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The impact of precision farming on the profitability of selected maize irrigation farms in the Northern Cape Province

by

Stefanus Francois van Zyl

Submitted
in partial fulfilment of the requirements
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DECLARATION

I, Stefan van Zyl hereby declare that the dissertation

The impact of precision farming on the profitability of selected maize irrigation farms in the Northern Cape Province

being submitted by me for the MSc degree in Agricultural Economics/Agribusiness Management at the University of Pretoria, is my own work and that the dissertation has not been previously submitted by me for degree purposes at this or any other tertiary institution.

Signature: ___________________ Date: 11 January 2010

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First of all, I would like to thank our heavenly Father who bestows on us our talent in honour of His Name. Without His grace, comfort and love I would have not been able to complete this thesis and therefore I dedicate this thesis to Him. All the praise to our glorious Father!

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Stefan van Zyl

Pretoria, January 2010

[1] Formerly lecturer at the Department of Agricultural Economics, Extension and Rural Development and now employee of SABMiller

[2] Senior lecturer at the Department of Agricultural Economics, Extension and Rural Development

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ABSTRACT

The impact of precision farming on the profitability of selected maize irrigation farms in the Northern Cape Province

by

Stefanus Francois van Zyl

Degree:	MSc Agric
Department:	Agricultural Economics, Extension and Rural Development
Supervisor:	Mr P.G. Strauss
Co-supervisor:	Dr Ferdinand Meyer

Maize is the most important grain crop produced in South Africa, serving as a food source for humans and animals, an input provider to other sectors, a source of job creation, a contributor of value added to the national economy, and an earner of foreign exchange. The South African maize industry plays an important role in the South African economy and consequently its role players should be supported to promote the industry. However, since the abolishment of the agricultural marketing boards and the deregulation of South African agriculture, farmers have suddenly found themselves exposed to global competition and a liberalised economy. Maize prices are uncertain and volatile, leading to increased risk. In addition, input prices have increased more rapidly than maize prices in some instances, and since no government protection exists, the cost squeeze effect places many farmers in a financial predicament. In order to mitigate the cost squeeze effect, farmers have started exploring farming methods and strategies that can improve their financial position.

Precision farming (PF) is identified as a technological tool that can improve the profitability of a maize farm through higher yields and lower input costs, and can also indirectly assist in the general farm management and financial functions on the farm. The literature indicates that PF has been successfully implemented on various

occasions with subsequent benefits, whether financial or qualitative. It could also be a useful tool to improve the profitability of South African maize farmers. Despite its various benefits, PF is associated with high capital expenditures and therefore farmers are reluctant to implement this technology on their farms. However, a PF service system that requires little capital expenditure is implemented by an agribusiness (Griekwaland-Wes Koöperasie) in the Northern Cape Province. Farmers who are part of this program only pay PF service fees that are charged on a per-hectare basis. Most of the PF technologies and knowledge are provided by GWK and/or affiliated fertilizer companies, which subsequently mitigate the burden of high capital expenditures.

The general objective of the study was to investigate the impact of PF on the profitability of selected maize irrigation farms in the Northern Cape Province. This was achieved by comparing the profitability and risk position of selected farms under a conventional farming (CF) system with the profitability of the same farms when converting to a PF system. The specific objectives of the study were to determine whether PF would generate better profits than CF; to determine whether PF would improve the farmer's ability to repay his debt and generate an income (thereby improving the financial survivability of the farm); to determine whether PF would improve the debt-to-asset position of the farmer; and to determine whether PF is less risky than CF with respect to net farm income and cash position.

The Bureau for Food and Agricultural Policy (BFAP) farm-level model developed by Strauss (2005) proved to be a useful tool to achieve the set objectives, since the BFAP farm-level model is linked with the BFAP sector model, which enables it to accurately analyse the impact of changes in policies and markets at both farm and sector level in South Africa. A positivistic approach was followed in order to answer the question, "What will the likely outcome be?" The model has the capacity to do simulations in both deterministic and stochastic modes.

Three maize irrigation farms in the Northern Cape Province were chosen by a panel of agricultural specialists who are accustomed with the irrigation farms and PF system in this province. The farms were analysed by means of the BFAP farm-level model in order to determine the impact of PF on the profitability of each farm. The

BFAP baseline of 2008 was used for this purpose. Key input variables were identified and simulated based on the BFAP baseline of 2008, as well as actual data, assumptions regarding PF and CF farming, and reported features and benefits associated with PF. In order to simulate the risk associated with CF and PF through stochastic modelling, correlated probability distributions were assigned to the relevant key input variables by de-trending the historical data of the key input variables. A correlation matrix based on the absolute deviation of a specific variable from its trend was subsequently constructed. Each variable was then simulated by means of a correlated empirical distribution, with 500 model iterations being run for each simulation in order to obtain stable probability distributions.

From the results obtained in the study, the conclusion can be drawn that PF not only improves profit margins, but indirectly contributes to improved financial management. Considering the higher profit margins, more cash is at the disposal of the farmer. When this extra cash is again reinvested in the farming business, debt (in terms of production loans and medium- and long term loans) can be repaid more quickly and/or less debt has to be incurred, leading to lower interest payments that in turn further increase profit margins, ultimately improving the debt and cash position of the farm. The results also indicate that the risk position of the participating farms improved significantly with the implementation of PF. It can therefore be concluded that PF could also serve as a valuable risk management tool. From the discussions with the farmers it also became apparent that their overall farm management abilities were improved significantly, due to the informative nature of PF. Based on the results of this study, it can be concluded that the hypothesis as stated in Chapter 1 cannot be rejected.

In addition, several other aspects pertaining to PF should be considered. Firstly, the results are applicable to the specific participating farms in the study only, and cannot be attributed to all maize farms in general. Secondly, despite a meticulous process of data verification and validation, the conclusions drawn in the study are based on the quality of the data provided by the stakeholders. Thirdly, factors such as farming operations, management decisions, market, weather and disease conditions might divert from the assumptions made in the study and thereby affect the actual results in future. Fourthly, since the study focuses solely on irrigation farming, a similar study can be conducted on dryland maize farming, since the majority of maize is produced under dryland conditions. Fifthly, the study could serve as a starting point for a comprehensive study on the impact of PF on maize farming throughout South Africa. Sixthly, the study could pave the way for an investigation into using PF as a tool to negotiate lower crop insurance premiums for farmers. Lastly, it would be useful to conduct a similar study on the impact of PF on maize farming where farmers are responsible for the acquisition of their own PF equipment, unlike on the participating farms where no extra capital expenditures were required. This could enable researchers to provide a better answer on the question of costs involved when converting to a PF system, as well as the ideal farm size in terms of economies of scale.

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LIST OF ABBREVIATIONS

Abbreviation	Meaning
AFMA	Animal Feed Manufacturers Association
AMD	Agricultural Markets Division
AMPEC	Agricultural Marketing Policy Evaluation Committee
ARC	Agricultural Research Council
BFAP	Bureau for Food and Agricultural Policy
CARD/TAPD	Trade and Agricultural Policy Division of the Centre for Agricultural and Rural Development
CF	Conventional Farming
CNFAP	Centre for National Food and Agricultural Policy
CSIR	Council for Scientific and Industrial Research
DGPS	Differential Global Positioning System
FAL	Federal Agricultural Research Centre
FAO	Food and Agricultural Organisation
FAPRI	Food and Agricultural Policy Research Institute
FES	Financial-Economic Simulation Model
FLIPSIM	Farm-Level and Income Simulator
GAI	Green Area Index
GIS	Geographic Information System
GPS	Global Positioning System
GSA	Grain South Africa
GWK	Griekwaland-Wes Koöperasie
Ha	Hectares
HTF	High-Technology Farming
IRR	Internal Rate of Return
K	Potassium
Kg	Kilograms
Km	Kilometres
KOV	Key Output Variable
LEI	Landbou Economisch Instituut
Lb	Pounds
N	Nitrogen
NDVI	Normalised Differentiated Vegetative Index
NPV	Net Present Value
P	Phosphorous
PC	Personal Computer
PF	Precision Farming
PPI	Producer Price Index
R/ha	Rand per Hectare
R/t	Rand per Ton
SAAU	South African Agricultural Union
SACU	Southern African Customs Union
SADC	Southern African Development Community
SAFEX	South African Futures Exchange
SSM	Site-Specific Farming
UMC	University of Missouri-Columbia
US	United States
USA	United States of America
VRA	Variable-Rate Application
WTO	World Trade Organisation

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Maize is the most important grain crop produced in South Africa, serving as a food source for humans and animals, an input provider to other sectors, a source of job creation, a contributor of value added to the national economy, and an earner of foreign exchange (Vink & Kirsten, 2000). The maize industry is thus an industry that must be supported and promoted in order to sustain its important function in the South African economy. For this reason the focus is on the maize farmer, who plays a vital role in the maize industry. A farmer will only produce maize when he can do so in a profitable and sustainable way. In early years maize farmers enjoyed favourable government policies that regulated the maize industry. Farmers knew what prices they would get for their maize and, since maize prices were mainly determined on the basis of production costs, farmers were able to plant maize and still break even or even reap a profit. Price uncertainty was also eliminated by the regulation of the maize industry (Bayley, 2000; Geyser, 2000).

However, the maize landscape changed dramatically after the deregulation of the agricultural sector during the 1990s. Farmers were suddenly exposed to global markets and a liberated economy. As a result of the free market system, farmers have been continuously exposed to a high level of price and market risk on both input and output prices as a result of the free market system (Bayley, 2000; Geyser, 2000). The cost squeeze effect of lower maize prices and higher input prices subsequently resulted in declining profit margins for maize farmers. The cost squeeze effect is presented in Figure 1.1 by means of producer and input price indices. From Figure 1.1 it can be observed that farmers experienced continuous pressure on profit margins from 1994 to 2000 as a result of rising input costs and declining producer prices. From 2000 onwards, profitability levels were erratic due to periods of favourable producer prices and input costs (the “boom” years), followed by periods with low producer prices and high input costs (the “bust” years). Figure 1.1 further indicates that the producer price trends are overshadowed by rising input costs in the longer term, thereby confirming the cost squeeze theory.

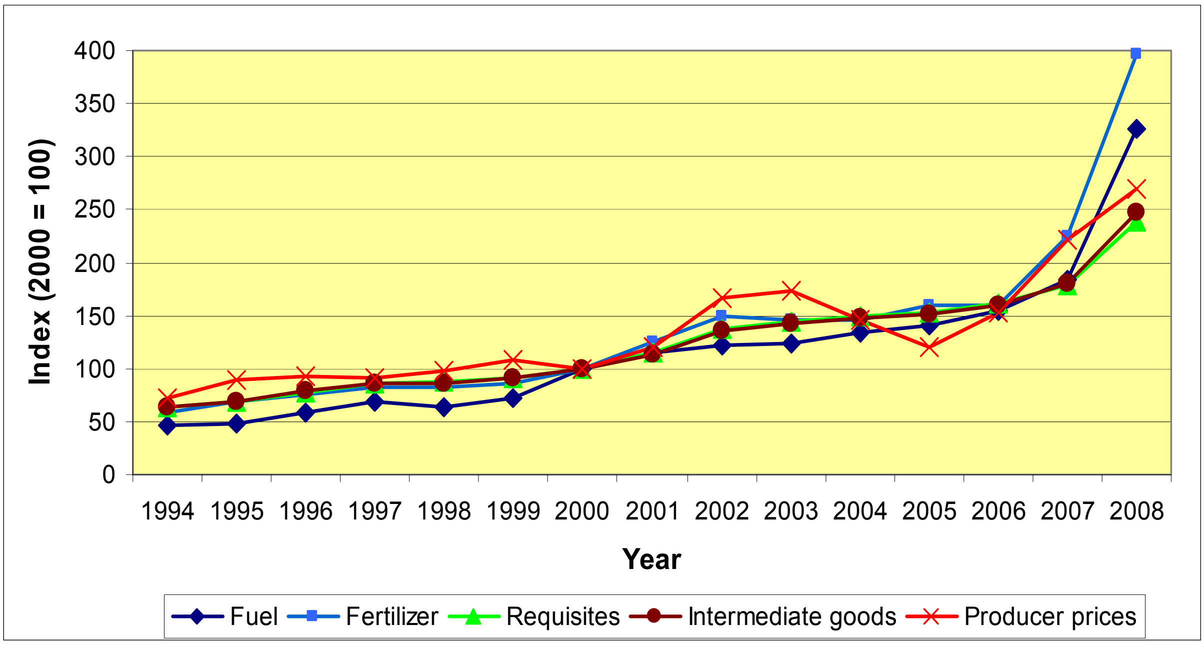

Figure 1.1: Comparison of producer and input price indices[3] for 1994 - 2008

Source: NDA (2009)

In order to mitigate the adverse effects of the cost squeeze at farm level, several strategies can be implemented such as improving farming practices, improving farm and financial management, taking unproductive soil (marginal soil) out of production, implementing supportive policies to the maize industry, and applying improved technologies. The latter was selected to be investigated as a possible solution to the cost squeeze problem, due to the various associated benefits.

Precision farming (PF) is an emerging technology in the agricultural arena with significant benefits for farmers, the environment and society (Batte, 1999). Precision farming has been adopted extensively in developed countries such as the United States of America (USA), Canada and European Union (EU) countries (Silva, Ribeiro do Vale, Pinto, Müller & Moura, 2007). PF has the potential to enhance profitability on South African soils, which are characterised by great variability in depth and fertility within given fields (Maine, 2002). Efficiency in production techniques could in turn

[3] Producer price index is the combined price index for field crops.

increase the overall competitiveness of the maize industry in South Africa by enabling the available arable land to be used more efficiently. In addition, since PF and more specifically variable rate application (VRA) involve the application of the correct amount of chemicals in the appropriate field areas, it has the potential to contribute to the reduction of nutrient loss to the environment (Maine, 2006).

1.2 PROBLEM STATEMENT

South African maize farmers experience constant pressure on profit margins. Prior to the deregulation of the maize market, prices were controlled and therefore price volatility was much lower on average. However, since the deregulation of South African agricultural markets, the price risk of both outputs and inputs increased significantly (Strauss, 2008). This is also confirmed by Figure 1.1, which indicates cost squeeze effect that has negatively affected the profitability of farming businesses in the long term. The combined impact of lower profitability and higher risk has had an adverse effect on the sustainability of farming businesses, especially those of maize farmers, since maize often trades at export parity prices. Consequently, farming practices and strategies should be implemented in order to improve the profitability of maize farmers in South Africa while attempting to reduce their risk. In this manner, productivity and competitiveness in the South African maize industry could be improved as well.

A technological tool being increasingly used lately for more efficient production is PF. However, the question arises as to whether this farming method will enhance the profitability of producers in the longer term. If no additional profit is made in the longer term and the farmer is exposed to a high level of risk, it could well lead to the farming business closing down in the medium and long run.

1.3 RESEARCH OBJECTIVES

1.3.1 <u>General objectives</u>

The general objective of the study was to investigate the impact of PF on the profitability of selected maize irrigation farms in the Northern Cape Province. This was done by comparing the profitability of the selected farms under a conventional farming (CF) system with the profitability of the same farms when converting to a PF system. A comparison between the risk associated with PF and CF with respect to profitability was also done, since risk is inherent to agriculture.

1.3.2 Specific objectives

In order to determine the impact of PF on the profitability of the maize irrigation farms in the Northern Cape Province, appropriate key output variables (KOVs) were selected and analysed. The following were among the KOVs analysed:

- Net farm income
- Cash position (cash surplus or deficit)
- Debt-to-asset ratio
- Risk position with respect to net farm income
- Risk position with respect to cash surplus or deficit

The study aimed to determine what effect the implementation of a PF system would have on these KOVs. In order to determine this, the selected KOVs were firstly analysed under a CF system (the “benchmark”) and then under a PF system. The impact of PF was then determined by comparing the results of the KOVs under the CF system with those of the PF system. The specific objectives of the study can thus be summarised as follows:

- To determine whether PF would generate better profits than CF;
- To determine whether PF would improve the farmer’s ability to repay his debt and generate an income (thereby improving the financial survivability of the farm);
- To determine whether PF would improve the debt-to-asset position of the farmer; and
- To determine whether PF is less risky than CF with respect to net farm income and cash position.

1.4 STATEMENT OF HYPOTHESIS

The hypothesis can be formulated as follows:

The various benefits associated with PF result in higher yields and lower input costs, subsequently leading to a significant improvement in financial management and general farm management abilities, ultimately resulting in increased profitability and lower risk for selected maize irrigation farms in the Northern Cape Province that have correctly implemented a PF system in their farming operations.

1.5 IMPORTANCE AND BENEFITS OF THE STUDY

From a theoretical perspective, the study could make a valuable contribution by expanding the existing knowledge base in terms of profitability, investment potential and risk associated with PF and CF respectively. The study can also contribute to both agricultural economists' and farmers' understanding of the relationship amongst production, sales price and input price with regard to PF, and how these variables differ between PF and CF. The study could expand the theoretical understanding of farm management with regard to PF, as it provides a tool that could improve the level of farm management in South Africa (Maine, 2006).

From a practical perspective, PF could be a useful on-farm tool for competitive maize production as a result of increased yields, reduced per-unit costs, improved crop quality, and lower manpower costs (Maine, 2002). Maine (2006) argued that the most important benefit of PF is the fact that it has the potential to raise the profit margins of farming businesses in South Africa and subsequently lead to the growth and sustainability of these farming businesses. The study has the potential to make a valuable contribution to the decision-making process of producers and equip them for their battle against inflation, declining profit margins and risk factors.

At macro level, PF has the potential to increase the competitiveness of the maize industry in South Africa with regard to production efficiency while improving the survivability, growth and sustainability of the South African maize industry in the long term.

1.6 DELIMITATIONS AND ASSUMPTIONS

1.6.1 Delimitations

Several issues fall beyond the scope of the study.

Firstly, it is important to note that the study focused on the impact of PF on the profitability of only the selected maize irrigation farms. According to Maine (2006) the impact of PF will differ from farm to farm, and hence the results and subsequent conclusions are applicable to the farms under consideration only.

Secondly, the study is only applicable to maize crops under irrigation, and therefore the conclusions drawn from the proposed study cannot be applied to other crops or to dryland farming. The reason for the study's focus on maize under irrigation is because the variability in weather conditions and yields makes it difficult to attribute improvements in dryland production solely to technological advancements such as PF. A dryland farmer does not have much control over water application and soil management as opposed to an irrigation farmer (Haarhoff, 2008b). The implementation of technological advancements thus plays a pertinent role in irrigation farming, which consequently justifies the investigation of the impact of PF on maize irrigation farms. Irrigation farms therefore also provide a good starting point for determining the effects of PF on the profitability of maize farms in South Africa.

Thirdly, it should be noted that the Bureau for Food and Agricultural Policy (BFAP) farm-level model used in the study was not used to make forecasts, but merely to analyse the impact of PF on the profitability of the farms under consideration.

Fourthly, it was learned through the course of the research process that the PF system being used by the participating farmers consisted of PF services rendered by Griekwaland-Wes Koöperasie (more commonly known as *high-technology farming*) that require no additional significant capital expenditure. Capital expenditure in this regard refers to the purchase of PF technologies that are discussed in Chapter 3. The study therefore does not account for additional capital expenditure with respect to PF that could influence the financial position of the participating farms.

Fifthly, although the study was conducted on irrigation farms, weather conditions do have an impact on the profitability of the operation and cannot be controlled. Therefore it might alter the actual results in future.

Lastly, the study does not take into consideration any economic variables other than those specified in this report. However, the qualitative benefits of PF that became obvious during the course of the study were recorded.

1.6.2 Assumptions

The following assumptions apply to the study:

- The analyses in the study were done with the assumption that the farmers would continue with their current crop-rotating systems in future. In cases where farmers gave an indication that certain crop rotations would change, the analyses were conducted accordingly.
- The PF system in the Northern Cape Province was being implemented correctly by the farmer, as explained in Chapter 3, section 3.4, regarding the PF system in use in the Northern Cape Province.
- It was assumed that weather patterns in future would not differ significantly from historical patterns, and therefore weather conditions were assumed to be normal in future.
- It was assumed that the cash surplus at the end of the farmer’s financial period would be reinvested in the farming business and not used for private wealth creation or for investment elsewhere (for example a holiday home).
- The same farmer was or would be farming on the same specific field for the period under consideration.
- It was assumed that the farm structure and composition of the farm would remain the same over the period under consideration and would only change as a result of simulated changes in the sector model (Strauss, Meyer & Kirsten, 2008). The BFAP sector model was linked to the BFAP farm-level model and used to generate projections on variables such as output prices, input prices, yields and area planted. The projections from the BFAP sector model were then

used as inputs for the BFAP farm-level model. The link between the BFAP farm-level model and the sector model is explained in more detail in Section 4.6 of Chapter 4.

- The physical production potential and quality of management remains constant over the period under consideration (Strauss *et al*, 2008).
- Since the BFAP farm-level model is linked to the sector model, with the outputs of the sector model being used as inputs in the farm-level model, the changes in the productivity process on the farm will be directly as a result of changes simulated by the sector-level model (Strauss *et al*, 2008). For example, if the sector model projected an increase in fertilizer costs for a specific year, this change would be applied on farm-level (in the farm-level model) with subsequent changes in the financial position of the farm.
- All assumptions made with regard to the BFAP farm-level model applies to the study. These assumptions are discussed in further detail in Chapter 5.

1.7 RESEARCH DESIGN AND METHODS

1.7.1 Description of overall research design

For purposes of the study, an empirical and evaluative multiple-case study approach was followed. The reason for this approach is that general farming conditions require data from a specific farm in order to allow for a comparative analysis between the PF and CF systems for different farmers. Subsequently the approach can be regarded as the most appropriate given the research design and method. Secondary numeric data was collected and used to conduct a comparative and quantitative analysis of the profitability for both the CF and PF systems.

1.7.2 Sampling

- **Target population and unit of analysis**

The study focused on maize irrigation producers in the Northern Cape Province who had previously produced crops under the CF system but were currently producing under the PF or high-technology farming (HTF) system as implemented by GWK.

Since the aim of the study was to conduct a comparative analysis between the profitability of the CF system and the profitability of the PF system, the unit of analysis was therefore the profitability of both CF and PF systems for a specific maize irrigation farmer in the Northern Cape Province. As stated in the section on the specific objectives of the study, the profitability of the selected farms was measured in terms of net farm income, debt-to-asset ratio and cash surplus or deficit. Risk was measured by determining the possible outcomes of net farm income and cash position of each farm by means of empirical probability distributions in stochastic modelling.

- **Data sources**

Data was mainly obtained from the Financial Bureau of GWK (a financial service offered by GWK whereby data is gathered from clients and financial recommendations are made). In cases where no or incomplete data was available, data was obtained directly from the participants. The participants were also interviewed in order to verify and validate the data obtained.

- **Sampling methods**

A panel of agricultural specialists, consisting of agronomists, soil scientists and agricultural economists familiar with the PF system and irrigation farming in the Northern Cape Province, assisted the researcher in selecting appropriate candidates for the case study. The selection of the producers was based on the reliability and availability of their data, whether they met the criteria for practising PF in the Northern Cape, the period of practising PF, and the type of crop being produced. The agricultural specialists and agricultural economists who assisted the researcher in the study had in-depth understanding and experience of irrigation farming in the Northern Cape, were pioneers in the field of PF and were also familiar with the producers in the Northern Cape and therefore they were the most suitable persons to make the most appropriate selections.

A problem that arose was the possibility that the quality of the data obtained from the producers might not have been suitable for the study due to inconsistent recordkeeping, crop rotation systems in which crops other than maize were cultivated in a specific year, and factors such as climatic conditions, level of farm management, water quality and volatility of crop prices that cannot be ascribed or PF. In order to mitigate the problem, three participants were selected by the panel of agricultural specialists and agricultural economists, as described in the paragraph detailing the method of selecting participants. The data of all the participants was analysed and compared to determine the effect of PF.

1.7.3 <u>Data collection</u>

- **Nature of data collected**

Secondary and numeric data was collected from the Financial Bureau of GWK and verified by interviewing the participants. The main variables focused upon were net farm income, cash surplus or deficit, and debt-to-asset ratio. The approach that was used in the study is discussed in more detail in the section on data analysis.

- **Pilot testing**

The collected data was verified and validated by presenting it to the panel of agricultural experts to determine whether it made sense from an economic perspective. The data was also discussed with the participants in order to verify the accuracy and reliability.

1.7.4 <u>Data analysis</u>

The key output variables, namely net farm income, cash surplus or deficit, and debt-to-asset ratio, were analysed by means of the BFAP farm-level model developed by Strauss (2005). This model is discussed in more detail in Chapter 4. In the case of this particular study, the farm-level model was used to analyse the likely impact of PF on the profitability of maize irrigation farming in the Northern Cape Province. According to Strauss *et al* (2008) the linked system of models, namely the BFAP sector and farm-level models respectively, proved to be useful in analysing the impact of change in policies and markets at both the sector and farm level, showing that the farm-level model has the ability to simulate a representative farm rather accurately. This subsequently provides justification for the use of the BFAP farm-level model as a tool to analyse the variables mentioned in this paragraph, since a producer's decision to implement an PF system on his farm can be regarded as a change in "policy" at farm level.

1.7.5 Assessing and demonstrating the quality and rigour of the research design

The main challenge faced by the researcher was proving that the observed impact on the profitability was as a direct result of PF. This was difficult, since there were many exogenous factors that could have had an impact on the profitability of a producer. Examples of such exogenous factors are climatic conditions, the producer's level of management (good, average or poor), the price received by the producer for his harvested crop in a given year, the correct implementation of the PF system, the occurrence of diseases and pests, and differences in the productivity potential of the soils, making comparisons difficult. These challenges were addressed by implementing specific mechanisms or criteria for selecting participants for the study.

Firstly, special care was taken in cases where climatic conditions and pests and diseases had a substantial impact on the financial position of a farm. These effects were taken into account when assessing the impact of PF on the profitability of the selected farm.

Secondly, the panel of agricultural experts assisted the researcher in selecting a participant with an acceptable level of management, preferably on an average management level. It should be noted that the PF system was expected to improve the level of management, and the researcher attempted to measure this expected change in order to determine what the impact would be on profitability.

Thirdly, possible candidates were screened based on their implementation of the PF system. The participants had to comply with the criteria for the PF system as provided by GWK. In order to compensate for the possible different productivity potentials of the soils, a homogeneous area where the productivity potential of the soil did not differ significantly was selected for the proposed study.

In order to assess the quality, credibility and rigour of the proposed study, agricultural specialists and people familiar with the irrigation farming system in the Northern Cape Province were actively involved. These role-players assisted the author in the modelling and simulation process, as well the verification and validation of the model.

1.8 ORGANISATION OF THE STUDY

The dissertation is organised into six chapters. The first chapter gives the problem statement, the study objectives and the hypothesis statement. The second chapter introduces an overview of the South African agricultural sector, and more specifically the South African maize industry. A historical overview of the South African maize industry is also included in this chapter, while the importance of maize production in South Africa is emphasised. In the third chapter, the literature review on PF technologies, techniques and profitability is reflected, followed by a description of the PF system implemented in the Northern Cape Province, which forms the main focus of the study. The benefits associated with PF in the region are also discussed in order to create the foundation for the analyses in Chapter 5. In Chapter 4, the concepts of profit, risk and modelling in agriculture are discussed. Various risk concepts and analysis tools are also explored in this chapter, along with all the different models used to measure risk and profitability. Chapter 4 concludes with an explanation of the working and structure of the BFAP farm-level model used in the study. A background and description of the case studies, the baseline, analysis approach, input data and assumptions applicable to the participating farms are provided in Chapter 5, which also represents the results obtained from the analysis of the participating farms and a discussion of the results. Chapter 6 provides a summary of the study and the concluding remarks.

CHAPTER 2

THE SOUTH AFRICAN MAIZE INDUSTRY: AN OVERVIEW

2.1 INTRODUCTION

The South African maize industry is historically an industry characterised by many controversial political decisions and debates. In early years commercial maize farmers enjoyed the protection of favourable government policies, and farmers always knew what prices they would get for their maize, thereby eliminating price uncertainty. However, the political landscape changed dramatically, and reform policies in agriculture were unavoidable. The agricultural sector was deregulated in 1996 with the promulgation of the Marketing Act (Bayley, 2000; Geyser, 2000; Vink & Kirsten, 2000). As a result of the free market system, farmers have been continuously exposed to a higher level of price and market (Bayley, 2000; Geyser, 2000). A conceptual understanding of the economic and political environment in which South African farmers operate is important in order to understand the conditions under which decisions are made and price formations occur and how profitability and risk are influenced by agricultural policies and markets.

In this chapter a historical perspective on the South African agricultural sector is provided, with special emphasis on the maize industry. This is followed by a discussion of the current state of South African agriculture and the importance of maize production within this context. The purpose of this chapter is to illustrate the importance of competitive maize production in South Africa, as well as the market environment in which maize farmers must currently operate.

2.2 HISTORICAL OVERVIEW OF THE SOUTH AFRICAN MAIZE INDUSTRY

2.2.1 <u>Regulation of the South African agricultural sector</u>

During the early 1860s South Africa was producing agricultural products sufficiently to meet the requirements of its population. Agricultural production was mainly on a subsistence-farming basis, while commercial farming was pursued by only the coastal-based farmers, who had better access to export facilities. Products being exported included wool, wine, hides and ostrich feathers, while wheat, fruit, butter, beef and maize were being produced for domestic consumption (Wilson in Bayley, 2000).

However, the South African economic landscape changed dramatically with the discovery of diamonds in 1867 and gold in 1886 in the interior of the country. Urbanisation occurred at a rapid pace, while the demand and subsequent prices for agricultural commodities increased significantly. Farmers responded to the increasing demand for these agricultural commodities, but production was not sufficient to meet these requirements. As a result, large quantities of wheat, maize, meat, eggs, milk and butter were imported (Wilson in Bayley, 2000).

The average annual production of maize in the Union of South Africa from the 1910s through the 1920s amounted to approximately 12 million bags, where a bag size was the equivalent of 200 lb or 90.7 kg of maize. The maize supply was sufficient to meet the demand for maize, with relatively small surpluses. In the 1920s producers generally received high prices for their maize, leading to a general optimistic agricultural and economic outlook. After 1924, maize production increased significantly, but the demand remained on the same level. This resulted in a huge surplus where approximately one-third of the marketable crop was exported. Despite good harvests during the 1927-1929 seasons and a positive harvest forecasting for the next season, average domestic prices remained at a then high level of R12.90 per ton for a grade two maize classification (Maize Board, 1986).

After July 1929, however, domestic and world prices of agricultural commodities started to drop dramatically. In the United Kingdom (UK), prices tumbled from an average of R16.64/t in 1929 to R10.80/t in 1930. In the 1930/1931 marketing season, the average domestic price for maize in South Africa was a devastating R7.44/t. In the 1931/1932 marketing season, low world prices and high domestic yields resulted in very poor domestic prices for South African maize farmers, since prices were determined by net prices received in the export market (export parity). The effect of export parity stems from the fact that when a surplus of maize exists under free marketing conditions, the domestic relationship of demand and supply overshadows the world demand and supply relationship. When exports are allowed, the domestic prices received by farmers are thus the same as the prices determined by market forces in the world markets; i.e. export parity. This is the reason why domestic prices are mainly determined by export parity prices, and they will therefore fluctuate in accordance with price fluctuations in the world market. In addition to low prices, South African exporters were not concerned with maize production and thus the removal of the domestic maize surplus, which placed maize farmers in a desperate position. From this critical condition, only two possible solutions emerged, namely government support or the enhancement of co-operative marketing (Maize Board, 1986).

2.2.2 <u>Government support by means of the Maize Control Act of 1931</u>

In order to support domestic prices, the government promulgated the Maize Control Act of 1931, which forced domestic buyers to purchase and export a part of the exportable maize surplus. The aim of this Act was to ensure that producers would receive higher prices for their maize in the near future and to separate domestic and world prices, especially in the case of low world prices. By means of this system, whereby higher domestic prices were promoted, exporters could be compensated for losses made on exports of their export quotas, while maize farmers in turn received higher prices for their maize. However, this scheme was not without shortcomings. Firstly, export quotas had to be determined on the basis of harvest forecasts early in the season. This was a difficult task, since the final outcome of the harvest was uncertain. Secondly, export quotas were made negotiable and quota certificates were based on the difference between export and consumer prices. This resulted in a speculative market, since huge fluctuations in world market prices provided opportunities for speculative profits. In order to stabilise the export quota system, purchase prices for quotas were warranted by the government. Government thus incurred high costs, especially in surplus years when surplus quotas had to be bought. For example, in the 1935/36 and 1937/38 marketing seasons, the costs were R600 000 and R1 060 000 respectively.

2.2.3 The co-operative movement

The government hoped that the orderly marketing of agricultural products through co-operatives would help to stabilise the marketing environment for agricultural products. However, co-operative members used the credit facilities provided by co-operatives, but did not always deliver their products to the co-operatives. Instead, they took advantage of opportunistic prices on the open market, thus denying the co-operatives their entitled share of the harvest. This resulted in high cost structures and subsequent financial pressure for co-operatives. In some cases, co-operatives also experienced management problems, and together with the financial pressure they could not provide a competitive marketing environment to their members. This caused the co-operative movement to lose support.

A commission of inquiry into co-operative and agricultural credit was appointed in 1934 to determine the role of co-operatives in the marketing of agricultural products. The commission mainly found that serious flaws existed in the export system.

2.2.4 Establishment of the Maize Board and government intervention

On 3 May 1935, the government promulgated the Maize Control Act (Act 89 of 1935), which enabled the establishment of the Maize Board as an advisory body. The Maize Board consisted of eight maize producers plus seven members representing other sectors of the South African economy. The role of the Maize Board was to advise the Minister of Agriculture on the problems associated with the maize industry and maize exports.

Dramatic changes worldwide in the agricultural economics arena from 1933 onwards resulted in a review of South African agricultural legislation by the Minister of Agriculture. Thousands of farmers were ruined financially due to low prices, high price volatility and severe droughts in 1932 and 1933. After considering a report on agricultural marketing systems abroad, the government announced the Marketing Act of 1937 (Act no. 26) (Kassier, 1992; Maize Board, 1986). The objectives of the Marketing Act of 1937 were to improve the stability of agricultural prices, to reduce the spread between the producer and consumer prices by means of rationalisation, and lastly to improve the efficiency of production, marketing, processing and distribution for both producers and consumers (Bayley, 2000; Kassier, 1992; Maize Board, 1986). The Act bestowed on the Maize Board significant control over the marketing system of the South African maize industry. The Marketing Act of 1937 was amended a few times and later repromulgated in 1968 as the Marketing Act of 1968 (Act no. 59 of 1968). Other amendments to the Act were made in 1970, 1972, 1973, 1984 and 1987 (Groenewald, 2000; Kassier, 1992; Maize Board, 1986; Vink & Kirsten, 2000). The single-channel fixed-price scheme was a direct result of the promulgation of the 1937 Marketing Act.

2.2.5 Single-channel fixed-price scheme

When maize surpluses became deficits and the Second World War started, it became necessary to implement stricter regulations in order to strategically control maize stocks. During 1941/42 the domestic consumption of maize started to increase, while maize traders kept their stocks from the market in anticipation of higher prices at the end of the season. As a result the Maize Board was enabled to fix the sales prices of maize and maize products. In 1942, by means of the War Act (Act 20 of 1942), the Maize Board was given the power to claim maize from persons storing more maize than necessary. The Maize Board was also authorised to appoint agents who would receive and distribute maize on its behalf. These extra powers enabled the Maize Board to gain greater control over maize stocks in South Africa. A food control organisation was also established in 1942, in which the Maize Board participated. As the maize deficits became greater during the 1942/1943 season, a permit system with the Maize Board as administrator was introduced in order to limit the use of maize stocks. During the 1943/44 season, producer prices were announced early in order to promote earlier deliveries by farmers. The storage capacities of co-operations were not sufficient to accommodate the maize, resulting in maize being stored outdoors and exposed to the weather elements. This resulted in huge losses due to prolonged and heavy rains. In spite of fierce opposition it became evident that a single-channel system would provide the best solution (Maize Board, 1986).

The first trial period for a single-channel fixed-price scheme for maize was introduced during the 1944/45 marketing season.

2.2.6 Deregulation of the South African agricultural marketing system

Further developments in the South African maize industry should be considered against international developments and the effects of the General Agreement on Tariffs and Trade (GATT). After the Great Depression during the 1930s, government intervention in the economy and especially agriculture occurred worldwide. After the Second World War, the notion of national food self-sufficiency was widely propagated at international level. Developing countries were encouraged by institutions such as the World Bank and bilateral aid agencies to strive for food self-sufficiency at national level. Policies were subsequently introduced and resulted in increased food production, global surpluses and expensive stockpiling of food. However, many households around the world still suffered from malnutrition and hunger. The focus subsequently shifted from food security at national level to food security at household level. In other words, more attention was subsequently paid to the exploitation of trade opportunities that arose as result of comparative advantages of different producers and regions at domestic and international level. Examples of such policy shifts are the Green Revolution in Asia, farm liberalisation in the USA, New Zealand, Australia, Chile and Kenya, and the Uruguay Round of the GATT. The World Bank and bilateral aid agencies in turn shifted their focus in Africa to correcting prices and increasing the responsiveness of supply by farmers. Towards the 1960s it became obvious that government intervention was not proving successful, which resulted in an international trend towards deregulation, privatisation and small government (Bayley, 2000; Geyser, 2000; Kassier, 1992).

This international deregulating trend also spilled over to South Africa during the 1970s, although at a later stage (Kassier, 1992). The GATT negotiations called for the abandoning of quantitative import controls and the introduction of tariffs on all agricultural commodities. These measures were aimed at reducing distortions due to quantitative controls, diminishing the role of government in the allocation of licences by creating a more commercial environment in the planning of imports, and facilitating increased competition. After 1985 a general trend away from quotas and towards tariffs occurred. However, these measures were only applied to agricultural commodities in 1992 (Vink & Kirsten, 2000).

During the 1980s agricultural profitability started to decline and a detriment in the terms of trade by primary producers occurred. South African agricultural marketing and trade controls resulted in inflated agricultural production and marketing costs, distorted relative prices, and financial and other economic welfare transfers (Bayley, 2000). Substantial pressure started to mount from within the system, as farmers increasingly became discontented with some aspects of the controlled marketing of agricultural products (Vink & Kirsten, 2000). In addition, the slow productivity growth of the agricultural sector as a whole also raised some concerns (Thirtle in Vink & Kirsten, 2000) A reversal of the policies implemented during the previous two decades subsequently occurred during the 1980s. Marketing policy that required registration as well as price controls was generally reduced during this period. Shifts toward more market-based pricing systems occurred, in contrast to traditional pricing procedures.

In 1987 the marketing system was reformed, thereby making the Maize Board itself responsible for determining maize prices (Maize Board, 1986). Three basic processes were used to determine prices for a specific marketing season, namely price scenario, delivery price, and final price. In the price scenario process, current market conditions such as crop size, international market conditions, exchange rates, domestic demand, marketing costs, operational financing and government aid (if any) were taken into account when determining prices for a specific marketing season. The price scenario provided farmers with a realistic framework and was announced approximately eight months before the planting period. The delivery price was based on the price scenario method, except that it was calculated at the end of the marketing year (March and April). Upon delivery of his maize to the Maize Board agents, a farmer was paid the delivery price. The final price was based on the actual outcome of market factors during a marketing season and, in cases where actual market factors were better than expected, surpluses were paid out as additional payments to producers.

Although unitary pricing was still intact, the Maize Board could no longer carry over surpluses or losses as a result of exports, nor could it use loans to fund a particular marketing year. After 1987, the producer price was mainly based on actual performance and operated as a pooled price. During the 1990s, the single-channel marketing system of the Maize Board came under pressure as a result of the widening gap between buying and selling prices. At that stage the system encouraged farmers to use maize as feed for their livestock instead of incurring the imposed levies by selling their maize to the Board (Geyser, 2000).

In 1992 the Kassier Committee had the task of conducting an in-depth investigation into the various schemes of the individual control boards (including the Maize Board) with respect to export and domestic marketing and determining their relevance to farmers and consumers. At the announcement of the Kassier Report, the Minister of Agriculture also announced the appointment of the Agricultural Marketing Policy Evaluation Committee (AMPEC). In their reports (January 1994 and April 1994), AMPEC generally supported the findings and recommendations of the Kassier Committee. It became evident that the marketing system should become more market-oriented, but AMPEC also recommended that room should be left for continued statutory involvement in agricultural marketing. It was subsequently announced that the AMPEC Report would form the basis for rewriting the Marketing Act of 1968 (Bayley, 2000).

The Kassier Report also resulted in the fixed single-channel grain marketing scheme being replaced by a maize marketing scheme in 1995. The new scheme prevented the Maize Board from operating actively on the domestic market. Instead, the onus fell solely on buyers to remove the maize surplus on a pooled basis. Formerly controlled markets were also deregulated. In 1996 the Marketing of Agricultural Products Act (Act no. 47 of 1996) was promulgated. Interventions were limited to registration and information collection (Geyser, 2000). The new Act paved the way for the establishment of the National Agricultural Marketing Council, which among other things was responsible for the dismantling of all the undesired restricting regulations (Groenewald, 2000). The new Act also attempts to protect the interests of all interest groups instead of only a few farmers (Vink & Kirsten, 2000).

The functions of the Maize Board were terminated at the end of 1996, leaving producers responsible for the marketing of their own maize. Price controls were removed and the single-channel markets abolished as a result (Du Plessis, 2008; Geyser, 2000). Following the deregulation of agricultural commodities, the problem arose that market concentrations as a result of the control board system could neutralise the potential benefits of deregulation. The government is therefore responsible for monitoring the impact of market concentration on the performance of deregulated agricultural markets. In cases where problems are identified, the government is able to implement policies to counteract these problems by means of competition legislation or sector initiatives (Geyser, 2000).

After the dismantling of the Maize Board in 1996, the Maize Trust was established in August 1998 with the primal goal being to promote the South African maize industry (Du Plessis, 2008; Maize Trust, 2008). For this purpose the assets of the Maize Board were transferred to the Maize Trust (Du Plessis, 2008; The Baker, 2007). The Trust mainly provides financial support to research institutions such as the Agricultural Research Council (ARC) and the Council for Scientific and Industrial Research (CSIR) that focus on maize production and marketing. Other objectives of the Trust include the acquisition, assimilation and dissemination of market information for the local maize industry. It furthermore provides support for training, technical assistance and the creation of marketing infrastructure, thereby facilitating market access for South African maize (Maize Trust, 2008).

2.2.7 Aftermath of the reform process

The deregulation of agriculture in South Africa resulted in several substantial developments in response to the changing agricultural arena. Some of the effects of deregulation (particularly on the South African maize industry) can be summarised as follows (Bayley, 2000; Geyser, 2000; Vink & Kirsten, 2000):

- As a result of declining real prices, real farm incomes continued to decline during the mid 1990s.
- Since prices were no longer guaranteed by a control board, farmers were exposed to greater price risk.

- Despite an improvement in aggregate debt repayment by farmers, several farmers were experiencing financial difficulties.
- The cropping patterns of farmers started to change towards higher value commodities as a result of risks and prices to which farmers were exposed.
- The real value of South African agricultural trade, especially exports, increased significantly.
- New agricultural and food enterprises started to emerge at an increasing rate.
- A substantial number of co-operatives converted into companies in order to raise capital and to adopt a more flexible and commercial outlook in a deregulated marketing environment.
- The private sector proved capable of accommodating carryover stocks of maize.
- An Agricultural Markets Division (AMD) was established by the South African Futures Exchange (SAFEX)
- As a result of deregulation, freer trade of agricultural commodities within the Southern African Development Community (SADC) began to provide better export opportunities to countries like Zimbabwe and Zambia.
- The deregulation of the marketing system has made it more difficult for other members of the Southern African Customs Union (SACU), such as Botswana, Lesotho, Namibia and Swaziland (the BLNS countries), to implement import restrictions.

Some of the impacts at farm level mentioned in the preceding paragraph were also as a result of other factors like adverse weather conditions, and therefore the impact of deregulation should not be viewed in isolation, but rather with the bigger picture in mind.

In the section that follows, an overview of the current situation in the South African agricultural sector is provided in order to compile a picture of the environment in which maize farmers are currently operating since deregulation, while the current importance of maize production in South Africa is emphasised.

2.3 OVERVIEW OF THE CURRENT SITUATION IN THE SOUTH AFRICAN MAIZE INDUSTRY

2.3.1 Background to maize production in South Africa

Maize is planted during late spring and early summer. The majority of maize produced in South Africa is cultivated under dryland conditions. However, varieties with a shorter growing period are produced under irrigation. Major maize production areas in South Africa include the Free State, North West and Mpumalanga provinces, followed by Gauteng and the Northern Cape to a lesser extent (Northern Cape, 2007). Figure 2.1 illustrates the contribution of each province to maize production in South Africa.

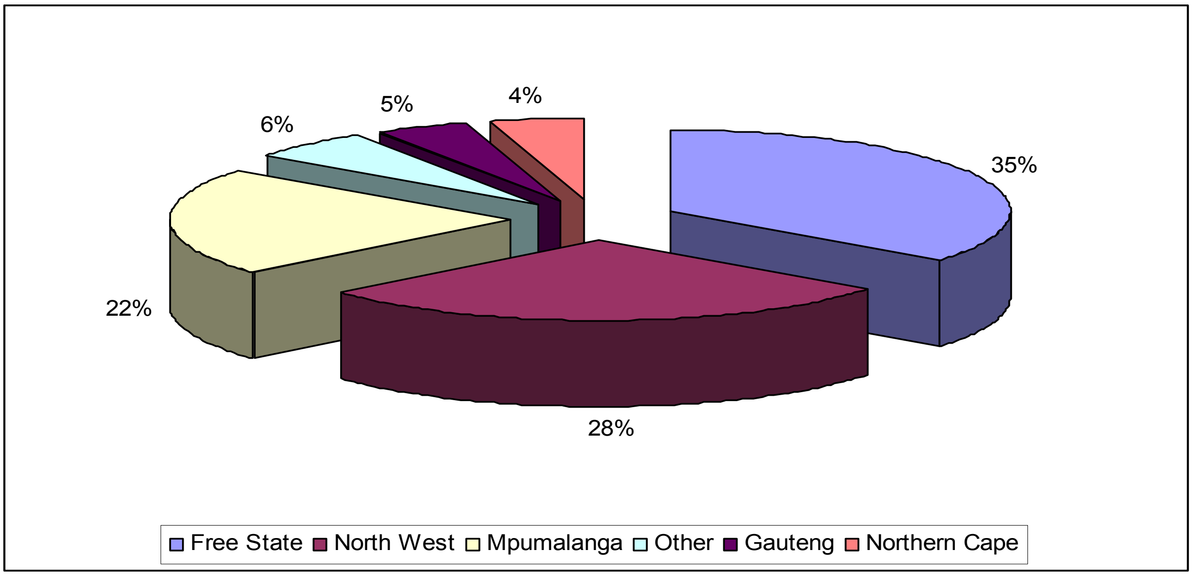

Figure 2.1: Average contribution to maize production by province for the period 1996-2006
Source: NDA (2008a)

South Africa's official marketing year starts in May and ends in April. Maize delivery takes place between May and August. During this delivery period, production generally exceeds domestic consumption, leading to an increase in maize stocks. From September to April maize stocks start to decline as consumption exceeds production during this period (Northern Cape Province, 2007). Figure 2.2 shows the area harvested and production figures for maize for the production period 1975 to 2007. From Figure 2.2 it can be observed that the area harvested decreased in size from 4.5 million hectares in 1975 to just over 2.5 million hectares in 2007. It should be noted, however, that despite the substantial decline in area planted over the past decades, production has not declined significantly. This can be ascribed to the fact that marginal production areas have been left out of production and that average yields have improved due to technological improvements (NDA, 2008b).

Although producer prices were based on production costs during the mid 1970s, farmers were not fully compensated for the cost increases. During that time, export prices started to drop in comparison with domestic prices, which depressed the producer price of maize. During the 1980s the area planted decreased further as a result of a deteriorating external environment. In the 1990s the drought years of 1992/1992 and 1994/1995 caused a significant drop in area planted, as can be observed from Figure 2.2. Figure 2.3 is included in order to illustrate nominal price movements during the 1990s. However, as a result of government subsidies and grants through the Maize Board and other government policies, farmers were able to recover quickly (Essinger *et al.* in Mqadi, 2005). As from 2000, the area harvested has generally varied between approximately 3.25 million hectares and 2.5 million hectares, with the exception of the 2006/2007 season when the area planted fell below 2.5 million hectares. In the early 2000s the depreciation in the exchange rate and inaccurate market signals of a possible crop failure in the SADC region resulted in a sharp increase in the maize producer price. Producers responded to this price increase, and the area planted during this period increased significantly. The increased area planted in the 2002/2003 production period with its subsequent higher production and the appreciation of the exchange rate caused producer prices to drop drastically (Meyer, 2003). Producers adjusted to this decline in the producer price, and the area planted decreased substantially during the 2004/2005 and 2005/2006 production periods. However, lower plantings in the domestic market together with the increased demand of biofuels in the international market (which influenced the import and export parity price band in which local prices can move), resulted in a significant recovery in the producer price for maize during the 2006/2007 and 2007/2008 production seasons (BFAP, 2008). The recovery in producer price subsequently caused farmers to increase plantings during 2008/2009, which can be observed in Figure 2.2.

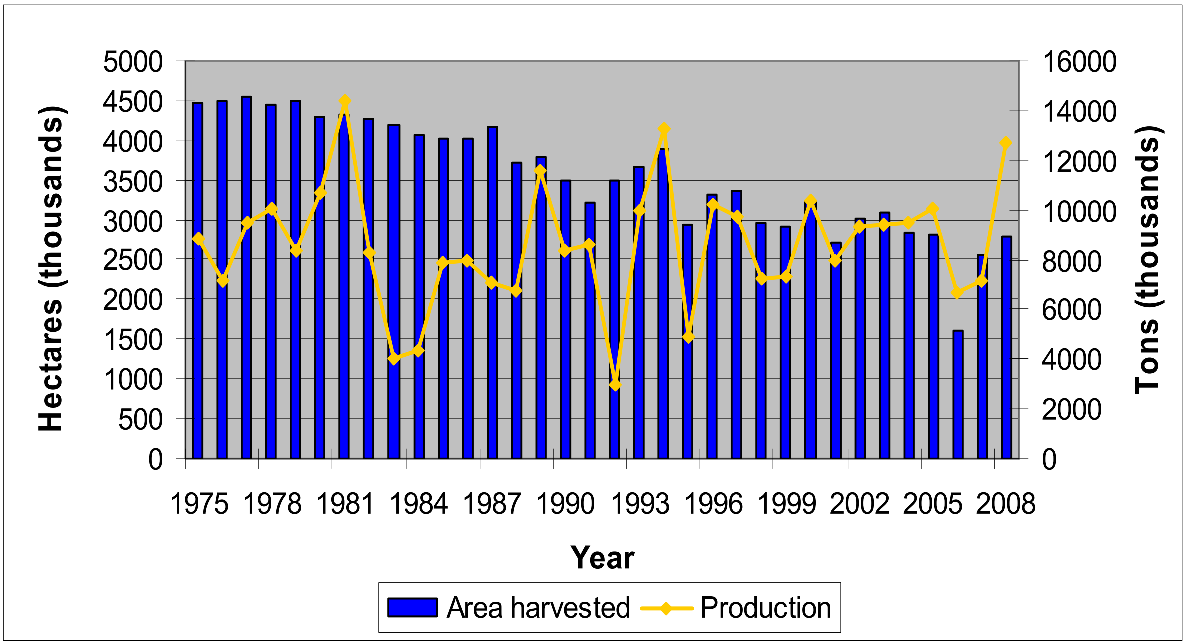

Figure 2.2: **Area planted and production of maize in South Africa for the period 1975-2008**

Source: BFAP (2008)

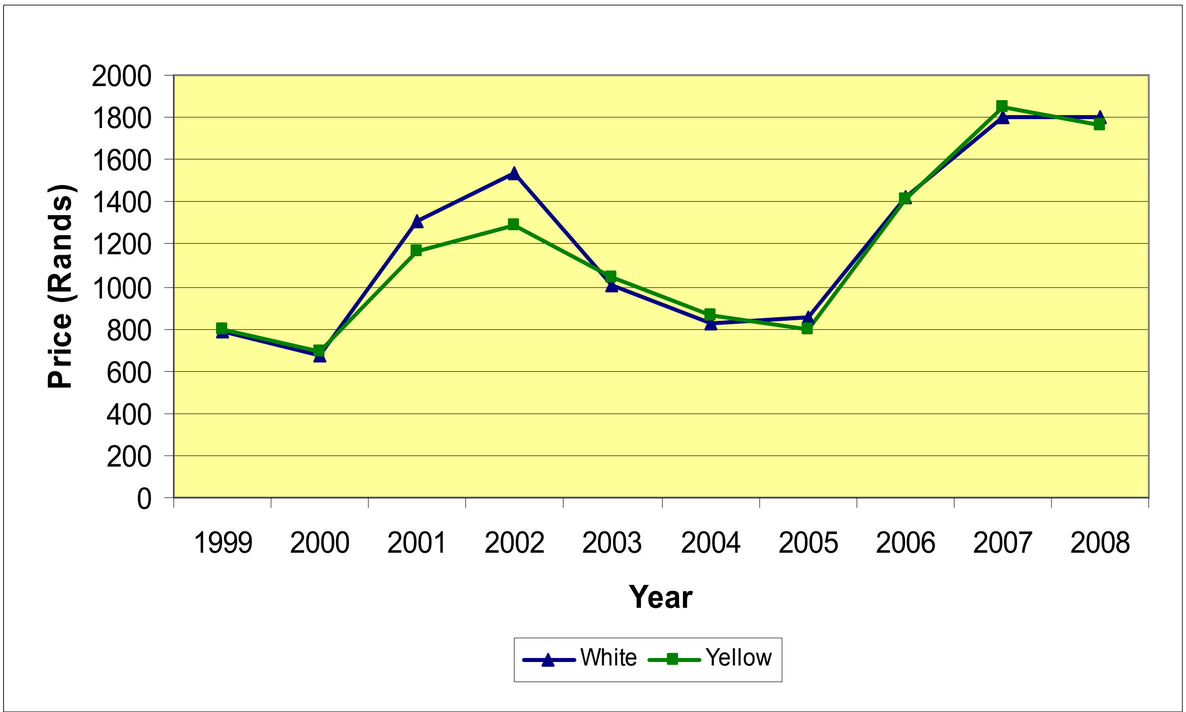

Figure 2.3: **Nominal producer prices for white and yellow maize in South Africa for the period 1999 - 2008**

Source: BFAP (2008)

Since the production of maize exceeds the domestic consumption thereof, South Africa is regarded as a net exporter of maize. This is also confirmed by Figure 2.4, which indicates that exports have exceeded imports for most periods. Maize is regarded as an important earner of foreign revenue through maize exports. In surplus years, maize is mainly exported to Zimbabwe, Japan, Zambia, Malawi, Mauritius, Kenya and Mozambique. White maize is the staple food of a large section of the African population, which accounts for approximately 94 percent of white maize meal consumption (Meyer, 2003). In 2007, the consumption of maize was estimated at approximately 8 million tons, with a white-to-yellow-maize ratio of 62:38, meaning that approximately 62 percent of all maize planted consists of white maize while the remaining 38 percent consists of yellow maize (NDA, 2008c).

However, it is important to observe from Figure 2.4 that yellow maize is also imported to a large extent. The reason for this is that yellow maize is mainly used for animal feed, while large feed mills are located close to the Durban and Cape Town harbours. Consequently it is cheaper for feed mills to import yellow maize than to transport it from inland production areas to the feed mills on the coast (Meyer, 2006).

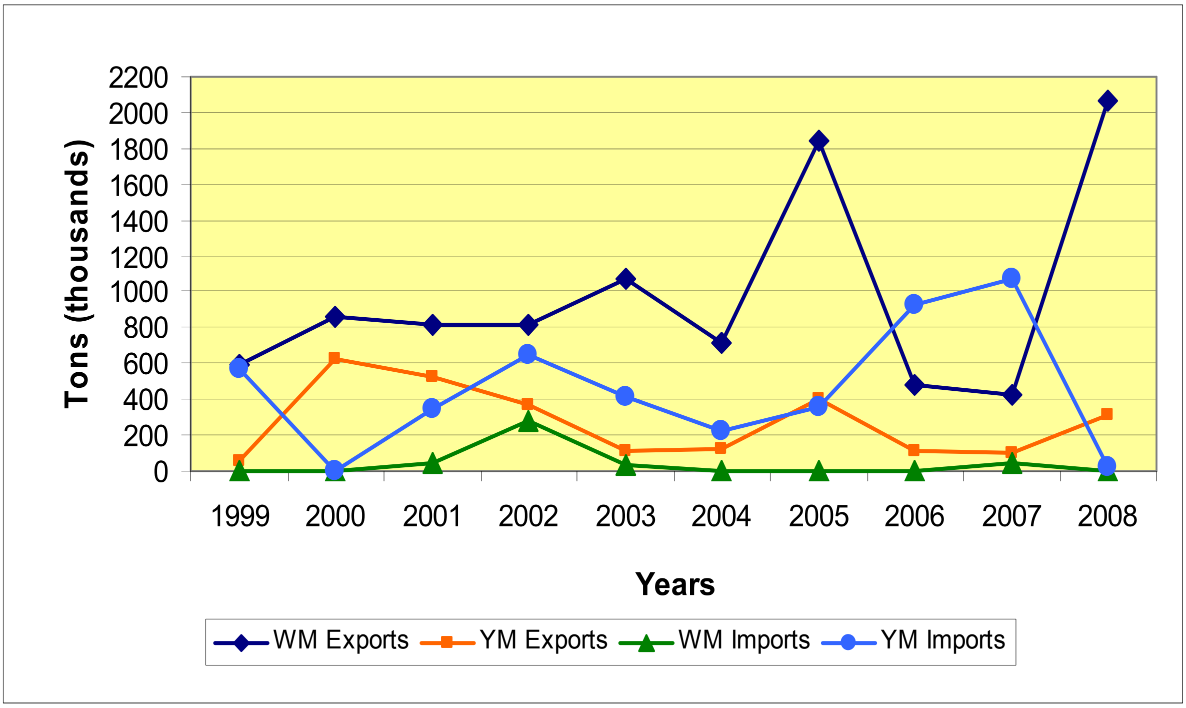

Figure 2.4: **White and yellow maize imports and exports for the period 1999 - 2008**

Source: BFAP (2008)

2.3.2 Global position of South Africa in terms of maize production

In the international arena, South Africa is generally ranked by the Food and Agricultural Organisation (FAO, 2009) as being between the ninth and fourteenth largest maize producer in the world. Although South Africa can be regarded as an important role-player in the global white maize production arena, South Africa is a very small producer of yellow maize relative to other maize producing countries like the US, China and Brazil. The total maize area harvested, total production and average yields in South Africa are compared with other important maize-producing countries in Figures 2.5, 2.6 and 2.7 respectively. Figures 2.5 through 2.7 indicate that, given the arable land available, South Africa compares well with other countries. However, Figure 2.7 suggests that in terms of yield there is significant room for improvement. The question subsequently arises as to whether technologies such as precision farming (PF) can be used to improve South African maize production and the competitiveness thereof with respect to other maize-producing countries.

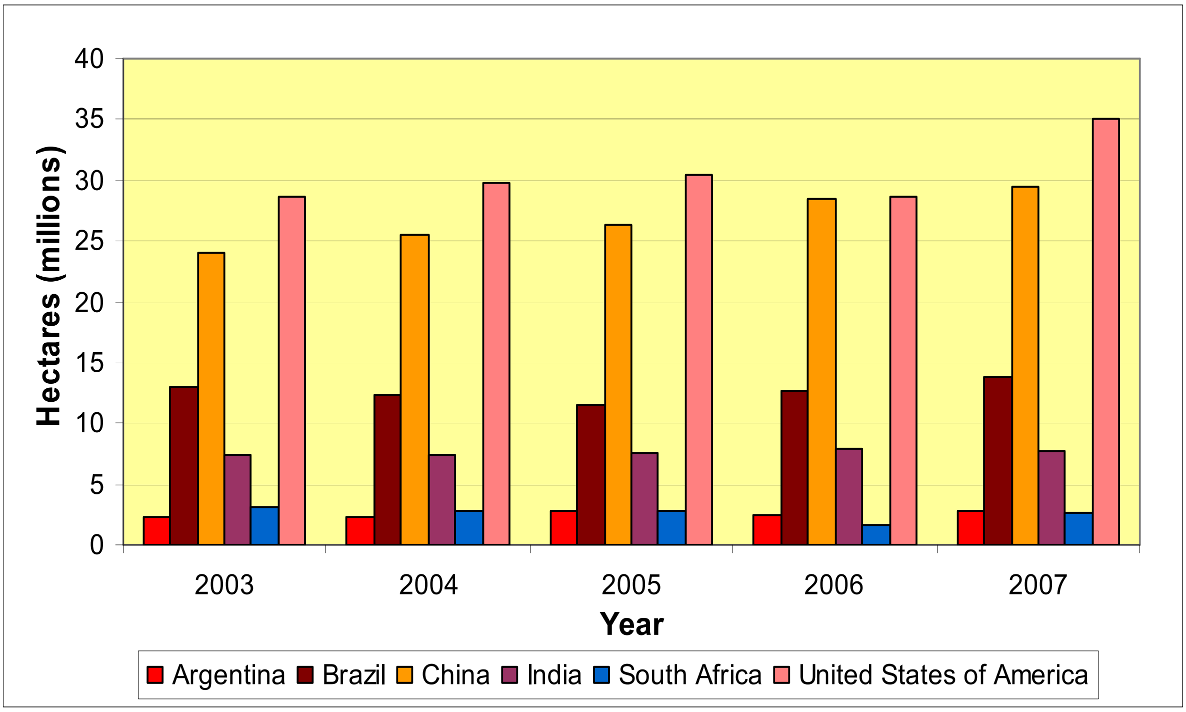

Figure 2.5: Comparison of maize area harvested in South Africa with other countries, 2003 - 2007

Sources: BFAP (2008), FAO (2009)

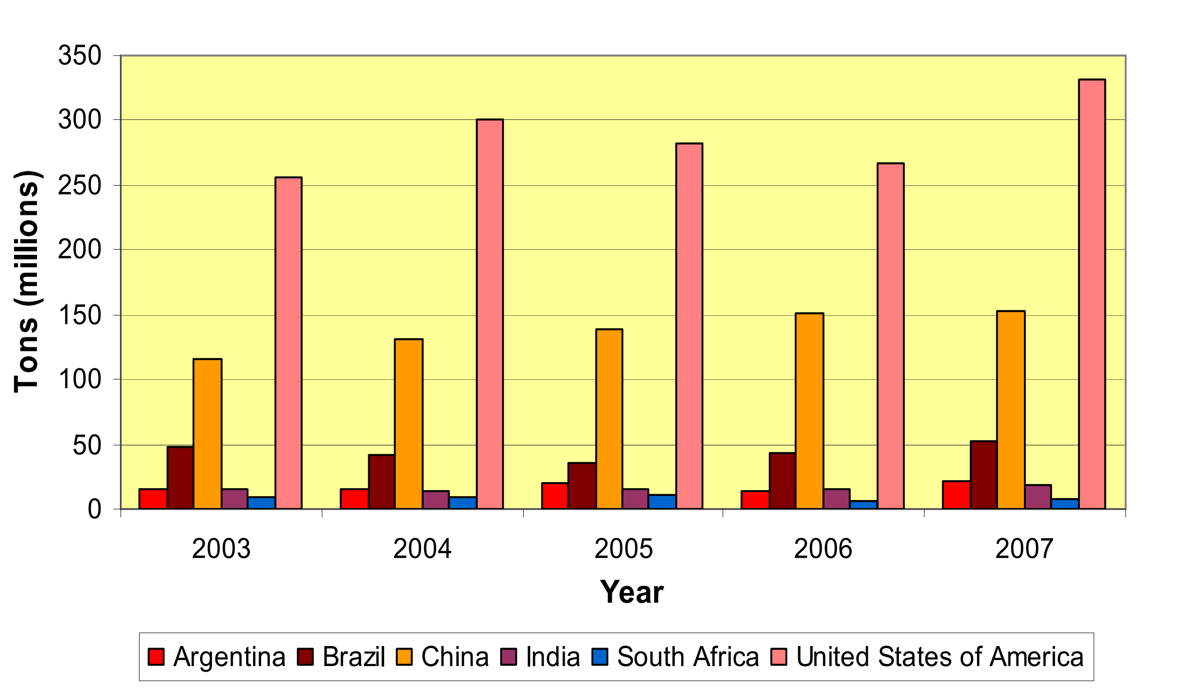

Figure 2.6: **Maize production in South Africa compared with other important maize-producing countries, 2003 - 2007**

Sources: BFAP (2008), FAO (2009)

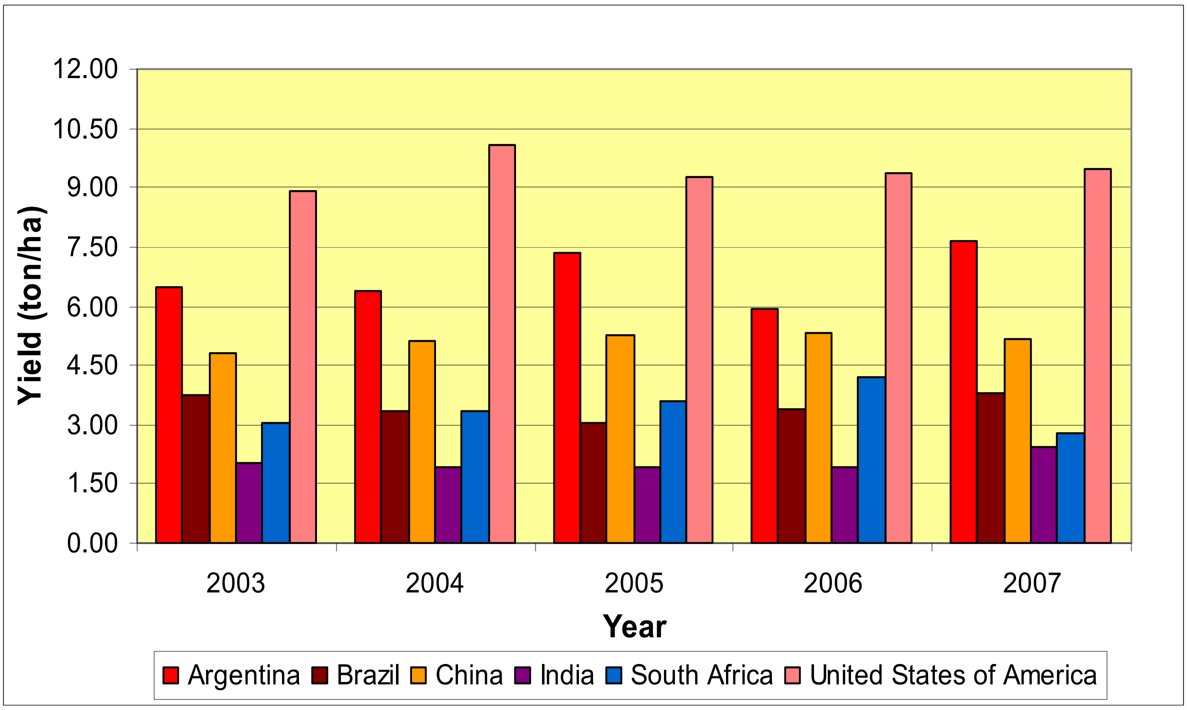

Figure 2.7: **Average maize yields in South Africa compared with other important maize-producing countries, 2003 - 2007**

Sources: BFAP (2008), FAO (2009)

2.3.3 Importance of agriculture, and the maize industry in particular, in South Africa

This section explains the importance of agriculture, and especially maize production, in South Africa and illustrates why strategies must be implemented to promote the maize industry.

- **Maize as a food source, input provider and earner of foreign exchange**

Maize is the major feed grain and staple food for the majority of the South African population and is subsequently the most important crop produced in South Africa. The South African maize industry is the largest in Africa by far (Meyer, 2003). Demand for maize during the last decade is represented by Figure 2.8, while the distribution of maize demand is illustrated by Figure 2.9. From Figure 2.8 it can be observed that the total demand for maize (including exports) ranged from approximately 8 million tons in 1999 to approximately 13.78 tons in 2008. Demand for maize is almost equally distributed between gross human consumption and animal feed (40 to 45 percent of total demand). Approximately 10 to 20 percent of maize demand can be attributed to exports, indicating that the maize industry can be regarded as a vital earner of foreign exchange. The remainder of total demand for maize is mainly for seed or on-farm consumption.

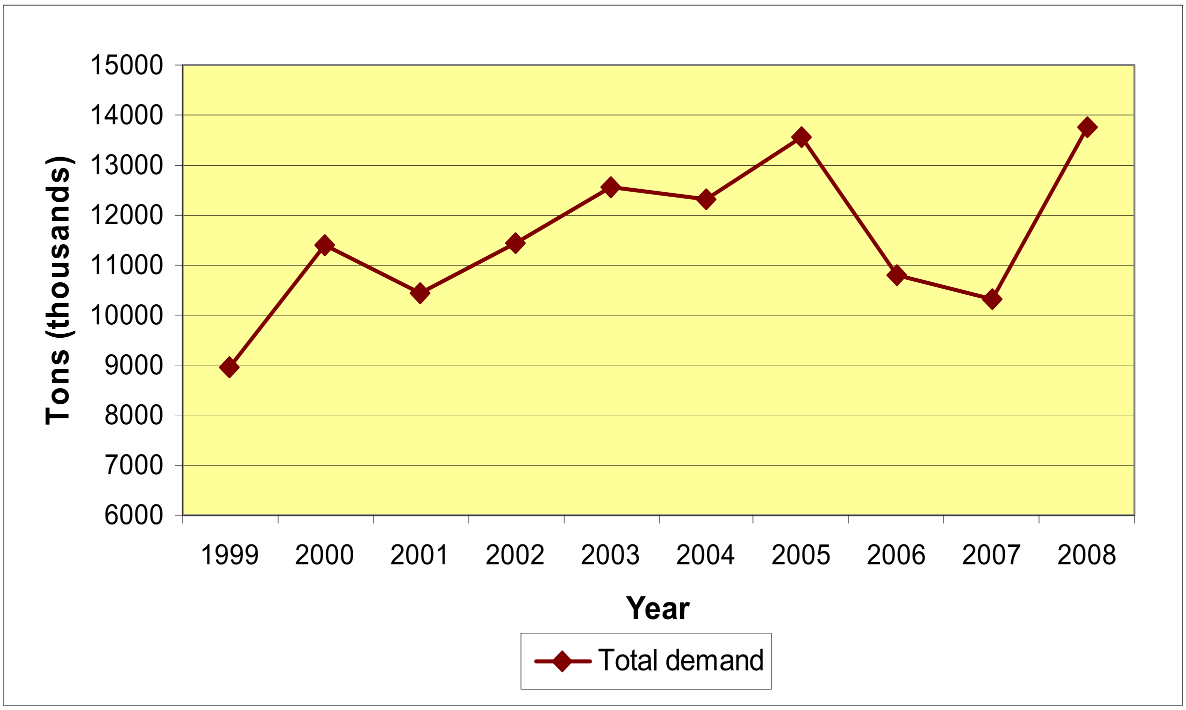

Figure 2.8: **Total demand for maize for the period 1999 - 2008**

Source: BFAP (2008)

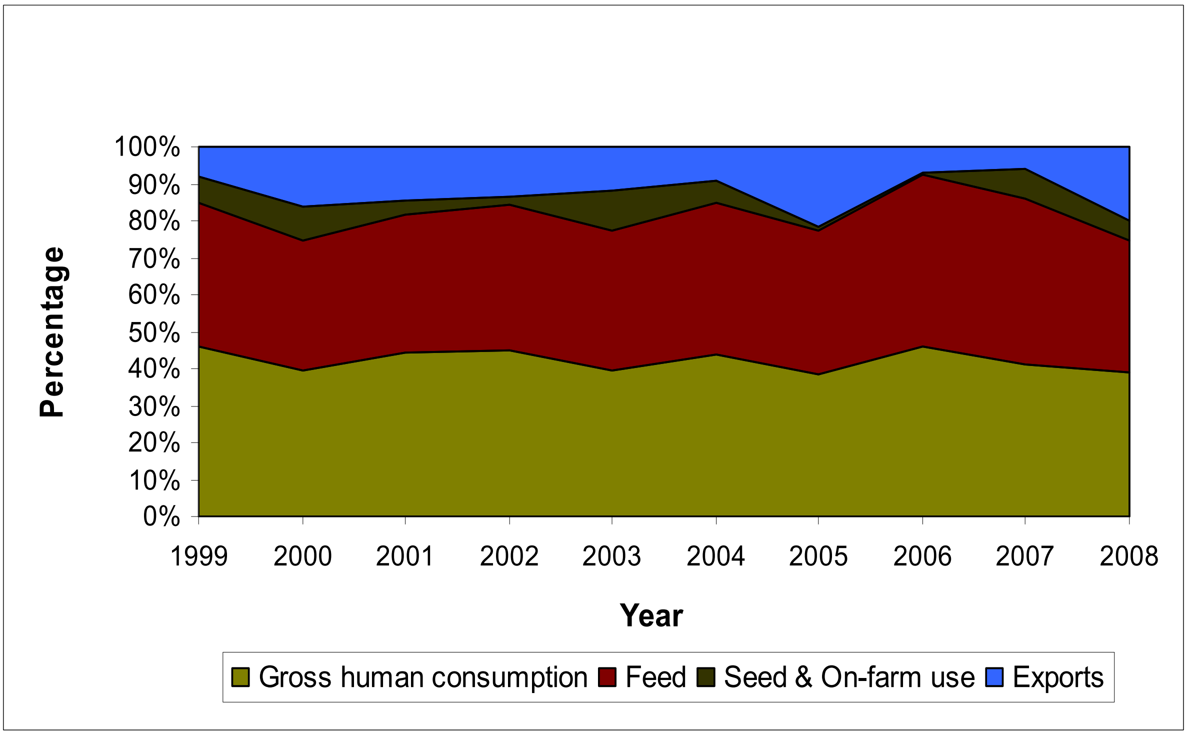

Figure 2.9: **Breakdown of demand for maize for the period 1999 - 2008**

Source: BFAP (2008)

The total gross value of agricultural production in South Africa for the 2006/2007 period is estimated at approximately R91.8 billion (NDA, 2008a). The gross value for the top ten individual agricultural products for 2006/2007 is represented by Figure 2.10. For the 2006/2007 period, maize was ranked third at R11.45 billion (16.4 percent) after poultry and beef production at R14.1 billion (20.1 percent) and R12.5 billion (17.9 percent) respectively. However, it should be noted that during 2002/2003 maize was the largest contributor (13.78 percent) to the total gross value of agricultural production with a gross value of R9.5 billion, followed closely by poultry production at R8.6 billion (12.5 percent) (Meyer, 2003). When compared with other field crops, maize production heavily outweighs the second and third largest contributors, namely sugar cane and wheat at R4.03 billion (5.8 percent) and R3.22 billion (4.6 percent) respectively. In addition, it should be noted that maize has strong linkages with the beef and poultry sectors, which are dependent on maize production for feed. Figure 2.9 also suggests that maize – in addition to being one of the agricultural products with the highest gross value – is also an important input provider for other large industries such as beef and poultry by means of animal feed. The importance of maize as input provider is also confirmed by Table 2.1, which represents the amount of maize used by members of the Animal Feed Manufacturers Association (AFMA).

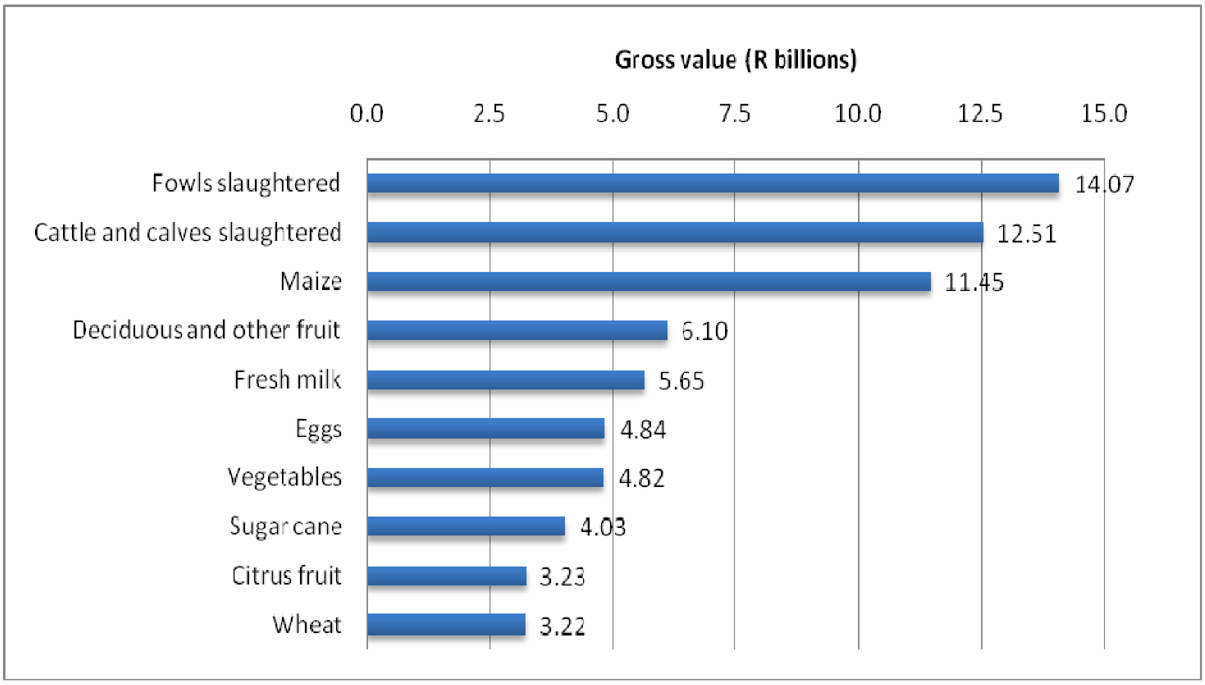

Figure 2.10: Gross value for the top ten individual agricultural products for 2006/2007

Source: NDA (2008a)

Table 2.1: Maize usage by animal feed manufacturers

	Maize usage (tons)		
	2005	**2006**	**2007**
Maize	2 200 797	2 267 008	2 464 189
Other maize products	70 260	65 894	65 268
Total	**2 271 057**	**2 332 902**	**2 529 457**

Source: AFMA (2008)

- **Value adding to the national gross domestic product (GDP)**

From the second quarter of 2000 to the second quarter of 2008, primary agriculture contributed on average R29.229 billion or 2.92 percent in real terms to the total GDP of the South African economy. It should be noted that for agriculture only, primary production figures are included, while all value added is reflected in the downward industries (Northern Cape Province, 2008). This suggests that agriculture indirectly contributes far more than what is indicated in the official figures. Figure 2.11 illustrates the contribution of primary agriculture to the national GDP over the period 1993 to 2007. Figure 2.11 shows that the contribution of agriculture to the national economy has declined substantially over the past decades. This can be ascribed to agriculture being previously a traditionally dominant sector, but the reintegration of the South African economy into the global economy resulted in a shift of economic structure from predominantly primary (agriculture and mining) to secondary (manufacturing) and a large service sector. The expansion of the services and manufacturing sectors was mainly as a result of investments by many foreign services and manufacturing companies in South Africa after economic isolation (Anon, 2008b). Nonetheless, agriculture's relatively smaller contribution to the GDP cannot be regarded as a declining industry, but rather as South Africa experiencing proper economic growth (Anon, 2007). For example, the primary agricultural sector has experienced an average growth rate of 11.8 percent since 1970 in comparison with the 14.9 percent growth rate of the economy as a whole. This subsequently resulted in a decline in agriculture's share of the national GDP from 7.1 percent in 1965 to only 3.2 percent in 2007 (NDA, 2008d).

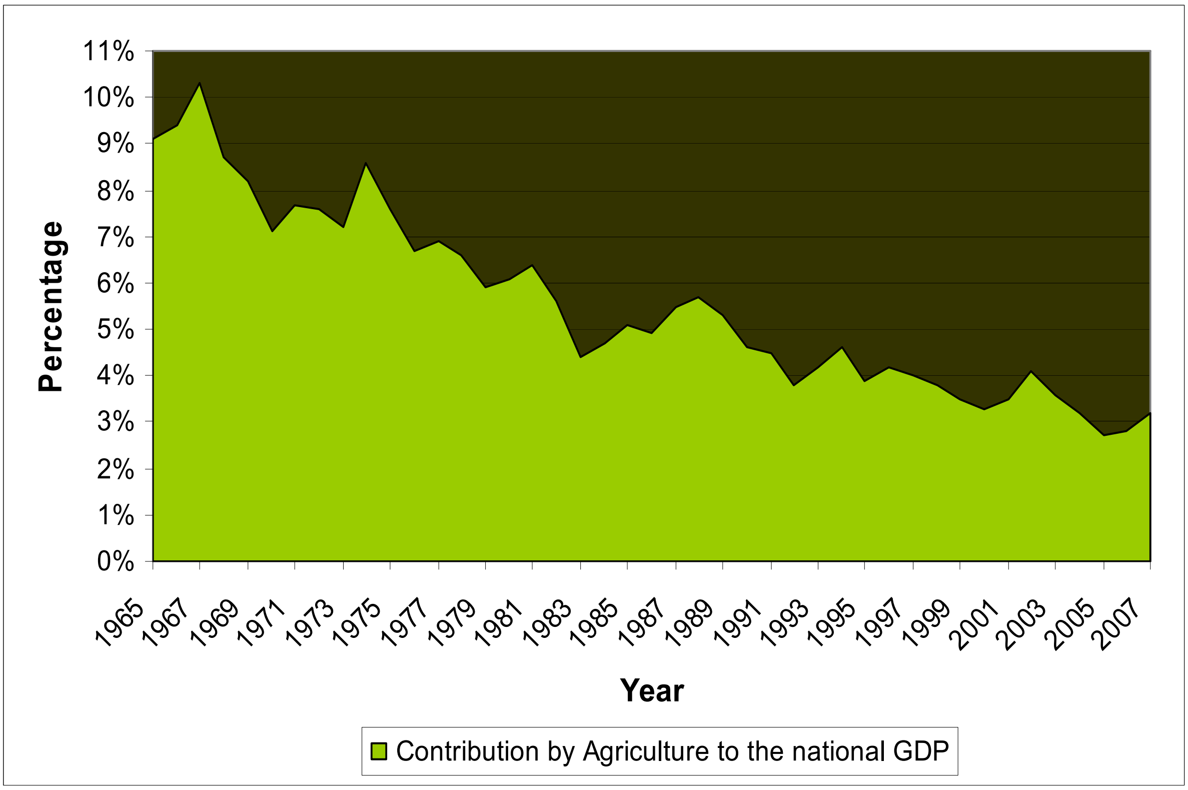

Figure 2.11: **Percentage contribution by agriculture in nominal terms to the annual gross domestic product for the period 1965 - 2007**

Source: NDA (2008a)

- **Job creation**

South African agriculture's labour force consists of approximately one million farm workers, representing approximately ten percent of total employment in South Africa. Agriculture's contribution to employment is subsequently almost three times larger than its contribution to the GDP. Agriculture provides approximately 10.5 percent of South Africa's jobs directly, while additionally it creates 16 percent of the work force in other sectors. However, over the past twenty years, agriculture's employment figure declined from 1.3 million in 1985 to 1.05 million in 2007 (NDA, 2008a). The rationale behind this decline is partly provided by Vink and Kirsten (1999) who argued that poor government policies resulted in restricted export opportunities, while the development of labour-saving technologies promoted capital-intensive farming practices. They recommended that in order to become a major creator of employment opportunities, a wider and deeper export drive supported by policies promoting the employment of a larger workforce would be necessary.

An important contribution by agriculture to the South African economy lies in its backward and forward linkages with other sectors, which create approximately 1.6 jobs for every job in agriculture. The backward linkages consist of purchases of fertilisers, chemicals and implements from the manufacturing sector. Forward linkages with the manufacturing industry include the supply of raw materials. Approximately 68 percent of agricultural output is used as intermediate products, which makes agriculture a significant player and source of growth for the rest of the economy (NDA, 2008d). The role of the maize industry should not be neglected in this regard, due to its substantial share in the South African agricultural sector.

2.3.4 <u>Current situation of maize farmers</u>

The current situation of maize farmers in South Africa is clearly illustrated in Figure 1.1, which indicates that input costs (fuel, requisites and intermediate goods) almost doubled between 2006 and 2008, and in the case of fertilizer more than doubled. Although producer prices also increased during this time, the increase in producer prices was not sufficient to prevent profit margins from declining significantly. The subsequent cost squeeze effect put some farmers in a financial predicament.

Although it can be argued that the level of input and output prices could have a significant impact on the profitability of farming businesses, the effect of other factors such as productivity levels should not be ruled out. For this reason Figure 2.12 is included as a guideline of profitability levels. The financial difficulties being experienced by South African farmers are further emphasised in Figure 2.12, which represents production costs and profitability estimates by Grain South Africa (GSA) and other agribusinesses for the period 2002 to 2011. Figure 2.12 indicates that maize farmers are expected to barely break even during the period 2009 to 2011. Figures 2.12 and 2.3 also show that South African maize farmers are subjected to extreme price volatility and therefore are exposed to a high level of risk. This combined effect of lower profitability and higher risk could have an adverse effect on the sustainability of farming businesses, especially those of maize farmers, since maize often trades at export parity prices.

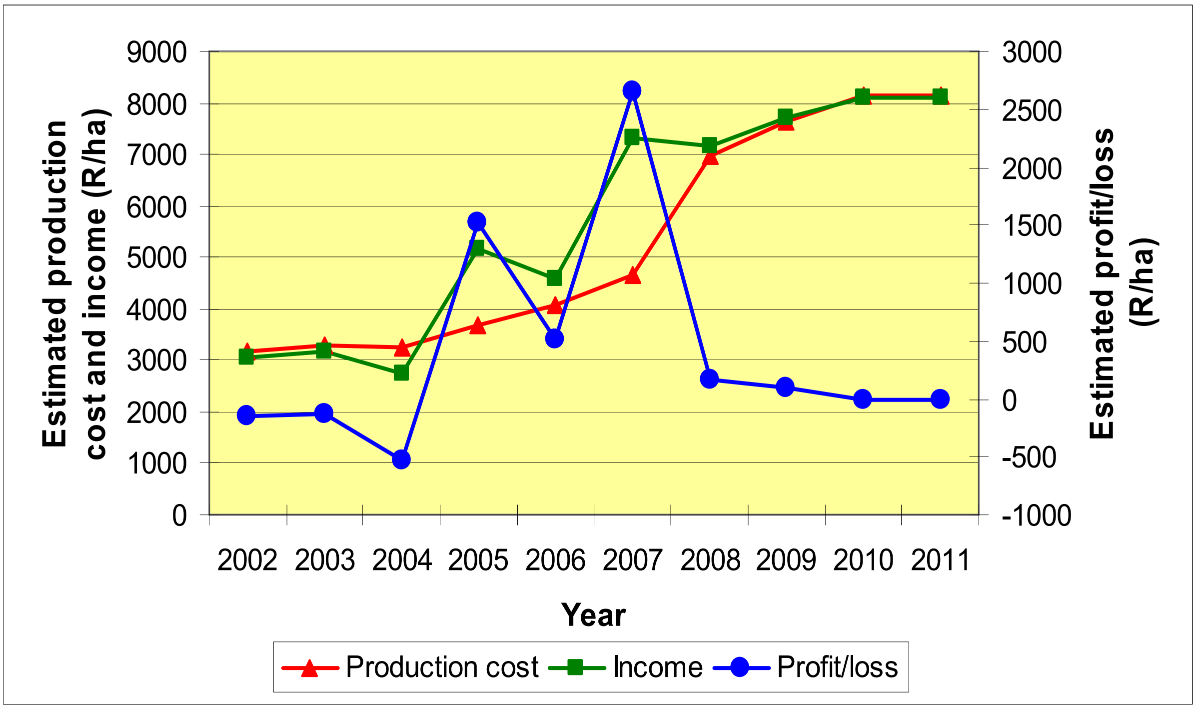

Figure 2.12: Estimated average production cost, income and profitability for maize production in South Africa at current prices[4], 2002 - 2011

Source: Van Zyl (2008)

4 Average income was calculated by multiplying average yield per hectare by the average price for maize over this period, while production cost consists of total variable cost per hectare plus total capital cost per hectare. The estimated prices and profit margins are based on production cost estimates of GSA and industry specialists. The estimations of the forecasted figures are based on inflation of inputs.

2.4 SUMMARY AND CONCLUSION

The historical background to agriculture and more specifically the maize industry in South Africa was given with a view to painting a complete picture of the conditions under which farmers operate, as well as the type of policies implemented. This chapter also provided an overview of the South African agricultural sector, and in particular the South African maize industry. The economic issues pertaining to the South African agricultural sector were described, as was its significance in the South African economy. The structure of the maize industry and its significant contribution to the gross value of agricultural production was explained. The impact of certain policies on farmers and the maize industry was also described. Some invaluable lessons can be learned from this experience for future decisions.

Based on the evidence provided, it can be concluded that the agricultural sector, and specifically the maize industry, plays an important role in the economy of South Africa and its SADC counterparts by means of food provision for humans and animals. The importance of South African agriculture and the maize industry in terms of job creation, foreign currency earnings and value adding to the GDP was also emphasised. It would therefore be of great importance to investigate how this industry can be supported and promoted. The current situation of high input prices that exacerbate the cost squeeze effect requires farmers to seek alternatives to raise their profit levels. Precision farming is potentially such an alternative that can be used to improve the financial position of maize farmers in South Africa. A country with profitable maize farmers will result in a prosperous maize industry that can compete on even grounds with international competitors, with subsequent effects on economic growth. Chapter 3 discusses the investigation into precision farming as a worthwhile possible tool for improved farm profitability.

CHAPTER 3

PRECISION FARMING

3.1 INTRODUCTION

Understanding precision farming (PF) is helpful in the sense that the underlying reasons for differences in crop yields, production efficiency, decision-making, and subsequently gross margins can be better understood. By investigating PF in more detail, one can gain insight into the various tools at the disposal of a farmer who strives to maximise his profit margins. This does not only involve the maximisation of yield, but also the level of farm management and the decision-making process, all of which can contribute to improved profitability.

In addition, since the aim of the study was to analyse the impact of PF on the profitability of a maize irrigation farm, a comprehensive and clear description of this concept should be provided. Topics on PF that are described in this section include background information on PF, technologies used in PF, the general PF cycle, profitability issues pertaining to PF, factors that are influenced by PF, the benefits of PF, and lastly a description of the PF system being implemented by Griekwaland-Wes Koöperasie (GWK) in the Northern Cape Province. This chapter concludes with a summary and some concluding remarks.

3.2 BACKGROUND TO PRECISION FARMING

Precision farming has it origins in Europe as a result of the technological evolution of agricultural machinery. The advancement in agricultural technology, together with increased demand for more efficient and thus competitive agricultural products, resulted in larger equipment being manufactured and sold (Rüsch, 2001). During these developments, an increase also occurred in the average size of fields due to the consolidation of the world's farms. Subsequently various fields with different soil potentials were added together. Research was done in the early 1980s in order to determine the differences in yield on a specific field. The difference in yields recorded during the trial was approximately 20 percent. The geo-referenced locating system used during the trial was based on the triangulation of beacons that were erected around the trial fields (Moore in Rüsch, 2001). The geo-referenced system formed the basis of the PF system as it is known today (Rüsch, 2001).

The term *precision farming* is a broad concept that is also variously referred to as *site-specific management (SSM) farming,* v*ariable rate application (VRA) farming, prescription farming,* and *precision agriculture* (Batte, 1999; Lowenberg-DeBoer & Boehlje, 1996; Maine, 2006).

In Batte (1999), the National Research Council Committee on Assessing Crop Yield: Site-Specific Farming, Information Systems, and Research defines SSM as *"a management strategy that uses information technologies to bring data from multiple sources to bear on decisions associated with crop production"*. According to Batte (1999), SSM should not be regarded as a single technology, but rather as a set of various technologies that captures data at the best time and scale, interprets and analyses the collected data for management decisions, and implements these management decisions at the best time and scale. Lowenberg-DeBoer and Swinton (1997) define SSM as the *"electronic monitoring and control applied to data collection, information processing and decision support for the temporal and spatial allocation of inputs for crop production"*.

VRA can be described as the precision application of inputs, meaning that inputs are varyingly applied according to the pre-determined yield potential of the soil (Maine, 2006).

Precision farming is defined as a crop management tool for a crop field where different levels of inputs are required (Godwin, Earl, Taylor, Wood *et al.* 2002). Lowenburg-DeBoer and Boehlje (1996) defined PF as a monitored and controlled approach to agriculture that includes the monitoring of crops and employees, the timing of operations and the site-specific application of inputs. Maine (2006) described PF as a method whereby a producer can manage variation within his field more proactively by observing site-specific differences in yield, soil texture, soil nutrients, pH, moisture and topography and treating these differences accordingly.

According to Batte (1999), PF is based on the application of inputs to a specific cropland with its specific soil type, fertility levels and other endowments of that site. Rüsch (2001) defined PF as *"…a process whereby a large field is divided into a finite number of sub-fields, allowing variation of inputs in accordance with the data gathered"*.

According to a communication by Mr. A. Bekker of GWK, an agribusiness that provides agricultural services to producers in the Northern Cape Province, PF is referred to as *high-technology farming* (HTF). With HTF it is implied that high-technology tools are used in conjunction with PF methods in farming systems with the objective of improving the productive value of the soil (Bekker, 2008).

The most comprehensive description of PF was provided by Blackmore (2003), who defined PF as a term used to explain the objective of increasing efficiency in agricultural management and also described it as a developing technology that combines existing and new methods to expand the set of management tools for the farmer. Since computing and electronics also form an integral part of the system, a more sophisticated system approach should be followed. Blackmore (2003) argued that PF stretches much further than simply enabling farmers to apply variable treatments at farm level. It must in fact also be regarded as the precise monitoring and assessment of the farming business at farm level, and a complete understanding of the processes involved is necessary to apply inputs in such a way that enables the farmer to achieve a specific goal. This goal might not only be to achieve maximum yield, but also to maximise financial advantage for the farmer in a constrained environment.

From the definitions provided in this section, the conclusion can be drawn that it does not matter whether this agricultural practice is termed *precision farming*, *site-specific farming*, *variable-rate application farming*, *prescription farming* or *precision agriculture*. Although the methods and technologies used might differ slightly, the same principle applies to all, namely the implementation of new technologies in order to improve decision-making, efficiency and effectiveness on the farm for financial advantage. However, for simplicity, the term *precision farming* (PF) will be used and its definition as provided by Blackmore (2003) and Bekker (2008) is accepted as most appropriate for purposes of the study. The following section provides an overview of the various technologies used in PF.

3.2.1 Technologies in PF

According to Batte (1999), four technologies are mainly used in PF, namely remote sensing, the global positioning system (GPS), the geographic information system (GIS), and process control or VRA technologies. Maine (2006) included grid soil sampling, yield monitors and maps, proximate censors, auto-guidance technologies and computer hardware and software in her list of PF technologies in addition to those mentioned by Batte (1999).

Remote sensing data is used to distinguish crop species and locate stress conditions and includes yield monitors, moisture monitors and soil nutrient monitors (Batte, 1999). Digital images of the developing crop during the season are collected by remote sensing technologies such as satellites, aircraft or farm vehicle-mounted sensors. The images presented by remote sensing are directly related to the growth stage of the crop at the time of recording and this is referred to as the green area index (GAI) (Anon, 2008a). Remote sensing is also used to determine the normalised difference vegetation index (NDVI), which represents the chlorophyll content and water absorption of the crop. Proximate sensors are devices mounted on farm vehicles such as tractors and are used to collect data on soil and crop properties while moving across the field (Maine, 2006).

The GPS is a navigation system and consists of a network of satellites orbiting the earth, which helps the user to locate his position on earth in terms of longitude, latitude and elevation. The GPS allows the user to identify field locations so that a certain number of inputs can be applied to specific identified field areas (Batte, 1999). The accuracy of the GPS is based on a 95% probability that the given position will be within 20 m horizontally from the true position (Shropshire in Blackmore, 2003). However, differential GPS (DGPS) is more commonly used, as it achieves greater accuracy, thereby enabling the farmer to return to the specific point repeatedly (Maine, 2006).

GIS technology assists the user in storing input and output data on digital maps, which can be used for future input allocation decisions. VRA technologies allow the user to draw information from the GIS system in order to control farming processes such as fertilizer application, seeding rates, herbicide selection, and application rates in a variable way.

Grid sampling is used to determine whether a variable-rate application is required, while soil sampling assists the farmer in determining the required input rates and location thereof (Franzen, 1999). Grid sampling is done by dividing the field under consideration into blocks that range from 0.5 to 5 hectares and taking soil samples in those grids. Several samples are taken from these grids and sent to laboratories to analyse the variability in nutrients and pH. This information is then captured by GPS, which associates it with a certain latitude and longitude. GIS software is used to construct maps of the nutrients and pH and the information is loaded on a computer card that is read by the input applicator with variable-rate technology (Maine, 2006; Rains & Thomas, 2001).

Yield monitors are used to generate geo-positioned databases and site-specific yield maps through GPS technology on farming vehicles such as combine harvesters. These vehicles are usually equipped with a vehicle positioning system integrated with a yield recording system. Data collected from the yield monitor on the farm vehicle is then used to construct yield maps, which will be discussed later in the section on the PF cycle.

Auto-guidance systems are entirely dependent on GPS technology and consist of a base station on or near the farm, a rover unit for each farm vehicle and a computer with the necessary software. The operation of this system is based on satellite signals that are sent to the system every few seconds, and any accuracy errors are corrected by signals from the base station. Auto-guidance systems help to eliminate overlapping and skipping of rows in the field as a result of human error, and thus improve efficient applications of pesticides and fertilisers. However, auto-guidance systems require greater capital, maintenance and repair expenditure (Lewis, 2003).

Computer hardware and software are necessary for analysing data captured during the data collection process and will be discussed in more detail in the following section on the PF cycle.

3.2.2 The precision farming cycle

The general PF system can be broken down into four basic processes, namely data collection, data analysis, decision-making and the implementation of decisions (Anon, 2008a). Figure 3.1 illustrates the PF cycle along with its different components. The processes involved are discussed in the sections that follow.

- **Data collection**

The first step in the data collection process is to determine the causes and degree of variability in the fields. Variability is determined by using yield maps in conjunction with soil maps on combine harvesters, as well as soil sampling and historic records of the soil (Figure 3.1). Yield maps are used to create historical databases that are in turn used for future crop management decisions. Yield maps are useful in the sense that they can be used to isolate agronomic problems in a specific field and also show the impact of certain treatments. For example, increasing evidence suggests that the physical properties of soil (which influence the availability of water) have a substantial impact on yield. In the case of soil compaction, yield maps have the ability to point out this problem (based on historical data) and enable the farmer to correct it (future management decisions) to prevent water-logging, with subsequent yield benefits (Anon, 2008a).

Once the variability within the fields has been identified, local knowledge is used to find possible reasons for this variability. These reasons can include factors such as pests and diseases, water-logging and the presence of old ponds and shaded areas. The second step is to examine the physical properties of the soil. Possible reasons for variability in this regard might be the compacting of soil, poor drainage, different soil types, and shallow soil. Lastly the chemical properties of the soil are evaluated. Chemical factors that might have an effect on the variability of soil include the pH of the soil, the amount of soil nutrients and the presence of some chemical elements.

Previous years' yield maps are then compared after which the application of seed, fertiliser and chemicals takes place according to the yield potential of that specific area. It is, however, important to determine first whether the corrective actions are economically viable before implementation (Anon, 2008a).

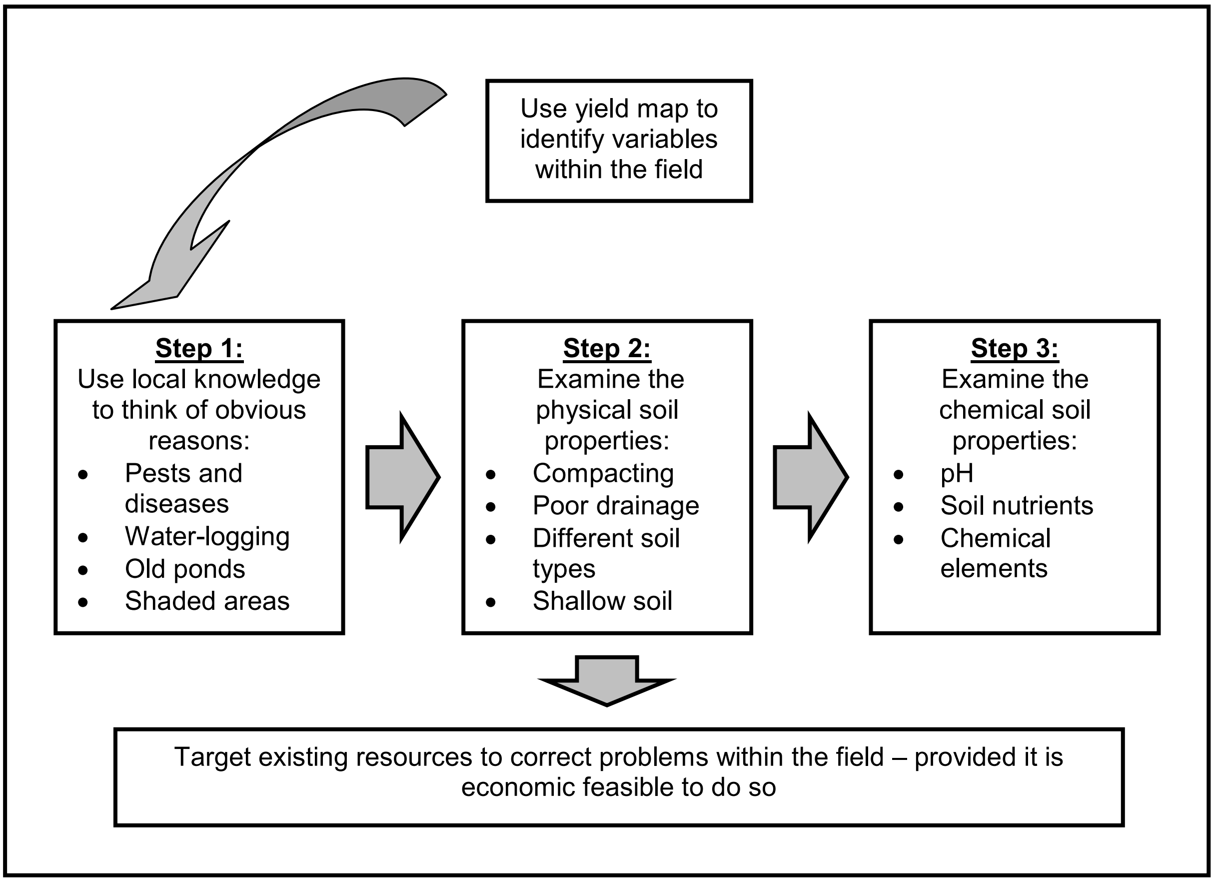

Figure 3.1: The precision farming cycle

Source: Anon (2008a)

Markers are generally used to indicate the position of a specific object or feature in a field such as the presence of pests and diseases, areas where soil samples were taken (including the specific soil properties of that sample) and obstructions (Anon, 2008a).

Another data collection tool that is generally used in PF is remote sensing, which has already been discussed in the section on PF technologies. The GAI generated by remote sensing indicates the exact nutrient needs of the crop under investigation, thereby enabling the farmer to apply nutrients according to the crop's specific needs.

One point of GAI is the equivalent of 30 kg of soil mineral nitrogen (Anon, 2008a). Remote sensing has the additional advantage that the condition of crops can be monitored in "real time", thereby allowing the farmer to make mid-season decisions to improve crop performance (Welsh *et al.* in Maine, 2006).

The importance of on-farm trials in the data collection process should not be neglected. A farmer should conduct field trials on his farm and records the results. For this purpose yield maps can be used. The farmer can experiment with different varieties, pesticide treatments, and fertiliser applications on a small scale with the objective to adopt the most efficient inputs and application measures across the entire farm (Anon, 2008c). However, it should be noted that farmers are generally reluctant to sacrifice some of their productive land for experimental purposes, thereby inhibiting on-farm research and the development of these technologies (Haarhoff, 2008b).

It should be noted that most PF systems, such as the AGCO Corporation's Fieldstar® system, automatically log all the information collected and thereby provide traceability of the process. This enables the farmer to observe all the stages involved in the production of the crop, the types of treatments given and the dates, providing an invaluable information system for the farmer (Anon, 2008a).

- **Data analysis**

During the data analysis process the information obtained from yield and soil maps is combined and used in conjunction with the farmer's knowledge of the specific field. This "basket" of combined information is then used to determine the potential of the field under consideration and also to assess its performance (Anon, 2008a).

Data collected during the data collection process is transferred with a data card from the implement to the farmer's personal computer (PC). Companies that specialise in PF technologies such as Fieldstar® usually provide software that assists farmers in analysing data and determining possible reasons of yield loss. This allows the farmer to identify "management zones", in other words, areas that perform similarly and that can subsequently be categorised as high-yielding, medium-yielding or low-yielding zones (Anon, 2008a).

The data analysis process consists of different components, namely marker overlay maps, yield index maps, yield distribution charts and gross margin maps. A marker overlay map is information being recorded by markers (as described in the section about data collection) and overlaid on field maps. The software uses the markers (such as areas infested by weed) to display information in various colours on the field map. The marker overlay maps are useful since they explain yield variances within a specific field. Yield index maps are used to determine where yield variances in a specific field occur, and this information is displayed on a map similar to marker overlay maps. However, it should be noted that marker overlay maps indicate problem areas, while yield index maps indicate variance in yields. Yield distribution charts are graphics and charts generated by PF software to indicate the distribution of yield within a field. These charts also show the percentage of a field that represents a certain yield and thus enable farmers to determine the extent of the variance.

At the end of the season, a gross margin map is constructed to provide a summary of the financial performance for a specific field. In constructing gross margin maps, the yield maps are considered as farm income from the field, while the fixed and variable costs represent the expenditure being applied uniformly (Anon, 2008a). The gross margin is then calculated by subtracting the expenditure from the farm income and presented it on a map similar to the marker overlay and yield index maps (Blackmore, 2003). By using gross margin maps, the farmer can determine the exact return on his investment and subsequently use it for future decisions and investments. Gross margin maps also have the advantage of clearly indicating areas in the field that are not economically viable and that should be taken out of production, set aside or converted into conservation areas (Anon, 2008a).

- **Decision-making**

Once management zones have been identified in the data analysis process, PF software is used to construct a treatment plan that takes the specific crop, growing conditions, soil type, previous years' yields and yield potential of the soil into account. Different plans can be constructed, depending on the season and specific needs of the farmer. These include harvest plans, fertiliser plans, seeding plans, cultivation plans, spraying plans, scouting jobs and position logging. Decisions on the application of seed, fertiliser and chemicals are based on these evaluations in order to match the yield potential of the areas under consideration. This method of applying inputs at a variable rate is also commonly referred to as VRA, already described earlier in this chapter on the background to PF.

- **Implementing decisions**

Once decisions on the input applications have been made, the variable rate treatment plan is created by the farmer on his PC and transferred to the farm vehicle or implement equipped with variable-rate technology. The farm vehicle or implement is connected to GPS and enables the farmer to apply the inputs according to the pre-constructed treatment plan. This information is used to correct problems initially identified during the data analysis process, and can be used on various implements that use automatic rate controllers. The automatic rate controllers have the ability to apply inputs at a variable rate according to the treatment plans. For example, a yield map obtained during the data collection process might indicate that soil compaction might have an adverse effect on the yield. The yield map will also enable the farmer to locate the specific problem area and subsequently implement sub-soiling cultivation in order to rectify the problem. Other examples of VRA uses include nitrogen (N), phosphate (P) and potash (K) application, as well as “patch spraying” of pesticides (applying pesticides to specific problem areas). The VRA feature forms the cornerstone of modern PF since it is the most important factor that determines the efficiency of production (Anon, 2008a).

3.3 PROFITABILITY OF PRECISION FARMING

Lowenberg-DeBoer and Swinton (1997) and Maine (2006) argued that the impact of PF on profitability is the most important factor that determines whether this technology will be adopted successfully. PF might be an attractive farm management system, but it is not always profitable (Lambert & Lowenberg-DeBoer, 2000). In addition, Lowenber-DeBoer (1999) argued that most people are not concerned with upside variation (for example higher yields, output prices and profits), as they are concerned with the downside. Risk is therefore also an important variable in the equation and subsequently a section is devoted to risk in Chapter 4. The literature subsequently suggests that it is important to analyse the economic properties of the PF system before implementing it.

Lambert and Lowenburg-DeBoer (2000) conducted a study on the economic viability of PF in the United States of America (USA) based on 108 cases. The economic study indicated that 63 percent of these cases generated profits and positive returns after adopting PF, while 26 percent and 11 percent yielded uncertain and negative results respectively. The study subsequently confirmed the economic viability of PF in certain parts of the USA. It should be noted that studies using response functions or simulation to estimate yield obtained slightly higher percentages of positive results than studies using field trials. Positive results were reported for 67 percent of field trial studies, while 60 percent of response functions and 75 percent of crop growth simulation studies obtained positive results. In terms of crops, positive profits were obtained for maize, soybean and sugar beet studies in over two thirds of cases.

Griffen, Lowenberg-DeBoer, Lambert, Peone *et al.* (2004) updated the PF review of Lambert and Lowenberg-DeBoer (2000). Approximately 234 studies were reviewed with 210 studies reporting losses or benefits. Of the 210 reported studies, 68 percent reported benefits from PF technology. Thirty-seven percent of the reviewed studies were experiments with maize alone, with benefits reported from about 73 percent of those PF experiments. Wheat was the second most reported crop, which occurred in about 11 percent of the studies, half of which reported benefits. Nine percent of the reviewed studies consisted of maize and soybeans, and benefits were reported in 75 percent of the cases. In the soybean, barley and oats studies, all reported benefits associated with PF, while no benefits were reported for maize and cotton combination studies (Griffen *et al.*, 2004).

In another study, Silva *et al.* (2007) performed a comparative analysis of the costs and economic profitability and viability indicators between conventional farming (CF) and PF practices regarding maize and soybean crops in the state of Mato Grosso do Sul, Brazil. The precision system in this context refers to a system where precision agriculture methods were used, namely yield and soil mapping, while the conventional system refers to the direct plantation system mainly in use in Mato Grosso do Sul. The objective of the study was to determine whether it would be economically viable to implement PF with maize and soybean crops. The production costs involved in the precision and conventional systems were estimated, while determining the profitability and viability for both farming systems under risk conditions. The profitability indicators used in the study were gross revenue (GR[5]), gross margin in relation to the effective operational cost (GMEOC[6]), gross margin in relation to the total operational cost (GMTOC[7]), break-even point[8] for both effective operational cost (EOC) and total operational cost (TOC), operational profit (OP[9]), and the profitability index (PI[10]).

Table 3.1 provides a summary of the profitability indicators of the two production systems under consideration. From Table 3.1 it is evident that the precision system's performance was superior to that of the conventional system in terms of gross revenue, gross margin, break-even point, operational profit and profitability index. From Table 3.2 it is obvious that both systems are financially viable and attractive from an investment perspective. However, PF showed higher financial viability and investment attractiveness than the conventional system, since its net present value (NPV) and internal rate of return (IRR) is higher. Table 3.3 summarises the results of financial viability and investment attractiveness in a risky environment. Although the precision system is the riskier alternative due to a higher standard deviation, it has greater investment attractiveness since its mean value was higher than the conventional system.

The results indicate that PF could be used as a strategic tool in reducing cost and increasing productivity, thus leading to increased profitability. Profitability is especially important for the farmer whose main objective as an entrepreneur is to maximise profit. The use of PF technology could assist the farmer in his pursuit of profitability, and awareness of this development could increase productivity and also minimise environmental impact once implemented. Silva *et al.* (2007) concluded that economic, viability and investment risk results under PF outperformed those results

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5 GR is calculated as the product of the quantity produced and the unit price of the product.
6 GMEOC is the GR less the EOC in relation to the EOC, expressed in percentage.
7 GMETOC is calculated in the same way as GMEOC, except that TOC is used instead of EOC.
8 The break-even points show the minimum quantity that should be produced in order to obtain a profit of zero.
9 OP is the difference between the GR and the TOC per hectare.
10 PI constitutes the relationship between OP and GR, expressed as a percentage.

under CF. Silva *et al.* (2007) emphasised that although total operational costs are lower under the conventional system, the additional benefits of PF, which include higher production and decreasing costs per unit, should lead to greater rewards on a long-term basis compared to CF.

Table 3.1: Summary of profitability indicators for PF and CF systems

Item	Unit	Precision system	Conventional system
Gross revenue[11]	US$/ha	61 931.88	51 827.16
Gross margin (GMEOC)	%	72.42	54.01
Gross margin (GMTOC)	%	50.23	37.76
Break-even point (EOC)	Kg	5 058.60	4 739.40
Break-even point (TOC)	Kg	5 805.60	5 298.60
Operational profit	US$	61 244.83	51 200.13
Profitability index	%	33.43	27.41

Source: Silva *et al.* (2007)

Table 3.2: Net present value (NPV) and internal rate of return (IRR) for PF and CF systems

System	Viability indicators	
	NPV (million US$)	IRR (%)
Precision	16.82	11.35
Conventional	13.45	10.69

Source: Silva *et al.* (2007)

Table 3.3: Net present value simulation results for a risky environment

System	NPV (million US$)			
	Minimum value	Average value	Maximum value	Standard deviation
Precision	-14.86	16.82	52.45	10.46
Conventional	-15.46	13.43	47.23	9.80

Source: Silva *et al.* (2007)

11 A mean yield of 8722.80 kg/ha was considered for the precision system and 7299.60 kg/ha for the conventional system with the mean price of US$ 7.10/kg.

A number of other studies comparing the PF and CF systems have been conducted. In their study, Lu, Sadler and Camp (2005) evaluated the economic feasibility of VRA of irrigation water in maize production in South Carolina, USA. According to Lu *et al.* (2005), producers traditionally treated the entire field as if it were a homogeneous unit despite variations in soil types, fertility and yield potentials. Average rates of inputs were subsequently applied over the entire field, resulting in over-application in some areas and under-application in other areas. This practice led to lower profits and chemical and nutrient losses to surface and ground water. In contrast, the PF enabled producers to apply exact amounts of fertilizers, pesticides, water, seeds and other production inputs to specific areas according to the needs of plants to grow optimally.

In order to implement a VRA system, different equipment and control systems need to be purchased and producers will subsequently have to make additional capital investments for this technology. In order to justify this additional capital investment, it is crucial for producers to know whether or not the system is profitable. Lu *et al.* (2005) used net returns[12] to measure profitability. Variable costs consisted of seed, fertilizers, lime, herbicides, insecticides, irrigation, drying and hauling, operation of tractors and machinery, labour, and interest on operating capital. Economic returns and irrigation efficiency of VRA and uniform applications were compared. The results indicated that the VRA applications performed better in terms of net returns than the uniform applications in both yield-maximising and profit-maximising strategies. However, Lu *et al.* (2005) also noted that changes in relative prices of maize and irrigation water could have a substantial effect on the benefits of VRA. It is important to note that in order to implement a VRA system, the benefits acquired by the new technology should outweigh the additional costs involved. This was, however, not the case in this study, since the VRA system was developed for research purposes. Higher costs were subsequently incurred to build more sophisticated equipment than what would have been needed for commercial production. Lu *et al.* (2005) concluded that the VRA system in their study was not profitable for corn in the Southeast USA and that VRA application of irrigation water would not be profitable compared to uniform applications. Despite their findings, Lu *et al.* (2005) also argued that VRA

[12] Net returns equal total returns minus total variable costs.

costs are dropping as equipment and control systems are further refined through research.

Batte (1999) explored the farm-level economics and environmental impact of site-specific management[13] (SSM) while identifying the factors that influence the profitability of a farm that has adopted SSM. Batte (1999) argued that revenues and costs of a profit-maximising farmer will definitively be altered by SSM. According to Batte (1999), the value of the crop is the single source of income for the farmer, and total gross receipts are equal to the product of yield, price and area harvested. The impact on each of these factors is determined by the specific farm situation and how the farmer manages the technology. Batte (1999) stated that it is obvious that SSM will have a substantial impact on yield, despite the fact that the direction of the impact cannot be determined. Average yields could be increasing, decreasing or constant, depending on the regulation of several inputs. It is argued that SSM will allow identification of both over- and under-application of inputs, thus enabling the farmer to rectify any input application imbalances. It is common knowledge that price received will have an impact on gross receipts. Although crop quality is not likely to change in such a way to impact price, SSM has the potential to highlight the specific characteristics of crops like organic or high-lysine crops and therefore subject these crops to premium prices. Total receipts can also be influenced by the area harvested, and Batte (1999) suggested that the area harvested is likely to remain constant or even decrease upon implementation of SSM. The change in direction of total gross receipts cannot be determined due to the unknown directional changes of yields, prices and area harvested, which are impacted by site-specific factors.

Costs incurred by the farmer that can be influenced by SSM include variable costs such as data acquisition costs, fertilizers, pesticides, herbicides and seed varieties. Fixed costs, unlike variable costs that depend on the level of production, include depreciation, interest on investment and insurance costs (Batte, 1999).

The change in profit, which is the difference between total receipts and total costs, is dependent on the relative magnitude of changes in the costs and receipts. It should

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13 Note that site-specific management refers to precision farming for purposes of the study.

be noted that the relative magnitude of changes in the cost structures differs from farm to farm and also depends on the farm size. Farm size thus plays an important role in the average cost relationship and is illustrated in Figure 3.2. From Figure 3.2 it can be seen that average variable cost and average fixed cost diminish as farm size increases. The average total cost curve, which represents average variable cost and average fixed cost, naturally follows the same trend and its shape is primarily determined by the shape of the average fixed cost curve. This is known as economies of scale and will subsequently be more profitable for larger farms than smaller ones (Batte, 1999). Lastly, Batte (1999) argued that environmental impacts are likely to occur, but because the relative changes in magnitude of fertilizer and other chemical inputs are difficult to determine, it is not possible to determine to what extent environmental pollution can be prevented by SSM.

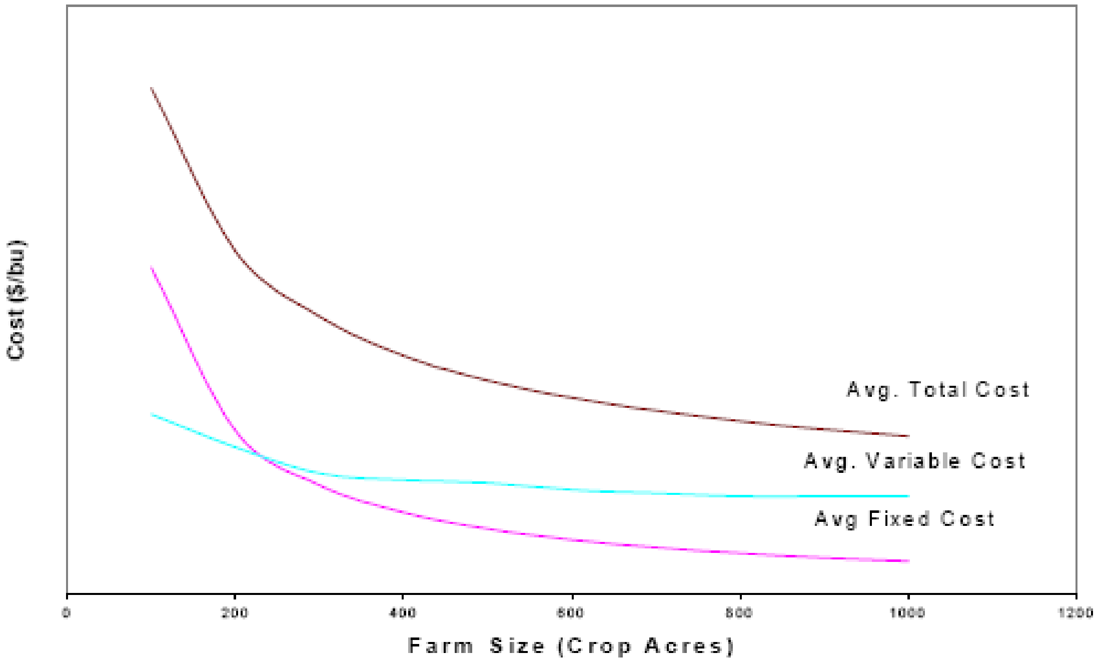

Figure 3.2: Expected average cost relationships for SSM technologies
Source: Batte (1999)

3.4 PRECISION FARMING IRRIGATION SYSTEM IN THE NORTHERN CAPE PROVINCE

The Northern Cape Province is located in the western part of South Africa and borders in the north-west with Namibia (Anon, 2009). Figure 3.3 shows a map of the

Northern Cape Province, while a detailed map of the districts under consideration is provided by Figure 3.4. For the study, special emphasis is placed on the Douglas, Barkley-Wes and Luckhoff districts in Figure 3.4. Since the greater part of the Northern Cape Province is arid to semi-arid, maize is mainly produced under irrigation. The Orange, Vaal, Modder, Riet and Harts River systems are the major irrigation sources in the Northern Cape (Haarhoff, 2008a).

Figure 3.3: **Map of the Northern Cape Province**

<u>Source:</u> Anon (2009)

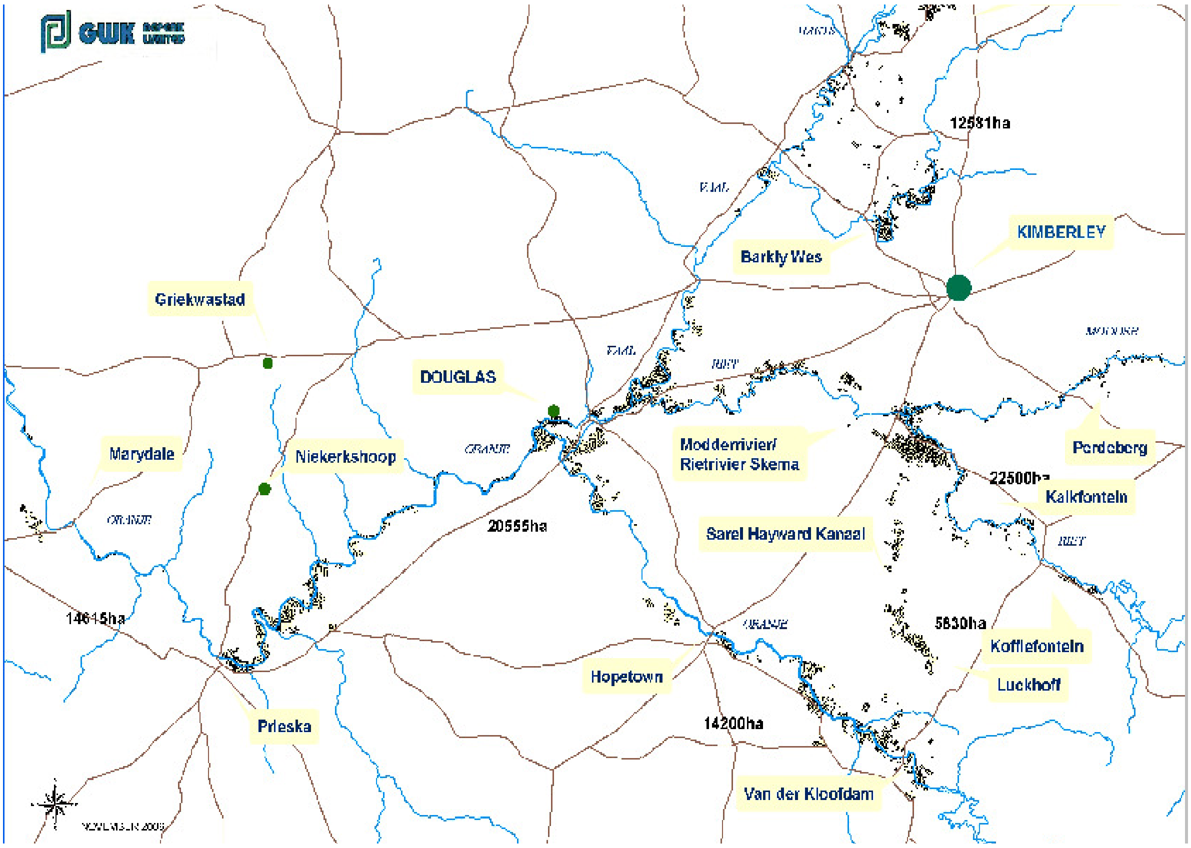

Figure 3.4: **Detailed map of the Northern Cape Province with emphasis on the Douglas, Barkley-Wes and Luckhoff districts**

Source: Haarhoff (2008a)

Table 3.4 represents production, area harvested, and yields of white and yellow maize in the Northern Cape Province for the past five years. As mentioned in Chapter 2, the Northern Cape contributes approximately four percent of South Africa's total maize production. It should be noted that yields in the Northern Cape are far above the national yield average for maize, due to the fact that maize production in the Northern Cape takes place under irrigation. Since irrigation farmers have more control over important cultivation practices such as water application and soil management, the Northern Cape proved to be the ideal setting to determine the impact of PF on a maize irrigation farm.

Table 3.4: Production, area harvested and yields of white and yellow maize in the Northern Cape Province for the past five years

	White maize			Yellow maize		
Year	**Production**	**Area harvested**	**Yield**	**Production**	**Area harvested**	**Yield**
2004	62 400	6 200	10.1	448 500	42 500	10.6
2005	30 500	3 000	10.2	526 400	47 000	11.2
2006	165 000	15 000	11.0	278 000	25 000	11.1
2007	42 700	3 770	11.3	498 000	45 000	11.1
2008	36 000	3 000	12.0	626 000	52 000	12.0

Source: SAGIS (2008)

The purpose of this section is to explain the PF system being implemented in the Northern Cape Province in order to understand the methods used and benefits acquired. This knowledge provides insight into how to correctly analyse the impact of PF on the profitability of each participating farm discussed in Chapter 5.

In order to investigate the possible impact of PF on farm profitability, farmers started to enrol a section of their acreage in PF programmes being offered by several fertilizer companies. This enabled farmers to learn about PF at low cost and without large capital purchases of PF equipment (Lowenberg-DeBoer, 1999). With the same objectives in mind, this low-cost approach for farmers is being followed by GWK in the Northern Cape Province of South Africa.

Like most traditional co-operatives, GWK was converted into a company after the deregulation of South African agriculture. GWK's shareholders are mostly farmers who had been members of GWK before it was converted into a company. GWK aims to create sustainable welfare for its shareholders and for this reason a research and development division was established to develop a high-technology farming (HTF) service (GWK, 2009).

Fifty-nine farmers in the Northern Cape Province and certain parts of the Free State Province are incorporated in this HTF system, which was established in 2005. The main objective of this project is to improve the farmer's ability to realise a higher yield and better quality harvest by providing tools that will improve management on the farm (Anon, 2008c; Bekker, 2008; Haarhoff, 2008b).

Presently, GWK provides the HTF service to irrigation producers in the Northern Cape region and certain parts of the Free State Province in South Africa. The HTF package consists of three phases. The first phase consists of an evaluation of the soil chemistry and subsequent chemistry maps of a producer's farm, followed by a physical evaluation of the soil. The second phase of the HTF package includes irrigation scheduling, NDVI images, temperature monitoring, and nitrogen tests. During the third phase, farm-level yield maps and gross margin maps are created, comparisons amongst the different economics of the farm are drawn, and all the information is subsequently stored on the GIS system of GWK for referral.

The soil physics are evaluated by using penetrometers on soils with less than 15 percent clay. A penetrometer measures the degree of soil compaction on farm-level. An example of a penetrometer is provided in Figure 3.5. The soil physics are evaluated in order to prevent compaction of the soil, which inhibits crop growth and development, and to determine the type of cultivation to be done the following season. In cases where the clay percentage of a specific area is too high, profile holes are used to evaluate the soil physics. Figure 3.6 represents soil compaction curves measured by a penetrometer before and after the compaction problem has been addressed.

Figure 3.5: Penetrometer used for measuring the degree of soil compaction on a farm

Source: Haarhoff (2008a)

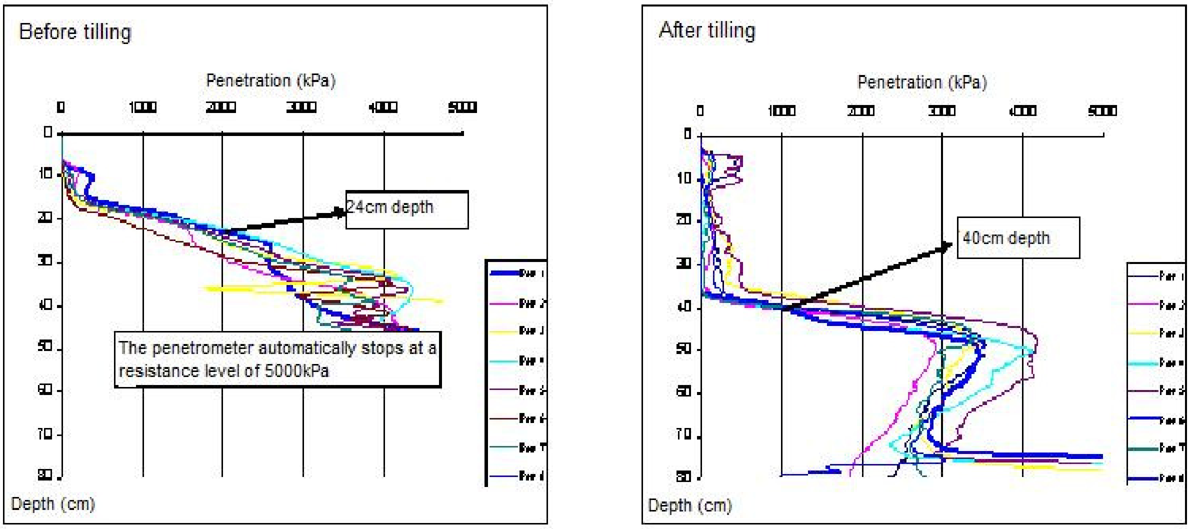

Figure 3.6: **Example of soil compaction curves as measured by a penetrometer before and after tilling**

Source: Haarhoff (2008a)

The soil chemistry is determined by obtaining soil samples from a 100m x 100m (1 hectare) grid and testing these samples in laboratories. Twenty-two chemical maps and chemical ratios are then provided with optional diagnoses such as clay percentages, conductibility and resistance of the soil. An example of a chemical map is provided in Figure 3.7. The producer can subsequently either correct the imbalances in the soil himself or contract a fertilizer company that offers these services. In order to correct these imbalances, the fertilizer company provides a self-propelled fertilizer applicator whereby the fertilizer is applied to the land at a variable rate according to the specific needs of the soil.

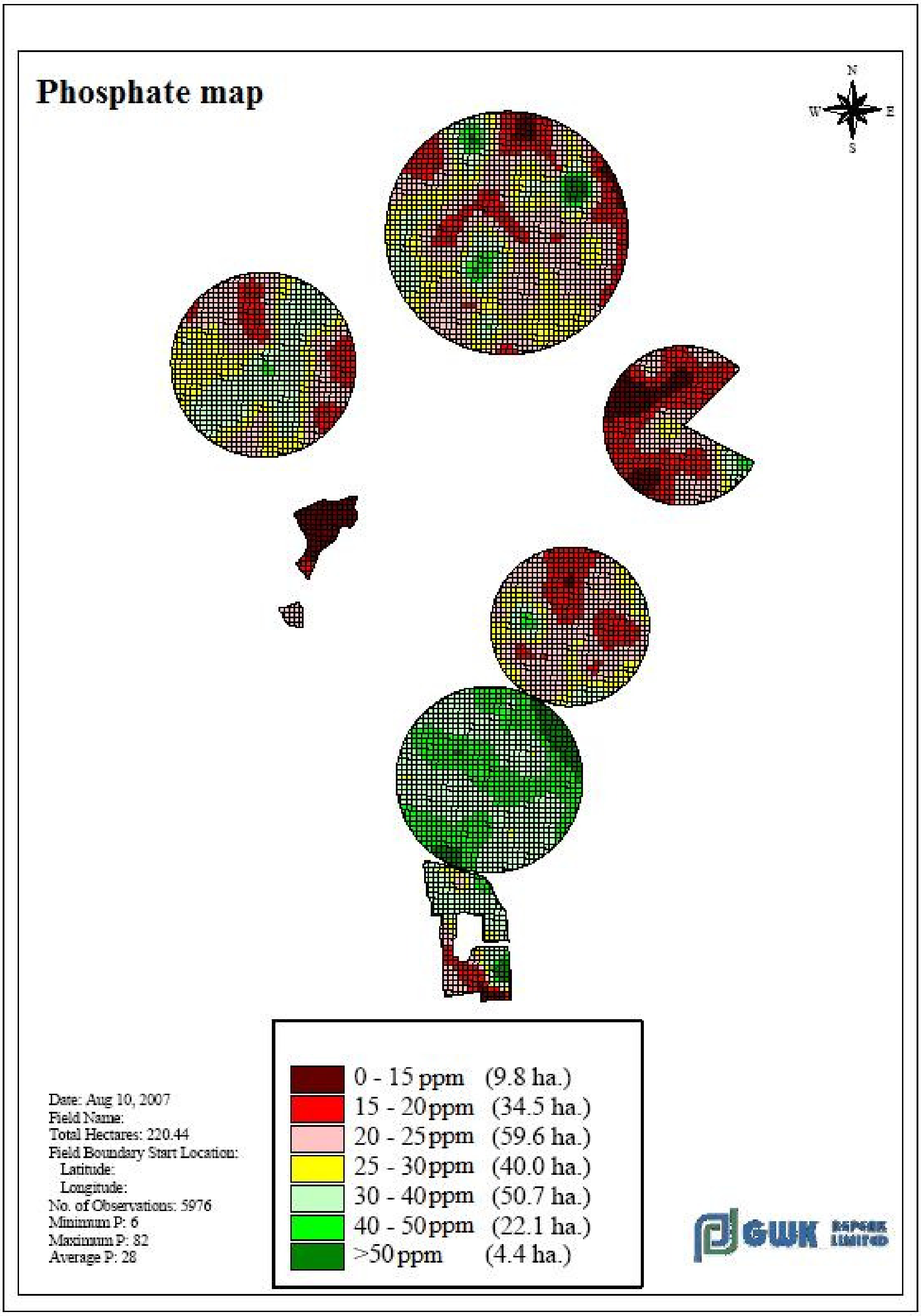

Figure 3.7: Example of a chemical (phosphate) map for a specific farm[14]

Source: Haarhoff (2008a)

[14] The abbreviation *ppm* refers to parts per million.

Another auxiliary farm management tool provided by GWK for HTF producers is irrigation scheduling. The water-holding capacity of the soil is evaluated by using neutron humidity meters for *in situ* measurements. Detailed drainage curves are also created to support the system. The water-holding capacity of the soils is determined and the scheduling is modified accordingly for optimal water usage.

Nitrogen measurements on the crops' leaves are also taken on a weekly basis in order to ensure that the nutritional needs of the crops are satisfied. NDVI images of the crop areas are taken twice during a planting season and discussed with producers. This enables the farmer to identify and rectify nutrition imbalances during the growth stage of the crops, which has the advantage that the quality of the crop can be improved within the season. An example of an NDVI image is provided in Figure 3.8.

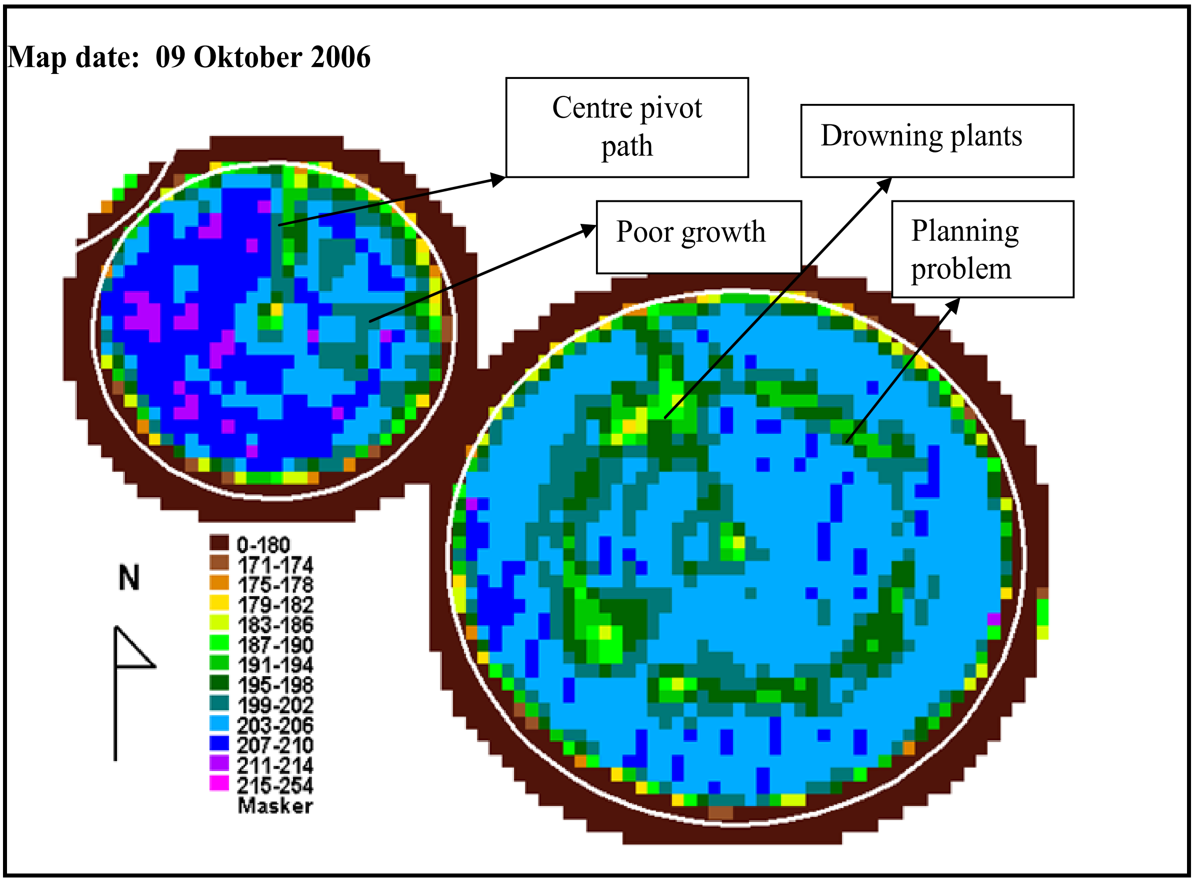

Figure 3.8: **Example of an NDVI image**

Source: Haarhoff (2008a)

Since climate can have an enormous impact on crop yield, temperature sensors are placed in strategic places in the cultivated area to measure temperatures on an hourly basis. The data obtained from the temperature sensors are then used to determine the impact of climatic conditions on crop yield.

At the end of the planting season, yield maps are constructed from the harvest information obtained and used to construct gross margin maps and an economic report that are discussed with each producer individually. An example of a gross margin map is provided in Figure 3.9.

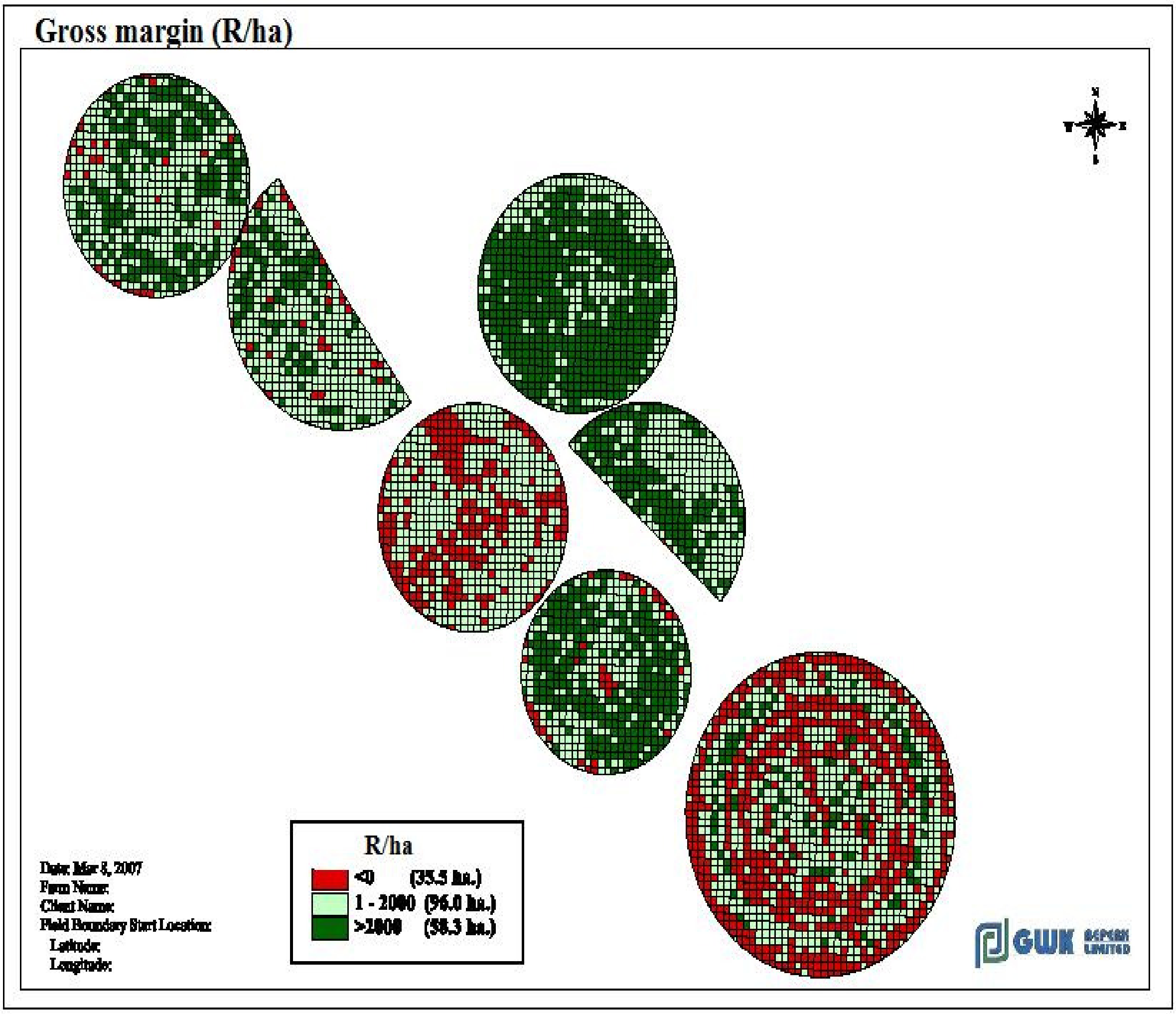

Figure 3.9: Example of a gross margin map

<u>Source:</u> Haarhoff (2008a)

According to Haarhoff (2008b) information obtained through the HTF system has proven invaluable. Producers are able to see graphically how cultivated areas differ from one another in terms of chemical and physical attributes. Site-specific cultivation and fertilizer application are therefore preferable above standard cultivation and application, as inputs can be used more efficiently. Again, as Lowenberg-DeBoer (1999) stated, this kind of PF management programme provides farmers with a low-cost way to learn about PF without long-term investment in equipment.

3.4.1 Summary of reported benefits of HTF in the Northern Cape Province

After a number of interviews with the various role players involved in the HTF system in the Northern Cape Province, several benefits associated with HTF were identified. It is important to note the reported benefits, since the assumptions of the PF analysis is based thereon. The benefits were identified and summarised as follow (Anon, 2008d; Bekker, 2008; Bothma, 2008; Haarhoff (2008b); Hattingh, 2008; Kluge, 2008):

- Scheduling ensures that the correct amount of water is applied to the crops at the appropriate time, leading to more efficient use of water and therefore lower water cost in comparison with conventional water application. More efficient water application can also lead to lower irrigation electricity costs. Another benefit associated with scheduling is that less leaching of fertilizer occurs due to efficient water application. Thus, fertilizer loss is limited and therefore scheduling leads to more efficient fertilizer utilization and thus lower fertilizer costs.
- Through the use of penetrometers and other soil physics evaluation services, soil compaction problems can be identified and rectified accordingly. Hence soil cultivation is done more efficiently. More efficient soil cultivation subsequently results in lower fuel costs, since the right spots are treated according to the level of compaction as opposed to uniform soil cultivation.
- The evaluation of the chemical properties of the soil ensures that chemical imbalances in the soil can be identified and corrected in a timely manner. Hence, the correct amount of chemicals or nutrients can be applied in the correct zones, leading to further savings on input costs, especially chemical and nutrient applications. In addition, the water capacity of the soil can be determined by evaluating the chemical and physical properties of the specific

soil and scheduling can then be adjusted accordingly, resulting in more efficient water and electricity usage.

- The use of NDVI images enables farmers and agriculturalists to identify possible problems on the fields such as drowning plants, poor growth and nutrient deficits. Armed with this information, farmers and agriculturalists can then rectify the problems while the crops are still in the growth stages, thereby eliminating possible yield losses.
- Gross margin maps are used in conjunction with the other maps such as NDVI images and chemical maps in order to determine the economic effect of various input applications (fertilizer, water, pesticides and other chemicals) in a specific position in the field. Gross margin maps also assist farmers in identifying unprofitable areas in the field which can be left out of production in the next production season.
- An important feature of the HTF system is the fact that no astronomical capital expenditures are needed, as the necessary equipment for HTF is provided by GWK. HTF services and equipment are provided by GWK and a service fee is charged on a per-hectare basis. This service fee has the effect that only the direct allocatable costs (variable costs) of the farm increase. Other equipment, such as harvest monitors and GPS appliances, are already in possession of the farmers. More expensive precision machinery such as fertilizer applicators equipped with GPS is usually provided by fertilizer companies and can be contracted by the farmer.
- All role-players reported a significant improvement in the general farm management ability of the farmer. The informative nature of HTF keeps the farmer informed about all the latest development on the fields and farming operations, thereby expanding his farming knowledge. Possible problems can be identified more easily and decision-making is also improved. Although there is a definitive improvement in farm management after the implementation of HTF, it is difficult to quantify this improvement in terms of economic impact on the profitability of the farm.

3.4.2 Costs associated with HTF in the Northern Cape Province

Farmers are often concerned about the costs (especially capital expenditures) associated with PF, hence it is subjected to intense scrutiny. In this regard, the HTF service being rendered by GWK is unique in the sense that no substantial capital purchases are required. The HTF technologies are provided by GWK and its affiliates (for example, fertilizer companies), and operated by qualified agricultural specialists. Although essential PF equipment such as GPS monitors are not provided by GWK, harvesters are usually already equipped with these appliances. Also, it should be kept in mind that farmers generally use contractors whose harvesters and other machinery are equipped with the necessary PF equipment. Farmers who implement the HTF system on their farm are charged a service fee (per-hectare) for the amount of hectares under the HTF system. A breakdown of this service fee as charged in 2008 is provided in Table 3.5. The HTF service fee varies from one farmer to another, depending on the options being selected. Table 3.5 indicates that a farmer who wanted to implement the HTF system in 2008, could have expected his variable costs to increase with approximately R180 per hectare for a standard package (assuming his harvester was already equipped with a GPS monitor). A complete breakdown of the variable costs of the farms under consideration is provided in Chapter 5.

Table 3.5: Breakdown of costs for a standard HTF package as charged by GWK in 2008

Description of HTF service	Amount (R/ha)
Scheduling	90.00
Nitrogen testing	10.00
Satillite images	14.00
Penetrometer	30.00
Yield and economics maps	16.50
Administration costs	15.00
Geographic Information System (GIS)	4.50
Total	**180.00**

Source: Haarhoff (2008b)

It is important to note that the reported PF benefits were quantified and used in conjunction with actual data during the analysis process in order to determine the impact thereof (by means of the BFAP farm-level model) on the profitability of the farms under consideration. The service fee is also included in the analyses, which are discussed in Chapter 5.

3.5 SUMMARY AND CONCLUSION

In this chapter an overview of the PF system was provided and its various definitions explained. A brief overview of the technologies used in PF was provided, followed by a description of the general PF cycle. A literature review on the profitability of PF was conducted, indicating that depending on factors such as the nature of technologies used, operating conditions and costs, PF has the potential to improve farm profitability. Lastly, the HTF system in the Northern Cape Province was explained in order to familiarise the reader with the specific PF technologies and methods being implemented in the region under investigation. The reported benefits and associated costs of PF in the Northern Cape Province were included with the aim of taking them into account when determining the impact of PF on the profitability of the participating farms. This is subsequently included in Chapter 5. It was stressed that the PF system being implemented by GWK in the Northern Cape Province mitigates the problem of high initial capital expenditure, since GWK offers the necessary PF equipment and expertise. A participating farmer is charged a PF service fee on a per-hectare basis, which subsequently increases the variable costs of the participating farm. The farmer thus has to decide whether he can afford this increase in variable costs before implementing the PF system.

This chapter highlighted the importance of a profitable PF system. If the system does not prove to support higher profitability in the longer term, this might lead to a *"technological dead-end"* (Lowenberg-DeBoer & Swinton, 1997). The literature also explicitly suggests that the impact of PF on profitability does not necessarily lie in its potential to improve yields, but also in its ability to improve other aspects of farming, namely the farm management capabilities of the farmer and production efficiency. It became obvious in this chapter that PF can be used as a tool for more competitive production when implemented successfully. However, it is important for farmers to first consider the financial implications of their decisions before implementing a PF system.

Chapter 4 provides an overview of profitability and risk, and describes the link that exists between these two concepts. The methods that can be used to determine the impact of PF on profitability are also discussed in Chapter 4.

CHAPTER 4

PROFIT, RISK AND MODELLING

4.1 INTRODUCTION

Farmers are continuously exposed to an endless list of possibilities – possible output prices, possible yields, and possible input prices – making it a financially risky business. This is especially applicable after the deregulation of the South African agricultural market, when farmers were left to handle their own marketing and were heavily exposed to price and market risks (for more details, refer to Chapter 2). Within this dynamic and uncertain domain, farmers have to make decisions based on the information at hand, which has a substantial impact on their financial returns and welfare. The consequences of farmers' decisions or events are mostly uncertain until a significant amount of time has passed. Hence actual outcomes may be either better or worse than initially expected. For example, when aggregated crop output or export demand changes dramatically, farm prices will change accordingly, with the result that farmers realise return that differs substantially from their expectations (Harwood, Heifner, Coble, Perry *et al.* 1999).

In addition, globalisation contributes to this uncertainty to a great extent as competition increases and farmers are more exposed to economic cycles of world markets, changing technologies and global warming. This environment with its uncertain future requires farmers and decision-makers to acquire a better understanding of risk and risk management, as well as the relevant instruments of measuring risk, in order to make the best decisions possible with the information at hand.

However, decision-makers are not aware of all the possible activities and outcomes that accompany each decision, and most decisions are made with imperfect knowledge about the future. This is particularly applicable to grain producers who have to take both natural and economic environments into account in the decision-making process. For example, weather elements and pests have a substantial impact on decisions about planting and the use of fertilizer and pesticides (Geyser, 2000).

The role of precision farming (PF) in this regard cannot be ignored. Like many other technologies and innovations, PF may either mitigate or increase some types of risks. For example, although PF has the potential to increase yields and returns, it is not exempted from a possible crop failure. This subsequently increases variability, as PF services such as the variable-rate application (VRA) of inputs requires higher input costs and consequently aggravates losses in a bad season (Lowenberg-DeBoer, 1999). On the other hand, PF might have risk-reducing benefits, as reported by Lowenberg-DeBoer (1999). These aspects will be discussed in more detail in this chapter.

Since risk and profits are inseparable and one affects the other, it was also essential to conduct an investigation into the definition of profit and its connection with risk, as described in this chapter. There are various methods that can be used to measure risk. The most widely used methods are described briefly in this chapter and the appropriate method is highlighted. The aim of this chapter is therefore to provide insights into profit, risk and modelling while the interrelationship amongst these components with regard to PF is exposed. A background is provided to the different modelling methods and instruments being used to analyse and understand changes that occur in the agricultural economic environment. In order to analyse the impact of PF on profitability, the Bureau for Food and Agricultural Policy (BFAP) farm-level model was selected, as it was deemed to be the most appropriate tool available to date.

4.2 PROFIT AND RISK DEFINED

A farm is said to make a profit when its revenues exceed the total expenses or costs incurred by the farm for inputs, finance, and services received. Profit can also be described as the remuneration for labour, capital and management contributed by the farmer (AGSF-FAO, 2007; NDA, 2005). Basically, profit can be defined as revenue minus costs and can be mathematically expressed as follows (Varian, 1999):

$$\pi = \sum_{i=1}^{n} p_i y_i - \sum_{i=1}^{n} w_i x_i$$

Of which: π = profit

p_i = price per unit of output y_i

y_i = unit of output y_i

w_i = price of unit of input x_i

x_i = unit of input x_i

The first term $(\sum_{i=1}^{n} p_i y_i)$ represents revenue and the second term $(\sum_{i=1}^{n} w_i x_i)$ the costs (consisting of variable and fixed costs). The ultimate goal of a farmer is to maximise profit (Van Zyl, Kirsten, Coetzee & Blignaut, 1999). From this perspective, one should also consider the basic investment principle that higher returns involve higher risk (Moolman, 2007).Therefore profit and risk should not be regarded separately. For example, a farmer might consider planting maize during a period of high maize prices, while variable weather conditions pose a high risk (occurrence of floods or pests and diseases). In cases where favourable weather and farming conditions prevail, then the payoff might be rewarding in terms of profitability. On the other hand, in cases of unfavourable weather conditions, then a farmer might suffer a loss and possibly find himself in a financial predicament.

Risk is generally defined as imperfect knowledge where the probabilities of the possible outcomes are known, while uncertainty is when these probabilities are unknown (Casavant, 1984; Hardaker, Huirne & Anderson, 1997). Bodie and Merton (in Harwood *et al.*, 1999) described risk as uncertainty that has an impact on an individual's welfare, which is usually linked with adversity and loss. Hardaker *et al.* (1997) argued that risk can be more accurately described as uncertain consequences, especially the exposure to unfavourable consequences, with uncertainty described as imperfect knowledge. For example, uncertainty might exist regarding future weather conditions in a given area, indicating that there is imperfect knowledge of the future. In cases where a person does not know whether or not it will rain the following day, this implies that alternative consequences exist. Risk and uncertainty therefore imply that imperfect knowledge exists about the different outcomes of an action, and that the outcome might be unfavourable. To take a risk means that one is exposing oneself to a greater possibility of injury or loss (Hardaker *et al.*, 1997)

Harwood *et al.* (1999) explained risk as uncertainty that "matters", and may involve the probability of losing money, possible harm to human health, repercussions that affect resources such as water for irrigation, as well as credit and other types of events that affects an individual's welfare.

An example of uncertainty is price volatility in agricultural markets. Farmers have imperfect knowledge of the direction and magnitude of price changes, thereby suggesting that no probability can be assigned to the occurrence of a specific price on a future date. Prices are influenced by conditions in world markets, government policy, monopolies, politics and so forth, thereby contributing to the uncertainty of price outcomes. The magnitude of the uncertainty about price outcomes in turn determines the magnitude of risk (Geyser, 2000).

In another noteworthy argument about risk with regard to PF, Lowenberg-DeBoer (1999) argued that few people object to upside variations such as higher yields, higher output prices and higher profits, but they are more concerned about the downside. Hardaker *et al.* (1997) described downside risk as those situations in which any significance variations from the 'norm' lead to worse outcomes. For example, crop yield depends on numerous variables such as rainfall and temperature at each stage in the growing period. Large variations of these variables from their expected values usually have an adverse impact on crop yield.

4.3 SOURCES OF RISK IN AGRICULTURE

Farmers are continuously exposed to risky farming decisions, whether day-to-day decisions or those that can lead to possible significant losses. These decisions can have a substantial impact on the overall performance of the farming business. Therefore the risks involved and their possible outcomes should be analysed carefully in order to make the best choices possible (Hardaker *et al.*, 1997). Some major sources and types of risk are listed as follows (Geyser, 2000; Hardaker *et al.*, 1997; Harwood *et al*, 1999; Holmes, 2002; Lowenberg-DeBoer, 1999; Maine, 2006; Malan, 2007; Patrick, 1998; Stephens, 2001):

- **Production or yield risk**

Production risk emerges as a result of the unpredictable nature of the weather, as well as uncertainty about the effect of factors such as pests and diseases, insufficient rainfall, extreme temperatures and hail can have on the performance of crops. It is important to note that PF can play an important role in reducing this source of risk. Site-specific treatment of problem areas such as pests and diseases can reduce the probability of low yields, thereby reducing yield risk. Despite being considered a risk-reducing technology, PF can also increase production risk. For example, PF involves additional costs for PF services such as soil sampling and, during a bad production period, losses could be aggregated due to the higher variable costs associated with PF.

- **Technology risk**

Technology is an important factor in reducing production risk as new crop varieties and production techniques can improve efficiency. However, the possibility of obsolescence can result in another kind of risk – for example, where a farmer uses certain machinery of which the parts might become unavailable. Precision farming might contribute to technological risk mainly in the form of obsolescence, since it is a technology that changes rapidly. A producer might, for instance, buy PF technologies only to find out later that new products are being sold or that the company has gone out of business, been merged or decided that the product is no longer worth supporting.

- **Price or market risk**

Price or market risk refers to uncertainty about the prices of farm inputs and outputs and the existence of price volatility in the input and output markets. It should be noted that agricultural production occurs over a long period in which returns might not be realised. Due to the complexity of markets together with domestic and international market considerations, far-off regions in the world can have a substantial impact on producer returns.

- **Institutional risk**

Institutional risk is associated with changes in policies and regulations that can have a substantial impact on the profitability of farming. For example, grain producers can be dramatically affected by restrictions on the use of herbicides. Another example of institutional risk is the change in marketing policies as a result of the deregulation of agricultural markets.

- **Human or personal risk**

The profitability of the farming business can be influenced by the actions, welfare and health conditions of the farm operators, which are a source of human or personal risk. Prolonged illness of one of the farm workers can result in increasing costs and production losses, while the death or divorce of the owners could threaten the existence of the farming business itself. Negligence by farm operators could also result in significant losses for the farming business. This is especially true during the operation of machinery or the handling of livestock. Another example of human risk is in the case of an operator who has the necessary skills and experience to operate PF equipment and interpreting PF data. When this person is no longer available, it can leave the farming operations vulnerable. Human risk is also present in the case of layering of PF maps, since the possibility of poor decisions always exists.

- **Business risk**

Business risk is the combined effect of production, market, institutional and personal risk and involves all the uncertainties having an impact on profitability. Business risk has an impact on the business performance in terms of net cash flow or net farm income generated, but is independent from the manner in which it is financed.

- **Financial/interest rates risk**

The use of borrowed funds to finance the farm often leads to financial risk. Interest must be deducted first from the operating profit in order to meet the debt payment obligations before the owner can allocate the returns to himself. This effect, commonly known as leverage, can in turn have a substantial effect on the farm's business risk. The higher the debt-capital-to-total-capital ratio, the greater the effect on the business risk will be. Financial risk consists of three basic components, namely the cost and availability of financing, the ability to meet cash flow needs on time, and the ability to maintain and increase equity. Examples of financial risk include unexpected rises in interest rates, insufficient funds to repay lenders, unexpected loan withdrawals by lenders and the possibility of a lack of financing. However, in the case where a farm is wholly owned by the farmer, no financial risk exists in terms of leverage, but the owner's capital is still exposed to the possibility of declining equity or net worth.

Precision farming also has the possibility of increasing financial risk. For example, costs such as VRA of inputs, soil sampling and other services might raise input costs. When the crop season later turns out to be poor, losses might be higher due to higher input costs.

4.4 MEASURING RISK

A farmer is continuously confronted by decisions amongst different alternative actions. For instance, a farmers should choose between different combinations of crops to produce, types of farming practices (for example PF versus CF), what inputs to use, how much inputs to use, different marketing and financial strategies for his farm, to name a few. In a risk-free environment the decisions will naturally be based on one easy parameter – the alternative with the best economic return. However, when decisions should be made under risky conditions, a farmer does not have the luxury of such a simple parameter like economic returns to decide on the best alternative. The reason for this is because each alternative with which the farmer is faced (under risk) is not a single value, but a distribution of returns. In this regard, stochastic modelling can be used to facilitate decision-making in the presence of risk, amongst other methods, to simulate the alternative strategies in order to estimate the distribution for the return of each alternative and make decisions based on these simulated distributions (Richardson, 2004). Richardson (2004) explained the purpose of simulation in risk analysis as being "to estimate distributions of economic returns for alternative strategies so that the decision-maker can make better management decisions". Besides stochastic modelling, various other tools have been developed to measure risk. Some of these methods are briefly discussed in the next few sections, followed by a more detailed discussion of stochastic modelling.

4.4.1 Volatility

Volatility is the most basic statistical risk measurement tool. Volatility gives an indication of the extent and ease of variation for a given variable. In financial analysis, the volatility of a variable is expressed as the standard deviation for that particular variable. For example, the volatility of an asset indicates how much the value of that asset can vary over a given period of time. Volatility is expressed in percentage as the expected value of the variable over a specific period. However, a major shortcoming of volatility as a risk measurement tool is the fact that it is based on historical data. This suggests that the estimated volatility for a specific variable is based on past fluctuations in the value of the variable, thereby giving no indication of future "riskiness" of the variable. This shortcoming is, however, addressed by the development of the *value at risk* (VAR) risk measurement method. The VAR method also takes historical volatilities into account, but in addition it also incorporates the correlation of different variables in order to estimate the immediate riskiness of a portfolio (Malan, 2007; Stephens, 2001).

4.4.2 Value at risk (VAR)

Stephens (2001) defined VAR as "an amount of money, such that the portfolio will lose less than that amount over a specified period with a specified probability". VAR is consequently also referred to as 'dollars at risk', 'capital at risk' or 'earnings at risk'. VAR is a powerful measurement used to estimate the market risk of a portfolio in the absence of historical data. In estimating VAR, all the sources of market risk associated with the assets that are part of the profitability-probability distribution are included in the estimates. Two types of VAR methods exist, namely closed-form VAR and Monte Carlo VAR. The closed-form VAR method is limited by two assumptions: The portfolio for which the estimate is done is assumed to be a normally distributed profitability and the profitability depends linearly on applicable risk factors. If these conditions are not conformed to, the closed-form VAR method cannot be used. In order to analyse these more complex portfolios, either the Monte Carlo simulation method or Latin Hypercube sampling can be used (Malan, 2007; Stephens, 2001).

- **Monte Carlo simulation**

The Monte Carlo simulation method is based on generating sampling data from probability distributions. Large numbers of random inputs are fed into a simulation model while recording a range of outputs. This sampling method is best described by the roulette wheel, hence the name “Monte Carlo” (Winston, 2003). Uncertainty is naturally part of this simulation method. All the probability distributions for all the uncertainties are combined in the simulation model, which are run several times (iterations) to produce an approximation of the probability distribution for the outputs or payoffs of various alternative strategies. Risk and decision analysis is subsequently done by analysing the final results of risk profiles and average outcomes (Clement, 2001).

However, since the Monte Carlo procedure randomly selects values from the probability distributions, a greater percentage of the random values are sampled in the area about the mean, while the tails of the probability distributions are under-sampled. In order to counter the under-sampling of the tails during Monte Carlo simulations, a large number of iterations should be used. For the same reason (under-sampling of the tails of the probability distributions) an alternative sampling technique called the Latin Hypercube sampling procedure is preferred (Richardson, 2004).

- **Latin Hypercube**

The Latin Hypercube sampling procedure follows the same basic principles in generating sampling data from probability distributions. However, the Latin Hypercube technique segments the distribution into a given number of intervals (N) and makes sure that at least one value is randomly selected from each interval. The number of intervals (N) is the number of iterations. By sampling from N intervals, the Latin Hypercube thus ensures that all areas of the probability distribution are considered in the simulation. In addition, smaller numbers of iterations are needed to reproduce the parent distributions as opposed to the Monte Carlo procedure (Richardson, 2004). It can be concluded that the Latin Hypercube sampling procedure is the better sampling method and it was consequently incorporated in the BFAP farm-level model for purposes of the study. The workings of the simulation model for modelling under risky conditions are explained in the section to follow.

4.4.3 Stochastic modelling

Solutions for complex systems obtained from analytical models are usually inferior or inadequate for implementation, since these complex systems require too many simplifying assumptions. An alternative left for the analyst or decision-maker is simulation. Simulation is a very powerful and widely used management science technique for analysing and investigating complex systems (Malan, 2007; Winston, 2003).

According to Richardson (2004), a simulation model can be defined as "a mathematical representation of a business or economic system that reflects sufficient detail of the system to address the questions at hand". Simulation is the process of solving a mathematical simulation model consisting of a set of exogenous variables that represents an economic system. The exogenous variables are alternative management strategies and policy scenarios, and represent the "What if..?" question in a numerical form. Simulation models usually consist of a set of assumptions about the operation of the system expressed as mathematical or logical relations between the objects of interest in the system (Malan, 2007; Winston, 2003). It is, however, important to distinguish between simulation and modelling. Johnson and Rausser (1977) distinguished between these terms by describing modelling as the building of a representation of a system, while simulation was defined as "experimentation with the represented system by means of the model". Csáki (1976) argued that simulation implies an experiment of which the aim is to represent or reproduce the relationships between objects or person in a real world system and to predict the likely behaviour or response of these objects or persons in that particular system.

The working of a simulation model is based on "solving" the model several times in order to achieve a statistically significant representation of all the possible outcomes of the random variables. The results of the simulations are several simulated values for key output variables (KOVs) that represent empirical estimations of the probability distribution for the variables. KOVs are the variables that are important for decision-making and determine the type of model to be constructed. The values obtained from simulation also provide a quantified representation of risk associated with the variables (Richardson, 2004).

Johnson and Rausser (1977) argued that the type of system being modelled as well as the purpose of modelling or simulating the system determines the type of farm simulation model used. Two basic types of model can be distinguished in the literature, namely deterministic and stochastic models. The type of model depends on the type of agricultural system under investigation (France & Thorniley, 1984; Johnson & Rausser, 1977; Richardson, 2004).

Depending on the objective of modelling or simulation, two approaches can be followed, namely a normative approach and a positive approach. The normative approach is based on optimising a system or quantifying an answer on the question of "what ought to happen". An example of normative modelling is a mathematical programming model, which usually consists of mathematical relationships and constraints (Csáki, 1976; Richardson, 2004; Strauss, 2005). In contrast with the normative approach, the positivistic approach to farm-level simulation generally consists of statistical relationships that are estimated from historical data and accounting identities. A system based on these statistical relationships is then simulated in order to find "positive" answers; in other words, answering the question of "what the likely outcome is". This approach thus incorporates the use of actual farm-level data to estimate behavioural trends on which to base its assumptions on future interrelationships in the system, thereby attempting to represent reality as accurately as possible (Richardson, 2004; Strauss, 2005).

4.5 TYPES OF MODELS

In practice, models are generally used to facilitate an understanding of changes that occur at the sector level. An example of such a model in South Africa is the BFAP sector model, as described in Meyer (2002), Meyer, Westhoff, Binfield and Kirsten (2006) and Cutts, Reynolds, Vink and Meyer (2007). It should be noted that these models only have the capacity to simulate factors like the impact of changes in markets and policies at *sector level*, and thus the impact at *farm level* is not indicated (Strauss *et al*, 2008). However, several positivistic farm-level models that are linked to sector models have been developed in the international arena. This enables decision-makers to determine the impact of changes at both farm and sector level. Examples of these international models are briefly described in the following sub-sections:

- **Farm-Level Income and Policy Simulator (FLIPSIM) of Richardson and Nixon (1986)**

The FLIPSIM model was developed for the first time in 1981 by James Richardson and Clair Nixon at the Texas A&M University. Since then various modifications have been made in order to improve the model. The model can be used as a stochastic or deterministic model, depending on the specific needs of the user. Individual as well as representative farms can be simulated over a multiple-year planning horizon, and outputs are presented as probabilities. FLIPSIM is used for various simulations and analyses including policies, changes in technology, risk management strategies, tax provisions, baseline projections, insurance options, farm management, and marketing and financing of livestock, dairy, grain or mixed farms. Producer information used in the model is collected from panel groups in different states in the USA. The panel groups are identified by local grant personnel and consist of producers and persons who are familiar with the area and farming practice under consideration (Richardson & Nixon, 1986; Strauss, 2005).

- **Technology Impact and Policy Impact Calculations Model (TIPI-CAL)**

TIPI-CAL is a deterministic recursive production and accounting model developed by the Federal Agricultural Research Centre (FAL) in Europe as a modified version of the FLIPSIM model. This Excel-based model is used for the simulation and analysis of farm management strategies, policies, technology, production cost and cost components for dairy, arable, beef and hog farms. Output variables include farm profit, development of equity, cost of production, and survivability (Strauss, 2005; TIPI-CAL, 2003).

- **Financial Economic Simulation (FES) Model**

The FES model was developed by the Landbou Economisch Instituut (LEI) of Wageningen University in the Netherlands. It is mainly used by Dutch banks, farmers' organisations and the Dutch government for decision-making with regard to future financial economic developments of various farm types and sizes across different agricultural sectors in the Netherlands. The model can be classified as a discrete-event stochastic micro-simulation model and consists mainly of accounting identities. The model can be used for both deterministic and stochastic modelling. Due to the inclusion of accounting identities, both the historical and possible future developments of the firm can be evaluated. The model operates in the sense that the impacts of changes within the farm and its environment can be updated, analysed and predicted by means of financial statements and accounts of the farm. Financial ratios are also used to analyse and predict the possible outcomes of the changes over a specific future time period (FES, 2004; Strauss, 2005).

- **Food and Agricultural Policy Research Institute (FAPRI) modelling systems**

FAPRI is a dual-university research programme established in 1984 by a grant from the United States (US) Congress. This programme includes participants from the Center for National Food and Agricultural Policy (CNFAP) at the University of Missouri-Columbia (UMC) and the Trade and Agricultural Policy Division of the Center for Agricultural and Rural Development (CARD/TAPD) at Iowa State University (FAPRI-UMC, 2007).

FAPRI's role includes the analysis of complex economic interrelationships of the food and agricultural industry by using comprehensive data and computer modelling systems. FAPRI uses its modelling systems to estimate the impact of various changes in agricultural practices on farm finances to the local environment. Annual baseline projections for the US agricultural sector and international commodity markets are prepared and published as FAPRI Outlook. This baseline is used to evaluate and compare scenarios regarding macro-economic, policy, weather and technology variables. International research partnerships are established with various countries, namely Ireland, the UK, Japan, Korea and South Africa (FAPRI-UMC, 2007).

Other international models worth mentioning are the models developed by Hardin (1978), Held and Helmers (1981) and Patrick and Eisgruber (1968). In South Africa examples of farm-level models include the models developed by Louw (1979) and Meiring (1994).

Louw's model was based on simulation models developed by Eisgruber in 1965, the modified version of the Eisgruber model by Patrick and Eisgruber (1968), as well as the model developed by Harshbarger (1969). The model is capable of simulations in both deterministic and stochastic modes and is presented in Fortran IV format. The purpose of the model was to simulate the effect of various growth strategies on the growths of farm businesses in a dynamic environment under risk and uncertainty. The model further aimed to improve decision-making within the farm with regard to labour decisions, livestock purchases, inflation, land classification, asset rental, production functions, system of evaluating budgeted results, exclusion of production and price cycles, tax calculations, management capabilities and assumptions on the initial financial position of the farm under consideration. In order to verify and validate the model, data was obtained from farmers in the former Wes-Transvaal (presently North West Province) and used to simulate a representative farm. Livestock enterprises, equations on grain and fodder purchases and sales, machinery and fixed improvement requirements, depreciation on machinery and fixed assets, debt repayment, tax, a financial summary and stochastic yield and price calculations were included in the model (Louw, 1979; Strauss, 2005).

Meiring (1994) also developed a decision support system in order to conduct an economic evaluation of risk management at farm level.

4.6 BFAP FARM-LEVEL MODEL

The Bureau for Food and Agricultural Policy (BFAP) plays an important role in the development of partial equilibrium models in the South African commodity markets. Meyer and Westhoff (2003) developed a multi-commodity partial equilibrium model for the South African grain, oilseeds, livestock and dairy markets, generally referred to as the BFAP sector model. The model is maintained within BFAP and is based on the FAPRI modelling approach. The most important determinants of supply and demand as well as a selection of price relationships are included in the model for various agricultural commodities. This means that for a typical crop, the area under production, yield per hectare, total production, direct human consumption, industrial use, exports, imports and ending stocks are included (Meyer, 2006).

The projections from the BFAP sector model such as output prices, input prices, yields and area planted are in turn used as inputs in the BFAP farm-level model. The BFAP farm-level model was developed by Strauss (2005) with the objective to analyse the impact of changes in policies and markets on farm-level accurately. In order to determine the impact of changes in policies and markets on the KOVs, alternative scenario results are compared to the baseline results. The baseline serves as a benchmark or reference scenario, and consists of the first set of projections by the sector model (Strauss *et al.*, 2008).

According to Strauss (2005), a baseline projection should not be considered as a forecast, but rather as a possible market and policy outlook. The development of a baseline is therefore based on a set of assumptions regarding exogenous variables and endogenous variables. Examples of such variables are macro-economic variables, agricultural and economic policies, climatic variables, asset replacement strategies and asset values, farm size, and combination of farm activities. It is assumed that no change will occur in these variables (Strauss, 2005).

A more detailed description of the specific assumptions that apply to the baseline used in the study is provided in Chapter 5. It is important to note that since this study was conducted at farm level, the focus falls on the BFAP farm-level model used in the study. Subsequently the BFAP farm-level model is thoroughly discussed in the paragraphs to follow.

The BFAP farm-level model is both a deterministic and stochastic farm-level model, which is linked to the partial equilibrium BFAP sector model and encompasses the grain and livestock sectors of South Africa. This linked model system was developed in order to analyse the likely effects of changes in policies and markets at sector level as well as farm level in South Africa (Strauss *et al.*, 2008). The stochastic process used in the model is discussed in section 4.6.1.

The BFAP farm-level model is an Excel-based positivistic type of model and data is entered manually. It is important to note that the model does not attempt to describe what should happen to the farm, but rather what the likely outcomes will be given the combination of farm activities, management practices and financial position. A normative modelling approach on the other hand tends to answer the question of "what ought to be" (Strauss, 2005). However, since the aim of the study was to determine the impact of PF on the profitability of a maize irrigation farm, the question of "what is the likely outcome" needs to be answered. This implies that outcomes are based on actual behavioural events, and consequently justified the use of a positivistic modelling approach in the study.

The model was constructed by using the "top-down" approach described by Richardson (2004), which means that the KOVs are determined first, and by working backwards the equations and calculation requirements are determined in order to calculate the output variables. In the case of the BFAP farm-level model, the KOVs are the ending cash surplus or deficit and the debt-to-asset ratio. The reason why these specific variables were selected is because the ending cash surplus gives an indication of the operational liquidity of the farm (Louw, 1979), while solvability of the farm is represented by the debt-to-asset ratio (Strauss *et al.*, 2008). A description of the KOVs applicable to the study is provided in Chapter 5.

The KOVs were calculated by using a set of financial statements as part of the model output with an underlying simple model of the production structure of the farm. Factors incorporated in the model include operation size in terms of hectares, livestock numbers and tenure (own land vs. rented land); composition of the operation such as the different types of crops and livestock; production cost for each individual enterprise, total fixed cost for the whole farming business; and a vehicle and machinery fleet and asset replacement strategy. The calculations are done by using mainly accounting identities with the exception of the asset replacement function where econometric equations are used (Strauss *et al.*, 2008).

In Figure 4.1 the basic structure of the model is illustrated. The model can be divided into three basic blocks, namely an input block, a calculations block and an output block. The input block consists of a section on managerial variables (control variables) and one on exogenous variables that are simulated by the sector model. The calculations block encompasses sheets on various grains and livestock enterprises being produced by the representative farm; a sheet on replacement of moveable asses and repayment of long-, medium- and short-term debt; tax, interest, land rental payments; and inflation on expenses and assets. The output block consists of a set of financial statements (income statement, cash flow statement and statement of assets and liabilities) from which the key output variables are calculated and summarised.

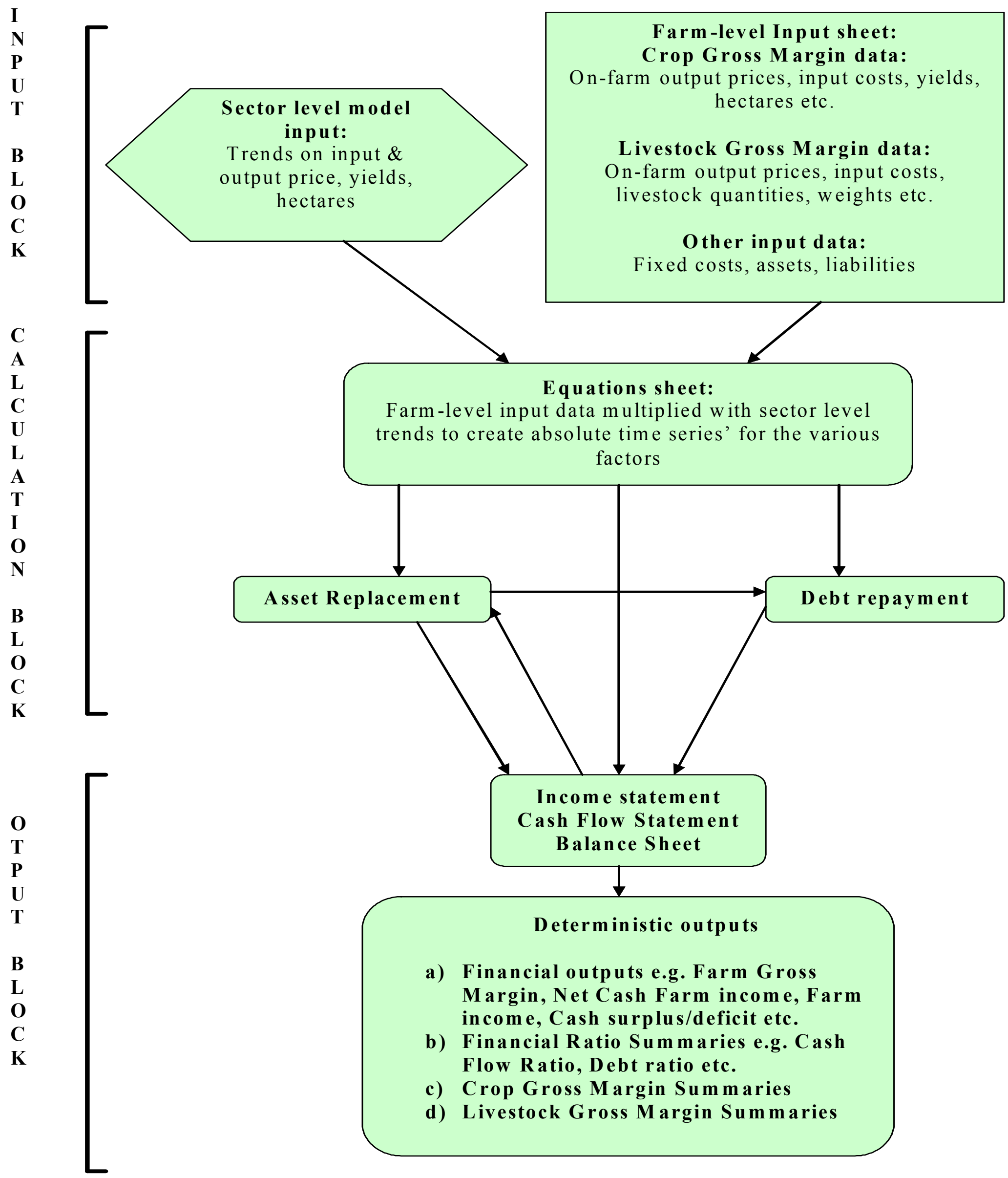

Figure 4.1: Structure of the BFAP farm-level model[15]

Source: Strauss *et al.* (2008)

The model is used to simulate the financial position of a specific farm over any period from one to ten years. The output data for year t_{-1} is used as inputs for year t to calculate the values for year t. A base year is selected in which the input data for that year is used for the simulation and depends on the availability of data. Input and output prices, yields and hectares planted as generated by the sector model are multiplied with the base-year data. A data series is subsequently created that

15 It should be noted that in the output block the outputs are labelled as deterministic and not stochastic outputs. The reason for this is that the previous version of the model was a deterministic model which was lately modified in order to take stochastic variables into account.

indicates the absolute level at farm level while following the trend as projected by the sector model. This allows the modeller to capture movements in input and output prices, yields and hectares. Absolute differences between national-level and farm-level prices and yields are also captured by the model (Strauss *et al.*, 2008).

4.6.1 Stochastic process of the BFAP farm-level model

Based on the FAPRI stochastic modelling systems, the stochastic process starts with the construction of a deterministic model of the specific farm under consideration. The stochastic model is calibrated in such a way that the same estimates are generated as the deterministic estimates when all exogenous variables are set at the levels expected for the deterministic model. When the means of the stochastic baseline differ from the deterministic results, it does not imply that the models generate different results for the same set of model assumptions, but rather that non-linearities exist in the models, asymmetries occur in policies, or random draws exist (Westhoff, Brown & Hart, 2005).

A large set of variables exist in maize farming that are uncertain. Since stochastic modelling is both a "science" and an "art" (Westhoff *et al.*, 2005), an attempt is made to draw an adequate number of variables from the large sample of uncertain variables. The variables that are drawn should accurately represent the uncertainties and risks at farm level. The resulting price and quantity distributions should be satisfactorily consistent with historical observations and analyses.

Empirical distributions from exogenous variables are used from which correlated random draws are made. The model is then solved for each of the 500 sets of exogenous variables to generate 500 alternative outcomes for the endogenous variables. Variables that are used for the stochastic analysis usually include those variables that are likely to influence the financial position of the considered farm (Westhoff *et al.*, 2005). For example, for a maize irrigation farm, variables that are most likely to be used include maize price, yields, fertilizer, fuel, insecticides and herbicides. Generally, 20 or more observations are required to conclusively estimate the parameters of a distribution with a high degree of certainty. However, since it is difficult to obtain ten observations under the same economic policy, farm management and programme or trade policy, a minimum of ten observations are required to estimate the parameters of a distribution with reasonable certainty (Richardson, 2004).

Stochastic draws of exogenous variables are made with SIMETAR software developed by Dr James Richardson at Texas A&M University. Since limited historical observations prevent one from developing reliable estimates of the correlations of all the selected exogenous variables together, the exogenous variables are grouped on the basis of similarity or observed correlation. The stochastic solution is obtained by solving the model for each of the 500 sets of correlated random draws of the exogenous variables (Westhoff *et al.*, 2005).

4.6.2 <u>Limitations of the BFAP farm-level modelling approach</u>

Strauss *et al.* (2008) stated that the linked system of models proved to be useful in analysing the impact of change in policies and markets at both the sector and farm level, and that the farm-level model provides an accurate tool to simulate a representative farm. This subsequently provides justification for the use of the BFAP farm-level model as a tool to analyse the impact of PF on the profitability of a maize irrigation farm. However, several limitations of this approach were raised by Strauss *et al.* (2008).

Firstly, due to the probability that data might be inaccurate and incomplete, the process of validation and verification might be difficult and time consuming.

Secondly, in the positivistic approach, the assumption is made that during the simulation process no changes occur in the farm structure except those being simulated by the sector model. This might not be correct, since producers strive to adjust to changes as soon as they occur in order to improve their survivability and growth.

Thirdly, it should be noted that simulation must be as close as possible to reality due to the positivistic nature of the farm-level model. This suggests that the modeller should have both theoretical and practical knowledge of the modelling system under consideration. This can be problematic, since in cases where the modeller does not have the necessary knowledge of the system it might be difficult to achieve a realistic simulation. However, this can be mitigated by making use of agricultural specialists in the area by involving them actively in the study.

Fourthly, Westhoff *et al.* (2005) emphasised that the stochastic process requires the analyst to decide what variable to select for stochastic modelling and what methods to use to detrend or adjust data. In order to construct a model to generate 500 sets of “reasonable” outcomes, a robust model is required that should be frequently updated and revised.

Lastly, it should be stressed that time series data cannot be expected to provide all the information needed for model development (Just, 2001).

4.7 SUMMARY AND CONCLUSION

The current turbulence in the international and South African agricultural arena has led to uncertainty in this sector, which has a substantial impact on decision-making at farm level. Farmers are faced with an endless list of uncertainty about output prices, input prices, yields, weather conditions, etc. Since the outcomes of each decision on the farm are unpredictable, the farmer is subjected to a certain level of risk. The impact of PF plays an important role, since from the literature it became evident that PF has the ability to either worsen or to mitigate some of the risks present in farming.

Due to the high price volatility and general uncertainty in the South African agricultural market, risk is often a deciding factor in the decision-making process of a farmer. Various methods exist that are used to measure risk, such as volatility and VAR. The VAR method proved to be a better risk measurement method due to its ability to give an indication of the future riskiness of alternative strategies. Two probability sampling methods that are widely used are the Monte Carlo and Latin Hypercube sampling procedures. Due to its ability to ensure that all areas of a probability distribution are considered in a simulation, the Latin Hypercube sampling method has been identified as the most appropriate. Due to the complexity of the systems being analysed, simulation models are preferred above analytical models, since they have the capability to analyse risk in complex systems. Two types of models exist, namely stochastic and deterministic models, depending on the system to be analysed. In addition, two approaches can be followed, namely a normative approach or a positive approach, while the preferred choice in turn depends on the objective of modelling.

Since the research objective was to determine the impact of PF on the profitability of a maize irrigation farm, along with the common knowledge that farming always incorporates risk, a stochastic model was the obvious choice for this study. By using a stochastic simulation model as a decision-making tool in the presence of risk, a model could be constructed with uncertain variables (stochastic) but with known probability distributions. With stochastic simulation it is implied that uncertain economic systems, which are a function of risky variables, are simulated. The interaction between risky variables and other variables ensures that the risk involved in a given decision can be projected under different management strategies. Hence the likely outcomes of alternative management decisions under risk can be determined (Richardson, 2004).

Since actual historical data is used to simulate future behavioural trends, a positivistic approach was followed in order to determine the impact of PF on the profitability of a maize irrigation farm. In other words, the positivistic approach followed implies that an attempt was made to answer the question of “what is the likely outcome”.

The different farm-level models used to facilitate decision-making were identified and explored. These models include international models such as the FLIPSIM model, TIPI-CAL model, FES model, the models of Hardin (1978), Held and Helmers (1981) and Patrick and Eisgruber (1968), as well as the models developed by FAPRI. Models developed in South Africa include those of Louw (1979) and Meiring (1994). The BFAP farm-level model was identified as the preferable data and decision analysis tool. This stems from the fact that the linked system of the BFAP farm-level with the BFAP sector model has the ability to analyse the impact of changes in policies and markets at both farm and sector level in South Africa accurately. The stochastic process used in the BFAP farm-level model was also explained.

In Chapter 5 the case studies, baseline, input data and assumptions that apply to them are described. The selected farms were eventually simulated by means of the BFAP farm-level model, which was identified in this chapter as an appropriate tool for the purposes of the study, and the results explained.

CHAPTER 5

BACKGROUND, ANALYSIS AND RESULTS OF SELECTED FARMS

5.1 INTRODUCTION

The literature in the preceding chapters provided the platform on which the case studies of the selected farms and subsequent results were built, as described in this chapter. In order to improve the profitability of maize farmers and thus the overall wellbeing of the South African maize industry, technological advancement by means of precision farming (PF) were identified as one method to achieve sustainable profitability on the long run. It was therefore a logical step to investigate the impact of PF on the profitability of a maize farm. For this purpose, the Bureau for Food and Agricultural Policy (BFAP) farm-level model was identified in Chapter 4 as a suitable model to analyse the profitability of the different farming systems for each farm. The high-technology farming service provided by Griekwaland-Wes Koöperasie (GWK) to its clients in the Northern Cape Province creates an ideal setup in which to conduct the study.

For purposes of the study, three farms were selected by a panel of agricultural specialists, consisting of agronomists, soil scientists and agricultural economists. Data was obtained from the financial bureau of GWK and the participants, while all the relevant stakeholders were interviewed and provided assistance with the verification of the data.

In this chapter the input data, their assumptions, the baseline and analysing approach are described. The results obtained in the analyses are also presented and discussed in this chapter. The aim of this chapter is to finally achieve the main objectives and specific objectives as stated in Chapter 1. The hypothesis as stated in Chapter 1 will also ultimately be tested in this regard.

5.2 OVERVIEW AND INPUT DATA OF THE SELECTED FARMS

In order to illustrate the impact of PF on the profitability of a maize irrigation farm in the Northern Cape Province, the farms had to have three crucial features in order to provide an acceptable representation for the study. Firstly, in order to be able to make an adequate comparison between the profitability of conventional farming (CF) and precision farming (PF), the conventional farming method – meaning inputs are applied uniformly across the field without the use of new precision technology – should have initially been practised on the farms under investigation. These initial conventional farmers should have then converted their farming operations into PF, as per the definition provided the study. Secondly, the contribution of maize production to the total turnover of the farm would have to be significant in order to classify the farm as a maize production farm. Lastly, the farm would have to be located in the Northern Cape Province, especially in the GWK region where the PF service is mainly delivered. In order to comply with the criteria, a panel of seven agriculturalists, including two agricultural economists and five plant production and soil scientists, assisted in the selection process. The panel subsequently selected three farms that were truly representative of CF/PF farming in the Northern Cape Province. Data for the selected farms were obtained from the Financial Bureau of GWK and the farmers themselves. The selected farms were visited on various occasions for extensive interviews, as well as data verification and validation. The three farms selected were located in the Luckhoff, Douglas and Barkley-Wes districts respectively. The data and subsequent results were discussed with all the stakeholders involved in order to ensure the accuracy thereof.

Data for 2004 was used as the basis for the simulations. In other words, 2004 serves as the base year. The data collected included hectares planted, yields, input costs, fixed costs, output prices, assets and liabilities. The results were tested and refined after several discussions with all the relevant stakeholders and knowledgeable individuals in order to ensure the accuracy of the data. Simulation results for 2005, 2006, 2007 and part of 2008 were compared to actual data for these periods in order to verify and validate simulation results and thus the model itself. Tables 5.1 through 5.3 provide a summary of the general structure for each farm. It should be noted that data from the base year, 2004, as well as data from 2007 is depicted in Tables 5.1 to

5.3 in order to provide a broader insight into the financial positions of the respective farms over these periods and to indicate possible changes that might have occurred in the general structures of the farms.

- **Luckhoff farm**

The Luckhoff farm is located on the Northern Cape/Free State boundary, in the region of the Van der Kloof Dam, which is technically situated on the Free State side of the boundary. Water for irrigation is obtained from the Orange-Riet River water scheme. Conventional farming was practised up until June 2006, when the farmer officially started to implement the PF system of GWK. The first harvest of the newly implemented PF system was the wheat harvest in December 2006. The farm consists of a total area of 520 hectares whereof approximately 100 hectares are arable land under irrigation for wheat and maize production. Other farm enterprises include cotton and livestock production.

Table 5.1 shows that maize and wheat production contributed almost equally to the total turnover in 2004, with maize slightly higher at 22 percent of total turnover. Other income consists of livestock and cotton production. It should be noted that other income in 2004 was high at 58 percent due to a significant contribution by cotton production (no data other than total turnover for cotton production was available, hence its inclusion in other income). However, from 2007 onwards, the turnover composition of maize, wheat and other income changed drastically to approximately 62 percent, 33 percent and 4 percent respectively, mainly because the cotton enterprise was discontinued whilst the farmer had no intention of producing cotton in the near future. Cash farm expenses amounted to 116 percent of farm income, mainly due to 2004 being a poor harvest year. A better picture unfolded in 2007 with cash farm expenses being substantially lower at 67 percent of total cash farm income. Interest, debt principal payments and asset replacements were approximately 11 percent in both 2004 and 2007, 9 percent (5 percent in 2007) and 0 percent (1 percent in 2007) respectively. The farmer's net worth increased from R4.5 million in 2004 to R5.6 million in 2007, with the debt-to-asset ratio being constant at 25 percent.

Table 5.1: Summary of simulated data for the Luckhoff farm for 2004 and 2007

Description	2004		2007	
FARM AREA COMPOSITION	**Hectares**	**%**	**Hectares**	**%**
Maize	70	13%	101	19%
Wheat	40	8%	46	9%
Barley	0	0%	0	0%
Lucerne	0	0%	0	0%
Other	410	79%	379	72%
Total area[16]	**520**		**526**	
ANNUAL CONTRIBUTION TO TURNOVER	**Rand**	**% (of turnover)**	**Rand**	**% (of turnover)**
Maize	386 708	22%	2 214 781	62%
Wheat	344 077	20%	1 188 778	33%
Barley	-	-	0	-
Lucerne	-	-	0	0%
Other income	989 061	58%	153 932	4%
FARM INCOME AND COST COMPOSITION	**Rand**	**% (of farm income)**	**Rand**	**% (of farm income)**
Cash farm income	1 719 846	100%	3 557 491	100%
Cash farm expenses	1 996 568	116%	2 391 156	67%
Interest	188 943	11%	392 669	11%
Debt principal payments	158 935	9%	182 169	5%
Asset replacement payments	-	-	33 865	1%
FARM FINANCIAL POSITION	**Rand**	**%**	**Rand**	**%**
Total assets	5 985 342	-	7 508 389	-
Total liabilities	1 511 402	-	1 888 046	-
Net worth	4 473 940	-	5 620 343	-
Debt to asset ratio	-	25%	-	25%

- **Douglas farm**

The Douglas farm is situated in the region between Douglas and Kimberley. This farm obtains water for irrigation from the Vaal and Riet rivers. Table 5.2 shows that maize, wheat and lucerne are the main enterprises at 19 percent, 23 percent and 17 percent of the total farm area respectively. Other land makes up approximately 42 percent of the total area. A significant increase in area planted with maize in 2007 (from 19 to 28 percent) can be observed, together with a smaller increase in wheat planted (from 23 to 24 percent), all at the expense of lucerne (from 17 to 11 percent in 2007). In 2004 lucerne was the major contributor to the annual total turnover of the

[16] Total area includes double cropping area.

farm at 40 percent, followed by maize, wheat and other income at 31 percent, 19 percent and 10 percent respectively. However, in the period leading up to 2007 a shift occurred with wheat (41 percent) and maize (40 percent) as the major contributors to the annual total turnover, followed by lucerne (17 percent) and other income (2 percent). Other income includes income from livestock and horticulture. Total cash farm expenses decreased from 90 percent in 2004 to 70 percent of the total cash farm income, indicating possible favourable farming conditions and more efficient farm management. Interest payments were almost constant at 14 percent of total turnover in 2004 and 13 percent in 2007. Debt principal payments decreased from 12 percent in 2004 to 5 percent in 2007. The more favourable position due to higher farm income relative to farm expenses also resulted in more asset replacements, which explains the increase in asset replacement payments from zero percent of cash farm income in 2004 to 3 percent in 2007. The debt-to-asset ratio varied from 43 percent in 2004 to 46 percent in 2007, indicating that this farm was highly dependent on debt to finance its assets and operations.

Table 5.2: Summary of simulated data for the Douglas farm for 2004 and 2007

Description	2004		2007	
FARM AREA COMPOSITION	**Hectares**	**%**	**Hectares**	**%**
Maize	80	19%	128	28%
Wheat	95	23%	110	24%
Barley	0	0%	0	0%
Lucerne	70	17%	50	11%
Other	174	42%	174	38%
Total area[17]	**419**		**462**	
ANNUAL CONTRIBUTION TO TURNOVER	**Rand**	**% (of turnover)**	**Rand**	**% (of turnover)**
Maize	871 299	31%	1 857 600	40%
Wheat	536 729	19%	1 895 884	41%
Barley	-	-	-	-
Lucerne	1 105 750	40%	766 646	17%
Other income	283 935	10%	77 082	2%
FARM INCOME AND COST COMPOSITION	**Rand**	**% (of farm income)**	**Rand**	**% (of farm income)**
Cash farm income	2 797 713	100%	4 597 212	100%
Cash farm expenses	2 525 524	90%	3 226 342	70%
Interest	404 784	14%	597 427	13%
Debt principal payments	322 554	12%	249 794	5%
Asset replacement payments	14 569	-	154 223	3%
FARM FINANCIAL POSITION	**Rand**	**%**	**Rand**	**%**
Total assets	10 758 476	-	11 822 702	-
Total liabilities	4 644 626	-	5 401 491	-
Net worth	6 113 850	-	6 421 211	-
Debt to asset ratio	-	43%	-	46%

- **Barkley-Wes farm**

The Barkley-Wes farm is situated in the Barkley-Wes/Kimberley region alongside the Vaal River and the Vaalharts irrigation scheme channels, which are subsequently the sources of irrigation water. It should be noted that this farmer was already practising biological farming at the time of the study and hence yields were already a little above average compared to other farms in this region.

It is important to note that the Barkley-Wes farm consists of two farm enterprises, namely grains and livestock, which are interconnected. Half of the maize produced by the grain enterprise is processed into feed pellets used as input in the livestock

[17] Total area includes double cropping area.

enterprise. It was therefore difficult to accurately determine the impact of PF on the profitability of the Barkley-Wes farm, since the value of the maize being processed into feed pellets could not be accounted for. In order to assail the problem, the value of the maize being processed into feed pellets was handled as maize “sold” by the grain enterprise to the livestock enterprise. The value of the processed maize was calculated by multiplying the amount in tons of processed maize by the average price the farmer received for the other half of maize actually sold on the market. The same process was followed with the farm under a CF system. In this way, the impact of PF on the profitability of the Barkley-Wes farm could be determined. For purposes of the study, the focus was on the grain enterprise of the Barkley-Wes farm.

In 2004, the grain enterprise of the Barkley-Wes farm consisted of maize (11 percent of total farm area), wheat (8 percent), barley (8 percent) and lucerne (2 percent). The remaining 71 percent of the total farm area consisted of other land not being cultivated. Maize was the major contributor to the annual turnover in 2004 at 37 percent, followed by barley (22 percent), wheat (18 percent), other income (19 percent) and lucerne (5%). Other income consists of feed production. In 2007 the annual turnover was equally distributed amongst maize, barley and other income at 25 percent, followed by wheat and lucerne at 20 percent and 4 percent respectively. An expansion in the area planted can be observed for all the crops in 2007 compared to 2004. The turnover composition in 2007 indicates that the farm was more balanced in terms of diversification, thereby reducing production and price risks in case of drastic adverse price and yield fluctuations.

Cash farm expenses accounted for about 104 percent and 79 percent in 2004 and 2007 respectively, again indicating less favourable farming conditions in 2004. Interest payments decreased from 17 percent of total farm income in 2004 to 9 percent in 2007. Debt principal payments also decreased from 19 percent of farm income to just 5 percent in 2007, indicating a better debt position of the farm. The more favourable debt position of the Barkley-Wes farm in 2007 is confirmed by the debt-to-asset ratio, indicating that debt-to-assets was 31 percent in 2007 as opposed to 44 percent in 2004. The net worth increased from approximately R4.78 million in 2004 to R6.64 million in 2007.

Table 5.3: Summary of simulated data for the Barkley-Wes farm for 2004 and 2007

Description	2004		2007	
FARM AREA COMPOSITION	**Hectares**	**%**	**Hectares**	**%**
Maize	80	11%	105	12%
Wheat	55	8%	94	11%
Barley	55	8%	110	13%
Lucerne	17	2%	52	6%
Other	510	71%	510	59%
Total area[18]	**717**		**871**	
ANNUAL CONTRIBUTION TO TURNOVER	**Rand**	**% (of turnover)**	**Rand**	**% (of turnover)**
Maize	823 962	37%	1 405 981	25%
Wheat	397 520	18%	1 160 675	20%
Barley	480 095	22%	1 434 129	25%
Lucerne	115 252	5%	240 808	4%
Other income	415 319	19%	1 421 780	25%
FARM INCOME AND COST COMPOSITION	**Rand**	**% (of farm income)**	**Rand**	**% (of farm income)**
Cash farm income	2 232 148	100%	5 663 373	100%
Cash farm expenses	2 322 544	104%	4 463 946	79%
Interest	383 012	17%	532 303	9%
Debt principal payments	422 655	19%	255 571	5%
Asset replacement payments	0	-	0	0%
FARM FINANCIAL POSITION	**Rand**	**%**	**Rand**	**%**
Total assets	8 500 817	-	9 639 674	-
Total liabilities	3 716 563	-	3 002 497	-
Net worth	4 784 254	-	6 637 177	-
Debt to asset ratio	-	44%	-	31%

5.3 THE BASELINE

The baseline consists of projections based on a series of assumptions about the general economy, agricultural policies, the weather, and technological changes. Institutions such as Global Insight, FAPRI, ABSA Bank and the Actuarial Society of South Africa provide forecasts on which the macro-economic assumptions of the baseline were based.

The baseline was also based on simulations from the BFAP sector model for input costs, yields and prices for the period 2009 to 2011. The baseline simulations thus

[18] Total area includes double cropping area.

indicate what the possible outlook for the farms under consideration could be, given a specific set of assumptions. An important assumption regarding the baseline is that the world economies would grow according to adjusted projections developed by Global Insight, while productivity in general would increase in line with past trends. The outlook of world commodity prices was adopted from an updated version of the FAPRI 2008 US and World Agricultural Outlook. The macro-economic indicators and world commodity prices were then used to generate the outlook for input costs, yields and prices as used in the baseline projections. The deterministic outlooks of macro-economic indicators and world commodity prices are presented by Tables 5.4 and 5.5 respectively.

- **Oil prices**

According to the BFAP baseline of 2008, global economic growth is expected to slow down as a result of high energy and food prices, as well as slower growth in developed countries. As a result, demand for energy is likely to slow down somewhat and oil prices are projected to remain between $76 and $69 for the period 2009 to 2011.

- **Population**

Population growth is a key driver in the demand for food (BFAP, 2008). The baseline indicates that the total population in South Africa is projected to increase from 47.73 million to a level of 48.13 million in 2011.

- **Exchange rate**

The Rand/US Dollar exchange rate is one of the main driving forces behind price levels and trade volumes of food in the South African agricultural sector (BFAP, 2008). The Rand is projected to gradually depreciate against the US Dollar from approximately R7.53/US$ in 2009 to R8.32 in 2011.

- **GDP per capita**

Gross domestic product (GDP) is an important key driver of demand for food (BFAP, 2008). Against the backdrop of declining global economic growth, economic growth in South Africa is expected to slow down in 2008 and 2009 due to pressure on consumer expenditure and constraints on the supply side. Real GDP growth per capita in South Africa is expected to decrease after 2008 and 2009 and then increase again as from 2010 onwards to a level of R21 342 in 2011 in real terms.

- **Consumer price index (CPI)**

The CPI as indicator of inflation plays an important role as a driving-force behind price levels. The baseline projected the CPI to constantly increase from an index of 185.54 in 2009 to a level of 205.58 in 2011 (2000 as base year).

- **Interest rates**

The South African prime interest rate is projected to remain constant and only increase minimally from 13.56 in 2009 to 13.69 in 2011.

- **World grain prices**

World grain prices rose sharply during the 2007/08 season due to unfavourable weather conditions that resulted in supply shortages, but are projected to decrease again slightly between 2009 and 2011 as a result of increased supply.

Table 5.4: Outlook of macro-economic indicators for the period 2009 to 2011

Indicator	Unit	Year		
		2009	**2010**	**2011**
US refiners' acquisition oil price	US$/barrel	76.15	69.82	69.26
Total population of SA	Millions	47.79	47.96	48.13
Exchange rate	SA cent/US$	752.70	792.96	831.71
South African real GDP per capita	R/capita	19 205.46	20 226.03	21 342.16
CPI: Food	Index (2000=100)	185.54	195.80	205.58
Interest rate (prime)	%	13.56	13.63	13.69

Source: BFAP (2008), adjusted from Global Insight

Table 5.5: Outlook of world commodity prices for the period 2009 to 2011

Indicator	Unit	Year		
		2009	**2010**	**2011**
Yellow maize, US No.2, fob, Gulf	US$/ton	194.59	193.61	188.32
Wheat, US No. 2 HRW fob (ord) Gulf	US$/ton	251.28	248.20	246.64
Barley, SPG malting scarlett, France FOB	US$/ton	336.58	332.47	330.37

Source: BFAP (2008), adjusted from the FAPRI 2008 baseline

The South African input cost and commodity price projections that were generated by the BFAP sector model are presented in Tables 5.6 and 5.7 respectively. Input prices are projected to increase constantly from 2009 to 2011 due to depreciation in the exchange rate. Grain prices are also projected to increase from 2009 to 2011 in response to the depreciation of the Rand against the US Dollar. Only yellow maize is included in the commodity price projections (Table 5.7), since all the farms involved produce only yellow maize.

Table 5.6: Deterministic input cost projections

Variable	Unit	Year		
		2009	**2010**	**2011**
Fuel	Index (2000=100)	218.26	230.32	241.83
Fertilizer	Index (2000=100)	211.07	222.74	233.87
Requisites	Index (2000=100)	200.70	211.78	222.37
Intermediate goods	Index (2000=100)	200.44	211.52	222.10

Source: BFAP (2008)

Table 5.7: Deterministic South African commodity price projections

Variable	Unit	Year		
		2009	**2010**	**2011**
Yellow maize producer price	R/ton	1,801.0	1,890.2	1,909.9
Wheat producer price	R/ton	3,541.8	3,668.8	3,830.4
Barley producer price	R/ton	3,099.6	3,251.4	3,407.6

Source: BFAP (2008)

It is important to simulate the impact of PF on the maize irrigation farms as realistically as possible. At the time of conducting the empirical analysis of this study, the BFAP baseline of 2008 provided the latest updates regarding the macro-economic and world price outlooks. This suggests that economic indicators and prices in the baseline are as realistic as possible in order to enable accurate farm-level simulations, which consequently justifies the use of the BFAP baseline of 2008 for this particular study.

The generated input costs and commodity prices in the BFAP sector model are subsequently applied in the BFAP farm-level model for each farm under consideration. The approach that was followed in the analysis process is discussed in section 5.4 that follows. The importance of the BFAP baseline in this process is emphasised, since it plays a crucial role in projecting the KOVs that were used to determine the impact of PF.

5.4 ANALYSIS APROACH

5.4.1 General approach to farm-level analysis

Each farm was simulated and analysed based on the assumption that the farm was being operated from the base year (2004) through 2011 by means of conventional farming (CF). Conventional farming means that all inputs are applied uniformly regardless of the specific requirements of a specific spot in the cultivated area. The farm was then simulated for a second time under the assumption that PF had been implemented in a specific year. In this regard, PF refers to the high-technology farming system as implemented by GWK in the Northern Cape Province (Chapter 3). In short, the farm under the CF assumptions formed the "benchmark" against which the impact of PF was measured.

Key output variables (KOVs) were identified and used in the simulations. The KOVs that formed the focus of the study to compare the profitability of PF and CF were net farm income[19], cash surplus or deficit[20] and the debt-to-asset ratio[21]. The purpose of analysing these specific key output variables was to achieve the objectives and hypothesis as stated in Chapter 1. The specific objectives as set out in Chapter 1 were as follows:

- To determine whether PF would generate better profits;
- To determine whether PF would improve the farmer's ability to repay his debt and generate an income (thereby improving the financial survivability of the farm);

[19] Net farm income is calculated as total cash farm income minus total cash farm expenses, interest and depreciation.

[20] Cash surplus or deficit is the total cash inflows (cash reserves; net cash farm income; non-farm income; interest on cash reserves; and positive cash difference after asset replacement), minus total cash outflows (net cash farm loss; non-farm expenses; negative cash difference after asset replacement; principals on debt; interest; and taxes), expressed in Rand.

[21] The debt-to-asset ratio is total assets divided by the total liabilities, expressed as a percentage.

- To determine whether PF would improve the debt position of the farmer; and
- To determine whether PF is less risky than CF with respect to net farm income and cash position.

The analyses were done in both deterministic and stochastic modes. Key output variables that were deterministically analysed were net farm income, cash surplus or deficit and debt-to-asset ratio, while net farm income and cash surplus or deficit were analysed stochastically. The stochastic results also indicate the risks involved and since probability theory was incorporated, the stochastic results indicate probabilities of each specific KOV being higher than a specified value. The approach to the stochastic analyses is described in more detail in section 5.4.3, while the analysis of PF relative to CF is discussed in section 5.4.2 to follow.

5.4.2 Approach to analysing PF in comparison with CF

The baseline and the assumptions applicable to the baseline, as explained in section 5.3, are identical in both the CF and PF analyses. Furthermore, the assumptions with regard to the BFAP farm-level model (Chapter 4) and the general assumptions as set out in Chapter 1 are also applicable. Thus, both CF and PF systems are simulated under the same baseline and BFAP farm-level model assumptions.

In order to simulate the impact of PF on the profitability of the participating farms relative to CF, key input variables were identified. The key input variables were identified by determining those variables with a significant impact on the profitability of a farm when technologies are brought into consideration. From this perspective, the features and benefits of PF as discussed in Chapter 3 were used as a starting point to determine the key input variables. Actual data obtained from GWK and the participating farms was used for the period 2004 to 2008. It is important to distinguish between the two farming systems in terms of data as well as the type of crop under consideration. Since the first harvest under the PF system was obtained in 2006 for winter crops (wheat and barley), data for PF is applicable from 2006 for winter crops. Subsequently, the first summer crop (maize) harvest took place in 2007 and applied as such.

The key input variables used in the analyses are quantitatively presented in Tables 5.8 through 5.14 by means of calculated trends. In Tables 5.8 through 5.14 it can be observed that actual data is included in the tables for the base year (2004). From 2005 trends were used to quantify the key input variables used for each year. The trends for each year were determined by calculating the percentage change from the base year. It is important to note that the trends for the period 2005 to 2008 are based on actual farm data. The trends from 2009 onwards are based on the assumptions of the features and benefits associated with PF, the BFAP baseline projections and historical data, and were subsequently applied as such in the simulations. In Tables 5.8 to 5.14 the yellow shaded cells indicate the period from which PF was implemented in order to compare the two systems (PF and CF) with each other. Again, it should be noted that 2006 was the year when the first harvest for winter crops (wheat and barley) under the PF system took place, while the first harvest for summer crops (maize) took place in 2007. For the CF trends, the baseline projections start from 2007 for maize and 2006 for winter crops, because the farmers switched to PF and no data subsequently exists for CF for these years. For this reason, the baseline projections were used in order to enable comparisons between CF and PF. For the PF trends, the baseline projections start from 2009 for both summer and winter crops. The baseline projections are indicated in blue text in Tables 5.8 through 5.14. The trends for the CF system reflect the yield and input costs of the farms under the assumption that the farmer did not implement PF. The benefits of PF (such as improved yields and lower input costs) thus do not apply in the CF simulations. The PF trends (expressed as percentage change from the base year 2004) reflect the yields and input costs after the farmer switched to PF. It is emphasised that the PF trends are also based on the base year data of CF in order to enable comparisons of the various trends between CF and PF. It should be noted that although some of the farms might have produced crops other than maize, wheat and barley (for example, lucerne), these crops were not produced under the PF system and therefore are not included for comparison.

Since output prices are not dependant on the type of farming system (CF or PF), it is important to note that the output prices for each farm were kept the same for both CF and PF analyses. Consequently output prices should be ruled out as a factor that can influence profitability and risk when comparing the two farming systems.

The trends of the key input variables for the respective farms as presented in Tables 5.8 through 5.14 are explained in the sub-sections to follow. In order to understand these tables, the legend that accompanies each table should be consulted. It should be kept in mind that the purpose of the tables is to compare the trends between the CF and PF farming systems.

- **Key input variable trends for the Luckhoff farm**

Based on actual data, projections from the BFAP baseline and evidence on the benefits of PF as presented in Chapter 3, trends for the yellow maize enterprise of the Luckhoff farm indicate that yields under the PF system increase with an average of 6 basis points for the period 2007 to 2011 relative to CF (Table 5.8). Table 5.8 further suggests that fertilizer costs are on average 1 basis point lower with PF relative to CF over the same period. This implies that PF does not necessarily lower fertilizer costs but rather that fertilizer is applied more efficiently according to the soil requirements of a specific area in the field. In other words, in certain areas with lower soil potential less fertilizer is applied, as opposed to high potential soils on which more fertilizer is applied. Fuel, herbicide and seed costs are respectively on average 5, 4 and 3 basis points lower with PF relative to CF. More drastic savings on insecticide cost can be observed with an average of 49 basis points, followed by water cost with an average of 15 basis points lower under the PF system. As expected, PF fees increase the variable costs of PF relative to CF, because there are no PF costs involved with CF. From Table 5.8 it can thus be observed that an additional cost of R91 per hectare is introduced for PF from 2007, followed by its trend. Irrigation cost (sprinklers, pipes and maintenance of irrigation equipment) is expected to remain the same for both CF and PF systems, since it is not significantly influenced by the implementation of PF.

Table 5.8: Quantitative comparison of key input variables under the CF and PF systems for the Luckhoff farm: Yellow maize production

Variable	Base year	Percentage change from base year						
	2004	2005	2006	2007	2008	2009	2010	2011
CONVENTIONAL FARMING								
Yield (ton/ha):	**10.68**	36%	40%	**19%**	**44%**	**38%**	**40%**	**41%**
Expenses (R/ha):								
Fertilizer	**2,124**	24%	62%	**128%**	**137%**	**149%**	**156%**	**167%**
Fuel	**263**	30%	50%	**82%**	**108%**	**119%**	**121%**	**129%**
Herbicide	**317**	-3%	1%	**26%**	**27%**	**47%**	**55%**	**63%**
Insecticide[17]	**-**	**R89**	-1%	**6%**	**14%**	**22%**	**29%**	**35%**
Irrigation electricity	**359**	-28%	12%	**3%**	**11%**	**20%**	**26%**	**33%**
Seed	**1,257**	-5%	10%	**29%**	**70%**	**67%**	**76%**	**85%**
Irrigation cost	**13**	136%	135%	**156%**	**199%**	**195%**	**211%**	**227%**
Water	**464**	-14%	21%	**8%**	**20%**	**25%**	**31%**	**38%**
Precision farming	**N/A**	N/A	N/A	N/A	N/A	N/A	N/A	N/A
PRECISION FARMING								
Yield (ton/ha):	**-**	**-**	**-**	24%	51%	**45%**	**46%**	**48%**
Expenses (R/ha):								
Fertilizer	**-**	**-**	**-**	128%	137%	**148%**	**155%**	**166%**
Fuel	**-**	**-**	**-**	74%	102%	**115%**	**117%**	**124%**
Herbicide	**-**	**-**	**-**	18%	27%	**44%**	**52%**	**59%**
Insecticide[17]	**-**	**-**	**-**	25%	-82%	**-31%**	**-27%**	**-24%**
Irrigation electricity	**-**	**-**	**-**	-20%	-4%	**10%**	**16%**	**22%**
Seed	**-**	**-**	**-**	29%	68%	**65%**	**75%**	**83%**
Irrigation cost	**-**	**-**	**-**	156%	199%	**195%**	**211%**	**227%**
Water	**-**	**-**	**-**	-7%	7%	**10%**	**16%**	**22%**
Precision farming[18]	**-**	**-**	**-**	**R91**	27%	**45%**	**53%**	**61%**

Legend:

- Black text: Actual data (CF: 2004-2006; PF: 2007-2008)
- Blue text: Projections from the BFAP baseline (CF: 2007-2011; PF: 2009-2011)
- Yellow shaded area: Period when enterprise was converted to PF (from 2007 onwards)
- Both CF and PF trends indicate the percentage change from the base year (2004 or as indicated otherwise)

Actual data from Table 5.9 indicates that wheat yields are between 2 and 8 basis points higher under the PF system when compared to CF during 2006 to 2008. The

[17] The base year for insecticide is 2005 since no data exists for 2004. The trend (from 2006) for insecticide is thus based on R89 per hectare in 2005.
[18] PF was implemented from 2007 onwards. The subsequent trend for PF costs is therefore based on R91 per hectare in 2007.

trend is expected to remain 8 basis points higher for the PF system relative to CF from 2009 to 2011. Input costs in the wheat enterprise such as fertilizer (1 basis point), fuel (6 basis points), electricity (13 basis points), seed (8 basis points), and water cost (10 basis points) seem to remain lower with PF relative to CF for the period 2006 to 2011 (Table 5.9). Insecticide cost is higher with PF (3 basis points), which could be ascribed to corrections of pests problems being done in the fields. Irrigation cost is expected to remain the same for both farming systems, while the introduction of a PF service fee in the PF system led to higher variable costs for PF relative to CF in this regard. Again, it should be noted that the trends are based on actual data obtained from GWK and the farmer, projections from the BFAP baseline (Section 5.3) and reported benefits of PF (Chapter 3), which are expected to continue in the future.

Table 5.9: Quantitative comparison of key input variables under the CF and PF systems for the Luckhoff farm: Wheat production

Variable	Base year	Percentage change from base year						
	2004	2005	2006	2007	2008	2009	2010	2011
CONVENTIONAL FARMING								
Yield (ton/ha):	**8.45**	-5%	**-16%**	**-3%**	**6%**	**-2%**	**7%**	**-1%**
Expenses (R/ha)								
Fertilizer	**1,613**	53%	**17%**	**128%**	**269%**	**255%**	**291%**	**280%**
Fuel	**218**	14%	**46%**	**66%**	**129%**	**101%**	**134%**	**110%**
Herbicide	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Insecticide	**28**	2%	**152%**	**235%**	**626%**	**35%**	**185%**	**50%**
Irrigation electricity	**278**	26%	**17%**	**17%**	**43%**	**38%**	**60%**	**53%**
Seed	**243**	-15%	**22%**	**14%**	**97%**	**71%**	**120%**	**89%**
Irrigation cost	**-**	**R25**	**7%**	**16%**	**27%**	**34%**	**41%**	**49%**
Water	**400**	39%	**19%**	**12%**	**14%**	**34%**	**27%**	**48%**
Precision farming	**N/A**	N/A	N/A	N/A	N/A	N/A	N/A	N/A
PRECISION FARMING								
Yield (ton/ha):	**-**	**-**	-14%	3%	13%	**6%**	**15%**	**7%**
Expenses (R/ha)								
Fertilizer	**-**	**-**	17%	128%	269%	**254%**	**289%**	**278%**
Fuel	**-**	**-**	46%	57%	125%	**93%**	**130%**	**101%**
Herbicide	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Insecticide	**-**	**-**	152%	240%	626%	**41%**	**185%**	**57%**
Irrigation electricity	**-**	**-**	12%	2%	27%	**31%**	**34%**	**45%**
Seed	**-**	**-**	-9%	15%	93%	**68%**	**109%**	**86%**
Irrigation cost	**-**	**-**	7%	16%	27%	**34%**	**41%**	**49%**
Water	**-**	**-**	19%	7%	-5%	**23%**	**11%**	**37%**
Precision farming[22]	**-**	**-**	**R108**	9%	19%	**25%**	**32%**	**39%**

Legend:

- Black text: Actual data (CF: 2004-2005; PF: 2006-2008)
- Blue text: Projections from the BFAP baseline (CF: 2006-2011; PF: 2009-2011)
- Yellow shaded area: Period when enterprise was converted to PF (from 2006 onwards)
- Both CF and PF trends indicate the percentage change from the base year (2004 or as indicated otherwise)

22 Since PF was implemented from 2006 onwards. The subsequent trends for PF costs are therefore based on R108 per hectare in 2006.

- **Key input variable trends for the Douglas farm**

Table 5.10 indicates that yellow maize yields for the Douglas farm are on average 5 basis points higher from 2007 to 2008 under the PF system in comparison with CF. Evidence from Chapter 3 suggests that this trend can be expected to continue during 2009 to 2010, since PF is associated with higher yields. Comparisons between PF and CF for input cost in the maize enterprise in Table 5.10 show that savings are achieved for fuel (with an average of 6 basis points), herbicide and insecticide (5 basis points), irrigation electricity (4 basis points), seed (6 basis points) and water cost (11 basis points) by implementing a PF system. Fertilizer costs are expected to be lower for PF with an average of 1 basis point from 2009 to 2011. The PF costs are introduced in the PF system which subsequently increases its variable costs with R118 per hectare from 2007 (and with the resultant trend) in comparison with CF. Table 5.10 shows that irrigation cost and herbicide and insecticide cost have a negative percentage change from the base year for both systems. The reason is that the costs of the mentioned inputs were above normal in the base year for this particular farm. The trends that follow after the base year only show a correction back to normal, hence the negative changes. Irrigation cost is projected to be the same for both systems.

Table 5.10: Quantitative comparison of key input variables under the CF and PF systems for the Douglas farm: Yellow maize production

Variable	Base year	Percentage change from base year						
	2004	2005	2006[23]	2007	2008	2009	2010	2011
CONVENTIONAL FARMING								
Yield (ton/ha):	**11.89**	-7%	-	**-7%**	**6%**	**10%**	**10%**	**11%**
Expenses (R/ha):								
Fertilizer	**1,744**	71%	-	**76%**	**216%**	**226%**	**236%**	**250%**
Fuel	**451**	-30%	-	**14%**	**108%**	**72%**	**73%**	**79%**
Herbicide & insecticide	**1,701**	-96%	-	**-66%**	**-65%**	**-63%**	**-61%**	**-59%**
Irrigation electricity	**461**	-39%	-	**26%**	**63%**	**61%**	**70%**	**79%**
Seed	**1,039**	4%	-	**4%**	**101%**	**112%**	**124%**	**135%**
Irrigation cost	**1,762**	-92%	-	**-85%**	**-80%**	**-79%**	**-78%**	**-77%**
Water	**202**	-54%	-	**0%**	**177%**	**193%**	**209%**	**224%**
Precision farming	**N/A**	N/A	N/A	N/A	N/A	N/A	N/A	N/A
PRECISION FARMING								
Yield (ton/ha):	-	-	-	-2%	10%	**15%**	**16%**	**17%**
Expenses (R/ha):								
Fertilizer	-	-	-	76%	216%	**226%**	**235%**	**249%**
Fuel	-	-	-	10%	104%	**64%**	**65%**	**71%**
Herbicide & insecticide	-	-	-	-68%	-71%	**-69%**	**-67%**	**-66%**
Irrigation electricity	-	-	-	21%	57%	**58%**	**67%**	**75%**
Seed	-	-	-	0%	94%	**105%**	**117%**	**127%**
Irrigation cost	-	-	-	-85%	-80%	**-79%**	**-78%**	**-77%**
Water	-	-	-	-6%	169%	**179%**	**195%**	**209%**
Precision farming[24]	-	-	-	**R118**	59%	**68%**	**77%**	**86%**

Legend:

- Black text: Actual data (CF: 2004-2005; PF: 2007-2008)
- Blue text: Projections from the BFAP baseline (CF: 2007-2011; PF: 2009-2011)
- Yellow shaded area: Period when enterprise was converted to PF (from 2007 onwards)
- Both CF and PF trends indicate the percentage change from the base year (2004 or as indicated otherwise)

For the wheat enterprise of the Douglas farm, higher yields (between 6 and 12 basis points) were obtained for PF relative to CF from 2006 to 2008 (Table 5.11). In line with evidence collected from the farmers and GWK as discussed in Chapter 3, and the BFAP baseline, wheat yields are expected to be 12 basis points higher with PF relative to CF in from 2009 to 2011. Furthermore, input costs are lower for herbicide

[23] No maize was planted in 2006 on the Douglas farm.
[24] PF was implemented from 2007 onwards. The subsequent trend for PF costs is therefore based on R118 per hectare in 2007.

and insecticide (with an average of 7 basis points), irrigation electricity (4 basis points), seed (1 basis point) and water (10 basis points) under the PF system. Irrigation cost is the same for both systems, while PF costs are introduced in the PF system from 2007 onwards. Surprisingly, fuel cost is on average 31 basis points higher under the PF system from 2008 to 2011 as opposed to an average decline of 2 basis points during 2006 and 2007 wit PF relative to CF. A possible explanation for this phenomenon could be that higher fuel costs were incurred by the farmer in his quest to correct chemical imbalances in the field. The higher fuel costs associated with PF in this regard were obtained from actual data from the farm and are projected to continue from 2009 to 2011 (Table 5.11).

Table 5.11: Quantitative comparison of key input variables under the CF and PF systems for the Douglas farm: Wheat production

Variable	Base year	Percentage change from base year						
	2004	2005	2006	2007	2008	2009	2010	2011
CONVENTIONAL FARMING								
Yield (ton/ha):	**5.73**	22%	**-4%**	**15%**	**16%**	**16%**	**17%**	**18%**
Expenses (R/ha):								
Fertilizer	**2,295**	6%	**23%**	**74%**	**105%**	**112%**	**118%**	**127%**
Fuel	**415**	69%	**18%**	**81%**	**83%**	**86%**	**88%**	**94%**
Herbicide & insecticide	**212**	-22%	**288%**	**17%**	**28%**	**35%**	**43%**	**50%**
Irrigation electricity	**446**	8%	**73%**	**39%**	**52%**	**60%**	**69%**	**78%**
Seed	**709**	-32%	**-8%**	**-55%**	**28%**	**35%**	**43%**	**50%**
Irrigation cost	**680**	-76%	**-64%**	**-61%**	**-57%**	**-55%**	**-52%**	**-50%**
Water	**228**	45%	**76%**	**74%**	**90%**	**101%**	**112%**	**122%**
Precision farming	**N/A**	N/A	N/A	N/A	N/A	N/A	N/A	N/A
PRECISION FARMING								
Yield (ton/ha):	-	-	2%	26%	28%	**28%**	**29%**	**30%**
Expenses (R/ha):								
Fertilizer	-	-	23%	74%	105%	**112%**	**117%**	**126%**
Fuel	-	-	16%	79%	114%	**117%**	**119%**	**126%**
Herbicide & insecticide	-	-	285%	10%	20%	**27%**	**34%**	**41%**
Irrigation electricity	-	-	70%	35%	48%	**56%**	**65%**	**73%**
Seed	-	-	-8%	-59%	28%	**35%**	**43%**	**50%**
Irrigation cost	-	-	-64%	-61%	-57%	**-55%**	**-52%**	**-50%**
Water	-	-	63%	66%	81%	**91%**	**102%**	**112%**
Precision farming[25]	-	-	**R99**	103%	121%	**134%**	**147%**	**159%**

Legend:

- Black text: Actual data (CF: 2004-2005; PF: 2006-2008)
- Blue text: Projections from the BFAP baseline (CF: 2006-2011; PF: 2009-2011)
- Yellow shaded area: Period when enterprise was converted to PF (from 2006 onwards)
- Both CF and PF trends indicate the percentage change from the base year (2004 or as indicated otherwise)
- Negative trends of irrigation cost indicate that above normal high costs were incurred in the base year, with a subsequent move back to normal in years to follow

[25] PF was implemented from 2006 onwards. The subsequent trend for PF costs is therefore based on R99 per hectare in 2006.

- **Key input variable trends for the Barkley-Wes farm**

Table 5.12 shows that yellow maize yields under the PF system are on average 8 basis points higher than yields under a CF system. Fuel (with an average of 1 basis point), herbicide and insecticide (5 basis points), irrigation electricity (2 basis points), seed (2 basis points) and water (16 basis points) are lower with PF relative to CF. Fertilizer costs did not differ significantly between PF and CF systems during 2007 and 2008, although it is expected to decrease with 1 basis point relative to CF from 2009 onwards. Although irrigation cost trends are similar for both systems, a PF fee of R150 per hectare is introduced in 2007 in the PF system which increases its variable cost with this amount (and subsequent trend) with respect to CF.

Table 5.12: Quantitative comparison of key input variables under the CF and PF systems for the Barkley-Wes farm: Yellow maize production

Variable	Base year	Percentage change from base year						
	2004	2005	2006	2007	2008	2009	2010	2011
CONVENTIONAL FARMING								
Yield (ton/ha):	**9.68**	22%	12%	**-11%**	**4%**	**7%**	**8%**	**9%**
Expenses (R/ha)								
Fertilizer	**2,896**	-19%	-18%	**-32%**	**108%**	**110%**	**116%**	**125%**
Fuel	**1,031**	-23%	-15%	**-46%**	**-6%**	**-4%**	**-4%**	**0%**
Herbicide & insecticide	**381**	69%	-67%	**79%**	**52%**	**61%**	**70%**	**79%**
Irrigation electricity	**816**	-50%	-71%	**-26%**	**-38%**	**-34%**	**-31%**	**-27%**
Seed	**859**	22%	11%	**46%**	**40%**	**48%**	**56%**	**64%**
Irrigation cost	**3,347**	-87%	-98%	**-86%**	**-84%**	**-83%**	**-82%**	**-81%**
Water[26]			**R119**	**403%**	**523%**	**552%**	**583%**	**612%**
Precision farming	**N/A**	N/A	N/A	N/A	N/A	N/A	N/A	N/A
PRECISION FARMING								
Yield (ton/ha):	-	-	-	-6%	10%	**17%**	**18%**	**19%**
Expenses (R/ha)								
Fertilizer	-	-	-	-32%	108%	**109%**	**115%**	**124%**
Fuel				-48%	-7%	**-6%**	**-5%**	**-2%**
Herbicide & insecticide	-	-	-	75%	48%	**57%**	**65%**	**73%**
Irrigation electricity	-	-	-	-28%	-39%	**-36%**	**-32%**	**-29%**
Seed	-	-	-	44%	38%	**46%**	**54%**	**62%**
Irrigation cost	-	-	-	-86%	-84%	**-83%**	**-82%**	**-81%**
Water	-	-	-	390%	508%	**536%**	**566%**	**594%**
Precision farming[27]	-	-	-	**R150**	132%	**139%**	**147%**	**155%**

Legend:

- Black text: Actual data (CF: 2004-2006; PF: 2007-2008)
- Blue text: Projections from the BFAP baseline (CF: 2007-2011; PF: 2009-2011)
- Yellow shaded area: Period when enterprise was converted to PF (from 2007 onwards)
- Both CF and PF trends indicate the percentage change from the base year (2004 or as indicated otherwise)
- Negative trends of irrigation electricity, fuel and irrigation cost indicate that above normal costs were incurred in the base year for these inputs, with subsequent movements back to normal in years to follow

[26] Water cost in 2004 and 2005 was insignificantly small, hence it is excluded. For this reason 2006 (R119 per hectare) serves as base year for the water cost trends.

[27] PF was implemented from 2007 onwards. The subsequent trend for PF costs is therefore based on R150 per hectare in 2007.

With regard to the wheat enterprise of the Barkley-Wes farm, an average yield increase of 7 basis points with PF relative to CF can be observed from Table 5.13. Again, irrigation cost is projected to remain the same for both systems. Fertilizer (with an average of 1 basis point), fuel (2 basis points), herbicide and insecticide (2 basis points), irrigation electricity (3 basis points) and seed cost (1 basis point) are lower for PF in comparison with CF. Water cost is on average 4 basis points lower with PF. Since PF costs were introduced with PF, variable costs of PF increased with R146 per hectare in 2007 relative to CF.

Table 5.13: Quantitative comparison of key input variables under the CF and PF systems for the Barkley-Wes farm: Wheat production

Variable	Base year	Percentage change from base year						
	2004	2005[28]	2006[19]	2007	2008	2009	2010	2011
CONVENTIONAL FARMING								
Yield (ton/ha):	**6.22**	-	-	**-23%**	**-8%**	**-7%**	**-7%**	**-6%**
Expenses (R/ha)								
Fertilizer	**1,789**	-	-	**25%**	**138%**	**147%**	**153%**	**164%**
Fuel	**840**	-	-	**-32%**	**-18%**	**-17%**	**-17%**	**-14%**
Herbicide & insecticide	**448**	-	-	**-100%**	**28%**	**35%**	**43%**	**50%**
Irrigation electricity	**398**	-	-	**-5%**	**28%**	**35%**	**43%**	**50%**
Seed	**1,085**	-	-	**-47%**	**29%**	**36%**	**44%**	**51%**
Irrigation cost	**1,041**	-	-	**-75%**	**-73%**	**-71%**	**-70%**	**-68%**
Water[29]	-	-	-	**4%[30]**	**13%**	**20%**	**26%**	**33%**
Precision farming	**N/A**	N/A	N/A	N/A	N/A	N/A	N/A	N/A
PRECISION FARMING								
Yield (ton/ha):	-	-	-	-18%	-1%	**0%**	**0%**	**1%**
Expenses (R/ha)								
Fertilizer	-	-	-	25%	138%	**146%**	**152%**	**163%**
Fuel	-	-	-	-33%	-21%	**-19%**	**-19%**	**-16%**
Herbicide & insecticide	-	-	-	-100%	25%	**33%**	**40%**	**47%**
Irrigation electricity	-	-	-	-8%	25%	**32%**	**39%**	**46%**
Seed	-	-	-	-49%	28%	**35%**	**43%**	**50%**
Irrigation cost	-	-	-	-75%	-73%	**-71%**	**-70%**	**-68%**
Water	-	-	-	**R441**	9%	**15%**	**22%**	**28%**
Precision farming[31]	-	-	-	**R146**	9%	**15%**	**22%**	**28%**

Legend:

- Black text: Actual data (CF: 2004; PF: 2007-2008)
- Blue text: Projections from the BFAP baseline (CF: 2007-2011; PF: 2009-2011)
- Yellow shaded area: Period when enterprise was converted to PF (from 2007 onwards)
- Both CF and PF trends indicate the percentage change from the base year (2004 or as indicated otherwise)
- Negative trends of yield, fuel and irrigation cost indicate that above normal costs and yields occurred in the base year for these variables, with subsequent movements back to normal in years to follow.

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28 No wheat was planted in 2005 and 2006 on the Barkley-Wes farm.

29 Water cost in 2004 was insignificantly small, hence it is excluded. For this reason 2007 serves as base year for the water cost trends. Note that projections in this case are based on R441 per hectare, as it represents actual data.

30 This projected percentage change is based on the R441 per hectare water cost of PF. In other words, water cost with CF is 4 basis points higher than R441, thus R458 per hectare.

31 Since PF was implemented from 2007 for this enterprise, this period serves as the base year.

Table 5.14 indicates that yield trends for the barley enterprise of the Barkley-Wes farm with PF are on average 8 basis points higher than with CF. Comparisons for barley input cost trends between PF and CF in Table 5.14 show that savings are achieved with PF for fuel (with an average of 2 basis points), fertilizer (1 basis point), herbicide and insecticide (4 basis points), irrigation electricity (4 basis points), seed (3 basis points) and water cost (3 basis points). Due to the implementation of PF, PF service costs were incurred that increased variable cost of PF with R149 per hectare relative to CF in 2006. Irrigation cost is expected to remain the same for both farming systems.

Again, it should be noted that the trends were derived from a combination of actual data obtained from GWK and the specific farmer, evidence on the benefits of PF provided in Chapter 3 and the BFAP baseline of 2008.

Table 5.14: Quantitative comparison of key input variables under the CF and PF systems for the Barkley-Wes farm: Barley production

Variable	Base year	Percentage change from base year						
	2004	2005	2006	2007	2008	2009	2010	2011
CONVENTIONAL FARMING								
Yield (ton/ha):	**6.02**	78%	**-7%**	**5%**	**6%**	**7%**	**8%**	**9%**
Expenses (R/ha)								
Fertilizer	**1,216**	57%	**56%**	**76%**	**106%**	**115%**	**120%**	**130%**
Fuel	**840**	90%	**10%**	**-32%**	**-20%**	**-19%**	**-18%**	**-15%**
Herbicide & insecticide	**201**	26%	**-10%**	**-100%**	**6%**	**12%**	**19%**	**24%**
Irrigation electricity	**398**	123%	**75%**	**-2%**	**76%**	**86%**	**96%**	**106%**
Seed	**535**	73%	**14%**	**-1%**	**35%**	**43%**	**51%**	**58%**
Irrigation cost	**1,041**	21%	**-88%**	**-75%**	**-73%**	**-71%**	**-70%**	**-68%**
Water[32]	-	-	**3%[33]**	**-17%**	**-10%**	**-5%**	**0%**	**6%**
Precision farming	**N/A**	N/A	N/A	N/A	N/A	N/A	N/A	N/A
PRECISION FARMING								
Yield (ton/ha):	-	-	-7%	11%	14%	**17%**	**18%**	**19%**
Expenses (R/ha)	-	-						
Fertilizer	-	-	56%	76%	106%	**113%**	**119%**	**128%**
Fuel	-	-	8%	-33%	-22%	**-20%**	**-20%**	**-17%**
Herbicide & insecticide	-	-	-14%	-100%	2%	**8%**	**14%**	**19%**
Irrigation electricity	-	-	72%	-8%	72%	**82%**	**92%**	**102%**
Seed	-	-	11%	-3%	33%	**40%**	**48%**	**56%**
Irrigation cost	-	-	-88%	-75%	-73%	**-71%**	**-70%**	**-68%**
Water	-	-	**R550**	-20%	-12%	**-7%**	**-2%**	**3%**
Precision farming[34]	-	-	**R149**	-2%	7%	**13%**	**19%**	**25%**

Legend:

- Black text: Actual data (CF: 2004-2005; PF: 2006-2008)
- Blue text: Projections from the BFAP baseline (CF: 2006-2011; PF: 2009-2011)
- Yellow shaded area: Period when enterprise was converted to PF (from 2006 onwards)
- Both CF and PF trends indicate the percentage change from the base year (2004 or as indicated otherwise)
- Negative trends of fuel, irrigation cost and water cost indicate that above normal costs were incurred in the base year for these inputs, with subsequent movements back to normal in years to follow.

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[32] Water cost in 2004 and 2005 was insignificantly small, hence it is excluded. For this reason 2006 serves as base year for the water cost trends.
[33] This projected percentage change is based on the R550 per hectare water cost of PF. In other words, water cost with CF is 3 basis points higher than PF.
[34] 2006 serves as the base year for PF costs.

5.4.3 Stochastic modelling approach as applied in the study

With regard to stochastic modelling, the approach as described in Chapter 4, section 4.6.1, and by Westhoff *et al.* (2005) was followed. The exogenous variables (key input variables) that proved to have the most significant impact on the risk faced by grain producers were output prices (yellow maize, wheat and barley prices), fuel cost, fertilizer cost, intermediate goods cost (including herbicide, insecticide and seed), and crop yield of yellow maize, wheat and barley. Lucerne has been left out of the stochastic calculations since it was not expected to have a significant impact on risk. The key input variables selected for the analysis of PF relative to CF should not be confused with the key input variables selected for stochastic simulation.

Historical data on the selected key input variables for the past ten years (1998 to 2007) was used generate empirical distributions. The reason for using empirical distributions is because limited data was available to estimate the parameters for the true distribution. The selected variables were tested for trends, and the necessary trend adjustments were subsequently done. The relative deviates of the selected variables were also determined after correlation considerations and applied to the empirical distributions. Correlated uniform standard deviates were generated by means of a SIMETAR function from independent standard normal deviates and a correlation matrix (Richardson, 2004). Consequently, a stochastic series for the exogenous variables was generated after applying the correlated uniform standard deviates, means of the variables (obtained from the BFAP sector model) and empirical distributions. The stochastic series was then applied in the BFAP farm-level model.

By means of SIMETAR software, the model was solved for 500 sets for each key input variable to generate 500 alternative outcomes for the endogenous variables (net farm income and cash surplus or deficit for purposes of the study). The stochastic solution was thus obtained by solving the model for each of the 500 sets of correlated random draws of the exogenous variables, and presented in probability graphs in Excel spreadsheets.

The stochastic process as described in the preceding paragraphs was applied to all three participating farms, and it should be noted that similar correlation matrices and probability distributions were obtained for all three farms. In order to prevent unnecessary repetitions, only the correlation matrix and probability density function of the Douglas farm for 2010 are used to demonstrate the interrelationship between the key input variables and the probability distributions of the respective variables. These correlations and probability distributions are briefly discussed in order to sketch a background from which the stochastic simulations were done.

Table 5.15 represents the correlation matrix for the Douglas farm in order to illustrate the interrelationship between the key input variables. Since these interrelationships are seldom linear, rank order correlation was used to construct the correlation matrix. Table 5.15 indicates that yellow maize yield is negatively correlated to yellow maize prices, which indicates that as maize yield increases, the yellow maize price decreases as a result of supply and demand forces. A similar correlation exists between wheat yield and wheat price, which is unexpected since domestic wheat yields do not usually influence South African wheat prices. On the contrary, South African wheat prices are derived from import parity. The correlation between yellow maize yield and inputs (fuel, fertilizer and intermediate goods) is positive, confirming that an increase (decrease) in inputs results in an increase (decrease) in yellow maize yield. However, wheat yield seems to be negatively correlated to inputs, which could perhaps be ascribed to South African wheat cultivars not being developed fully to achieve substantial higher yields, despite input applications. This was also confirmed by the t-test for wheat yield, which showed a t-value of 0.899, indicating no trend in wheat yields. For the same reason (yellow maize yields improved over the years, while wheat yields did not, due to slower cultivar developments), wheat and maize yield are negatively correlated, albeit not to a large extent. Furthermore, wheat and yellow maize prices are positively correlated, which can be ascribed to the fact that in the Northern Cape Province maize is planted during summer and wheat in winter and therefore they are not substitutes. As expected, all the input variables (which movements normally correspond to inflation) are positively correlated with one another.

Table 5.15: Rank correlation matrix of key input variables for the Douglas farm

	Yellow maize price	Wheat price	Ferti-lizer	Interme-diate goods	Yellow maize yield	Yellow maize yield	Wheat yield
Yellow maize price	1	0.5273	0.5030	0.2364	0.0182	-0.4909	-0.3939
Wheat price		1	0.4545	0.5879	0.6485	-0.1273	-0.4545
Fuel			1	0.4303	0.3576	0.3818	-0.5758
Fertilizer				1	0.8909	0.3455	-0.6606
Intermediate goods					1	0.3818	-0.6485
Yellow maize yield						1	-0.2000
Wheat yield							1

The probability density functions for the key input variables are represented by Figures 5.1 to 5.8. Figure 5.1 indicates that yellow maize yield would have been most likely to realise around the estimated average yellow maize yield. For the Douglas farm, this would thus be in the region of 13 tons per hectare, with small probabilities of minimum and maximum yields. Figure 5.2 shows a maximum and minimum wheat yield of 7.53 and 6.09 tons per hectare respectively with a mean of 6.12 tons per hectare for the Douglas farm. Figure 5.2 gives no clear indication of the most likely wheat yield to be expected, but it has a slightly higher probability of being just below the average wheat yield.

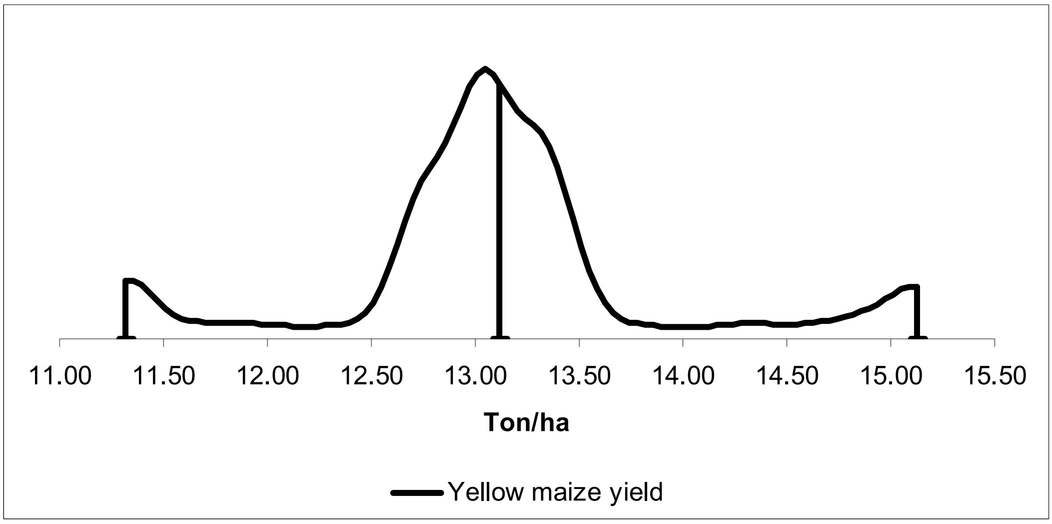


Figure 5.1: Probability density function of estimated yellow maize yield for the Douglas farm, 2010

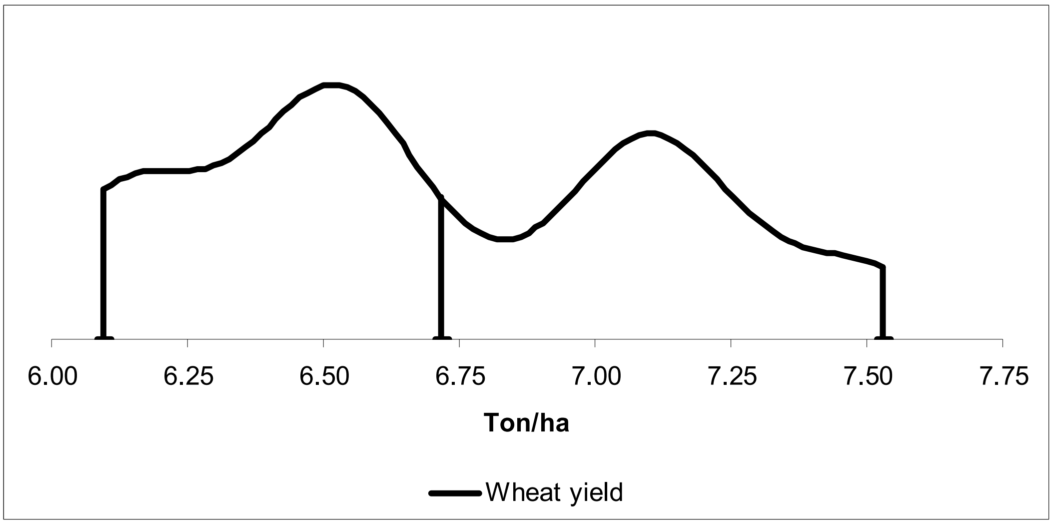


Figure 5.2: **Probability density function of estimated wheat yield for the Douglas farm, 2010**

Figure 5.3 indicates an average yellow maize price of R1670 per ton for the Douglas farm in 2010, with a minimum and maximum of R1122 and R2119 respectively. Figure 5.3 does not indicate the most likely yellow maize prices that would have been realised. Hence, there are almost equal probabilities that prices might have been around the estimated maximum, mean and minimum wheat prices. However, according to Figure 5.3, the benefit of the doubt should be given to a slightly higher probability for maximum yellow maize prices.

Figure 5.3: **Probability density function of estimated yellow maize price for the Douglas farm, 2010**

Figure 5.4 shows an average wheat price of R2494 per ton, with minimum and maximum prices estimated at R2062 and R3477 respectively for the Douglas farm in 2010. The probability density function of the wheat price is skewed to the left, indicating that the wheat price would have been likely to remain below the estimated average price.

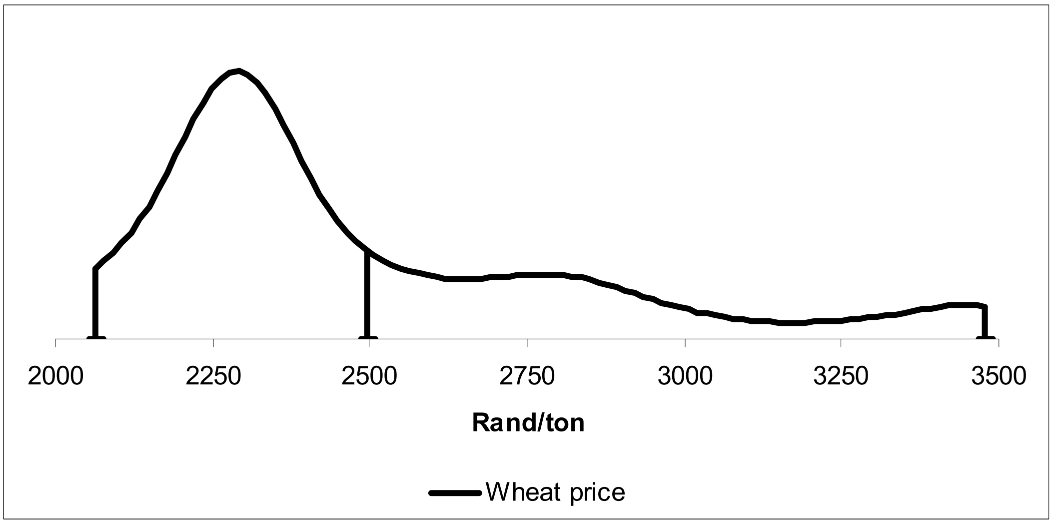


Figure 5.4: Probability density function of estimated wheat price for the Douglas farm, 2010

The probability density functions of input costs are presented in Figures 5.5 through 5.8. Again it should be stated that similar probability density functions were obtained for the input costs of the various crops. Hence, for demonstrative purposes, the probability distributions of input costs (fertilizer, fuel and intermediate goods) for yellow maize are used as an example. Figure 5.5 indicates that the probability density function for fertilizer is skewed to the left, thereby suggesting that fertilizer costs would have been likely to remain lower than the mean. In the case of yellow maize production on the Douglas farm, fertilizer costs are most likely to remain between the minimum of R5308 and R5859 per ton in 2010. Regarding fuel cost, Figure 5.6 gives no clear indication of the most likely fuel cost that would have been realised. Figure 5.6 does, however, show that there is a smaller probability that fuel costs would have been higher than the average fuel cost. With respect to herbicide and seed costs, it can be observed from Figures 5.7 and 5.8 that the probability density functions for the respective variables are skewed to the left, which suggest that herbicide and seed costs would have been most likely to be lower than the average.

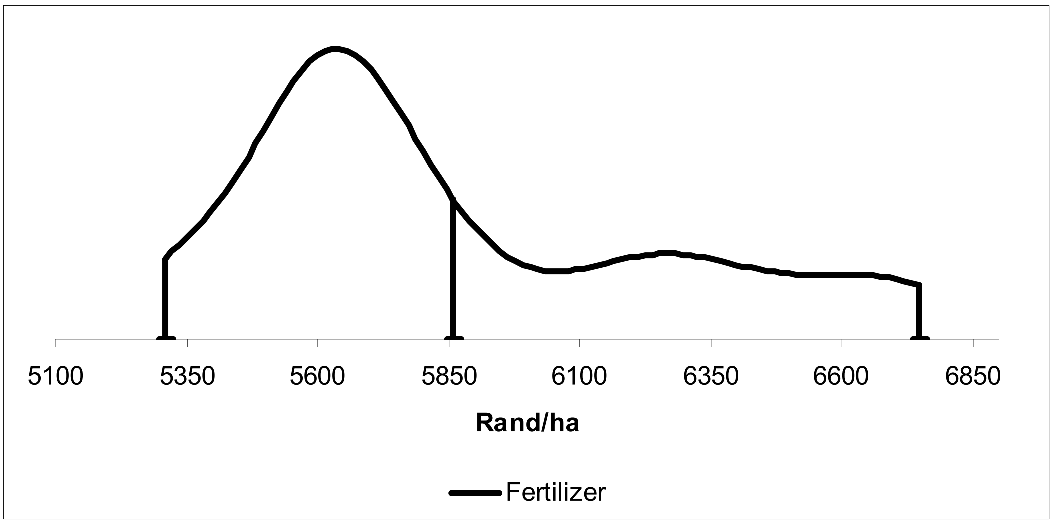


Figure 5.5: Probability density function of estimated fertilizer costs for the Douglas farm, 2010

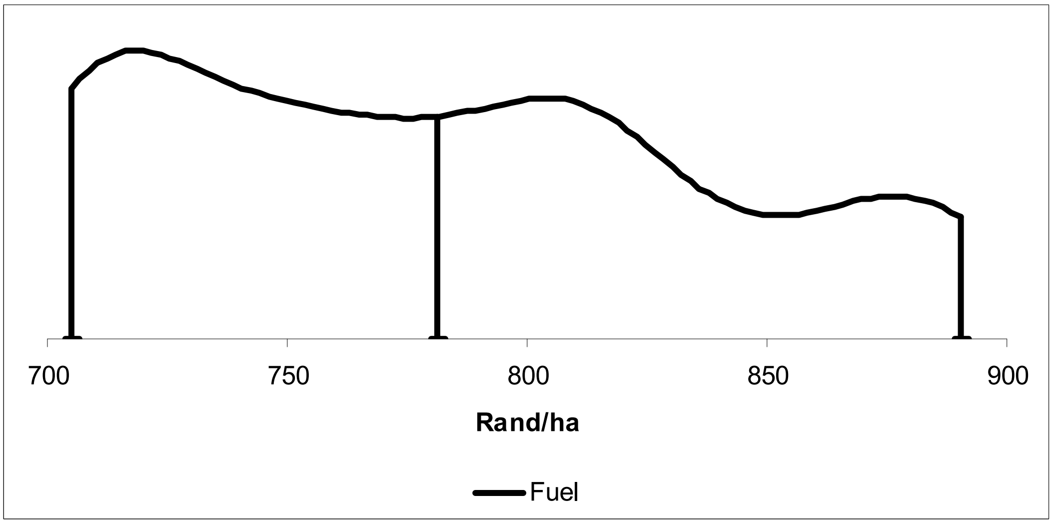


Figure 5.6: Probability density function of estimated fuel cost for the Douglas farm, 2010

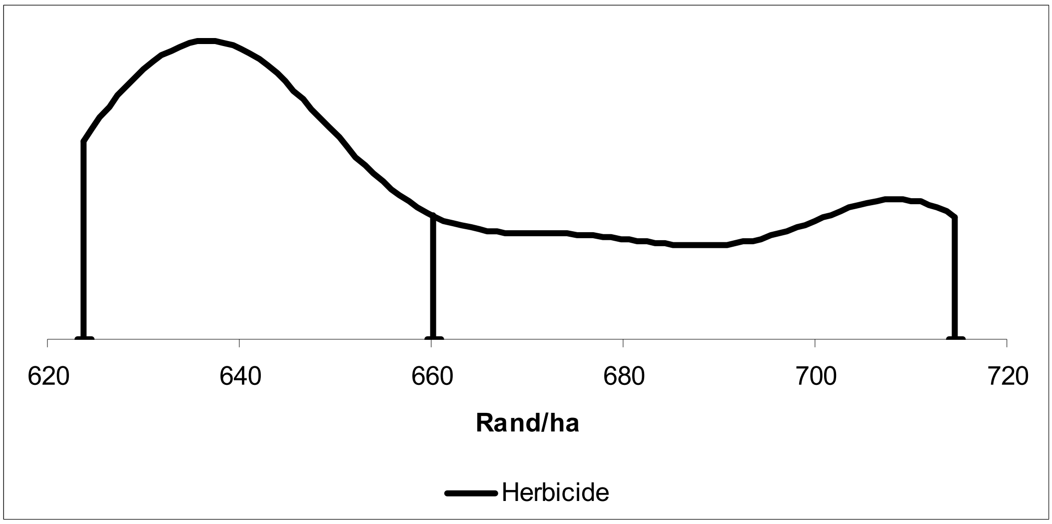


Figure 5.7: Probability density function of estimated herbicide cost for the Douglas farm, 2010

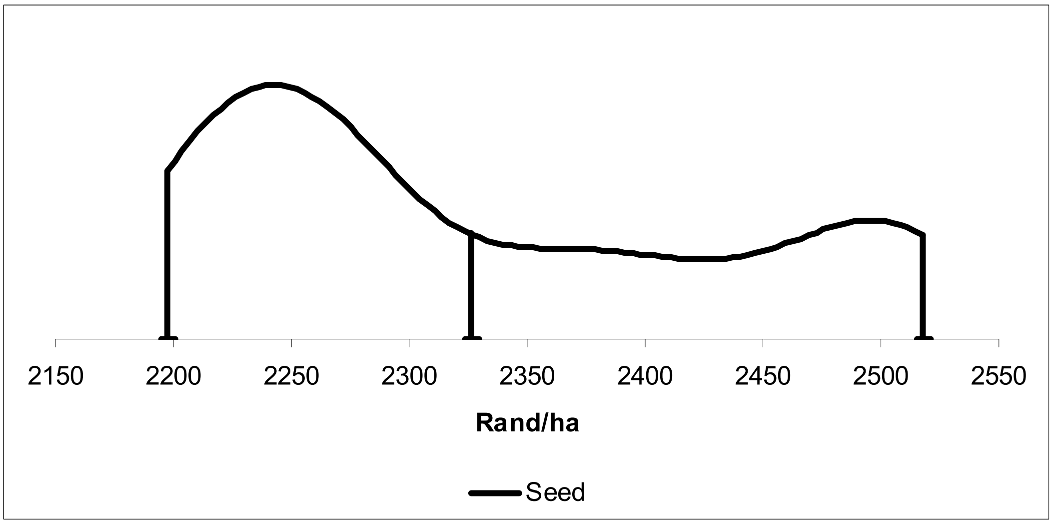


Figure 5.8: Probability density function of estimated seed cost for the Douglas farm, 2010

It should be noted that the probability distributions of the key input variables follow similar patterns for both the CF and PF systems. However, the minimum, maximum and mean values obtained for crop yields are higher under the PF system than the CF system. This indicates that farmers are more likely to get higher yields under the PF system relative to CF. Conversely, the minimum, maximum and mean values for inputs like fertilizer, fuel, herbicide and seed are lower under the PF relative to CF, indicating that farmers are more likely to have lower input costs with PF relative to CF. Probability distributions for crop prices are similar for the two systems, since crop prices are not influenced by the kind of farming system.

The key input variables, their correlations and probability distributions as discussed in this section are subsequently applied to the BFAP farm-level model. The results are discussed in Section 5.5 to follow.

5.5 RESULTS AND DISCUSSION

In this section the results for each participating farm are interpreted and discussed, based on the approach, key input variables, correlations and probability distributions as described in the preceding sections.

5.5.1 <u>Interpretation of results</u>

The results are presented deterministically as well as stochastically. The deterministic results for each farm are presented in the first three line graphs (for example, Figures 5.1 to 5.3), followed by two smaller column graphs (for example, Figure 5.4) that represent the stochastic results. The deterministic results should be interpreted by observing the impact of PF on the specific variable under consideration (net farm income, cash position or debt-to-asset ratio) from 2006 (or 2007, depending on the type of crop) onwards. Conventional farming is represented by a solid blue line, while the impact of PF is indicated by a broken red line. The impact of PF is subsequently determined by observing its diversion from the CF line.

The stochastic results are illustrated by using probability graphs (also called stoplight graphs), which indicate the probability of the key output variable being above a certain value (indicated in green), the probability of the key output variable being between two specified values (indicated in yellow), and the probability of the key output value being lower than a specified value (indicated in red). The specified values in the probability graphs do not necessarily indicate the probability of a loss, normal profit or above-average profit being made, but merely provide a measure to indicate the impact of PF on the risk position of a farm. However, for net farm income, the estimated deterministic net farm income for CF in 2009 is used as benchmark. It is important to note that the analysis approach as stated in section 5.4 was used to analyse all three participating farms. The results obtained in this section are thus based on trends of the key input variables (as discussed in section 5.4.2), their correlations and probability distributions (section 5.4.3).

5.5.2 Farm results

- **Luckhoff farm results**

Figures 5.9 to 5.11 represent the deterministic results for the Luckhoff farm. Figure 5.9 indicates that PF had a significantly positive impact on the net farm income, as can be seen in 2007, where the decline in net farm income (as illustrated by the CF line) was mitigated by PF. In 2008 the CF line indicates a loss of just over R200 000, whereas the PF line shows that a loss was prevented by implementing a PF system. This clearly indicates the capability of PF so support the farming business during a bust cycle. The higher net farm income generated by the PF system can be attributed to higher yields and lower input costs due to more efficient production methods associated with PF. In the longer run (2009 to 2011) it can be clearly seen that PF contributes to a large net farm income equal to the 2005 level. A noteworthy observation is the widening gap between the CF and PF lines (from 2008 onwards), which suggests that the higher income generated by PF results in lower interest costs as debt is paid off more quickly. The lower debt and resultant interest costs in turn lead to a higher net income the following year, thereby creating a positive snowball effect.

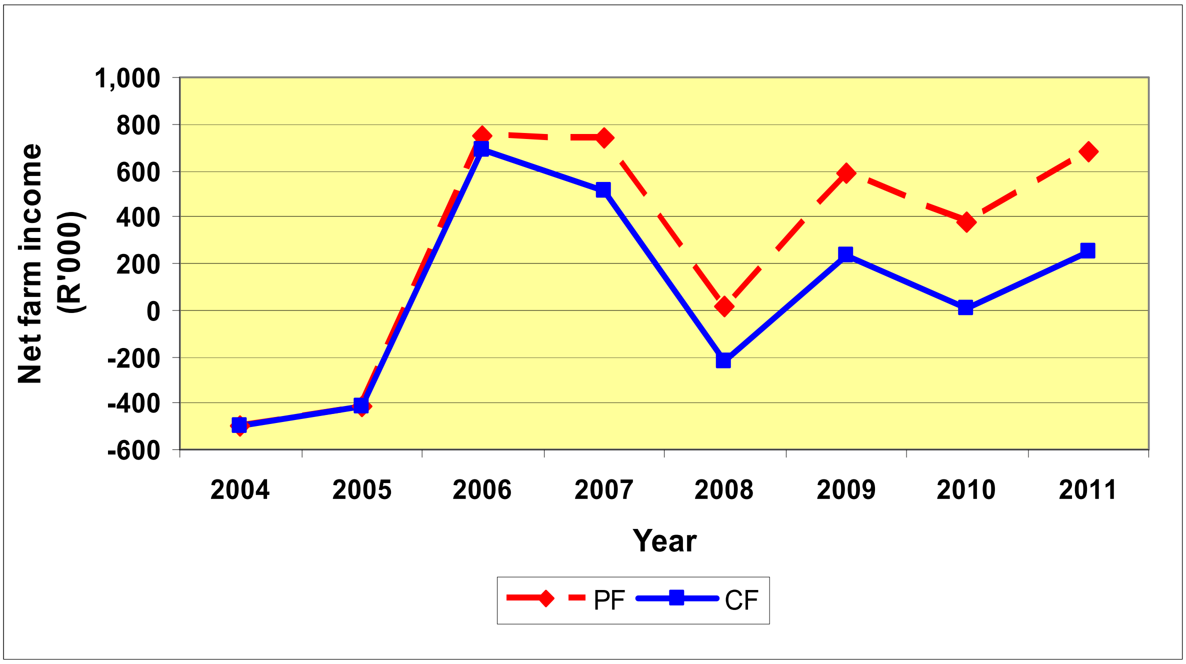


Figure 5.9: Impact of PF on net farm income of the Luckhoff farm, 2004 - 2011

The most significant impact of PF can be seen in Figure 5.10, which shows its impact on the cash position of the Luckhoff farm. As opposed to the CF line, which indicates that the farm could have severe cash flow problems without PF, threatening the financial survivability of the farm, the PF line visibly diverges upward from the CF line. It is obvious that the PF system is relieving the farm from a possible financial dilemma. In 2010 the farm generates a cash surplus for the first time under the PF system. This positive impact of PF on the cash position of the farm can be attributed to the improved net income, which in turn assists the farmer in paying off his debt more quickly and thereby saving on interest costs. The savings on interest costs ensure that the farmer has more cash at his disposal, hence the positive upward trend of the cash position of the farm with the PF system in Figure 5.10. This can be interpreted as an indication that PF significantly improves the farmer's ability to repay his debt and generate an income, thereby enabling him to survive financially in the long term. The assumption that cash is reinvested in the farm is especially applicable in this regard and should be kept in mind when analysing the cash position of the farm. The lower debt levels with the PF system are confirmed by Figure 5.11, which clearly shows the impact of PF on the debt-to-asset ratio. The PF line in Figure 5.11 indicates that the debt-to-asset ratio under the PF system is approximately 10 percent lower than that of the CF system.

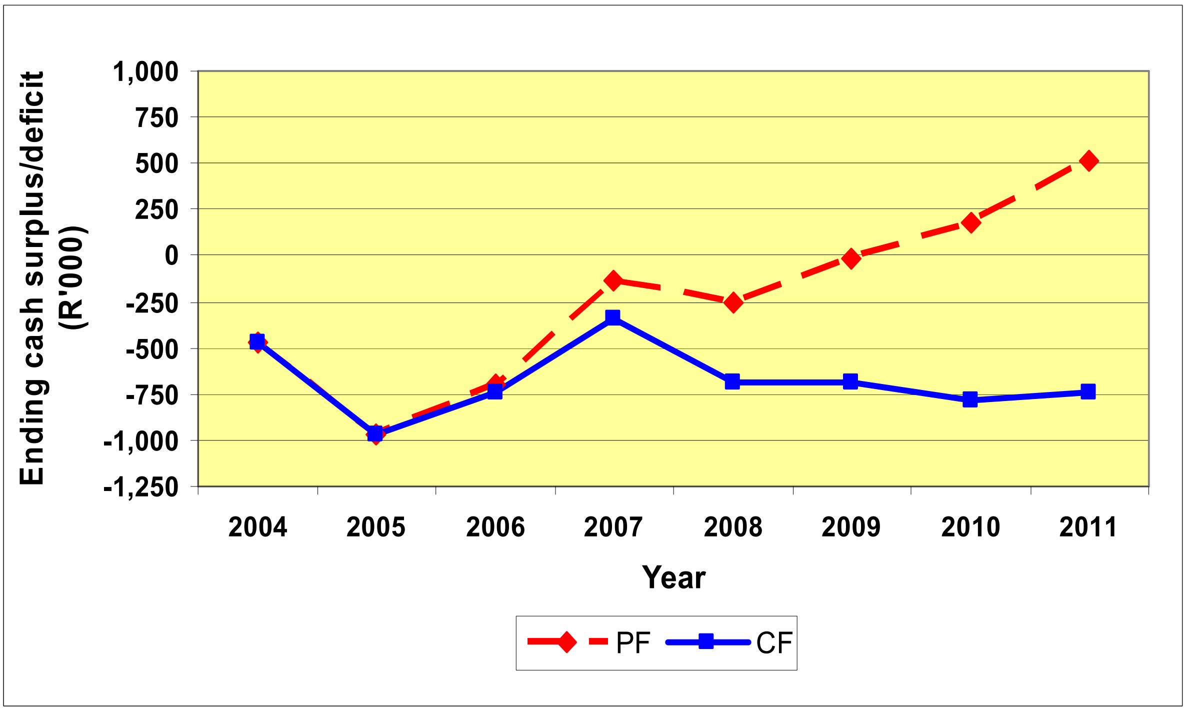


Figure 5.10: Impact of PF on the cash position of the Luckhoff farm, 2004 - 2011

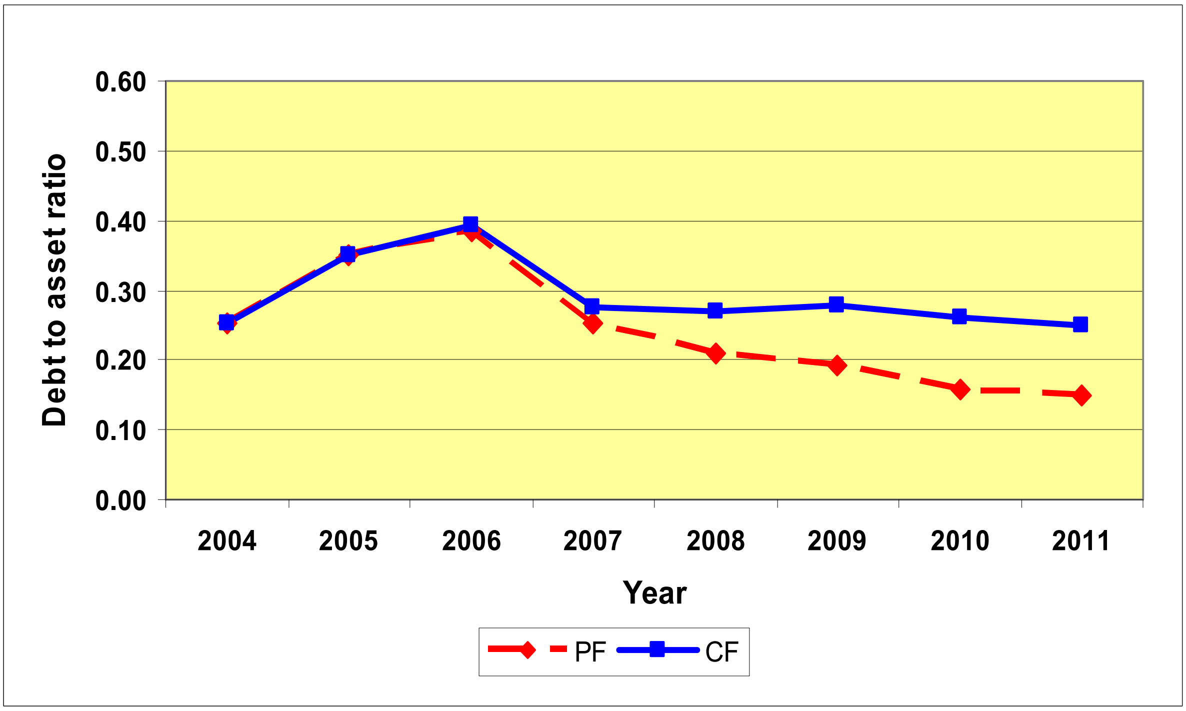
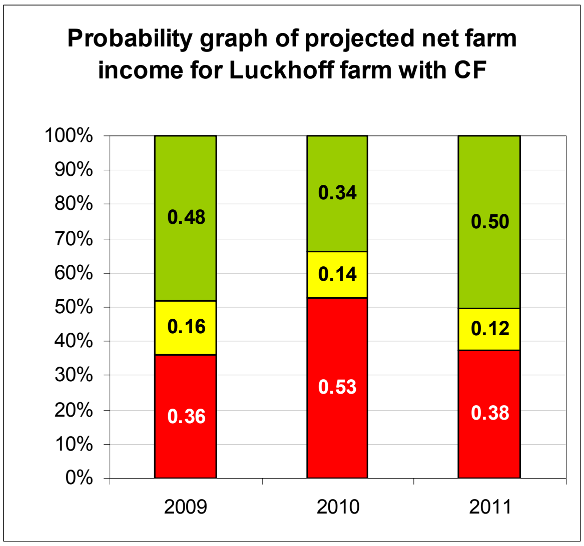
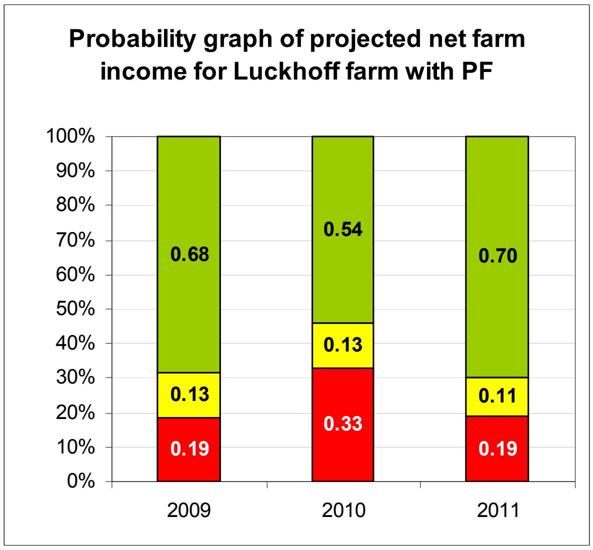


Figure 5.11: Impact of PF on the debt-to-asset ratio of the Luckhoff farm, 2004 - 2011

When comparing the risk involved in CF and PF with respect to the net farm income, Figure 5.12 illustrates that during the period 2009 to 2011, PF has on average approximately 20 percent less chance of making a loss and a 20 percent higher probability of generating a net income above R237 010 than CF. This clearly illustrates the ability of PF to alleviate the risk of making losses.



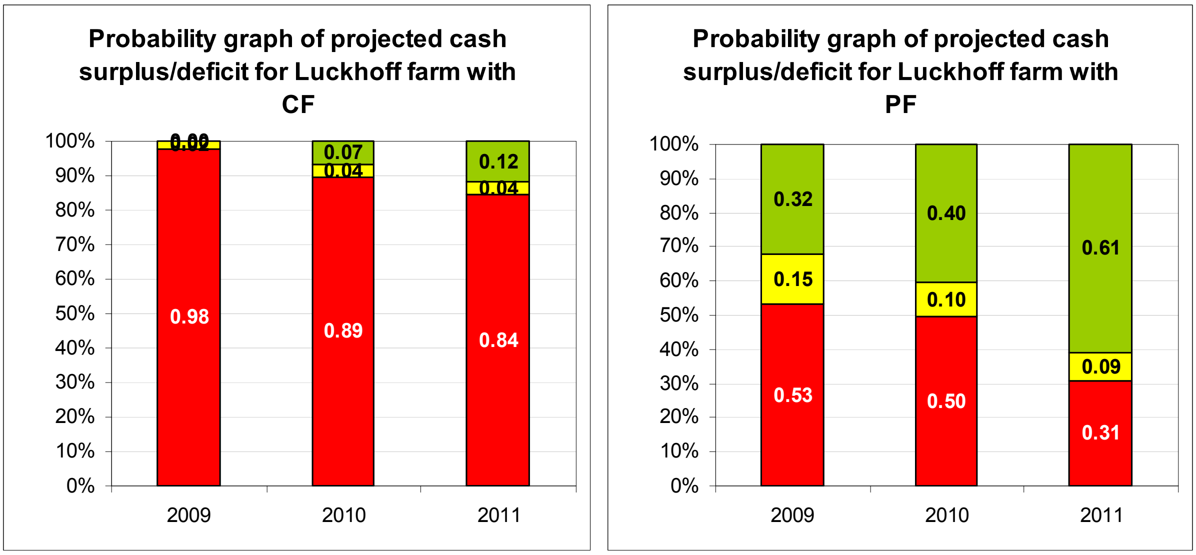


Legend:

- Green area: Probability that net farm income increases above R237 010
- Yellow area: Probability that net farm income is between R0 and R237 010
- Red area: Probability that a loss is made (net farm income below R0)

Figure 5.12: Probability graph indicating the impact of PF on the net farm income of the Luckhoff farm, 2009 - 2011

With regard to the cash position of the Luckhoff farm, the probability graph depicted by Figure 5.13 shows that the farm has a very small chance of surviving financially under the CF system. However, the risk of generating a cash deficit is almost halved (from 98 and 89 percent to 53 and 50 percent respectively, as indicated by the red areas) in 2009 and 2011 by implementing PF. In 2011 the probability of generating a cash deficit is reduced from 84 percent for CF, to 31 percent for PF. The probability graph of PF in general shows a sharp decline in the probability of a cash deficit from 2009 to 2011 as opposed to a moderate decline under a CF system. This indicates that PF drastically reduces the risk of the farm being in financial distress over the long run. Again it should be noted that cash is assumed to be reinvested in the farm.



Legend:

- Green area: Probability that cash surplus is higher than R200 000
- Yellow area: Probability that cash surplus is between R0 and R200 000
- Red area: Probability that a cash deficit occurs (below R0)

Figure 5.13: Probability graph indicating the impact of PF on the cash position of the Luckhoff farm, 2009 - 2011

Given the analysis approach, the baseline and key input variables as presented in this chapter, the following conclusions for the Luckhoff farm can be drawn:

- PF generates higher profits than CF as can be seen from the net farm income analysis.
- PF improves the farmer's ability to repay his debt and to generate and income, as illustrated by the cash position analysis.
- PF improves the debt position of the farm as pointed out by the debt-to-asset ratio.
- Based on the historical and projected trends, correlations and probability distributions of the key input variables as discussed in this chapter, it can be concluded that PF is to a large extent less risky than CF regarding financial losses and cash deficits.

- **Douglas farm results**

Figures 5.14 to 5.16 represent the deterministic results for the Douglas farm after the key input variables, assumptions regarding PF and baseline projections (as discussed in this chapter) were applied in the BFAP farm-level model. Figure 5.14 illustrates the impact of PF on the net farm income. In Figure 5.14, enormous losses can be observed in 2006. This is due to the fact that the farmer decided not to plant maize despite the possibility that higher maize prices and acceptable input costs could have contributed to reasonable profits. After implementation of the PF system in 2006, it can be observed that the PF line follows the same trend as the CF line, albeit at significantly higher profit levels. The PF line shows an increase from almost R250 000 in 2007 to approximately R360 000 in 2011 in net farm income, indicating an increasingly positive impact of PF. Like the Luckhoff farm, this increasing positive impact of PF can be attributed to higher yields and lower input costs, leading to higher profits. The higher profits in turn result in debt being paid off faster. The lower debt levels consequently lead to lower interest costs, which in turn ensure a higher net farm income. However, the increasing net farm income of PF relative to CF seems to stabilise from 2010 to 2011, but at a much higher level.

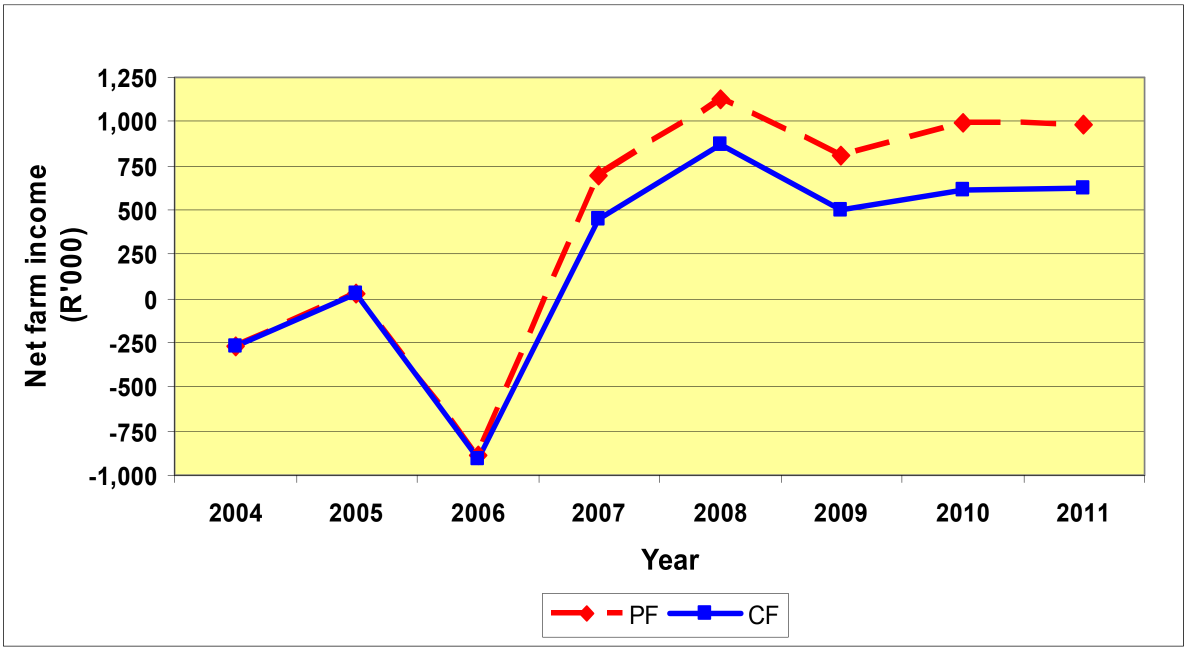


Figure 5.14: Impact of PF on net farm income of the Douglas farm, 2004 - 2011

The positive effect of PF on the net farm income of the Douglas farm can be seen in Figure 5.15 to spill over to the cash position of the farm. Rigorous cash flow problems can be observed during the 2006 and 2007 seasons. From 2008 the cash position of the farm for both CF and PF systems start to improve due to higher margins, eventually leading to more cash available for the farm. Although not as drastic as the Luckhoff farm, it can be seen that the cash position of the farm with PF improves more rapidly than under the CF system.

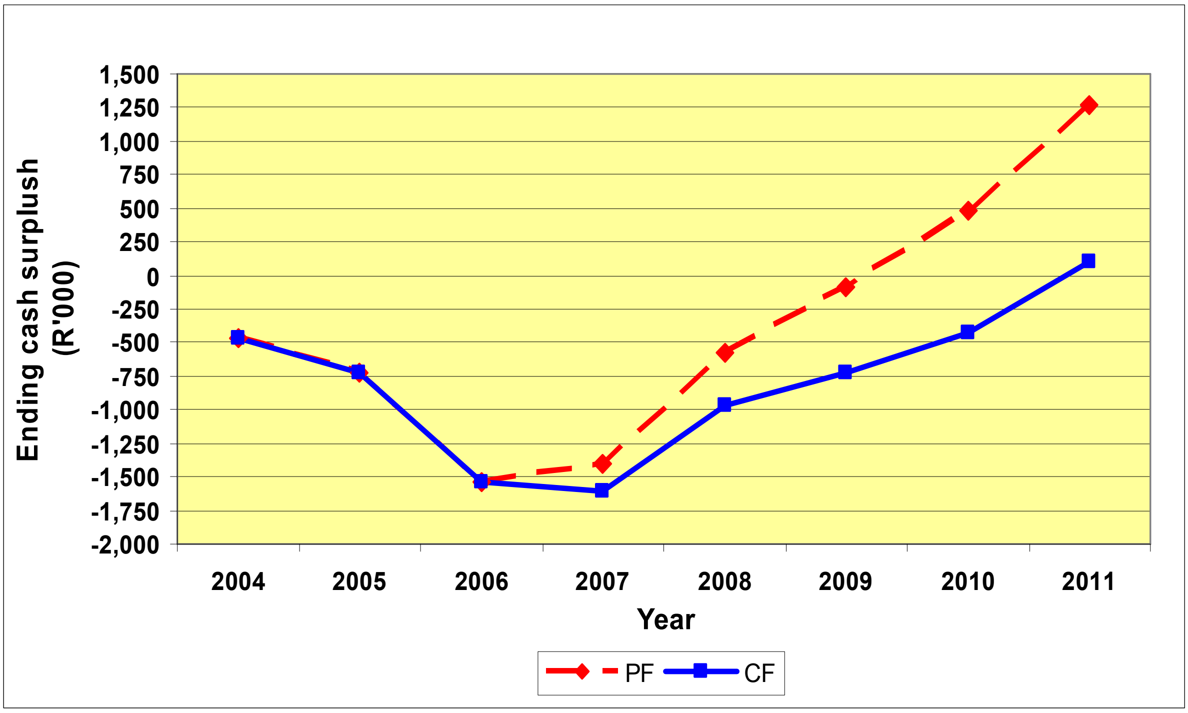


Figure 5.15: Impact of PF on the cash position of the Douglas farm, 2004 - 2011

With reference to the impact of PF on the debt-to-asset ratio in Figure 5.16, the lower debt levels as a result of PF can be observed. It can be observed that the debt-to-asset ratio of PF initially improves rapidly from a high 45% in 2007 to an acceptable 23%, but at a decreasing rate. In 2011 the CF level at 25% seems to get closer to the PF debt levels, which can be due to stabilisation in the increasing profit levels. This could be an indication that the farm might be nearing its optimal production capacity.

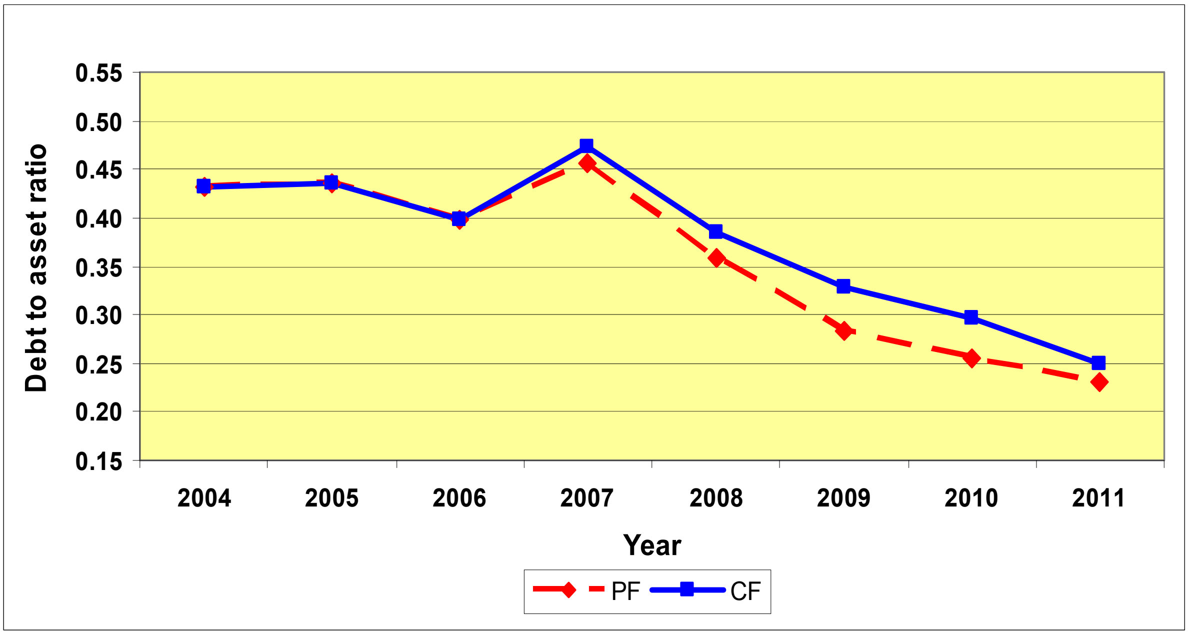
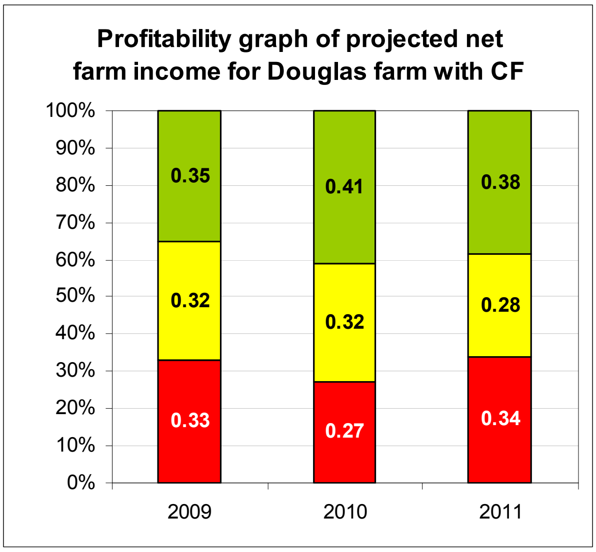
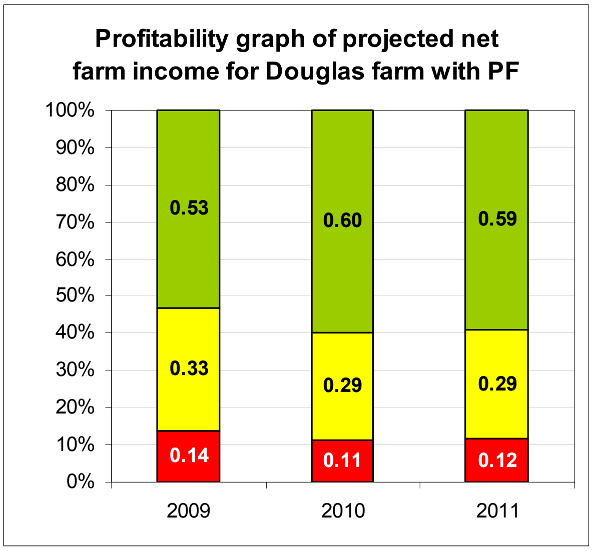


Figure 5.16: Impact of PF on the debt-to-asset ratio of the Douglas farm, 2004 - 2011

After applying the key input variable trends, correlations and probability distributions of the key input variables as discussed in this chapter, the stochastic results for the Douglas farm are presented in Figures 5.17 and 5.18. From Figure 5.17 a similar trend as the Luckhoff farm can be observed for the Douglas farm with respect to net farm income: The probability that losses will occur during 2009 to 2011 is greatly reduced (between 16 and 22 percent) with the implementation of PF, whereas the chances of earning above-normal net farm income (higher than R500 749) is higher at between 18 and 21 percent for the same period. Hence, it can be concluded that PF impacts positively on risk regarding the net farm income of the Douglas farm in the long term.



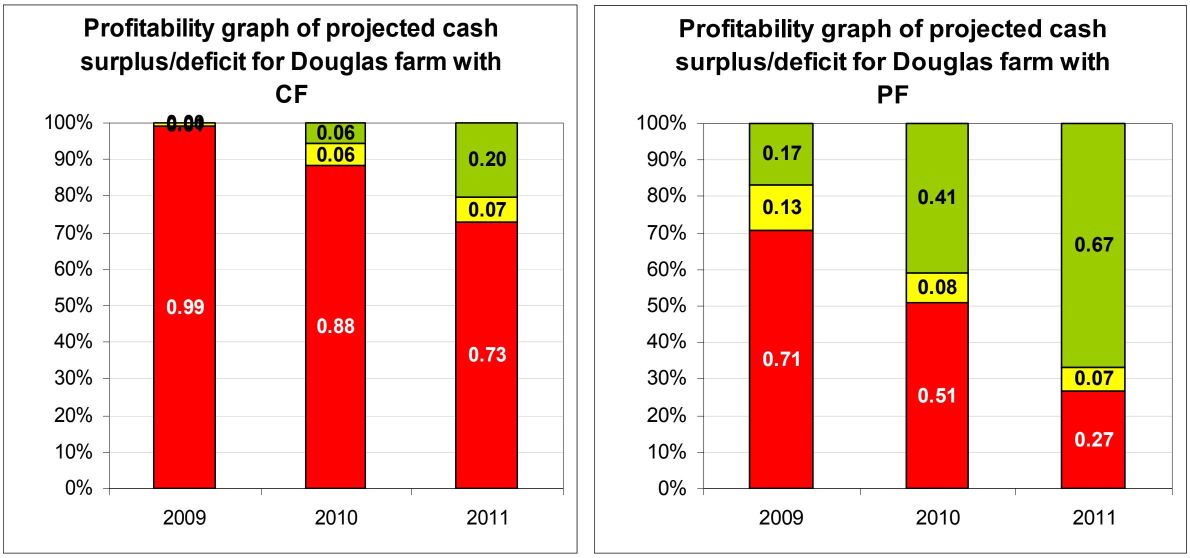


Legend:

- Green area: Probability that net farm income is higher than R500 749
- Yellow area: Probability that net farm income is between R0 and R500 749
- Red area: Probability that a loss is made (net farm income below R0)

Figure 5.17: Probability graph indicating the impact of PF on the net farm income of the Douglas farm, 2009 - 2011

Figure 5.18 also illustrates the same trend for the risk associated with the cash position of the Douglas farm as observed for the Luckhoff farm. The probability of attaining a cash deficit is reduced significantly from 99 percent to 71 percent in 2009 and from 73 percent to 27 percent in 2011 with the implementation of PF for the Douglas farm. This is thus an indication that PF has a substantially constructive impact on the riskiness of the Douglas farm's cash position.



Legend:

- Green area: Probability that cash surplus is higher than R200 000
- Yellow area: Probability that cash surplus is between R0 and R200 000
- Red area: Probability that a cash deficit occurs (below R0)

Figure 5.18: Probability graph indicating the impact of PF on the cash position of the Douglas farm, 2009 - 2011

Although on a smaller scale, the same conclusions for the Luckhoff farm can be drawn for the Douglas farm. That includes the fact that PF generates better profits, improves the farmer's debt position and ability to generate an income, and reduces the risk of financial losses to a great extent

- **Barkley-Wes farm results**

Precision farming also proves to have a constructive impact on the profitability and risk of the Barkley-Wes farm. Figure 5.19 shows a remarkable difference in net farm income between PF and CF from about R207 000 in 2007 to a difference of approximately R604 000 in 2011. Also noteworthy is that during periods of decreased net farm income (especially 2007 and 2009), PF shows again its capability to reduce the downturn in a bust cycle. During favourable years (the boom years), PF then seems to magnify the positive occurrence. The same factors that contribute to the improved net farm income for the Luckhoff and Douglas farms are at play in the Barkley-Wes farm, namely improved yields and lower input costs resulting in better profit margins. Better profits result in debt being paid of more quickly, which in turn leads to lower interest costs and higher net farm income. This is again confirmed by Figures 5.20 and 5.21, which show the better cash flow position and lower debt position respectively.

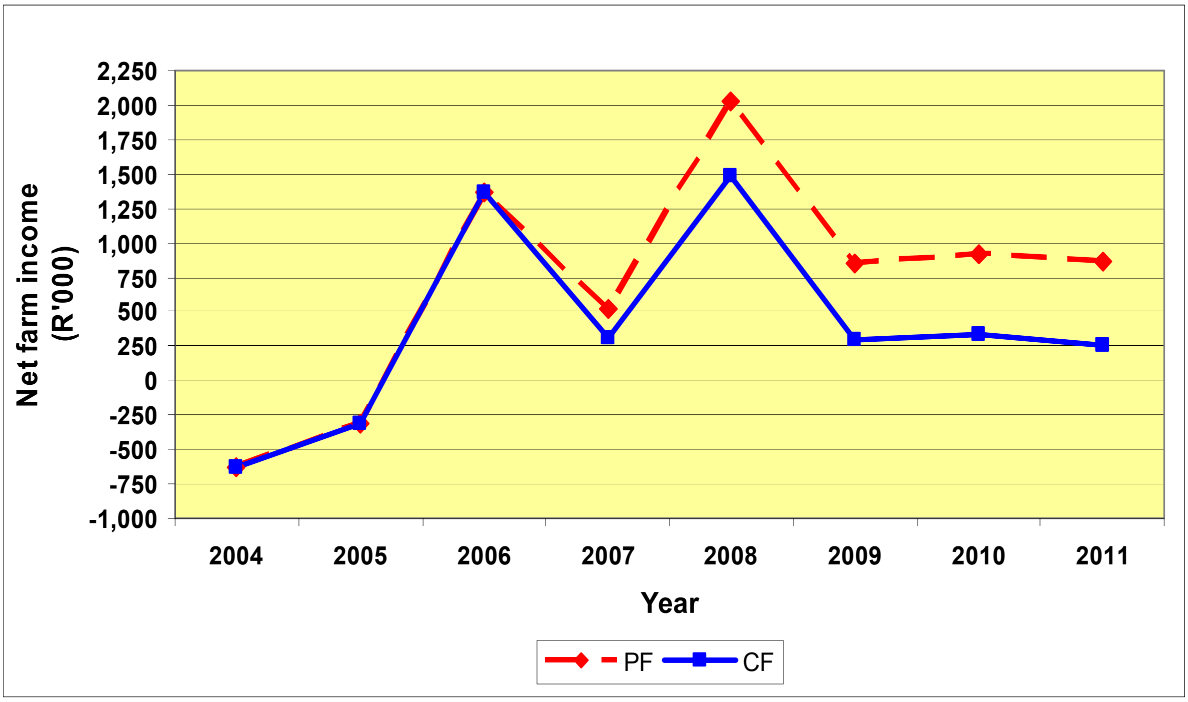


Figure 5.19: Impact of PF on the net farm income of the Barkley-Wes farm, 2009 - 2011

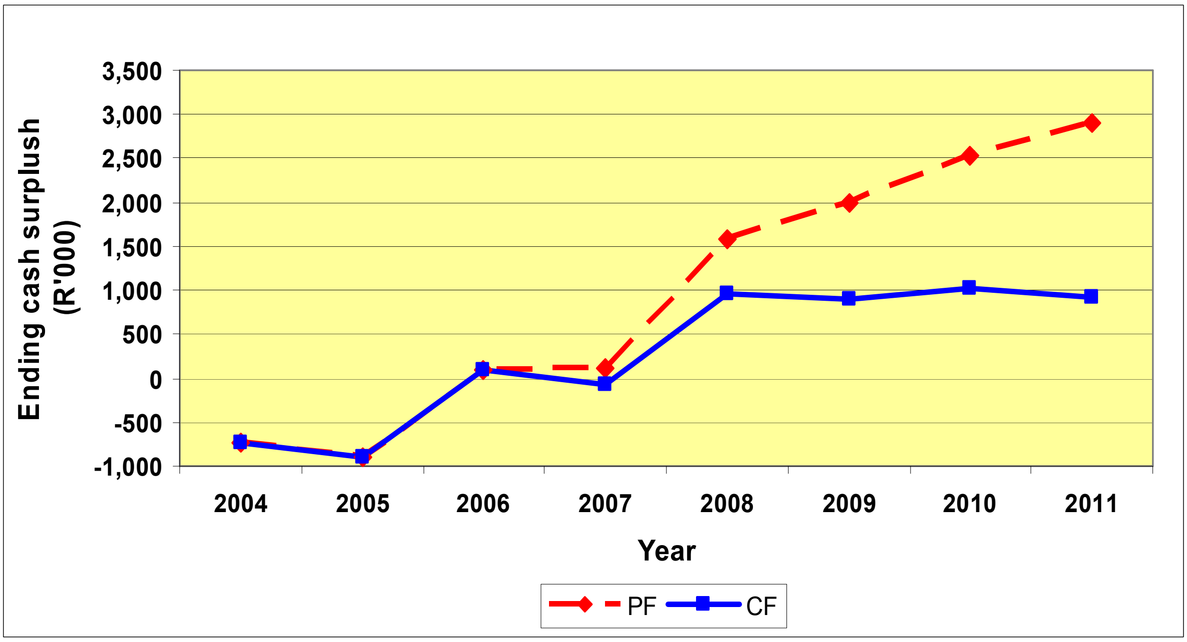


Figure 5.20: Impact of PF on the cash position of the Barkley-Wes farm, 2009 - 2011

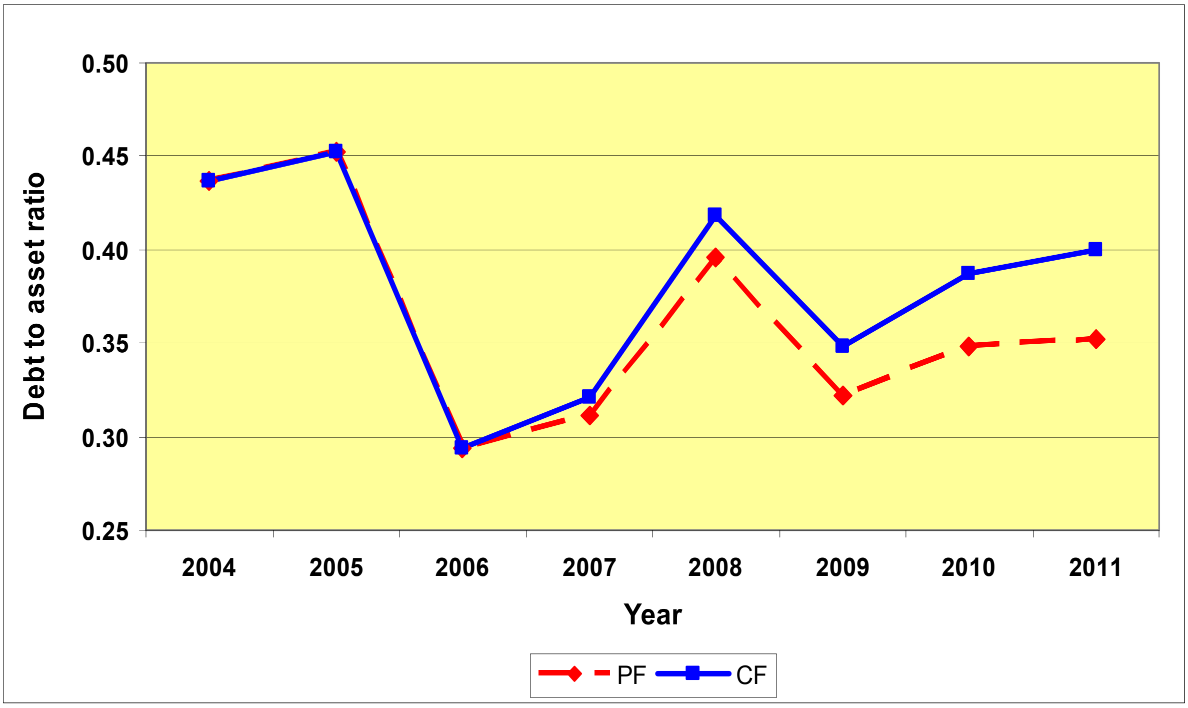
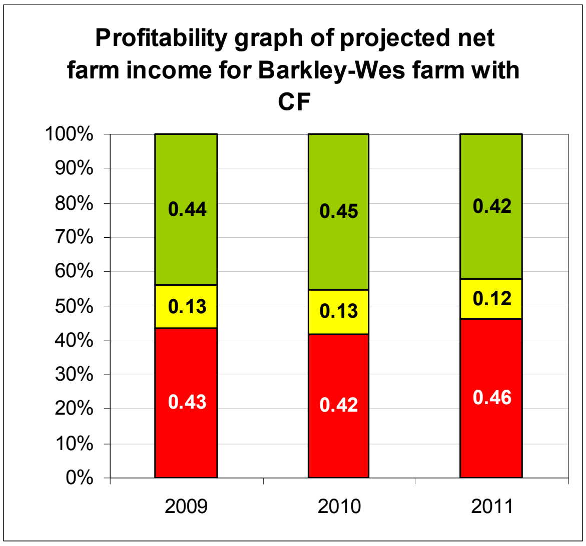
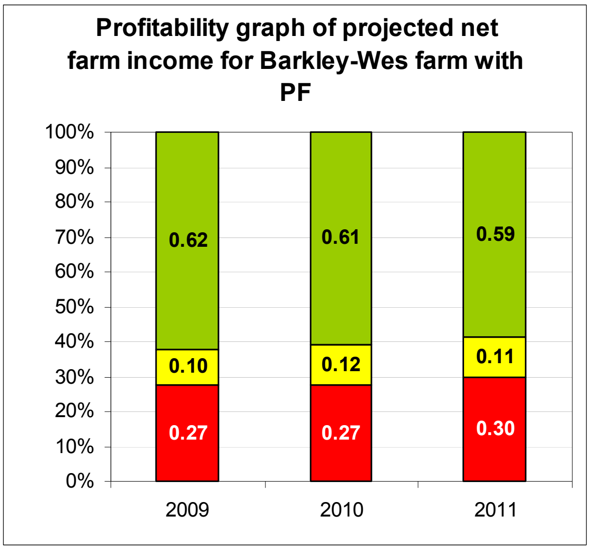


Figure 5.21: Impact of PF on the debt-to-asset ratio of the Barkley-Wes farm, 2009 - 2011

With respect to risk related to the net farm income and cash position of the Barkley-Wes farm, it can be observed from Figures 5.22 and 5.23 that PF, similar to the other farms, plays an important role in mitigating risk. Figure 5.22 illustrates that the probability of making a loss is reduced between 15 and 16 percent for the period 2009 to 2011 by implementing PF. The chances of obtaining an above-average net farm income (higher than R297 910) are also increased by PF between 16 and 18 percent for the same period.



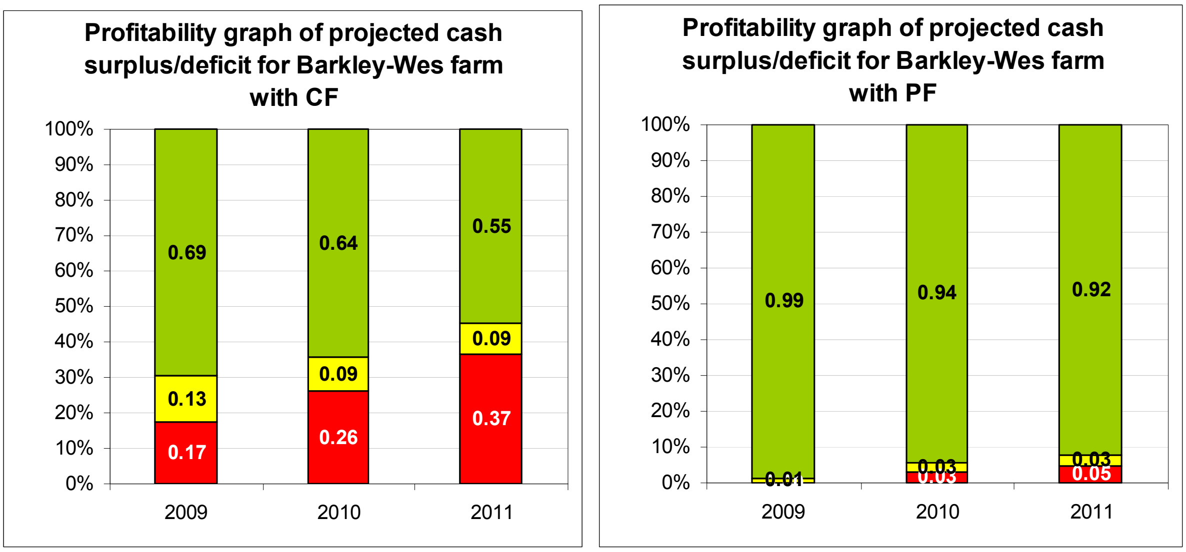


Legend:

- Green area: Probability that net farm income is above R297 910
- Yellow area: Probability that net farm income is between R0 and R297 910
- Red area: Probability that a loss is made (net farm income below R0)

Figure 5.22: Probability graph indicating the impact of PF on the net farm income of the Barkley-Wes farm, 2009 - 2011

The effect of PF on risk with respect to the cash position of the Barkley-Wes farm is illustrated by Figure 5.23. The Barkley-Wes farm is not experiencing such severe cash flow problems as is the case with the other two farms, but an alarming trend occurs over time. The probability of a cash deficit for the farm with CF increases sharply over time, but this threat is removed by implementing PF. Although the probability of a cash deficit still increases over time, this is greatly reduced by introducing PF.



Legend:

- Green area: Probability that cash surplus is higher than R300 000
- Yellow area: Probability that cash surplus is between R0 and R300 000
- Red area: Probability that a cash deficit occurs (below R0)

Figure 5.23: Probability graph indicating the impact of PF on the cash position of the Barkley-Wes farm, 2009 - 2011

Given the evidence presented in Figures 5.19 through 5.23, a conclusion similar to that for the Luckhoff and Douglas farms can be drawn. Given the analysis approach, the baseline and key input variables as presented in this chapter, it can be concluded that PF generates better profits, improves the farmer's debt position and ability to generate an income. Based on the correlations and probability distributions of the respective key input variables, the conclusion can also be drawn that PF reduces the risk of financial losses to a great extent

An interesting observation in the probability graphs is made that although the probability distributions of the key input variables differs only marginally between CF and PF (as described in section 5.4.3), the impact of these variables on the risk positions of the respective farms is dramatic. This can be ascribed to the snowball effect that takes place when a small improvement in for example, input costs per hectare, results in an increase in net farm income and ultimately leading to a substantial improvements in the cash-flow and debt-to-asset ratio of each farm in the study.

5.6 SUMMARY AND CONCLUSION

In the preceding chapters PF was identified as one of the instruments that can be used for more efficient production and especially improved profitability. Three Northern Cape farms using the PF service provided by GWK were selected to participate in a case study. These farms were located in the Luckhoff, Douglas and Barkley-Wes regions.

The process that was followed to achieve the objectives as set out in Chapter 1 can be summarised as follows:

- Firstly, an overview of each selected farm and its farming structure was provided to give a background for the analyses.
- Secondly, a brief description of the baseline applicable to the study was included in order to sketch a backdrop of the macro-economic situation in which the analyses were conducted.
- Thirdly, the simulation process and approach were described along with the key input variables used in the simulations, their trends, correlations, as well as the probability distributions. The key output variables (KOVs) were also explained.
- Finally, the results were presented and accompanied by a discussion.

The results were presented in deterministic as well as stochastic mode. The deterministic results indicate the impact of PF on the key output variables, namely net farm income, cash surplus or deficit, and debt-to-asset ratio. Based on their generated correlations and probability distributions, the stochastic results indicate the level of risk associated with each farming system in terms of net farm income and cash surplus or deficit. The results obtained from the analyses were fairly similar for each of the participating farms and they only differed in terms of magnitude. The main findings can be summarised as follows:

- Precision farming leads to better yields and lower input costs due to more efficient production methods and applications. This results in higher profit margins, which is shown in the net farm income graphs.
- The higher profits obtained from PF result in debt being paid off faster, thereby improving the farms' debt positions and lowering their interest costs.
- Lower interest costs lead to a higher net farm income and also improve the cash position of the farm. The declining debt and lower interest costs cause a snowball effect, as debt is eradicated at a faster rate, thereby decreasing interest costs and increasing the cash surplus also at an increasing rate. This snowball effect could also be observed in the stochastic results.
- Precision farming, as assumed in the study by excluding capital expenditure, is to a large extent less risky than CF regarding financial losses and cash deficits, as proven by the probability graphs.

It is important to note that the results are based on the assumption that cash is reinvested in the farm. Furthermore, the deterministic results are based on the trends of the key input variables as described in section 5.4.2 while the stochastic results were obtained after the correlations and probability distributions of the key input variables (section 5.4.3) were applied in the simulations.

CHAPTER 6

SUMMARY AND CONCLUSION

In Chapter 2 the history of the South African agricultural sector, and in particular the South Africa maize industry, was described, ending in an overview of the current situation in which maize farmers are operating. It was concluded that the South African maize industry plays an important role in the South African economy and consequently it should be supported and promoted.

However, maize farmers do not have the luxury of favourable government policies that protect them as in earlier years. After the abolishment of agricultural marketing boards and the deregulation of South African agriculture, farmers suddenly found themselves exposed to global competition and a liberalised economy. Maize prices are uncertain and volatile, leading to increased risk. In addition, input prices increased faster than maize prices in some instances and since no government protection exists, the cost squeeze effect placed many farmers in a financial predicament. In order to mitigate the cost squeeze effect, farmers should start exploring methods or strategies that can improve their financial position.

In the study, precision farming was identified as a technological tool that can improve the profitability of a maize farm through higher yields and lower input costs, and also indirectly lead to an improvement in the general farm and financial capabilities of a maize farmer. In Chapter 2 a literature review on precision farming was conducted in order explore the working and possible benefits that are associated with this technology. The literature indicates that precision farming has been successfully implemented on various occasions with subsequent benefits, albeit financial or qualitative.

The general objective of the study was to investigate the impact of PF on the profitability of selected maize irrigation farms in the Northern Cape Province. This was achieved by comparing the profitability and risk position of the selected farms under a conventional farming (CF) system with the profitability of the same farms when converting to a precision farming (PF) system. The specific objectives of the study were to determine whether PF would generate better profits than CF; to determine whether PF would improve the farmer's ability to repay his debt and generate an income (thereby improving the financial survivability of the farm); to determine whether PF would improve the debt position of the farmer; and to determine whether PF is less risky than CF with respect to net farm income and cash position.

The means by which the set objectives were achieved, namely profits, risk and modelling, were subsequently explored in order to determine the best method. After exploring various methods, it was concluded that the BFAP farm-level model developed by Strauss (2005) would provide a very useful alternative. This conclusion was drawn on the basis that the BFAP farm-level model is linked with the BFAP sector model, which enables it to accurately analyse the impact of changes in policies and markets at both farm and sector level in South Africa. The BFAP farm-level model also has the capability to conduct analyses in both deterministic and stochastic modes. The structure of the BFAP farm-level model and its stochastic modelling process were explained. A positivistic approach was followed in order to answer the question of "what will the likely outcome be".

Three maize irrigation farms in the Northern Cape were subsequently chosen by a panel of agricultural specialists who are accustomed with the PF system in this region. These farms were analysed by means of the BFAP farm-level model. The BFAP baseline of 2008 was used for this purpose, since it provided the latest updates regarding the macro-economic and world price outlooks at the time of conducting the empirical analysis of this study. Key input variables were identified and simulated based on the BFAP baseline of 2008, as well as actual data, assumptions regarding PF and CF farming, and reported features and benefits associated with PF. In order to simulate the risk associated with CF and PF through stochastic modelling, correlated probability distributions were assigned to the relevant key input variables by de-trending the historical data of the key input variables. A correlation matrix based on the absolute deviation of a specific variable from its trend was subsequently constructed. Each variable was then simulated by means of a correlated empirical distribution, with 500 model iterations being run for each simulation in order to obtain stable probability distributions. The following results were obtained:

- Precision farming leads to better yields and lower input costs due to more efficient production methods and applications. This results in higher profit margins, which are shown in the net farm income graphs in Chapter 5.
- The higher profits obtained from PF result in debt being paid off faster, thereby improving the farms' debt positions and lowering their interest costs.
- The lower interest costs lead to a higher net farm income and also improve the cash position of the farm.
- Precision farming is to a large extent less risky than CF regarding financial losses and cash deficits, as proven by the probability graphs.

The results obtained from the study indicate that PF not only improves profit margins, but indirectly contributes to improved financial management. The assumption that cash surpluses are ploughed back into the farming business is especially applicable in this case. Considering the higher profit margins, more cash is at the disposal of the farmer. When this extra cash is again returned to the farming business (in other words, the farmer uses it for farming operations and not to purchase, for example, a holiday home or other private purchases), debt can be repaid more quickly and/or less debt has to be incurred, leading to lower interest payments that in turn further increase profit margins, eventually resulting in a snowball effect where the debt and cash position of the farm improve at increasing rates.

The results also indicate that the risk position of the participating farms improved significantly with the implementation of PF, especially with respect to production and financial risk. It can therefore be concluded that PF could be a valuable risk management tool. The lower risk associated with PF could also have far-reaching consequences with regard to crop insurance. Farmers that practise PF could use this technology as a tool to negotiate lower premiums on crop insurance.

From the interviews with the farmers it also became apparent that their overall farm management abilities were improved significantly due to the informative nature of PF.

Important farming aspects such as nutrient and water requirements of the crops; yields; soil compaction, texture and quality; water, electricity and fuel consumption; status of pests and diseases; and temperature variations are monitored closely, thereby giving the farmers “hands-on” knowledge and enabling them to make timely decisions. Although it cannot be quantified, the farmers unanimously agreed that these aspects also positively impacted on the overall profitability of their farming businesses.

Ultimately, based on the results of the analyses, it can be concluded that the hypothesis as stated in Chapter 1 cannot be rejected. Consequently, from the analyses of the three participating farms it was found that a correctly implemented precision farming system leads to increased profitability and lower risk for the selected farms in the Northern Cape Province.

Despite the favourable outcomes of the study, there are several factors that should be kept in mind. Firstly, the results are applicable to the specific participating farms in the study only. One can therefore not generalise by assuming that the results indicate that PF would have a positive impact on any maize irrigation farm. The reason is that farms in South Africa differ significantly in terms of soil varieties and quality, water-holding capacities, water sources and quality to name a few. In addition, the management styles of farmers also differ substantially, which could influence the results. For example, one farmer could implement the PF system more efficiently and effectively than another farmer. The assumptions that are stipulated in the study should therefore be taken into account when assessing the results.

Secondly, the results were obtained by analysing the data provided by the participants in the study, and therefore all conclusions drawn in the study are based on the quality of the data provided by the stakeholders. However, through verification and validation of the results, the necessary steps were followed to ensure that the study would be conducted as accurately as possible.

Thirdly, factors such as farming operations, management decisions, markets, weather and disease conditions might divert from the assumptions made in the study and thereby affect the actual results in future. Since PF is still in its infancy in South

Africa and the study focuses on the likely outcomes of PF, a recommendation can be made that actual results in the future can be continuously evaluated and compared with the simulated results in order to learn valuable lessons based on hindsight. For example, what would happen if producer prices decrease instead of increase as assumed in the study? It is possible that losses could be aggregated due to the additional costs associated with PF (for example, PF service fees), which could result in smaller losses for CF relative to PF in the case of decreasing producer prices. As a result, production risk might also be higher for PF. Since this scenario was not tested, a recommendation is made for a study to test the impact of PF on the profitability of farming businesses in the event of decreasing producer prices.

Fourthly, since the study focuses solely on irrigation farming, a similar study could be conducted on dryland maize farming, as the majority of maize is produced under dryland conditions.

Fifthly, this study on the impact of PF on the profitability of selected maize irrigation farms in the Northern Cape Province could serve as a starting point for a more comprehensive study on the impact of PF on maize farming throughout South Africa.

Sixthly, this study could pave the way for an investigation into using PF as a means to negotiate lower crop insurance premiums by PF farmers, as this study evidently indicates that PF is less risky than CF (in the case of the participating farms).

Lastly, since the PF system evaluated in the study consists of a service provided by GWK in the Northern Cape Province, which includes PF services and equipment priced on a per-hectare basis, no significant capital expenditures with respect to PF are required. Although the farming businesses in this study indicated favourable results, several questions might arise in a farmer’s mind, namely:

- What are the costs of converting from a CF system to a PF system?
- Will the benefits of PF justify the additional costs thereof?
- In terms of economies of scale, what is the ideal farm size in order to reap the rewards of PF?

For a prospective maize irrigation farmer in the Northern Cape Province, the cost of converting from a CF system to a PF system is simply the PF (or HTF) service fee being charged by GWK (assuming his machinery is already equipped with the necessary GPS appliances such as monitors on harvesters), as explained in Chapter 3. The PF service fee will result in an increase in the variable costs of the farming business. With regard to economies of scale, it can be argued that since variable costs are not dependent on the size of the farm, farm size does not matter. Therefore, given his current financial and production situation, the *onus* lies on the farmer to determine whether he can afford the increase in variable cost as a result of PF, and whether the prospective benefits will outweigh the additional variable costs. However, when a farmer is required to make significant PF equipment purchases, the picture may change dramatically. For example, if a farmer had incurred debt in order to buy the necessary PF equipment, it can be argued that his fixed cost and risk might be substantially high during a declining producer price phase. This suggests that given the specific nature of the services provided by GWK, savings on capital investments as well as lower exposure to risk can be achieved by implementing PF. However, a study of the impact of PF on the profitability of maize farming where farmers are responsible for the acquisition of their own equipment (under an increasing as well as a decreasing producer price trend scenario) is strongly recommended.

REFERENCES

AFMA (Animal Feed Manufacturers Association). 2008. *Chairman's report*. Available online at: http://www.afma.co.za/imgs/Chairman's%20Report%202007_2008.pdf [Accessed: 2009-08-11]

AGSF-FAO (Agricultural Management, Marketing and Finance Service of the Food and Agricultural Organisation. 2007. *Training manual for farm planning and management for trainers of extension workers in Africa*. Available online at: http://www.fao.org [Accessed: 2009-08-13]

Anon. 2007. Agricultural prosperity still important. *Fin24,* 6 September. Available online at: http://www.fin24.com/articles/default/display_article.aspx?ArticleId=2175136&SurveyId=AGRI%20COMPANIES%20&SurveyCategory=surveys_this_week [Accessed: 2008-10-09]

Anon. 2008a. *Fieldstar*. Available online at: http://www.fieldstar.com/agco/FieldStar/FieldStarUK/ System/Precision.htm [Accessed: 2008-06-30]

Anon. 2008b. Measuring GDP in South Africa. *Optifinance*. Available online at: http://www.optifinance.co.za/16.Measuring+GDP+in+South+Africa.htm [Accessed: 2008-10-09]

Anon. 2008c. Tegnologie gee geld in die sak. *Landbouweekblad,* 2 May. Available online at: http://www.landbou.com [Accessed: 2008-05-15]

Anon. 2008d. Verbal communication with the author on 21 May and 22 May. Douglas, South Africa. (Notes in possession of the author.)

Anon. 2009. *Municipal Demarcation Board*. Available online at: http://www.demarcation.org.za [Accessed: 2009-08-12]

Bayley, B. 2000. *A revolution in the market: The deregulation of South African agriculture*. Oxford: Oxford Policy Management.

Batte, M.T. 1999. *Factors influencing profitability*. Paper presented at the Northern Ohio Crops Day Meeting, Wood County, Ohio, USA, January 1999.

Bekker, A. 2008. Verbal communication with the author on 15 May. Douglas, South Africa. (Notes in possession of the author.)

BFAP (Bureau for Food and Agricultural Policy). 2008 *The South African Agricultural Baseline*. Pretoria: BFAP.

Blackmore, B.S. 2003. *The role of yield maps in precision farming*. PhD Thesis. Cranfield University, Silsoe.

Bothma, I. 2008. Verbal communication with the author on 9 May. Douglas, South Africa. (Notes in possession of the author.)

Casavant, K. 1984. *Economics and agricultural management*. Virginia: Reston.

Clement, R.T. 2001. *Making hard decisions*. Boston: Duxbury.

Csáki, C. 1976. *Simulation and systems analysis in agriculture*. Amsterdam: Elsevier Science Publishers and Budapest: Akadémiai Kiadó.

Cutts, M., Reynolds, S., Meyer, F. & Vink, N. 2007. Modelling long-term commodities: The development of a simulation model for the South African wine industry within a partial equilibrium framework. *American Association of Wine Economists*, Working Paper No. 12, Paper presented at Agricultural Economics Association of South Africa, September 2007, Fourways, South Africa.

Du Plessis, L. 2008. Verbal communication with the author on 29 January. Pretoria, South Africa. (Notes in possession of the author.)

FAO (Food and Agricultural Organisation). 2009. *FAOSTAT*. Available online at: http://faostat.fao.org/site/339/default.aspx [Accessed on 2009-08-12]

FAPRI-UMC (Food and Agricultural Policy Research Institute-University of Missouri-Columbia). 2007. *Final report for the University of Missouri South African Education Program*. FAPRI-UMC Report #07-04. Available online at: http://www.fapri.missouri.edu/outreach/publications/2004/FAPRI_UMC_Report_07_04.pdf [Accessed: 2008-08-06]

FES (Financial-Economic Simulation Model). 2004. *FES model documentation*. Available online at: http://www.lei.dlo.nl/sites/FESmodel [Accessed: 2008-07-29]

France, J. & Thorniley, J.H.M. 1984. *Mathematical models in agriculture*. London: Butterworth.

Franzen, D. 1999. *Soil sampling and variable-rate fertilizer application. Site-specific farming, Number 2*. Available online at: http://www.ag.ndsu.edu/pubs/plantsci/soilfert/sf1176-2.htm [Accessed: 2008-07-04]

Geyser, J.M. 2000. *Decision support system to manage investment risk of grain farmers in South Africa.* Published PhD Thesis. University of Pretoria.

Godwin, R.J.; Earl, R.; Taylor, J.C.; Wood, G.A.; Bradley, R.I.; Welsh, J.P.; Richards, T.; Blackmore, B.S.; Carver, M.J.; Knight, S. & Welti, B. 2002. *Precision farming as a tool to reducing environmental damages in developing countries: A case study of cotton production in Benin*. Selected paper prepared for presentation at the American Agricultural Economics Association Annual Meeting, Denver, Colorado.

Griffen, T.W.; Lowenberg-DeBoer, J.; Lambert, D.M.; Peone, J.; Payne, T. & Daberkow, S.G. 2004. *Adoption, profitability, and making better use of precision farming data*. Staff Paper #04-06. West Lafayette, IN: Purdue University, Department of Agricultural Economics.

Groenewald, J.A. 2000. The Agricultural Marketing Act: A post-mortem. *South African Journal of Economics,* 68(3): 161-176. Available online at: http://www3.interscience.wiley.com/cgi-bin/fulltext/119007497/PDFSTART [Accessed: 2008-09-16]

GWK (Griekwaland-Wes Koöperasie). 2009. *GWK Jaarverslag*.

Haarhoff, D. 2008a. *Praktiese toepassing van hoër tegnologie boerdery (HTB) in die Noord Kaap.* Unpublished report. Douglas, South Africa.

Haarhoff, D. 2008b. Verbal communication with the author on 13 May. Douglas, South Africa. (Notes in possession of the author.)

Hardaker, J.B.; Huirne, R.B.M. & Anderson, J.R. 1997. *Coping with risk in agriculture*. Wallingford: CAB International.

Hardin, M.L. 1978. *A simulation model for analyzing farm capital investment alternatives*. PhD Thesis. Stillwater, OK: Oklahoma State University.

Harshbarger, C.E. 1969. *The effects of alternative strategies used in the decision making on firm growth and adjustment.* PhD Thesis. Purdue University, Indiana, USA.

Harwood, J.; Heifner, R.; Coble, K.; Perry, J. & Somwaru, .A. 1999. *Managing risk in farming: Concepts, research, and analysis*. Agricultural Economic Report No. 774. Available online at: http://www.ers.usda.gov/publications/aer774/ [Accessed: 2008-08-08]

Hattingh, H. 2008. Verbal communication with the author on 21 May. Douglas, South Africa. (Notes in possession of the author.)

Held, L.J. & Helmers, G.A. 1981. Growth and survival in wheat farming: The impact of land expansion and borrowing restraints. *Western Journal of Agricultural Economics* (no journal number provided).

Holmes, A. 2002 *Risk management*. Oxford: Capstone Publishing.

Johnson, S.R. & Rausser, G.C. 1977. System analysis and simulation: A survey of applications in agricultural and resource economics. In: G.G. Judge, R.H. Day, S.R. Johnson, G.C. Rausser & L.R. Martin (Eds.). *A survey of agricultural economics literature, Volume 2*. Minneapolis, MN: University of Minnesota Press.

Just, R. 2001. Addressing the changing nature of uncertainty in agriculture. *American Journal of Agricultural Economics,* 83(5):1131-1153.

Kassier. W.E. 1992. *Report of the Committee of Inquiry into the Marketing Act*. Pretoria: Department of Agriculture.

Kluge, A. 2008. Verbal communication with the author on 13 and 14 May. Douglas, South Africa. (Notes in possession of the author.)

Lambert, D. & Lowenberg-DeBoer, J. 2000. *Precision farming profitability review*. West Lafayette, IN: Purdue University, School of Agriculture, Site-specific Management Center.

Lewis, H. 2003. Determining the minimum acreage for cost-effective adoption of auto-guidance systems in cotton production. *ARE Update, 6(6)*. Davis, CA: University of California. Available online at: http://repositories.cdlib.org/giannini/areu/UpdateV6N6/ [Accessed: 2008-07-03]

Louw, A. 1979. *Groeistrategie vir boerdery-ondernemings*. Publsihed DSc (Agric) Thesis. University of Pretoria.

Lowenberg-DeBoer, J. 1999. Risk management potential of precision farming technologies. *Journal of Agricultural and Applied Economics,* 21(2): 275-285.

Lowenberg-DeBoer, J. & Boehlje, M.D. 1996. Revolution, evolution or dead-end: Economic perspectives on precision agriculture. *Proceedings of the Third International Conference on Precision Agriculture,* pp. 923-942. Madison, WI: ASA-CSSA-SSSSA.

Lowenberg-DeBoer, J. & Swinton, S. 1997. Economics of site-specific management in agronomic crops. In: F. Piere & E. Sadler (Eds.). *The state of site-specific management for agriculture USA.* Madison, WI: ASA-CSSA-SSSSA, pp. 369-396.

Lu, Y., Sadler, E.J. & Camp, C.R. 2005. Economikc Feasibility Study of Variable Irrigation of Corn Production in Southeast Coastal Plain. *Journal of Sustainable Agriculture*, 26(3). 2005.

Maine, N. 2002. *Precision farming in cash crop production in South Africa*. Poster presented at the 13th International Congress of the International Farm Management Association (IFMA), Wageningen, the Netherlands, July 2002.

Maine, N. 2006. *The profitability of precision agriculture in the Bothaville district*. Published PhD Thesis. University of the Free State.

Maize Board. 1986. *Mielieraad: 1935-1985*. Pretoria: Primedia.

Maize Trust. 2008. Maize Trust Website. Available online at: http://www.maizetrust.co.za/index.html [Accessed: 2008-09-19]

Malan, D.J.C. 2007. *Risk management for successful commercial agriculture*. Published MBA Dissertation. University of Pretoria.

Meiring, J.A. 1994. *Die ontwikkeling en toepassing van 'n besluitnemings-ondersteuningstelsel vir die ekonomiese evaluering van risikobestuur op plaasvlak*. PhD Thesis. University of the Free State.

Meyer, F.H. 2002. *Modelling the market outlook and policy alternatives for the wheat sector in South Africa*. Published MSc Dissertation. University of Pretoria.

Meyer, F.H. 2003. *Maize-to maize meal supply chain*. Unpublished report presented to the National Agricultural Marketing Council, Pretoria.

Meyer, F.H. 2006. *Model closure and price formation under switching grain market regimes in South Africa*. Published PhD Thesis. Pretoria: University of Pretoria.

Meyer, F.H. & Westhoff, P. 2003. *The South African grain, livestock and dairy model*. Unpublished Presentation at Maize Trust Meeting, Pretoria.

Meyer, F.H, Westhoff, P, Binfield, J. & Kirsten, J.F. 2006. Model closure and price formation under switching grain market regimes in South Africa, *Agrekon*, Vol 45, No 4, December 2006.

Moolman, M. 2007. *Finansiële onafhanklikheid vir die boer*. First Edition. Pretoria: Agri Connect.

Mqadi, L. 2005. *Production function analysis of the sensitivity of maize production to climate change in South Africa*. Published MSc Dissertation. University of Pretoria.

Northern Cape Province. 2007. *Maize industry: Situational analyses, market indicators and outlook for 2008 season*. Kimberley: Department of Agriculture and Land Reform.

Northern Cape Province. 2008. *Gross Domestic Product: Contribution of different industries and sectors towards GDP with reference to the agricultural sector: Quarter 2, 2008*. Kimberley: Department of Agriculture and Land Reform.

NDA (National Department of Agriculture). 2005. *Some agricultural economic concepts*. Pretoria: Department of Agriculture.

NDA (National Department of Agriculture). 2008a. *Abstract of agricultural statistics*. Pretoria: Department of Agriculture.

NDA (National Department of Agriculture). 2008b. *Chapter 2: The maize-to-maize meal value chain*. Available online at: http://www.nda.agric.za/docs/fpmc/Vol4_Chap2.pdf [Accessed: 2008-10-15]

NDA (National Department of Agriculture). 2008c. *Crops and markets*. Available online at: http://www.nda.agric.za/docs/CropsMarkets/Crops_0108.pdf [Accessed: 2008-10-15]

NDA (National Department of Agriculture). 2008d. *Economic review of the South African agriculture 2007/08*. Pretoria: Department of Agriculture.

NDA (National Department of Agriculture). 2009. *Abstract of agricultural statistics*. Pretoria: Department of Agriculture.

Patrick, G.F. 1998. *Managing risk in agriculture*. Available online at: http://agecon.uwyo.edu/RiskMgt/humanrisk/MangRiskinAG.pdf [Accessed: 2008-12-17]

Patrick, G.F. & Eisgruber, L.M. 1968. The impact of managerial ability and capital structure on growth of the farm firm. *American Journal of Agricultural Economics*, 50(3):491-506.

Rains, G.C. & Thomas, D.L. 2001. Soil sampling issues for precision management of crop production. *Cooperative Extension Service/The University of Georgia College of Agricultural and Environmental Sciences, Bulletin 1208*. Available online at: http://pubs.caes.uga.edu/caespubs/pubs/PDF/B1208.pdf [Accessed on 2008-07-04]

Richardson, J.W. 2004. *Simulation for applied risk management with an introduction to the Excel simulation add-in: Simetar©*. College Station, TX: Texas A&M University.

Richardson, J.W. & Nixon, C.J. 1986. *Description of FLIPSIM V: A general firm-level Policy simulation model*. College Station, TX: Texas A&M University.

Rüsch, P.C. 2001. *Precision farming in South Africa*. Published MEng Agric Dissertation. Pretoria: University of Pretoria.

SAGIS (South African Grain Information Service). 2008. *Area planted and final production estimate*. Available online at: http://www.sagis.org.za [Accessed: 2008-10-16]

Silva, C.B.; Ribeiro do Vale, S.M.L.; Pinto, A.C.; Müller, A.S. & Moura, A.D. 2007. The economic feasibility of precision farming in Mato Grosso do Sul State, Brazil: A case study. *Journal of Precision Farming*, 8: 255-256.

Stephens, J.J. 2001. *The business of hedging*. Prentice Hall.

Strauss, P.G. 2005. *Decision-making in agriculture: A farm-level modelling approach*. Published MSc Agric Dissertation. University of Pretoria.

Strauss, P.G. 2008. Verbal communication with the author on 25 January 2008. Pretoria, South Africa. (Notes in possession of the author.)

Strauss, P.G.; Meyer, F.H. & Kirsten, J.F. 2008. *Facilitating decision-making in agriculture by using a system of models*. Pretoria: University of Pretoria.

TIPI-CAL (Technology Impact and Policy Impact Calculations). 2003. *Documentation of the Model TIPI-CAL 3.0, Handbook Part 4*. Available online at: http://www.ifcnnetwork.org/04_M/Inhalt_Methods03.html [Accessed: 2008-08-06]

The Baker. 2007. The milling industry in short. *The Baker Magazine,* 11(2). Available online at: http://www.thebaker.co.za/ad_vol11no2shortmilling.html [Accessed: 2008-09-19]

Van Zyl, I.C.J. (sakkie.van_zyl@syngenta.com). 2008. *Estimations based on production cost data from Grain South Africa for the 2007/08 production season*. [E-mail to:] Van Zyl, S.F. (stefan.vanzyl@up.ac.za), 22 October 2009.

Van Zyl, M.J.; Kirsten, J.F.; Coetzee, G.K. & Blignaut, C.S. 1999. *Finance and the farmer*. Johannesburg: Standard Bank of South Africa.

Varian, H.R. 1999. *Intermediate microeconomics*. New York, NY: W.W. Norton & Company.

Vink, N. & Kirsten, J.F. 1999. A descriptive analysis of employment trends in South African agriculture. *Agrekon*, 38(2), June 1999.

Vink, N. & Kirsten, J.F. 2000. Deregulation of agricultural marketing in South Africa: Lessons learned. *Free Market Foundation Monograph No. 25*. Available online at: http://freemarketfoundation.com/htmupload/PUBDoc397.doc [Accessed: 2008-09-16]

Westhoff, P.; Brown, S., & Hart, C. 2005. When point estimates miss the point: Stochastic modeling of WTO restrictions. *FAPRI Policy Working Paper #01-05*, December 2005.

Winston, W.L. 2003. *Operations research: Applications and algorithms*. Boston: Duxbury.

APPENDIX A

- Financial results of the Luckhoff farm with *conventional* farming -

INCOME STATEMENT

YEAR	2004	2005	2006	2007	2008	2009	2010	2011
CASH FARM INCOME								
Grains	730,785	896,793	2,494,961	3,238,507	2,520,253	3,757,246	3,496,818	4,084,777
Livestock	-	-	-	-	-	-	-	-
Fruit	-	-	-	-	-	-	-	-
Wine	-	-	-	-	-	-	-	-
Vegetables	-	-	-	-	-	-	-	-
Other farm income	989,061	548,978	895,834	153,932	205,742	217,473	229,490	240,964
TOTAL CASH FARM INCOME	**1,719,846**	**1,445,771**	**3,390,796**	**3,392,438**	**2,725,995**	**3,974,719**	**3,726,308**	**4,325,740**
CASH FARM EXPENSES								
Grains	586,306	462,937	943,421	1,256,790	1,032,428	1,641,129	1,546,098	1,792,036
Livestock	-	-	-	-	-	-	-	-
Fruit	-	-	-	-	-	-	-	-
Wine	-	-	-	-	-	-	-	-
Vegetables	-	-	-	-	-	-	-	-
Accident insurance: employees	-	2,141	-	577	630	665	702	737
Auditor	8,371	6,853	11,064	12,034	13,130	13,878	14,645	15,378
Bank charges (admin costs)	5,211	6,086	6,908	2,083	6,921	7,316	7,720	8,106
Farm utilities (electricity, water, phone, etc.)	19,245	18,673	21,541	23,430	25,562	27,020	28,513	29,938
Fuel and lubricants (unallocated)	68,629	87,651	118,618	69,295	116,108	117,872	118,716	122,848
Full-time labour	150,515	144,191	168,470	183,242	199,920	211,319	222,996	234,145
Land rented	-	-	-	-	-	-	-	-
Licenses	-	2,380	-	2,982	3,018	3,190	3,366	3,534
Management salary	-	80,278	199,996	-	101,790	107,594	113,539	119,216
Membership fees	3,788	8,151	3,119	4,145	4,522	4,780	5,044	5,297
Monthly account	-	-	-	-	-	-	-	-
Other cash expenses	902,207	626,661	669,587	728,300	794,588	839,893	886,303	930,616
Professional services	-	-	-	-	-	-	-	-
Provincial government levy	2,426	3,000	3,807	-	3,804	4,020	4,243	4,455
Rent of moveable assets	480	480	480	-	550	581	613	644
Repairs and maintenance (unallocated)	152,776	44,559	85,227	126,386	137,889	145,751	153,805	161,494
Short term insurance	95,557	104,016	36,474	39,526	122,272	129,244	136,386	143,205
UIF	1,057	-	967	1,091	1,191	1,258	1,328	1,394
TOTAL CASH FARM EXPENSES	**1,996,568**	**1,598,056**	**2,269,679**	**2,449,882**	**2,564,321**	**3,255,512**	**3,244,016**	**3,573,043**
FARM GROSS MARGIN	**-276,722**	**-152,285**	**1,121,117**	**942,556**	**161,673**	**719,206**	**482,292**	**752,698**
INTEREST								
Interest Long-term debt	-	35,594	117,487	120,713	119,082	108,065	95,343	80,645
Interest Medium-term debt	66,753	44,851	30,186	13,029	-	7,750	6,196	15,405
Interest Operating loan	122,190	91,997	137,305	166,002	187,657	239,357	239,625	265,149
Interest Carryover debt	-	52,819	115,143	98,850	49,143	98,600	99,428	114,903
TOTAL INTEREST	188,943	225,262	400,121	398,594	355,881	453,771	440,592	476,102
NET CASH FARM INCOME	**-465,664**	**-377,547**	**720,996**	**543,962**	**-194,208**	**265,436**	**41,700**	**276,595**
Depreciation	36,736	34,899	33,154	31,497	29,922	28,426	31,621	30,040
NET FARM INCOME	**-502,401**	**-412,446**	**687,841**	**512,465**	**-224,130**	**237,010**	**10,079**	**246,555**

CASH FLOW STATEMENT

YEAR	2004	2005	2006	2007	2008	2009	2010	2011
CASH INFLOWS								
Beginning cash reserves	-	-	-	-	-	-	-	-
Net Cash Farm Income	-	-	720,996	543,962	-	265,436	41,700	276,595
Non-farm income	17,372	16,333	20,921	125,773	23,074	24,390	25,737	27,024
Interest on cash reserves	-	-	-	-	-	-	-	-
Cash difference asset replacement	276,722	152,285	-	-	-	-	-	-
TOTAL CASH INFLOWS	294,094	168,618	741,917	669,735	23,074	289,825	67,437	303,619
CASH OUTFLOWS								
Net Cash Farm Income	465,664	377,547	-	-	194,208	-	-	-
Non-farm expenses	-	-	-	-	-	-	-	-
Cash difference asset replacement	-	-	224,223	-	-	85,187	-	81,624
Principal long-term debt	-	150,987	81,896	78,670	80,301	91,318	104,040	118,738
Principal medium-term debt	158,935	142,856	157,521	99,511	-	8,066	9,619	21,232
Income taxes	-	-	51,588	90,023	90,023	107,799	56,967	37,023
Land taxes	-	-	-	-	-	-	-	-
Carryover debt	137,424	467,930	970,702	744,014	342,482	683,940	686,484	789,673
TOTAL CASH OUTFLOWS BEFORE FAMILY LIVING	762,023	1,139,320	1,485,931	1,012,217	707,014	976,310	857,110	1,048,290
RETURN TO FAMILY LIVING	**-467,930**	**-970,702**	**-744,014**	**-342,482**	**-683,940**	**-686,484**	**-789,673**	**-744,670**
Family living costs	-	-	-	-	-	-	-	-
TOTAL CASH OUTFLOWS	762,023	1,139,320	1,485,931	1,012,217	707,014	976,310	857,110	1,048,290
ENDING CASH SURPLUS/DEFICIT	**-467,930**	**-970,702**	**-744,014**	**-342,482**	**-683,940**	**-686,484**	**-789,673**	**-744,670**

STATEMENT OFASSETS AND LIABILITIES

YEAR	2004	2005	2006	2007	2008	2009	2010	2011
FIXED ASSETS								
Co-operative member funds	44,540	87,732	110,072	161,328	176,011	186,047	196,328	206,143
Land and fixed improvements	4,909,104	5,142,453	5,494,707	5,976,519	6,520,479	6,892,265	7,273,103	7,636,743
Other investments (shares etc.)	-	-	-	-	-	-	-	-
Other properties	176,502	176,502	476,501	465,651	508,033	537,000	566,672	595,005
Surrender value on policies	-	-	-	-	-	-	-	-
Water rights	-	-	-	-	-	-	-	-
TOTAL FIXED ASSETS	5,130,146	5,406,687	6,081,280	6,603,498	7,204,524	7,615,312	8,036,103	8,437,891
MOVEABLE ASSETS								
Breeding stock	-	-	-	-	-	-	-	-
Equipment and tools	7,085	7,085	16,889	16,889	18,426	19,477	20,553	21,581
Implements and machinery	629,724	629,724	642,699	642,700	663,070	700,877	739,604	776,583
Office equipment	-	-	-	-	-	-	-	-
Vehicles	105,000	105,000	105,000	242,567	242,567	256,398	270,565	284,093
TOTAL MOVEABLE ASSETS	741,809	741,809	764,588	902,156	924,063	976,751	1,030,722	1,082,256
CURRENT ASSETS								
Cash surplus	-	-	-	-	-	-	-	-
Debtors	47,491	-	-	-	-	-	-	-
Deposits	-	-	-	-	-	-	-	-
Marketable livestock	-	-	-	-	-	-	-	-
Production means	2,449	2,599	2,741	2,735	2,984	3,154	3,328	3,495
Stored crops	-	-	-	-	-	-	-	-
VAT receivable	63,447	-	-	-	-	-	-	-
TOTAL CURRENT ASSETS	113,387	2,599	2,741	2,735	2,984	3,154	3,328	3,495
TOTAL ASSETS	**5,985,342**	**6,151,096**	**6,848,609**	**7,508,389**	**8,131,570**	**8,595,217**	**9,070,153**	**9,523,642**
LIABILITIES								
LONG TERM LIABILITIES	-	315,332	990,462	908,566	829,896	749,595	658,277	554,237
MEDIUM TERM LIABILITIES	556,273	397,339	254,483	98,066	-	53,756	45,691	106,618
SHORT TERM LIABILITIES								
Cash deficit	467,930	970,702	744,014	342,482	683,940	686,484	789,673	744,670
Credit card (outstanding)	-	-	-	-	-	-	-	-
Creditors	-	-	-	-	-	-	-	-
Monthly accounts	-	-	-	-	-	-	-	-
Overdraft facility	318,862	337,561	433,793	351,633	350,402	411,127	404,531	446,364
Production loans	163,396	129,015	262,919	350,252	287,725	457,362	430,878	499,418
Tax provision	4,941	4,255	1,655	28,535	31,132	32,907	34,726	36,462
TOTAL SHORT TERM LIABILITIES	955,129	1,441,533	1,442,381	1,072,902	1,353,199	1,587,880	1,659,807	1,726,914
TOTAL LIABILITIES	**1,511,402**	**2,154,204**	**2,687,326**	**2,079,534**	**2,183,096**	**2,391,232**	**2,363,775**	**2,387,769**

FINANCIAL RATIOS	2004	2005	2006	2007	2008	2009	2010	2011
FARM GROSS MARGIN	-276,722	-152,285	1,121,117	942,556	161,673	719,206	482,292	752,698
NET CASH FARM INCOME	-465,664	-377,547	720,996	543,962	-194,208	265,436	41,700	276,595
NET FARM INCOME	-502,401	-412,446	687,841	512,465	-224,130	237,010	10,079	246,555
RETURN TO FAMILY LIVING	-467,930	-970,702	-744,014	-342,482	-683,940	-686,484	-789,673	-744,670
ENDING CASH SURPLUS/DEFICIT	-467,930	-970,702	-744,014	-342,482	-683,940	-686,484	-789,673	-744,670
TOTAL ASSETS	5,985,342	6,151,096	6,848,609	7,508,389	8,131,570	8,595,217	9,070,153	9,523,642
TOTAL LIABILITIES	1,511,402	2,154,204	2,687,326	2,079,534	2,183,096	2,391,232	2,363,775	2,387,769
NET WORTH	4,473,940	3,996,892	4,161,283	5,428,855	5,948,475	6,203,985	6,706,378	7,135,873
REAL NET WORTH	4,473,940	3,815,524	3,717,791	4,459,253	4,478,456	4,418,868	4,526,584	4,587,132
DEBT TO ASSET RATIO (TOTAL DEBT/TOTAL ASSETS)	25%	35%	39%	28%	27%	28%	26%	25%
OPERATING COST TO INCOME RATIO	1.16	1.11	0.67	0.72	0.94	0.82	0.87	0.83

APPENDIX B

- Financial results of the Luckhoff farm with *precision* farming -

INCOME STATEMENT

YEAR	2004	2005	2006	2007	2008	2009	2010	2011
CASH FARM INCOME								
Grains	730,785	896,793	2,507,434	3,403,559	2,672,837	3,979,499	3,695,456	4,326,753
Livestock	-	-	-	-	-	-	-	-
Fruit	-	-	-	-	-	-	-	-
Wine	-	-	-	-	-	-	-	-
Vegetables	-	-	-	-	-	-	-	-
Other farm income	989,061	548,978	895,834	153,932	205,742	217,473	229,490	240,964
TOTAL CASH FARM INCOME	**1,719,846**	**1,445,771**	**3,403,268**	**3,557,491**	**2,878,579**	**4,196,972**	**3,924,946**	**4,567,716**
CASH FARM EXPENSES								
Grains	586,306	462,937	944,320	1,255,739	1,021,753	1,633,873	1,533,068	1,784,017
Livestock	-	-	-	-	-	-	-	-
Fruit	-	-	-	-	-	-	-	-
Wine	-	-	-	-	-	-	-	-
Vegetables	-	-	-	-	-	-	-	-
Accident insurance: employees	-	2,141	-	577	630	665	702	737
Auditor	8,371	6,853	11,064	12,034	13,130	13,878	14,645	15,378
Bank charges (admin costs)	5,211	6,086	6,908	2,083	6,921	7,316	7,720	8,106
Farm utilities (electricity, water, phone, etc.)	19,245	18,673	22,308	26,823	26,472	27,981	29,528	31,004
Fuel and lubricants (unallocated)	68,629	87,651	118,618	69,295	116,108	117,872	118,716	122,848
Full-time labour	150,515	144,191	126,341	122,174	149,927	158,475	167,232	175,593
Land rented	-	-	-	-	-	-	-	-
Licenses	-	2,380	-	2,982	3,018	3,190	3,366	3,534
Management salary	-	80,278	199,996	-	101,790	107,594	113,539	119,216
Membership fees	3,788	8,151	3,119	4,145	4,522	4,780	5,044	5,297
Monthly account	-	-	-	-	-	-	-	-
Other cash expenses	902,207	626,661	669,587	728,300	794,588	839,893	886,303	930,616
Professional services	-	-	-	-	-	-	-	-
Provincial government levy	2,426	3,000	3,807	-	3,804	4,020	4,243	4,455
Rent of moveable assets	480	480	480	-	550	581	613	644
Repairs and maintenance (unallocated)	152,776	44,559	85,227	126,386	137,889	145,751	153,805	161,494
Short term insurance	95,557	104,016	36,474	39,526	122,272	129,244	136,386	143,205
UIF	1,057	-	967	1,091	1,191	1,258	1,328	1,394
TOTAL CASH FARM EXPENSES	**1,996,568**	**1,598,056**	**2,229,216**	**2,391,156**	**2,504,563**	**3,196,374**	**3,176,236**	**3,507,537**
FARM GROSS MARGIN	**-276,722**	**-152,285**	**1,174,052**	**1,166,335**	**374,017**	**1,000,598**	**748,710**	**1,060,179**
INTEREST								
Interest Long-term debt	-	35,594	117,487	120,713	119,082	108,065	95,343	80,645
Interest Medium-term debt	66,753	44,851	30,186	16,483	2,750	7,011	5,574	11,188
Interest Operating loan	122,190	91,997	134,857	162,023	183,283	235,009	234,618	260,288
Interest Carryover debt	-	52,819	115,143	93,451	18,850	36,908	1,983	-
TOTAL INTEREST	188,943	225,262	397,673	392,669	323,966	386,993	337,518	352,121
NET CASH FARM INCOME	**-465,664**	**-377,547**	**776,379**	**773,666**	**50,051**	**613,605**	**411,192**	**708,058**
Depreciation	36,736	34,899	33,154	31,497	31,781	30,192	33,594	31,914
NET FARM INCOME	**-502,401**	**-412,446**	**743,224**	**742,169**	**18,270**	**583,413**	**377,598**	**676,144**

CASH FLOW STATEMENT

YEAR	2004	2005	2006	2007	2008	2009	2010	2011
CASH INFLOWS								
Beginning cash reserves	-	-	-	-	-	-	-	178,556
Net Cash Farm Income	-	-	776,379	773,666	50,051	613,605	411,192	708,058
Non-farm income	17,372	16,333	20,921	125,773	23,074	24,390	25,737	27,024
Interest on cash reserves	-	-	-	-	-	-	-	6,495
Cash difference asset replacement	276,722	152,285	-	-	-	-	-	-
TOTAL CASH INFLOWS	294,094	168,618	797,300	899,439	73,125	637,995	436,929	920,134
CASH OUTFLOWS								
Net Cash Farm Income	465,664	377,547	-	-	-	-	-	-
Non-farm expenses	-	-	-	-	-	-	-	-
Cash difference asset replacement	-	-	234,810	33,865	-	137,721	-	138,699
Principal long-term debt	-	150,987	81,896	78,670	80,301	91,318	104,040	118,738
Principal medium-term debt	158,935	142,856	157,521	103,499	4,692	10,099	11,536	20,151
Income taxes	-	-	55,742	111,405	112,775	156,531	129,109	124,157
Land taxes	-	-	-	-	-	-	-	-
Carryover debt	137,424	467,930	970,702	703,371	131,371	256,014	13,688	-
TOTAL CASH OUTFLOWS BEFORE FAMILY LIVING	762,023	1,139,320	1,500,672	1,030,810	329,139	651,683	258,373	401,745
RETURN TO FAMILY LIVING	**-467,930**	**-970,702**	**-703,371**	**-131,371**	**-256,014**	**-13,688**	**178,556**	**518,389**
Family living costs	-	-	-	-	-	-	-	-
TOTAL CASH OUTFLOWS	762,023	1,139,320	1,500,672	1,030,810	329,139	651,683	258,373	401,745
ENDING CASH SURPLUS/DEFICIT	**-467,930**	**-970,702**	**-703,371**	**-131,371**	**-256,014**	**-13,688**	**178,556**	**518,389**

STATEMENT OFASSETS AND LIABILITIES								
YEAR	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**
FIXED ASSETS								
Co-operative member funds	44,540	87,732	110,072	161,328	176,011	186,047	196,328	206,143
Land and fixed improvements	4,909,104	5,142,453	5,494,707	5,976,519	6,520,479	6,892,265	7,273,103	7,636,743
Other investments (shares etc.)	-	-	-	-	-	-	-	-
Other properties	176,502	176,502	476,501	465,651	508,033	537,000	566,672	595,005
Surrender value on policies	-	-	-	-	-	-	-	-
Water rights	-	-	-	-	-	-	-	-
TOTAL FIXED ASSETS	5,130,146	5,406,687	6,081,280	6,603,498	7,204,524	7,615,312	8,036,103	8,437,891
MOVEABLE ASSETS								
Breeding stock	-	-	-	-	-	-	-	-
Equipment and tools	7,085	7,085	16,889	16,889	18,426	19,477	20,553	21,581
Implements and machinery	629,724	629,724	642,699	642,700	663,070	700,877	739,604	776,583
Office equipment	-	-	-	-	-	-	-	-
Vehicles	105,000	105,000	105,000	242,567	242,567	256,398	270,565	284,093
TOTAL MOVEABLE ASSETS	741,809	741,809	764,588	902,156	924,063	976,751	1,030,722	1,082,256
CURRENT ASSETS								
Cash surplus	-	-	-	-	-	-	178,556	518,389
Debtors	47,491	-	-	-	-	-	-	-
Deposits	-	-	-	-	-	-	-	-
Marketable livestock	-	-	-	-	-	-	-	-
Production means	2,449	2,599	2,741	2,735	2,984	3,154	3,328	3,495
Stored crops	-	-	-	-	-	-	-	-
VAT receivable	63,447	-	-	-	-	-	-	-
TOTAL CURRENT ASSETS	113,387	2,599	2,741	2,735	2,984	3,154	181,884	521,884
TOTAL ASSETS	**5,985,342**	**6,151,096**	**6,848,609**	**7,508,389**	**8,131,570**	**8,595,217**	**9,248,709**	**10,042,031**
LIABILITIES								
LONG TERM LIABILITIES	-	315,332	990,462	908,566	829,896	749,595	658,277	554,237
MEDIUM TERM LIABILITIES	556,273	397,339	254,483	124,060	22,006	50,176	40,077	76,746
SHORT TERM LIABILITIES								
Cash deficit	467,930	970,702	703,371	131,371	256,014	13,688	-	-
Credit card (outstanding)	-	-	-	-	-	-	-	-
Creditors	-	-	-	-	-	-	-	-
Monthly accounts	-	-	-	-	-	-	-	-
Overdraft facility	318,862	337,561	429,867	345,555	288,435	351,265	302,364	334,548
Production loans	163,396	129,015	263,170	349,959	284,750	455,340	427,247	497,183
Tax provision	4,941	4,255	1,655	28,535	31,132	32,907	34,726	36,462
TOTAL SHORT TERM LIABILITIES	955,129	1,441,533	1,398,064	855,420	860,331	853,200	764,336	868,193
TOTAL LIABILITIES	**1,511,402**	**2,154,204**	**2,643,008**	**1,888,046**	**1,712,233**	**1,652,971**	**1,462,690**	**1,499,176**

FINANCIAL RATIOS								
	2004	2005	2006	2007	2008	2009	2010	2011
FARM GROSS MARGIN	-276,722	-152,285	1,174,052	1,166,335	374,017	1,000,598	748,710	1,060,179
NET CASH FARM INCOME	-465,664	-377,547	776,379	773,666	50,051	613,605	411,192	708,058
NET FARM INCOME	-502,401	-412,446	743,224	742,169	18,270	583,413	377,598	676,144
RETURN TO FAMILY LIVING	-467,930	-970,702	-703,371	-131,371	-256,014	-13,688	178,556	518,389
ENDING CASH SURPLUS/DEFICIT	-467,930	-970,702	-703,371	-131,371	-256,014	-13,688	178,556	518,389
TOTAL ASSETS	5,985,342	6,151,096	6,848,609	7,508,389	8,131,570	8,595,217	9,248,709	10,042,031
TOTAL LIABILITIES	1,511,402	2,154,204	2,643,008	1,888,046	1,712,233	1,652,971	1,462,690	1,499,176
NET WORTH	4,473,940	3,996,892	4,205,601	5,620,343	6,419,337	6,942,246	7,786,019	8,542,856
REAL NET WORTH	4,473,940	3,815,524	3,757,385	4,616,541	4,832,957	4,944,704	5,255,305	5,491,578
DEBT TO ASSET RATIO (TOTAL DEBT/TOTAL ASSETS)	25%	35%	39%	25%	21%	19%	16%	15%
OPERATING COST TO INCOME RATIO	1.16	1.11	0.66	0.67	0.87	0.76	0.81	0.77

APPENDIX C

- Financial results of the Douglas farm with *conventional* farming -

INCOME STATEMENT								
YEAR	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**
CASH FARM INCOME								
Grains	2,513,778	1,655,598	915,197	4,260,780	5,059,482	4,745,175	4,976,888	5,131,593
Livestock	-	-	-	-	-	-	-	-
Fruit	-	-	-	-	-	-	-	-
Wine	-	-	-	-	-	-	-	-
Vegetables	-	-	-	-	-	-	-	-
Other farm income	283,935	621,327	1,109,151	77,082	377,134	398,638	420,665	441,697
TOTAL CASH FARM INCOME	**2,797,713**	**2,276,925**	**2,024,348**	**4,337,862**	**5,436,616**	**5,143,813**	**5,397,553**	**5,573,290**
CASH FARM EXPENSES								
Grains	1,679,990	1,511,769	695,527	2,060,449	2,682,838	2,802,775	2,906,930	3,049,682
Livestock	-	-	-	-	-	-	-	-
Fruit	-	-	-	-	-	-	-	-
Wine	-	-	-	-	-	-	-	-
Vegetables	-	-	-	-	-	-	-	-
Accident insurance: employees	4,305	3,170	164	180	5,718	6,044	6,378	6,697
Auditor	-	7,711	6,860	7,621	9,586	10,132	10,692	11,227
Bank charges (admin costs)	39,040	31,763	18,440	23,622	33,000	34,882	36,809	38,650
Farm utilities (electricity, water, phone, etc.)	25,743	17,370	19,944	19,410	27,141	28,689	30,274	31,788
Fuel and lubricants (unallocated)	-	-	-	-	-	-	-	-
Full-time labour	257,563	119,519	129,999	175,117	281,397	297,442	313,878	329,571
Land rented	-	-	-	-	-	-	-	-
Licenses	3,069	3,279	3,567	1,745	4,076	4,309	4,547	4,774
Management salary	8,975	17,685	10,431	-	-	-	-	-
Membership fees	-	-	-	-	-	-	-	-
Monthly account	-	-	-	-	-	-	-	-
Other cash expenses	428,331	-	1,416,932	780,205	568,927	601,367	634,596	666,324
Professional services	4,533	2,514	5,268	2,017	6,021	6,364	6,716	7,052
Provincial government levy	-	-	-	-	-	-	-	-
Rent of moveable assets	-	-	-	-	-	-	-	-
Repairs and maintenance (unallocated)	37,317	7,983	12,896	26,281	49,566	52,392	55,287	58,051
Short term insurance	92,299	77,879	97,993	115,913	118,103	124,837	131,735	138,321
UIF	4,359	1,080	5,066	3,197	5,790	6,120	6,458	6,781
TOTAL CASH FARM EXPENSES	**2,585,524**	**1,801,722**	**2,423,087**	**3,215,757**	**3,792,164**	**3,975,353**	**4,144,300**	**4,348,918**
FARM GROSS MARGIN	**212,189**	**475,203**	**-398,739**	**1,122,105**	**1,644,452**	**1,168,460**	**1,253,253**	**1,224,372**
INTEREST								
Interest Long-term debt	56,214	36,903	20,083	-	-	-	-	-
Interest Medium-term debt	154,655	155,732	137,470	124,607	128,495	89,434	85,003	61,610
Interest Operating loan	193,914	127,110	179,639	267,030	340,086	358,189	375,155	395,497
Interest Carryover debt	-	52,343	86,505	204,900	230,810	140,574	105,326	62,759
TOTAL INTEREST	404,784	372,088	423,697	596,537	699,391	588,197	565,483	519,866
NET CASH FARM INCOME	**-192,594**	**103,115**	**-822,436**	**525,568**	**945,061**	**580,263**	**687,770**	**704,506**
Depreciation	80,250	79,504	81,593	77,513	73,638	79,514	75,539	83,563
NET FARM INCOME	**-272,844**	**23,611**	**-904,028**	**448,055**	**871,423**	**500,749**	**612,231**	**620,943**

CASH FLOW STATEMENT								
YEAR	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**
CASH INFLOWS								
Beginning cash reserves	-	-	-	-	-	-	-	-
Net Cash Farm Income	-	103,115	-	525,568	945,061	580,263	687,770	704,506
Non-farm income	395,959	134,854	252,155	94,264	525,929	555,917	586,635	615,965
Interest on cash reserves	-	-	-	-	-	-	-	-
Cash difference asset replacement	49,920	66,501	398,739	-	-	-	12,771	12,071
TOTAL CASH INFLOWS	445,879	304,470	650,894	619,832	1,470,990	1,136,180	1,287,176	1,332,542
CASH OUTFLOWS								
Net Cash Farm Income	192,594	-	822,436	-	-	-	-	-
Non-farm expenses	1,066	1,116	1,193	1,297	60,000	63,421	66,926	70,272
Cash difference asset replacement	-	-	-	126,237	46,326	-	-	-
Principal long-term debt	169,831	189,142	203,168	-	-	-	-	-
Principal medium-term debt	152,723	218,669	236,931	249,794	300,690	339,751	374,066	140,792
Income taxes	-	2,656	1,771	35,375	100,732	136,517	182,434	195,401
Land taxes	-	-	-	-	-	-	-	-
Carryover debt	-	463,709	729,274	1,542,214	1,608,547	975,098	727,206	431,316
TOTAL CASH OUTFLOWS BEFORE FAMILY LIVING	516,214	875,293	1,994,772	1,954,918	2,116,294	1,514,788	1,350,632	837,781
RETURN TO FAMILY LIVING	**-70,336**	**-570,823**	**-1,343,878**	**-1,335,086**	**-645,304**	**-378,608**	**-63,456**	**494,761**
Family living costs	393,373	158,451	198,336	273,461	329,794	348,598	367,860	386,252
TOTAL CASH OUTFLOWS	909,587	1,033,744	2,193,108	2,228,379	2,446,088	1,863,386	1,718,492	1,224,034
ENDING CASH SURPLUS/DEFICIT	**-463,709**	**-729,274**	**-1,542,214**	**-1,608,547**	**-975,098**	**-727,206**	**-431,316**	**108,508**

STATEMENT OFASSETS AND LIABILITIES

YEAR	2004	2005	2006	2007	2008	2009	2010	2011
FIXED ASSETS								
Co-operative member funds	738,683	809,527	858,492	-	981,150	1,037,093	1,094,399	1,149,116
Land and fixed improvements	8,265,800	8,396,824	8,971,998	9,758,723	10,646,925	11,253,992	11,875,841	12,469,608
Other investments (shares etc.)	-	-	-	-	-	-	-	-
Other properties	-	-	-	-	-	-	-	-
Surrender value on policies	-	-	-	-	-	-	-	-
Water rights	-	-	-	-	-	-	-	-
TOTAL FIXED ASSETS	9,004,483	9,206,351	9,830,490	9,758,723	11,628,075	12,291,085	12,970,240	13,618,725
MOVEABLE ASSETS								
Breeding stock	-	-	-	-	-	-	-	-
Equipment and tools	-	-	-	-	-	-	-	-
Implements and machinery	1,271,996	1,187,821	1,110,617	590,335	1,235,290	1,305,724	1,377,873	1,446,763
Office equipment	-	-	-	-	-	-	-	-
Vehicles	333,000	333,000	333,015	1,233,088	1,345,319	1,422,026	1,500,601	1,575,628
TOTAL MOVEABLE ASSETS	1,604,996	1,520,821	1,443,632	1,823,423	2,580,608	2,727,750	2,878,474	3,022,392
CURRENT ASSETS								
Cash surplus	-	-	-	-	-	-	-	108,508
Debtors	50,524	-	-	-	67,108	70,934	74,854	78,597
Deposits	93,338	62,436	5,508	-	104,052	109,985	116,062	121,865
Marketable livestock	-	-	-	-	-	-	-	-
Production means	-	51,700	-	114,000	65,554	69,292	73,121	76,777
Stored crops	-	-	-	-	-	-	-	-
VAT receivable	5,135	23,476	167,147	126,557	29,401	31,077	32,794	34,434
TOTAL CURRENT ASSETS	148,997	137,612	172,655	240,557	266,115	281,288	296,831	420,180
TOTAL ASSETS	**10,758,476**	**10,864,784**	**11,446,777**	**11,822,702**	**14,474,798**	**15,300,123**	**16,145,545**	**17,061,296**
LIABILITIES								
LONG TERM LIABILITIES	562,141	392,310	203,168	-	-	-	-	-
MEDIUM TERM LIABILITIES	1,405,958	1,505,065	1,286,396	1,049,465	991,639	690,949	642,924	467,178
SHORT TERM LIABILITIES								
Cash deficit	463,709	729,274	1,542,214	1,608,547	975,098	727,206	431,316	-
Credit card (outstanding)	-	-	-	-	-	-	-	-
Creditors	227,272	376,393	111,245	276,689	301,872	319,084	336,716	353,551
Monthly accounts	-	-	-	-	-	-	-	-
Overdraft facility	378,754	289,330	741,223	679,094	725,943	618,344	600,802	519,211
Production loans	1,606,793	1,445,901	665,223	1,970,676	2,565,947	2,680,659	2,780,275	2,916,808
Tax provision	-	-	-	-	-	-	-	-
TOTAL SHORT TERM LIABILITIES	2,676,528	2,840,897	3,059,905	4,535,006	4,568,860	4,345,293	4,149,109	3,789,570
TOTAL LIABILITIES	**4,644,626**	**4,738,272**	**4,549,469**	**5,584,470**	**5,560,499**	**5,036,242**	**4,792,033**	**4,256,748**

FINANCIAL RATIOS

Year	2004	2005	2006	2007	2008	2009	2010	2011
FARM GROSS MARGIN	212,189	475,203	-398,739	1,122,105	1,644,452	1,168,460	1,253,253	1,224,372
NET CASH FARM INCOME	-192,594	103,115	-822,436	525,568	945,061	580,263	687,770	704,506
NET FARM INCOME	-272,844	23,611	-904,028	448,055	871,423	500,749	612,231	620,943
RETURN TO FAMILY LIVING	-70,336	-570,823	-1,343,878	-1,335,086	-645,304	-378,608	-63,456	494,761
ENDING CASH SURPLUS/DEFICIT	-463,709	-729,274	-1,542,214	-1,608,547	-975,098	-727,206	-431,316	108,508
TOTAL ASSETS	10,758,476	10,864,784	11,446,777	11,822,702	14,474,798	15,300,123	16,145,545	17,061,296
TOTAL LIABILITIES	4,644,626	4,738,272	4,549,469	5,584,470	5,560,499	5,036,242	4,792,033	4,256,748
NET WORTH	6,113,850	6,126,511	6,897,309	6,238,232	8,914,299	10,263,881	11,353,511	12,804,548
REAL NET WORTH	6,113,850	5,848,508	6,162,222	5,124,074	6,711,350	7,310,581	7,663,245	8,231,108
DEBT TO ASSET RATIO (TOTAL DEBT/TOTAL ASSETS)	43%	44%	40%	47%	38%	33%	30%	25%
OPERATING COST TO INCOME RATIO	0.92	0.79	1.20	0.74	0.70	0.77	0.77	0.78

APPENDIX D

- Financial results of the Douglas farm with *precision* farming -

INCOME STATEMENT

YEAR	2004	2005	2006	2007	2008	2009	2010	2011
CASH FARM INCOME								
Grains	2,513,778	1,655,598	928,834	4,520,130	5,348,256	5,022,386	5,287,923	5,454,662
Livestock	-	-	-	-	-	-	-	-
Fruit	-	-	-	-	-	-	-	-
Wine	-	-	-	-	-	-	-	-
Vegetables	-	-	-	-	-	-	-	-
Other farm income	283,935	621,327	1,109,151	77,082	377,134	398,638	420,665	441,697
TOTAL CASH FARM INCOME	**2,797,713**	**2,276,925**	**2,037,985**	**4,597,212**	**5,725,391**	**5,421,024**	**5,708,588**	**5,896,360**
CASH FARM EXPENSES								
Grains	1,679,990	1,511,769	696,636	2,071,034	2,739,199	2,829,461	2,932,399	3,076,299
Livestock	-	-	-	-	-	-	-	-
Fruit	-	-	-	-	-	-	-	-
Wine	-	-	-	-	-	-	-	-
Vegetables	-	-	-	-	-	-	-	-
Accident insurance: employees	4,305	3,170	164	180	5,718	6,044	6,378	6,697
Auditor	-	7,711	6,860	7,621	9,586	10,132	10,692	11,227
Bank charges (admin costs)	39,040	31,763	18,440	23,622	33,000	34,882	36,809	38,650
Farm utilities (electricity, water, phone, etc.)	25,743	17,370	19,944	19,410	27,141	28,689	30,274	31,788
Fuel and lubricants (unallocated)	-	-	-	-	-	-	-	-
Full-time labour	257,563	119,519	129,999	175,117	281,397	297,442	313,878	329,571
Land rented	-	-	-	-	-	-	-	-
Licenses	3,069	3,279	3,567	1,745	4,076	4,309	4,547	4,774
Management salary	8,975	17,685	10,431	-	-	-	-	-
Membership fees	-	-	-	-	-	-	-	-
Monthly account	-	-	-	-	-	-	-	-
Other cash expenses	428,331	-	1,416,932	780,205	568,927	601,367	634,596	666,324
Professional services	4,533	2,514	5,268	2,017	6,021	6,364	6,716	7,052
Provincial government levy	-	-	-	-	-	-	-	-
Rent of moveable assets	-	-	-	-	-	-	-	-
Repairs and maintenance (unallocated)	37,317	7,983	12,896	26,281	49,566	52,392	55,287	58,051
Short term insurance	92,299	77,879	97,993	115,913	118,103	124,837	131,735	138,321
UIF	4,359	1,080	5,066	3,197	5,790	6,120	6,458	6,781
TOTAL CASH FARM EXPENSES	**2,585,524**	**1,801,722**	**2,424,196**	**3,226,342**	**3,848,526**	**4,002,039**	**4,169,769**	**4,375,534**
FARM GROSS MARGIN	**212,189**	**475,203**	**-386,211**	**1,370,870**	**1,876,865**	**1,418,986**	**1,538,819**	**1,520,825**
INTEREST								
Interest Long-term debt	56,214	36,903	20,083	-	-	-	-	-
Interest Medium-term debt	154,655	155,732	137,470	124,607	127,731	88,825	81,285	59,136
Interest Operating loan	193,914	127,110	179,721	267,909	345,140	360,593	377,460	397,918
Interest Carryover debt	-	52,343	86,505	204,911	201,938	83,616	12,480	-
TOTAL INTEREST	404,784	372,088	423,779	597,427	674,809	533,034	471,226	457,053
NET CASH FARM INCOME	**-192,594**	**103,115**	**-809,991**	**773,443**	**1,202,056**	**885,951**	**1,067,593**	**1,063,772**
Depreciation	80,250	79,504	81,593	77,513	73,638	79,514	75,539	83,807
NET FARM INCOME	**-272,844**	**23,611**	**-891,583**	**695,930**	**1,128,419**	**806,437**	**992,055**	**979,965**

CASH FLOW STATEMENT								
YEAR	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**
CASH INFLOWS								
Beginning cash reserves	-	-	-	-	-	-	-	476,015
Net Cash Farm Income	-	103,115	-	773,443	1,202,056	885,951	1,067,593	1,063,772
Non-farm income	395,959	134,854	252,155	94,264	525,929	555,917	586,635	615,965
Interest on cash reserves	-	-	-	-	-	-	-	11,544
Cash difference asset replacement	49,920	66,501	386,211	-	-	-	-	-
TOTAL CASH INFLOWS	445,879	304,470	638,366	867,707	1,727,986	1,441,868	1,654,228	2,167,296
CASH OUTFLOWS								
Net Cash Farm Income	192,594	-	809,991	-	-	-	-	-
Non-farm expenses	1,066	1,116	1,193	1,297	60,000	63,421	66,926	70,272
Cash difference asset replacement	-	-	-	154,223	72,473	-	16,353	8,049
Principal long-term debt	169,831	189,142	203,168	-	-	-	-	-
Principal medium-term debt	152,723	218,669	236,931	249,794	299,796	338,701	369,195	135,710
Income taxes	-	2,656	1,771	53,966	138,597	197,309	271,713	293,016
Land taxes	-	-	-	-	-	-	-	-
Carryover debt	-	463,709	729,274	1,542,296	1,407,331	580,004	86,166	-
TOTAL CASH OUTFLOWS BEFORE FAMILY LIVING	516,214	875,293	1,982,327	2,001,576	1,978,196	1,179,436	810,353	507,047
RETURN TO FAMILY LIVING	**-70,336**	**-570,823**	**-1,343,960**	**-1,133,870**	**-250,211**	**262,432**	**843,875**	**1,660,249**
Family living costs	393,373	158,451	198,336	273,461	329,794	348,598	367,860	386,252
TOTAL CASH OUTFLOWS	909,587	1,033,744	2,180,663	2,275,037	2,307,990	1,528,034	1,178,213	893,299
ENDING CASH SURPLUS/DEFICIT	**-463,709**	**-729,274**	**-1,542,296**	**-1,407,331**	**-580,004**	**-86,166**	**476,015**	**1,273,997**

STATEMENT OF ASSETS AND LIABILITIES								
YEAR	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**
FIXED ASSETS								
Co-operative member funds	738,683	809,527	858,492	-	981,150	1,037,093	1,094,399	1,149,116
Land and fixed improvements	8,265,800	8,396,824	8,971,998	9,758,723	10,646,925	11,253,992	11,875,841	12,469,608
Other investments (shares etc.)	-	-	-	-	-	-	-	-
Other properties	-	-	-	-	-	-	-	-
Surrender value on policies	-	-	-	-	-	-	-	-
Water rights	-	-	-	-	-	-	-	-
TOTAL FIXED ASSETS	9,004,483	9,206,351	9,830,490	9,758,723	11,628,075	12,291,085	12,970,240	13,618,725
MOVEABLE ASSETS								
Breeding stock	-	-	-	-	-	-	-	-
Equipment and tools	-	-	-	-	-	-	-	-
Implements and machinery	1,271,996	1,187,821	1,110,617	590,335	1,235,290	1,305,724	1,377,873	1,446,763
Office equipment	-	-	-	-	-	-	-	-
Vehicles	333,000	333,000	333,015	1,233,088	1,345,319	1,422,026	1,500,601	1,575,628
TOTAL MOVEABLE ASSETS	1,604,996	1,520,821	1,443,632	1,823,423	2,580,608	2,727,750	2,878,474	3,022,392
CURRENT ASSETS								
Cash surplus	-	-	-	-	-	-	476,015	1,273,997
Debtors	50,524	-	-	-	67,108	70,934	74,854	78,597
Deposits	93,338	62,436	5,508	-	104,052	109,985	116,062	121,865
Marketable livestock	-	-	-	-	-	-	-	-
Production means	-	51,700	-	114,000	65,554	69,292	73,121	76,777
Stored crops	-	-	-	-	-	-	-	-
VAT receivable	5,135	23,476	167,147	126,557	29,401	31,077	32,794	34,434
TOTAL CURRENT ASSETS	148,997	137,612	172,655	240,557	266,115	281,288	772,846	1,585,668
TOTAL ASSETS	**10,758,476**	**10,864,784**	**11,446,777**	**11,822,702**	**14,474,798**	**15,300,123**	**16,621,560**	**18,226,785**
LIABILITIES								
LONG TERM LIABILITIES	562,141	392,310	203,168	-	-	-	-	-
MEDIUM TERM LIABILITIES	1,405,958	1,505,065	1,286,396	1,049,465	985,828	686,032	614,846	447,574
SHORT TERM LIABILITIES								
Cash deficit	463,709	729,274	1,542,296	1,407,331	580,004	86,166	-	-
Credit card (outstanding)	-	-	-	-	-	-	-	-
Creditors	227,272	376,393	111,245	276,689	301,872	319,084	336,716	353,551
Monthly accounts	-	-	-	-	-	-	-	-
Overdraft facility	378,754	289,330	739,114	687,207	698,187	551,715	492,539	452,065
Production loans	1,606,793	1,445,901	666,284	1,980,800	2,619,853	2,706,181	2,804,635	2,942,265
Tax provision	-	-	-	-	-	-	-	-
TOTAL SHORT TERM LIABILITIES	2,676,528	2,840,897	3,058,939	4,352,026	4,199,916	3,663,147	3,633,890	3,747,881
TOTAL LIABILITIES	**4,644,626**	**4,738,272**	**4,548,502**	**5,401,491**	**5,185,744**	**4,349,180**	**4,248,736**	**4,195,454**

FINANCIAL RATIOS

	2004	2005	2006	2007	2008	2009	2010	2011
FARM GROSS MARGIN	212,189	475,203	-386,211	1,370,870	1,876,865	1,418,986	1,538,819	1,520,825
NET CASH FARM INCOME	-192,594	103,115	-809,991	773,443	1,202,056	885,951	1,067,593	1,063,772
NET FARM INCOME	-272,844	23,611	-891,583	695,930	1,128,419	806,437	992,055	979,965
RETURN TO FAMILY LIVING	-70,336	-570,823	-1,343,960	-1,133,870	-250,211	262,432	843,875	1,660,249
ENDING CASH SURPLUS/DEFICIT	-463,709	-729,274	-1,542,296	-1,407,331	-580,004	-86,166	476,015	1,273,997
TOTAL ASSETS	10,758,476	10,864,784	11,446,777	11,822,702	14,474,798	15,300,123	16,621,560	18,226,785
TOTAL LIABILITIES	4,644,626	4,738,272	4,548,502	5,401,491	5,185,744	4,349,180	4,248,736	4,195,454
NET WORTH	6,113,850	6,126,511	6,898,275	6,421,211	9,289,053	10,950,943	12,372,824	14,031,331
REAL NET WORTH	6,113,850	5,848,508	6,163,086	5,274,373	6,993,493	7,799,950	8,351,247	9,019,717
DEBT TO ASSET RATIO (TOTAL DEBT/TOTAL ASSETS)	43%	44%	40%	46%	36%	28%	26%	23%
OPERATING COST TO INCOME RATIO	0.92	0.79	1.19	0.70	0.67	0.74	0.73	0.74

APPENDIX E

- Financial results of the Barkley-Wes farm with *conventional* farming -

INCOME STATEMENT

YEAR	2004	2005	2006	2007	2008	2009	2010	2011
CASH FARM INCOME								
Grains	1,816,829	1,296,979	2,031,292	4,006,600	8,701,493	6,794,130	7,160,708	7,434,120
Livestock	-	-	-	-	-	-	-	-
Fruit	-	-	-	-	-	-	-	-
Wine	-	-	-	-	-	-	-	-
Vegetables	-	-	-	-	-	-	-	-
Other farm income	415,319	780,023	2,284,937	1,421,780	1,551,185	1,639,631	1,730,230	1,816,738
TOTAL CASH FARM INCOME	**2,232,148**	**2,077,002**	**4,316,229**	**5,428,380**	**10,252,678**	**8,433,761**	**8,890,938**	**9,250,858**
CASH FARM EXPENSES								
Grains	1,692,115	1,290,192	1,231,995	1,874,894	4,709,728	4,451,559	4,608,154	4,815,041
Livestock	-	-	-	-	-	-	-	-
Fruit	-	-	-	-	-	-	-	-
Wine	-	-	-	-	-	-	-	-
Vegetables	-	-	-	-	-	-	-	-
Accident insurance: employees	386	404	4,652	-	513	542	572	600
Auditor	-	9,310	5,969	-	11,805	12,479	13,168	13,826
Bank charges (admin costs)	88,334	65,703	41,791	23,500	47,762	50,486	53,275	55,939
Farm utilities (electricity, water, phone, etc.)	18,571	19,454	13,299	13,371	24,667	26,073	27,514	28,890
Fuel and lubricants (unallocated)	-	-	-	-	-	-	-	-
Full-time labour	118,311	102,285	104,871	118,365	157,146	166,106	175,284	184,048
Land rented	-	-	-	-	-	-	-	-
Licenses	-	3,349	-	-	4,163	4,400	4,643	4,875
Management salary	-	23,245	-	17,265	18,836	19,910	21,011	22,061
Membership fees	-	-	-	-	-	-	-	-
Monthly account	-	-	-	-	-	-	-	-
Other cash expenses	176,008	294,501	819,999	2,183,229	2,381,938	2,067,505	2,181,747	2,290,830
Professional services	3,353	14,110	20,271	1,562	4,454	4,708	4,968	5,216
Provincial government levy	-	-	-	-	-	-	-	-
Rent of moveable assets	-	-	-	-	-	-	-	-
Repairs and maintenance (unallocated)	153,572	10,928	31,106	124,632	203,981	215,611	227,525	238,901
Short term insurance	63,553	44,062	73,154	79,812	81,320	85,957	90,707	95,242
UIF	8,341	2,617	4,278	2,237	5,766	6,095	6,431	6,753
TOTAL CASH FARM EXPENSES	**2,322,544**	**1,880,160**	**2,351,385**	**4,438,867**	**7,652,079**	**7,111,430**	**7,414,999**	**7,762,222**
FARM GROSS MARGIN	**-90,396**	**196,842**	**1,964,845**	**989,513**	**2,600,599**	**1,322,331**	**1,475,939**	**1,488,636**
INTEREST								
Interest Long-term debt	43,794	28,834	15,728	-	-	-	-	-
Interest Medium-term debt	130,933	91,533	128,757	89,032	149,324	100,060	188,194	210,538
Interest Operating loan	208,286	158,607	208,444	440,741	820,569	766,175	802,610	844,078
Interest Carryover debt	-	77,764	99,226	-	9,787	-	-	-
TOTAL INTEREST	383,012	356,737	452,154	529,773	979,679	866,235	990,804	1,054,616
NET CASH FARM INCOME	**-473,409**	**-159,896**	**1,512,691**	**459,740**	**1,620,920**	**456,096**	**485,135**	**434,019**
Depreciation	157,425	149,553	142,076	150,099	142,594	158,186	150,276	172,582
NET FARM INCOME	**-630,833**	**-309,449**	**1,370,615**	**309,641**	**1,478,326**	**297,910**	**334,858**	**261,437**

CASH FLOW STATEMENT

YEAR	2004	2005	2006	2007	2008	2009	2010	2011
CASH INFLOWS								
Beginning cash reserves	-	-	-	98,397	-	954,006	889,195	1,014,543
Net Cash Farm Income	-	-	1,512,691	459,740	1,620,920	456,096	485,135	434,019
Non-farm income	109,316	535,765	277,826	87,710	145,198	153,477	161,958	170,055
Interest on cash reserves	-	-	-	2,179	-	22,922	21,465	24,604
Cash difference asset replacement	90,396	-	78,676	-	68,108	-	238,960	201,457
TOTAL CASH INFLOWS	199,712	535,765	1,869,192	648,026	1,834,226	1,586,501	1,796,712	1,844,678
CASH OUTFLOWS								
Net Cash Farm Income	473,409	159,896	-	-	-	-	-	-
Non-farm expenses	-	22,478	166,954	190,954	27,943	29,536	31,168	32,726
Cash difference asset replacement	-	19,684	-	-	-	-	-	-
Principal long-term debt	122,692	137,651	148,560	-	-	-	-	-
Principal medium-term debt	299,964	259,521	370,192	255,487	380,132	237,114	388,554	525,578
Income taxes	-	-	102,796	126,019	236,894	259,237	181,555	177,940
Land taxes	-	-	-	-	-	-	-	-
Carryover debt	-	738,126	896,263	-	73,077	-	-	-
TOTAL CASH OUTFLOWS BEFORE FAMILY LIVING	896,064	1,337,356	1,684,765	572,460	718,046	525,887	601,277	736,245
RETURN TO FAMILY LIVING	**-696,352**	**-801,591**	**184,427**	**75,567**	**1,116,179**	**1,060,615**	**1,195,435**	**1,108,434**
Family living costs	41,774	94,672	86,030	148,644	162,173	171,420	180,892	189,936
TOTAL CASH OUTFLOWS	937,838	1,432,028	1,770,795	721,104	880,219	697,307	782,169	926,181
ENDING CASH SURPLUS/DEFICIT	**-738,126**	**-896,263**	**98,397**	**-73,077**	**954,006**	**889,195**	**1,014,543**	**918,498**

STATEMENT OFASSETS AND LIABILITIES

YEAR	2004	2005	2006	2007	2008	2009	2010	2011
FIXED ASSETS								
Co-operative member funds	145,100	191,132	224,578	17,806	192,728	203,717	214,973	225,722
Land and fixed improvements	4,448,200	4,659,641	4,978,822	5,415,398	5,908,287	6,245,167	6,590,249	6,919,747
Other investments (shares etc.)	125,115	100,001	100,001	100,001	126,336	133,539	140,918	147,964
Other properties	-	-	-	-	-	-	-	-
Surrender value on policies	-	-	-	-	-	-	-	-
Water rights	-	-	-	-	-	-	-	-
TOTAL FIXED ASSETS	4,718,415	4,950,774	5,303,401	5,533,205	6,227,351	6,582,423	6,946,140	7,293,433
MOVEABLE ASSETS								
Breeding stock	-	-	-	-	-	-	-	-
Equipment and tools	127,780	127,787	136,846	75,580	162,393	171,652	181,137	190,194
Implements and machinery	2,998,491	2,927,154	3,728,246	3,192,667	3,810,721	4,028,001	4,250,572	4,463,091
Office equipment	-	-	12,459	13,551	14,785	15,628	16,491	17,316
Vehicles	150,000	105,057	194,500	170,616	190,632	201,501	212,636	223,267
TOTAL MOVEABLE ASSETS	3,276,271	3,159,998	4,072,051	3,452,414	4,178,530	4,416,782	4,660,835	4,893,867
CURRENT ASSETS								
Cash surplus	-	-	98,397	-	954,006	889,195	1,014,543	918,498
Debtors	141,698	-	-	-	188,209	198,941	209,933	220,429
Deposits	156,833	288,487	174,487	257,414	208,312	220,190	232,357	243,974
Marketable livestock	-	-	-	-	-	-	-	-
Production means	207,600	256,206	238,900	194,400	275,743	291,465	307,571	322,949
Stored crops	-	-	-	-	-	-	-	-
VAT receivable	-	-	638	91,464	-	-	-	-
TOTAL CURRENT ASSETS	506,131	544,693	512,422	543,278	1,626,271	1,599,791	1,764,404	1,705,849
TOTAL ASSETS	**8,500,817**	**8,655,465**	**9,887,874**	**9,528,898**	**12,032,152**	**12,598,996**	**13,371,380**	**13,893,150**
LIABILITIES								
LONG TERM LIABILITIES	408,903	286,211	148,560	-	-	-	-	-
MEDIUM TERM LIABILITIES	1,168,003	868,040	1,161,967	791,776	1,180,394	800,262	1,402,581	1,566,550
SHORT TERM LIABILITIES								
Cash deficit	738,126	896,263	-	73,077	-	-	-	-
Credit card (outstanding)	-	-	-	-	-	-	-	-
Creditors	-	572,805	67,020	244,219	266,447	281,639	297,201	312,061
Monthly accounts	-	-	-	-	-	-	-	-
Overdraft facility	547,869	667,887	938,443	1,071,112	1,348,348	1,185,825	1,285,895	1,383,649
Production loans	792,736	604,440	577,175	878,366	2,206,452	2,085,503	2,158,866	2,255,790
Tax provision	60,926	21,655	7,952	-	34,436	36,399	38,411	40,331
TOTAL SHORT TERM LIABILITIES	2,139,657	2,763,050	1,590,590	2,266,774	3,855,683	3,589,367	3,780,373	3,991,832
TOTAL LIABILITIES	**3,716,563**	**3,917,301**	**2,901,117**	**3,058,550**	**5,036,077**	**4,389,629**	**5,182,953**	**5,558,382**

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FINANCIAL RATIOS

Year	2004	2005	2006	2007	2008	2009	2010	2011
FARM GROSS MARGIN	-90,396	196,842	1,964,845	989,513	2,600,599	1,322,331	1,475,939	1,488,636
NET CASH FARM INCOME	-473,409	-159,896	1,512,691	459,740	1,620,920	456,096	485,135	434,019
NET FARM INCOME	-630,833	-309,449	1,370,615	309,641	1,478,326	297,910	334,858	261,437
RETURN TO FAMILY LIVING	-696,352	-801,591	184,427	75,567	1,116,179	1,060,615	1,195,435	1,108,434
ENDING CASH SURPLUS/DEFICIT	-738,126	-896,263	98,397	-73,077	954,006	889,195	1,014,543	918,498
TOTAL ASSETS	8,500,817	8,655,465	9,887,874	9,528,898	12,032,152	12,598,996	13,371,380	13,893,150
TOTAL LIABILITIES	3,716,563	3,917,301	2,901,117	3,058,550	5,036,077	4,389,629	5,182,953	5,558,382
NET WORTH	4,784,254	4,738,164	6,986,757	6,470,348	6,996,076	8,209,367	8,188,426	8,334,768
REAL NET WORTH	4,784,254	4,523,159	6,242,138	5,314,734	5,267,168	5,847,227	5,526,917	5,357,813
DEBT TO ASSET RATIO (TOTAL DEBT/TOTAL ASSETS)	44%	45%	29%	32%	42%	35%	39%	40%
OPERATING COST TO INCOME RATIO	1.04	0.91	0.54	0.82	0.75	0.84	0.83	0.84

APPENDIX F

- Financial results of the Barkley-Wes farm with *precision* farming -

INCOME STATEMENT

YEAR	2004	2005	2006	2007	2008	2009	2010	2011
CASH FARM INCOME								
Grains	1,816,829	1,296,979	2,031,292	4,241,593	9,260,143	7,386,265	7,785,167	8,082,569
Livestock	-	-	-	-	-	-	-	-
Fruit	-	-	-	-	-	-	-	-
Wine	-	-	-	-	-	-	-	-
Vegetables	-	-	-	-	-	-	-	-
Other farm income	415,319	780,023	2,284,937	1,421,780	1,551,185	1,639,631	1,730,230	1,816,738
TOTAL CASH FARM INCOME	**2,232,148**	**2,077,002**	**4,316,229**	**5,663,373**	**10,811,328**	**9,025,896**	**9,515,397**	**9,899,306**
CASH FARM EXPENSES								
Grains	1,692,115	1,290,192	1,241,187	1,899,973	4,737,575	4,490,144	4,649,433	4,858,561
Livestock	-	-	-	-	-	-	-	-
Fruit	-	-	-	-	-	-	-	-
Wine	-	-	-	-	-	-	-	-
Vegetables	-	-	-	-	-	-	-	-
Accident insurance: employees	386	404	4,652	-	513	542	572	600
Auditor	-	9,310	5,969	-	11,805	12,479	13,168	13,826
Bank charges (admin costs)	88,334	65,703	41,791	23,500	47,762	50,486	53,275	55,939
Farm utilities (electricity, water, phone, etc.)	18,571	19,454	13,299	13,371	24,667	26,073	27,514	28,890
Fuel and lubricants (unallocated)	-	-	-	-	-	-	-	-
Full-time labour	118,311	102,285	104,871	118,365	157,146	166,106	175,284	184,048
Land rented	-	-	-	-	-	-	-	-
Licenses	-	3,349	-	-	4,163	4,400	4,643	4,875
Management salary	-	23,245	-	17,265	18,836	19,910	21,011	22,061
Membership fees	-	-	-	-	-	-	-	-
Monthly account	-	-	-	-	-	-	-	-
Other cash expenses	176,008	294,501	819,999	2,183,229	2,381,938	2,067,505	2,181,747	2,290,830
Professional services	3,353	14,110	20,271	1,562	4,454	4,708	4,968	5,216
Provincial government levy	-	-	-	-	-	-	-	-
Rent of moveable assets	-	-	-	-	-	-	-	-
Repairs and maintenance (unallocated)	153,572	10,928	31,106	124,632	203,981	215,611	227,525	238,901
Short term insurance	63,553	44,062	73,154	79,812	81,320	85,957	90,707	95,242
UIF	8,341	2,617	4,278	2,237	5,766	6,095	6,431	6,753
TOTAL CASH FARM EXPENSES	**2,322,544**	**1,880,160**	**2,360,577**	**4,463,946**	**7,679,926**	**7,150,016**	**7,456,278**	**7,805,743**
FARM GROSS MARGIN	**-90,396**	**196,842**	**1,955,652**	**1,199,427**	**3,131,402**	**1,875,880**	**2,059,119**	**2,093,564**
INTEREST								
Interest Long-term debt	43,794	28,834	15,728	-	-	-	-	-
Interest Medium-term debt	130,933	91,533	128,808	89,072	145,800	97,252	180,808	206,635
Interest Operating loan	208,286	158,607	209,259	443,231	823,555	770,332	807,078	848,811
Interest Carryover debt	-	77,764	99,226	-	-	-	-	-
TOTAL INTEREST	383,012	356,737	453,020	532,303	969,354	867,583	987,886	1,055,446
NET CASH FARM INCOME	**-473,409**	**-159,896**	**1,502,632**	**667,124**	**2,162,048**	**1,008,297**	**1,071,234**	**1,038,118**
Depreciation	157,425	149,553	142,076	150,099	142,594	158,186	150,276	172,537
NET FARM INCOME	**-630,833**	**-309,449**	**1,360,557**	**517,025**	**2,019,454**	**850,111**	**920,957**	**865,581**

CASH FLOW STATEMENT

YEAR	2004	2005	2006	2007	2008	2009	2010	2011
CASH INFLOWS								
Beginning cash reserves	-	-	-	89,939	110,776	1,577,144	1,987,394	2,535,810
Net Cash Farm Income	-	-	1,502,632	667,124	2,162,048	1,008,297	1,071,234	1,038,118
Non-farm income	109,316	535,765	277,826	87,710	145,198	153,477	161,958	170,055
Interest on cash reserves	-	-	-	1,992	2,649	37,895	47,975	61,496
Cash difference asset replacement	90,396	-	79,595	-	15,027	-	180,056	181,952
TOTAL CASH INFLOWS	199,712	535,765	1,860,053	846,764	2,435,699	2,776,813	3,448,616	3,987,432
CASH OUTFLOWS								
Net Cash Farm Income	473,409	159,896	-	-	-	-	-	-
Non-farm expenses	-	22,478	166,954	190,954	27,943	29,536	31,168	32,726
Cash difference asset replacement	-	19,684	-	-	-	-	-	-
Principal long-term debt	122,692	137,651	148,560	-	-	-	-	-
Principal medium-term debt	299,964	259,521	370,265	255,571	376,161	232,427	377,681	515,402
Income taxes	-	-	102,042	140,819	292,278	356,036	323,066	349,208
Land taxes	-	-	-	-	-	-	-	-
Carryover debt	-	738,126	896,263	-	-	-	-	-
TOTAL CASH OUTFLOWS BEFORE FAMILY LIVING	896,064	1,337,356	1,684,084	587,344	696,382	617,999	731,915	897,336
RETURN TO FAMILY LIVING	**-696,352**	**-801,591**	**175,969**	**259,421**	**1,739,317**	**2,158,814**	**2,716,702**	**3,090,096**
Family living costs	41,774	94,672	86,030	148,644	162,173	171,420	180,892	189,936
TOTAL CASH OUTFLOWS	937,838	1,432,028	1,770,114	735,988	858,555	789,418	912,806	1,087,272
ENDING CASH SURPLUS/DEFICIT	**-738,126**	**-896,263**	**89,939**	**110,776**	**1,577,144**	**1,987,394**	**2,535,810**	**2,900,160**

STATEMENT OFASSETS AND LIABILITIES

YEAR	2004	2005	2006	2007	2008	2009	2010	2011
FIXED ASSETS								
Co-operative member funds	145,100	191,132	224,578	17,806	192,728	203,717	214,973	225,722
Land and fixed improvements	4,448,200	4,659,641	4,978,822	5,415,398	5,908,287	6,245,167	6,590,249	6,919,747
Other investments (shares etc.)	125,115	100,001	100,001	100,001	126,336	133,539	140,918	147,964
Other properties	-	-	-	-	-	-	-	-
Surrender value on policies	-	-	-	-	-	-	-	-
Water rights	-	-	-	-	-	-	-	-
TOTAL FIXED ASSETS	4,718,415	4,950,774	5,303,401	5,533,205	6,227,351	6,582,423	6,946,140	7,293,433
MOVEABLE ASSETS								
Breeding stock	-	-	-	-	-	-	-	-
Equipment and tools	127,780	127,787	136,846	75,580	162,393	171,652	181,137	190,194
Implements and machinery	2,998,491	2,927,154	3,728,246	3,192,667	3,810,721	4,028,001	4,250,572	4,463,091
Office equipment	-	-	12,459	13,551	14,785	15,628	16,491	17,316
Vehicles	150,000	105,057	194,500	170,616	190,632	201,501	212,636	223,267
TOTAL MOVEABLE ASSETS	3,276,271	3,159,998	4,072,051	3,452,414	4,178,530	4,416,782	4,660,835	4,893,867
CURRENT ASSETS								
Cash surplus	-	-	89,939	110,776	1,577,144	1,987,394	2,535,810	2,900,160
Debtors	141,698	-	-	-	188,209	198,941	209,933	220,429
Deposits	156,833	288,487	174,487	257,414	208,312	220,190	232,357	243,974
Marketable livestock	-	-	-	-	-	-	-	-
Production means	207,600	256,206	238,900	194,400	275,743	291,465	307,571	322,949
Stored crops	-	-	-	-	-	-	-	-
VAT receivable	-	-	638	91,464	-	-	-	-
TOTAL CURRENT ASSETS	506,131	544,693	503,964	654,054	2,249,409	2,697,990	3,285,670	3,687,511
TOTAL ASSETS	**8,500,817**	**8,655,465**	**9,879,416**	**9,639,674**	**12,655,290**	**13,697,195**	**14,892,646**	**15,874,812**
LIABILITIES								
LONG TERM LIABILITIES	408,903	286,211	148,560	-	-	-	-	-
MEDIUM TERM LIABILITIES	1,168,003	868,040	1,162,427	792,162	1,154,155	777,994	1,347,627	1,536,962
SHORT TERM LIABILITIES								
Cash deficit	738,126	896,263	-	-	-	-	-	-
Credit card (outstanding)	-	-	-	-	-	-	-	-
Creditors	-	572,805	67,020	244,219	266,447	281,639	297,201	312,061
Monthly accounts	-	-	-	-	-	-	-	-
Overdraft facility	547,869	667,887	938,495	1,076,001	1,339,366	1,212,067	1,321,755	1,429,113
Production loans	792,736	604,440	581,482	890,115	2,219,498	2,103,580	2,178,205	2,276,179
Tax provision	60,926	21,655	7,952	-	34,436	36,399	38,411	40,331
TOTAL SHORT TERM LIABILITIES	2,139,657	2,763,050	1,594,948	2,210,335	3,859,747	3,633,685	3,835,572	4,057,683
TOTAL LIABILITIES	**3,716,563**	**3,917,301**	**2,905,935**	**3,002,497**	**5,013,903**	**4,411,680**	**5,183,199**	**5,594,646**

FINANCIAL RATIOS

Year	2004	2005	2006	2007	2008	2009	2010	2011
FARM GROSS MARGIN	-90,396	196,842	1,955,652	1,199,427	3,131,402	1,875,880	2,059,119	2,093,564
NET CASH FARM INCOME	-473,409	-159,896	1,502,632	667,124	2,162,048	1,008,297	1,071,234	1,038,118
NET FARM INCOME	-630,833	-309,449	1,360,557	517,025	2,019,454	850,111	920,957	865,581
RETURN TO FAMILY LIVING	-696,352	-801,591	175,969	259,421	1,739,317	2,158,814	2,716,702	3,090,096
ENDING CASH SURPLUS/DEFICIT	-738,126	-896,263	89,939	110,776	1,577,144	1,987,394	2,535,810	2,900,160
TOTAL ASSETS	8,500,817	8,655,465	9,879,416	9,639,674	12,655,290	13,697,195	14,892,646	15,874,812
TOTAL LIABILITIES	3,716,563	3,917,301	2,905,935	3,002,497	5,013,903	4,411,680	5,183,199	5,594,646
NET WORTH	4,784,254	4,738,164	6,973,481	6,637,177	7,641,388	9,285,516	9,709,447	10,280,166
REAL NET WORTH	4,784,254	4,523,159	6,230,276	5,451,767	5,753,007	6,613,728	6,553,556	6,608,368
DEBT TO ASSET RATIO (TOTAL DEBT/TOTAL ASSETS)	44%	45%	29%	31%	40%	32%	35%	35%
OPERATING COST TO INCOME RATIO	1.04	0.91	0.55	0.79	0.71	0.79	0.78	0.79