggested that by collecting crop yield maps for several years, a consistent pattern emerges which can be used either directly to adjust inputs, or to further delineate zones for further investigation. Information made available from fields mapped for several years indicate that consistent patterns do indeed occur and may account for up to 50% of yield variations in subsequent years.(Sylvester-Bradley, Lord, Sparkes, Scott, Wiltshire & Orson, 2006).

2.7.2 Costs

A full precision farming system comprises of hardware and software to enable variations in crop yield to be mapped and crop-related treatments to be variably applied on a site-specific basis. From the literature, it is evident that the cost of practising precision agriculture techniques is dependent on:

1. The level of technology purchased i.e. a full or partial system
2. Depreciation and current interest rate
3. The area of crops managed

It is also apparent that precision agriculture can be split into four separate, classes.

Class 1 – comprises of a fully integrated system from an original equipment manufacturer (OEM).

Class 2 – comprises of a full system from a specialist manufacturer.

Class 3 – comprises of a full system, which is a combination of OEM and specialist manufacturer.

Class 4 – comprises of a basic system from an OEM.

Table 2. gives an indication of the price variances between the various classes of PA-technologies. Systems range in functionality from fully integrated yield mapping and combine performance monitoring systems, which can be removed from combines and fitted to tractors or sprayers and include sub-metre DGPS (Class 1), to low-cost partial systems that provide full yield mapping functionality but reduced application rate control functions (Class 4) (Godwin *et al.*, 2003).

Table 2.4*:* Precision farming system cost (Godwin *et al.*, 2003).

PF-system type (class)	*Hardware cost, £*
1	11363
2	14100
3	16150
4	4500

Of the remaining classes, Class 2 is a full precision system produced by specialist manufacturers, and Class 3 is an addition of parts from Class 1 and 2. A more costly PA system setup has additional advantages such as, parallel systems set up which will allow two activities to be completed with a single pass by a tractor i.e. cultivate and spray (Godwin *et al.*, 2003). Time and cost implications are possible for the producer.

With the integration of information technology, precision agriculture increasingly requires comprehensive technology. While improving productive efficiencies, it is more expensive and requires a higher capital outlay (Auernhammer, 2001). Equipment ownership costs of PA-technologies include the initial investment, plus additional taxes, insurance and storage. Other costs that must also be taken into consideration are information gathering i.e. acquisition of geo-referenced spatial data on crop characteristics, subscription to a GPS signal network, custom prescription map making as well as data analysis and training expenses (Mooney *et al.*, 2009).

A general issue is to finance new precision equipment without over leveraging the business. Various studies have been completed which paint different pictures, (Mooney *et al.*, 2009) suggests that automated section control becomes profitable at input savings of 11% and above. Automated section control, automated guidance systems etc. have been analysed individually but have not considered the impact that various precision technologies have when working simultaneously (Shockley *et al.*, 2012). That being said, these studies have given producers and academics alike an insight into the cost saving potential of the technology. Producers then have the option to invest in a particular class or set of equipment that best suites the business. Investing in a Class 4 range of PA-technology, offers only a limited range of applications, but does allow producers to make an initial venture into precision agriculture without a large capital investment (Godwin *et al.*, 2003).

2.7.2.1 Marginality and opportunity cost of precision equipment

Investments in precision technologies require significant financial commitments by producers. These commitments place additional financial risk and financial strain on enterprises.

Precision technologies are embodied in a higher quality variable input, because its application is more skill and time intensive and may require the assistance of professionals. The price per unit of input applied with a precision technology is assumed to be higher than that of inputs applied with traditional technologies. More effective use of inputs results in increased yields, quality and reduced input costs. Precision technologies, therefore, affect applied inputs-use per unit asset in two opposing ways; it increases efficiency of the applied input and it's per unit cost. When existing efficiency of applied inputs is high, adoption will result in only small efficiency benefits. Due to positive precision effects, adoption, will lead to more efficient and effective input-use per asset unit, which increases output per asset unit. A producer is then faced with a trade-off between the benefits of adoption, input savings and higher yields, and higher application rate and fixed costs per unit (Khanna & Zilberman, 1997; Godwin *et al.*, 2003; Hendriks, 2011).

The opportunity cost of investing in PA technologies is to continue operations using conventional, URT. Which as discussed, has a lower cost per unit of input, but is more inefficient.

2.7.2.2 Cost sharing alternatives

Investing in precision agriculture involves many sunk costs, i.e. costs that are irrecoverable. These sunk costs include soil sampling, purchasing computer and mechanical technology, human capital training and lastly information search time. Large commercial producers are able to absorb these costs, more effectively, than small scale producers (Tozer, 2009).

Small scale producers that are not able to capitalise farming operations to the extent that their larger commercial counterparts are, need to find cost effective alternatives. One aspect of corporate strategy, which farmers can effectively utilise and implement, is sharing activities. The ability to share activities is a potent basis for corporate strategy because sharing often enhances competitive advantage by lowering cost, raising differentiation. It is important to note that not all sharing leads to competitive advantage, and organizations may encounter resistance from within the business.

A cost-benefit analysis can be complete to establish whether or not organisational synergism will occur. Sharing is able to lower costs, if it achieves economies of scale, boosts the efficiency of utilisation or helps a business move more rapidly down the learning curve (Porter, Goold & Luchs, 1996; Dyer & Singh, 1998).

In a South African context, where previously disadvantaged developing producers still have a lot to learn, information technology could assist in bridging the gap between developed farmers and developing farmers. The technology provides a platform to understand on farm, variable, conditions faster and be able to react to these factors in a timelier and cost effective manner, than did more traditional producers.

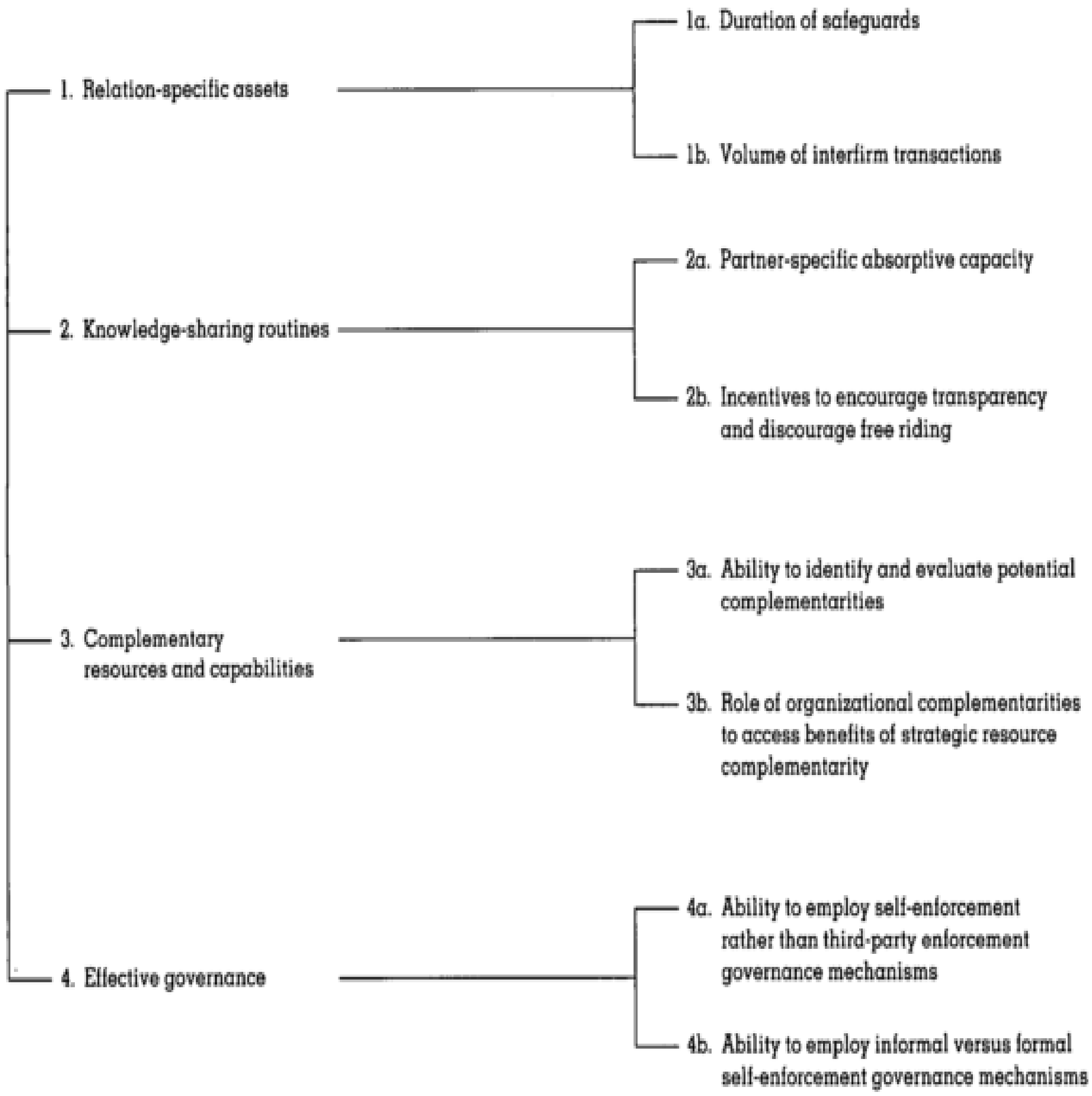

Figure 2.6: Determinants of inter-organisational competitive advantage (Dyer & Singh, 1998).

Error! Reference source not found. indicates the determinants of inter-organisational competitive advantage, left, and the sub processes required to achieve the required result, right. Sharing activities involves costs, which the resulting benefits must outweigh, one of the costs involved is the greater level of coordination of production activities. This requires more time, but can also be seen as a facilitator of the learning process for small scale producers.

2.8 Budgets as research tools

The focus of this study is the on farm financial implications, in terms of both cost and income, that PA technologies have on selected production strategies. The section to follow will discuss the budget models that will be used to complete the feasibility assessments. The models which will be discussed include;

- Enterprise budgets
- Partial budgets
- Total budgets
- Capital budgets
- Cash flow budgets

A budget is a written plan for future action, expressed in physical and financial quantities. Making predictions of the future, advanced planning of this nature is based on forecasts, historical data, assumptions and experience. For the user / stakeholder, the farmer, should keep in mind that the budgets and the assumptions on which they are based are subject to continuous change. Therefore, budgets should not be treated as ridged or fixed plans, but rather as management aids (Blignaut *et al*. 2000).

Enterprise budgets: are an important prerequisite for the development and compilation of other budgets. Enterprise budgets should be as detailed as possible, which will facilitate better and more accurate planning, especially when total, capital and cash flow budgets are being compiled.

The format of the enterprise budget will vary according to the circumstances, preferences and other reasons for compiling it. A complete enterprise budget will contain the following:

- Gross margin analysis – involves the estimated income and directly allocatable variable costs of an enterprise, on a per unit basis (per hectare, per stock unit etc.).
- Parametric or sensitivity analysis – of the gross margin takes into account the effect of fluctuating product prices and production quantities. It reflects various gross margins at both optimistic and pessimistic prices and yields. In effect, provides an indication of how sensitive the gross margin of a crop would be to price and yield fluctuations (Blignaut et al. 2000).

Partial budgets: serve as a management aid to test the profitability of a certain farming practice or enterprise, which would only affect a part or certain parts of the farm business. Partial budgets are typically used in the following circumstances:

- Comparing cultivation practices and production techniques within a certain enterprise of the farm business.
- When considering the expansion or contraction of a certain enterprise i.e. expanding the wheat or canola enterprise.
- When considering the total or partial replacement of an existing enterprise with another
- When considering the inclusion of a new or additional enterprise in the farm business i.e. incorporating a livestock component in an existing cropping system.

Only the relevant costs are taken into account. The result, only the changes in cost and income that will result from the proposed change are included in the budget. In order to compile an accurate and sensible partial budget, data on yield and price expectations, and production costs are required. This information is contained in the enterprise budgets, discussed earlier (Blignaut et al. 2000).

Total budgets: are necessary when a change in the existing farm business is envisaged. All aspects of the business are taken into account. A total budget enables the farmer / stakeholder to calculate the solvency, liquidity and profitability of the farm business and to consider alternative combinations of enterprise and cultivation practices.

When a total or comprehensive farm plan is compiled, the following aspects should be included:

- An inventory of the quality, quantity and availability of resources, such as land, labour, capital and management.
- Crop cultivation system and preferably a matching soil map that will maintain or improve existing productivity and sustainability and yield the maximum margin over variable costs.
- An adequate supply and efficient utilisation of labour, machinery, buildings and operating capital.
- A livestock system which is integrated with the available markets and the crop system, and which will lend stability to the business.
- A financial budget that summarizes all the above, and from which the expected profitability, liquidity and solvency of the proposed changes can be calculated.

The formation of a total budget can be time consuming and can prove fairly complicated, specifically when making assumptions which can be difficult due to certain risks and uncertainties. Despite these difficulties, there are distinct advantages of compiling a total budget. It promotes profit maximisation, with the inclusion of enterprises that are well coordinated in respect of their claims to limited resources. Underlying risks are taken into account; not only does it focus the farmers attention on these, but also provides the means of quantifying them. It provides the farm manager with an overview of the nature, extent and period of surplus capacity which leads to cost savings and greater profit opportunities (Blignaut et al. 2000).

Capital budgets: usually pertains to the capital investments in long-term and medium-term assets (i.e. land, fixed improvements, vehicles, implements, machinery and breeding-stock) as well as envisaged short-term capital projects. This includes information on aspects such as proposed projects, assets to be acquired, estimated investment amounts and investment periods, expected benefits and the duration thereof.

Capital expenses occur because;

- Growth takes place in a business.

- Assets age and wear and tear occur, making it essential to purchase new assets, and
- Assets become technologically outdated and have to be replaced with new technology in order to manage costs and increase productivity (Blignaut et al. 2000).

Cash flow budgets:

A cash flow statement provides useful information to evaluate the enterprises ability to generate cash and cash equivalents. Good cash flow is very important to the success of an enterprise. An enterprise must be able to generate cash from its profits. An enterprise that is unable to meet its short-term obligations will in all probability experience solvency problems over the long-term. The cash flow statement is in reality a summary of the movement in the bank balance of the enterprise during the year (Mey et al. 2014).

The cash flow (budget) is one of the most important aids in the modern farm business, the reason being that the farms cash flow is seasonal, whereas payments occur throughout the year. Funds needed to purchase production inputs at a time when crops and livestock are not yet ready to be sold. A cash flow budget can be used to make provisions for this eventuality, enabling the farmer to make timely arrangements with the relevant finance provider to:

- Extend credit facilities
- Defer the repayment of debt
- Take out additional loans to cover cash expenses
- Schedule the purchase of capital item in such a way as to coincide with cash surpluses
- Regulate enterprises in such a way that income becomes more regular

Cash flow budgets establish a sound basis for financing as well as financial control of the cash position of the business, based on a comparison between actual and projected cash flows. The budgets discussed previously emphasise the profitability of alternative plans and actions, whereas cash flow budgets focus on the viability of these various plans (Blignaut et al. 2000).

The budgeting techniques discussed above provide the format for the techniques applied in this study.

2.9. Conclusion

This chapter has discussed the various concepts relating to precision agriculture. By definition, precision agriculture can be seen as a management strategy which uses information technologies to bring data from multiple sources to bear on decision associated with crop production. In effect increasing the amount of right decisions per unit of land and time. Precision agriculture, is an on-going process in which data is gathered and analysed. As a result, actions are taken to ultimately reduce inputs, increase outputs and conserve the environment.

The precision agriculture cycle consists of different components, which can be divided into management and technical components. Management components of the PA cycle include data gathering, data analysis and interpretation, decision making and implementation. Sensors and controls i.e. soil sensors, flow rate monitors, remote sensors represent the technical components of the cycle. The development of these new precision technologies has developed new ways of thinking about management, production and crop protection. Geographic Information Systems (GIS), for example, is used to produce information maps that assist data evaluation and decision making. Variable rate technologies, use the information provided by the GIS information maps to apply inputs accordingly. VRT technologies, and associated technologies, have allowed farmers to strategically manage in field variations of soil quality, moisture and topography etc. which have allowed producers to become more productively efficient that previously achievable.

Awareness of the variations that exist within field boundaries, has allowed farmers to alter production strategies. By either incorporating a livestock component into the operation, or expanding mechanically to produce more efficiently and sustainably. South African producers have not adopted the technologies to a large extent. This can be attributed to a number of barriers which can slow or inhibit the adoption of precision technologies. For example, socio-economic factors, concerned with the background of the decision maker i.e. age, level of education and attitude toward risk all contribute towards a farmer adopting new production techniques. Other factors include agro-ecological factors, institutional factors and information factors, are contributors towards uneven and low adoption rates.

Economies of scope is a benefit of precision technologies, that yields both environmental and economic benefits. The applications of PA in CA has a number of environmental benefits, reduced environmental pollution from reduced agro-chemical use, reduced soil erosion and optimal water usage have significant off farm benefits to society at large. Economic benefits include increased marginal efficiency of crop production due to improved yields, higher qualities and reduced input use. Studies indicate that the largest benefit associated with the implementation of a PA system is the decision process and resource allocation, in other words taking a precision approach to investment management.

There is significant literature which discuss the numerous benefits of both the financial and environmental benefits of precision agriculture. The cost component of investing in precision equipment depends largely on three factors firstly, the level of technology purchased, depreciation and current interest rates and lastly the area under crops. There is no defined precision system package available, farmers are encouraged to customise / tailor fit the system to best suite their own unique situation. When taking this approach, producers may save on additional equipment that is of no use. In instances where producers require large capital outlays, which are not supported by large crop areas, there are multiple cost sharing initiatives available which farmers can take advantage to achieve desired production goals.

In conclusion, there are real benefits which farmers are able to realise when implementing a precision agriculture system. Due to some uncertainties, various institutional factors, machinery costs and a lack of information availability adoption of precision technologies has been uneven and slow. A lack of extension services, education levels and skills required to operate a PA system fully has proved to be a major obstacle facing producers.

Chapter 3: Materials and methods

3.1 Introduction

Chapter Two consisted of an in-depth overview of Precision Agriculture (PA) and its applications within modern commercial agriculture. The benefits of PA, the most popular technologies and the on farm financial implications of adopting these technologies were discussed. Data from more developed countries such as the US, has given insight into adoption rate patterns which South Africa is currently experiencing. This could assist in ensuring more consistent adoption patterns, and utilisation of precision technologies.

This chapter will focus on the research methodology used to obtain the research objectives, discussed in Chapter One. By analysing trial data collected locally, and by using key assumptions about the data, observations can be made in a South African context with regard to the savings potential of PA technologies. The proceeding chapter will discuss the data used in the development of a typical farm model from which these observations can be made. In addition, the process of building the required budget model and the key underlying assumptions and components will be discussed.

Chapter Four will present the study results, in order to understand certain concepts and key assumptions. The layout and composition of the budget model will also be discussed. A whole-farm budget model is comprised of three key components, each of which is made up of individual parts. These are; the input, calculation and output components. Each of which will be broken down and discussed in more detail, highlighting key parts and essential calculations.

3.2 Description of the Langgewens research trials

The empirical study focused on the winter grain producing area of the Swartland in the Western Cape. By utilising primary trial data and secondary farmer and other expet opinion data, a comprehensive whole farm, multi-period budget of a typical farm in the Swartland can be modelled.

Primary data was collected from the Langgewens experimental farm, which is run by the Western Cape Department of Agriculture and lead by Dr Johann Strauss.

For the purpose of the study, research trial data have been selected for use to establish typical yields and inputs to serve as a basis for the impact assessment. The combination is necessary as the trials used are not specific to economic research. However, by combining the data from the trials, it is possible to develop a more accurate simulation of practical farming systems taking place in the Middle Swartland and the costs involved. Thereby the derived gross margins can be simulated in a typical farm model to evaluate the implications of various systems (Knott, 2015).

Langgewens experimental farm is situated halfway between Malmesbury and Moorreesburg (-33.27665o; 18.70463o; altitude 191m) in the Western Cape Province of South Africa. Soils are predominantly Malmesbury and Bokkeveld shales, with a long-term average rainfall of 396.9mm. The experimental farm experiences a typical Mediterranean climate; hot dry summer months followed by winter rainfall from April to mid-October (Wiese, 2013; Knott, 2015).

All trial data are taken from trials conducted on the Langgewens experimental farm. Financial data was adapted from 2011 – 2015 production reports. From this data, typical production activities and their associated costs, which have been recorded, can be utilised to form the basis of the research. In addition to the financial reports, a study completed by (Knott, 2015) was used to determine the physical assumptions of a ‘typical farm’ in the Swartland, as well as essential planting dates etc. The effects which various tillage practices have on yield and quality of wheat was also incorperated (Agenbag, 2010, 2012).

There have been a number of trials conducted on the experimental farm with a number of goals, relating to the effects of various tillage practices and crop sequences on soil physical and chemical properties. These trials have provided valuable information to the agricultural community as a whole in establishing sustainability in crop production systems.

3.3 The budget model simulation

Models are designed as a representation to aid in visualising something that cannot be observed directly. Farm simulation is a useful tool when representing a real world situation, where factor variations may result in certain events occurring, these variations and their outcomes can then be measured. The alternative to modelling in farm research is observation of an actual farm, which will make research very expensive.

Developing a whole farm model requires a number of individual system compenents. The components must be included in order to understand the full affects that factor variations have on the whole farm profitability. The financial performance of a farm is influenced by a number of factors. The most influential of these factors, on farm profitability, are those which influence the price and / or quantities of outputs and inputs. Some of these factors can be managed, to a certain degree, however other external factors are beyond the control of the individual farmer. These external factors such as input cost prices are determined by the marco-economic markets.

With regards to machinery and equipment, the focus of the study, prices are determined by these external factor markets. Mechanical inputs form a significant cost component of the modern commercial grain farming operation, second too the purchasing of land. Therefore the potential impact of these factors on the profitability of the typical farm needs to be established, as well as the saving potential which precision technologies offer.

Mechnical information was gathered, using semi-structured questionnaires, from various mechanical suppliers in the Swartland region. PA-technology supplier (Smit, 2016) provided data regarding the cost and savings of precision technologies, which producers in the Swartland region are currently experiencing. Additional implement information (van Niekerk, 2016) provided information on planters which was used in establishing the most efficient tractor-planter combination. Langgewens trial data provided the basis for the mechanical production activities that occurr for each crop enerprise, as well as the production norms (time / efficiencies for each activity). The Guide to Machinery Cost, assisted in the mechanical cost calculations for additional production activities and equipment. The combination of information was used to develop a structure for each individual production system. Mechanical suppliers and industry (Overberg Agri) provided the validation of the complete model.

The purpose of developing the model was for the following reasons. Firstly, the models were used to determine the baseline financial position of a typical farm using conventional tillage based production methods. Secondly the models were used to measure and compare modern production practices against conventional methods. Precision and conservation agricultural practices, represent the modern production techniques. The assumptions were gained through reviewing relevant literature and discussions with individuals involved in the agricultural industry it was possible to incorperate these assumptions into the model and measure the impact that the various production methods had on a typical farm.

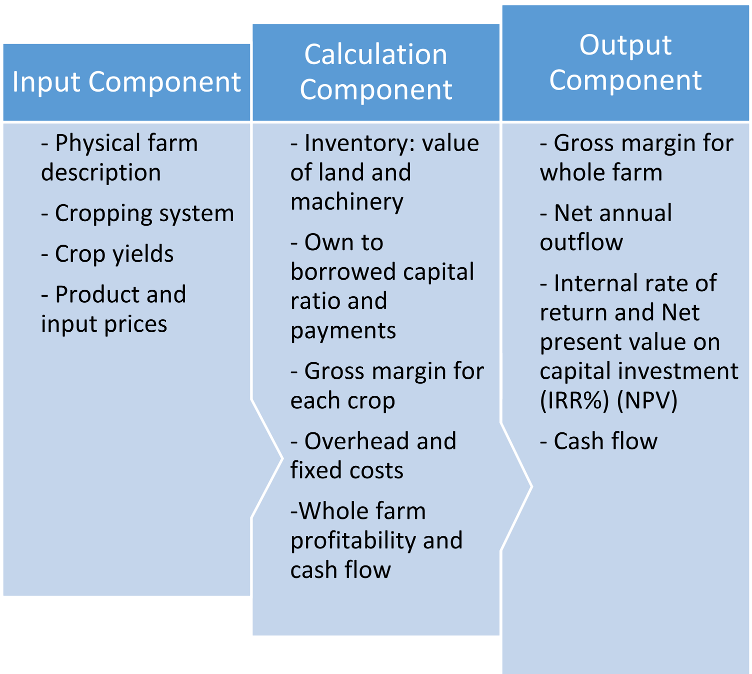

Figure 3.1: A graphic representation of the components of the whole-farm, multi-period budget model (Hoffmann & Kleynhans 2010)

Figure provides a graphic representation of the components that a whole-farm, multi-period budget model consists of. The study focuses specifically on the mechanical aspects which influence a farms profitability, therefore the livestock component of the farm was not incorporated. Each of these components will be discussed in further detail in the following sub-section. It is important to note that each component of a typical farm is formed by individual parts. Capturing, measuring and linking these parts and ultimately the three components, it is then possible to capture the various complexities that exist within a commercial farming operation.

How the model was developed, within the context of Figure 3.1 above, will be discussed below.

3.3.1 Input component

The input component of the budget model consists of a physical description of the farm, land use patterns i.e. cropping system, yield assumptions and input and output prices. By linking these parts, changing key values will systematically alter the output of the component.

The three production strategies in question namely; conventional, precision and conservation have a number mechanical requirements specific to each system. Personal communication with (Burger, 2016) provided critical mechanical activities for each production system. (Smit, 2016) together with observations made from analysis of the relevant literature provided the critical assumption of a 15% mechanical savings of PA-technologies. This assumption remained constant for a precision system, regardless of tractor-planter combinations. (Strauss, 2016) provided the necessary information regarding the benefits of CA and where various benefits and additional costs arise, specifically chemical cost variations.

Due to the significance of both PA and CA in modern commercial agriculture, the model made allowance for the fact that producers implementing either of these systems can make use of a minimum or no-till tractor planter combination.

3.3.1.1 Physical farm description and crop system

The objective of identifying a typical farm was to serve as a base to which farmers in a homogenous area can relate. By using the mode rather than the average of the physical farm factors, due to the misleading effect of outliers, the 'representative' farm can be identified. The description of the typical farm parameters was adapted from a previous research study (Knott, 2015). Which combined studies by (Hoffman & Kleynhans, 2010) and producer study-group information. As study group participation does not always reflect the broader producer populous, the information had to be validated by a panel of experts. These assumptions were put forward to an expert group, whom on consensus, agreed on the final descriptive parameters of the typical farm.

The typical farm description forms the basis for a number of other factors. Which include; land utilization, area cultivated, mechanisation requirements, labour requirements and overheads and fixed costs. A key assumption obtained from this description is the days required to plant and harvest the farm. The study will focus on the planting requirement. The expert group, indicated that producers have a 22 day window in which to complete planting and harvesting operations. This is due to the fact that the Swartland area has very distinctive climatic conditions, and extending planting times can have an impact on potential farm yields.

Figure 3.2, provides a graphic representation of the farm size, percentage cutivatable, land price per hectare and area cultivated under each crop. Each of these factors can have a significant influence on farm profitability. For example non-cultivatable land areas taken up by roads, rivers, mountains etc will have a significant influence on the productive capability of the business.

The model is able to adapt varying cropping systems using excel formulas which are able to automatically adapt according to the system. As can be seen in the model a simple wheat (75%) canola (25%) mix of cultivable land is used. This represents system B in the Langgewens crop trials. It is advised to plant only a quarter of productive land into canola due to pest issues. The study focus, discussed previously, is on the mechanical compoenet of the farming business and for this reason a simple cropping system is implemented.

Name:	Mieliefontein (ha)	R/ha	Value
Farm size	800	30000	24000000
Cultivatable	760		
Distribution: Percantage			
Cultivable	95%		
Uncultivable	5%		
Distribution: ha			
Wheat	570,00		
Canola	190,00		
Uncultivable	40		

Figure 3.2: Land distribution of a typical farm in the Swartland

The typical farm is described in financial terms by an inventory. The inventory provides land and fixed improvement values, movable assets in the form of machinery and equipment, all of which depend on the farm size.

3.3.1.2 Crop yields

Crop yields vary according to a number of yield determining factors. Climatic conditions have the most significant impact on yields. Management practices must be adapted according to rainfall within a specific year. Ensuring optimal yields given prevailing climatic conditions. This means PA cannot be managed according to a fixed recipe and should constantly be adapted.

Assumed crop yields for the purpose of the study where taken from GrainSA production reports 2016/17 for the middle Swartland, under conventional cropping practices (GrainSA, 2016). The Langgewens crop trials were also used, but the GrainSA information provided a more ‘typical’ yield basis. Wheat yields, not taking into account the impact of canola in rotation, is assumed at an average of 3.5 tonnes per hectare. Whereas canola was assumed at 1.5 tonnes per hectare. In terms of the middle Swartland area, with a canola wheat rotation system this is a fair assumption.

In terms of yield estimates used in the model canola yields represent 50 – 60 percent of wheat yields (Strauss, 2016). Assumed wheat yields of 3.5 tonnes per hectare in the Swartland region can be viewed as slightly high. However, a canola / wheat rotation system is known to moderately improve wheat yields. Lastly, farmers that typically invest in PA are seen as ‘above average’, therefore taking these factors into account a 3.5 tonne / hectare yield was assumed.

3.3.1.3 Product and input prices

Product and input prices for the two crop enterprises are listed in data tables in the budget model. Input prices per hectare, under certain yield assumptions, were again taken from the GrainSA production reports for the middle Swartland 2016 - 2017. The wheat price listed in the data table is determined by the SAFEX price less the Western Cape transport differential, grading and silo handling costs, which represents the farm gate price for wheat. Canola prices on the other hand are determined by individual Agri-businesses, which may vary according to supplier contracts, the price used from the GrainSA report is a representative of an average price for the 2015 – 2016 season.

Table 3.1: Production activity cost adapted (Guide to Machinery Costs, 2016)

Cost Programme for various activities								
					Tractor cost/ hour		Implement cost/hour	
Activity and implement	Power demand	tractor kw	ha/ hour	Fuel (l/hour)	Repairs & mainten	Total variable costs	Repairs & maintenance	Total variable c
Deep soil tillage (Ripper)	High	80	1,5	14,4	177,96	490,32	3,01	3,01
Light soil tillage (Disc)	High	80	3	14,4	177,96	490,32	37,5	37,5
Light soil tillage (Plough)	High	80	1	14,4	177,96	490,32	35,37	35,37
lime application (Lime spreader)	Medium	80	4	12,6	64,08	227,25	101,87	101,87
Fertilizer application (Spandikar)	Medium	80	11,9	12,6	64,08	227,25	24,97	24,97
Pesticide application (1000l spray tank)	Medium	80	5,9	12,6	64,08	227,25	9,44	9,44
Herbicide application (1000l spray tank)	Medium	80	5,9	12,6	64,08	227,25	9,44	9,44
Plant seed (planter: conventional)	High	93	2	20	77,88	293,02	45,20	202,05
Plant seed (planter: min-till)	High	157	1,5	28,26	153,07	527,52	50,88	169,6
Plant seed (planter: no-till)	High	116	2,5	21	86,42	347,48	150,00	640,34
load (Front end loader)		69	200	9,38	44,95	169,42	0	0
Fuel: contract harvestor	High		2	72,9				
Apply cover crop seed/snail pellets (Spar	Medium	80	11,9	12,6	64,08	227,25	101,87	101,87

					Vehicle cost/km		**Vehicle cost/ha**	
Activity and Vehicle			km/ha	Fuel(l)/km	Rep & Main	Var costs	Fuel(l)/ha	Fuel R/ha
Seed and Fertilizer (Truck 14t)			2,5	0,4	0,18	7,66	1	11,00
Grain Removal (Truck 14t)			18	0,4	0,18	7,66	7,2	79,20
General farm management 12000km (Bakkie 1)			15,00	0,102	0,98	2,72	1,53	16,83
General purpose 10000km (Bakkie2)			12,50	0,102	0,98	2,72	1,28	14,03

Machinery and implement running and purchase prices were adapted from two sources. Firstly, the Guide to Machinery Costs (Guide to Machinery Costs, 2016), were used for information regarding tractor and implement running costs per hour. The second source was adapted from the Langgewens trials, from which hours/ activity/ hectare was taken. Using this information, activity costs, for both tractor and implement per hectare, could be calculated. The running costs are then used in the gross margin calculations under the non-directly allocable costs for each enterprise. Table 3., provides an illustration of a mechanisation activity sheet, showing only the tractor costs per hour.

The focus of this study is on the non-directly allocable cost section of the gross margin calculation for each enterprise. Using assumptions gained from the literature and personal communications with individuals, parameters which influence costs mostly within selected strategies can be identified. Conventional practices serve as the base for comparison. Precision and conservation agricultural machinery costs can be compared and potential savings can be measured. Full inventory is shown in Annexure G.

3.3.2 Calculation component

The calculation component of the budget model consists of a number of interrelated calculations. These calculations connect the various inputs through a sequence of equations. These produce valid output in the form of economic profitability indicators. This component is essential for two reasons. Firstly, in order to accurately simulate the mechanisation and tillage process on the farm which is in question. In this case, the effect that various production strategies have on the mechanical cost of production per hectare. In other words, which is the most mechanically efficient practice. Secondly, for validity, the model structures all biological and physical factors and their interrelationships into a format of standard accounting principles which generate financial results that are universally acceptable. For example, the gross margin calculated from each crop enterprise input components are used in the calculation of the net annual flow after fixed and capital expenditure. This is then utilised in calculating the relevant economic indicators, internal rate of return (IRR) and net present value (NPV) for the various production systems.

3.3.2.1 Farm inventory

The inventory of a typical farm is essentially a list of anticipated capital requirements for a producer to operate sustainably. Capital requirements are a list of assets which comprise of;

i. fixed improvements - Land (usually the largest capital requirement) and houses, sheds, staff residents etc. and,
ii. movable assets – Machinery and equipment.

Information of the physical assets include the age of the asset, expected economic life time of the asset, number of items in each category, capacity of the asset, annual depreciation and the current value of the asset.

Previous studies (Hoffman & Kleynhans, 2010; Knott, 2015) provided necessary information regarding the typical farm size, capital requirements and the expected economic life time of assets in the Western Cape, respectively. The (Guide to Machinery Costs, 2016) indicates that assets have an estimated useful economic lifetime of approximately 12 years, however due to financial constraints machinery and equipment are kept for 15 years. This is a norm for the Swartland, however PA technological developments have increased exponentially over the past decade. New technological advancements may offer higher savings potential than older equipment to producers. For this reason, producers must analyse equipment replacement cycles to identify the feasibility of replacing 'outdated' PA-tech, with more advance equipment, prior to reaching its useful economic lifetime.

Mentioned in Chapter One as a secondary objective, is to establish the most efficient tractor planter combination. In order to achieve this objective, it is assumed that the mechanical variations between the three production strategies is the tractor planter combination. A general farm inventory was developed, again the 'typical' farm description discussed previously includes an inventory list that fits the land use pattern. The tractor planter combinations for each productive system represent the mechanical variations for each system. A conventional production system represents the base model, and a conventional tractor planter combination is included. Precision and conservation agricultural production strategies can make use of either minimum-tillage (MT) or no-tillage (NT) planters. By making use of an ' IF ' formula in excel, the model is able to accommodate for varying tractor planter combinations. A code is assigned to each combination, where the formula is then able to differentiate between these codes and input the required cost data according to each code.

For each planter a varying Kilowatt (Kw) per planter tine / row strength is required to operated and pull the planters. The cost implications for purchasing higher Kw tractors can be significant. The model assumes that a 22 row planter is used. Table 3.2 below indicates the Kw requirement for the various planters. Conventional planters have a requirement of five Kw per tine. This is due to the planters having a tine which opens up the planting row in order to place the seed. Like conventional planters MT planters too have a tine which opens the planting row, it is assumed that only in conventional practices is the soil tilled on an annual basis. Therefore, a MT planter in a PA or CA system has to till the soil in a sense, hence the high Kw requirement (7 Kw per tine). NT planters on the other hand utilise a cutting disc to open the planting row in the soil, which places far less friction on the tractor pulling the planter. However, NT planters have higher repairs and maintenance costs in comparison to MT planters, as tines last longer than discs (Burger, 2016; Smit, 2016; van Niekerk, 2016). This is a common argument amongst producers, and for this reason a costing will provide more insight and ensure producers produce in a more efficient capacity.

A discussion with (Smit, 2016) CrossCape Precision equipment supplier, at the Swartland Skou provided valuable insight into the PA industry and local farmer experiences with precision technologies. Mr Smit's sentiments where shared with other PA-tech supplier representatives at the show, such as John Deere and New Holland (OEM). (Smith, 2016) General Group Manager (Ronin, Precision Farming Systems), indicated that the PA market in South Africa is expanding with numerous new suppliers entering the market, this backs-up the sentiments of the equipments suppliers. Indicating that producers are beginning to realise the value of precision equipment, as the cost price squeeze intensifies.

Table 3.2: Calculation for tractor size requirement for various planters

Planting days required:	Code	Power		Work		Field efficiency	Hour/ha	ha/Hour	Hours/day	Days to complete
		Kw/tine	Requirement	Width: m	Speed: km/hr					
Conventional	1	5	110	6	7	85%	0,28	3,57	8	26,61
Min-till	1	7	154	6	7	85%	0,28	3,57	8	26,61
No-till	1	4	88	6	7	85%	0,28	3,57	8	26,61

3.3.2.2 Gross margin calculations

A gross margin (GM) calculation was developed for each crop enterprise, within the specified production system. The focus of the study is on the mechanical aspect of the farming operation, for this reason crop yields are assumed to be constant for the baseline model. It is important however, to note that seasonal yield variations do occur, mostly as a result of fluctuations in rainfall. The gross margin (GM) for each enterprise is calculated and included in the multi-period cash flow sheet. The GM for each enterprise per ha is multiplied by its respective area produced on the farm, described in the land distribution sheet. The GM for each enterprise is calculated under conventional, precision and conservation agricultural practices. The result is three multi-period cash flow sheets, one for a conventional tillage based agricultural system, one for precision agriculture (PA) and lastly for conservation agriculture (CA). The respective IRR and NPV calculations for each productive system can be identified, measured and used for comparative purposes. The GM is calculated by subtracting the total variable costs, made up of directly allocable and non-directly allocable costs, from the total Gross Production Value (GPV), on a per hectare basis.

3.3.2.3 Overhead and fixed costs

Fixed costs are a part of total costs that are regarded as fixed over the short-term. These costs cannot be avoided or controlled over the short-term, irrespective of the scale or intensity of production. Overhead costs are the part of costs that are not allocated to any farming enterprise (Depertment of Agriculture, 2005)

Fixed and overhead costs typically include administrative costs, bank charges, consultation costs, communication costs, water and electricity, municipal taxes, repairs and maintenance on fixed improvements and permanent labour costs.

3.3.3 Output component

The output component of the simulation model is comprised of two financial indicators along with the gross margins. First the internal rate of return (IRR) and net present value (NPV) of capital investments, represent the profitability of the whole farm operation. Second is the affordability of borrowed capital, which is represented by the businesses expected cash flow.

The simulation model was used to determine the expected profitability of the typical farm based on current production practices and financial circumstances. The relative expected financial impact of certain practices can be measured and compared. Prices in the model are kept constant, while the effects of inflation are incorporated into the model by using real interest rates in all cash flow and profitability calculations. Where the IRR and NPV are embedded in the whole-farm cash flow sheets.

The net annual flow of funds is calculated by subtracting overhead and fixed cost and capital expenditures from the whole farm gross margin. Where the IRR is calculated on the net annual outlay over the 20-year period.

3.3.3.1 Internal rate of return (IRR) and net present value (NPV) on capital investment

The NPV and IRR are similar in many aspects. The NPV is a monetary measure of the present value in terms of expected future cash flows. While the IRR is a measure of the growth generated by the cash flow, as a percentage return on the initial capital investment.

Working with projects or options that have varying start times, different capital investment / run for different periods of time, the NPV and IRR measurements provide the ideal basis for comparison and measure of impact on the whole-farm profitability. Which provides a clear indication of the attractiveness of each system.

3.3.3.2 Cash flow budget

The cash flow shows the effect of the ratio of borrowed capital to own capital, and the consequences of the effects of interest. This measure can be used to gauge the affordability of the investment. The cash flow budget, which includes cash items only, shows the impact of interest payments on the farm’s bank balance. The prices used in the model are kept constant, it is necessary then to convert the nominal interest rate to a real interest rate. This was achieved using the formula:

Real interest rate = {[(1+nominal interest rate) / (1+inflation rate)]-1} %.

The affordability of borrowed capital is indicated by using the break-even year of the operation in the cash flow budget. The impact of the replacement policy of machinery on expected cash flow can also be evaluated in the cash flow budget.

3.4 Conclusion

Data from two sets, both based on Langgewens experimental farm, provided the essential details to developed and run the simulation model for this study. Trial data from the Langgewens experimental farm provided significant information regarding mechanical costs that occur during the production process. The second data set, provided the necessary information regarding the attributes of a typical farm. Combining this information provided the input data needed to develop a multi-period whole farm, budget simulation.

The three components that make up a budget simulation made up of the Input, calculation and output component form the outline of the composition of the model. Using Microsoft excel it is possible to link these three components, by then manipulating various input components using assumptions established in the literature review and personal communications, it is possible to identify the financial implications of selected strategies.

Mechanical costs form a significant portion cost of a commercial farmer's total costs, second to that of land. This cost becomes evident when analysing the gross margin calculation for each crop enterprise, found under the non-directly allocable cost. By developing a base model, named conventional agriculture, it is possible to measure the mechanical financial implications that improved technologies have on a per hectare basis, and how that influences the whole farm profitability of the farming operation.

The proceeding chapter will analyse the results of the budget model. A comprehensive analysis requires that the model be dissected and the necessary individual parts of each component be discussed. Interpretation of the profitability indicators, internal rate of return (IRR) and net present value (NPV) it is possible to determine the full financial implications that improved technologies have on a commercial farm.

Chapter 4: Results

4.1 Introduction

Chapter Three discussed the data for the study, How it was obtained and which key assumptions were utilised in developing the model. In addition, the key components of a whole farm budget model where broken down and discussed. Important input components of the model include mechanical input costs, i.e. purchase price, expected useful economic life time and lastly the per hectare operational costs. Comparing the mechanical costs on a per hectare basis of different production systems within the gross margin /hectare cost calculation will assist in measuring the financial implications of adopting improved technologies. While simultaneously identifying the most efficient tractor planter combination which farmers can utilise to ensure efficient production.

The current chapter will present the results obtained from running the model, after placing all the necessary assumptions. Focal points will be essential mechanical input components, borrowed to own capital ratio, production activities and the effect on mechanical costs per hectare and finally a discussion of the profitability indicators, IRR and NPV.

By presenting the simulation results in a graphic form the usefulness of utilising a model as a budgeting tool is highlighted. The results will verify, in an inexpensive way, what the financial implications of certain technologies are on a whole-farm basis.

4.2 Gross margin calculation

To begin the discussion of the results, the gross margin calculation per hectare will be analysed. Section 3.3.1.1, provided the physical farm description of a typical farm in the Swartland. As the study focuses on the mechanical costs per hectare, the non-directly allocable costs of the gross margin calculation, represent the focal point for this research.

Table 6.1: Not-directly allocable cost component of the gross margin calculation, conventional agriculture

Operation activity	Tactor/Vehicle	R/ha Fuel	Rep & Main	Repition		Cost
Deep soil tillage (Ripper)	80	105,60	120,65	1		226,25
Light soil tillage (Disc)	80	52,80	71,82	0		0,00
Light soil tillage (Plough)	80	158,40	213,33	2		743,46
lime application (Lime spreader)	80	34,65	41,49	0,16		12,18
Fertilizer application (Spandikar)	80	11,65	7,48	1,5		28,70
Pesticide application (1000l spray tank)	80	23,49	12,46	2		71,91
Herbicide application (1000l spray tank)	80	23,49	12,46	2		71,91
Plant seed (planter: conventional)	93	110,00	61,54	1		171,54
Plant seed (planter: min-till)	157	207,24	135,96	0		0
Plant seed (planter: no-till)	116	92,40	94,57	0		0
load (Front end loader)	69	2,06	0,90	1		2,96
Fuel: contract harvestor		400,95	0,00	1		400,95
Apply cover crop seed/snail pellets (Spandikar	80	11,65	13,95	1		25,59
Seedbed roller	80	41,07	26,16	1		67,23
Seed and Fertilizer (Truck 14t)		11,00	0,45	1		11,45
Grain Removal (Truck 14t)		79,20	3,24	1		82,44
General farm management 12000km (Bakkie 1)		16,83	14,73	1		31,56
General purpose 10000km (Bakkie2)		14,03	12,27	1		26,30
Total non-Directly Allocatable Variable Costs						**1974,41**
Gross Margin						**4812,28**

Error! Reference source not found. 4.1 indicates the various mechanical operating activities that occur during the course of a growing season. The machinery power (Kw), is indicated as well as the fuel, repairs and maintenance cost of the vehicle and implement on a per hectare basis. Repair, maintenance and fuel costs for equipment and implements are calculated from assumptions used by the guide to machinery costs, which calculates costs according to purchase price and expected lifetime of the implement. While fuel costs are based on engine size, Kw power, and power demand of the activity.

Represented in Table 4.1 is the base model for conventional agricultural practices, which is defined by significant tillage practices.

By calculating the per hectare cost for each activity, the repetition of the activity then calculates the final cost per hectare for each activity. Table 4.1 above indicates the mechanical costs for the base model which is represented by a conventional agricultural system, based on soil tillage. The total mechanical costs per hectare amount to R1 974.41 of which soil tillage practices make up R 969.71. Conservation and precision agricultural systems, modern production systems which preserve the soil, utilise minimum and no-till practices. Simply by removing tillage costs, producers will realise a saving of 49%.

Annexure A provides the not-directly allocable variable costs for precision and conservation systems respectively.

Table 4.2: Mechanical costs per hectare summary, for each enterprise and production system.

Cost /ha:	Conventinal	Precision	Conservation
Wheat	1974,41	963,01	949,94
Canola	1974,41	963,01	949,94

Table 4.2 provides a summary of the total mechanical costs / hectare for each production system. Conservation practices, exclude tillage practice however additional mechanical costs occur during cover crop application. by simply reducing tillage costs it is clear that farmers are able to save significantly. A producer practicing conservation agriculture on the 'typical farm' in question would save a total of R 778 597.2 per annum ((1974.41 – 949.94) *760). Figures take into consideration different tractor-planter combinations, PA (MT) and CA (NT). Had both PA and CA systems utilised the same planting method, PA measured the lowest mechanical costs of all production practices.

Literature indicated that producers from various regions around the world experience saving of between eight and 10 percent when implementing a precision system. This is due to information data maps being developed which farmers can then use to control mechanical traffic per hectare which results in fuel, repair and maintenance costs saving for machinery and equipment. A saving of 15% was included on mechanical costs, as an assumption in the simulation. (Smit, 2016) indicated that farmers could have been experiencing savings of 18 – 22%. A conservative value of 15% was used.

Compared to the base model precision practices realised a 53% mechanical cost savings. Allowing for R 657 384.80 saving of fuel, repairs and maintenance costs p.a. (Smit, 2016) indicated that within any given field, tractors move over the same line anywhere between 6 – 8 times. By establishing layered data maps, farmers are able to control and manage expensive mechanical operations. The result is that after utilising PA technologies farmers in the Swartland typically are experiencing a payback period of two years / growing season, on precision technologies. The results from the budget simulation indicate that producers are able to realistically experience significant cost savings, which is a testament to what the literature has indicated.

4.2.1 Gross margin considering yield implications of different tillage practices

The model assumed constant yields for all three production systems and tillage practices. Different tillage practices have a number of yield implications, mentioned previously, which have an impact on crop enterprise gross margin / ha (Agenbag, 2012; Knott, 2015).

Table 4.3: Gross margin per hectare of different tillage practices for each crop enterprise

Tillage practice	Enterprise GM			
	Wheat		Canola	
CT	4812,28	0	-613,65	0
MT	5823,68	6915,68	397,75	1081,27
NT	5975,37	8022,87	543,98	1825,58

Conventional tillage (CT) practices represent the base model used for comparative purposes. It was assumed that MT practices increased crop yields by 8% while NT practices improved yields by 15% (Knott, 2015; Strauss, 2016). Data from Langgewens experimental farm provide evidence that production, tillage, practices are an important consideration when observing the long-term yield trends.

Table 4.3 provides an illustration of the effect that tillage practices have on crop enterprise GM. MT practices, 8% yield response, improve wheat GM by R1 092.00, (6915.68 – 5823.68). NT pratices, 15% yield response, increased the GM by R2 047.50, (8022.87 – 5975.37). MT gross margin was calculated in a PA system, while, NT gross margin was calculated in a CA system. The yield implications of the various tillage practices will depend on the system in use on each individual farm. Table 4.3, highlight the potential GM implication that the practices have. Making note of these potential benefits is important as producers, with this knowledge, have the potential to maximise operational efficiencies based on economic best practices. Implementation of best practices, has significant profitability implications, when producers are able to realise increase in GM of R 1 000 or more / ha.

4.2.2 Production activities

An important part of the calculation component of the model, is regarding the calculation of the mechanical costs per hectare of each production activity. Table 4.4, provides the assumptions used to calculate diesel consumption and repairs and maintenance costs that where included in the GM calculation. Implement cost assumption used the same assumption in terms of repair and maintenance costs as tractors. The assumptions used are based off the purchase price of a new vehicle, from which the relative assumptions can then be used to calculate the necessary costs for each activity. The (Guide to Machinery Costs, 2016), provided the relevant costs for both tractors and implements on an hourly basis. Using the Langgewens production norms for each activity it was possible to calculate the cost per hectare for each activity.

Annexure B provides the full list of production activities as well as the hourly and finally the cost/ha for each activity. The total variable costs per hectare, is calculated by adding the fuel and repair and maintenance costs. The GM calculation separates these costs in order to illustrate the contribution of each to the total cost.

Table 4.4: Tractor implement cost assumptions (Department of Agriculture, 2016)

Tractors		Unless specified all are 4wheel drive
	Salvage value =	10% of purchase price
	Depreciation = (Purchase price - salvage value)/life (hrs)	
	Licence & insurance =	2% of average investment / hors per annum
	Interest =	10% of average investment / hours per annum
	Repairs & maintenance =	120% of purchase price / lifetime (hrs)
Power demand	**Fuel price =**	R 11 / litre
Low	**Fuel usage =**	35% of tractor power (Kw)
	Litres used per kW hour	0.4
Medium	**Fuel usage =**	45% of tractor power (Kw)
	Litres used per kW hour	0.35
High	**Fuel usage =**	60% of tractor power (Kw)
	Litres used per kW hour	0.3
Implements		
	Depreciation cost per hour=	(Purchase price-salvage value) / life period (hrs)
	Salvage value=	10% of purchase price
	Average investment=	(Purchase price + salvage value) / 2
	Interest cost=	10% of average investment per annum / hours per annum
	Repairs & maintenance=	0.012% calculated as a percentage of purchase price

4.3 Whole farm financial performance

The budget model, which is a long-term measurement of the whole farm profitability, is done over a 20-year period. Financial performance is measured by the internal rate of return on capital investment (IRR) and the net present value (NPV), of the future expected cash flows. The IRR and NPV are calculated for each farming production system. The profitability indicators, IRR and NPV, are calculated in the whole-farm multi-period budget sheet. Annexure C shows a long-term cash flow budget, with a capital budget included, of a typical farm in the Swartland under different production systems.

Table 4.5 provides a summary of the profitability indicators for the various production systems, conventional, precision and conservation agricultural practices. Conventional systems represent the base model, and therefore the relative change is indicated as zero. From this both the relative change in IRR and NPV for both precision and conservation systems are compared to the base model.

Table 4.5: Summary of whole-farm profitability indicators, IRR and NPV, for varying production systems

Sytem:	Profitability indicators		Relative change
Conventional:	IRR	3,47%	0%
	NPV	R 16 267 458,42	0%
Precision:	IRR	5,83%	68%
	NPV	R 27 551 403,99	69%
Conservation:	IRR	6,65%	92%
	NPV	R 31 204 331,44	92%

Conventional production practices yielded an internal rate of return of 4.03%, which is similar to the expected IRR of the Swartland area. The net present value of the farming operation was valued at R 16 267 458.42, this is the current value of the business after discounting expected future cash flows, Annexure D, are the discounted values under the 'Net annual outlay'.

Precision agriculture yielded a higher IRR, at 5.83% which is an increase of 2.36%. This is a relative change of 68%. This can be associated to the mechanical costs saved during the production process. The impact on the NPV of the farm is significant, which has increased by 69%. This has a number of implications for the farmer, firstly the farmer can utilise the additional value of the farm as collateral if the farmer seeks to expand the operation. More importantly the farmer will be able to secure additional financing during drought years, during seasons where productive capabilities have been hindered by some external climatic / economic factors. Conservation agriculture measured the highest IRR of the three production methods at 6.65%. Compared with conservation agriculture, there was an increase of 3.18%, and 0.82% with precision agriculture. NPV increased by 92% compared too conventional and 23% with precision agriculture.

It is evident is that modern production techniques are in the long-run, more profitable and ultimately more sustainable. Environmentally it also contributes to sustainability as can be seen by the decrease in mechanical costs per hectare. By reducing mechanical inputs numerous risks can be mitigated, important to make note of for the study, is the effect that the exchange rate has on fuel and equipment prices for the producer.

Although precision agriculture measured a lower IRR than conservation agriculture, the long-term benefits of information technologies cannot be underestimated. As the literature indicated the long-term benefits are not the physical input saving technologies, but rather the information which is generated by the technology. Information that producers are able to utilise when making financial commitments or external factors (climatic, economic) place strain on the farming business. Quantifying these benefits is difficult, and were not included in the IRR / NPV calculations. Conservation agricultural practices have a number of benefits that are equally as difficult to quantify, which have significant financial benefits, and were also not included in the IRR / NPV calculations.

The budget-model was developed using historical data, forecasts, individual stakeholder experience and assumptions. These assumptions are subject to change over the years, however the simulations provide stakeholders with an inexpensive decision making tool from which certain aspects of an operation can be analysed.

4.4 Analysis of most efficient tractor planter combination

There have been a number studies completed on the effects that various tillage practices have on the chemical composition of the soil (Agenbag, 2012; Knott, 2015). Additionally, what the implications are of the various tillage practices on crop yield and quality. The modern commercial farmer has an obligation to ensure that soil is nurtured to ensure maximum productive efficiency. The next step is to attempt to determine the most efficient tractor planter combination, from which farmers will be able to make more informed decisions.

Three tractor planter combinations have been included and analysed in the whole-farm simulation. Conventional tillage based planters, minimum and no-till planters where included in the model. Where conventional planter tractor combinations were used as a base, and minimum and no-till planters are interchangeable between precision and conservation production systems.

Using the calculations available in excel, it is possible, by using codes (1, 2 and 3) for conventional, minimum and no-till planters respectively, to adapt the model to change tractor planter combinations for each system. The mechanical costs for each tractor planter combination can then be analysed in terms of the total costs per hectare. The associated costs can be seen in annexure A, where each combination is listed.

Assumptions could be made about tractor power requirements per planter row / tine by a series of interviews (Burger, 2016; Smit, 2016; Strauss, 2016; van Niekerk, 2016)

Table 4.6: Tractor planter combinations and assumptions

Planter costs:	Code	Power		Work		Field efficiency	Hour/ha	ha/Hour	Hours/day	Days to complete
		Kw/tine	Requirement	Width: m	Speed: km/hr					
Conventional	1	5	110	6	7	85%	0,28	3,57	8	26,61
Min-till	1	7	154	6	7	85%	0,28	3,57	8	26,61
No-till	1	4	88	6	7	85%	0,28	3,57	8	26,61

Source: Adapted from Langgewens trial data.

Table 4.6 provides an illustration of the tractor-power per tine / row requirement for each planter. As can be seen conventional planters require 5 Kw / row, min-till planters 7 Kw / tine and no till planters require 4 Kw / row. The cause of varying power requirements for seemingly similar planters, is regarding the degree to which the planter tills the soil. For example, conventional and min-till planters have a ‘tine’ which is a bar which opens a line for the seed to be placed. Tines have a large surface area, in contact with the soil, which cause significant friction and therefore a tractor requires more power to pull the planter. No-till planters on the other hand have a rotating cutting disc, in place of a tine, which cuts open the soil to place the seed. The discs have a significantly smaller soil surface area and therefore require less tractor power to pull the implement. Important to make note of is that tined planters are less expensive than disc planters and require significantly less repair and maintenance costs, as tines are more durable than discs.

Table 4.6 indicates, varying tractor sizes are required to pull the various planters. A 22-row planter requires a 110 Kw, 154 Kw and 88 Kw, for conventional, min-till and no-till planters respectively. The size (Kw) of a tractor has a significant influence on the repair and maintenance and more importantly the fuel costs, see Table 4.6. Table 4.7 provides a breakdown of the total planting costs / ha. By analysing the tillage, tractor and implement costs it is possible to develop a clear understanding of the allocation of costs.

Table 4.7: Break down of the planting costs per hectare for different planters

Planting costs/ha:	Tillage costs	tractor		Implement	TOTAL COST
		Rep & main	Diesel	Rep & main	
Conventional:	969,71	38,94	110,00	22,60	1141,24
Min-till:	19,23	102,04	207,24	33,92	362,43
No-till:	22,62	34,57	92,40	60,00	209,59

Tillage costs for a conventional production system, discussed in Section 4.2, form the largest cost component of planting (85%). Tillage is necessary in order to prepare an adequate seedbed in which to plant. Tractor and implement costs for no-till are the lowest of all three tractor planter combinations. As mentioned previously tined planters have a low maintenance cost which is evident from the implement cost / ha.

Minimum-tillage planters have a low repair and maintenance costs / ha, R 33.92, second to conventional planters. By removing the seedbed / tillage practices from the equation, costs are reduced exponentially. However due to the large tractor Kw power demand to pull the planter, tractor costs / ha are high. The large 154 Kw tractor requires R 207.24 of diesel per hectare, more than the diesel requirement of conventional and no-till combined.

No-till planters which are notably more expensive than conventional and min-till planters, have the highest repair and maintenance costs / ha, R 60. However, the 22-row planter requires only 88 Kw of tractor power. Resulting in lower tractor costs / ha, R 126.97. The large repair and maintenance costs of the planter are offset by the low tractor costs. Which for a producer is important, as mechanical and fuel costs form a large component of a farms total costs.

From a mechanical perspective the most efficient planting method is a no-till tractor planter combination. A no-till planter combination will save a producer R 152.84 / ha in planting costs, compared to a MT combination. As discussed previously, Chapter Three, various tillage / planting methods have a number of effects in terms of yield and quality. Therefore, from a managerial perspective a producer can ultimately decide if the mechanical costs savings are beneficial to the whole farm operation or if a more expensive method will improve yields and quality to an extent that the mechanical costs can be justified in terms of a higher GM /ha.

4.4.1 Time saving potential of precision technologies

Precision technologies have numerous benefits, input saving being the focus of the study. In line with this, there is an additional benefit of implementing a precision production system. This is the time saving potential of the technologies.

A common saying amongst farmers is, ‘the difference between a good farmer and a great farmer, is a week’. Table 4.8 provides a representation of the days needed to complete planting, using the assumed 22 row planter. The table provides the tractor power required to pull each planter, work width (m), planting speed (km/hr) and lastly the field efficiency of each planter. This information was obtained from production norms obtained from Langgewens trial data.

The top section of Table 4.8, provides the time required (days) to complete planting on a typical Swartland farm, using various planters which are not assisted by precision technologies. As the table indicates, without the assistance of precision technologies, planting with a single planter will extend the planting time to outside of the 22day window, discussed in Section 3.3. Precision technologies allow producers, with a single planter to complete planting operations within the recommended time frame. Producers in the scenario of the top part of the table, would either have to work longer hours during the day or finance an additional planter.

Precision technologies save this time when the tractor has to turn and realign and continue planting. GPS systems placed on the tractor and planter, consider implement width, distance between tractor and implement etc. This allows the operator to continue driving and simply turn into another row further down the field, instead of turning around and re-entering the row next to the row that has just been planted. In fields where obstacles are present on field boundaries, trees or steep banks for example, operators can waste time turning around and realigning the planter.

Table 4.8: Planting time saving potential of precision technologies

Planter costs:	Code	Power		Work		Field efficiency	Hour/ha	ha/Hour	Hours/day	Days to complete
		Kw/tine	Requirement	Width: m	Speed: km/hr					
Conventional	1	5	110	6	7	85%	0,28	3,57	8	26,61
Min-till	1	7	154	6	7	85%	0,28	3,57	8	26,61
No-till	1	4	88	6	7	85%	0,28	3,57	8	26,61
Precision planting time saving:										
Min-till	1	7	154	6	7	85%	0,28	3,57	8	22,62
No-till	1	4	88	6	7	85%	0,28	3,57	8	22,62

4.5 Sensitivity analysis

Rand / Dollar exchange rate = R13.54 (2016, October 31).

The mechanisation of commercial farming operations over the past decade has been compounded due to a number of internal and external farming factors. The farm problem, decreasing product prices and increasing input costs, has placed significant pressure on producers to become ever more efficient in production. Mechanising operations has allowed producers to expand production and spread costs over a larger area. External pressures which include a fluctuating exchange rate, increasing labour prices and land reform policies are placing pressure on the profitability of producers.

The mechanisation of a farming business leaves producers vulnerable to exchange rate devaluations, as most machinery is imported. This will increase the cost of replacing machinery, and ultimately impact the long-term profitability of the whole-farm operation. By modelling a farm over a 20-year period, the impact on IRR and NPV, can be measured as capital is replaced.

The sensitivity analysis seeks to measure the impact that an increase / decrease in the exchange rate will have on the whole farm profitability. This will be achieved by simulating a 10% and 20% increase and decrease in the fuel and price of the tractor planter combinations.

Fertilisers and chemicals (herbicides and pesticides), are other production inputs that are also imported into South Africa. The exchange rate ultimately will impact any form of input that is imported, however, over time the exchange rate should act as a supporting mechanism to the wheat price.

Table 4.9: Long-term farm sensitivity to a 10 and 20% price increase in fuel and tractor-planter combinations

System:	Current prices		10 % increase			20 % increase		
	IRR	NPV	IRR	Relative change	NPV	IRR	Relative change	NPV
Conventio	3,47%	R 16 267 458,42	2,99%	13,86%	R 14 053 110,95	2,51%	27,62%	R 11 838 763,48
Precision	5,83%	R 27 551 403,99	5,42%	7,10%	R 25 705 163,51	5,01%	14,13%	R 23 858 923,04
Conservat	6,65%	R 31 204 331,44	6,24%	6,19%	R 29 400 510,52	5,83%	12,34%	R 27 596 689,61

Table 4.10: Long-term farm sensitivity to a 10 and 20% price decrease in fuel and tractor-planter combinations

System:	Current prices		10 % decrease			20 % decrease		
	IRR	NPV	IRR	Relative change	NPV	IRR	Relative change	NPV
Conventio	3,47%	R 16 267 458,42	3,96%	13,95%	R 18 481 805,89	4,44%	28,00%	R 20 696 153,36
Precision	5,83%	R 27 551 403,99	6,25%	7,16%	R 29 397 644,46	6,67%	14,40%	R 31 243 884,94
Conservat	6,65%	R 31 204 331,44	7,07%	6,31%	R 33 008 152,35	7,49%	12,66%	R 34 811 973,26

The agricultural machinery market in South Africa is largely import oriented, meaning that mechanised operations are extremely sensitive to fuel and exchange rate fluctuations. Table 4.9 indicates what the effect on long-term profitability of a typical farm in the Swartland will be after a 10% and 20% increase in fuel and tractor-planter combinations. Table 4.10 indicates the alternative scenario of a price 10% and 20% decrease in fuel and tractor prices. The discussion will focus on a ‘typical farms’ long-term financial sensitivity to input price increases.

In a highly mechanised system fuel price fluctuations have a significant effect on the profitability of the farm. By simulating a 10% price increase in the fuel and tractor-planter combinations, the result is a decrease in IRR of 13.86%, 7.1% and 6.19%, for the respective systems. The increase of the fuel price of the whole farm accounts for the most significant impact on the farm profitability, of a conventional system (11.61%, IRR), while a tractor-planter price increase to a lesser extent (2.25%, IRR).

A 20% price increase resulted in a relative change in IRR of 28%, 14.4% and 12.66% for the respective systems. The results indicate that in terms of a systems resilience to price increases, precision and conservation systems proved to be more resilient to price increases than a conventional system. Precision agriculture proved to be the most resilient, had both CA and PA utilised the same planting system. Although, the margin was relatively small between the two systems. Therefore, by adopting modern production practices producers can mitigate risks and ensure the rigidity of their operations.

Table 4.10 provides an indication of the long-term financial impacts of a price decrease of 10%and 20%. More inefficient production systems benefit the most from an input price reduction. The profitability implications are similar to that of a price increase, however, it is important to measure how a farm business will benefit from a price reduction.

Had the sensitivity analysis considered a price increase of all machinery and equipment, the results would provide a different scenario. This again highlights the importance of producer's ability to mitigate risks.

Precision agriculture requires significant capital investments in technology which in the short-run may not seem feasible, depending on how informed the producer is. In the long-run, precision technologies provide the ability to improve capital efficiency and streamline the farm level production process. This allows producers to reduce input costs, while simultaneously incorporating a new sustainable holistic aspect in the operation.

4.6 Conclusion

Using the parameters and assumptions of a typical farm in the Swartland, a multi-period budget model was developed and constructed. The model was used firstly to establish the profitability of a typical farm utilising a conventional approach to production. Additionally, the model was used to test the long-term profitability impacts that modern production techniques have on the whole farm, particularly what the mechanical implications per hectare are for each system. All of which had a positive impact on IRR and NPV. Finally, the model simulated the effects that mechanical and fuel price fluctuations have on a whole farm level. The simulation, is able to capture the complex interrelationships which exist in a typical farm. By modelling these complexities, more informed results can be obtained from the model.

After reviewing relevant literature and having discussions with stakeholders and experts in the industry it was possible to insert key assumptions into the model. Benefits and costs that certain production techniques, precision agriculture, have on a typical farm could be assessed. The model allowed the complexities and impacts which certain strategies have, to be calculated and measured in a quick time and accurately. By changing certain input combinations and parameters it is possible to measure, accurately, the expected impact on profitability.

Conventional production practices showed the least profitable outcome, and proved most vulnerable to input price fluctuations. Conservation agriculture measured the highest profitability of the three systems. In terms of system resilience to mechanical and fuel price fluctuations, conservation agriculture was more resilient than conventional practices. Precision agriculture measured the most resilient of all systems, however, margins compared to conservation practices were relatively small. Precision agriculture did notably improve mechanical efficiency per hectare, which had a significant impact on long-term farm profitability as measured by IRR and NPV.

Chapter 5: Conclusion, summary and recommendations

5.1 Conclusion

The South African commercial farmer of the 21st century has a variety of obligations and risks to contend with. Natural resource scarcity and the farm problem have made the primary agriculture sector a risky venture. This is exacerbated by climatic conditions, especially in the Swartland winter cereal production area. Producers must become dynamic businessmen to ensure maximum productive efficiency. Additionally, farmers have a large social obligation which result in additional risks on the operation. Growing consumer awareness and traceability of consumer products have meant that producers are obligated to produce in a more environmentally sustainable manner than in previous years.

Precision agriculture is a conceptualised systems approach which seeks to reorganise the entire agriculture system, towards a low input, high efficiency, sustainable system. This concept has benefited due to the emergence of several technologies. Geographic Information Systems (GIS), Global Positioning System (GPS), miniaturised computer components, remote sensing, automatic control, telecommunications, have allowed users to capture comprehensive data in spatial and temporal variabilities. This allows agricultural producers to make more ‘right’ decisions per hectare of land, per unit of time and with the expected net benefits. The research will seek to analyse the financial implications that improved technologies have on certain production strategies.

The fundamentals of PA have been appreciated for many centuries. Where conventional tillage(CT) is focused on soil tillage for production. CA is a more holistic production strategy which seeks to; reduce / remove soil tillage practices to revert soil to its natural state, incorporate crop rotations to improve soil microbial diversity and lastly, ensuring permanent soil cover to improve soil moisture retention. PA or site specific management is a systems approach (technologically orientated) based on observations, measurements and responding to in-field variability amongst crops. Before the advent of agricultural mechanisation, small field sizes allowed farmers to vary production treatments manually. However increasing field sizes have made it difficult to manage in-filed variability without significant technological improvements.

The Middle Swartland area of the Western Cape is predominantly a grain producing area, characterised by a Mediterranean climate. Productions systems are limited by shallow shale soils and precipitation, which is 90 percent limited to winter. The harsh farming environment results in farmers having limited production alternatives to increase profitability sustainably. Sustainability is referred to in a sense of continued profitable production and natural resource protection. Precision agriculture / technology provide producers with the ability to incorporate data from multiple sources into managerial decisions. Informed decision making allows the production process to be streamlined, while minimising resource wastage during the process. Ensuring efficient production reduces some of the effects which the cost price squeeze places on the operation.

A farm operates as a system made up of several components, and often synergistic effects occur when individual components are combined. The sum of the output of each component is measured in financial terms by farm profitability. Knowledge of the complexities that exist within each component is essential for the decision-making process. It is important to evaluate proposed production methods within a whole-farm context. This accounts for the synergistic effects that occur amongst components, as well as measure the profitability implications. Using information from previous studies, assumptions and parameters were identified.

Additional information regarding proposed production system were obtained from individuals and experts within the industry. Confirming certain activities / processes, while allowing theoretical data / assumptions obtained from relevant literature to be confirmed and adjusted where necessary, to reflect observations in a South African context.

In this research project, long-term whole-farm profitability based on a PA approach were highlighted. Emphasising the profitability impacts which PA has on the whole-farm operation, by incorporating the interconnected components of the farming system. A whole-farm budget model was developed to incorporated these interrelationships. The model was based on a ‘typical farm’ in the Middle Swartland area. The exploratory nature of the research meant data was obtained from relevant literature, consultation with stakeholders in the industry, additionally crop trial data was obtained from Langgewens experimental farm. These assumptions where validated by experts from the industry.

Langgewens crop trial data was used to establish various mechanical activities and their relevant parameters, for each crop enterprise. Once the model was built, assumptions regarding the varying production systems could be included. These were used to measure the long-term profitability of each system. Additionally, different tillage (planting) systems where included in the model to establish the most cost efficient tractor-planter combination.

The model is comprised of three components; Input, Calculation and Output components, discussed in Chapter Three. Using a sequence of mathematical and accounting equations, it was possible to capture the complexities that exist within a farming operation. Each calculation, corresponds to a set of input data. The Price, yields and assumptions sheet define the parameters on condition for the model, and each production system. By manipulating the input component, a series of changes will occur in the model, consistent with a real farm situation. Thus, providing a simulation of a real-life situation.

The method used in the study, of whole-farm modelling, have met the requirements of answering the research question. The model was developed with the assistance of similar studies previously complete, which focused on different aspects of the farm. Assumptions in the model have been validated by relevant literature and experts. The assumptions were manipulated to mimic the possible variations in external factors and evaluate the impact on farm profitability. The sensitivity of the relevant exogenous factors on farm profitability was measured in the actual and relative change to IRR for simulated scenarios. Three scenarios / production methods were compared in the model, to comprehensively make comparisons of improved technologies on a typical farm.

Initial farm level evaluation of the production systems under different planting methods and mechanical variations, indicated that a conventional production system was the least profitable. The conventional system served as a base model, from which alternative production systems could be compared to. The IRR and NPV was used to measure the long term profitability of each alternative system. PA generated a positive, notably higher NPV and IRR compared to the base model, indicating positive investment potential in PA. CA measured the most attractive system, compared to the base, with an IRR and NPV significantly higher than both conventional and PA systems. Important to note is that under CA and PA systems, production techniques in terms of tillage practices are altered. These changes have several implications on the directly allocable variable costs for each crop enterprise, yield, quality and input costs. Although not in the scope of the study a scenario was included to highlight the impact on enterprise GM, of the yield implications that various systems experience. The study focus was primarily the mechanical, non-directly allocable variable costs of production. However, including additional scenarios provides industry stakeholders with a clearer perspective.

A break-down of the mechanical production activities, provided information in terms of the most efficient tractor planter combinations. Again, three combinations were considered, CT, MT and NT planters, each of which require different tractor sizes due to mechanical component variations. The results indicated that conventional tractor planter combinations, considering soil tillage costs, were the most inefficient, due to the large soil preparation costs involved. MT planters proved more efficient than the base model, however a NT planter combination proved the most efficient. MT planters have a lower cost per hectare than NT planters, however, the tractor power (Kw) requirements to pull each planter proved to be the deciding factor. MT planters require more tractor Kw's per tine than NT planters, therefore the lower maintenance cost per hectare of a MT planter is offset by the high tractor costs, mostly fuel costs.

The expected impact of inflation on input prices, specifically price of fuel and tractor-planter combinations was assessed with scenarios. The sensitivity of farm profitability was measured in the actual and relative change to IRR and NPV, in the event of a percentage increase in prices. A 10% and 20% increase / decrease of prices was assessed. A conventional system proved the most susceptible to price fluctuations indicating the most significant change in IRR. PA was measured as the most resilient system of the three, although the relative change in IRR compared with CA was too small to differentiate.

It is important to note that the study focused on the mechanical components of the typical farm under various production systems. Quantifying the numerous long-term benefits that arise from implementing a precision system is difficult, likewise with a CA system. As the literature indicated the real long-term benefits of a PA system arise in terms of decision making, managerial and investment, quantifying these benefits is difficult. CA have several long-term benefits which are equally as difficult to quantify.

It should be stated that modern production systems, with the assistance of improved technologies, can be more resilient and profitable than traditional systems. PA has the ability to reduce the financial constraints of the farm problem, which will improve the overall sustainability of the agricultural sector in the region.

5.2 Summary

The relatively low profitability and growing environmental concerns over agricultural production has been the driving force behind the search for alternative production methods. Population growth has been placing pressure on agricultural output, with global food demand set to increase by 1.5 – 2 times compared to current production levels. The industrial; and green revolution, have provided the necessary foundation on which modern commercial agriculture must expand to meet food demand in the future. This growth will intensify current pressures on the limited natural resources available for agricultural production. Globalisation and government policies to promote a free market economy promote / create a competitive business environment, exacerbating the low profitability currently experienced by commercial farmers. The majority of population growth is expected to occur in developing nations, highlighting the importance of affordable food.

Sustainability applies equally to the natural resources and the producers' livelihood. The natural resources should be used in a manner that either sustains or enhances the quality and productive capacity of the resource. This responsibility lies with the producer as the custodian of the natural resources. The importance of the producers' role in sustaining these resources for present and future generations must be appreciated. The viability of the producers best practice production methods should be maintained by the market to ensure sustainable use of natural resources.

The Middle Swartland area of the Western Cape, South Africa, is characterised by a relatively dry Mediterranean climate and shallow soils. The area produces mainly wheat, where agricultural research focuses on grain farming, normally within the boundaries of a specific scientific field. The method used in this study try to incorporate a multi-disciplinary approach by using assumption from various scientific fields, which assist is measuring the effect which certain practices have on farm profitability. Confining studies to a single scientific field may for example result in a disregard for technical aspects of a farm, when considering the financial implications of an activity.

Sustainable agriculture is concerned with four main aspects; worldwide food security, protecting the environment and natural resource base, sustaining natural resources for present and future generations, and to sustain the economic viability of farm operations and farmer livelihoods. It is important to sustain both the natural resource base and farmer livelihoods for present and future generations to ensure global food security.

PA offers practical, economic and environmental solutions. Increased yields, reduced inputs costs and more productive operation times, should result in higher profits. The fundamentals of PA have been appreciated for many centuries. Before the advent of agricultural mechanisation, small field sizes allowed farmers to vary production treatments manually. However increasing field sizes have made it extremely difficult to manage in-filed variability without significant technological improvements. PA is a conceptualised systems approach which seeks to reorganise the total system of agriculture towards a low input, high efficiency, sustainable agriculture system, driven by technological advancements.

PA can be defined as a management strategy that uses information technologies to incorporate data from multiple sources into decisions associated with crop production. This can be interpreted further by the primary applications (PA); (i) developing a comprehensive database as a result of monitoring production variability in both space and time components, and (ii) improving the intended managerial response.

PA has a number of financial and socio-economic benefits, however, there are also a number of challenges associated with the system. As the definition indicates, PA are essentially a variety of information technologies, which provide the user with the ability to layer information on maps which is then used in the decision process. By mapping in field soil variations, farmers are able to adjust plant densities according to the productive potential of the soil. Over a number of years producers are able to develop comprehensive information maps, which can be used to build trends in terms of yield potential during various seasons, pest control measures, weed mapping etc. The long-term benefits of having access to this information is difficult to quantify, but informed decisions should enhance long-term sustainability of the farming operation.

The biggest challenge with operating precision technologies is the operator's ability to, effectively, manage software to construct valuable information maps. A farmers education is a key component and presents a major barrier to the adoption of precision technologies. Age has a negative correlation with the adoption of PA technologies, this is due to the conservative nature of older producers. Competent human capital is essential for the effective implementation of a PA system, changing an individuals mind-set to look / learn new dynamic systems is key. Topographical features of a farm present another challenge. For location technologies, GPS, to operate the receiver must be connected to a minimum of three satellites at any time. Therefore, large physical objects such as forests, mountains etc. can obstruct connections and ultimately render an important component of the system ineffective.

Precision technologies represent a new age of dynamic management tool that extend the production possibilities frontier of individual farmers to new levels. The applications of the technologies are broad and flexible. One of these applications are precision technologies in CA. The major mechanical benefits arising from CA can be attributed to precision technologies. Precision application of fertilisers, herbicides and pesticides, where required, have reduced input use and ultimately reduce environmental effects that these inputs have.

Financially PA requires an initial large capital outlay for the equipment. This initial capital expenditure is significant and can often deter potential investors. Both the literature and personal communications indicated that there is no single ideal PA technological setup, each farmer must assess their individual situation and identify which equipment will be most beneficial to the operation. There are different levels of PA system, with the technological capacity of the system contributing largely to the costs of equipment. Precision technologies embodies in a higher quality variable input. The capital, time and consultations required to operate the system mean that cost of production per unit input are higher than a conventional system. By utilising inputs more effectively and efficiently, producers are able to improve crop yields, product quality and reduce total inputs. While traditional systems have a lower variable cost, inefficiencies result in more input units / unit output. Literature indicates that the saving potential of improved technologies is, so much that the estimated average payback period for these technologies is two production seasons. This was confirmed in personal communication with experts of the technology in the middle Swartland area.

For the purpose this research project a systems approach that focuses on a whole-farm was required. Traditionally the scientific approach to understanding and managing complex problems, has been a reductionist approach where one component is analysed in isolation. The systems approach, promotes a more holistic approach to problem solving. The farm is acknowledged as a complex and interrelated system of biological, mechanical and economic components. This notion makes a systems thinking approach ideal for studying farm related issues.

Farming occurs over a large area and output is usually not continuous, but rather seasonal. For this reason, developing a model of the system is a time and cost efficient way of studying farm systems. In terms of the financial evaluation of a farm, a computerised model is ideal to accommodate multiple mathematical and accounting calculations. Whole farm profitability considers all the components and interrelationships forming the farm system. The farm can best be studied by simulating the operations over an extended time-period because the issues of tillage and capital replacement are longer term orientated

The Middle Swartland area is a relatively homogeneous grain producing area. This research makes use of a 'typical farm' rather than an average farm to avoid the skewing effect of outliers. A typical farm would more closely follow the most common characteristics of farms found in the homogeneous area. It presents a method that accurately relates the impact of certain factors to profitability in a context that other role-players can associate with.

A multi-disciplinary technique was used to generate and validate the typical farm values and characteristics. In order to model a farm accurately, various perspectives are necessary to explain certain processes or to understand and more accurately foresee their impact on the farm system.

Langgewens trial data provided information regarding the essential mechanical activities and production norms. PA was measured as a competitive mechanical system, in terms of mechanical costs per hectare, compared to other production strategies.

In meeting with the objectives, the most efficient tractor planter was established. By taking into account tillage costs, tractor and planter fuel, repair and maintenance costs / hectare, it was possible to make observations regarding the most cost efficient system. The NT tractor planter combination proved the most efficient combination, while MT was the second most efficient combination.

Data and results were captured in a whole-farm, multi-period budget. A whole-farm budget simulation comprises of three components. Firstly the input component, which includes, the physical farm description / layout, farming mechanical practices, yield assumptions and input and output prices. Altering any of these factors will result in a change in the whole-farm profitability through a series of interconnected mathematical and accounting formulas. This forms part of the calculation component and results in the output component which quantifies results in predetermined profitability criteria. The calculation component is comprised of different calculations that represent the biological, physical and financial interrelationships of the whole-farm system. This can be seen in the individual enterprise GM calculation where data from the input component are used to calculate the gross margin / hectare. Gross margins and over-head costs are then used in the output component to calculate net annual flows. The output component refers to two key profitability measurements. The first measurement is the internal rate of return on capital investment (IRR) of the whole-farm. While the second, measures the affordability of borrowed capital, in terms of multi-period cash flows.

Two scenarios were simulated with the whole-farm model. The first scenario aimed to determine the impact of fuel price inflation on the farm. Increments of 10% and 20% were used to assess the impact of an increase / decrease in the fuel price on expected profitability. The simulation highlighted the significance of tillage practices.

The second scenario evaluated the implications of tractor-planter combination, inflation. The simulation measured relatively small changes in IRR, however, this did provide insight into the extreme sensitivity of a farm in terms of mechanical price variations.

In conclusion, the main aim of the research project was to financially quantify the implications that improved technologies have in terms of profitability. The methods that were used during this research were successfully used to achieve the goals of the research. The most important lesson was that the interrelatedness of PA as a farming principle necessitates a systems perspective.

5.3 Recommendations

The research project focused on the benefits which improved technologies have on a typical farming operation in the middle Swartland, Western Cape. Using scientific and personal communications with individuals in the industry, it was possible to construct a whole-farm budget model of a typical farm in the Swartland. The model was used to compare various production systems, while analysing the savings potential of PA technologies. The study was exploratory in nature, therefore, a long term working and research relationships between all scientific disciplines and producers is recommended for PA in the Western Cape. Precision production practices are unique and specific for each individual situation, by generating knowledge that is relevant and applicable to producers, the most efficient use of improved technologies can be ensured. A study to determine the effects of PA and CA on yields and other inputs than mechanisation should be valuable.

After conducting a comprehensive review of the relevant literature, it is evident that precision technologies will for the foreseeable future play a key role in the primary agricultural sector in South Africa. It is recommended that a study similar in nature be completed for summer grain producing areas. This will broaden awareness amongst farmers and assist in future developing the sector.

Finally, research of new production techniques along with crop rotation and tillage systems has provided producers with essential information which can be used constructively in the decision-making process. The conversion process have a number of financial and production risks which producers must manage. The final recommendation is that a study be complete on an implementation strategy which producers can follow in order to remain as profitable as possible while managing these risks.

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Annexures

Annexure A: Not-directly allocable variable costs per hectare for each production system.

Precision and conservation agriculture respectively.

R/ha			
Fuel	Rep & Main	Repition	Cost
105,60	120,65	0,1	19,23
0,00	0,00	0	0,00
0,00	0,00	0	0,00
34,65	41,49	0,16	10,35
11,65	7,48	1,5	24,39
23,49	12,46	2	61,12
23,49	12,46	2	61,12
0,00	0,00	0	0,00
207,24	135,96	1	291,72
0,00	0,00	0	0,00
2,06	0,90	1	2,52
400,95	0,00	1	340,81
0,00	0,00	0	0,00
0,00	0,00	0	0,00
11,00	0,45	1	11,45
79,20	3,24	1	82,44
16,83	14,73	1	31,56
14,03	12,27	1	26,30
			963,01
			5823,68

R/ha			
Fuel	Rep & Main	Repition	Cost
105,60	120,65	0,1	22,62
0,00	0,00	0	0,00
0,00	0,00	0	0,00
34,65	41,49	0,16	12,18
11,65	7,48	1,5	28,70
23,49	12,46	2	71,91
23,49	12,46	2	71,91
0,00	0,00	0	0,00
0,00	0,00	0	0,00
92,40	94,57	1	186,97
2,06	0,90	1	2,96
400,95	0,00	1	400,95
0,00	0,00	0	0,00
0,00	0,00	0	0,00
11,00	0,45	1	11,45
79,20	3,24	1	82,44
16,83	14,73	1	31,56
14,03	12,27	1	26,30
			949,94
			5975,37

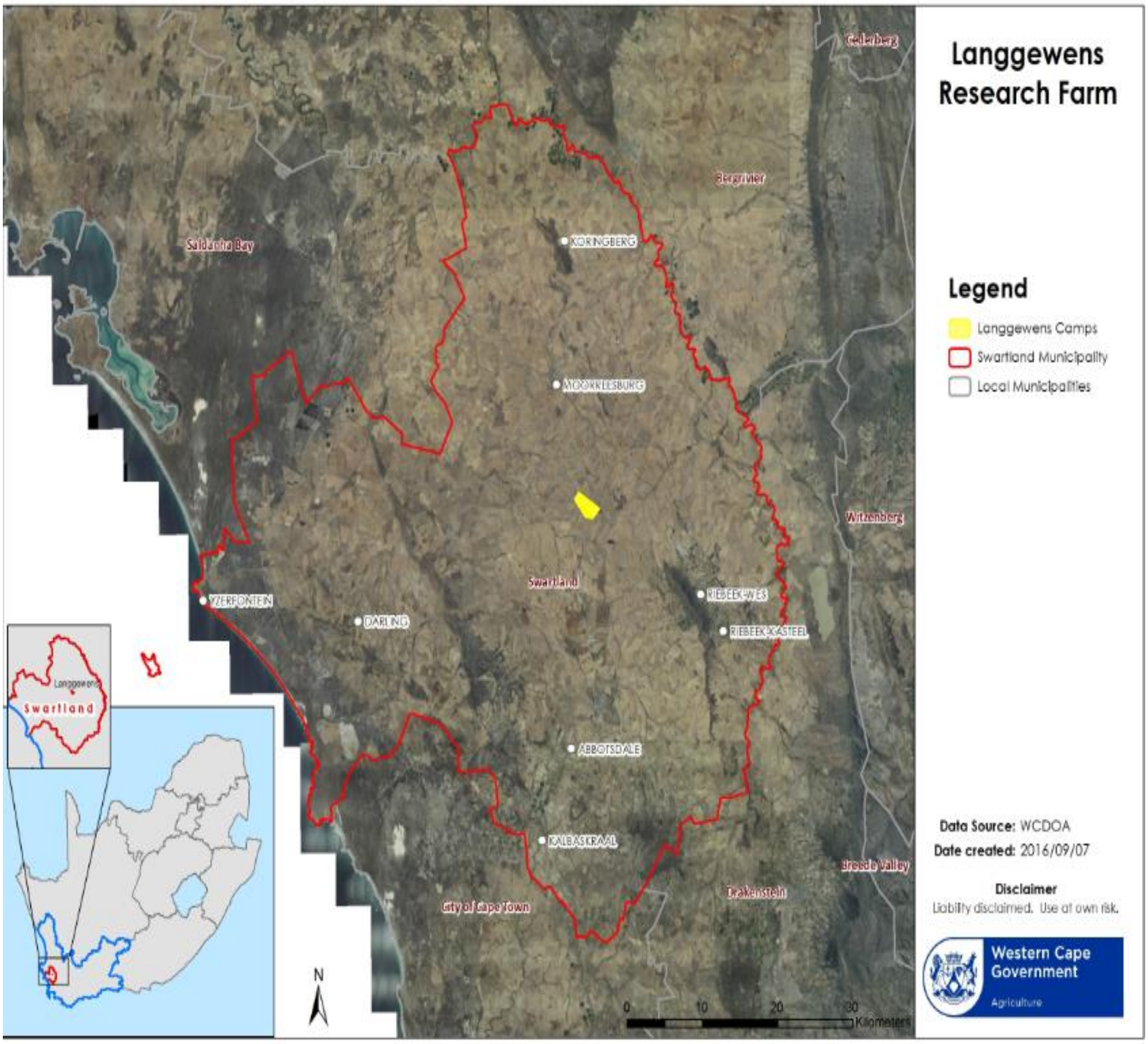
Annexure B: Production activities costs / ha

Cost Programme for various activities

Activity and implement	Power demand	tractor kw	ha/ hour	Fuel (l/hour)	Tractor cost/ hour		Implement cost/hour		Tractor cost/ ha		Implement cost/ha			
					Repairs & mainten	Total variable costs	Repairs & maintenar	Total variable c	Repairs & mainter	Total variable costs	Repairs &	Total variable	Fuel (l)/ha	Fuel R/ha
Deep soil tillage (Ripper)	High	80	1,5	14,4	177,96	490,32	3,01	3,01	118,64	326,88	2,01	2,01	9,6	116,16
Light soil tillage (Disc)	High	80	3	14,4	177,96	490,32	37,5	37,5	59,32	163,44	12,50	12,50	4,8	58,08
Light soil tillage (Plough)	High	80	1	14,4	177,96	490,32	35,37	35,37	177,96	490,32	35,37	35,37	14,4	174,24
lime application (Lime spreader)	Medium	80	4	12,6	64,08	227,25	101,87	101,87	16,02	56,81	25,47	25,47	3,15	38,12
Fertilizer application (Spandikar)	Medium	80	11,9	12,6	64,08	227,25	24,97	24,97	5,38	19,10	2,10	2,10	1,058824	12,81
Pesticide application (1000l spray tank)	Medium	80	5,9	12,6	64,08	227,25	9,44	9,44	10,86	38,52	1,60	1,60	2,14	25,84
Herbicide application (1000l spray tank)	Medium	80	5,9	12,6	64,08	227,25	9,44	9,44	10,86	38,52	1,60	1,60	2,14	25,84
Plant seed (planter: conventional)	High	93	2	20	77,88	293,02	45,20	202,05	38,94	146,51	22,60	101,03	10	121,00
Plant seed (planter: min-till)	High	157	1,5	28,26	153,07	527,52	50,88	169,6	102,04	351,68	33,92	113,07	18,84	227,96
Plant seed (planter: no-till)	High	116	2,5	21	86,42	347,48	150,00	640,34	34,57	138,99	60,00	256,14	8,4	101,64
load (Front end loader)		69	200	9,38	44,95	169,42	0	0	0,22	0,85	0,00	0,00	0,05	0,57
Fuel: contract harvestor	High		2	72,9									36,45	441,05
Apply cover crop seed/snail pellets (Spar	Medium	80	11,9	12,6	64,08	227,25	101,87	101,87	5,38	19,10	8,56	8,56	1,06	12,81

Activity and Vehicle	km/ha	Vehicle cost/km			Vehicle cost/ha			
		Fuel(l)/km	Rep & Main	Var costs	Fuel(l)/ha	Fuel R/ha	Rep & Main	Var costs
Seed and Fertilizer (Truck 14t)	2,5	0,4	0,18	7,66	1	12,10	0,45	19,15
Grain Removal (Truck 14t)	18	0,4	0,18	7,66	7,2	87,12	3,24	137,88
General farm management 12000km (Bakkie 1)	15,00	0,102	0,98	2,72	1,53	18,51	14,73	40,80
General purpose 10000km (Bakkie2)	12,50	0,102	0,98	2,72	1,28	15,43	12,27	34,00

Annexure C: Map of Langgewens experimental farm, Swartland Western Cape.



Annexure D: Cash flow statements of each production system.

CASH FLOW STATEMENT: Conventional Agriculture

	Year									
Income	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Cash inflows										
'-Wheat	2742999,32	2742999,32	2742999,32	2742999,32	2742999,32	2742999,32	2742999,32	2742999,32	2742999,32	2742999,32
-Canola	-116593,59	-116593,59	-116593,59	-116593,59	-116593,59	-116593,59	-116593,59	-116593,59	-116593,59	-116593,59
Sundry										
Gross Margin: farm total	**2626405,729**	**2626405,73**	**2626405,729**	**2626405,73**	**2626405,73**	**2626405,7**	**2626405,729**	**2626405,729**	**2626405,729**	**2626405,729**
Yearly overhead & fixed costs										
Labour: Staff	240000	240000	240000	240000	240000	240000	240000	240000	240000	240000
Licences	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000
Bank charges	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000
Auditors fees	30000	30000	30000	30000	30000	30000	30000	30000	30000	30000
Electricity	40000	40000	40000	40000	40000	40000	40000	40000	40000	40000
Water	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000
Municipal tax	12000	12000	12000	12000	12000	12000	12000	12000	12000	12000
Communications	25000	25000	25000	25000	25000	25000	25000	25000	25000	25000
Administration	35000	35000	35000	35000	35000	35000	35000	35000	35000	35000
Environmental regeneration	60000	60000	60000	60000	60000	60000	60000	60000	60000	60000
Fixed improvements:										
Repairs	60000	60000	60000	60000	60000	60000	60000	60000	60000	60000
Insurance	40000	40000	40000	40000	40000	40000	40000	40000	40000	40000
Consultation fees	20000	20000	20000	20000	20000	20000	20000	20000	20000	20000
Entrepreneurs wage	540000	540000	540000	540000	540000	540000	540000	540000	540000	540000
Total	**1142000**	**1142000**	**1142000**	**1142000**	**1142000**	**1142000**	**1142000**	**1142000**	**1142000**	**1142000**
Margin after fixed and overhead c	**1484406**	**1484406**	**1484406**	**1484406**	**1484406**	**1484406**	**1484406**	**1484406**	**1484406**	**1484406**
Foreign Factor costs:										
Rent										
Management	0	0	0	0	0	0	0	0	0	0
Interest										
Total:	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

Margin after foreign factor costs:	**1484406**	**1484406**	**1484406**	**1484406**	**1484406**	**1484406**	**1484406**	**1484406**	**1484406**	**1484406**
Capital outflow										
Long-term:										
Land & fixed improvements	24000000	0	0	0	0	0	0	0	0	0
Intermediary capital:										
Total: (a) + (b)	1526407,37	2063662,2	602790,3	1258656,3	70200	165600	22500	893580,3	576690,3	923280,3
Total Capital outflow:	25526407,37	2063662,20	602790,30	1258656,30	70200,00	165600,00	22500,00	893580,30	576690,30	923280,30
Net annual outlay	-24042001,64	-579256,47	881615,43	225749,43	1414205,73	1318805,73	1461905,73	590825,43	907715,43	561125,43
IRR	3,47%									
Redemption of debt:										
Interest	127200,00	224490,40	235854,77	272037,87	238757,19	205127,27	158387,88	175031,06	174588,64	199810,28
Capital	14711,51	146413,09	201936,69	305418,99	346489,34	398494,88	218738,96	234362,97	159131,79	228571,26
Total	**141911,51**	**370903,50**	**437791,46**	**577456,86**	**585246,52**	**603622,14**	**377126,84**	**409394,03**	**333720,43**	**428381,54**
Bank account										
Yearly surplus/deficit	1342494,22	1113502,23	1046614,27	906948,87	899159,21	880783,58	1107278,89	1075011,70	1150685,30	1056024,19
Begin balance	0,00	1373879,17	2545531,62	3676123,39	4690215,72	5720043,81	6755142,11	8046229,36	9334478,22	10730286,58
Flow before interest	1342494,22	2487381,40	3592145,89	4583072,26	5589374,92	6600827,40	7862421,00	9121241,06	10485163,52	11786310,77
Interest (+) Bank	31384,95	58150,22	83977,50	107143,46	130668,89	154314,71	183808,36	213237,16	245123,06	275541,39
END BALANCE	1373879,17	2545531,62	3676123,39	4690215,72	5720043,81	6755142,11	8046229,36	9334478,22	10730286,58	12061852,16
NPV:	R 16 267 458,42									

Income	11	12	13	14	15	16	17	18	19	20
Cash inflow										
'-Wheat	2742999,32	2742999,32	2742999,32	2742999,32	2742999,32	2742999,32	2742999,32	2742999,32	2742999,32	2742999,32
-Canola	-116593,59	-116593,59	-116593,59	-116593,59	-116593,59	-116593,59	-116593,59	-116593,59	-116593,59	-116593,59
Sundry										
Gross Margin: farm total	**2626405,73**	**2626405,73**	**2626405,73**	**2626405,73**	**2626405,73**	**2626405,73**	**2626405,73**	**2626405,73**	**2626405,73**	**2626405,73**
Yearly overhead & fixed costs										
Labour: Staff	240000	240000	240000	240000	240000	240000	240000	240000	240000	240000
Licences	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000
Bank charges	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000
Auditors fees	30000	30000	30000	30000	30000	30000	30000	30000	30000	30000
Electricity	40000	40000	40000	40000	40000	40000	40000	40000	40000	40000
Water	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000
Municipal tax	12000	12000	12000	12000	12000	12000	12000	12000	12000	12000
Communications	25000	25000	25000	25000	25000	25000	25000	25000	25000	25000
Administration	35000	35000	35000	35000	35000	35000	35000	35000	35000	35000
Environmental regeneration	60000	60000	60000	60000	60000	60000	60000	60000	60000	60000
Fixed improvements:										
Repairs	60000	60000	60000	60000	60000	60000	60000	60000	60000	60000
Insurance	40000	40000	40000	40000	40000	40000	40000	40000	40000	40000
Consultation fees	20000	20000	20000	20000	20000	20000	20000	20000	20000	20000
Entrepreneurs wage	540000	540000	540000	540000	540000	540000	540000	540000	540000	540000
Total	**1142000**	**1142000**	**1142000**	**1142000**	**1142000**	**1142000**	**1142000**	**1142000**	**1142000**	**1142000**
Margin after fixed and overhead c	**1484406**	**1484406**	**1484406**	**1484406**	**1484406**	**1484406**	**1484406**	**1484406**	**1484406**	**1484406**
Foreign Factor costs:										
Rent										
Management	0	0	0	0	0	0	0	0	0	0
Interest										
Total:	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

Margin after foreign factor costs:	**1484406**	**1484406**	**1484406**	**1484406**	**1484406**	**1484406**	**1484406**	**1484406**	**1484406**	**1484406**
Capital outflow										
Long-term:										
Land & fixed improvements	0	0	0	0	0	0	0	0	0	0
Intermediary capital:										
Total: (a) + (b)	373500	0	26100	1021720,5	621690,3	893580,3	1122941,7	25200	338976	893580,3
Total Capital outflow:	373500,00	0,00	26100,00	1021720,50	621690,30	893580,30	1122941,70	25200,00	338976,00	893580,30
Net annual outlay	1110905,73	1484405,73	1458305,73	462685,23	862715,43	590825,43	361464,03	1459205,73	1145429,73	24590825,43
IRR										
Redemption of debt:										
Interest	190309,73	158972,79	125427,81	147198,30	146453,93	162686,82	184951,79	142244,24	109485,01	108506,88
Capital	261141,20	289981,46	227267,45	254879,24	222158,01	263635,25	365976,26	408583,95	365583,19	396731,29
Total	**451450,93**	**448954,25**	**352695,26**	**402077,54**	**368611,94**	**426322,07**	**550928,06**	**550828,19**	**475068,20**	**505238,17**
Bank account										
Yearly surplus/deficit	1032954,80	1035451,48	1131710,47	1082328,19	1115793,79	1058083,66	933477,67	933577,54	1009337,53	979167,56
Begin balance	12061852,16	13400938,49	14773885,15	16277438,01	17765604,32	19322809,07	20857359,00	22300264,74	23777005,06	25365799,85
Flow before interest	13094806,96	14436389,97	15905595,62	17359766,20	18881398,11	20380892,72	21790836,67	23233842,28	24786342,59	26344967,40
Interest (+) Bank	306131,53	337495,17	371842,39	405838,12	441410,96	476466,27	509428,07	543162,78	579457,26	615894,93
END BALANCE	13400938,49	14773885,15	16277438,01	17765604,32	19322809,07	20857359,00	22300264,74	23777005,06	25365799,85	26960862,33

CASH FLOW STATEMENT: Precision Agriculture										
	Year									
Income	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Cash inflows										
'-Wheat	3319496,92	3319496,92	3319496,92	3319496,92	3319496,92	3319496,92	3319496,92	3319496,92	3319496,92	3319496,92
-Canola	75572,27	75572,27	75572,27	75572,27	75572,27	75572,27	75572,27	75572,27	75572,27	75572,27
Sundry										
Gross Margin: farm total	**3395069,19**	**3395069,2**	**3395069,2**	**3395069,2**	**3395069,2**	**3395069,2**	**3395069**	**3395069**	**3395069**	**3395069**
Yearly overhead & fixed costs										
Labour: Staff	240000	240000	240000	240000	240000	240000	240000	240000	240000	240000
Lisences	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000
Bank charges	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000
Auditors fees	30000	30000	30000	30000	30000	30000	30000	30000	30000	30000
Electricity	40000	40000	40000	40000	40000	40000	40000	40000	40000	40000
Water	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000
Munisipal tax	12000	12000	12000	12000	12000	12000	12000	12000	12000	12000
Communications	25000	25000	25000	25000	25000	25000	25000	25000	25000	25000
Administration	35000	35000	35000	35000	35000	35000	35000	35000	35000	35000
Environmental regeneration	60000	60000	60000	60000	60000	60000	60000	60000	60000	60000
Fixed improvements:										
Repairs	60000	60000	60000	60000	60000	60000	60000	60000	60000	60000
Insurance	40000	40000	40000	40000	40000	40000	40000	40000	40000	40000
Consultation fees	20000	20000	20000	20000	20000	20000	20000	20000	20000	20000
Entreperneurs wage	540000	540000	540000	540000	540000	540000	540000	540000	540000	540000
Total	**1142000**	**1142000**	**1142000**	**1142000**	**1142000**	**1142000**	**1142000**	**1142000**	**1142000**	**1142000**
Margin after fixed and overhead c	**2253069**	**2253069**	**2253069**	**2253069**	**2253069**	**2253069**	**2253069**	**2253069**	**2253069**	**2253069**
Foreign Factor costs:										
Rent										
Management	0	0	0	0	0	0	0	0	0	0
Interest										
Total:	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

Margin after foreign factor costs:	**2253069**	**2253069**	**2253069**	**2253069**	**2253069**	**2253069**	**2253069**	**2253069**	**2253069**	**2253069**
Capital outflow										
Long-term:										
Land & fixed improvements	24000000	0	0	0	0	0	0	0	0	0
Intermediary capital:										
Total: (a) + (c)	2839771,00	1264036,5	665790,3	982680,3	514800	1950581,7	22500	893580,3	716190,3	923280,3
Total Capital outflow:	26839771,00	1264036,50	665790,30	982680,30	514800,00	1950581,70	22500,00	893580,30	716190,30	923280,30
Net annual outlay	-24586701,81	989032,69	1587278,89	1270388,89	1738269,19	302487,49	2230569,19	1359488,89	1536878,89	1329788,89
IRR	5,83%									
Redemption of debt:										
Interest	127200,00	186108,37	206538,44	235765,40	232956,29	291872,70	239337,87	238842,59	226739,99	226673,89
Capital	14711,51	96065,55	149514,16	229329,24	289262,56	446790,28	361559,39	387331,13	369862,96	415255,63
Total	**141911,51**	**282173,92**	**356052,60**	**465094,63**	**522218,84**	**738662,98**	**600897,26**	**626173,73**	**596602,96**	**641929,52**
Bank account										
Yearly surplus/deficit	2111157,68	1970895,27	1897016,59	1787974,56	1730850,34	1514406,21	1652171,93	1626895,46	1656466,23	1611139,67
Begin balance	0,00	2160512,51	4227992,19	6268199,76	8244512,26	10208567,50	11997034,40	13968298,65	15959779,92	18028080,28
Flow before interest	2111157,68	4131407,78	6125008,78	8056174,32	9975362,61	11722973,70	13649206,33	15595194,12	17616246,15	19639219,94
Interest (+) Bank	49354,83	96584,41	143190,99	188337,94	233204,89	274060,69	319092,33	364585,80	411834,13	459127,38
END BALANCE	2160512,51	4227992,19	6268199,76	8244512,26	10208567,50	11997034,40	13968298,65	15959779,92	18028080,28	20098347,33
NPV:	R 27 551 403,99									

Income	11	12	13	14	15	16	17	18	19	20
Cash inflows										
'-Wheat	3319496,92	3319496,92	3319496,92	3319496,92	3319496,92	3319496,92	3319496,92	3319496,92	3319496,92	3319496,92
-Canola	75572,27	75572,27	75572,27	75572,27	75572,27	75572,27	75572,27	75572,27	75572,27	75572,27
Sundry										
Gross Margin: farm total	**3395069**	**3395069**	**3395069**	**3395069**	**3395069**	**3395069**	**3395069**	**3395069**	**3395069,2**	**3395069,19**
Yearly overhead & fixed costs										
Labour: Staff	240000	240000	240000	240000	240000	240000	240000	240000	240000	240000
Lisences	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000
Bank charges	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000
Auditors fees	30000	30000	30000	30000	30000	30000	30000	30000	30000	30000
Electricity	40000	40000	40000	40000	40000	40000	40000	40000	40000	40000
Water	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000
Munisipal tax	12000	12000	12000	12000	12000	12000	12000	12000	12000	12000
Communications	25000	25000	25000	25000	25000	25000	25000	25000	25000	25000
Administration	35000	35000	35000	35000	35000	35000	35000	35000	35000	35000
Environmental regeneration	60000	60000	60000	60000	60000	60000	60000	60000	60000	60000
Fixed improvements:										
Repairs	60000	60000	60000	60000	60000	60000	60000	60000	60000	60000
Insurance	40000	40000	40000	40000	40000	40000	40000	40000	40000	40000
Consultation fees	20000	20000	20000	20000	20000	20000	20000	20000	20000	20000
Entreperneurs wage	540000	540000	540000	540000	540000	540000	540000	540000	540000	540000
Total	**1142000**	**1142000**	**1142000**	**1142000**	**1142000**	**1142000**	**1142000**	**1142000**	**1142000**	**1142000**
Margin after fixed and overhead co	**2253069**	**2253069**	**2253069**	**2253069**	**2253069**	**2253069**	**2253069**	**2253069**	**2253069**	**2253069**
Foreign Factor costs:										
Rent										
Management	0	0	0	0	0	0	0	0	0	0
Interest										
Total:	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

Margin after foreign factor costs:	**2253069**	**2253069**	**2253069**	**2253069**	**2253069**	**2253069**	**2253069**	**2253069**	**2253069**	**2253069**
Capital outflow										
Long-term:										
Land & fixed improvements	0	0	0	0	0	0	0	0	0	0
Intermediary capital:										
Total: (a) + (c)	436500	139500	26100	1021720,5	1066290,3	2678562	309816	88200	76500	893580,3
Total Capital outflow:	436500,00	139500,00	26100,00	1021720,50	1066290,30	2678562,00	309816,00	88200,00	76500,00	893580,30
Net annual outlay	1816569,19	2113569,19	2226969,19	1231348,69	1186778,89	-425492,81	1943253,19	2164869,19	2176569,19	25359488,89
IRR										
Redemption of debt:										
Interest	197795,22	171356,11	134743,17	153077,55	171683,06	268006,01	232333,34	179474,52	118884,14	102829,00
Capital	276125,91	315547,79	255901,73	271470,18	268733,61	421198,60	475770,19	535519,86	491224,90	488115,46
Total	**473921,12**	**486903,90**	**390644,91**	**424547,73**	**440416,67**	**689204,60**	**708103,53**	**714994,38**	**610109,04**	**590944,46**
Bank account										
Yearly surplus/deficit	1779148,07	1766165,29	1862424,28	1828521,46	1812652,52	1563864,59	1544965,66	1538074,80	1642960,15	1662124,72
Begin balance	20098347,33	22388949,38	24719815,03	27203681,20	29710920,01	32260533,34	34615147,63	37005467,55	39444616,62	42048125,70
Flow before interest	21877495,40	24155114,67	26582239,31	29032202,67	31523572,53	33824397,93	36160113,29	38543542,36	41087576,78	43710250,43
Interest (+) Bank	511453,98	564700,36	621441,89	678717,35	736960,81	790749,70	845354,26	901074,27	960548,93	1021862,02
END BALANCE	22388949,38	24719815,03	27203681,20	29710920,01	32260533,34	34615147,63	37005467,55	39444616,62	42048125,70	44732112,45
NPV:										

CASH FLOW STATEMENT: Conservation Agriculture

	Year									
Income	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Cash inflows										
-Wheat	3405962,52	3405962,52	3405962,52	3405962,52	3405962,52	3405962,52	3405962,52	3405962,52	3405962,52	3405962,52
-Canola	103355,88	103355,88	103355,88	103355,88	103355,88	103355,88	103355,88	103355,88	103355,88	103355,88
Sundry										
Gross Margin: farm total	**3509318,4**	**3509318,4**	**3509318,4**	**3509318,4**	**3509318,4**	**3509318,4**	**3509318,4**	**3509318,4**	**3509318,4**	**3509318,4**
Yearly overhead & fixed costs										
Labour: Staff	240000	240000	240000	240000	240000	240000	240000	240000	240000	240000
Lisences	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000
Bank charges	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000
Auditors fees	30000	30000	30000	30000	30000	30000	30000	30000	30000	30000
Electricity	40000	40000	40000	40000	40000	40000	40000	40000	40000	40000
Water	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000
Munisipal tax	12000	12000	12000	12000	12000	12000	12000	12000	12000	12000
Communications	25000	25000	25000	25000	25000	25000	25000	25000	25000	25000
Administration	35000	35000	35000	35000	35000	35000	35000	35000	35000	35000
Environmental regeneration	60000	60000	60000	60000	60000	60000	60000	60000	60000	60000
Fixed improvements:										
Repairs	60000	60000	60000	60000	60000	60000	60000	60000	60000	60000
Insurance	40000	40000	40000	40000	40000	40000	40000	40000	40000	40000
Consultation fees	20000	20000	20000	20000	20000	20000	20000	20000	20000	20000
Entreperneurs wage	540000	540000	540000	540000	540000	540000	540000	540000	540000	540000
Total	**1142000**	**1142000**	**1142000**	**1142000**	**1142000**	**1142000**	**1142000**	**1142000**	**1142000**	**1142000**
Margin after fixed and overhead c	**2367318,40**	**2367318,40**	**2367318,40**	**2367318,40**	**2367318,40**	**2367318,40**	**2367318,40**	**2367318,40**	**2367318,40**	**2367318,40**
Foreign Factor costs:										
Rent										
Management	0	0	0	0	0	0	0	0	0	0
Interest										
Total	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

Margin after foreign factor costs:	**2367318,40**	**2367318,40**	**2367318,40**	**2367318,40**	**2367318,40**	**2367318,40**	**2367318,40**	**2367318,40**	**2367318,40**	**2367318,40**
Capital outflow										
Long-term:										
Land & fixed improvements	24000000	0	0	0	0	0	0	0	0	0
Intermediary capital:										
Total: (a) + (d)	2483451,17	2312536,50	602790,30	919680,30	70200,00	165600,00	22500,00	893580,30	576690,30	1895550,30
Total Capital outflow:	26483451,17	2312536,50	602790,30	919680,30	70200,00	165600,00	22500,00	893580,30	576690,30	1895550,30
Net annual outlay	-24116132,77	54781,90	1764528,10	1447638,10	2297118,40	2201718,40	2344818,40	1473738,10	1790628,10	471768,10
IRR	6,65%									
Redemption of debt:										
Interest	127200,00	236436,37	245920,32	263726,51	230648,24	197245,01	150759,51	171000,98	174588,64	246479,24
Capital	14711,51	162083,19	219487,19	303732,31	344600,25	396379,10	188753,23	200778,95	159131,79	289789,16
Total	**141911,51**	**398519,56**	**465407,52**	**567458,82**	**575248,49**	**593624,11**	**339512,74**	**371779,94**	**333720,43**	**536268,40**
Bank account										
Yearly surplus/deficit	2225406,89	1968798,84	1901910,88	1799859,58	1792069,91	1773694,29	2027805,66	1995538,46	2033597,97	1831050,00
Begin balance	0,00	2277432,65	4345500,26	6393463,66	8384867,45	10414854,69	12473493,93	14840312,22	17229440,66	19713371,62
Flow before interest	2225406,89	4246231,49	6247411,14	8193323,23	10176937,37	12188548,98	14501299,59	16835850,69	19263038,64	21544421,62
Interest (+) Bank	52025,75	99268,77	146052,52	191544,22	237917,32	284944,95	339012,64	393589,97	450332,98	503667,35
END BALANCE	2277432,65	4345500,26	6393463,66	8384867,45	10414854,69	12473493,93	14840312,22	17229440,66	19713371,62	22048088,97
NPV:	R 31204 331,44									

Income	11	12	13	14	15	16	17	18	19	20
Cash inflows										
-Wheat	3405962,52	3405962,52	3405962,52	3405962,52	3405962,52	3405962,52	3405962,52	3405962,52	3405962,52	3405962,52
-Canola	103355,88	103355,88	103355,88	103355,88	103355,88	103355,88	103355,88	103355,88	103355,88	103355,88
Sundry										
Gross Margin: farm total	**3509318,4**	**3509318,4**	**3509318,4**	**3509318,4**	**3509318,4**	**3509318,4**	**3509318,4**	**3509318,4**	**3509318,4**	**3509318,4**
Yearly overhead & fixed costs										
Labour: Staff	240000	240000	240000	240000	240000	240000	240000	240000	240000	240000
Lisences	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000
Bank charges	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000
Auditors fees	30000	30000	30000	30000	30000	30000	30000	30000	30000	30000
Electricity	40000	40000	40000	40000	40000	40000	40000	40000	40000	40000
Water	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000
Munisipal tax	12000	12000	12000	12000	12000	12000	12000	12000	12000	12000
Communications	25000	25000	25000	25000	25000	25000	25000	25000	25000	25000
Administration	35000	35000	35000	35000	35000	35000	35000	35000	35000	35000
Environmental regeneration	60000	60000	60000	60000	60000	60000	60000	60000	60000	60000
Fixed improvements:										
Repairs	60000	60000	60000	60000	60000	60000	60000	60000	60000	60000
Insurance	40000	40000	40000	40000	40000	40000	40000	40000	40000	40000
Consultation fees	20000	20000	20000	20000	20000	20000	20000	20000	20000	20000
Entreperneurs wage	540000	540000	540000	540000	540000	540000	540000	540000	540000	540000
Total	**1142000**	**1142000**	**1142000**	**1142000**	**1142000**	**1142000**	**1142000**	**1142000**	**1142000**	**1142000**
Margin after fixed and overhead c	**2367318,40**	**2367318,40**	**2367318,40**	**2367318,40**	**2367318,40**	**2367318,40**	**2367318,40**	**2367318,40**	**2367318,40**	**2367318,40**
Foreign Factor costs:										
Rent										
Management	0	0	0	0	0	0	0	0	0	0
Interest										
Total	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

Margin after foreign factor costs:	**2367318,40**	**2367318,40**	**2367318,40**	**2367318,40**	**2367318,40**	**2367318,40**	**2367318,40**	**2367318,40**	**2367318,40**	**2367318,40**
Capital outflow										
Long-term:										
Land & fixed improvements	0	0	0	0	0	0	0	0	0	0
Intermediary capital:										
Total: (a) + (d)	373500,00	1125000,00	26100,00	1021720,50	621690,30	893580,30	246816,00	25200,00	0,00	1865850,30
Total Capital outflow:	373500,00	1125000,00	26100,00	1021720,50	621690,30	893580,30	246816,00	25200,00	0,00	1865850,30
Net annual outlay	1993818,40	1242318,40	2341218,40	1345597,90	1745628,10	1473738,10	2120502,40	2342118,40	2367318,40	24501468,10
IRR										
Redemption of debt:										
Interest	229632,54	244067,91	192807,80	194737,34	171771,10	176061,93	142897,76	106809,92	65193,93	121749,72
Capital	329705,26	437607,58	392608,70	440061,44	321675,21	375094,52	310811,98	346799,95	275041,86	356542,91
Total	**559337,80**	**681675,49**	**585416,50**	**634798,78**	**493446,32**	**551156,45**	**453709,74**	**453609,87**	**340235,79**	**478292,62**
Bank account										
Yearly surplus/deficit	1807980,60	1685642,91	1781901,90	1732519,62	1873872,08	1816161,95	1913608,66	1913708,53	2027082,61	1889025,78
Begin balance	22048088,97	24413778,83	26709576,28	29157554,43	31612224,87	34268937,83	36928700,36	39750367,89	42638102,80	45709371,99
Flow before interest	23856069,57	26099421,74	28491478,18	30890074,04	33486096,95	36085099,77	38842309,02	41664076,42	44665185,42	47598397,76
Interest (+) Bank	557709,26	610154,54	666076,24	722150,83	782840,87	843600,59	908058,86	974026,39	1044186,57	1112759,46
END BALANCE	24413778,83	26709576,28	29157554,43	31612224,87	34268937,83	36928700,36	39750367,89	42638102,80	45709371,99	48711157,23
NPV:										

Annexure E: Gross margin data from Langgewens experimental farm.

GROSS MARGIN & MARGIN ABOVE SPECIFIED COSTS:							
Crop:	**Wheat**			**Date:**	**25-Nov-14**		
				YEAR	**2014**		
Counrty:	**SA**						
Province:	**Western Cape**						
Location:	**Langgewens**						
Comment:	**Swartland crop rotation trials**						
Camp:	**46/3**	**System:**	**B**	**Wheat-Wheat-Wheat-Canola**			
		Unit	**Price/unit Rand**	**Quantity**	**R per ha**	**R/yield unit**	Code:
Gross Income							
Product income:							
Wheat							
Wheat: B3		ton	3186,00	3,56	11354,90	3186,00	102
Marketing cost:							
Gross income minus marketing cost					**11354,90**	**3186,00**	
ALLOCATABLE VARIABLE COSTS:					**5964,65**	**1733,26**	
Directly Allocatable Variable Costs:					**5286,76**	**1543,06**	
Pre Harvest Cost:					**5074,20**	**1449,59**	
Plant material:							
Seed							
SST 087		kg	6,84	85,00	581,40	163,13	200
Fertilizer:							
Geoflo 42		t	3902,23	0,23	897,51	251,83	316
Bortrac		l	68,40	1,000	68,40	19,19	312
Coptrac		l	199,50	0,50	99,75	27,99	313
Mantrac		l	150,48	0,50	75,24	21,11	314
Zintrac		l	144,78	0,50	72,39	20,31	326
Cura A44		t	6696,37	0,14	924,10	259,29	315
Coptrac		l	199,50	0,50	99,75	27,99	313
Amiplus SS		t	6366,89	0,08	477,52	133,98	325
#N/A		#N/A	#N/A		0,00	0,00	
Lime & Gypsum							
Gips		t	518,70	0,50	259,35	72,77	330
#N/A		#N/A	#N/A		0,00	0,00	
Weed Control:							
Glifosaat 360		liter	43,32	1,50	64,98	18,23	400
Bladbuff		liter	51,30	0,12	6,16	1,73	418
2,4D Amine		liter	44,18	0,50	22,09	6,20	421
Sakura		kg	4051,56	0,13	506,45	142,10	410
Resolve		liter	295,26	0,75	221,45	62,13	403
Brush-Off		kg	2188,80	0,01	10,94	3,07	404
Wetcit		liter	112,86	0,20	22,57	6,33	417
#N/A		#N/A	#N/A		0,00	0,00	
Pest Control:							
Mospilan		gram	0,71	50,00	35,50	9,96	431
#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	
Fungicide control:							
Duett		liter	226,86	0,80	181,49	50,92	424
Tebuconazole		liter	149,00	0,85	126,65	35,54	425
Prosper Trio		liter	316,24	0,50	158,12	44,37	426
#N/A		#N/A	#N/A		0,00	0,00	
#N/A		#N/A	#N/A		0,00	0,00	
Hire							
Lime spreading:		R/ton	74,00	0,50	37,00	16,27	502
Aero spray:		R/ha	125,40	1,00	125,40	55,15	500
#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	
Harvest cost:					212,56	93,47	
Grain							
Transport:		R/ton	59,64	3,56	212,56	93,47	501
MARGIN ABOVE DIRECTLY ALLOCATABLE COSTS:					**6068,15**	**1642,94**	

In Directly Allocatable costs:	**677,89**	**190,21**
PRE HARVEST COST:	**465,21**	**130,53**
Energy	298,38	83,72
Repairs and Maintenance	162,30	45,54
Tyres	4,53	1,27
HARVEST COST:	**212,68**	**59,68**
Energy	114,13	32,02
Repairs and maintenance	97,35	27,31
Tyres	1,20	0,34
TOTAL PRE HARVEST COSTS	**5539,41**	**1554,27**
TOTAL HARVEST COSTS	**425,24**	**119,32**
GROSS MARGIN ABOVE ALL ALLOCATABLE COSTS:	**5390,26**	**1512,42**

Annexure F: Crop rotation system trials at Langgewens.

Langgewens experimental farm conducts eight crop rotation system trials. Each crop rotation system has a specific sequence, indicated below, which are modelled over a four year period.

GENERAL INFORMATION ON PRODUCTION:		
Langgewens		
System	A	Wheat-Wheat-Wheat-Wheat
System	B	Wheat-Wheat-Wheat-Canola
System	C	Wheat-Canola-Wheat-Lupins
System	D	Wheat-Wheat-Lupins-Canola
System	E	Wheat-Medic-Wheat-Medic
System	F	Wheat-Medic/clover-Wheat-Medic/clover
System	G	Medic-Wheat-Medic-Canola
System	H	Wheat-Medic/clover-Wheat-Medic/clover (With Ouman-soutbos pastures)

Annexure G: Farm model inventory list

Inventory								
Fixed-Improvements/ Imovable assets: (a)								
non-Farming improvements	**Units**	**R/Unit**	**Vaue R**	**Age (Yrs)**	**Expected life time (Yrs)**	**Depreciation P.A/Unit**	**Total Depreciation R**	**Current Value**
Farmers House	1	300000	300000	15	50	6 000	90 000	210 000
Managers House	1	160000	160000	20	50	3 200	64 000	96 000
Foremans house	1	50000	50000	2	50	1 000	2 000	48 000
General Labourers accomodation	3	20000	60000	2	50	400	800	59 200
Farming Improvements								
Sheds	3	400000	1200000	6	60	6 667	40 000	1 160 000
Pump houses	4	120000	480000	4	50	2 400	9 600	470 400
Reservior	2	50000	100000	20	50	1 000	20 000	80 000
Silos	3	100000	300000	3	20	5 000	15 000	285 000
TOTAL			2650000				241 400	2 408 600
Movable assets: (b)								
	Unit	**R/Unit**	**Age (Yrs)**	**Expected life**	**Depreciation P.A/Unit**	**Total Depreciation R**	**Current Value**	**KM/ Year**
Vehicles:								
Bakkie: 1		352100	5	6	58683,33	293416,67	58683,33	12000
2		352100	3	6	58683,33	176050	176050,00	10000
sub-Total		704200					234733,33	
Machinery:								
Tractors: 80 Kw	1	640767	5	6	106794,5	533972,5	106794,50	
80 Kw	2	640767	4	6	106794,5	427178	213589,00	
80 Kw	3	640767	3	6	106794,5	320383,5	320383,50	
Font end loader (69kw)	1	415000	5	15	27666,67	138333,33	276666,67	
Truck: 14t	1	90000	14	15	6000,00	84000	6000,00	
sub-Total		2427301				1503867,33	923433,67	
	Unit	**R/Unit**	**Age (Yrs)**	**Expected life**	**Depreciation P.A/Unit**	**Total Depreciation R**	**Current Value**	
Spandikar fertilizer applicator: 800l	2	33000	2	15	2200	4400	28600	
		33000	6	15	2200	13200	19800	
Chemical spray tanks: 1000l 12m	2	28000	7	12	2333,33	16333,33	11666,67	
		28000	8	12	2333,33	18666,67	9333,33	
Five tine ripper: subsoil ripper	2	20000	10	15	1333,33	13333,33	6666,67	
		25000	9	15	1666,67	15000	10000	
Lime spreader: 5ton	1	136000	10	15	9066,67	90666,67	45333,33	
Plough: 6 furrow mouldboard	1	80378	11	12	6698,17	73679,83	6698,17	
Disc: 4,88m	1	156240	14	15	10416	145824	10416	
Fire tanker: 10000l	1	50000	6	10	5000	30000	20000	
Slasher mowers: 1,8m	2	29000	7	10	2900	20300	8700	
		29000	8	10	2900	23200	5800	
Bailer: medium 1,6m	1	390000	11	12	32500	357500	32500	
Forage rake: 10 wheel, 5,5m	1	40000	15	20	2000	30000	10000	
Bale Fork: loader	1	5000	10	20	250,00	2500,00	2500,00	
sub-Total		1082618				854603,83	228014,17	

Conventional Agriculture							
Equipment							
	Code						
Tractor	1	973473	14	15	64898,20	908574,80	64898,20
Planter	1	376640	12	15	25109,33	301312,00	75328,00
Seedbed roller	1	27000	5	15	1800,00	9000,00	18000,00
		1350113					140226,20
Precision Agriculture							
Equipment							
GPS monitor: Planter		85000	9	10	8500,00	76500,00	8500,00
Flow rate monitor: planter		85000	2	10	8500,00	17000,00	68000,00
Additional precision equipment		70000	8	12	5833,33	46666,67	23333,33
		70000	9	12	5833,33	52500,00	17500,00
		70000	10	12	5833,33	58333,33	11666,67
		70000	7	12	5833,33	40833,33	29166,67
		70000	2	12	5833,33	11666,67	58333,33
		70000	1	12	5833,33	5833,33	64166,67
		70000	4	12	5833,33	23333,33	46666,67
Tractor	2	1913313	5	10	191331,30	956656,50	956656,50
Planter	2	424000	6	10	42400,00	254400,00	169600,00
sub-Total		2997313				1543723,17	1453589,83
Conservation Agriculture							
Equipment							
Tractor	3	1080300	1	10	108030	108030	972270
Planter	3	1250000	9	10	125000	1125000	125000
sub-Total		1250000				1125000	1097270

	Code				
Planter	**Sensitivity**	**Combinati**	**R/Unit**	**Tractor: Kw**	**R/Unit**
Conventional	1	1	376640	93	973473
Min-till	1	2	424000	157	1913313
No-till	1	3	1250000	116	1080300