A risk-based planting schedule design for a Sandveld potato farm: Case study Taaiboskraal farm

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SUMMARY

Risk in agriculture can primarily be classified systematically according to, the type, frequency and severity of an event. The outcome of the relevant unknown event determines the consequences of the chosen option. To manage risk, the prospective risk first needs to be identified. The interlink ages between the different sources of risk affects the farmers' overall exposure to risk. An integrated risk assessment therefore helps to identify numerous sources of risk and leads to more efficient decision making. Managing risk does not mean removing risk: rather, it means ensuring that the risk that could occur is at an acceptable level for the decision maker. The best method of managing risk depends upon the nature of the risk involved and the appetite for risk.

Potato producers in the Sandveld, farm in conditions of uncertainty. Farmers therefore constantly have to find ways in which to reduce their exposure. The purpose of this research was to determine an optimal four-year planting schedule for a farmer in the Elands Bay region in the Sandveld using Taaiboskraal farm as a case study. There are two predominant electricity tariffs that can be used, namely Ruraflex and Landrate. The farmer can choose between the Cape Town, Durban, Pretoria and Johannesburg fresh produce markets. The main objective of this research was therefore to evaluate the best planting schedule. This would be over four years for Taaiboskraal Farm in the Sandveld regarding the decision maker's appetite for risk, preferred market and optimal electricity tariff.

To obtain the gross margins for each pivot in each state of nature, the potential yields had to be determined using the LINTUL model. The irrigation costs, area and yield dependent costs needed to be determined using a cash flow model. The real prices were obtained for each of the four markets. Once the gross margins were determined, the correlation between prices and yield were determined using multivariate estimates (MVE). Stochastic Efficiency with Respect to a Function (SERF) is the most recent approach in ranking risky alternatives in terms of certainty equivalents (CE) for a specified range of attitudes to risk based on expected utility theory. The SERF model was then used to ascertain the optimal planting schedule after having determined the risk preference of the decision maker.

The results indicate that Ruraflex is the best electricity tariff for Taaiboskraal farm. It would therefore not be a good investment to pay the fees to switch to Landrate. When the farmer could choose between the Cape Town, Durban, Pretoria and Johannesburg markets, the Cape Town market was the predominant market of choice. An optimal four-year planting schedule was determined taking into account all the possible opportunity costs.

OPSOMMING

Risiko in die landbou kan hoofsaaklik sistematies geklassifiseer word ten opsigte van die tipe, frekwensie en omvang van 'n gebeurtenis. Die uitslag van die betrokke onbekende gebeurtenis bepaal dus die gevolge van die gekose opsie. Ten einde risiko te bestuur moet die voornemende risiko eers geïdentifiseer word. Die interafhanklikhede tussen die verskillende bronne van risiko beïnvloed die produsent se algehele blootstelling aan risiko. 'n Geïntegreerde risiko-assessering help dus om verskeie bronne van risiko te herken en lei tot meer doeltreffende besluitneming. Die bestuur van risiko beteken nie die verwydering van risiko nie. Eerder beteken dit om te verseker dat die risiko wat kan voorkom op 'n aanvaarbare vlak vir die besluitnemer is. Die beste metode van bestuur van risiko hang af van die aard van die betrokke risiko en die besigheid/eienaar se risiko-aptyt.

Aartappelprodusente in die Sandveld boer in toestande van onsekerheid en hulle moet voortdurend maniere vind om hul blootstelling te beperk. Die doel van hierdie navorsing is om 'n optimale vier jaar plant skedule te bepaal vir 'n boer in die Elandsbaai streek in die Sandveld met behulp van Taaiboskraal plaas as 'n gevallestudie. Daar is twee elektrisiteitstariewe wat van toepassing is: naamlik Ruraflex en Landrate. In die Sandveldkanboere slegs een keer elke vier jaar 'n land gebruik om aartappels te plant. Die boer is in staat om te kies tussen die Kaapstad, Durban, Pretoria en Johannesburg se varsproduktemarkte. Die hoofdoel van hierdie navorsing is dus om die beste plantskedule oor vier jaar vir Taaiboskraal plaas in die Sandveld te evalueer ten opsigte van aptyt van die besluitnemer vir risiko, verkose mark en optimale elektrisiteitstarief.

Om die bruto marges vir elke spilpunt vas te stel in elke staat van die natuur en om potensiële opbrengste te bepaal is die LINTUL model gebruik. Die besproeiingskoste, omgewing en opbrengs faktore is bepaal met behulp van 'n kontantvloei model. Die werklike pryse behaal vir elk van die vier markte is aangeteken. Die Stochastic Efficiency with Respect to a Function (SERF) model is die mees onlangse benadering tot die rangskikking van riskante alternatiewe in terme van sekerheidsekwivalente (CE) vir 'n bepaalde reeks van verhoudings. Die SERF model is daarna gebruik om die optimale plant skedule vir die plant siklus te bepaal nadat die risiko voorkeur van die besluitnemer bepaal is. Die uitslag van hierdie studie dui daarop dat Ruraflex die beste elektrisiteitstarief vir Taaiboskraal plaas is, en daarom sou dit nie 'n goeie belegging wees om die fooie te betaal om oor te skakel na Landratenie. Wanneer die boer tussen die Kaapstad, Durban, Pretoria en Johannesburg se markte kies is die Kaapse mark die oorheersende mark van keuse. 'n Optimale vier jaar plant skedule is vasgestel en geoptimaliseer met inagneming van al die moontlike geleentheidskoste.

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CHAPTER 1
Introduction

1.1 Background and Motivation

Agriculture has evolved over the centuries from small subsistence farming to large scale technologically advanced production systems. Agriculture has therefore had to adapt to new techniques, creating the need for farmers to become more efficient. Of South Africa's GDP, three percent is comprised of primary agriculture; this percentage may seem small; however, it has important forward and backward linkages to the South African economy which emphasizes the importance of the sector (Ministry for Agriculture and Land Affairs, 2015). Due to agriculture being so important to the sustainability of the country, the South African government used to subsidize farmers and assist them in times of financial strain. The Marketing of Agricultural Products Act, 1996 (Act No. 47 of 1996) came into effect in January 1997 which stated that government intervention in agricultural markets should be the exception, not the rule to improve efficiency and productivity (Ministry for Agriculture and Land Affairs, 2012). Farmers lost their safety net when the Act came into effect and are now exposed to further possible risk scenarios. Over the last few years the agricultural sector has been in turbulence, especially with an increase in price volatility which has caused sharp swings in product and input prices. With agricultural policies that are more decoupled from production and prices, and increased exposure to the international markets post-apartheid, farmers are now more exposed to market forces than in the past. Farmers therefore need to enhance their understanding and management of risk.

Agriculture is a complex integrated system in an environment of numerous unknowns. These unknowns originate from various sources of which the two main sources, namely production risk and market risk. Production risk results from activities that occur on the farm and any other factor that affects the farmer's ability to plant and harvest crops. This has an impact on the quantity and quality of production. Market risks are centred around the farmer`s ability to market the produce and make a profit. Both sources of risk transfer into farm income risk. Net income is largely reliant on the total yield which is subject to the time of harvest, input prices and seasonal variation (Bauer, 1999). This assertion implies that agricultural risk investigation should therefore not be emphasized on a specific factor, but should take into consideration the dependence amongst factors affecting risk sources and their contribution to the overall risk (El Benni and Finger, 2012). In order to incorporate the dependence amongst risk sources, a good management system needs to be followed. Risk management therefore entails the opportunity cost between changes in risk, expected returns and enterprise freedom. Risk management in agriculture is an essential tool for farmers to anticipate, avoid and react to shocks. Many shocks cannot be avoided, but numerous production risks can be decreased or eliminated through economic or agronomic practices (Hoag, 2010). Risk managers therefore have an option to control risk through combining four central techniques. Firstly, risk can be avoided through producing low-cost bulk-commodity crops rather than specialized crops (Boehlje *et al.*, 2004). Extreme risk avoidance can however, have severe impacts such as potentially new and greater risks or huge losses in potential income. Secondly risk can be reduced through diversification (Loubser and Nel, 2004); however, the ability to diversify can be minimised due to local restrictions. Geographic diversification can be optimally structured on a macro and micro level. At a macro level, the area that the farmer decides to farm will influence the type of farming activity that takes place. At a micro-level the farmer can control geographic diversification by taking into consideration factors such as frost, geographical aspect, rainfall and soil types. Vertical integration reduces risks associated with a variation in quantity and quality of inputs (backward integration) or outputs (forward integration). Thirdly, risk can be assumed or retained through complimentary risk management strategies where there is a positive correlation between return and risk. Lastly, risk can be transferred through insurance or future markets. Consequently, the techniques the farm manager chooses to combine directly affects the farms income.

Implementing the correct management practice is vital to the overall viability of a farm and farmers need to farm efficiently to ensure funds are wisely spent (Knutson *et al*., 1998). When evaluating management decisions, the farmer can make use of a detailed simulation model to develop simultaneous evaluations of different options available to the farmer as various conditions of uncertainty are considered and the long-term effects can be better analysed (Grant *et al*., 1986). Farmers farm in a volatile dynamic environment where their day to day decisions determine their long-term sustainability. Low output prices and increasing input costs have left many farmers with no room for error in planning and budgeting (Blignaut *et al*., 2010). Managing a successful commercial agricultural business requires the producer to consider the future, identify risks and connect them with expected returns. In order for a farmer to be successful, risks must be recognized, their respective returns identified and the best decision made going forward (Blignaut *et al*., 2010).

The potato farmers in the Sandveld, Western Cape, farm in tough conditions with sandy soils and extreme seasonal temperatures (Du Plessis, 2012). They do not have the option of using pricing mechanisms such as futures contracts. Farmers are therefore left with the option to alter factors at a micro level through management decisions concerning factors such as the type of cultivar, electricity tariff choice, geographic location and the season in which they plant, in order to minimize their risk. Because of the Sandveld' s unique farming conditions their risks need to be recognised and effectively dealt with, in order to minimise risk and ensure a sufficient cash flow.

1.*2* ***Problem statement***

The increase in market options and planting flexibility within the potato industry has enhanced the farmer's options to manage their risk (Richardson *et al*., 2000). Due to the limited capacity of a producer being able to anticipate future events, producers are frequently exposed to circumstances of uncertainty (Rosa, 2013). Agricultural commodity producers are exposed to two main types of risk namely production risk and market risk, therefore when planning the coming planting season, it is important to consider the consequence of yield and price variability on income volatility (Manfredo and Leuthold, 1998). When a producer produces a commodity, they fall in the category of being a price taker because they have no control over the price they receive (Hofstrand, 2007). The climatic conditions and the type of crop can have a significant impact on the final yield. In the absence of effective adaptation strategies, a commodity producer can be exposed to severe economic stresses. Diversification is an important tool for farmers to increase income certainty and to make trade-offs between risk and expected incomes (Kehkha *et al*., 2005). The main issue caused by the variability of price and production is how to react dynamically and strategically to opportunities or threats in order to create income or avoid loss (Pannell *et al*., 2000). Not all risks can be incorporated concurrently and hence it is important to focus on the main factors such as electricity tariff, market choice and planting schedule. Potato producers in the Sandveld lacks a planting schedule model that considers all the major relevant types of risks related to potato farming and provides the most optimal income given their appetite for risk.

A stochastic programming model can be used within a stochastic efficiency framework (Hardaker *et al*., 2004) to rank risky farm strategies and assess policy questions under risk (Lien *et al*., 2007). In stochastic programming, some of the data fundamentals used in the constraint or objective function are uncertain (Kall and Wallace, 1994; Dupačováand and Sladký, 2002). There has been a lot of mathematical programming research done which adapts a static framework and incorporates risk aversion in the objective function. Quadratic programming (Markowitz, 1952; Freund, 1956) and its linear approximations like the Minimization of Total Absolute Deviations (MOTAD) model (Hazell, 1971, Kehkha *et al*., 2005 and Rosa, 2013) have been widely used in agricultural economics. Research on conventional farming enterprises has also made use of stochastic programming with recourse (Kaiser and Apland, 1989; Kingwell, 1994; Torkamani and Hardaker, 1996; Pannell and Nordblom, 1998; Lien and Hardaker, 2001; Torkamani, 2006). The stochastic efficiency with respect to a function (SERF) model is a more recent approach to incorporating risk in decision models. SERF selects the utility efficient alternatives and does not find a subset of dominated alternatives like the Stochastic Dominance with Respect to a Function (SDRF) model. The SERF categorises options in terms of certainty equivalents over an acceptable range of risk aversion levels (Grove, 2006, Lien *et al*., 2007a, Ascough *et al*., 2009, Schumann *et al*., 2009 and Venter, 2015). The applications of these models are very problem specific which makes it difficult to apply the model exactly to a different scenario. The model must therefore be adapted in order to optimally solve a problem.

1.3 Aim

To provide the Sandveld potato farmer with a tool to develop an integrated and optimal planting schedule over a four-year cycle by taking into account the producer's risk appetite, geographical diversification, market preference and best electricity tariff.

1.4 Research objectives

1.4.1 Primary objectives

There are three primary objectives in this study. The three objectives are focused on electricity tariff, market and optimal planting schedule because these are factors that the farmer can manage to mitigate risk. There is a direct interlinkage between these factors and the income of each field.

- Establish the best electricity tariff to use on Taaiboskraal farm in the Sandveld.

  Eskom has various tariffs of which Landrate and Ruraflex are the two main tariffs used in agriculture. A farmer needs to determine which tariff is best for his enterprise therefore the SERF model will be used. There is an opportunity cost in choosing tariff therefore the optimal tariff needs to be determined to ensure the farmer is using the most feasible tariff. There is a conversion tariff when switching between the tariff therefore for this case study where Ruraflex is currently being used Landrate needs to be considerably more efficient for the farm to switch. Ruraflex is prices on time of use where Landrate is a fixed rate.

- Ascertain the best market for the sale of the potatoes between Cape Town, Pretoria, Durban and Johannesburg market for the sale of potatoes.

  The transport costs to the market will have an impact on price of potatoes because of higher costs; however, a large market may be able to have higher prices as the demand could be more which could counter the high transport costs. Taaiboskraal farm can choose between the Cape Town, Pretoria, Durban and Johannesburg market as the main markets for the produce. Cape Town is the closest market to the farming enterprise and Johannesburg has a large market with a high demand for potatoes because of the large population who tend to have a strong buying power.

- Determine the optimal four-year planting schedule for potatoes for different appetites to risk.

  The margin of error increases as the probability for obtaining a desired result diminishes. When a decision maker takes a bigger risk, he/she wants a higher return for taking on the risk therefore the SERF model must be used to obtain the best four-year planting schedule. The producer in the Sandveld can only plant potatoes every four years due to soil conditions.

1.4.2 Secondary objectives

- Determine the potential yields of potatoes over 12 states of nature in the Sandveld using the Light Interception and Utilization (LINTUL) simulation model.
- Determine the potential prices for 12 states of nature and the price risk in the four main markets using the ARCH/GARCH approach.
- Establish the irrigation costs on Taaiboskraal farm for Ruraflex and Landrate
- Determine the yield and dependent costs through an enterprise budget for potato production on Taaiboskraal farm.

1.5 Outline of the study

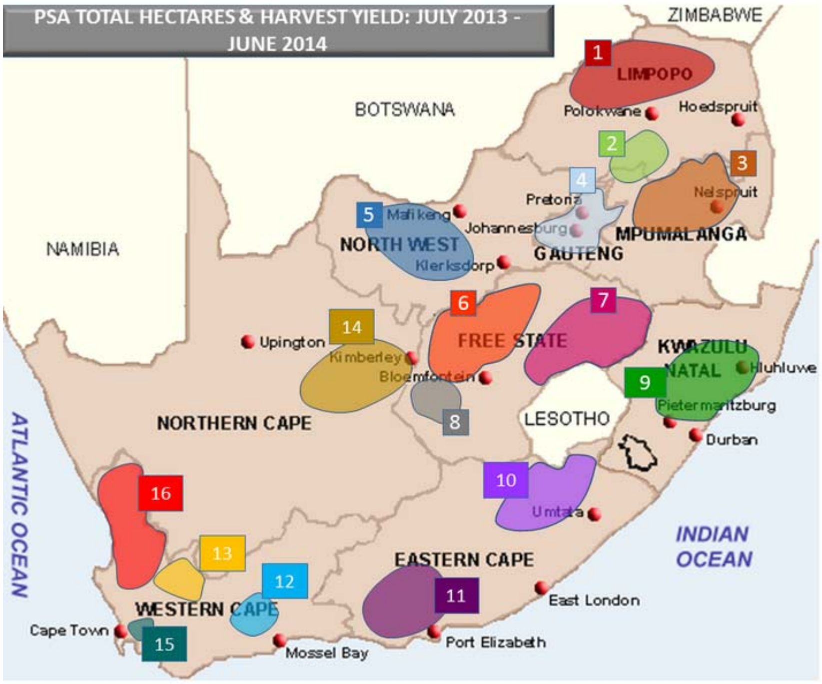
This thesis is presented as follows: Chapter 2 elaborates on the case study and the South African potato industry. Chapter 3 is a literature review related to risk in agriculture and risk management models. Chapter 4 describes the methodology of the integrated models to establish an optimal planting schedule over four years. Chapter 5 presents the results and concludes the findings. The final chapter, Chapter 6, covers the discussions and recommendations of the application of the models developed in this research.

CHAPTER 2
Case Study and Potato Industry

2.1 Introduction

In South Africa, potatoes are produced in 16 different regions as indicated in Figure 2.1 of which most of the potato production occurs on the eastern side of the country. The main producing areas are situated in Limpopo, the Free State, the Western Cape, Mpumalanga and KwaZulu-Natal. In South Africa, potatoes are planted on roughly 52 000 hectares and yield nearly 228 million 10kg pockets per annum (PotatoesSA, 2015). The eastern region of South Africa produces the most potatoes largely because of the higher rainfall. The majprity of South Africa's potatoes are cultivated under irrigation therefore yield risk is largely eliminated opposed to rainfed areas like the Eastern Free State.

The study area for this research is situated in the Sandveld region which is in the Fynbos biome, in the Western Cape. The Sandveld is the Western Cape's largest potato-producing region and third largest production area in South Africa. In this region, farmers cultivate roughly 7 279 hectares of potatoes annually under centre pivot irrigation in comparatively standardised production conditions (PotatoesSA, 2015). The yield for the Sandveld region in 2014 was 33 695 400 10kg pockets, which contributes 15% of the national yield harvested annually. This is higher than 2013 in Figure 2.1 because of a good season and farmers converted from seed potatoes to table potatoes. Farmers in the Sandveld region generally own large holdings due to the sandy soils and needing to give the fields extensive resting periods between plantings. Often only a portion of the farm is cleared for irrigated production. Irrigation constitutes a major investment in potato production in the Sandveld. The case study is conducted on Taaiboskraal farm, which is a family run farm situated at 32º33'23"S and 18º24'37"E. Case study method facilitates a researcher to carefully study the data within a specific context. Generally a case study method selects a small geographical area (Yin, 1994). The farm has an elevation ranging from 80m to 262m above sea level. Taaiboskraal farm is one of the largest potato producers for the fresh market in the Sandveld area, which was a strong motivating factor to use the farm as a case study. There is a weather station in the vicinity of the farm which provides accurate weather data and Taaiboskraal's financial records are all up to date which allows for accurate research to be conducted. The information on the farm was collected by Louw Smit over the course of the study.



	2013 Harvest	Hectares	Harvest Yield (10 kg bags)
1	Limpopo	9 619	45 721 646
2	Marble Hall	1 113	4 787 300
3	Mpumalanga	2 333	10 291 800
4	Gauteng	835	3 161 609
5	Northwest	1 917	10 538 414
6	W Free State	6 776	33 821 401
7	E Free State	9 989	33 106 489
8	SW Free State	970	5 088 435
9	KZN	4 204	18 319 000
10	NE Cape	1 590	7 190 009
11	E Cape	1 354	5 385 070
12	S Cape	206	960 548
13	Ceres	1 046	4 483 237
14	N Cape	1 524	6 099 487
15	SW Cape	57	241 200
16	Sandveld	6 409	28 187 300
	Total	49 942	217 382 945

Figure 2.1: Potato production regions and their respective yields in South Africa
Source: PotatoesSA, 2015.

2.2 Overall description and layout of Taaiboskraal farm

2.2.1 Crops

The types of crops on a farm are important because the composition of the various enterprises have a significant effect on the overall feasibility of the farm. Taaiboskraal farm's main farming enterprise is table potatoes of which there are 484 hectares available for potato production. The main types of potato cultivars that Taaiboskraal farm plant, are: 25% Mondial, 35% BP1, 20% Sifra, 10% Avalanche and 10% Eos. The smaller enterprises, to total income, on the farm are cattle and merino sheep. Due to the farm producing table potatoes, the potential market is broader than the seed potato market because the producer has the option to sell to the fresh market, export market and processing market.

2.2.2 Labour

Labour can be broken down into two main categories, namely permanent labour and causal labour. The number of labourers, especially permanent labour, can have an effect on cash flow because they are fixed costs throughout the year irrespective if production has taken place or not. A farm manager will have estimates on the number of casual labourers that are required for planting, harvesting and in the pack house. Yield variations will ultimately determine the amount of casual labour required. However, for irrigation the yields do not vary to the same extent as dryland potato production. Labour is therefore an important factor in a farming enterprise as it can be a high expense in the enterprise budget. Harvesting, planting and especially packaging is labour intensive. Management therefore needs to structure the labour in such a way that costs are kept to a minimum while still operating efficiently. Taaiboskraal farm has a total of 40 workers, where 30 workers work in the packing sheds from June to December, four workers are employed for harvesting from June until December and there are six permanent staff members. The farm is overseen by the Smit family and a manager oversees the packing shed.

2.2.3 Infrastructure

2.2.3.1 Irrigation systems

The design of the irrigation system is mainly reliant on the layout of the terrain and the type of farming enterprises. The terrain on Taaiboskraal farm has gradual sloping hills. Because potatoes can only be planted once every four years on a pivot, it is best to have at least four pivots per line because then the pump on the line can be used every year. The total number of hectares planted with potatoes per annum is roughly 120 hectares. The layout of the irrigation system, the gradient and distance that water must be pumped, the pressure and the field sizes all impact on the running costs of the irrigation system. The Sandveld receives a high winter rainfall therefore irrigation in the summer months is important and costlier. Taaiboskraal farm has 32 fields under centre pivot irrigation for potato production as indicated in Figure 2.2. The hectare sizes of the fields vary from 12 hectares to 20 hectares as illustrated in Table 2.1. The gradient of the fields varies from 1 % to 15.5% and the static head pump's range from 78m to 113m. The pressure at the centre varies as the pivot moves (with the slope), but is always above 1bar because of the use of a variable speed drive. The efficiency of the pumps is 70 %. There are 8 fields per line with varying pump sizes. A maximum of two pivots per line can be used in a season because of constraints from the packing shed.

Water stress, whether from too much or too little water, may have serious adverse effects on potato plants and tubers. Water requirements vary during different stages of the growing season on Taaiboskraal farm. Water scheduling on the farm is therefore done on experience and the general Observable condition of the soil and plants. Probes were used on Taaiboskraal; however, this system gave problems as they were found to produce irregular and inaccurate information. Management on Taaiboskraal now check the soils with a spade to see how wet the soils are and how the foliage is looking overall thereby relying on experience to determine when to irrigate daily. Management also monitors the humidity and temperature to gauge roughly how much evapotranspiration there was. The irrigation system makes use of 4 boreholes. The water is of a good quality and varies in depth but are not very deep.

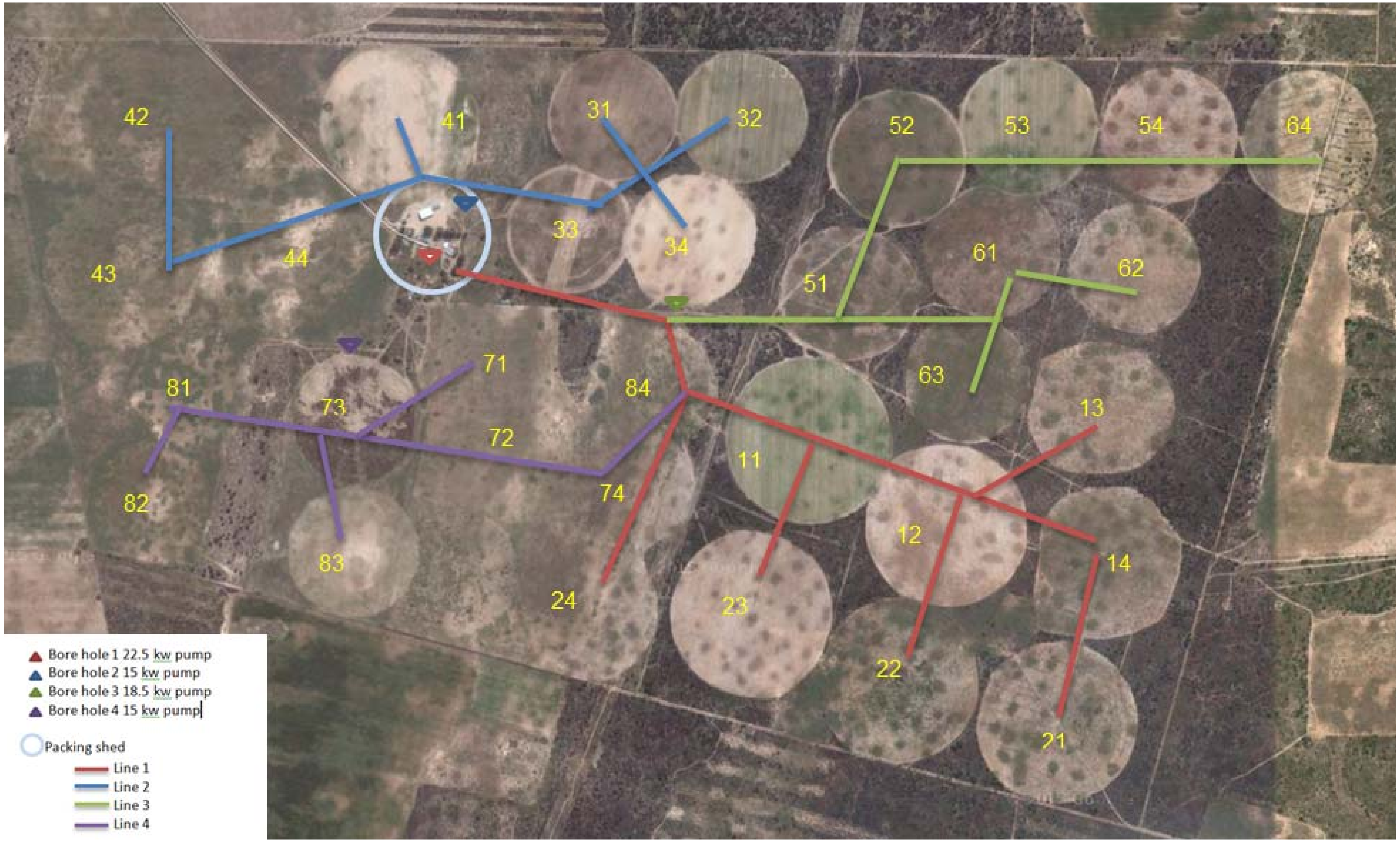


Figure 2.2: Layout of the center pivots on Taaiboskraal Farm

Source: Smit, 2016

2.2.3.2 Packing shed

The packing shed's capacity and distance from the pivot has a direct impact on the yield dependent costs because it affects the transport costs from the field to the shed and the initial cost of mechanisation in order to grade the potatoes. The packing shed's capacity and running expenses have a direct effect on the yield dependent costs for each pivot, so it is important to consider and incorporate it in the enterprise budget. Taaiboskraal farm has a packing shed on the farm and packs on average 70 000 10kg pockets per day (70 tons/day) in harvesting season (July to December). The packing shed only operates from Monday to Thursday. Taaiboskraal has one truck to transport their produce to the market and they hire additional trucks as needed.

2.2.4 Water

Having sufficient water throughout the year is essential to the crop and the cost of water contributes to the running cost of the pivot. When rainfall is high the running costs regarding water-use is lower, therefore in states of nature with low rain fall and extreme temperatures the use of water will be very high. In the Sandveld region ground water is used for the irrigation of potatoes. This underground water is obtained from subterranean aquifers situated between 0.5 and 100 m below ground level (Low and Pond, 2003). Taaiboskraal farm relies solely on underground water from a spring at the top of the valley. Taaiboskraal farm has a total of 730 000 m^3 of water rights per year. In 2014 the water tariff for the Sandveld area was R5.37 per kilo litre.

2.2.5 Electricity

The distance from the main source of electricity and the choice in electricity tariff are two of the main factors that affect the cost of electricity. Farmers in South Africa mainly use Ruraflex or Landrate tariffs on their farms. Taaiboskraal currently uses Ruraflex, which is a tariff that uses peak and off-peak times to ascertain the total electricity costs. The Ruraflex tariff is problematic due to the farm's sheds operating in the tariff's peak hour which increases the electricity costs. Due to the Sandveld experiencing lower tempertures in winter there is less evapotranspiration, less irrigation is required in the winter months (mainly May to July) thereby decreasing the electricity costs on Ruraflex when the tariffs are higher in the peak months. There is a conversion cost when switching between electricity costs therefore there must be a strong mitigating factor to warrant a switch between tariffs. The study will aim to determine if Ruraflex is the best tariff for the farm or if Landrate is the optimal tariff.

2.2.6 Mechanisation

The cost of machinery can be expensive especially when imports are required with a weak local currency. Machinery has an initial expense when being purchased then there are continuous expenses of maintenance which have a direct effect on the cash flow. Taaiboskraal farm makes use of a lot of mechanisation in order to operate. The running costs must be carefully considered as it can have an impact on the expenses of the farm. Taaiboskraal has a 2648 Mercedes Benz truck and a 20-ton trailer. The truck can load 30 tons at a time. There is a two-row automated harvester with a 206 KW engine. There are four tractors with 51 KW engines that have six ton trailers. There is a ripper. All the tractors have a four by four traction. There are two forklifts in the pack shed. The farm has two three litre four by four bakkies and one four point two bakkie and they all do 20 000 km on average per year. There is a large cement mixer on the farm for mixing purposes as this works out cheaper than buying the fertiliser already mixed. The cost of fuel is directly related to the use of machinery and can have a significant effect on the costs of operation. Taaiboskraal farm has a large diesel tank on the farm which enables the machinery to be refilled on the farm.

2.2.7 Climate

2.2.7.1 Rainfall

The amount of rainfall on the farm determines how much irrigation is required, which has a direct effect on the irrigation costs. The Sandveld has a dry Mediterranean climate with hot summers (November to April) and mild winters (June to August). Most of the annual rain falls in winter, with a long-term average annual rainfall of roughly 320 mm. Figure 3 depicts the annual rainfall from 2001 to 2010 for Taaiboskraal Farm where the years 2006, 2007 and 2008 had an above average rainfall.

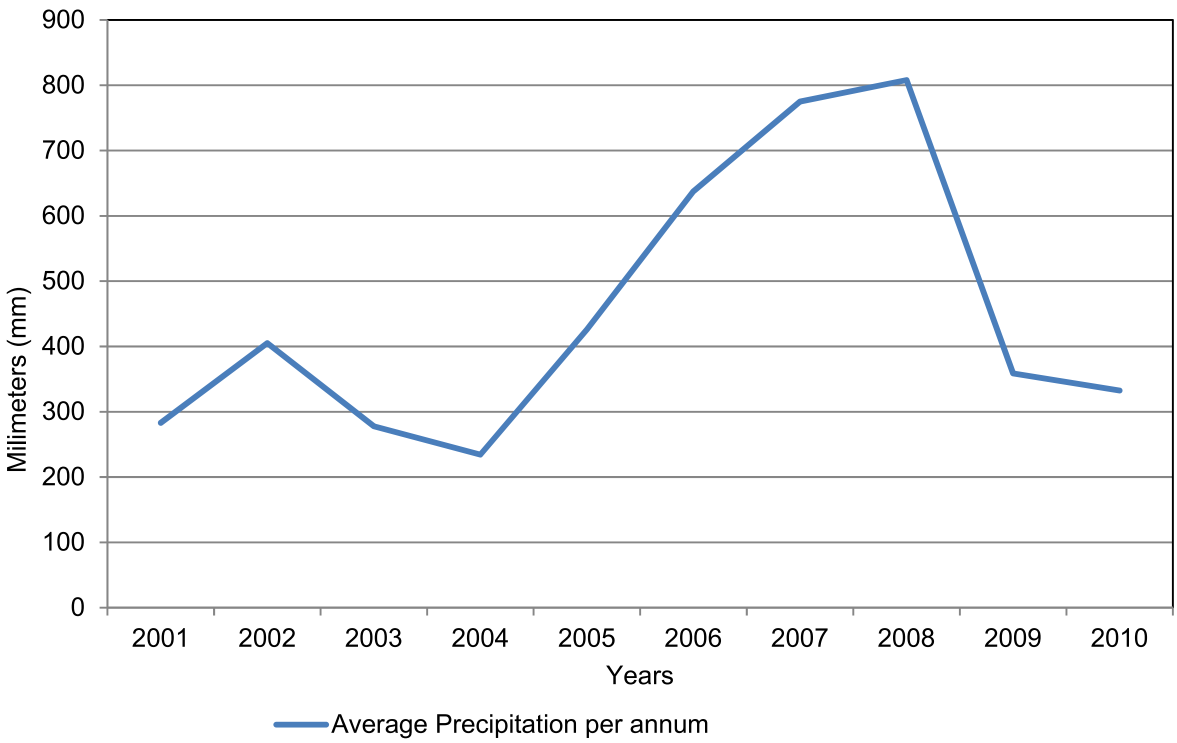


Figure 2.3: Average annual precipitation from 2001 to 2010 for Taaiboskraal Farm

Source: Weather Station, Elands Bay

2.2.7.2 Temperature

Temperature can be a limiting factor for growth if the threshold for growth is exceeded. The maximum and minimum monthly temperatures of Taaiboskraal farm from 2007 to 2010 are indicated in Figure 4. In summer, temperatures reach between 40 to 45 ºC which can often limit plant growth. The hottest summer months are January, February and March. In summer, there are more days that have a maximum temperature above 30 degrees, which is detrimental to potato growth (Franke *et al*., 2012). In winter the minimum temperatures reach below zero. Winter falls in the months: June, July and August. In winter photosynthesis is restricted due to cool temperatures and low radiation intensities. Frost only occurs in the more inland areas in the Sandveld in winter (Franke *et al*., 2011). The range of temperatures in summer is 15ºC and in winter the range is 10ºC, therefore there is more volatility in summer than winter with respect to temperatures.

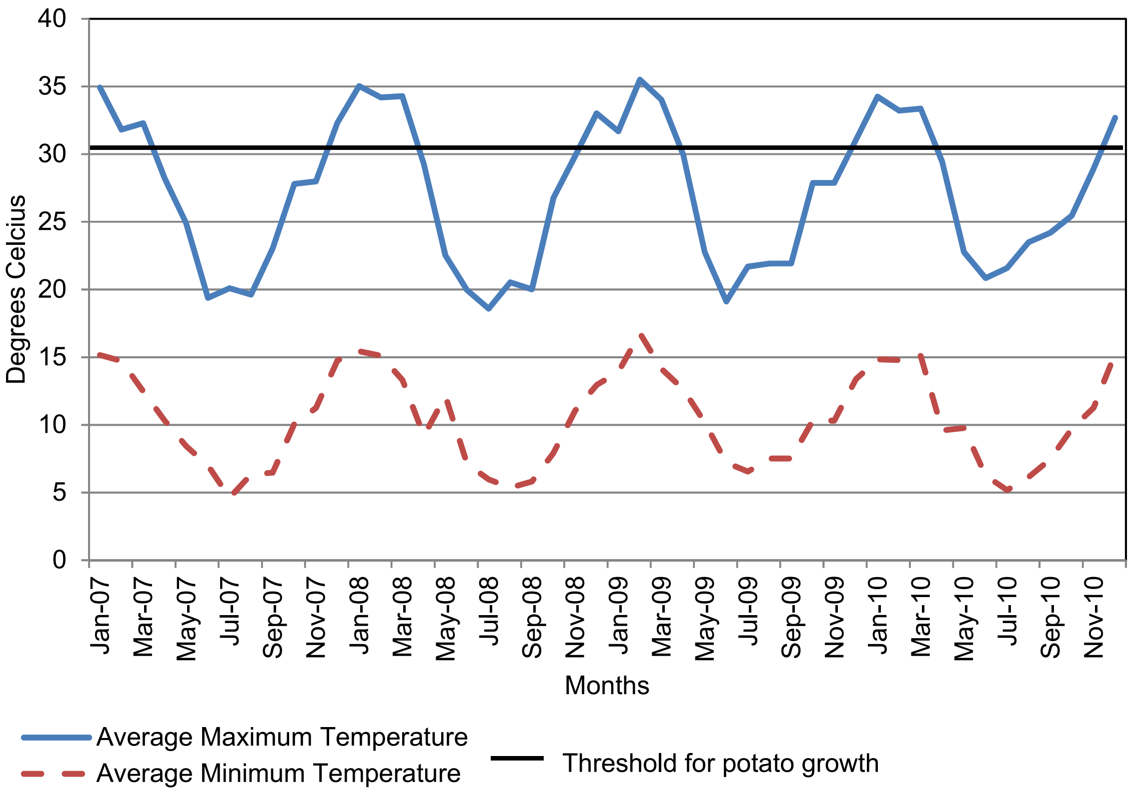


Figure 2.4: Monthly temperatures from 2007 until 2010 for Taaiboskraal Farm

Source: Weather Station, Elands Bay

2.2.8 Soil

The Sandveld has sandy soils which are homogeneous across all the lands on Taaiboskraal farm. The sand has a low moisture retention capacity therefore frequent irrigation is required. The need for frequent irrigation can therefore comprise a large part of the costs in the enterprise budget. The coarse sand is unable to hold a high organic matter content therefore frequent fertilization with nutrients such as nitrate and potassium is essential. The low water holding capacity implies that the risk of water drainage and nutrient leaching is high during irrigation. Although sandy soils are typically ideal for mechanical tillage and harvesting, these soils have a restricted water holding capacity and will only produce good yields if the rainfall is sufficient or if efficient irrigation supervision is practiced (Franke *et al*., 2011). Compacted layers or plough layers frequently develop on sandy soils and must be alleviated by deep ripping. The sandy soils in the Sandveld region (Taaiboskraal farm) limit the potential to profitably grow crops other than potatoes (Du Plessis, 2012).

2.3 Production conduct

The Sandveld is historically an important seed potato production area and in the last decade farmers have started producing table potatoes. Taaiboskraal plants roughly 120 hectares of table potatoes a year. The farm applies a four-year rotation cycle to the production of potatoes. A potato crop is in the field for less than one third of the year. The potatoes are planted in year one, then wheat is planted in year two and for year three and four the land is not utilized. The potato crop stays in the ground for approximately 120 days in summer and 130 days in winter. In winter Taaiboskraal plants the higher fields due to frost in the low-lying areas. Taaiboskraal uses modern equipment for groundwork, planting and spraying biocides. Pests (aphids) and diseases (Phytophthora Infestans and Alternaria Alternata) necessitate a regular application of crop protection agents. Due to the soil having minimal nutrients frequent fertilizing is essential on Taaiboskraal farm during planting. Farmers in the Sandveld grow potatoes year-round and typically attain an average yield of 40–45 tons per ha. From July to August Taaiboskraal farm harvests roughly 40-45 tons/ha then from September to October the farm harvests roughly 35-40 t/ha and from November to December the farm harvests 50 t/ha.

When planting begins, the field is first dug over, then gypsum is applied. The land is disked; then super phosphate is applied and the land is tilled. The potato seed is then planted. The potatoes are fertilised weekly and are sprayed with pesticides through the centre pivot. The sandy soils allow a lot of leaching to occur hence the regular need for fertilisation. The farm has a large mixing truck where the fertilizers are mixed. By buying the individual products the farmer aims to save on expenses. When the potatoes are ready to be harvested, the fields are not irrigated and a chemical agent is mechanically applied to defoliates the plants in order to ensure even ripening and stronger skins before harvesting. This ensures the fields are not wet and that the harvester can move through the field easily. A self-powered straddle harvester is used to take the potatoes out of the ground and take the potatoes to the tractors at the end of the field. The tractors with trailers take the potatoes to the pack house where they are washed, sorted and packaged. The pack house is occupied from June until December.

2.4 Performance

The farm's main income comes from potatoes, followed by the sales from the livestock. With the production of potatoes, Taaiboskraal's main production costs are fertilizer, packaging, irrigation and diesel. Taaiboskraal Farm currently operates at a profit; however, this profit can be optimised through diversifying the plant dates and pivots while considering the risks and the best possible returns.

2.5 Market structure

Potatoes are sold through various marketing channels in South Africa such as the National Fresh Produce Market (NFPM), informal trade and directly to processors and retailers. Figure 2.5 indicates the percentage of buyers of potatoes on the fresh produce markets in 2013. In 2013 the informal trade had the largest percentage of the fresh market sales, followed by the formal traders, the processors and then lastly the exporters. The type of marketing channel that a producer therefore sells the produce through, will have a significant effect on the price received which will impact the total returns. Taaiboskraal sells their produce to the two largest market types. These are namely to the formal market then to the informal market. Currently Taaiboskraal sells all their rejected potatoes to the informal markets in Cape Town and surrounding towns. The rejected potatoes are potatoes that do not fall within the grading criterea of potatoes. The increase in this type of trading in urban areas has occurred due to changes in urban eating behaviors and urbanization (PotaoesSA, 2015).

The sales of potatoes on the NFPM have declined over the years; however, the NFPM remains a significant channel for the sale of fresh potatoes in South Africa (PotatoesSA, 2013). The key reason for the lack of growth in potato sales has been the departure from the NFPMs by potato producers to direct sales to processors, wholesalers and retailers. This dispersion of sales to different markets is good for the demand of Taaiboskraal's produce on the fresh market. The largest potato market is Johannesburg Fresh Produce Market with a 32% share followed by Tshwane with 18%, Cape Town with 10% and Durban with 10% share (Potatoes SA, 2015). Taaiboskraal Farm markets most of their potatoes to the Cape Town formal market, however if the prices are better on the Johannesburg markets, the potatoes are then sold there. Taaiboskraal farm currently obtains the weekly prices via email and make their decisions based on this and historic prices to make the best decision regarding the price that they receive.

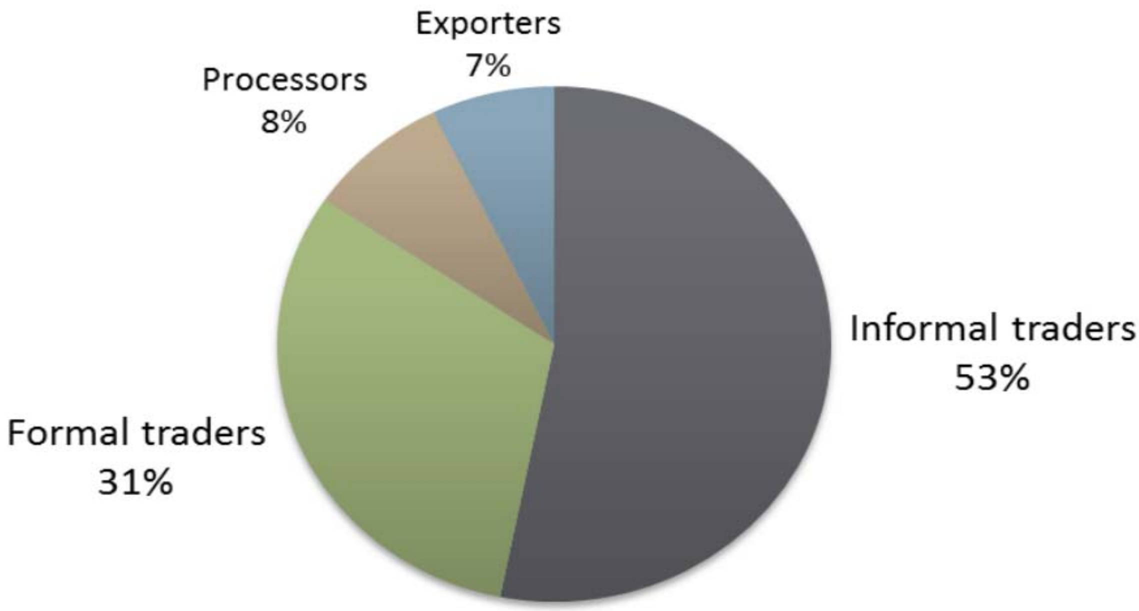


Figure 2.5: Percentage of buyers of potatoes on the fresh produce markets – 2013
Source: PotatoesSA, 2015

The formal sector consists mainly of the large retailers in South Africa. The formal market consumes an estimated 46% of all fresh potatoes produced, apart from any processed potato products that also go through formal trading channels. The formal market trade in potatoes generally concentrates on the sale of high quality fresh potatoes, either loosely or in smaller packaging. The informal market trading sector is the largest fresh produce market as illustrated in Figure 2.5. Taaiboskraal package their potatoes on the farm into 10kg brown paper pockets for the formal market.

2.6 Challenges affecting the potato industry and Taaiboskraal Farm

One of the main potential challenges facing the potato industry includes an increased supply of potatoes from the international markets. On the domestic market side, a challenge is because of the weak exchange rate and the increase in production costs. South Africa's water resources are extremely limited which is of special importance to the potato industry. Potatoes have a high dependency on water for irrigation given that 70% to 80% of all the country's potatoes are produced under irrigation. Rapid escalation in production costs, especially fuel and the lack of infrastructure in remote rural areas in accessing markets, especially for small-scale producers is a threat to the industry (PotatoesSA, 2013). Taaiboskraal farm can be put under pressure to always stay ahead with new innovations and technologies as a result of economies of scale putting pressure on the farm's cash flow. Staying ahead can be costly and time consuming to the farming business. The risks are also increased as new production practices, technology adoption, cultivars and markets are utilized and they don’t always work or are not always feasible in the long run.

The main aspects that effect the consumption of potatoes and various marketing strategies are supply (availability), price/value for money, quality (Trust in the product), perceptions, convenience, traditions, health, exports, processing, advertising and ethics (preference and taste). PROKON (Product Control for Agriculture) is an Article 21 company which establishes and maintains product quality control (PotatoesSA, 2013). Taaiboskraal therefore should ensure that there is a reliable manager on duty at all times when packing, to ensure that only the best potatoes are packed and that everything is run correctly. The processing market of potatoes is growing due to the expansion of the fast food industry, the higher average income of the population, the enlargement of processing facilities and the fast rate of urbanization. The processing industry uses fresh potatoes where French fries, frozen and chilled products and crisps comprise most of the market. The increase in the processing market will widen the gap for Taaiboskraal to be able to increase their share in the processing market however a switch in cultivar will be required because processing potatoes have their own cultivar. From a production point of view, the input costs for potato production has been high, especially with escalating international fuel and input prices. The costs of fertilizer and fuel have had a significant impact on Taaiboskraal’s cash flow. Potatoes are a costly crop to produce due to the large expenditures with regard to variable inputs and large investments in expensive, specialized equipment (Bohl and Johnson, 2010).

CHAPTER 3
Literature Review

3.1 Introduction

Research is a methodical process of accumulating, analysing and understanding information in order to enhance ones understanding of an aspect that one is interested in (Leedy and Ormrod, 2010). To understand an area of research it is therefore important to do a thorough investigation of the literature available on research already conducted by others. This section therefore analyses the literature related to modelling risk in agriculture.

The literature in this section will first explore risk in agriculture then the sources and management thereof. The second section will explore risk quantification. Lastly risk models and their application to problems will be explored in order to find the best models for the optimal planting schedule for Taaiboskraal farm taking into account the various opportunity costs.

3.2 Risk in agriculture

Agriculture is a unique sector as a result of its dependence on various variables such as biological and climatic factors and consequently its exposure to adverse natural events (Girdžiūtė, 2012). Risk in agriculture can mainly be classified according to a systematic character with regard to the type, frequency and severity of an event. For risk to occur there needs to be uncertainty however, uncertainty will not always result in a risky situation. Risk therefore includes the possibility of both potential gain and potential loss. Risk can thus be defined as uncertainty that affects an individual's welfare (Khandani *et al*., 2013). Uncertainty is associated with probability because it is impossible to analyse risk without knowing the likelihood of an occurrence (Anderson *et al*., 1985). When making decisions under uncertainty, the decision maker should choose one option above various other options. Producers frequently make gambled decisions when committing a resource, based on prevailing physical and financial constraints as a result of the uncertainty regarding the final return (Hazell and Norton, 1986, Domingo *et al*., 2015). The outcome of the relevant unknown event determines the consequences of the chosen option. It is thus assumed that decision maker understands the likelihood of the option occurring and has a preference of a possible outcome (Anderson *et al*., 1985). A farmer is often obligated to choose between higher average returns and lower risks as a result of an uncertain future.

3.2.1 Sources of risk

If the decision maker has a limited understanding of risk it implies that the decision maker is not rational in terms of statistical facts (Smith, 2013). In order to manage risk the prospective risk first needs to be identified (Crane *et al*., 2013). Risk identification is the procedure that is used to find, recognize and understand the risks that could affect the ability to achieve the desired objectives (Rădulescu and Rădulescu, 2014). Risk assessment includes evaluating the significance of potential threats by either qualitative or quantitative means. The decision maker therefore needs to choose between risky probabilities that are known and those that are less known (Smith, 2013; Hansson, 2016).

As agriculture becomes more industrialized, strategic risks are likely to become increasingly more difficult to manage (Miller *et al.,*2004). In agriculture there are five main sources of risk, namely yield risk, financial risk, political/personal risk, price risk and environmental risk (Hoag, 2010). Changes in rainfall and climatic conditions (environmental risk) have a direct effect on soil moisture and, crop growth which subsequently affects the crop yields. Price risk is the price variability farmer's face in selling their produce and purchasing inputs (Browne *et al*., 2013). Prices and yields generally have a negative correlation because they tend to move in opposite directions (Hueth and Furtan, 1994). The sources of risk in agriculture are therefore not isolated but interlinked between a combination of economic, natural and socio-political uncertainties (Harwood *et al*., 1999). The inter linkages between the different sources of risk, affects the farmer's overall exposure to risk. An integrated risk assessment therefore helps to recognise numerous sources of risk and leads to a more efficient way in making decisions (Baquet *et al*., 1997).

3.2.2 Risk management strategies

Risk management strategies are affected by an individual's ability to bear risk. Decision makers therefore strive to reduce any adverse consequences when assessing and making their decisions pertaining to risk (Smith, 2013). Managing risk does not mean removing risk it means ensuring that the risk that could occur is at an acceptable level for the decision maker. Decision makers can therefore be categorized into one of three broad categories, according to their risk tolerance, namely; risk averse, risk neutral and risk seeking (Moschini and Hennessy, 2001). Risk averse producers are the most cautious risk takers. Risk neutral producers understand they must take some chances to get ahead, but recognize that there are degrees of risk in every situation. Risk seeking individuals wants higher returns and looks for the chance to take risks. If the decision maker does not incorporate a risk averse approach when making decisions it can lead to the overestimation of the value of important resources or output levels of risky enterprises (Hazell, 1982). A decision maker who is risk averse is prepared to accept a lower average return for a lower uncertainty subject to the decision maker's level of risk aversion (Harwood *et al*., 1999).

Risk management includes understanding the sources of risk, setting risk management priorities and understanding the techniques available to make informed decisions pertaining to risk (Piggott *et al*., 2006). Farming enterprises can cope with risks by adapting strategies based on a combination of management strategies. The management strategies chosen by a decision maker either results in a direct financial cost or an opportunity cost forgone. Some strategies however are often constrained by the existence and accessibility to certain resources required to fulfil the strategy (Santeramo *et al*., 2012).

Within agriculture, decision makers have various options available to them to manage their risk. The four general procedures for managing risk are; avoidance, reduction, assumption/retention, and transfer (Holzmann and Jogersen, 2001 and Miller *et al.*, 2004). The best method of managing risk depends upon the nature of the risk involved and the appetite for risk. Risk management in agriculture typically ranges from informal strategies at a farm level to formal strategies like agriculture insurance and futures markets (Jain and Parshad, 2012). At a micro level a farmer can diversify the farm's enterprises, vertically integrate into the value chain or alter the financial structure of the farm. Diversification involves making use of more than one activity and is an effective way of reducing income variability (Hardaker, *et al*., 2015). The farmer's appetite to overall farm risk, price risk and yield risk has a significant impact on the risk management strategy (Harwood *et al*., 1999).

The main aim of risk management is to have the best combination of expected income and income certainty, given the resources available and the risk preference of the decision maker. Effective risk management therefore requires a comprehensive strategy that incorporates numerous responses to variability as a result of various possible risks. The preferred combination used by a decision maker will depend on the types of risk faced, the current and possible recourses available and the risk preferences. As a production response to risk, farmer's generally attempt to maintain flexibility in the use of farm assets and operating procedures (Hardaker*et al*., 2015).

3.2.3 Discussion

In agriculture, risk can be classified according to a systematic character with regard to the type, frequency and severity of an event. If the decision maker has a limited understanding of the potential risk it implies that the decision maker is not making an informed decision. In order to manage risk, the prospective risk first needs to be identified and the decision maker needs to choose between risky probabilities that are known and those that are less known. There are numerous interlinked sources of risk in agriculture and the combination of economic, natural and socio-political uncertainties therefore needs to be understood. Risk management strategies are affected by an individual's ability to bear risk. There are three main categories of risk which are categorised, according to the decision makers risk tolerance, namely risk averse, risk neutral and risk seeking. Farming enterprises can cope with risks by adapting strategies based on a combination of management strategies given the decision makers tolerance to risk. The main aim of risk management is therefore to have the best combination of expected income and income certainty given the resources available and the risk preference of the decision maker.

3.3 Approaches to characterisation of risk decision-making

There are various techniques available to characterise decision making in an uncertain environment. Two approaches that will be further explored in this study are the state-contingent approach and the parameterised distribution approach.

3.3.1 Parameterised distribution approach

Disregarding how risk is approached, there are two mutual features, the first is the perception that multiple outcomes are probable and secondly the end result is a matter of chance (Hurley, 2010). Risky decisions are predominately determined by the utility hypothesis theory in economics which was first defined by Bernoulli (1783) and then later delineated by Morgenstein and von Neumann (1947). The expected utility theory assumes the decision maker desires to maximize expected utility using a utility function to rank risky alternatives. Expected utility has three main components: the desirability of possible outcomes, the possible outcomes and the possibility of possible outcomes. The utility from an outcome resembles an individual's attitude towards risk. Expected utility given a parameterized distribution can therefore be defined as:

$$EU\ (x) = \int_{\underline{c}}^{\bar{c}} U(c) f((c|x) dc \qquad 3.1$$

where:

- c Unremitting random variable, bounded by $\bar{c}$ and $\underline{c}$ that represents a set of mutually exclusive outcomes,
- x Reflects an individual's preference over different activities that affect the allotment of outcomes (e.g., the amount of pesticides applied to a crop),
- U(c) Utility of outcome c
- $f(c|x)$ Individual's biased perception about the likelihood of outcome c given the choice of x^2

If not otherwise affirmed c will be referred to in the framework of income.

The parameterized approach is not the best model due to the canvasser not being given the chance to exploit the option of actively responding to uncertainty or to make use of the opportunities uncertainty provides. There is therefore a need for production economic models to actively attend to uncertainty, because uncertainty plays a vital part when making production economic decisions (Rasmussen, 2011). The alternate approach to the parameterized distribution approach, which has not been extensively explored in relevant research, is the state-contingent designed by Chambers and Quiggin (2000) depiction of input use decision-making under uncertainty. The slight dissimilarity in interpretation among parameterized distribution and the state contingent approach relates to how an individual's perception of the probability of likelihood outcomes is characterized. If an appropriate conversion of the random variable exists, the parameterized distribution approach and the state contingent approach are mathematically equivalent. Certain questions however, are best answered with a specific approach. In a state-contingent environment an individual's choices can't affect the likelihood of chance outcomes where in a parameterized distribution approach they do.

3.3.2 State contingent theory

When making decisions under uncertainty, the state-contingent theory provides the basis for the criteria (Rasmussen, 2003). There are three states within the state-contingent theory. The first state is state-general inputs, are inputs that influence production during numerous or all states of nature. These inputs are applied with a view of overall increase in output no matter what state of nature occurs. The second state is state-specific inputs which are a unique case of state-general inputs. The input works in one state of nature or a state specific input is applied with the point of increasing the output in one state of nature. Lastly there are state-allocable inputs which are when inputs could influence an output in numerous states of nature and can be assigned to various states of nature. This state removes the predicament of free disposability that is assumed with state contingent output that can result in, inefficient production (Matthews, 2014). The state contingent theory needs understanding of the transformation function. For the Expected Utility model to accurately model input use decisions, it is vital that the inputs are correctly stated as state-general, state-specific or state-allocable.

The optimal circumstances for different input classifications are a production function (one-input one-output), an isoquant (two inputs, one output) and transformation function (one input-two output) all portray the association between the inputs and output graphically (Rasmussen, 2011). Pope and Just (1978) dispute that empirically; numerous risk averse producers often over utilize rather than underutilize inputs. Due to the state of nature effect, goods produced in diverse states are classified as different products. The state contingent plan and the parametric approach are the same if there are an appropriate transformation functions for the random variables available (Hurley, 2010). A decision maker's risk choice determines a "good" or "bad" state of nature.

3.3.3 State contingent approach

The state contingent approach determines individual's perceptions according to the occurrence of a state of nature instead of the variation in the outcome variable. The producer is therefore able to change the input levels in every state in a response to different states of nature. According to Rasmussen (2011) the expectation of receiving certain quantities of the product conditional on the state provides utility not the product. The likelihood of an outcome, based on the decision maker`s opinion of a state of nature occurring, characterises the state contingent approach (Matthews, 2014).

Characterization of state contingent risk is:

$$EU\ (x) = \int_{\underline{s}}^{\bar{s}} U\big(c(x|s)\big) f(s) ds \qquad 3.2$$

Where:

s	Continuous random variable, bounded by $\bar{s}$ and $\underline{s}$ that depicts a set of mutually exclusive outcomes
U (c$(x|s)$)	Level of income for preference x given outcomes
$f(s)$	An individual’s biased viewpoints about the probability of outcome s.

The term U (c$(x|s)$) indicates that the utility for outcome *c* depends on the input choice *x* in a specific state of nature *s*. The producer is therefore able to change the input levels in each state of nature depending on the response to the difference in states of nature. The ability to change the level of inputs enables the producer to actively respond to uncertainty (Matthews, 2014). The term $f(s)ds$ determines probability of the chance outcomes within a state-contingent environment.

The benefit of using state-contingent response functions are that no distributional assumptions are necessary to model the impact of input use on changes in production risk (Quiggin & Chambers, 2002). As a result of the production risk being empirically quantified, the procedure could be used with any of the decision models that use empirical representations of output distributions such as MOTAD (Hazell, 1971), Target-MOTAD (Tauer, 1983) and Direct Expected Utility Maximisation (Kaylen et al., 1987; Biosvert & McCarl, 1990). Furthermore, the method overcomes the problem where the input use decision is represented by a combination of input levels for the same technology set and if the stochastic production function is represented by different activities for discrete levels of input use (Grové, 2010).

A concern regarding the state contingent approach is that it characterises numerous state-variables (O’Donnell et al., 2010). Many state-contingent variables are not independent variables therefore numerous states can be combined thereby decreasing the number of states considerably.

3.3.4 Discussion

Literature on decision-making under uncertainty has focussed primarily on the use of parameterised distributional approach. The parameterised approach does not however allow the decision maker the opportunity to explore the opportunities that uncertainty offers (Rasmussen, 2011). In the parameterised approach, the distribution of the outcome variable is established on the choice of the input variable. In the state-contingent approach, the distribution of the outcome variable is based on the state of nature. The individuals' choice, within the state-contingent approach can therefore not affect the likelihood of a chance outcome because the state of nature determines the likelihood of a chance outcome. The state-contingent approach therefore incorporates uncertainty due to factors external to the decision maker's decision-making process. This is a more realistic classification of risk in comparison to the parameterised approach. The research framework therefore implies that the state-contingent production function needs to be estimated. The state-contingent production functions allow for the development of transformation functions that can be used to describe production of a good between different states. Because production risk is empirically quantified, the state-contingent method can be used with any decision models that use empirical representations of output distributions.

3.4 Risk quantification

Risk can be quantified using various methods such as deductive, probability, empirical, subjective probabilities and econometric methods. The aim of these methods is to develop probability distributions (Haile, 2003). Risk is a structural component of agriculture therefore ignoring risk in modelling farm decisions is likely to cause biased results. Risk faced by farmers can be introduced either by introducing uncertainty in the supply of limiting inputs and the technical coefficients specification or randomising the trend of input and output prices (Arata *et al*., 2014).

Through a combination of modelling, extracting and quantifying individual judgment about uncertain variables, the probability distributions of prices, production levels and net income are typically obtained. The modelling process includes defining the relevant variables and characterizing their relationships in a formal model. The variables that can be modelled can either be decision variables such as the hectares to be planted or variables that are beyond the decision maker's control, such as price per unit of output and yield per hectare. Variables such as variable cost per hectare are partially under the decision makers' control. The farmer can therefore control the quantity of many variable inputs applied, but the quantity of some yield related inputs and the input prices are often beyond the operator's control. Uncertainty is therefore incorporated into the analysis by assigning probability distributions to the significant uncontrolled variables. The perspective of subjective probability indicates the probability assessment should reflect the decision maker's information about a given quantity or event (Eidman, 1989).

There are various models that have been developed in order to incorporate risk in a mathematical programming framework. The most common models are the mean-variance approach (Paris, 1979; Coyle 1992 and Coyle 1999), the Minimisation of the Total Absolute Deviations (MOTAD) (Hazel, 1971; McCarl and Onal, 1989), the Target MOTAD (Tauer, 1983), the Chance Constrained Programming (Charnes and Cooper, 1959), the discrete stochastic sequential programming (Kaiser and Messer, 2011) and Stochastic

Efficiency with Respect to a Function (SERF) (Hardaker *et al*., 2004). For the purpose of this study normal and empirically distributed outcomes were further researched.

3.4.1 Quantifying price risk

After the deregulation of the South African Agricultural marketing boards in 1996, the effects of price risk increased (Oxford Policy Management, 2000). In most farming activities, the main production decisions are taken well in advance to the sale of the product which means there is always uncertainty about the price (OECD, 2009). Price risk is associated with the change in price for inputs or outputs once production has commenced. Commodity prices especially agricultural prices are exposed to serious price fluctuations globally and domestically, therefore price risk can be rife. This fluctuation is largely due to the short-run inelasticity's of supply and demand for agricultural products (Cutts and Geyser, 2007). The potential prices for a season can alter considerably year on year as a result of stock levels, demand and various other factors. The potato industry experiences extremely volatile prices and high transaction costs which are related to the marketing of potatoes (Strydom *et al*., 2012). With respect to optimization and volatility, market prices can be better controlled through production and supply management strategies (McGary and Zobell, 2012). The more unstable the potato prices are during the season the more indecision the decision maker experiences (McGary and Zobell, 2012). In the short run, production is set and is affected by environmental conditions. Price risk is vast and is increased at each stage of production as the product moves along the value chain. Therefore, to quantify price risk researchers have developed numerous models over the years.

The methods to measure volatility include the standard deviation of prices, the coefficient of variation and the Black-Scholes-Merton model (Black and Scholes, 1973). Unconditional standard deviation and the coefficient of variation assume that past realisations of price and volatility do not affect present or future realisations (Jooste *et al*., 2006: Jordaan *et al*., 2007). Therefore, neither method distinguishes between the known and unknown components of price series therefore overestimating the degree of uncertainty. The Black-Scholes-Merton model assumes that the price varies in a deterministic way therefore the model is unable to account for periods of unchanging volatility (Jooste *et al*., 2006: Jordaan *et al*., 2007).

After the brief overview of various models, it is evident that none of them are suitable to quantify volatility precisely. A model that accounts for the predictable and unpredictable components in the price process which meets the requirements as stated by Moledina *et al.,* (2003) and Just and Pope (2002) is the Autoregressive Conditional Heteroscedasity (ARCH) or Generalised Autoregressive Conditional Heteroscedasity (GARCH) approach. This approach was used in recent studies by Du Preez and Grové (2010). The model concentrates on homoscedasticity and treats heteroscedasticity as a variance to be modelled. This results in the correction of the deficiencies of least squares and the computation of the prediction for the variance of each error term (Engle, 2001). The ARCH model has short comings of not having a longer memory and a more flexible lag structure therefore the GARCH is used to extend this model.

The GARCH approach generalises the purely autoregressive ARCH model to an Autoregressive moving average model. The weights on past squared residuals are understood to decline geometrically at a rate approximated from the data (Engle, 2004). Engle (2004) goes on further to state that the GARCH prediction variance is a weighted average of three different variance forecasts. The first forecast is a constant variance that corresponds to the long-run average, the second forecast is the forecast made in the prior period and the third prediction is the forecast that is made with the new information that was not available in the previous period. The weights of these three predictions determine how quickly the variance changes with new information and how rapidly it goes back to the long-run mean. Due to these reasons the GARCH approach is better than other models of the information on volatility contained in the time series.

The marketing risk of producing table potatoes and processing potatoes was investigated by Strydom and Grové (2012). They looked at the price difference that was determined using a support model which evaluated Gross Production Values (GPV), Risk quantifications and Utility Weighted Premiums for both channels considering different risk preferences. The model provided the producer with a range of production that justified production as the producer can evaluate his current costs; GPV’s and benchmark himself against other producers in the same area. This research done by Grové and Strydom (2012) only considered price as the main risk factor. Diversification on a whole-farm basis was ignored in terms of the monthly cash flow for all production, occurring on the farm and the consideration of different states of nature possibly occurring thereby impacting the initial decisions.

3.4.2 Normally distributed outcomes

3.4.2.1 Quadratic programming

The mean-variance (E-V) programming model (Markowitz, 1952) has a quadratic programming (QP) function for income U(Y). QP assumes that the farmer has preference between various alternatives based purely on expected income (E) and related variance (V) (Kaiser and Messer, 2011). Quadratic programming assumes the farmer’s preferences are ordered only based on expected income, E, and the associated income variance, V amongst different farm plans. It is therefore assumed that the farmer has a quadratic utility function. Quadratic programming also assumes that the farmer is a risk averter (Boehlje and Kaiser, 1980) where a risk averter will prefer the distribution with the smallest variance when any two distributions have equal means (Boisvert and McCarl, 1990). Parametric quadratic programming can be used to derive efficiency sets with the equations below:

$$Max: U = \sum_{j=1}^{a} E(c_j)x_j - b\sum_{i=1}^{n}\sum_{j=1}^{m} v_{ij}\, x_i x_j \qquad 3.3$$

s.t.:

$$\sum_{j=1}^{n} E(c_j)x_j \leq b_i\ i9 = 1, \dots, n \qquad 3.4$$

$$x_j \geq 0\ j = 1, \dots, m \qquad 3.5$$

Where:

$E(c_j)$ expected returns of the jth activity

x_j level of jth activity

b agent's absolute risk aversion coefficient

v_{ij} variance of the jth activity when j is equal to i and covariance between jth and ith activity when i is not equal to j

a_{ij} amount of resource i required per unit of the jth activity

b_i amount of resource i available

The short coming of this model is that it is tricky to formulate large mathematical programming models (Hazell and Norton, 1986). When E-V frontiers are derived by QP the farm plans projected are efficient for risk-adverse decision makers. The parameters in the constraint set of QP models are treated non-stochastically over time. When distribution is not normal, the QP may not always include the preferred decision strategy of the farmer (Kaiser and Messer, 2011). The final downfall of this model is that the absolute risk aversion coefficient increases with income.

3.4.2.2 MOTAD

Profit maximising linear programming (LP) does not include the comparative riskiness of enterprises under consideration and therefore groups higher incomes and greater risky enterprise combinations which is not the norm in actual operations (Held and Kink, 1982). Hazell (1971) developed the Minimisation of Total Absolute Deviations (MOTAD) model to include income unpredictability directly into the LP model. The MOTAD model (Hazell, 1971) measures risk by absolute deviations from the average returns rather than the variance of the total returns. The MOTAD model therefore chooses the optimal combination of enterprises that yield minimum revenue variability at precise levels of income given known selected resource constraints. MOTAD is therefore a Linear Program (LP) alternative of the QP E-V analysis, (Boisvert and McCarl, 1990) and is presented in equation 3.6:

$$\max \sum_{j=1}^{n} \bar{C}_j X_j - \alpha\sigma \qquad 3.6$$

Where:

$\sum_{j=1}^{n} \bar{C}_j X_j$ the expected term

σ the approximation of the standard error

α a risk aversion parameter

The strengths and weaknesses of MOTAD are like the E-V model; however even under normality the MOTAD model estimates the variance less efficiently than the QP model (Kaiser and Messer, 2011). According to Boisvert and Mccarl (1990) there are a few comments on the MOTAD model of which the first comment is that the MOTAD model has the incentive to "diversify' because covariance is not ignored. The second comment is that the deviation symmetry determines the equivalence of the total negative deviation formulation. The third comment is that the model uses an approximated standard deviation as a measure of risk.

3.4.3 Empirically distributed outcomes

3.4.3.1 Cumulative distribution function (CDF)

A non-parametric approach is the ideal method of analysis where there is limited data available (Goodwin and Mahul, 2004). A technique to analyse the possible outcomes and probabilities of their occurrence is to construct the cumulative distribution function (CDF) (Piggott *et al.*, 2006). CDF allows both discrete and continuous probability to be described by the same notion. The highest possible outcome will have a cumulative probability of one. A CDF is the cumulative sum of all probabilities of a dependent variable less than or equal to a specific value of an independent variable over time (Theodore, 2016). In order to quantify the cumulative distribution functions (CDF) of potential yields a non-parametric approach must be adopted for all the planting months' potential yields.

3.4.3.2 Multivariate Empirical (MVE) probability distributions

The main concerns when solving farm-level simulation models are, non-normally distributed random yields and prices, intra- and inter-temporal correlation of output prices, intra-temporal correlation of production across fields and enterprises, enterprises that are affected by climatic conditions and carried out over a lengthy growing season and strategic risks associated with technology adoption, competitor responses, and contract negotiations (Richardson *et al.*, 2000). In order to generate correctly correlated inter- and intra-temporal matrixes of gross margins that are required to include risk in the optimal planting schedule, stochastic budgeting procedures are used. Price and yield risk need to be quantified before stochastic simulations can be conducted. It is important to include correlation in stochastic simulation models that evaluate risk-management alternatives. Richardson *et al.*, (2000) used a semi-parametric Monte Carlo simulation technique that includes intra- and inter- temporal correlation which enables the control of the heteroscedasticity of the random variables over time. The research described and demonstrated an applied procedure to simulate stochastic yields and prices in large scale firm-level simulation models assuming there is limited data on historical prices and yields. The research therefore elaborated on a simple process to estimate the parameters for a multivariate empirical distribution. Cloete *et al.*, (2007) incorporated enterprise budgets into a stochastic net present value model to generate the results of the profitability and feasibility analyses of the farm. Risk simulations that use multivariate empirical distributions (Richardson *et al.*, 2004) to characterize risk were then used to incorporate price risk into the analysis.

3.4.3.3 SERF optimisation

Stochastic dominance analysis with respect to a function (SDRF) (Meyer, 1977) is a method that reduces the absolute risk aversion bounds to $r_L(w) \leq r_a(w) \leq r_U(w)$because all the risky scenarios are ranked between absolute risk aversions between lower bound $r_L(w)$and upper bound$r_U(w)$. SDRF often causes ambiguous rankings that imply that the rankings change between the lower and upper bounds (Schumann, Richardson, Lien, and Hardaker, 2004). Stochastic Efficiency with Respect to a Function (SERF) (Hardaker *et al*., 2004) entails comparing each alternative with all the other alternatives concurrently, not pair wise, as with conventional SDRF. SERF therefore yields a subset of the efficient set found by SDRF. SERF is readily applied in a simple spread sheet with no special software required (Hardaker and Lien, 2003). SERF is the most recent approach in ranking risky alternatives (Hardaker *et al*., 2004). SERF (Hardaker *et al*., 2004) lists a set of risky alternatives in terms of certainty equivalents (CE) for a specified range of attitudes to risk. SERF is based on expected utility theory which in turn is based on the existence of an ordinal utility function that permits alternatives to be ranked. The axioms that enable the alternatives to be ranked are continuity, ordering, transitivity and independence.

Both the SERF and SDRF assume a lower and upper bound with regard to the risk aversion. SERF however also assumes that all risk aversion measures are of the same form as these lower and upper bound functions. When either procedure is implemented, the assumption made most often, is that these lower and upper bounds are constants. SERF assumes all decision makers have a Constant Absolute Risk Aversion (CARA) on risk preferences where SDRF makes no such assumption. The efficient set identified under SERF is therefore typically smaller than that recognised using SDRF.

In the SERF approach continuity implies that subjective probability $P(a_1)$ exists (not 0 or 1) when a_1 is preferred to a_2 and a_2 to a_3. The $P(a_1)$ makes the decision maker indifferent to a_2 and a lottery yielding $a_{1c}$with probability $P(a_1)$ and a_3 with probability $1\text{-}P(a_1)$. Ordering implies that a decision-maker is either indifferent or prefers one prospect above another when faced with two risky prospects a_1 and a_2. Transitivity implies that if a_1 is preferred to a_2 and a_2 is preferred to a_3, then a_1 is preferred to a_3. Independence is when $P(a_1)=P(a_2)$ and if a_1 is preferred to a_2 and a_3 is any other risky prospect then the decision-maker will prefer a lottery yielding a1 and a3 to a lottery yielding a_2 and a_3.

As long as the axioms are not violated the ordinal utility function (U ( )) will enable one to rank alternatives according to utility because if a_1 is preferred to a_2 the $U(a_1) > U(a_2)$. The best alternative is therefore selected by maximising the expected utility (EU) where the probability weighted average of all the discrete outcomes is the utility of a risky prospect.

Certainty equivalent (CE) is the sure sum with the same utility as the expected utility of the risky prospect. Hardaker *et al.,* (2004) developed SERF because ranking alternatives with certainty equivalents (CE) is the same as ranking risky alternatives in terms of utility. The decision maker will therefore be indifferent to the risky prospect and the CE. The form of the utility function determines the CE because CE is the inverse of the utility function as given in equation 3.7.

$$CE(x, r_a(x)) = \ln(\sum_r^n \frac{1}{n} (-e^{-r_a(x)x_j})^{\frac{-1}{r_a(x)}} \qquad 3.7$$

Where:

$r_a(x)$The level if absolute risk aversion

n the size of the random sample of risky alternative *x*.

Evaluating equation 3.7 over a range of $r_a(x)$ values the relationship between CE and risk aversion is determined. The relationship for numerous alternatives is determined by repeating the different risky alternatives and presenting the results in a graph (Hardaker *et al.*, 2004). Given the specific level of risk aversion, the highest CE is preferred when presented with alternatives based on CE. The choice of $r_a(x)$ is crucial in ensuring that the level of risk aversionused in the model is in accordance with the actual risk averseness of the decision-maker. The range and the scale of the data influence the absolute risk aversion; therefore, it is not possible to infer the degree of risk aversion from the risk aversion coefficients used without information on the risky prospects. The next section therefore indicates a method to represent risk aversion consistently.

3.4.4 Choice of risk aversion level

Risk premium measures an individual's risk outlook. A positive risk premium indicates risk adverse and an individual with no risk premium is considered risk neutral. An alternative to the risk premium approach to characterize risk attitudes are the Arrow-Pratt coefficients of absolute risk aversion and relative risk aversion (Arrow, 1954 and 1970, and Pratt 1964). Both these coefficients are dependent on income which progresses to more taxonomical delineations: Increasing Absolute Risk Aversion (IARA), Constant Absolute Risk Aversion (CARA) and Decreasing Absolute Risk Aversion (DARA), Increasing Relative Risk Aversion (IRRA), Constant Relative Risk Aversion (CRRA) and Decreasing Relative Risk Aversion (DRRA).

The Arrow-Pratt measure of absolute risk aversion $r_a\ (x)$ has the following three properties according to Hey (1979). Firstly $r_a\ (x)$ is larger for a more risk-averse individual than for a less risk-averse individual. Secondly $r_a\ (x)$ is unaffected by an arbitrary linear transformation of the utility function. Thirdly if $r_a\ (x)$> 0, =0 or <0 then the individual displays risk-averse, risk-neutral or risk-seeking preferences respectively. CARA infers that subtracting or adding a constant to all payoffs does not affect the risk preferences (Hardaker *et al*., 2004) due to the variability around the mean remains the same.

The choice of $r_a\ (x)$ is very important in ensuring that the level of risk aversion in the model is in line with the actual risk averseness of the decision makers. If the same coefficient is used, the Arrow-Pratt absolute risk aversion measure is being viewed as a constant and not a function, which it is. Therefore, for each study the $r_a\ (x)$ needs to be rescaled. By assuming CARA the impact of wealth on risk aversion is not incorporated.

Babcock *et al.,* (1993) developed a method to choose the absolute risk aversion level by ensuring that all the alternatives that are being compared are equal to the risk premium, which is a percentage of the size of the gamble. This technique acknowledges the effect of the range of the risky prospect on implied risk aversion levels. Grové (2008) took the Babcock et al. (1993) method further and standardised the procedure by normalising the data in such a manner that the standard deviation of the transformed data equates to one. The relationship between $r_a(x)$ and a standardised measure of risk aversion $r_s(x^s)$ is derive, given a transformation of *x* such that:

$$x^s = \frac{x}{\sigma_x} \qquad 3.8$$

Therefore

$$x = x^s\sigma_x \qquad 3.9$$

Where:

x is the original data with standard deviation of σ_x and

x^s is the standardised data with a standard deviation of $\sigma_x^s = 1$

U(x) and U(x^s) are therefore illustrated by equation, whilst assuming a negative exponential function.

$$U(x) = -e^{-r_a(x)x} \qquad 3.10$$

$$U(x^s) = -e^{-r_a(x^s)x^s} \qquad 3.11$$

If utility is assumed constant whether the outcome variable is x or x^s gives:

$$r_a(x)x = r_s(x^s)x^s \qquad 3.12$$

Because *e* is a constant one can then substitute equation 3.9 into 3.12 and obtain the relationship between $r_s(x^s)$and x^s:

$$r_a(x)x = \frac{r_s(x^s)x}{\sigma_x} \quad 3.13$$

Therefore

$$r_s(x)^s = r_a(x)\sigma_x \quad 3.14$$

And

$$r_a(x) = \frac{r_s(x^s)}{\sigma_x} \quad 3.15$$

Equation 3.14 illustrates that $r_s(x)^s$ is a function of $r_a(x)$ and the size of the gamble given by σ_x. The value of $r_s(x)^s$ can therefore be determined exactly for any $r_a(x)$ value using equation 3.15 without changing utility or inverse values of $r_a(x)$ for a risky prospect with a given range shown by σ.

3.5 Applications of direct expected utility maximisation

Risk can be analyzed using numerous models. Many models used in risk, ascertain a certain level of profitability. Most techniques to aid farmers look at risk in the gross margin, this is good guidance for the farmer but when the farmer's income falls below the expected income the farmer is at a loose end. A support model which evaluates Gross Production Values (GPV), Risk quantifications and Utility Weighted Premiums for two different states can be used to formulate a strategy considering different risk preferences (Strydom and Grové, 2012). Meiring and Oosthuizen (1993) designed a model to evaluate the economic effect of risk management at a farm level by using a decision support system.

3.5.1 Quadratic programming

As a result of risk and uncertainty being included in the technical and economic coefficients used and the quantities and prices of resources Manos and Kitsopanidis (1986) used the E-V model in their study. The results from the E-V model were preferred to that of linear and mixed-integer programming models because it includes crops anticipated to give the highest minimum total gross margin with the same total fixed costs. The farmers prefer a plan that achieves the highest and the most stable economic results.

Bussell and Punkett (1984) investigated the problem with regard to spring cabpockete displaying variability in yield when harvested weekly from areas of equal size transplanted from each autumn sowing. The researchers used quadratic programming analysis to determine the proportion of the total area which is required to be transplanted from each sowing in order to give the least discrepancy in weekly yield. The results indicated that proportions that could be planted from a series of sowings to give the least variation in yields could be reasonable accurate in one year. Wiens (1976) has used E-V modelling in China and found it to agree with survey data far more than straight forward linear programming.

Mustafa et al., (2016) used a quadratic programming model subject to linear constraint in order to obtain the best optimal values of the cost parameters under certain limitations to attain maximum net returns. To maximize the quadratic function subject to the linear constraints a calibration constant was implemented in the constraints, which makes the model distinguishable from the usual LP format. The main aim of the study was to estimate the cost parameters and maximization of net returns to management, subject to the linear constraint. The results of the unknown parameters were significant and offer a distinctive optimal solution when convex optimization techniques along with Lagrange's multipliers were applied. From this study, it could be concluded that one can gain a unique and optimal solution by using the convex optimization approach in quadratic programming model.

3.5.2 MOTAD

Held and Zink, (1982) selected a group of farmers and used a group interview approach to obtain information regarding crop production practices. They assumed capital was not a limiting factor. Maximum hectare limits were implemented to ensure a minimum number of crop rotations. Prices were established from an eleven-year period. It was concluded that replacing higher risk higher, return crops (dry-beans) with lower risk lower returns. It was found that considering a single representative farm limits the basis to make general evaluation of the producer's retort to risk. It was found that the dual crop-livestock system yields dual remuneration over a long run time span. The net farm income was found to be higher and the variability of net income is less, due to negative correlation of returns between livestock and crops. They concluded that further research could be done on including the flexibility associated with livestock operations within the MOTAD model. It was found that farm plans formulated with MOTAD are only optimal with respect to assumptions and limitations, therefore a more useful approach will be to apply the MOTAD results as benchmarks for comparison with multiple suboptimal solutions. This comparison however has very little difference in equivalent risk levels.

Due to yield varying over various states of nature and crop rotation strategies, production risk is included as a variability of income (Ghebretsadik and Visagie, 2005). MOTAD was used in the research conducted by Ghebretsadik and Visagie, (2005) to determine the expected income of the various levels of risk. The crop rotation type and size strategy chosen vary considerably depending on the choice of risk. The value of the objective function increased as risk became less constricting. The conclusion on the results drawn indicated that the as the level of risk increases so does the increase in diversity of the crop system. Regardless of the decision maker's choice in risk aversion, the ideal farm plan includes a varied crop system. The best choice to maximize the gross margin at a specific risk level was an integrated crop-livestock environment diversification.

Kehkha *et al*. (2005) applied the MOTAD risk programming model in the Fars Province of Iran in order to determine the effects of risk on cropping patterns and farming incomes. The risk effects of shadow prices were also analysed. In this study, it was found that future studies should focus on the producer's risk attitudes, establishing an expectation with regard to yields and prices and the use of advanced time series. Osaki and Batalha (2014) used MOTAD in a study in Brail on double-crop production systems to provide farmers with a decision support model on production planning in multiproduct farms under risk conditions. The study aimed to provide farmers with a tool to support decision making to improve agricultural planning under risk conditions. The model helps choose the best products to ensure higher returns and lower risks.

3.5.3 SERF optimisation

In recent literature, a variant of stochastic dominance called stochastic efficiency with respect to a function (SERF) has been developed and used to analyse data. Unlike traditional stochastic dominance approaches, SERF uses the concept of certainty equivalents (CEs) to rank a set of risk-efficient alternatives instead of determining a subset of dominated alternatives. Fathelrahman *et al*., (2001) chose to use SERF in their study because unlike traditional stochastic dominance methods, SERF uses the notion of certainty equivalents (CEs) to rank a set of risk-efficient alternatives instead of finding a subset of dominated alternatives. The study evaluated the efficiency of the SERF technique for analysing conservation and conservational tillage systems using economic budget data from 1990 to 2003 from 36 experimental plots at the Iowa State University Northeast Research Station near Nashua, IA, USA. The SERF approach was used to determine which of two different tillage systems (chisel plough and no-till) on continuous corn and corn/soybean (Glycine max) rotation cropping systems were the most risk-efficient in terms of maximizing economic profitability by crop over a range of risk aversion preferences. It was found that the no-till tillage system was preferred to the chisel plough tillage system when ranking within the continuous corn and the corn-soybean rotation cropping systems for both gross margin and net return. This study found that the SERF method is a useful and easily understood instrument to solve problems involving agricultural risk.

Grové and Oosthuizen (2010) developed an expected utility optimisation model to economically determine deficit irrigation within a multi-crop setting whilst accounting for increasing production risk of deficit irrigation. Risk aversion was constantly represented amongst alternatives by standardising the values of risk aversion. The standard risk aversion was used to explain the simultaneous decreasing and increasing relationship between the increasing levels of absolute risk aversion and the utility weighted premiums and it was found to be more consistent than using a constant absolute risk aversion.

Evaluating the risk of a decision depends on the underlying utility function risk related to the aversion of the decision maker. Schumann *et al.*, (2004) used stochastic efficiency with respect to a function (SERF) to compare the ranking of risky alternatives using alternative utility functional forms. Venter, MM (2015) used CDF and then SERF to prove that an adaption of routine strategies is better than not using any strategy at all. The results indicated that the choice between strategies depends on the risk aversion level of the producer and that every crop has a different strategy.

3.6 Overall summary

Risk in agriculture can primarily be classified according to a systematic character with regard to the type, frequency and severity of an event. The outcome of the relevant unknown event determines the consequences of the chosen option. To manage risk the prospective risk first needs to be identified. The interlink ages between the different sources of risk, affects the farmer's overall exposure to risk. An integrated risk assessment therefore helps to recognise numerous sources of risk and leads to a more efficient way in making decisions.

Managing risk does not mean removing risk, it means ensuring that the risk that could occur is at an acceptable level for the decision maker. A decision maker who is risk averse is prepared to accept a lower average return for a lower uncertainty subject to the decision maker's level of risk aversion. Risk management therefore includes understanding the sources of risk, setting risk management priorities and understanding the techniques available to make informed decisions pertaining to risk. The best method of managing risk depends upon the nature of the risk involved and the appetite for risk.

There are various techniques available to characterise decision making in an uncertain environment. For this study, the parameterised distribution approach and the state-contingent approach were explored. The parameterised approach does not allow the decision maker the prospect to explore the opportunities that uncertainty offers because the outcome variable is established on the choice of the input variable. In the state-contingent approach the distribution of the outcome variable is based on the state of nature. The state-contingent production functions allow for the development of transformation functions that can be used to describe production of a good between different states. Because production risk is empirically quantified the method can be used with any decision models that use empirical representations of output distributions. Because of the production risk being empirically quantified the procedure could be used with any of the decision models that use empirical representations of output distributions. CDF allows both discrete and continuous probability to be described by the same notion.

SERF is the most recent approach in ranking risky alternatives in terms of certainty equivalents (CE) for a specified range of attitudes to risk based on expected utility theory. The axioms that enable the alternatives to be ranked are continuity, ordering, transitivity and independence. SERF assumes all decision makers have a Constant Absolute Risk Aversion (CARA) on risk preferences.

CHAPTER 4
RESEARCH TECHNIQUE

4.1 Introduction

When a producer plans the planting year ahead, the economic and environmental factors that can potentially unfold are unknown. A potato producer in the Sandveld is faced with an unusual predicament that a field can only be planted once every four years. The producer therefore requires a planning tool in order to plant the fields that field the highest return in conditions of uncertainty when committing resources for four years. In order to do an economic risk analysis of various geographical diversification options, it is important to identify the numerous parameters and constraints which will affect the optimal irrigation planning and the economic trade-off between planting dates and pivots. The main objective of this study is therefore to develop a planning model that ensures a feasible planting schedule given numerous volatile conditions and the decision maker's appetite for risk when making geographical decisions at a micro-level. The starting point to the final solution is to determine the four main input parameters namely the potential yields, prices, the yield and area dependent costs and irrigation costs for each state of nature for the respective planting/harvesting months. These input parameters are required to obtain the gross margins for each planting date in each state of nature for all pivots. The gross margins are then used to conclude the study to determine the best electricity tariff, the best market and best planting rotation for the producer's risk appetite with the use of the SERF method.

The results presented in Chapter 5 will use the Research technique explained in Chapter 4. This chapter is broken up into two sections. The first section specifies the mathematical formulation and parameters used to calculate the gross margins for each pivot in each planting month for each state of nature for the SERF approach. The second section discusses the methods of data collection and calculation of input parameters to determine the respective gross margins.

4.2 Demarcation of field study

An in-depth farm-level case study will be the most suitable design for this study according to Bryman and Bell (2007). This is primarily because this study focuses only on the potato industry on a specific farm and not the whole vegetable industry. Quantitative components, using secondary data collection strategies and models will be used in the case study. This research layout will be used to ascertain the optimal planting schedule give the producer's approach to risk. The case study design is important because it will be used to conclude the best four-year planting schedule after having integrated the respective appropriate models. With the information gained through the case study, it will be possible to formulate an understanding of the potato market and the impact of the planting schedule on the farms cash flow. Motivations for the chosen design will be further elaborated on.

4.3 Yield potentials

To quantify yield risk and determine the gross margin for each pivot, the potential yields for Taaiboskraal farm's pivots first needs to be ascertained. The most appropriate potato growth model therefore needs to be researched and used to simulate potential yields using various states of nature's environmental conditions that correlate to the time period of the relevant prices for potatoes on the respective markets. Once the potential yields have been ascertained the yield risk can be determined using a CDF as this was researched inChapter 3.

4.3.1. Introduction

Crop production takes place in an integrated system of biological, agronomical and market dynamics (Ghebretsadik and Visagie, 2005). For a given crop, yield variability varies depending on the soil quality and type, use of irrigation and climate. Weather varies greatly therefore it is reasonable to assume that any state of nature can occur. In cases where practical management is feasible the consideration of planting density as a decision variable maybe included as a risk-efficient production strategy (Lee and Teague, 1988). The timing of numerous field operations in crop production can have an impact on the crop's yield (Misra and Spurlock, 1991). The yield of the crop can therefore be managed to a large extend with the correct knowledge and techniques. There are various growth models available to determine the potential yields of a crop.

4.3.2 Literature review

In order to simulate potential yields for a commodity in a given area, a growth model that is designed for the commodity needs to be used. A potato is very sensitive to variations in photoperiods and consequently temperature. These two factors have a significant effect on the growth rate and development of the potato. The dry matter production and distribution depends on whether tuber initiation is early or later in the growing season. Tuber initiation is increased by warmer temperatures and longer days. It is therefore important that the chosen model can accommodate the effects of photoperiod on growth in order to precisely simulate potato growth and yields.

The CROPWAT (Smith, 1992), SAPWAT (Crosby, 1996) and Soil Water Balance (SWB) (Annandale et al., 1999) irrigation scheduling models make use of the methodology proposed in FAO-56 (Allen, *et al*. 1998) to formulate the crop water requirements. Annandale et al., (1998) however found that caution should be advised to blindly accepting Allen *et al*., (1998) parameters at a local level due to local conditions, management and cultivators altering the crop growth periods and basal crop coefficients (Kcb). The SWB model is a sophisticated model to simulate water requirements of crops in the absence of crop-specific growth parameters. The SWB model is a generic crop model, which was developed for the irrigation management of various crops, including potatoes. In earlier periods the SWB model was locally standardized and effectively used for the irrigation scheduling of potatoes. Steyn (2008) did a study where the SWB model was applied for potatoes and the findings confirmed limitations of the SWB model for potato growth modelling. The SWB model is currently not able to simulate the effects of different growing seasons on potato crop growth, development and yield accurately due to the various sets of crop parameters required.

The Light Interception and Utilization Simulator (LINTUL) (Haverkort and Kooman, 1995) model simulates potential crop growth, under conditions of abundant water supply and nutrients in a disease-, weed-and pest- free environment, under the prevailing weather conditions provided for each state of nature. The rate of dry matter accumulation is therefore a function of irradiation and crop characteristics. The model utilises the general observation that the crop growth rate under good conditions is proportional to the amount of light intercepted (Monteith, 1977). Dry matter production is therefore modelled as the product of light interception and constant light use efficiency. The dry matter produced is partitioned among the various plant organs, using partitioning factors defined as a function of the phenological development stage of the crop. The dry weights of the plant organs are obtained by integration of their growth rates over time. The LINTUL model (Haverkort and Kooman, 1995) is therefore the best model to obtain the maximum yield potentials for potatoes.

4.3.3 Methodology

The LINTUL model is comprised of a few mathematical equations and functions that explain the processes leading to dry matter production and final tuber yields. Crop growth starts with surfacing, which can be initiated by an accumulation of heat units or by obtaining a present date. In this study the accumulation of heat units were considered. The model determines the potential tuber yield as well as the single crop coefficient (K_c) in the development stage for each planting date in each state of nature. The K_c coefficient integrates crop characteristics and averaged effects of evaporation from the soil which is required to determine the water requirements of the plant when irrigating (Allen *et al*, 1998).

The crop develops over a number of developmental stages (DVS) which controls the partitioning of assimilates or dry matter. Temperature usually has the most significant effect on development. The development rate can't be defined directly and must be determined from the period of time elapsed between two distinctive development stages. The rate of development, (dDist / dt), can therefore be found using equation 4.1.

$$\left\{ \frac{dDist}{dt} = \frac{\text{distance between 2 stages}}{\text{time period between these 2 stages}} \right\}_{T_a} \qquad 4.1$$

where "distance between 2 stages" could be the distance between emergence and anthesis, this distance does not have a unit as it is termed 1 or 100%. The "time period between these 2 stages", is measured in days and must be determined for a series of constant air temperatures, T_a. The development rate correlates relatively linearly with temperature over a wide range even though there is a maximum in the response curve when the development rate decreases again. Due to the instantaneous reaction of the crop to a change in temperature, the sum of the temperature works well as a measure for the development stage. The daily weather data for the 12-year period was put into the LINTUL model along with the rooting depth for a potato which is 0.5 meters (Allen *et al*., 1998).

Evapotranspiration is the consolidation of two different processes that occur simultaneously namely transpiration which is when water is lost through the leaves and evaporation where water is lost through the soil. The main factors affecting evapotranspiration are weather parameters, crop factors, management and environmental conditions. The amount of solar radiation on the soil decreases as the growing season progresses. Therefore, at planting almost 100% of evapotranspiration is due to evaporation and when the crop is at full cover 90% of evapotranspiration is due to transpiration. The evapotranspiration rate from a reference surface that is not short of water is known as the reference crop evapotranspiration and is denoted by ET_o. The reference surface is a theoretical grass reference crop with precise characteristics and climatic parameters are the only factors affecting ET_o. The crop coefficient K_c is reliant on the area that is wet, wetting frequency and soil type (Annandale and Jovanovic, 1998). As the single K_c coefficient averages soil evaporation and transpiration, the approach is used to compute ET_c which is required to determine the irrigation requirements and consequently the irrigation costs later in this chapter.

In the single crop coefficient approach to evapotranspiration, the effect of crop transpiration and soil evaporation are pooled into a single crop coefficient (K_c). The coefficient combines the variations in the soil evaporation and crop transpiration rate between the crop and the grass reference surface. As soil evaporation, may vary daily due to rainfall or irrigation, the single crop coefficient conveys only the time-averaged (multi-day) effects of crop evapotranspiration. Equation 4.2 determines the $K_{cinitial}$ value using the FAO-56 approach (Allen*et al*., 1998) with a soil texture of 0 to 5% silt and clay for the Sandveld.

$$K_{c\,initial=} \frac{TEW-(TEW-REW)exp\left(\frac{-(t_w-t_1)E_{so}\left(1+\frac{REW}{TEW-REW}\right)}{TEW}\right)}{t_w ET_o} \qquad 4.2$$

Where

$E_{so} = 1.15\ ET_o$

$t_1 = REW/\ E_{so}$

The total evaporable water (TEW) is the maximum amount of water that can be lost to evaporation from the surface soil layer. The maximum total depth of water can be lost due to evaporation in stage 1, known as readily evaporable water (REW). According to Allen *et al*., (1998) the $K_{c\ final}$ for potatoes is 1.15. The K_c values in stage 2 for each planting date in each state of nature were determined using equation 4.3.

$$K_c = K_{c\,initial} * \left(1-\frac{Groundcover}{100}\right) + \left(K_{c\,final} * \frac{Groundcover}{100}\right) \qquad 4.3$$

As the crop develops, the ground cover, crop height and leaf area change. Due to the variation in evapotranspiration during the range of growth stages, the K_c value for a given crop will differ over the growing period. The growing period can therefore be divided into four distinct growth stages: initial, crop development, mid-season and late season. For potatoes planted in semi-arid climatic conditions the lengths for the initial stage is roughly 25 days, for the development stage is roughly 30 days, for the mid-season stage the number of days is roughly 30-45 and for the final stage there are roughly 30 days. In total over the growing stages there are roughly 120 days depending on the season.

The interception of radiation by the crop is essential for photosynthesis. Light exponentially decreases with the cumulative leaf area index, when assuming a homogeneous canopy. Equation 4.4 measures from the top of the canopy to the soil surface according using Lambert-Beer's law:

$$I = I_0 e^{-kL} \qquad 4.4$$

Where, I_0 is the incident radiation flux of photosynthetically active radiation (*PAR*[1], MJ $m^{-2}d^{-1}$), *I* the radiation flux that reaches the soil (*PAR*, MJ $m^{-2}d^{-1}$),

k the radiation extinction coefficient (*K*, m^2 (ground) m^{-2} (leaf)),

L the leaf area index (*LAI*, m^2 (leaf) m^{-2} (ground)).

The leaf characteristics and the architecture of the crop affects the radiation extinction coefficient, *k, as* erect leaves intercept less radiation in comparison to more horizontal leaves. The incident radiation flux of photosynthetically active radiation, I_0, is about 50% of the daily total radiation (*DTR*), so I_0 = 0.5 *DTR*.

The amount of intercepted photosynthetically active radiation, I_{int}, is the discrepancy between the incident radiation, I_0, and the total light reaching the soil surface, *I*:

$$I_{int} = I_0 (1 - e^{-kL}) = 0.5\ DTR\ (1 - e^{-kL}) \qquad 4.5$$

In equation 4.5 L and DTR differ in the total amount of intercepted radiation and time. The total daily radiation is measured and obtained from the weather data and the LINTUL model. Due to the growth of new leaves the (green) leaf area index, L increases with time until the leaf senescence will be stronger and the leaf area will diminish again. The daily growth rate of a crop is determined by merging the actual amount of intercepted photosynthetically active radiation with the radiation use efficiency. The difference between growth and development is that growth is the product of radiation interception and the efficiency that radiation is used to form crop assimilates and development.

In the radiation use efficiency (RUE) approach, however, radiation is directly used to calculate the production of dry matter via the value of the RUE. Thus, dry matter is partitioned over the plant organs namely the roots, stem, leaves and storage organs. In the initial stages a lot of dry matter is invested in the roots and the leaves, and after flowering, when the development stage equals 0.5, root and leaf growth stop and all the dry matter production is invested in the storage organs. Due to leaves partly senescing during the growing season, the equation for the net rate of change of green leaves, dW_{lvg}/dt (*RWLVG*), is given in equation 4.6:

$$\frac{dW_{lvg}}{dt} = \frac{dW_{lv}}{dt} - r_d\, W_{lvg} = RUE\ I_{int}\ F_{lv} - r_d\, W_{lvg} \qquad 4.6$$

The leaf death rate is taken proportional to the green leaf weight, W_{lvg} (*WLVG*, g DM m^{-2}) and a relative senescence rate, r_d (*RDR*, d^{-1}).

The calculation of intercepted photosynthetically active radiation (*PAR),* is mainly based on the surface area of the leaf. The correct simulation of the time of the leaf area index, *L* (*LAI*) is therefore vital. There are two main situations regarding the formation of the new leaf area, namely sink-limited and source-limited. In the early stages of growth sink-limited prevails due to temperature being the main reason for growth due to the rate of leaf appearance and final leaf size being constrained by temperature through its effect on cell division and extension and not by the supply of assimilates. In the early, sink-limited stages, leaf area increases exponentially with time subsequently; the slope of the exponential curve can be approximated by equation 4.7:

$$\frac{dL}{dt} = \frac{L_{t+\Delta t} - L_t}{\Delta t} = \frac{L_t e^{(r_l T_{eff} \Delta t)} - L_t}{\Delta t} = \frac{L_t (e^{(r_l T_{eff} \Delta t)} - 1)}{\Delta t} \qquad 4.7$$

r_l = the relative growth rate of leaf area during the juvenile exponential growth phase $(^{\circ}Cd)^{-1}$,
T_{eff} = effective temperature, which equals (T_a–T_b) if $T_a \geq T_b$:
$r_g = r_l\ T_{eff}$
L_t = the current leaf area
$L_{t+\Delta t}$ = the leaf area at the end of a time step Δt

Assimilate supply increasingly restricts leaf growth in later development stages. Branching and tillering creates an increasing number of sites per plant where leaf instigation can occur and an increasing number of cells that can expand, while mutual shading of plants and leaves minimises the assimilate supply per growing point and per cell.

4.4 Price and price volatility

4.4.1 Introduction

Quantifying price variability on the fresh potato market is important because price variability can have a significant impact on the overall feasibility of the farming enterprise. Price volatility refers to the amount of unpredictable change in prices over time. The error terms acquired from the prediction of prices is therefore linked to volatility (Jordaan, Grové, Jooste and Alemu, 2007). Volatility is measured using conditional standard deviation. The presence of discrete spikes and the secular increase in such spikes in data are two conditions for the occurrence of price volatility (du Preez and Grové, 2010). When planning, decisions are based on overestimated risk or inaccurately measured risk, the costs can land up being larger than the benefits hence the importance of accurately measuring price volatility. There are four main potato markets, namely Cape Town, Duran, Pretoria and Johannesburg (PotatoesSA, 2015). The 12 year prices from 1998 until 2010 were used which correlates with the weather data used. The prices used for the gross margin were made real using 2014 as the base year. Chapter 3 explored the best model to use in order to determine the price risk in each of the four fresh produce markets.

4.4.2 Methodology

The fundamental structure that is followed to quantify the volatility in prices of potatoes on the Cape Town, Durban, Pretoria and Johannesburg fresh potato market is depicted in the flow chart in Figure 4.1. The first step is to test for stationarity by doing the unit root test. The second step is then the application of the Box-Jenkins method to determine the order of the ARIMA process. The Box-Jenkins must be performed on data made stationary by means of differencing. The presence of Auto Regressive Conditional Heteroscedasity (ARCH) effect was then determined with the ARCH-LM test. ARCH models are used to illustrate and model observed time series. They are used when there is anticipation that the error terms will have a distinctive size or variance (Engle, 1982). ARCH models assume the variance of the current error term to be a function of the actual sizes of the previous time periods' error terms. If the ARCH effect was detected, then a GARCH approach was used.

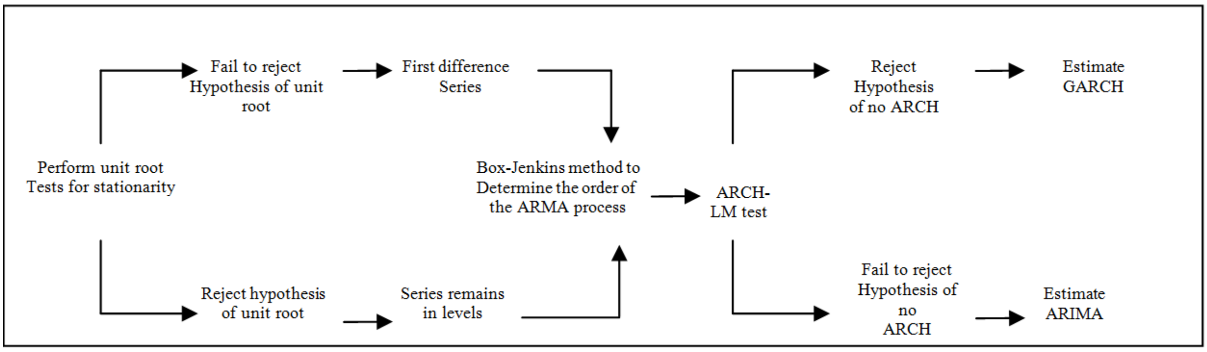


Figure 4.1: Flowchart of methodology to compute conditional volatility
Source: Moledina *et al*., 2003

The predictable components such as inflation, trend and seasonality of the pricing process need to be removed in order to leave only the stochastic component, then only the stationarity of the time series using the root test can be tested (Moledina *et al.*, 2003). The seasonal effect is removed by using seasonal dummy variables. Seasonality is eliminated once the real prices are regressed on the seasonal dummy variables and the residuals from the regression are used as the deseasonalised prices in further analysis. From the twelve months within a year eleven seasonal dummies were included. The inclusion of only eleven months is to avoid falling into the dummy variable trap, which is a situation of perfect collinearity. In this research January was highlighted as the base dummy variable for potatoes in the four main markets. The effect of inflation is removed by deflating the nominal prices with the consumer price index (CPI) (Richardson *et al*, 2004).

The incidence of a unit root and to ascertain how many times a series must be differenced to make it stationary, was tested using the Augmented Dickey Fuller (ADF) test. The number of times a series needs to be differentiated indicates its order of integration and consequently the value of d in ARIMA (p,d,q) process. The Box-Jenkins methodology was then used to determine the values of p and q in the ARIMA (p,d,q) (Jordaan *et al*, 2007). The Box-Jenkins approach assumes that the residuals are homoscedastic therefore the standard error is a measure of volatility thereby implying volatility remains the same over time. In the ARIMA (d) is therefore 0.

According to Jooste *et al*., (2006) and Jordaan *et al*., (2007) the ARIMA process is presented by equation 4.8:

$$y_t = \alpha_0 + \sum_{p}^{p\max} \phi_p y_{(t-p)} + \sum_{q}^{q\max} \theta_q \varepsilon_{(t-q)} + \sum_{n}^{n\max} \eta_n D_t \qquad 4.8$$

From the computation of (AR 0-6) by (MA 0-6) forty-nine combinations were obtained based on equation 4.8. The largest value of either AIC or SBC is considered to theoretically determine the values of *p* and *q.* An ARIMA (*p,d,q*) process indicates that the intercept has to be lagged *p* times, to yield a stationary series the series needs to be differenced *d* times, and to generate the desired results the error term is going to be lagged *q* times. The components of the GARCH model needs to be significant, therefore the largest AIC or SBC value serves only as a guideline (Jooste *et al*., 2006; Jordaan *et al*., 2007).

If a series is found to vary over time it indicates that the GARCH approach should be used. The rejection of the null hypothesis of no ARCH effect indicates a time varying series. The Box-Jenkins approach assumes that the residuals stay constant over time, in other words are homoscedastic. The homoscedastic assumption has the insinuation that volatility (uncertainty) remains steady over time since the standard error of equation 4.9 and 4.10 is used as a measure of volatility (Jooste *et al*., 2006; Jordaan *et al*., 2007). According to Jooste *et al*., (2006) and Jordaan *et al*., (2007) the presence of ARCH effect has to be tested in the conditional variance of:

$$h^2 = Var(u_t / \Omega_{t-1}) \qquad 4.9$$

$$h^2 = \rho_o + \rho_1 u^2{}_{t-1} + \rho_2 u^2{}_{t-2} +,,, \rho_q u^2{}_{t-q} \qquad 4.10$$

Where u_t^2 is the squared residual in period *t*, and ρ_o, ρ_1, ρ_2, ρ_q are the parameters to be estimated.

Lagrange Multiplier (LM) and F-tests were used to test the null hypothesis of no ARCH effect when the ARCH equations were fitted. Volatility is said to vary over time if the null hypothesis is rejected at the five percent level of significance indicated by probability values lower than 0.05 or at the 10 percent level of significance indicated by probability values of less than 0.10 (McIntosh *et al.*, 2008).

The GARCH approach is applied when the hypothesis of no ARCH effect is rejected. The univariate GARCH (1,1) model is presented in equation 4.11 as:

$$\sigma_t^2 = \gamma_0 + \gamma_1 \varepsilon_{(t-1)}^2 + \gamma_2 \sigma_{(t-1)}^2 \qquad 4.11$$

Where σ_t^2 is the variance of ε_t conditional upon information up to period *t*.

The conditional standard deviation is the measure of volatility when using the GARCH approach and is given by the square root of each of the fitted values of σ_t^2 (equation 4.11). Contrasting to the volatility in the absence of ARCH effect, the conditional standard deviation varies over time. Due to the volatility varying over time it impossible to present the conditional volatility as a single value over a period therefore it is presented graphically instead.

4.5 Irrigation dependent costs

In South Africa, the cost of energy is very high and is expected to increase in the coming years. The cost of irrigation is therefore important as it has a significant impact on the cash flow. Each pivot has its cost because of the numerous factors that affect irrigation such as water related costs, electricity related costs and mechanisation related costs. Repair and maintenance costs, waters costs, labour costs and electricity costs of the irrigation system determine the irrigation dependent costs (IDC). The formula to calculate IDC is represented by equation 4.12:

$$IDC_{v,pl,s} = IW_{v,pl,s} + EC_{v,pl,s} + LC_{v,pl,s} + RMC_{v,pl,s} \qquad 4.12$$

Where:

$IDC_{v,pl,s}$ Total irrigation dependent costs for pivot v in planting month *pl* and state of nature *s* (R)

$IW_{v,pl,s}$ Total water costs for pivot v in planting month *pl* and state of nature s (R)

$EC_{v,pl,s}$ Total electricity costs for pivot v in planting month *pl* and state of nature s (R)

$LC_{v,pl,s}$ Total labour costs for pivot v in planting month *pl* (and state of nature s R)

$RMC_{v,pl,s}$ Total repair and maintenance costs for pivot v in planting month *pl* and state of nature s (R)

v Pivot

s State

pl Planting month

4.5.1 Water

The area and the allocation of water determined by the water user association, determines the maximum amount of water allocated. The constraint in equation 4.13 stipulates that the amount of irrigation applied or the average water budget for the total area planted cannot exceed the allocation of the total area available.

$$\frac{\sum_{pl,s} IR_{pl,s,i}}{\eta_s} A_{pl} \leq Alloc \times Pivot\ Size \tag{4.13}$$

Where:

$Alloc$ Allocation of water (m^3/ha)

The maximum irrigation application within an irrigation cycle is given in equation 4.14. The length of the cycle needs to be specified. The irrigation cycle therefore determines the day an irrigator can choose to irrigate. The assumption is made that the maximum irrigation application within an irrigation cycle cannot exceed the maximum irrigation amount per irrigation cycle where the irrigation amount is founded on the average irrigation applications of the water budgets.

$$\frac{\sum_{pl,s} IR_{pl,s,i}}{\eta_s} \leq irc_i \tag{4.14}$$

Where:

irc_i Irrigation amount per cycle for planting month pl in sate of nature *s*on irrigation day *i* (mm/cycle)

4.5.2 Electricity charge

According to Breytenbach *et al*., (1996) at an enterprise level electricity overheads account for one of the main variable cost items therefore the amount of irrigation, the design of the system and the electricity tariffs must be managed efficiently to reduce the fee of electricity. The increase in electricity tariffs will have a large effect on the farmer's ability to realise sustainable profits under potential average and adverse conditions Therefore the best management practices are to minimize water use, irrigate efficiently, supply water at a rate the soil can absorb, uniform irrigation and provide good drainage (U.S. Environmental Protection Agency, 2012).

In agriculture, the main Eskom electricity tariffs are Ruraflex, Night Save Rural and Landrate. The most common tariff options which Eskom uses to bill farmers for their electricity usage is Ruraflex and Landrate. Both tariffs have a variable cost and fixed cost component. If a producer wishes to switch between the two tariffs there are switching costs opportunity costs involved because of the two tariffs operating differently. The Ruraflex tariff option is designed to encourage users to use electricity in off-peak periods and in low demand seasons. Ruraflex is an electricity tariff that measures the time of use for rural customers with dual and three-phase supplies with an NMD from 25 kVA, with a supply voltage less than or equal to 22kV (or 33 kV where designated by Eskom as rural). Ruraflex is charged seasonally and the time-of-use differentiated cents per kilowatt-hour (c/kWh) active energy charges including losses, based on the voltage of supply and the transmission zone. There are three time-of-use periods, namely: peak, standard and off-peak. Public holidays are calculated on the day of the week the holiday occurs. The excess reactive energy is calculated using the billing interlude totals and will only be appropriate during the high-demand season. A rand per account per day service fee is based on the monthly utilised capacity of every account (Eskom, 2014/15). Variable costs consist of a reliability energy charge, active energy charge and network demand charge. Different rates apply for the distances from Johannesburg to the farm which are broken up into four categories namely 0 to 300km; 301 to 600km; 601 to 900km; and further than 900km (Eskom, 2014/15).

Landrate is the electricity tariff for rural clients with solitary, dual or three-phase conventionally metered supplies with an NMD up to 100kVA and a supply voltage less than or equal to 500 V. There is a single c/kWh active power charge measured at the point of delivery and there is a price per day service and administration charge for every point of delivery per premises. The monthly charge will be payable whether electricity was used or not, based on the appropriate daily fee and the number of days in the month. Landrate's fixed costs include a service charge, network access charge and administration charge.

The electricity costs and constraints in this research equate to the 2014 Eskom tariffs. Ruraflex is designed to encourage users to use electricity in off-peak and low demand seasons. The variable costs are comprised of an environmental levy charge, active energy charge, reactive energy charge and reliability energy charge. The Ruraflex tariff option is comprised of a fixed and a variable cost. The variable cost component depends on monthly electricity usage. how much electricity is used in the month. The variable cost component is determined by the units of electricity used and is a function of electricity tariffs, the irrigation system design (kW) and management (hours pumped). For every kilowatt (kWh) consumed the active energy charge is billed. The active energy charge is broken into three time usages namely off-peak time (OP), standard time (ST) and peak time (PE). Off-peak time consists of 82hours/week and is when demand is the lowest during the day. Conversely when demand is at its highest during the day nationwide the time slot is known as peak time and covers 25 hours/week. Ruraflex has an installed capacity of up to 5 Megavolt-Ampere (MVA), on rural networks in rural areas as determined by ESKOM from time to time and which accept supply from 400 V to 22 kV. The rate applied determines on the user's distance from Johannesburg and the supply size required which in the case of the Sandveld a distance of more than 900 km is used. The fixed cost portion is paid every month regardless of how much electricity was used in the month. The fixed cost is composed of service charge, network access charge and administration charge.

Landrate is a flat rate that depends on the supply of the size and for the purposes of this study Landrate 2 is applicable for Taaiboskraal Farm. The fixed cost component is comprised of a service charge, network access charge and administration charge. The service charge (R/day) for each POD is based on the applicable daily rate and the number of days in the month. The network access charge (R/day) is based on the NMD of the supply. Variable costs include a network demand charge, an active energy charge and a reliability service charge. The network demand charge (c/kWh) and the reliability service charge (c/kWh) are based on the active energy measured at the POD. The active energy charge (c/kWh) is a single charge measured at the POD. The total electricity costs are calculated in equation 4.15:

$$EC = \sum_{i,ti}\left(ta_{i,ti} + rc_{i,ti} + dc_{i,ti}\right) kWPH_{i,ti} + \sum_{i,ti} tra_{i,ti} kvarPH_{i,ti} \quad 4.15$$

Where:

$PH_{i,ti}$ Pumping hours on day *i* in timeslot *ti* (hours)

$kvar$ Kilovar (kVAR)

kW Kilowatt (kW)

$tra_{i,ti}$ Reactive energy charge on day *i* in timeslot *ti* (R/kVARh)

$ta_{i,ti}$ Active energy charge on day *i* in timeslot *ti* (R/kWh)

$rc_{i,ti}$ Reliable energy charge (R/kWh)

$dc_{i,ti}$ Demand energy charge (R/kWh)

The product of the pumping hours and the kW requirement of an irrigation system determine the electricity tariffs which are broken down into a demand, reliable and active energy charge. The irrigation management determines the pumping hours. The irrigation system design and layout determines the kW requirement.

When time of use electricity tariffs is used, restrictions are placed on the irrigation hours especially in peak hours. The pumping hours and the kilovar (kVAR) of an irrigation system determine the reactive energy charge. The power factor (PF) of the pump (kVAR = $\cos^{-1}$ PF) is used to calculate the kVAR. There is a unique power factor for each pump that can be acquired for the manufacturer. Of the *kVARh* used, the user pays for 70%. The type of electricity tariff determines the fixed electricity costs (fec) used in the input parameter of the model.

$$FCR = \sum_{12}^{m}((nac_m * KVA) + (sc_m * dm_m) + (ac_m * dm_m)) \quad 4.16$$

Where:

FCR Ruraflex fixed cost

nac Network access charge

sc Service charge

ac Administration charge

m Month

dm Days in month

KVA Kilovolt Ampere

$$FCL = \sum_{12}^{m}((nac_m * dm) + (sc_m * dm)) \quad 4.17$$

Where:

FCL Landrate fixed cost

The network charge, service charge, administration charge are input parameters in the model.

4.5.3 Labour, repair and maintenance costs.

Based on formulas proposed by Meiring (1989) the calculation procedures for labour and repair and maintenance costs of the irrigation system are explained in equation 4.18 and 4.19 respectively.

$$LC_{pl,s,v} = \sum_{i,ti} \frac{PH_{i,ti}}{24} lh_{pl,s,v}\, lw \quad 4.18$$

Where:

lh Labour hours needed per 24 hours' irrigation for a given size center pivot v in planting month *pl in state of nature s* (hours)

lw Labour wage (R/hour)

When permanent labour is employed in a specific enterprise it takes on the attribute of a variable cost because the labour can be used in different enterprises. The number of labour hours required for a centre pivot is determined by the number of hours that the system works for makes the labour costs variable. The type of task being performed and the size of the system influence the extent of the labour required per operating hour. For every 24 hours that the system is operated the model determines the labour demand. In order to calculated the total labour costs the calculated labour demand is multiplied with the labour wage and the total pumping hours. The repair and maintenance tariff is expressed as percentage per 1000 hours pumped because the maintenance and repair cost of the pump is directly connected to the use of the pump. The maintenance and repair costs of the pivot, pipe and motor is not included in the calculations because they are not linked to the use of the pivot and would linearly decrease the profit (Meiring, 1989).

$$RMC_{pl,s,v} = \sum_{i,ti} PH_{i,ti}\, rt_{pl,s,v} \qquad 4.19$$

Where:

rt Maintenance and repair tariff per 1000 hours pumped for pivot *v* in planting month *pl* in state of nature s (R/1000hours)

PH Pumping hours

The area planted, the irrigation water applied and the water tariff charged by the water user association determines the water charge. The water tariff is calculated on a fixed volumetric unit basis and includes all the payments made for the irrigation service. The charge per millilitre is determined by dividing the total charge by the allocated volume of water.

According the Burger *et al.* (2003) pumping hours can be calculated using equation 4.20 on an annual basis for all the fields or systems supplied from one pumping station.

$$PH_{v,i,t} = \frac{\frac{\sum_c IR_{pl,v,i}}{\eta_{s_v}} A_{pl,v} 10}{q_v} \qquad 4.20$$

Where:

q Flow rate (m^3/h)

η_s System efficiency (%)

The flow rate and system efficiency are input parameters in the model and the amount of irrigation is calculated in the model. The average irrigation of the water budgets included in the model determines the amount of irrigation. The spray loss of the irrigation system (wind drift) determines the system efficiency.

Eskom's time-of-use electricity tariffs have been constructed in such a way to encourage irrigation farmers to use electricity in off-peak hours and in the low demand season. The time-of-use tariffs are divided in three time slots with different rates applicable to each time-slot. The number of pumping hours needs to be limited to the available hours within an irrigation cycle and time-of-use. Equation 4.21 illustrates the equation used to restrict the pumping hours within the available hours in an irrigation cycle.

$$PH_{i,ti} \leq thc_{i,ti} \tag{4.21}$$

Where:

$thc_{i,t}i$ Available irrigation hours within each irrigation cycle on day *i* in timeslot *ti* (h)

The pumping hours in a time-slot cannot exceed the allocated irrigation hours in that specific time-slot.

4.6 Yield and area dependent costs

The yield and area dependent costs are an important component when determining the gross margins of a pivot. A potato enterprise budget for each pivot was set up in order to determine both the area and yield dependent costs as illustrated in equation 4.22 to 4.30.

4.6.1 Yield dependent costs

$$YC_{pl,v,s} = \frac{\sum(ma_{pl,v,s}+ft_v)}{y_{pl,v,s}} \tag{4.22}$$

Where:

YC yield cost for pivot *v* in planting month pl and state of nature *s* (R/ton)

ma marketing and packaging costs (R/ton)

ft field transport for pivot *v* (R/ton)

y potential yield for a pivot *v* in plating month *pl* and state of nature *s* (t/ha)

$$ft = \sum(In_i * (fl\left(\frac{y_{pl,v,s}}{1000}\right) * (d\ x\ 2) * dp) \tag{4.23}$$

Where:

y *yield (pockets/ha)*

d *distance (km)*

dp *diesel price (R/l)*

fl *fuel usage (l/ha)*

The distance, diesel price, fuel usage and yield are input parameters in the model.

4.6.2 Area dependent costs

The inputs that will change with the area planted comprise the area dependent costs on a per hectare level.

$$AC = se + fr + i + mr + fu + l \tag{4.24}$$

Where:

AC area dependent costs (R/ha)

se seed cost (R/ha)

fr fertilizer cost (R/ha)

i Insecticide, fungicide and herbicide cost (R/ha)

mr mechanisation running and ownership cost (R/ha)

fu mechanisation fuel cost (R/ha)

l labour cost (R/ha)

The cost of the seed (se) is calculated by summing the input parameters of application pockets per hectare, price per pocket and transport cost per pocket.

$$se = ab + prb + tb \tag{4.25}$$

where:

ab application pockets per hectare

prb price per pocket

tb transport cost per pocket

$$mr = O + R \tag{4.26}$$

where:

O ownership costs

R running costs

$$O = \sum((In_{im}) * (\sum^{tr,im} D_{tr,im} + I_{tr,im} + DC_{tr,im})) \tag{4.27}$$

where:

D Depreciation (R/Ha)

I Interest cost (R/Ha)

DC Diverse costs (R/Ha)

in Number of implements

tr Tractor

im Implement

The diverse costs, depreciation and interest costs are input parameters in the model.

$$R = \sum((In) * (\sum^{tr,im} Mt_{tr,im})) \quad 4.28$$

Where:

Mt maintenance (R/Ha)

The labour costs are the sum of permanent labour, casual labour and management. The cost of a permanent labourer per month, number of permanent labourers, cost of a manager per month, labour per hectare and number of managers are input parameters in the model.

$$l = \frac{(lp*12)*lb}{nha} + \frac{(mp*12)*mb}{nha} \quad 4.29$$

Where:

lp cost of a permanent labourer per month (R/month)

lb number of permanent labourers

nha labour per hectare

mp cost of a manager per month (R/month)

mb number of managers

Fuel:

$$fu = \sum(In_i * (flxdp) \quad 4.30$$

4.7 Risk analysis

The main objective of this research is to evaluate the best planting schedule over four years with regard to the decision maker's appetite for risk, preferred market and to determine the optimal electricity tariff for Taaiboskraal Farm. The information obtained from equations 4.3 to 4.6 will therefore be used to obtain the respective gross margins to be used to obtain the final solution. Boisvert and McCarl (1990) presented the Direct Expected Maximisation Non-linear Programming (DEMP) model which was the objective function of the model which is maximised in equation 4.33. Stochastic efficiency with respect to a function (SERF) was developed by Hardaker *et al*. (2004) and is a technique used to determine the stochastic efficiency of alternative planting strategies for decision-makers with variable levels of risk aversion. SERF is based on the concept that ranking risky alternatives with regard to utility is the equivalent to ranking alternatives with certainty equivalents (CE) (Venter, Strydom and Grove, 2012). The alternatives are therefore ranked according to CE whereby the alternative with the highest CE is preferred, given the specific level of risk aversion. When applying SERF the risk associated with a risky alternative like a CDF must be quantified and the range of risk aversion levels must be quantified. The analysis requires the use of SIMETAR add in in Excel © (Richardson *et al*., 2004).

$$GM_{plvs} = \left(pr_{pls}\ x\ y_{plvs}\ x\ ha_v\right) - [(AC\ x\ ha_v) + (y_{vs}\ x\ ha_v\ x\ YC_{cvs}) + (((EC_{vpls}\ x\ ha_v) - fc)) \qquad 4.31$$

$$E = CE = \frac{\sum_y^s gm}{s*y} \qquad 4.32$$

Where:

pr = price received at harvesting for planting month *pl* in state of nature *s (R/ton)*

y = potential yield for pivot *v* in planting month *pl* and state of nature *s* (t/ha)

ha = total hectares for pivot *v*

$$Max\ CE = \frac{\ln(-\ \sum_{r_s}^{s\frac{1}{}}(-e^{-r_a(x)})(gm_{s,y,pl}d_y)}{-r_a\ (x)} \qquad 4.33$$

Where:

d discount rate

Where:

real d = ((1+ interest rate)/ (1 +inflation rate))-1

wacc = (1*real discount rate)*(1- tax rate)

discount = 1 / ((1+wacc)-1)

The assumed constants in the gross margins correlate to the year 2014 with an interest rate of 9%, an inflation rate of 6.4% and a tax rate of 28%.

4.7.1 Risk Aversion

The Arrow-Pratt measure of absolute risk aversion $r_a\,(x)$ has the following three properties according to Hey (1979). Firstly, if $r_a\,(x)$> 0, =0 or <0 then the individual displays risk-averse, risk-neutral or risk-seeking preferences respectively. Secondly, $r_a\,(x)$ is unaffected by an arbitrary linear transformation of the utility function. Thirdly, if $r_a\,(x)$ is larger for a more risk-averse individual than for a less risk-averse individual. Constant absolute risk aversion (CARA) infers that subtracting or adding a constant to all payoffs does not affect the risk preferences (Hardaker *et al*., 2004) due to the variability around the mean that remains the same. By assuming CARA in this study the impact of wealth on risk aversion is not incorporated.

The choice of $r_a\,(x)$ is important in ensuring that the level of risk aversion in the model is in line with the actual risk averseness of the decision makers. If the same coefficient is used, the Arrow-Pratt absolute risk aversion measure is being viewed as a constant and not a function which it is. Therefore, for each study the $r_a\,(x)$ needs to be rescaled. Using the ratio of standard deviations to scale $r_a\,(x)$ has been proven to be the most accurate technique to formulate a consistent presentation of risk aversion (Grové, 2007). The $r_a\,(x)$ should therefore be selected in such a way that the standardised measure of risk aversion ($r_s(r^s)$) is between 0 and 2.5.

The electricity tariff with the lowest RAC was Ruraflex, with a RAC value of 0.00000000353112. The varying levels of RAC are illustrated in Table 4.1. The values of ra (x) that were used during optimisation were chosen in such a way that the ex post calculations of rs (xs) do not exceed 2.5.

Table 4.1: Risk aversion coefficients (RAC)

RAC1	0.0000000000000000
RAC2	0.0000000000000035
RAC3	0.0000000000000353
RAC4	0.0000000000003531
RAC5	0.0000000000035311
RAC6	0.0000000000353112
RAC7	0.0000000003531120
RAC8	0.0000000035311200
RAC9	0.0000000353112000
RAC10	0.0000003531120000

4.7.1 Resource constraints:

The following constraints in equation 4.34 to 4.36 stipulate the order of pivot choice and line use over the planting months.

Only one pivot can operate at a time on a line.

$\boldsymbol{VLn_{v,x}} \leq \mathbf{1}$ 4.34

Where:

A different pivot must be chosen each year on each line.

Y * V$Ln_{v,x}$ ≤ 1 4.35

All planting months in a year need to be planted and only one planting month can be utilised annually as a result of the packing shed's capacity limit.

pl_y= 1 4.36

4.8 Data Requirements

In order to determine the gross margins for each centre pivot the decision maker needs to obtain certain inputs. The data obtained from the farming business being studied must correlate as closely as possible to the data used in the model (Hazell and Norton, 1986). The data and model's requirements are based on Taaiboskraal Farm in the Sandveld, Western Cape, South Africa. The data for this study was collected from numerous sources namely PotatoesSA, Louw Smit from Taaiboskraal farm and consultations with various specialists on agronomic and economic models. The price and weather data spanned from 1998 to 2010 to ensure a correlation between the prices and yield (weather for the area in that time frame).

4.8.1 Yield potential

The input data required to determine the K_c values (required for irrigation requirement calculations) and the potential yields, pertains to the type of plant and the weather data. The daily simulated weather data for Taaiboskraal farm was acquired for the years 1998 to 2010. The weather data obtained was the maximum temperature (T_{max}), the minimum temperature (T_{min}), ET_o, radiation and precipitation. The planting and harvesting dates were obtained from Taaiboskraal farm, where the planting months are February, March, April, May, June, July and August. The harvesting months are roughly four months or 120 days after planting, therefore the respective harvesting months are June, July, August, September, October, November and December.

4.8.2 Price

The input data required to determine the Cape Town, Durban, Pretoria and Johannesburg market prices and volatility are shown in this section. The weekly potato prices for the four main fresh potato markets were obtained from PotatoesSA. The prices obtained from PotatoesSA were for the fresh potato market in Cape Town, Durban, Pretoria and Johannesburg for the respective harvesting months. For this research, historic prices are used and were discounted to 2014 as illistrated in Table 4.2 to Table 4.5. The transportation costs for a pocket of potatoes from the Taaibosplaas to the respective market was incorporated. The historic prices were taken from the same period as the weather data (1987 to 1999) in order to include the correlation between the prices and yield as a result of the prevailing weather conditions in that time period because yield and price have a negative correlation as indicated in the research reviewd in Chapter 3.

Table 4.2: Potential prices (R/t) received at harvesting for harvesting months June to December for the Johannesburg fresh produce market

	Plant1	Plant2	Plant3	Plant4	Plant5	Plant6	Plant7
State1	2928	1880	2825	4251	5141	4952	4678
State2	3974	3242	4620	4953	4902	4144	4423
State3	2553	2030	1496	1326	1505	1488	1444
State4	3182	3206	3266	3406	3556	2810	2573
State5	4828	4126	2456	2228	1715	2127	2176
State6	2724	2258	3253	4483	6930	7285	5660
State7	3069	2574	2546	2842	2678	2251	2255
State8	2029	1883	1250	1530	1994	2074	2737
State9	2695	2802	3464	5244	4931	3028	2648
State10	3100	2375	2387	2313	2182	1809	2013
State11	3218	1903	2039	2296	2199	2599	2324
State12	2823	2315	2263	2321	2896	2862	2981
Average	3094	2550	2655	3099	3386	3119	2993

Table 4.3: Potential prices (R/t) received at harvesting for harvesting months June to December for the Cape Town fresh produce market

	Plant1	Plant2	Plant3	Plant4	Plant5	Plant6	Plant7
State1	3358	3065	3425	4942	5581	4518	4382
State2	3166	4064	5566	6613	6106	4968	4778
State3	2222	2360	2421	1977	2158	1959	1739
State4	3488	4088	4315	3842	3908	3150	2789
State5	3489	3623	3489	2861	2288	2581	2746
State6	2082	2107	3515	4104	6396	6518	5695
State7	2541	2662	3190	3649	2985	2598	2495
State8	2323	2245	1905	1941	2467	2323	2658
State9	3013	3532	4296	4969	5731	3388	2982
State10	2774	2738	2877	2607	2390	2089	2086
State11	3059	2176	2375	2427	2154	2540	2425
State12	2164	2000	2644	2572	2789	2762	2852
Average	2806	2888	3335	3542	3746	3283	3136

Table 4.4: Potential prices (R/t) received at harvesting for harvesting months June to December for the Durban fresh produce market

	Plant1	Plant2	Plant3	Plant4	Plant5	Plant6	Plant7
State1	2778	1936	2892	4068	5064	4835	4564
State2	4149	3301	4584	4607	4741	3873	4285
State3	2511	2108	1464	1457	1719	1520	1426
State4	3219	3180	3244	3277	3328	2556	2427
State5	4158	4058	2468	2079	1870	2222	2094
State6	2614	2337	3161	4297	6064	6889	5586
State7	3433	2847	2589	2950	2653	2297	2498
State8	2206	1752	1168	1654	1976	1967	2595
State9	2877	2994	3515	4927	4194	2770	2577
State10	2945	2364	2397	2247	2005	1616	2051
State11	2669	1693	1952	2167	1962	2378	2159
State12	2398	2320	2158	2187	2660	2701	2870
Average	2996	2574	2633	2993	3186	2969	2928

Table 4.5: Potential prices (R/t) received at harvesting for harvesting months June to December for the Pretoria fresh produce market

	Plant1	Plant2	Plant3	Plant4	Plant5	Plant6	Plant7
State1	2793	1782	2746	4292	5490	5033	4579
State2	3902	3198	4791	5017	5023	4066	4396
State3	2408	1998	1453	1394	1555	1525	1514
State4	3105	3250	3294	3491	3645	2788	2545
State5	5120	4177	2629	2356	1888	2243	2229
State6	2676	2262	3190	4615	6955	7273	5569
State7	3117	2571	2602	2882	2675	2296	2321
State8	2064	1880	1146	1518	2030	1964	2724
State9	2615	2688	3474	5147	4331	2796	2562
State10	2890	2381	2367	2192	2097	1686	1994
State11	3258	1761	1963	2200	2096	2565	2246
State12	2672	2230	2237	2330	2883	2819	2895
Average	3052	2515	2658	3119	3389	3088	2965

4.8.3 Electricity Tariffs

The Eskom tariffs and charges booklet for the year 2014/15 was used to determine the electricity costs (Eskom, 2014/15). The electricity tariffs preferences namely Ruraflex and Landrate2 applicable to the Sandveld region are used to calculate electricity costs. Table 4.6 and 4.7 exemplifies the Ruraflex and Landrate 2 charges respectively used in the study. The active energy ($ta_{i,t}$) and network access charges (fixed charge) are based on the greater than 900km range transmission zone and a voltage of smaller than 500V. Reliability and network charge use a voltage smaller than 500V. A 200 and a 100-kilovolt ampere (KVA) point of delivery was used for the fixed electricity costs. Kilovar hours are calculated for each irrigation system design and is a function of the power factor of the pump. Network demand ($dc_{i,t}$), reactive energy charge ($tra_{i,t}$) and reliability ($rc_{i,t}$) charge are also determined by a voltage smaller than 500V. The total fixed costs for Ruraflex and Landrate 2 are R95 479.80 and R 34 740.70 respectively.

Table 4.6: Fixed and variable electricity tariffs for Ruraflex in the Sandveld region for 2014/15

Fixed Electricity Costs Tariffs			
Network Access Charge (R/KVA/month)			*13.37*
Service Charge (R/Account/day)			*44.32*
Administration Charge (R/POD/day)			*20.54*
Variable Electricity Costs Tariffs			
Active Energy Charge (c/kWh)	Low (September until April)	**Off-Peak**	33.57
		Standard	52.91
		Peak	76.87
	High (June until August)	**Off-Peak**	*38.76*
		Standard	*71.4*
		Peak	235.67
Reliability service Charge (c/kWh)			0.29
Network Demand Charge (c/kWh)			18.8
Reactive Energy Charge (c/kVArh)	Low (September until April)		0
	High (June until August)		6.35

Source: Eskom (2014/15)

Table 4.7: Fixed and variable electricity tariffs for Landrate 2 in the Sandveld region for 2014/15

Variable Electricity Costs Charges	
Energy Charge (c/kWh)	*75.27*
Reliability Service Charge (c/kWh)	*0.29*
Network Demand Charge (c/kWh)	*18.8*
Fixed Electricity Costs Charges	
Network Access Charge (R/POD/day)	*30.9*
Service Charge (R/POD/day)	*16.69*

Source: Eskom (2014/15)

For Ruraflex and Landrate respectively the tariffs that will have the biggest effect on variable electricity costs are active energy and energy charge. Ruraflex's active energy charge is divided into a high and low season as well as time-of-use tariffs. Ruraflex's active energy charge in the low season during peak time is roughly the same as Landrate's energy charge, whereas the active energy charge in high season during peak time is three times Landrate's energy charge. Ruraflex consists of reactive energy charge during the high season. The other two variable electricity tariffs are the same for both tariffs. Ruraflex has three fixed electricity tariffs compared to the two of Landrate. Ruraflex's network access charge is 2.3 times smaller than Landrate's network access charge, but the service charge of Ruraflex is 2.6 times greater the service charge of Landrate. Ruraflex also has an additional administration charge.

4.8.4 Other Irrigation Dependent Input Parameters

For the application of this model a minimum wage of R12.41 (DOL, 2014) and labour hours of 0.58 hours per 24 hours of irrigation was used. The method proposed by Meiring (1989) was used to determine the repair and maintenance tariffs which are dependent on the irrigation system design. The tariff is expressed as per 1000 hours pumped and is a function of the initial investment of the pump. The repair and maintenance of R4.85 per hour is used based on the base year of 2014 (DAFF, 2014). The water is based on a volumetric-based charge with an allocation of 10 000 m^3/ha. The tariff per millimetre water applied is determined by dividing the tariff with the water allocation which makes the charge per millilitre equal to R0.536/mm.

4.8.5 Irrigation System Design Data

The centre pivot designs are required in order to ascertain the effect of the various irrigation rotation options on the gross margin, water management and energy costs. Irrigation system design data was collected for the 34 pivots on Taaiboskraal Farm from Smit (2016). The hectare sizes of the lands vary from 12 ha to 20hectares. Each line has eight centre pivots. In order to calculate the kilowatt requirement in the model the pump rate, centre pressure and efficiency of the pump. The pipe diameter is 160mm and flow rate in the pivots is 60 m^3/ha. The efficiency of the pump friction is 70% and assumes the spray loss is 10%. The size and capacity of the centre pivot, which varies between the designs of the centre pivots and in turn determines the pump rate, centre pressure and efficiency of the pump, are required. The irrigation hours of the irrigation system is determined by the designed capacity of the centre pivot and the size of the pivot determines the flow rate. Table 4.8 shows the design of each centre pivot.

Table 4.8: Design of 32 different fields

Line	Field Name	Distance to packing shed from pivot (km)	Size Ha	Line	Field Name	Distance to packing shed from pivot (km)	Size Ha
1	11	1.2	20	3	51	1.2	13.5
1	12	2.0	20	3	52	1.7	13.5
1	13	2.3	20	3	53	2.2	13.5
1	14	2.4	20	3	54	2.7	13.5
1	21	2.6	20	3	61	2.4	13.5
1	22	2.3	20	3	62	3.0	13.5
1	23	1.9	20	3	63	1.7	13.5
1	24	2.0	20	3	64	3.1	13.5
2	31	0.6	12	4	71	0.3	12
2	32	1.4	12	4	72	0.5	12

2	33	0.6	12	4	73	0.5	12
2	34	1.0	12	4	74	0.1	12
2	41	0.1	18	4	81	0.9	12
2	42	0.9	18	4	82	1.0	12
2	43	0.8	18	4	83	0.8	12
2	44	0.1	18	4	84	0.8	12

4.8.6 Production costs

The costs and data to determine the production costs were obtained from the local agricultural cooperative. The diesel (50 ppm) price used was R13.23/l. The various input costs used to determine the yield and area costs are provided in Table 4.9 to 4.15.

Table 4.9: Fertilizer and seed costs

	Cost (R)/ha
Fertilizer	
Pre Plant	23508
Gips	1 260
Chemicals	
Fungicide	328
Nematode	2 126
Wetter	6 630
Seed treatment	2 870

Table 4.10: Seed costs

Seed	Application pockets /ha	Price /pocket	Transport/pocket
Mondial	160	175	14

Table 4.11: Taaiboskraal farm's labour costs

Labour	Cost (R) /month	Total
Permanent	2921	15
Manager	17120	1

Table 4.12: Running costs of Taaiboskraal farms pack house

	Cost /pocket
Chemicals	**R 0.06**
Transport to FPMs	**R 2.50**
Empty 10 kg pocket	**R 1.90**
Pallet	**R 0.12**
Stitch	**R 0.04**
Net	**R 0.04**
Electricity	**R 0.09**
Commission (FPMs)	**R 2.01**
Labour (shed)	**R 0.79**
Diesel (shed)	**R 0.21**
Maintenance (shed)	**R 0.10**

Table 4.13: Running costs of Taaiboskraal farm's mechanisation actions

				Depreciation		Interest cost		Diverse costs		Maintenance		Fuel
Mechanization action	**Implement**	**Amount**	**KW**	**Tractor R/ha**	**Implement R/ha**	**Tractor R/ha**	**Implement R/ha**	**Tractor R/ha**	**Implement R/ha**	**Tractor R/ha**	**Implement R/ha**	**L/ha**
Rip after plant	JD 913 V-Ripper 3T	1	93	100.83	15.62	73.94	11.46	40.33	6.25	134.44	17.36	18.9
Plough - 1st cultivation activity	JD 975-3S	1	93	109.34	33.83	80.18	24.81	43.73	15.53	145.78	56.39	20.5
Spreading gypsum and fertilizer	F400 lime spreader 400 litre (Falcon)	7	73	5.63	1.11	4.13	0.81	2.25	0.44	7.5	0.62	1.2
Crop spray	Rovic and Leers ASTASA bulk spray 800liter (12m)	12	67	7.45	2.96	5.46	1.81	2.98	0.99	9.93	3.29	1.69
Plant	Potato planter	1	93	282.33	175.2	207.4	128.48	112.93	70.08	376.44	155.73	52.93
Harvest	Potato harvester (1.5m)	1	93	338.79	236.02	248.45	173.08	135.52	94.41	451.72	209.79	63.51
Scarifier	JD 975-3S	1	33.83	109.34	33.83	80.18	24.81	43.73	15.53	145.78	56.39	20.5

Table 4.14: Running costs of Taaiboskraal farm's trucks

Truck	Depreciation R/km	Interest cost R/km	Depreciation + Interest R/km	Diverse cost R/km	Maintenance R/km	Fuel l/100km
2500 cc Diesel single cab 40000km 4x2	0.9645	0.4244	1.3889	0.6035	0.5358	8
3000 cc Diesel single cab 40000km 4x4	1.3459	0.6415	1.9874	0.9876	0.81	10.2

Table 4.15: Taaiboskraal farm's transport from lands cost

Transport from land 30 km/ha	Depreciation		Interest cost		Diverse koste		Maintenance		Fuel
	Tractor R/km	Implement R/km	Tractor R/km	Implement R/km	Tractor R/km	Implement R/km	Tractor R/km	Implement R/km	L/km
10 ton BP massa trailer	6.9166575	1.089	5.0722155	1.331	2.766663	0.726	9.22221	0.363	1.43

CHAPTER 5
Results

5.1 Introduction

Agriculture operates in a volatile enviroment resulting from numerous unknowns therefore, when a farmer is making decisions pertaining to the farming enterprise, the farmer is continuously faced with an uncertain outcome Producers have the option to reduce costs and increase yields in order to improve profits, however they are price takers when it comes to price. The producer is therefore left with the option of selling the potatoes to one of South Africa's fresh produce markets where the price is best, obtaining higher yields and cutting costs especially with regard to electricity tariffs which can constitutes a large portion of the enterprise budget. This case study aims to provide the producer with a tool to determine the best planting schedule given a certain appetite for risk. In this chapter the procedures described in Chapter 4 are applied in order to assist the farmer in making decisions under uncertainty.

The first section of this chapter provides the results required to determine, the gross margins then the decisions flow chart is explained where the decision maker commits resources to a four-year planning period. Once the most optimal tariff has been selected the decision maker then needs to decide on the market and finally his/her appetite for risk.

5.2 Potential yields

There are numerous interrelated factors that affect the yields of a potato plant therefore when determining the potential yields all the factors need to be considered. The LINTUL model was found to be the most accurate model in determining the stimulated potential yields over 12 states of nature and obtain the k_c values for each planting date which is required for the irrigation scheduling model. A state of nature is a random climatic condition that has prevailed in a season. Table 5.1 illustrates the potential yields for each planting date in each state of nature. The yields in Table 5.1 were obtained by correlating the average yields that Taaiboskraal farm obtains and the yields stimulated by the LINTUL model.

Table 5.1: Potential yields for planting months February to August

	February	March	April	May	June	July	August
State1	46	41	40	45	45	49	56
State2	42	37	37	40	44	48	49
State3	42	40	40	39	43	48	50
State4	42	39	35	38	44	49	52
State5	43	43	39	38	41	46	50
State6	43	40	35	39	42	46	50
State7	40	40	38	45	49	50	53
State8	42	40	37	42	45	47	51
State9	42	41	37	41	43	45	45
State10	43	39	37	37	38	44	50
State11	44	41	37	40	45	46	50
State12	43	39	40	44	45	45	45
Average	43	40	38	41	44	47	50

The later in the planting season the potato crop is planted the higher the potential yields are. The longer the potato plant is exposed to low temperatures in its growing period the lower the yields are, as evident in Table 5.1. Figure 5.1 illustrates the cumulative distribution functions (CDF) of the various possible yields for planting months February to August. The CDF illustrates that as the planting months precede the probability of obtaining higher yields increase. August is the planting month with the highest yields at all probabilities. When comparing the minimum and maximum from the probability distribution for each planting month the cumulative probability distribution indicates that February has higher yield variability than the other planting months. August therefore dominates July and July dominates June by first degree stochastic dominance criteria. This information was used to quantify the deviations of the states of nature from the expected gross margins that are required for the SERF formulation.

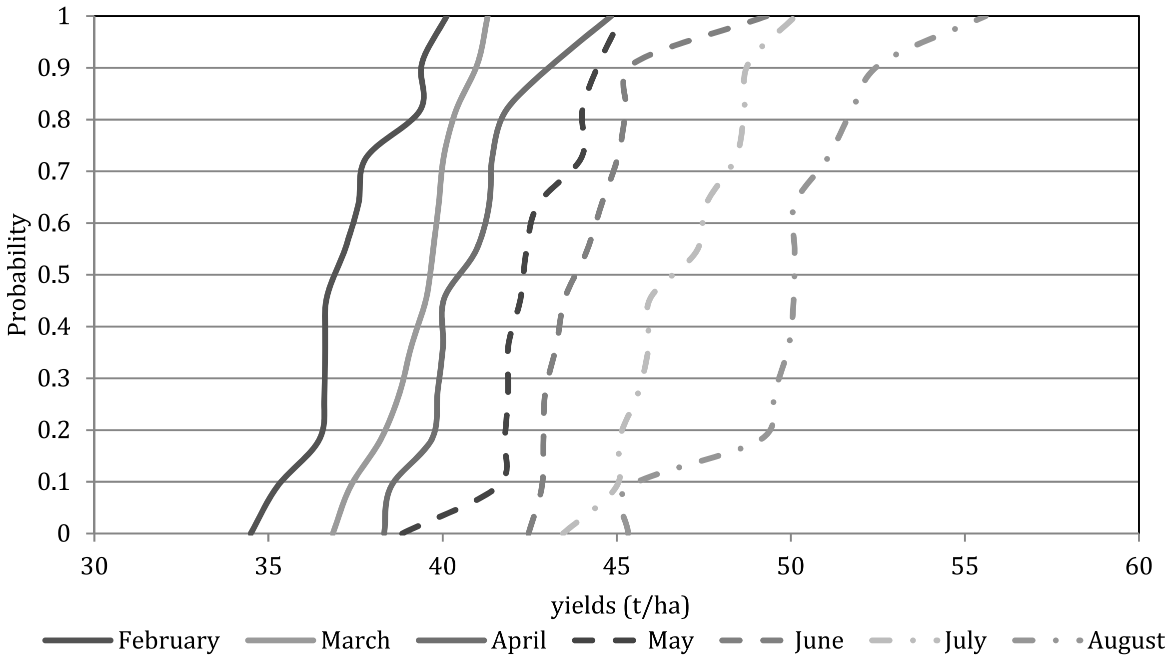


Figure 5.1: Cumulative probability distributions of possible yield outcomes for planting months February to August.

5.3 Price volatility

Volatility is tricky to predict therefore when making management decisions it is important to understand the volatility over time in order to make the best informed decision. The aim of this section was to quantify the true stochastic components in the prices of potatoes in the four main markets as acurately as possible by removing some of the known components like seasonality and inflation. The ARCH/GARCH approach was found to be best suited for the quantification of volatility. The approach allows new information to influence volatility and thus allows volatility to move over time. The ARCH/GARCH approach also distinguishes between known and unknown components in the price process. The effect of seasonality and inflation were removed as known variables from the price data before the approached was applied. The GARCH approach also makes better use of the information on volatility contained in the time series in comparison to the other models.

The incidence of a unit root and to ascertain how many times a series must be differenced to make it stationary, was tested using the Augmented Dickey Fuller (ADF) test. The number of times a series needs to be differenced indicates its order of integration and consequently the value of d in ARIMA (p,d,q) process. The d value indicates the degree of differencing; p indicates the order of the autoregressive model and q indicates the order of the moving average model. The Box-Jenkins methodology was then used to determine the values of p and q in the ARIMA (p,d,q) process (Jordaan *et al*, 2007). The Box-Jenkins approach assumes that the residuals are homoscedastic therefore the standard error is a measure of volatility, thereby implying volatility remains the same over time. In the ARIMA (d) is therefore 0. From the computation of (AR 0-6) by (MA 0-6) forty-nine combinations were obtained. From the Box-Jenkins it was found that the values in Table 5.2 were the best fit for the respective markets. The components of the GARCH model needs to be significant, therefore the largest AIC or SBC value serves only as a guideline (Jooste *et al*., 2006; Jordaan *et al*., 2007).

Table 5.2: Values of p and q in the ARIMA (p,d,q) process determined using the Box-Jenkins methodology and the d using the Akaike information criterion.

Market	**p**	**d**	**q**
Durban	7	0	7
Johannesburg	6	0	7
Pretoria	6	0	7
Cape Town	7	0	5

Lagrange Multiplier (LM) and F-tests were used to test the null hypothesis of no ARCH effect when the ARCH equations were fitted. Table 5.3 shows the results for the heteroscedasticity test for ARCH. The test for the presence of ARCH effect confirmed the presence of ARCH (2) in the Johannesburg market, ARCH (3) in the Pretoria market and ARCH (6) in the Durban market. The results indicate that the volatility in the prices in these three markets is time varying and therefore the GARCH approach must be used instead. In the Cape Town market, no ARCH effect was detected and therefore no need to apply the GARCH approach. The measure for volatility for the Cape Town market is therefore the standard error of the ARIMA process which is 0.086062. Cape Town market's price volatility remains constant over time. Both the mean and variances are important determinants of future decisions.

Table 5.3: ARCH-LM test results

Market	F-statistic	Probability
Cape Town (ARCH7)	1.315654	0.2393
Durban (ARCH6)	2.330697	0.0306
Johannesburg (ARCH2)	3.122634	0.0445
Pretoria (ARCH3)	3.543344	0.0142

The GARCH approach was then applied when the hypothesis of no ARCH effect was rejected. Contrasting to the volatility in the absence of ARCH effect, the conditional standard deviation varies over time. Due to the volatility varying over time it is impossible to present the conditional volatility as a single value over a period therefore it is presented graphically instead.

Highly leptokurtic behavior was found in the standard deviation graphs of Johannesburg, Durban and Pretoria as shown in Figures 5.2 to 5.4. Leptokurtic behavior is a statistical distribution where the points are clustered resulting in a higher kurtosis than in a normal distribution. In Figure 5.2 the conditional standard deviation as a measure of volatility in the price of potatoes in the Johannesburg market indicated the mean to be around 0.0056. Figure 5.4 indicates the conditional standard deviation as a measure of volatility in the price of potatoes on the Pretoria market. There weren't many notable spikes in recent year's which implies that there weren't any increased variations. Figure 5.3 depicts the conditional standard deviation as a measure of volatility in the price of potatoes in the Durban market, were cyclic deviations did not pass the 2+ standard deviation line except for 3 exceptions. The volatility in the Durban market fluctuates within the acceptable 2+ standard deviation bracket except for the increase in variations which were most likely rare infrequent events like an early hail or drought in the main producing areas.

The presence of leptokurtic behavior indicates the need for traders to use different marketing/hedging strategies during the various parts of the year in order to account for the various levels of risk they are exposed to. The frequency in which the Johannesburg, Durban and Pretoria markets exceed the two standard deviation boundaries indicates that the volatility associated with the price of the potatoes in the respective markets is inconsistent and unforeseen events could have occurred in the market. In the Johannesburg market, there is a sharp spike in the middle of 2007 in Figure 5.2. The reason for the spike was a slight drop in potato yield in the 16 winter potato production areas. The 2007 winter season was a longer, colder and wetter season which resulted in lower volumes being supplied to retailers in September and October; however the situation was short-lived (PotatoesSA, 2007).

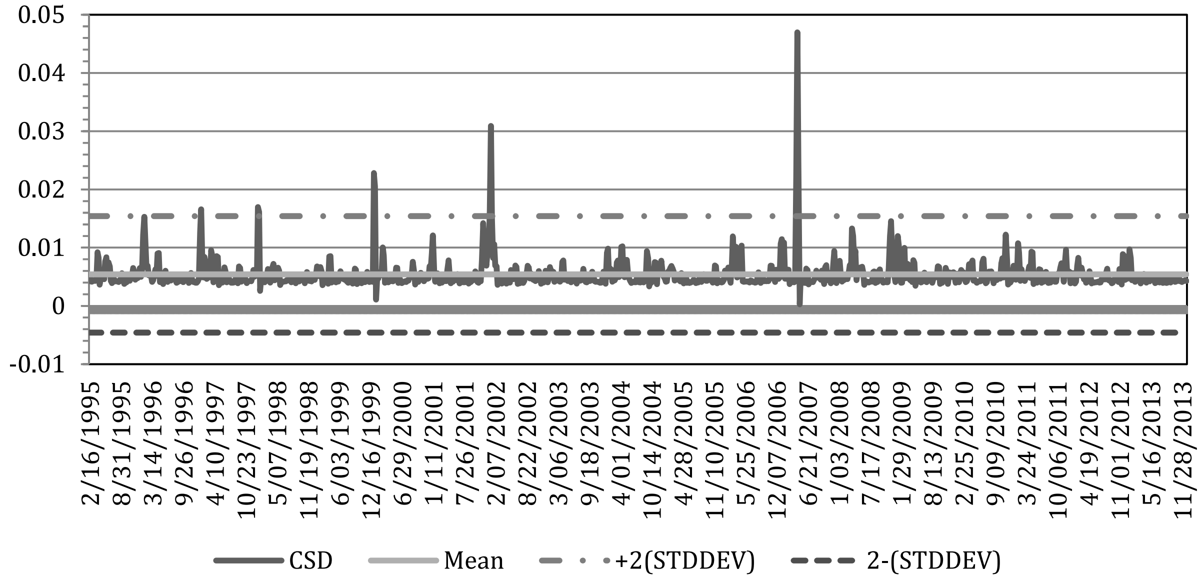


Figure 5.2: Conditional Standard Deviation as a measure of volatility in the price of potatoes in the Johannesburg market

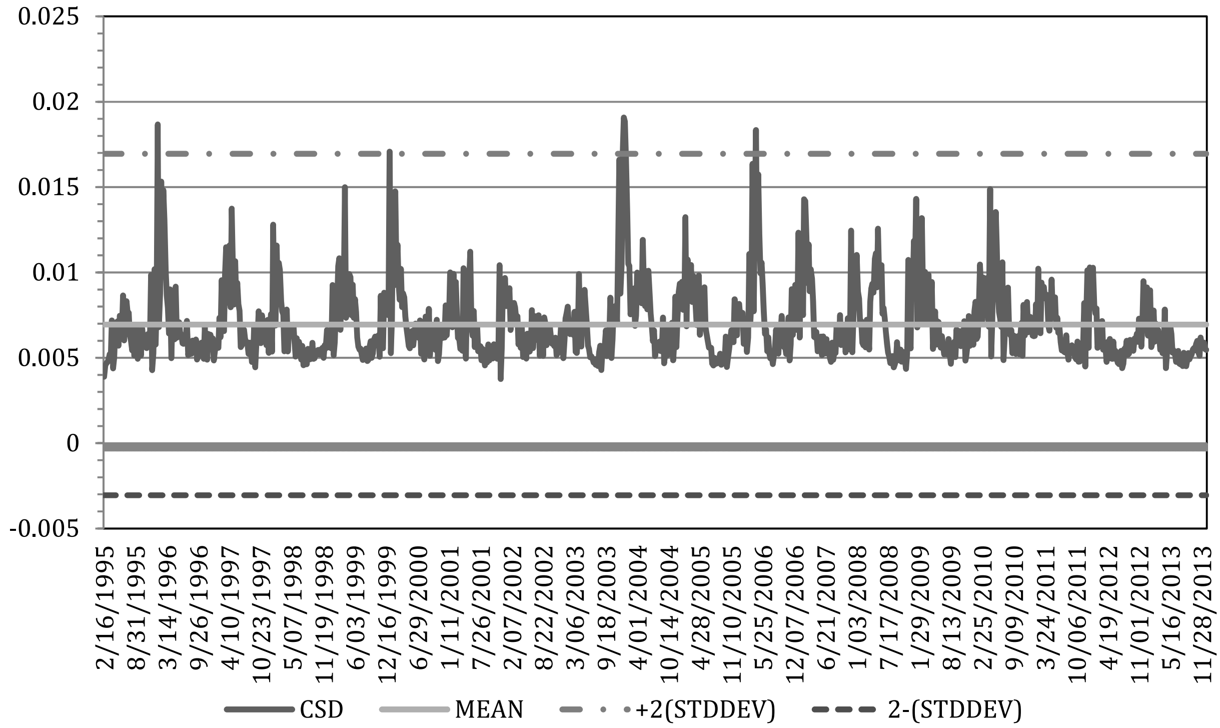


Figure 5.3: Conditional Standard Deviation as a measure of volatility in the price of potatoes in the Durban market

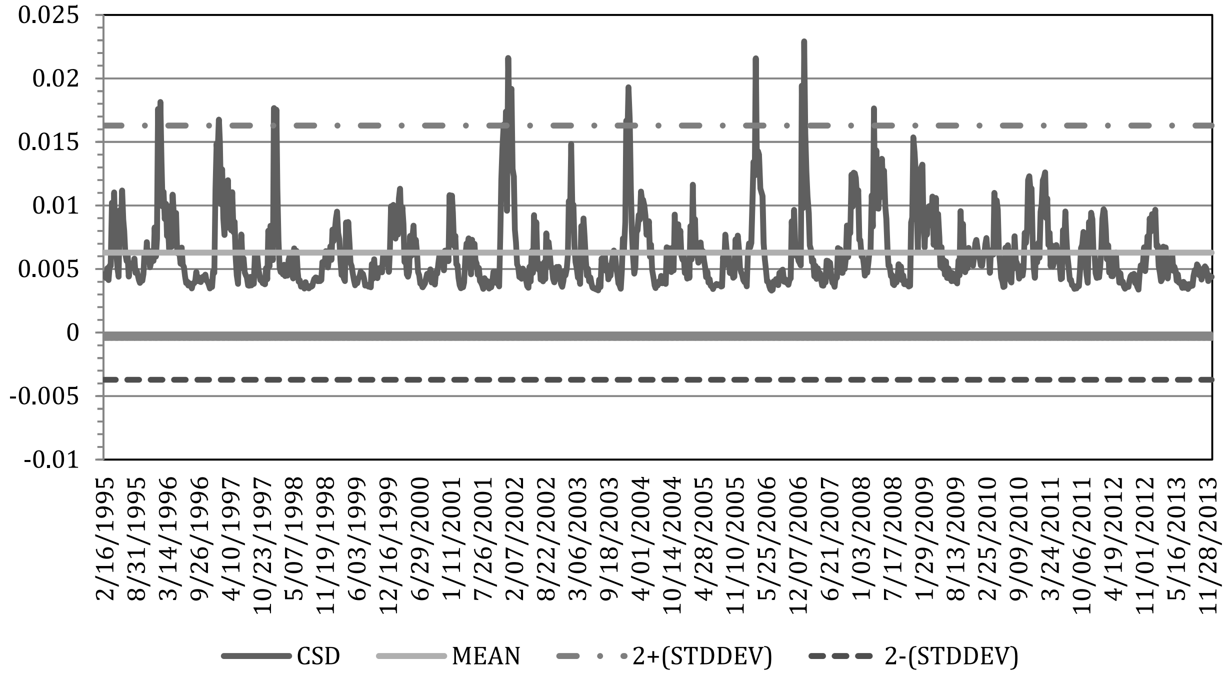


Figure 5.4: Conditional Standard Deviation as a measure of volatility in the price of potatoes in the Pretoria market

Table 5.4 shows the standard deviation for the prices in the Fresh potato market in Cape Town and Figure 5.5 illistrates the respective standard deviations.

Table 5.4: Coefficient and standard deviations (STD Dev) for the prices on the Cape Town Market from January until December

Month	Coefficient	Neg, STD Dev	Pos, STD Dev
January	3.242	2.969	3.515
February	3.204	2.931	3.476
March	3.216	2.944	3.489
April	3.262	2.989	3.535
May	3.290	3.017	3.562
June	3.241	2.968	3.514
July	3.202	2.929	3.475
August	3.219	2.946	3.491
September	3.355	3.082	3.627
October	3.432	3.159	3.704
November	3.253	2.981	3.526
December	3.148	2.876	3.421
Number of STD Dev		3	3
S.E. of regression		0.091	0.091

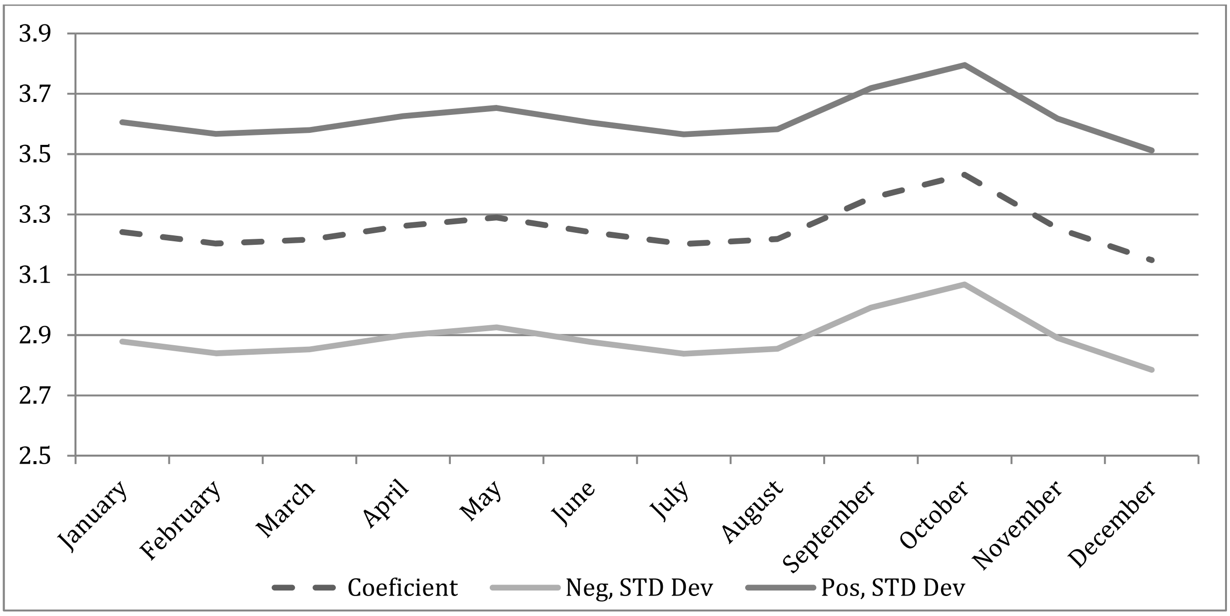


Figure 5.5: Standard deviation of the prices in the Cape Town fresh produce market from January until December.

The price risks associtated with Durban, Johannesburg and Pretoria markets are higher than the Cape Town market. The high frequency of spikes in the conditional standard deviations in the Durban, Johannesburg and Pretoria markets that exceeds the 2 standard deviation boundries suggest that these markets experience higher price risk.

5.4 Multivariate probability distributions

The resulting gross margins from the stochastic gross income and operating costs are stimulated according to the general procedure described to simulate multivariate probability distributions and the distributions of prices and yields. The procedures for the parameter estimation and simulation of MVE distributions are robust and are good for large scale simulation models. The histroical mean yields and prices that correlated to the weather data for the yields from 1998 to 2010 were used and discounted to the year 2014. The correlation structure between the variables determines the combination of the variables. Table 5.5 to 5.8 illustrates simulation of the assumed correlations between crop yield and price in the Cape Town, Durban, Pretoria and Johannesburg markets respectively. A comparison of the simulated and historical distribution statistics validate the MVE procedure. The simulated means for each crop’s yield compares very well to the histroical means as do the other statistics. The simulated mean prices are very close to the historic actual prices.

Table 5.5: Correlations between yields and prices on the Cape Town fresh potato market at harvesting

		Yield							Price						
		June	July	August	September	October	November	December	June	July	August	September	October	November	December
Yield	June	1	0.38	0.39	0.04	-0.33	-0.33	0.17	0.12	0.14	0.26	0.27	0.22	0.39	0.27
	July	0.38	1	0.42	0.10	-0.05	-0.20	0.05	-0.11	-0.17	-0.12	-0.14	-0.02	-0.15	-0.13
	August	0.39	0.42	1	0.48	0.16	0.07	0.04	-0.34	-0.28	-0.13	-0.16	-0.24	-0.37	-0.31
	September	0.04	0.10	0.48	1	0.80	0.48	0.17	0.05	0.11	0.35	0.26	0.13	-0.35	-0.21
	October	-0.33	-0.05	0.16	0.80	1	0.78	0.31	-0.01	0.02	0.16	0.07	0.03	-0.51	-0.32
	November	-0.33	-0.20	0.07	0.48	0.78	1	0.63	0.02	0.06	0.07	-0.01	-0.08	-0.37	-0.08
	December	0.17	0.05	0.04	0.17	0.31	0.63	1	0.02	0.04	0.16	0.21	0.22	0.18	0.24
Price	June	0.12	-0.11	-0.34	0.05	-0.01	0.02	0.02	1	0.97	0.83	0.72	0.59	0.56	0.07
	July	0.14	-0.17	-0.28	0.11	0.02	0.06	0.04	0.97	1	0.90	0.81	0.67	0.56	-0.01
	August	0.26	-0.12	-0.13	0.35	0.16	0.07	0.16	0.83	0.90	1	0.97	0.86	0.61	0.03
	September	0.27	-0.14	-0.16	0.26	0.07	-0.01	0.21	0.72	0.81	0.97	1	0.95	0.71	0.04
	October	0.22	-0.02	-0.24	0.13	0.03	-0.08	0.22	0.59	0.67	0.86	0.95	1	0.73	0.01
	November	0.39	-0.15	-0.37	-0.35	-0.51	-0.37	0.18	0.56	0.56	0.61	0.71	0.73	1	0.39
	December	0.27	-0.13	-0.31	-0.21	-0.32	-0.08	0.24	0.07	-0.01	0.03	0.04	0.01	0.39	1

Table 5.6: Correlations between yields and prices on the Johannesburg fresh potato market at harvesting

		Yield							Price						
		crop1	crop2	crop3	crop4	crop5	crop6	crop7	crop1	crop2	crop3	crop4	crop5	crop6	crop 7
Yield	crop1	1	0.38	0.39	0.04	-0.33	-0.33	0.17	0.04	-0.31	-0.16	-0.02	0.09	0.24	0.24
	crop2	0.38	1	0.42	0.10	-0.05	-0.20	0.05	0.18	0.08	-0.34	-0.10	-0.12	-0.04	-0.15
	crop3	0.39	0.42	1	0.48	0.16	0.07	0.04	0.04	-0.17	-0.44	-0.38	-0.36	-0.27	-0.20
	crop4	0.04	0.10	0.48	1	0.80	0.48	0.17	-0.36	-0.43	-0.13	0.08	0.11	0.09	0.18
	crop5	-0.33	-0.05	0.16	0.80	1	0.78	0.31	-0.23	-0.26	-0.08	0.00	0.00	0.00	0.05
	crop6	-0.33	-0.20	0.07	0.48	0.78	1	0.63	0.00	0.03	0.15	0.12	0.07	0.04	0.12
	crop7	0.17	0.05	0.04	0.17	0.31	0.63	1	0.02	-0.19	-0.12	-0.08	0.02	0.15	0.19
Price	crop1	0.04	0.18	0.04	-0.36	-0.23	0.00	0.02	1	0.83	0.42	0.13	-0.09	-0.05	-0.03
	crop2	-0.31	0.08	-0.17	-0.43	-0.26	0.03	-0.19	0.83	1	0.50	0.23	-0.02	-0.11	-0.11
	crop3	-0.16	-0.34	-0.44	-0.13	-0.08	0.15	-0.12	0.42	0.50	1	0.89	0.73	0.54	0.57
	crop4	-0.02	-0.10	-0.38	0.08	0.00	0.12	-0.08	0.13	0.23	0.89	1	0.90	0.70	0.69
	crop5	0.09	-0.12	-0.36	0.11	0.00	0.07	0.02	-0.09	-0.02	0.73	0.90	1	0.92	0.89
	crop6	0.24	-0.04	-0.27	0.09	0.00	0.04	0.15	-0.05	-0.11	0.54	0.70	0.92	1	0.96
	crop7	0.24	-0.15	-0.20	0.18	0.05	0.12	0.19	-0.03	-0.11	0.57	0.69	0.89	0.96	1

Table 5.7: Correlations between yields and prices on the Durban fresh potato market at harvesting

		Yield							Price						
		crop1	crop2	crop3	crop4	crop5	crop6	crop7	crop1	crop2	crop3	crop4	crop5	crop6	crop7
Yield	crop1	1	0.38	0.39	0.04	-0.33	-0.33	0.17	-0.29	-0.39	-0.16	-0.06	0.11	0.24	0.20
	crop2	0.38	1	0.42	0.10	-0.05	-0.20	0.05	-0.05	0.06	-0.31	-0.11	-0.13	0.00	-0.15
	crop3	0.39	0.42	1	0.48	0.16	0.07	0.04	-0.12	-0.15	-0.42	-0.39	-0.29	-0.22	-0.20
	crop4	0.04	0.10	0.48	1	0.80	0.48	0.17	-0.29	-0.36	-0.11	0.11	0.15	0.11	0.21
	crop5	-0.33	-0.05	0.16	0.80	1	0.78	0.31	-0.06	-0.20	-0.08	0.04	0.03	0.02	0.08
	crop6	-0.33	-0.20	0.07	0.48	0.78	1	0.63	0.26	0.09	0.17	0.16	0.16	0.07	0.14
	crop7	0.17	0.05	0.04	0.17	0.31	0.63	1	0.09	-0.19	-0.10	-0.04	0.11	0.19	0.21
Price	crop1	-0.29	-0.05	-0.12	-0.29	-0.06	0.26	0.09	1	0.87	0.62	0.29	0.08	-0.02	0.03
	crop2	-0.39	0.06	-0.15	-0.36	-0.20	0.09	-0.19	0.87	1	0.56	0.28	0.07	-0.06	-0.07
	crop3	-0.16	-0.31	-0.42	-0.11	-0.08	0.17	-0.10	0.62	0.56	1	0.89	0.73	0.51	0.56
	crop4	-0.06	-0.11	-0.39	0.11	0.04	0.16	-0.04	0.29	0.28	0.89	1	0.90	0.68	0.70
	crop5	0.11	-0.13	-0.29	0.15	0.03	0.16	0.11	0.08	0.07	0.73	0.90	1	0.92	0.92
	crop6	0.24	0.00	-0.22	0.11	0.02	0.07	0.19	-0.02	-0.06	0.51	0.68	0.92	1	0.96
	crop7	0.20	-0.15	-0.20	0.21	0.08	0.14	0.21	0.03	-0.07	0.56	0.70	0.92	0.96	1

Table 5.8: Correlations between yields and prices on the Pretoria fresh potato market at harvesting

		Yield							Price						
		crop1	crop2	crop3	crop4	crop5	crop6	crop7	crop1	crop2	crop3	crop4	crop5	crop6	crop7
Yield	crop1	1	0.38	0.39	0.04	-0.33	-0.33	0.17	0.00	-0.33	-0.19	-0.03	0.13	0.25	0.22
	crop2	0.38	1	0.42	0.10	-0.05	-0.20	0.05	0.25	0.06	-0.33	-0.10	-0.13	-0.02	-0.15
	crop3	0.39	0.42	1	0.48	0.16	0.07	0.04	0.03	-0.18	-0.42	-0.37	-0.32	-0.24	-0.20
	crop4	0.04	0.10	0.48	1	0.80	0.48	0.17	-0.34	-0.46	-0.14	0.08	0.12	0.10	0.18
	crop5	-0.33	-0.05	0.16	0.80	1	0.78	0.31	-0.18	-0.27	-0.08	0.01	0.01	0.01	0.06
	crop6	-0.33	-0.20	0.07	0.48	0.78	1	0.63	0.02	0.04	0.16	0.15	0.13	0.06	0.14
	crop7	0.17	0.05	0.04	0.17	0.31	0.63	1	0.04	-0.15	-0.13	-0.06	0.11	0.19	0.20
Price	crop1	0.00	0.25	0.03	-0.34	-0.18	0.02	0.04	1	0.82	0.41	0.10	-0.09	-0.04	-0.04
	crop2	-0.33	0.06	-0.18	-0.46	-0.27	0.04	-0.15	0.82	1	0.53	0.22	-0.03	-0.10	-0.09
	crop3	-0.19	-0.33	-0.42	-0.14	-0.08	0.16	-0.13	0.41	0.53	1	0.88	0.67	0.49	0.53
	crop4	-0.03	-0.10	-0.37	0.08	0.01	0.15	-0.06	0.10	0.22	0.88	1	0.88	0.70	0.71
	crop5	0.13	-0.13	-0.32	0.12	0.01	0.13	0.11	-0.09	-0.03	0.67	0.88	1	0.94	0.93
	crop6	0.25	-0.02	-0.24	0.10	0.01	0.06	0.19	-0.04	-0.10	0.49	0.70	0.94	1	0.96
	crop7	0.22	-0.15	-0.20	0.18	0.06	0.14	0.20	-0.04	-0.09	0.53	0.71	0.93	0.96	1

5.5 Gross margins

There are various factors that a farmer can control and then there are the factors that can`t be controlled. The farmer therefore needs to incorporate all these factors in such a way that the farm has an optimal planting schedule over a four year period taking into account the resources that will be commited for four years. The best way to incorporate the factors were found to determine the gross margins for each pviot. In order to determine the gross margins the real prices (using 2014 as the base year) and the potential yields from the lintul model as explained above were used. The irrigation, electricity, area and yield dependent costs determined in Chapter 4 were put into the gross margin equation. Following the decision makers optimal choice in tariff the decision maker then needs to decide which market the farm will be best to sell the fresh potatoes to and finally the degree of risk adversion as illistarated in Figure 5.6. The decison that is then made to plant of cetain fields at the beginning of planting cannot be changed until a new cycle starts four years later as the decision maker has commited a sequence of fields inorder to optimise the returns over a four year planting cycle. The decision maker therefore locks the farms planting schedule into a four year cycle after making an informed decision.

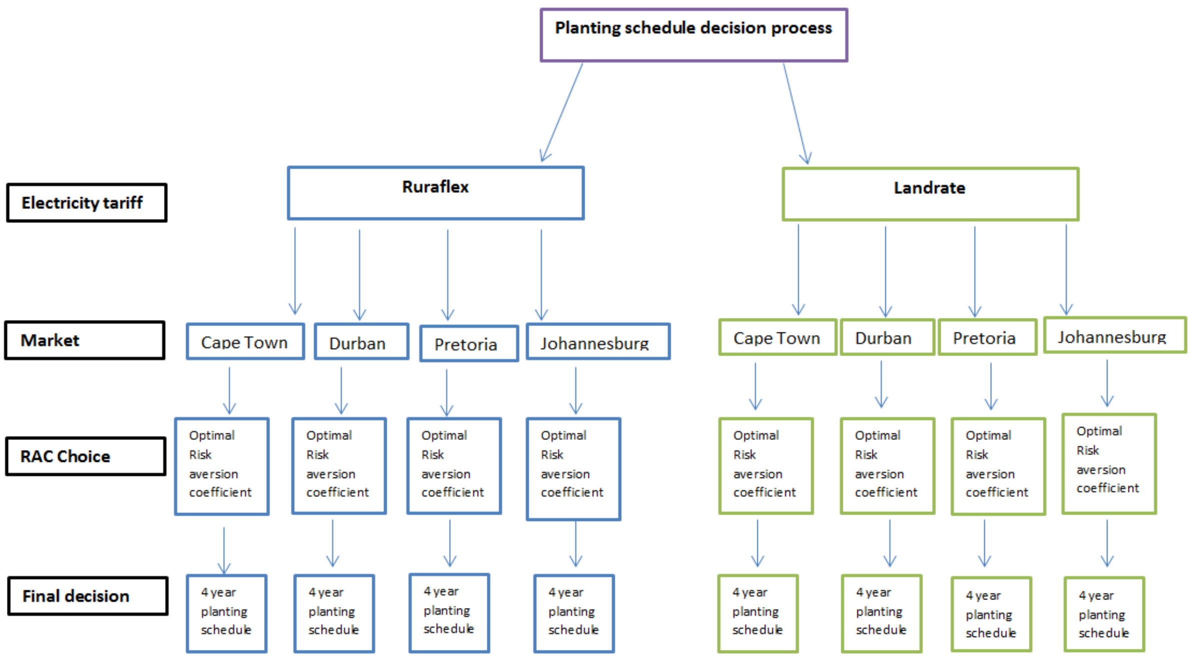


Figure: 5.6: Decision process to ascertain the optimal 4-year planting schedule.

5.5.1 Optimal electricity tariff for Taaiboskraal farm

The first step in determining the planting schedule is to ascertain the best electricity tariff for Taaiboskraal farm. Figure 5.7 shows the objective function values that were optimised for the two electricity tariffs namely Ruraflex and Landrate. The values of $r_a(x)$ were select in such a way during the optimisation that the *ex post* calculations did not exceed 2.5. The stochastic efficiency frontier of the two scenarios indicates that risk aversion has a substantial influence on the optimised CE's. The reduction in the CE's from risk neutrality to the most risk adverse level of $r_a(x)$ is R21 245 260.47 for Landrate and R21 214 453.71 for Ruraflex.The alternative with the largest CE at a certain level of risk aversion indicates the preferred option which in this case in Ruraflex.

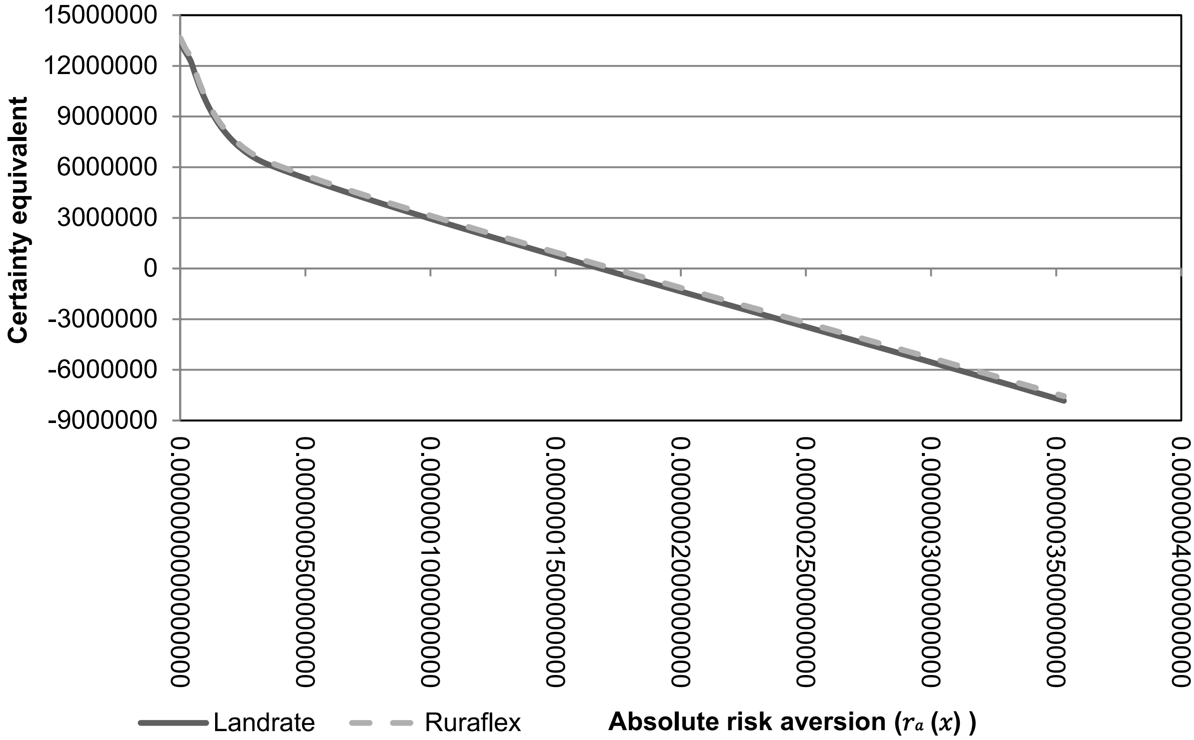


Figure 5.7: Constant absolute risk aversion stochastic efficiency frontiers for optimized solutions of Ruraflex and Landrate

5.5.2 The best market for Taaiboskraal Farm's potatoes

In order to determine the best market for Taaiboskraal the gross margins for all four markets namely Durban, Johannesburg, Pretoria and Cape Town were pooled and the best planting schedule was modelled. The Cape Town market is the optimal market as the majority of the markets for the sale of the potatoes is Cape Town followed by Johannesburg, Pretoria and Durban. The more risk adverse the produce becomes the more the Cape Town market is preferred. The best market for Taaiboskraal is therefore Cape Town.

5.5.3 The four-year planting schedule on Taaiboskraal Farm

The decision makers approach to risk determines the chance the decision maker is prepared to take for the chance to receive a higher income. Table 5.9 to Table 5.12 illustrates the best planting schedule for the Cape Town market using the Ruraflex tariff over four years. The decisions risk preference therefore needs to be determined in order to narrow down the planting schedule down to one planting schedule over four years.

Table 5.9: Ruraflex Cape Town year 1

			RAC							
Line	Pivot	rac1	rac2	rac3	rac4	rac5	rac6	rac7	rac8	rac9
1	12								June	
1	13									June
1	21		February							
1	21	June								
1	22					July				
1	23			July	July		July			
1	24							June	August	
2	31			August	August					
2	32					August	August			
2	33	February	August					August		August
2	34								May	
2	41		July					July		
2	42									July
2	43			February	February	February	June			
2	44	August							July	
3	51		April							
3	52					April		February		
3	53	April		June	March		April		March	February
3	61			March					February	
3	62	May			April					
3	62									May
3	63		June					May		
3	64					June	March			
4	71	July							April	April
4	72		May			May				
4	73						May			
4	74			April	June			April		
4	81	March			May					
4	82		March							March
4	83							March		
4	84			May		March	February			

Table 5.10: Ruraflex Cape Town year 2

		RAC								
Line	Pivot	rac1	rac2	rac3	rac4	rac5	rac6	rac7	rac8	rac9
1	12									June
1	13								June	
1	21			June						
1	21								August	
1	23					February		June		
1	24	June	July		July		July			
2	31					August		July		August
2	32			August	August				July	
2	33						August			
2	34	February	August							
2	41	August			February					July
2	42		February	February				August	May	
2	44					July	June			
3	51	April				March			February	May
3	52		March		June		May			
3	54			July				February		
3	61	May	June				February	April		
3	63			April	March	April			April	March
4	72						March	March	March	
4	73	March		May	April	May				
4	74		April							February
4	81						April			
4	83			March		June				April
4	84	July	May		May			May		

Table 5.11: Ruraflex Cape Town year 3

			RAC							
Line	Pivot	rac1	rac2	rac3	rac4	rac5	rac6	rac7	rac8	rac9
1	11									June
1	14								June	
1	22	April			July		February	August	August	
1	23		August							August
1	24			February		July				
2	31		July				August		July	
2	32	February						June		
2	33			August	August	August				
2	34									May
2	42				February	February	July			
2	43	August	February					July	May	
2	44			July						July
3	51			June	May					
3	52								February	
3	53					March		February		
3	54	March	June				June			February
3	61				April	April				
3	62		April				April	May		
3	63	May								
3	64			March					March	
4	71		May		June					
4	72	July		April						April
4	73							April	April	
4	74					May	March			
4	81					June		March		March
4	82			May	March					
4	83	June	March				May			

Table 5.12: Ruraflex Cape Town year 4

			RAC							
Line	Pivot	rac1	rac2	rac3	rac4	rac5	rac6	rac7	rac8	rac9
1	11								June	
1	14									June
1	21				March	July	June	July		
1	22		August	February						
1	23	June							August	
2	31	February								
2	32		February							August
2	33								july	
2	34			August	August	August	August	August		
2	41			July		February	July		May	
2	42	August								
2	43									July
2	44		July		July			June		
3	51						February	May		
3	52	July		March						May
3	53		June							
3	54				April	June			April	
3	62			May		April			March	
3	63						March			
3	64	April	May		May			March		March
4	71			April		March	May	April		
4	72				February					
4	73		March							April
4	74	March							February	
4	81		April	June						
4	82	May				May	April	February		
4	83				June					
4	84									February

In order to determine the best risk aversion coefficient (RAC) the CE for each RAC over 4 years needs to be determined and the RAC with the highest CE is the decision makers preferred RAC. As indicated in Figure 5.8 the RAC value 3.53 x 10^{-9} is the decision makers referred risk preference.

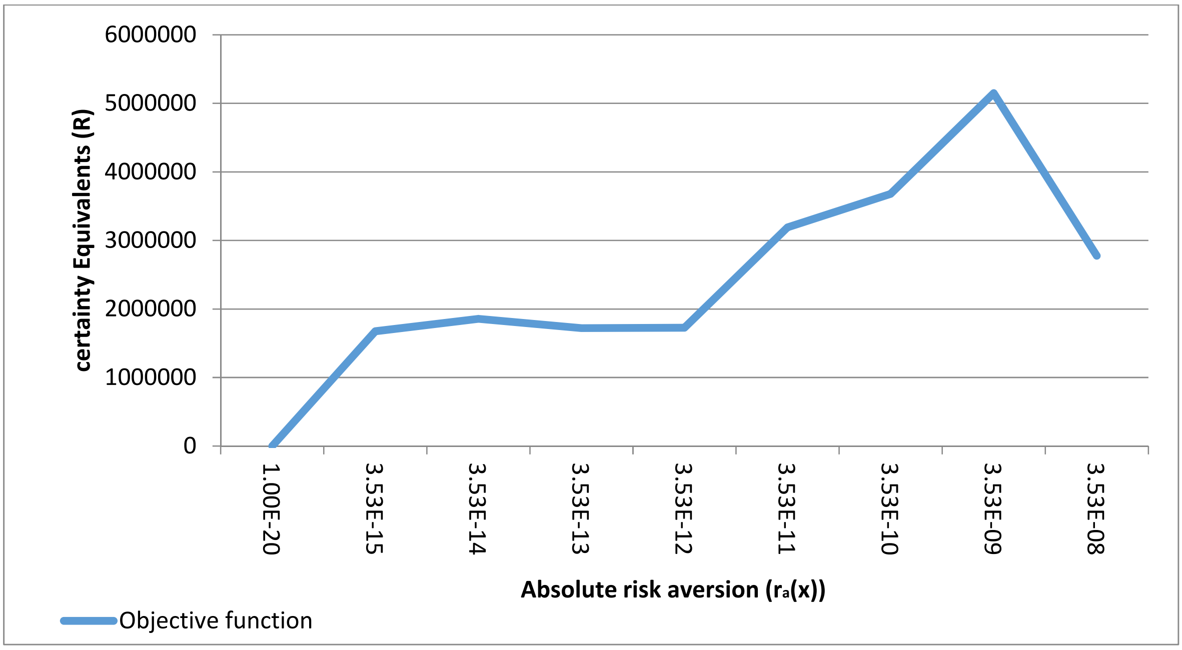


Figure 5.8: Risk aversion coefficients (RAC)

The final planting schedule for Taaiboskraal farm is shown in Figure 5.9. The farmer will dedicate the farms resources for four years to the planting schedule. Through optimising each step in the decision process the opportunity cost is minimised because the schedule has been selected to incorporate most risks and align them to the decision maker's preferences.

Figure 5.9: The final planting schedule for Taaiboskraal farm

5.6 Summary

An important conclusion that emerged from the results is that the more risk adverse the decision maker becomes, the more the Cape Town market is favoured especially when transport costs to the market are considered. Ruraflex is the preferred electricity tariff to use for the farm when considering the constant absolute risk aversion stochastic efficiency frontiers for optimized solutions of Ruraflex and Landrate. The current tariff that the farm makes use of is Ruraflex, so it would not be within the financial interests of the farm to pay the conversion costs and switch to Landrate. The optimal planting schedule was found to be when the decision maker is more risk averse. Following the decision tree steps in Figure 5.6 the decision maker has made an informed decision regarding planting schedule whilst acknowledging the opportunity costs foregone.

CHAPTER 6

Summary and Recommendations

6.1 Summary

When a decision maker makes a decision under uncertain circumstances the decision maker makes his/her decision in line with his/her risk preference. The less risk a decision maker is prepared to take, the lower the returns but the higher the probability of obtaining the return is (Hoag, 2012). Potato producers in the Sandveld farm in conditions of uncertainty and they must continuously find ways in which to reduce their exposure. The purpose of this research was to determine an optimal four-year planting schedule for a farmer in the Sandveld using Taaiboskraal farm as a case study. In the Sandveld the land can only be planted once every four years hence the requirement for a four-year planning schedule. The farmer can choose between the Cape Town, Durban and Pretoria and Johannesburg fresh produce markets. Cape Town is the closest market to the farming enterprise and Johannesburg has a large market with a high demand for potatoes because of the large population.

The main objective of this study was to provide the decision maker on Taaiboskraal farm with a tool to make planting decisions over a four-year period whilst considering the best market and risk appetite. The decision maker first needs to determine the optimal electricity tariff for the farm and then the preferred market and finally the appetite for risk.

In order to obtain the gross margins for each pivot in each state of nature the potential yields had to be determined using the LINTUL model. The irrigation costs, area and yield dependent costs needed to be determined using a cash flow. The real price (2014 base year) that correlates with the same time period as the weather data for the LINTUL model were determined for each of the four markets. Once the gross margins were determined the correlation between prices and yield were determined. The SERF model was then run in order to ascertain the optimal planting schedule for the plant after having determined the risk preference of the decision maker.

The results obtained in this study indicated that Ruraflex is the best electricity tariff for Taaiboskraal farm and therefore it would not be a good investment to pay the fees to switch to Landrate. When the farmer was able to choose between the Cape Town, Durban, Pretoria and Johannesburg market, the Cape Town market was the predominant market of choice.

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This case study provided Taaiboskraal farm with an optimised planting schedule over four years. The resources are committed for four years, however the opportunity costs have been minimised because of making informed optimised decisions at each step to obtaining the final planting schedule.

6.2 Recommendations

Taaiboskraal currently makes use of the Ruraflex electricity tariff and this tariff was found to be marginally more feasible than Landrate. The conversion costs from Ruraflex to Landrate would therefore not be a good investment. The farm is therefore using the correct electricity tariff. Because of transport costs Cape Town was found to be the best fresh produce market. The Cape Town market has the least volatility when compared to Durban, Johannesburg and Pretoria. The farm can carry on supplying the Cape Town fresh produce market. The farm does not make use of all the pivots and given the optimal risk preference of the farmer the farmer can make use of the model to plan the planting schedule for four years.

6.2.1 Optimal planting schedules and electricity tariff

- Marginally Ruraflex is a more optimal tariff choice than Landrate for Taaiboskraal farm.
- Cape Town was found to be the best market for the sale for Taaiboskraal's fresh potatoes because of the transport costs when the Cape Town and Johannesburg markets were pooled together to find the best planting schedule.
- The farmer was found to be more risk averse

6.2.2 Further research

- Intra-seasonal competing crops, such as groundnuts and maize could be included in the decision making as the crops will compete for water in the same growing season in another region other than the Sandveld.
- The financial implications of each pivot in the planting rotation could be pulled into the farms cash flow.
- A whole-farm context that includes risk aversion in the decision maker's objective function as well as both non-embedded risk (stochastic programming without recourse) and embedded risk (stochastic programming with recourse).
- A limitation with the approach used in this study is that the decision maker must make a decision that cannot be altered for four years which includes the choice in market, risk preference and pivot planting.
- The major risks could have been identified and all could have been included in the study.

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