EVALUATING CROP INSURANCE AS PRODUCTION RISK MANAGEMENT STRATEGY

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DECLARATION

I, Frikkie Alberts Maré, hereby declare that this dissertation submitted for the degree of *Magister Scientiae Agriculturae* in the Faculty of Natural and Agricultural Sciences, Department of Agricultural Economics at the University of the Free State, is my own independent work, and has not previously been submitted by me to any other university. I furthermore cede copyright of the thesis in favour of the University of the Free State.

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DEDICATION

This dissertation is dedicated to my parents,
Petrus and Christine Maré,
to whom I will always be grateful for this life opportunity.

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"I learned about the strength you can get from a close family life. I learned to keep going, even in bad times. I learned not to despair, even when my world was falling apart. I learned that there are no free lunches. And I learned the value of hard work."

Lee Iacocca

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LIST OF ACRONYMS AND ABBREVIATIONS

ACSND	Adjusted Correlated Standard Normal Deviates
ART	Alternative Risk Transfer
CE	Certainty Equivalent
CUD	Correlated Uniformly Distributed values
CSND	Correlated Standard Normal Deviates
ER	Expected Return
FCIC	Federal Crop Insurance Corporation
FSD	First-degree Stochastic Dominance
GSA	Grain South Africa
HDF	Hail Day Frequency
ha	hectare
ISND	Independent Standard Normal Deviates
MPCI	Multi Peril Crop Insurance
MVE	Multivariate Empirical
NPV	Net Present Value (After interest and tax)
PDF	Probability Distribution Function
R	South African Rand
RP	Risk Premium
SA	South Africa
SAFEX	South African Futures Exchange
SDRF	Stochastic Dominance with Respect to Function
SERF	Stochastic Efficiency with Respect to a Function
SEU	Subjective Expected Utility
SSD	Second-degree Stochastic Dominance
Stdev	Standard deviation
t	Ton
USA	United States of America
UWRP	Utility Weighted Risk Premium
WII	Weather Index Insurance

Scenarios

ART 25	ART policy with a contribution equal to 25 % of the gross margin
ART 50	ART policy with a contribution equal to 50 % of the gross margin
ART PC	ART policy with a contribution equal to the premium of *Insurance*
Base	No crop insurance in place
Insurance	Short-term Crop Insurance
No Hail	No hail occurrence

ABSTRACT

The primary objective of this study was to evaluate the effectiveness of Alternative Risk Transfer (ART) against Short-term Crop Hail Insurance as risk management strategies for crop hail insurance in two regions, Standerton and Lichtenburg. While Short-term Crop Hail Insurance has a fixed premium as percentage of the value of the crop, the decision maker can determine how much the contribution to the ART fund should be. Three different ART contributions had been analysed; *ART 25* and *ART 50* with respective contributions equal to 25 % and 50 % of the gross margin, and *ART PC* with a contribution equal to the premium of Short-term Crop Hail Insurance.

A farm financial simulation model was developed to simulate the influence of hail damage and the different crop insurance policies on a maize enterprise with variable levels of yields and prices. Since the historical data of hail damage and the data on yields and prices did not match the same time series, the yield and price data were simulated with the procedure for estimating and simulating multivariate empirical (MVE) probability distributions. The risk efficiency of the different crop insurance options was analysed with stochastic efficiency with respect to a function (SERF). SERF expresses the certainty equivalents in monetary values and enables the calculation of the utility weighted risk premiums that are used to determine the benefit between alternatives.

The results indicated that hail damage does occur in both the Standerton and Lichtenburg regions, but the impact thereof is not the same in each region. The negative impact of hail damage on the cumulative probability distribution of the Net Present Value (NPV) after interest and tax was larger in the Standerton than in the Lichtenburg. Decision makers in both regions were willing to pay for crop hail insurance options, but much more so in Standerton than in Lichtenburg. The difference between the costs and benefits of a crop hail insurance policy determines the net advantage (or disadvantage) that it will bring to financial position of the enterprise. The insurance options with the largest net benefit to the enterprise were *ART PC* in Lichtenburg and Short-term Crop Hail Insurance in Standerton. However, in Standerton *ART PC* emerged as the second-best option, which also makes it an option to consider. The last test for effectiveness on the different crop hail insurance options was the ability of the different options to provide continuous cover against hail risk. The differences between the claim pay-out of Short-term Crop Hail Insurance and *ART PC* indicate the instances where the *ART PC* was too small to provide the necessary cover. While it can be concluded that *ART PC* is ineffective in Standerton, owing to its inability to provide continuous cover and the large differences in pay-outs, the same conclusion cannot necessarily be made for Lichtenburg. The differences in pay-outs are small enough to be counter for by the decision maker, especially because the enterprise never returns a negative NPV, even without insurance, while the financial impact on the enterprise and the maximum benefit of the policy provides a total financial advantage for the enterprise.

In conclusion, it was found that both Short-term Crop Hail Insurance and ART might be effective measures for the mitigation of hail damage, as long as these products are implemented according to findings of proper research for the option that will provide the enterprise with the largest net benefit in the specific area it is situated. Since the model can easily be adapted to be applied not only on other field crops, but also on horticultural crops with different types of risk perils, it is suggested that the model might be applied to other sectors of agriculture to test the effectiveness of insurance on these sectors.

Keywords: Risk, Insurance, Alternative Risk Transfer, Simulation Model, MVE Distributions, SERF, Certain Equivalent, Utility Weighted Risk Premium.

CHAPTER 1

INTRODUCTION

1.1 Background and motivation

Agriculture in South Africa, as in the rest of the world, consists of various aspects that include different types of crops and livestock, as well as different cultivation and reproduction methods. Agricultural production, or farming, is faced by risks that are numerous and diverse and these risks must be countered by either management strategies or risk mitigation through insurance. Knowledge of the risks that influence farming is important for the farmer to minimize losses, for the insurer to create products that helps to cover these risks, and for the government which considers risk management among its policy objectives.

Risk management is of crucial importance in any investment, financing or production decision made by farmers. Basic risk management strategies in agriculture, such as choice of plant varieties and animal breeds, crop and animal husbandry practices, diversification of farm enterprises and precautionary prevention measures against adverse weather events, can be used to reduce the impact of these risks (Roberts, 2005). These basic strategies, however, may not be sufficient to manage the severe impact of some adverse weather events and natural disasters. Insurance can play a vital role in managing these losses, and crop insurance is the branch of risks management that is especially geared to cover the farmer against losses from adverse weather and other events beyond his control (Roberts, 2005). Crop insurance may be one of the most quoted tools for risk management, but it can only play a limited role in managing the risks related to the production of crops. Insurance, in any given situation, is only applicable when it is based on the consideration of its cost-effectiveness in means of addressing a given risk. Crop insurance is thus only an adjunct to a set of risk management measures, of which good farm management practices are an important element. Crop insurance, as a part of risk management to complement other measures, must be tested on its cost/benefit ratio to the farmer and insurance providers to ensure that it can benefit all the involved parties.

Crop insurance, as a method to transfer risk, has existed for almost two centuries. The first insurance programme started in France and Germany during the 1820s as protection against hail damage to grapes, while the United States of America (USA) introduced it in 1883 for tobacco (Rao, 2011). Multi-Peril Crop Insurance was first introduced in the USA in 1939 with the establishment of the Federal Crop Insurance Corporation (FCIC). In the USA, the current primary crop insurance programme is a public-private partnership that provides farmers with a base multi-peril catastrophic yield insurance, of which the premium is fully subsidised by the Federal government (Solloway, 2010). Farmers may then purchase additional insurance, of which the premiums are partly subsidised, beyond the catastrophic level. The South African government do not subsidise insurance premiums, as in the case of developed countries such as the USA. South African farmers must cover all insurance premiums themselves, as the only type of risk management the government provides is disaster management funding in the case of severe drought or other natural disaster.

Different types of crop insurance policies exist in South Africa and these range from Single Peril Crop Insurance for different perils and crops to Multi-Peril Crop Insurance, Index Insurance and Alternative Risk Transfer (ART). The wide choice of crop insurance products complicates the decision that the farmer has to take in order to protect crops.

Crop insurance must be effective as a production risk management strategy in terms of the cost of the insurance product, as well as its ability to mitigate the risk. The specific risk must be important to the decision maker in order for him or her to be willing to pay for the mitigation of it. In the event of the availability of more than one insurance product, the decision maker must be able to rank the options in order of preference, based on the efficiency of the different options to cover the risk.

1.2 Problem statement and objectives

As new types of crop insurance enter the market, decision makers are uncertain about which crop insurance product is the most effective in terms of the enterprise's needs. The uncertainty stems from a lack of information on the risks that may influence the enterprise and the crop insurance products that may be used to mitigate the risks. Decision makers are thus unable to analyse the influence of the risks and available crop insurance policies on the farming enterprise.

Various authors have addressed the effectiveness of crop insurance as a risk management tool in their research (Roumasset, 1978; Kurosaki & Fafchamps, 2002; Yang, Wang & Xian, 2010; Shaik, 2013). The specific focus of the different studies varies, however, and it is further complicated, or polarised, by the country, crop/s and the type of insurance that was being researched. The country that the research is focused on is of specific importance, as most of the countries surveyed subsidise crop insurance premiums to a certain extent. The focus of the research is then shifted towards the effectiveness (and fairness) of government subsidies and not the effectiveness of the insurance as a risk management tool for the producer (Yang *et al.*, 2010). Different crop choices in a specific region shift the focus of insurance efficiency to how crop choices will be affected by the presence of price and yield risk (Kurosaki & Fafchamps, 2002). Kurosaki and Fafchamps (2002) determined whether the presence of risk and the effectiveness of any type of insurance to transfer this risk also had an effect on the crop choices of the farmers in the study. Shaik (2013) has evaluated the importance of federal crop insurance programmes in altering agricultural production efficiency. It was argued that crop insurance reduces the risk of production and that producers are willing to adopt innovative technology and efficiency-enhancing production practices that they would otherwise (in the case of more risk) not be willing to adopt.

In light of the literature referred to above, it is clear that very little attention has been given specifically to the effectiveness of a certain crop insurance product's ability to counter a specific risk in terms of the cost-benefit analysis of the product. Very little research exists on ART, as a newer type of insurance, and on the ability and effectiveness of ART as a crop insurance product. In order to determine if a specific crop insurance product is effective, it is necessary to evaluate the cost (premium and excess) of the product against the benefit (payment for losses suffered) of the product over the long term, applying possible occurrences of production risk (hail) to the crop.

The primary objective of this study is to evaluate the effectiveness of ART against Short-term Crop Hail Insurance as risk management strategies for crop hail damage.

In order to achieve the primary objective, the following secondary objectives must be reached:

- **Determine the financial extent of hail risk's impact.**
  The extent of the impact of hail risk on the financial position of the enterprise must be determined in order to decide if there is a need for crop insurance. The difference in the cumulative probability distributions of the Net Present Value (NPV) of the margin after interest and tax in the event of hail and the event of no hail will provide a graphic indication of the financial impact of hail. To determine if the decision maker is willing to pay in order to remove the impact of hail on the enterprise, the utility weighted risk premium (UWRP) must be calculated with the use of stochastic efficiency with respect to a function (SERF) analysis. The calculated maximum benefit (or UWRP) that the decision maker will receive through the elimination of hail will set the upper limit for the cost of crop insurance.

- **Determine the financial advantage of the different crop insurance strategies.**
  The cost and benefit structures, and the influence these have on the financial position of the enterprise, differ between all the available crop insurance strategies. The strategy providing the largest net benefit will be the most preferred option. Although the cumulative probability distributions of the Net Present Value (NPV) of the margin after interest and tax give an indication of the financial influence of the insurance option, it does not supply enough information to rank the alternatives. The stochastic efficiency with respect to a function (SERF) analysis will rank the options in order of preference according to the decision maker's risk-aversion level, while the decision maker can also calculate the maximum benefit (UWRP) of the preferred option.

- **Evaluate the ability of different crop hail insurance policies to provide continuous risk cover.**

  In order for a crop hail insurance product to be effective, it must be able to provide continuous cover against hail. Concern is raised regarding the ability of ART to provide continuous cover as the product consists of a fund that must be built up over time. In the event where the value of the hail damage is more than the accumulated funds of the ART policy, it will not be able to cover the claim. To determine if ART can provide continuous hail cover, the claim pay-outs of ART and Short-term crop insurance will be compared.

The focus of this study will be on hail as production risk, while the insurance policies that will be analysed consist of Short-term Crop Hail Insurance and Alternative Risk Transfer (ART) as crop hail insurance. Hail, as the production risk, was chosen as it was the first production risk for which single crop insurance was designed and it is one of the few perils for which long-term data is available. Short-term Crop Hail Insurance is used, as it was the first designed single-peril crop hail insurance product and it is also the most used crop insurance product in South Africa. ART, although not initially designed as a crop insurance product, is one of the newer types of insurance and may be used for crop hail insurance. The advantage of both Short-term Crop Hail Insurance and ART for this study is that neither needs indexes of previous data, such as rainfall, to determine the premium of the product. The premium of single-peril crop insurance products is thus more stable than that of multi-peril crop insurance products.

The objectives will be analysed and presented in the results, based on five scenarios. These scenarios are applied in the Lichtenburg and Standerton regions and the financial outcomes (NPV of the margin after interest and tax) of each scenario are used for the results. The first one is the *Base* scenario where no crop hail insurance product is used. The second one is the *Insurance* scenario that makes use of Short-Term Crop Hail insurance. The third and fourth scenarios are *ART 25* and *ART 50,* which make use of ART insurance at respective policy contributions of 25 % and 50 % of the gross margin (before interest and tax). The last scenario is *ART PC* where ART insurance is also used, but the contribution to the fund is equal to the premium that would have been paid for the Short-term Crop Hail Insurance policy.

1.3 The South African maize industry

Maize, as the most important grain crop in South Africa, is grown in all nine provinces of the country (irrigation and dry land), with the largest part of production being in the Free State, North West and Mpumalanga provinces. Maize is both the major feed crop and staple feed in the country, with about 60 % white maize production (mainly for human consumption) and about 40 % yellow maize production (mainly for animal feed) (DAFF, 2011a). Maize, as a summer crop, is mainly planted between mid-October and mid-December, with the rainfall period and other weather conditions determining the length of the planting, growing and harvesting season (DAFF, 2011b). Hailstorms are also associated with the rain season and summer crops (maize) are thus more exposed to hail than winter crops (Le Roux & Olivier, 1996).

Since the deregulation of the agricultural marketing boards in 1996, the maize market has matured considerably and has become a player in the larger international arena. Pre-1996, the producer price of the crop was determined and fixed by the Maize Board and the farmer knew what he would receive for the crop, even before planting had started. Since the deregulation, the forces of demand and supply determine the price of maize. The international market also influences the domestic prices directly as maize is an internationally traded commodity (DAFF, 2011a).

The free market in which maize is now trading after the deregulation has brought many advantages, but also disadvantages, to the producer. Although the producer is now able to compete in the international market, the volatility of the price has increased. Where the price of maize for South African producers was fixed before deregulation, it now varies daily according to domestic, as well as international, market forces. Jordaan, Grové, Jooste and Alemu (2007) found that the price volatility of maize is significantly higher when compared to other crops, such as wheat and soybeans. The high volatility of the maize price exposes producers to a higher level of price risk, especially in the short run. This high-risk exposure creates opportunities where the producer may not only lose money, but also make money, with the upward spike of the price. The volatility is difficult to predict and it is only with correct application of marketing tools, such as forward contracting, that producers can brace themselves against the price risk (Jordaan *et al.*, 2007). The volatility of the maize market in South-Africa contributes to the riskiness of producing maize, together with the other production risks such as hail, drought, wind and frost.

1.4 History of the South African crop insurance industry

Crop insurance in South Africa is a method of risk management or risk transfer that has already been in use for almost a century. According to Burger (1962), it started as early as 1916 when a group of farmers in the Western Cape Province established their own organisation for insuring wheat stacks against fire. The introduction of the combine-harvester later on made this type of insurance superfluous. The second large crop insurance scheme that was set up in South Africa was by a number of farmers in the Ficksburg in 1929 that organised a small unregistered mutual concern, The Conquered Territory Mutual Hail Insurance Society, which operated on co-operative lines to insure their crops against damage by hail (Doyer, 2013).

The Conquered Territory Mutual Hail Insurance Society developed quickly and by 1934 it was necessary to dissolve it and replace it with a registered co-operative company, which had 3 000 members at that time. By 1937, its members had reached 5 700 farmers spread all over the country, with insurance undertaken for a number of crops. One of the most important milestones in the South African insurance industry was the registration of the Central Board for Co-operative Insurance Limited (Sentrakas) under the Co-operative Act in 1950 (Burger, 1962).

Reinsurance was out of the question during those days and farmers realised that they needed a more guaranteed form of insurance to insure their crops against hail and other natural disasters. In 1951 Sentrakas and the Farmers Hail Assurance managed to secure some reinsurance through Santam, thereby offering their members the first form of guaranteed insurance in South Africa. Sentraoes was established in 1970 by consolidating the hail portfolios of the aforementioned businesses (Doyer, 2013).

1.4.1 South African participation in crop insurance

The current participation levels in crop insurance in South Africa is low when compared to some other countries, as can be seen in Table 1.1 below. These figures, however, only represent the traditional (indemnity based) types of insurance, as the data for the other types of crop insurance is not available.

Table 1.1: Market penetration of crop insurance in different countries in 2012

Country	MPCI [Million Euro]	Hail [Million Euro]	Total [Million Euro]	Market Penetration [%]
France	160	170	330	87 % (32 %MPCI / 55 % Hail)
USA	5401	486	5887	80 %
Australia	0	104	104	80 %
Austria	20	68	88	79 %
Republic of Korea	56	0	56	72 %
Germany	5	159	164	61 % (Hail only)
Canada	1038	193	1231	60 %
Spain	430	0	430	55 % (incl. Livestock)
Argentina	3	116	119	45 %
South Africa	21	72	93	33 %
China	1019	0	1019	25 %
Italy	165	115	280	20 % (1 % MPCI / 19 % Hail)
India	182	0	182	20 %
Brazil	142	39	182	12 %
Russia	217	0	217	10 %
Mexico	114	0	114	8 %
Turkey	43	3	46	5 %
Total	**9016**	**1525**	**10541**	

Source: Melville (2012)

The total market penetration of traditional insurance in South Africa is only 33 % of the total available market (Melville, 2012). The low market penetration may be due to expensive premiums that are driven by various reasons, such as (Mahlase, 2013):

- Government does not subsidise crop insurance in South Africa.
- High weather event volatility and the expected impact on climate change.
- High transaction costs with a wide distribution of clients in remote rural areas.

Figure 1.1 below gives an indication of the total value of premium contributions for traditional insurance over the last number of years. It is clear to see that the premium contributions for MPCI have stabilised at approximately R200 milliard, while the premium contributions for Hail insurance are increasing over time.

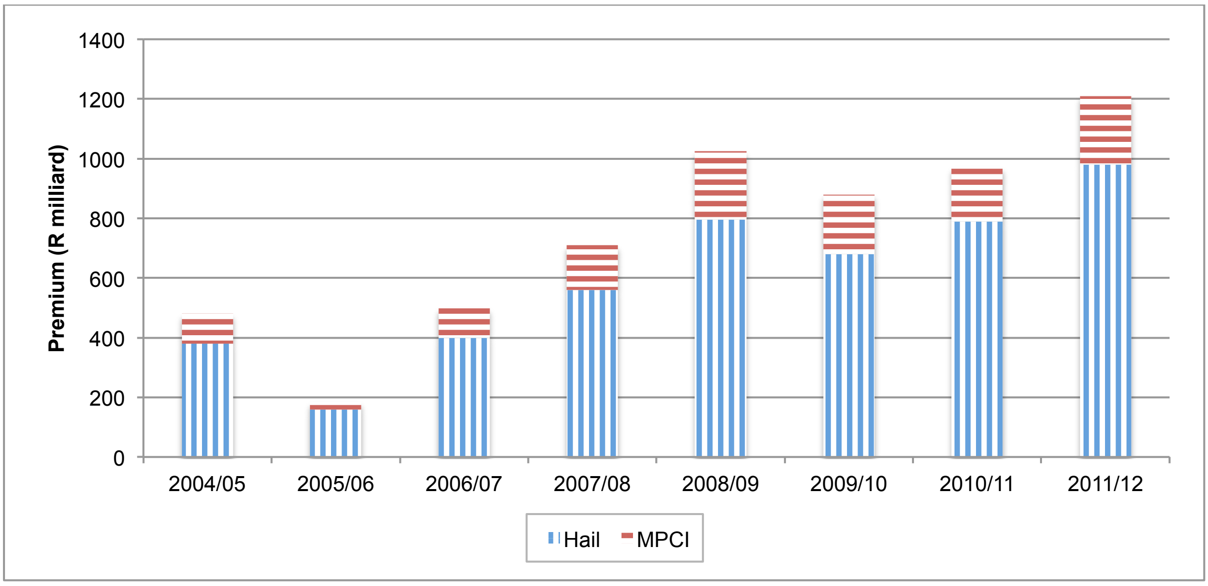

Figure 1.1: Premium contributions for traditional insurance in South Africa
Source: Mahlase (2013)

1.5 Choice of study area

The study is based on two large maize production areas in South Africa. The two areas were specifically chosen because both are known for large-scale maize production, while the one, Standerton (Figure 1.2 below), is a high hail risk area, and the other, Lichtenburg (Figure 1.3 below), is a relative low-risk area. The two areas will be discussed and the geographical differences between them, which influence hail occurrence, will be indicated.

Standerton is situated in the Mpumalanga province of South Africa. The town is approximately 1 569 meters above sea level and almost on the 27° S latitude and the 29° E longitude. Lichtenburg is situated in the North-West Province of South Africa at an altitude of approximately 1 424 meters and on the 26° S latitude and the 26° E longitude.

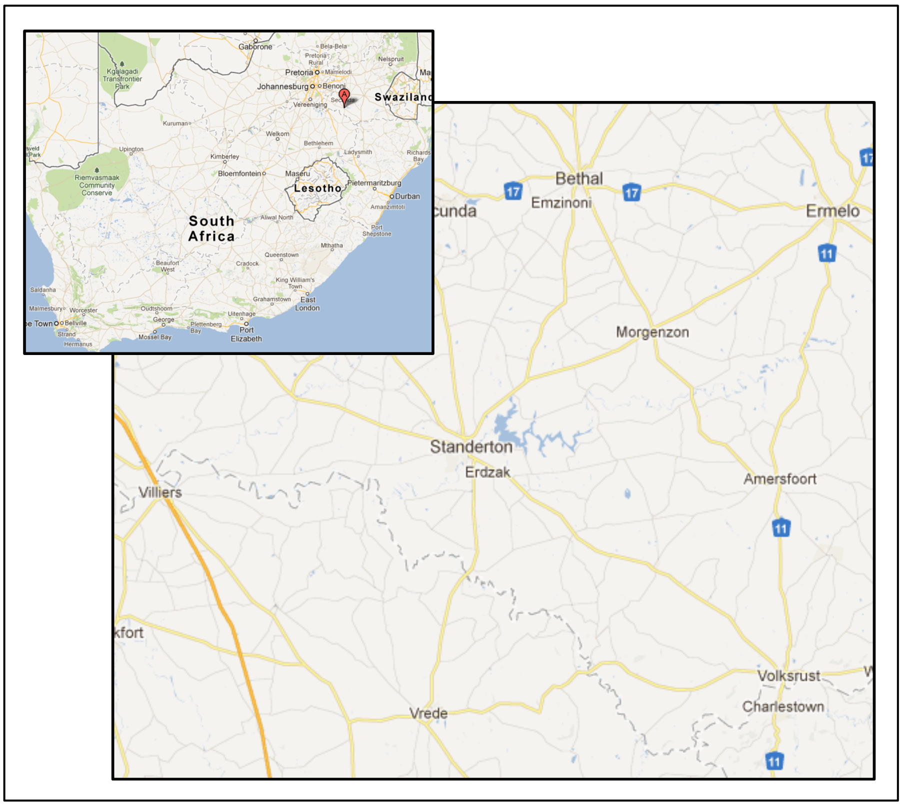

Figure 1.2: Geographical location of Standerton
Source: Google Maps (2014a)

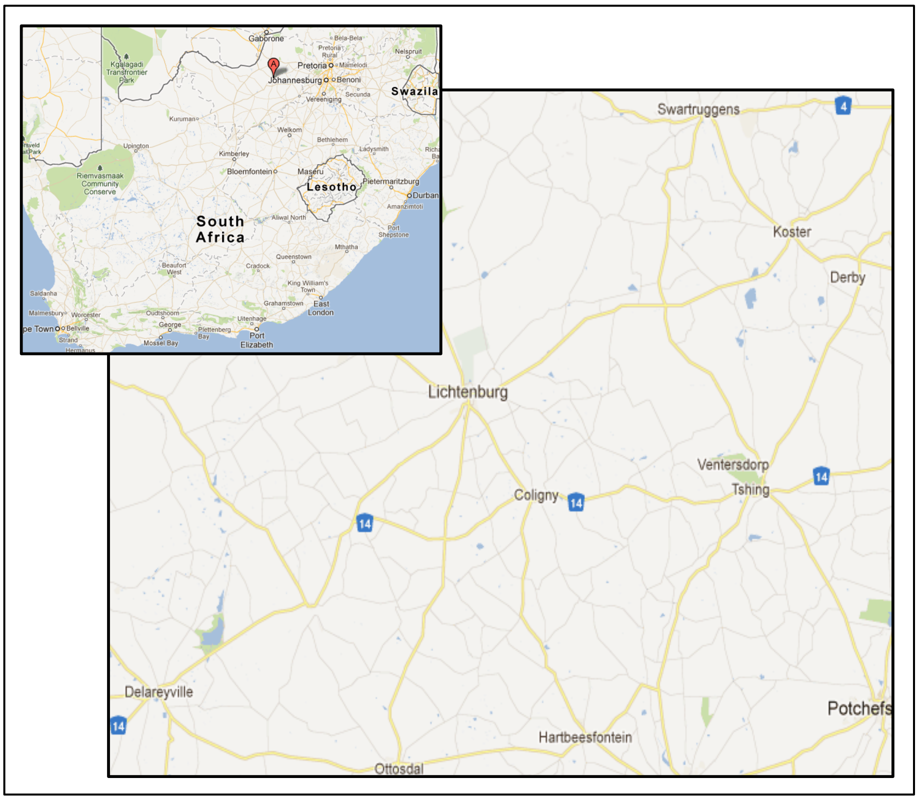

Figure 1.3: Geographical location of Lichtenburg
Source: Google Maps (2014b)

According to Le Roux and Olivier (1996), the latitude and altitude of a specific location in South Africa determines the hail day frequency (HDF) of that location. The research indicated that hailstorm activity peaks at the latitude of 27°S, from where it rapidly decreases to the North, while it decreases slower to the South. The positive linear relationship between HDF and the altitude of location indicates that areas with a higher altitude are more susceptible to hailstorms.

Taking the two study areas into consideration, it is clear that Standerton (Latitude 27° S, Altitude 1 569m) is a higher hail risk area than Lichtenburg (Latitude 26° S, Altitude 1 424m).

1.6 Dissertation outline

Chapter 2 is a literature review of the overview of risk and uncertainty in agriculture, the available crop insurance products, factors affecting the adoption of crop insurance, risk simulation and risk efficiency analysis. *Chapter 3* describe the procedures that were used in the study. Focus will fall on the working of the farm financial simulation model, risk simulations for the data used in the model, and risk efficiency analysis to compare the results. *Chapter 4* is a discussion of the results on hand of the financial extent of hail risk's impact, the financial advantage of different crop hail insurance options and the ability of different crop hail insurance policies to provide continuous hail risk cover. The final chapter, *Chapter 5*, draw a conclusion and make some recommendations in view of the findings in the study.

CHAPTER 2
LITERATURE REVIEW

2.1 Introduction

The literature that is reviewed in this study covers a wide range of aspects on risk, uncertainty, insurance and the analysis of risk-related problems. An overview of risk and uncertainty is done to describe the impact of risk on agriculture, the approaches to risk analysis, the different sources from where agricultural risks derive, and the available risk management strategies in agriculture. The focus then falls on crop insurance as a risk management strategy, describing the different available crop insurance products and the factors affecting the adoption of crop insurance. Lastly, methods of risk simulation and risk efficiency analyses are investigated to provide possible procedures that can be applied in this study.

2.2 Overview of risk and uncertainty

Risk and uncertainty are factors involved in every step of life. Every decision influences future outcomes and it is almost impossible to identify the outcomes of the decision. The uncertainty of the outcomes or the risk involved in the decision should, however, not intimidate the decision maker, but it should be seen as a cost that must be carried in order to make some profit. In business, it is often quoted that "*no risk means no gain.*" Risk must thus not be avoided, but it should be managed effectively to withstand adverse outcomes. The concepts *ris*k and *uncertainty* are often used together and it is accepted that *risk* stems from the *uncertainty* of an event. But do all uncertain situations imply a certain degree of risk? It is important to make a distinction between *risk* and *uncertainty* to avoid potential confusion in the terminology of this dissertation.

Robinson and Barry (1987) describe the noun *uncertainty* as an event, the outcome of which is not definitely known. Further, they explain that there are no levels of uncertainty. If more than one event is thus uncertain, it is impossible to say that one event is more uncertain than the other. According to Hardaker, Huirne, Anderson and Lien (2004) a *"risky event"* comprises "*those uncertain events whose outcomes alter the decision maker's well-being.*" They define "*uncertainty"* as "*imperfect knowledge*" because the probabilities of the outcome are not known, while *"risk"* is defined as "*uncertain consequences*" because the probabilities of the possible outcomes are known. A third set of definitions for risk and uncertainty is given by Moschini and Hennessy (2001) where they indicate that *"risk"* is derived from "*uncertainty."* According to them, *"uncertainty"* describes the environment in which economic decisions are made, while *"risk"* characterises the economic relevant implications of *"uncertainty*." The different definitions for *uncertainty* and *risk* indicate that the two concepts are very closely related and that confusion may occur in the usage of these terms. For the purposes of this study, *uncertainty* will be used to describe a decision or action, the outcomes of which are not definitely known and the magnitude of the different outcomes cannot be measured, while *risk* will refer to the negative, measureable outcomes of the decision or action that alter the economic position of the risk taker.

2.2.1 Impact of risk on agriculture

The different risks associated with agriculture must influence the farming enterprise in some way to justify a study of agricultural risk. The question may thus be asked: Why does risk in agriculture matter? What is the final outcome if a risky event has taken place within a farming enterprise? If a crop farmer suffers from severe hail or frost damage, the production of the crop will most probably be lower or of an inferior quality. But is the loss in production or quality the reason that makes the occurrence of hail and frost risky, or is it rather the loss in income from selling less produce owing to lower production or from receiving a lower price for the inferior quality of the product?

Hardaker *et al.* (2004) reason that risk in agriculture matters for two reasons. The first is the fact that most people dislike risk. Most people tend to be risk averse when it comes to income and wealth. They will rather forgo some of the expected returns in order to reduce the risk they have to face. The trade-off between the amount of risk and the forgone returns gives an indication of how risk averse the individual is. It is due to the risk averseness of farmers that there is a market for different agricultural insurance policies.

The second reason, as explained by Hardaker *et al.* (2004), is the existence of *downside risk* in agriculture. The variation of any of the variables, rain for example, away from the mean will influence the production of the crop. As it is not known whether the rain will be above (more) or below (less) the mean, both scenarios propose a certain amount of risk, as too much rain may be equally as bad as too little. The overall risk brought about by the possible variation of the production season away from the normal (not much variability from the mean) season is the downside risk of the enterprise. The origin of downside risk can be described as nature that is unkind to human endeavours. When a production enterprise is considered, it is important to think about what may go wrong and what may go right. Usually, the bad outnumber the good, which means that all the bad outcomes from the enterprise are not fully offset by the good outcomes, resulting in a loss of production and the capacity to generate income. *Downside risk* can thus be summarised as the probability of the negative outcomes of an enterprise.

Both the reasons that make risk important to agriculture, as described by Hardaker *et al.* (2004), come back to the fact the farmer fears the disturbance in income or wealth that is brought about by risky events. An event that does not influence the financial position of the farming enterprise is not seen as a risk to the enterprise. Although events that do not influence income, wealth or consumption may be risks in other areas of society, this is not the case in terms of business or farming risks. Harwood, Heifner, Coble, Perry and Somwaru (1999) define farming as a "*financial risky occupation.*" The ever-changing landscape of possible price, yield and other outcomes confronts farmers on a daily basis by affecting their financial returns and overall welfare. Traditionally, risk measurement was related to the variability of income or consumption and was measured by the variance or standard deviation of the income or consumption (Holzmann & Jorgensen, 2001). Swanson (2011) states that farmers and agribusinesses have been dealing with risks and looking for ways to deal with it since the first farmers put some of their grain back in the ground instead of consuming it. Today the principle is the same, but farmers and agribusinesses take grain and other inputs of a certain value and apply it in the production process in the hope of a higher value tomorrow.

The outcomes of concern in a farming enterprise on an annual basis constitute the gross margin of the individual crop or livestock enterprise and either the net cash flow or the net farm income of the total business (Eidman, 1990). The final impact of risk in agriculture is thus the reduction in income or wealth of the enterprise. This reduction in wealth may be brought about by various factors that reduce the production output or the quality of the produce. It may also be brought about by market-related risk, such as price volatility, by financially related risks, such as an increase in interest rates, or even by political/institutional-related risks, such as the introduction of higher income tax or limits on the amount of farmland that may be owned. Eidman (1990) summarises the outcome of a risky event in agriculture by stating that economic risk research is typically concerned with estimating the risk in terms of a monetary outcome.

2.2.2 Approaches to risk analysis

It is universally acknowledged that risk and uncertainty play an important international role in agriculture. Although all farmers have understood the existence of risk and have adjusted their management to accommodate it in the way they run their farms, rather little practical use has been made of formal methods of risk analysis in agriculture (Hardaker *et al.*, 2004). A substantial amount of research had been done that focused on techniques for analysing risky decisions (Martin, 1996). Hardaker, Pandey and Patten (1991) identify some of the risk programming models and approaches used to generate risk-efficient outcomes which can be used to aid decision-making under uncertainty as linear programming, quadratic risk programming, MOTAD programming, target MOTAD and stochastic programming. Some of the reasons suggested for the fact that very few of these formal analysis methods are applied for practical purposes include (Hardaker *et al.*, 2004; Martin, 1996; Malcolm, 1994; Hardaker *et al.*, 1991):

- The effective elimination of some sources of risk through government schemes.
- The complexity of these analysis types against the commonly-used budgeting methods.
- The lack of skills to convert the reality of uncertainty into a planning model.
- The lack of understanding of farming systems to specify the boundaries wide enough.

Figure 2.1 below gives a schematic representation of the linear and holistic approaches to risk management. One of the standard approaches that may be used to analyse risk is the linear approach which consists of three linear steps: Step 1: Measuring the risk or variability. Step 2: Use the information to analyse the optimal risk management tool, accounting for endowments and risk preferences. Step 3: Decide on appropriate policies to improve this risk management strategy (Antón, 2009). The problem with this approach is that linkages between the risk elements are not linear in nature and it can thus not be accepted that the analysis will flow in the suggested way. It is suggested by Antón (2009) that a holistic approach should rather be followed and that the elements must rather be represented on three axes with links between them that can move in any direction. The risk management system can then be seen as a set of relations that involve the original sources of risk, the available tools and strategies to manage these risks and policy measures. To analyse risk management in such a way, the adopted approach must simultaneously analyse all three elements. Because no single risk, strategy or policy can be analysed in isolation, the whole set of elements, together with their interactions, needs to be accounted for (Antón, 2009).

The problem with the holistic approach, as suggested by Antón (2009), is the limited role of the State in South African risk management. As already mentioned, the role of the State is very small in terms of risk management in South Africa as it is almost only involved in cases of severe disaster. Owing to this problem, the holistic framework in South Africa may be reduced to only two axes, Farming risk and Farmer's strategies, with linkages between them. All the risks that influence the farming enterprise must thus be combined and handled as a single problem in order to identify the best suitable strategies to hedge against these risks.

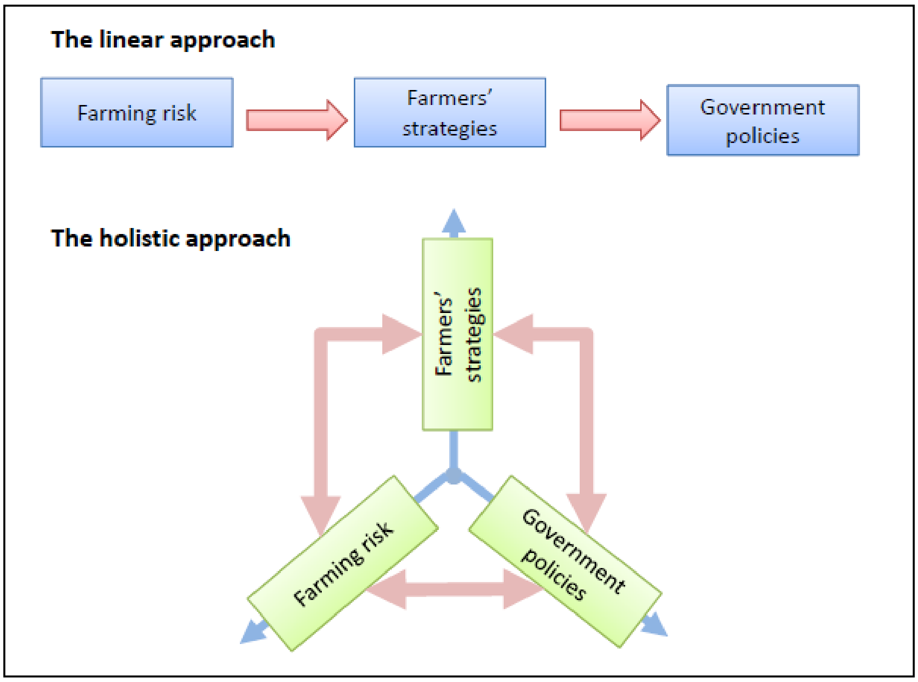

Figure 2.1: Two approaches for the analysis of agricultural risk management
Source: Antón (2009)

2.2.3 Sources of agricultural risk

The risks associated with agriculture and the sources from which they are derived are quite diverse, have different characteristics and can be classified in different ways. There is no correct classification of risk and it may thus be classified according to the purpose it is used for. Risks are usually classified and categorised according to the management sector it originates from, such as business risks, which can further be divided into production and market risk, or financial risks. Some of the technical characteristics of risks apply across different classes and this is very important in determining action plans on how to deal with the specified risk (Antón, 2009). The characteristics of risks must be considered in the risk classification process and it is therefore important to differentiate between the most important characteristics of risk.

The characteristics of risks mainly determine or describe the occurrence of the risk, the predictability of the risk, and whether different risks can be related to one another. Different authors have identified certain characteristics of risks and some of these characteristics are:

- *Systematic and non-systematic risk*

  Newbery and Stiglitz (1981) first distinguish between these two risk characteristics where *systematic risk* is defined as events that repeat in a pattern of probabilities over time in such a way that the actuarial odds can be analysed and estimated over time. *Non-systematic risk* is just the opposite and is recognised by imperfect or very short records of occurrence and no pattern can be identified in the distribution of outcomes.

- *Cognitive failure*

  This is very closely associated with *non-systematic* risk and is defined as an event where the individual does not know the probability or potential magnitude of a given event (Skees & Barnett, 1999).

- *Downside risk*

  This term is well known in the press and is often use to describe some of the risks in different sectors. *Downside risk* refers to any outcome of the event away from the norm that will cause a decrease in the expected value. This character of risk is especially applicable in the agricultural sector if the different variables of the weather can vary in either direction from the norm, for example, too little rain can cause as much damage to the crop as too much rain (Hardaker *et al.*, 2004).

- *Idiosyncratic and systemic risk*

  Risks are usually most easily characterised on grounds of their frequency (probability of occurring) and intensity (magnitude of the loss). This, however, is seen as a simple explanation for a complex reality where the distribution of the frequency, as well as the outcomes, must be considered. The links between risky events then becomes important and a risk can be characterised as *idiosyncratic* if it is uncorrelated with any other risks. In the event of correlation between different risks, it is called *systemic* risks. The correlation (positive or negative) can be on geographical similarity or it can occur over time (Antón, 2009).

- *Catastrophic risk*
  As the name suggests, this is basically a risk that is brought about by catastrophe. *Catastrophic risk* is defined as a risk with a low occurrence but high losses. The concept can also be related to high overall losses in a country or region and can thus be closely related to *systemic* risk (Skees & Barnett, 1999).

These risk characteristics are measurable or observable factors that are used to assign each risk to one of the risk classes of a risk classification system. The risk classification system assigns risks to groups based upon the expected cost of the event and the source of the risk. Although some risk groups affect, and are common to, all types of businesses, the risks that affect agriculture can be classified more specifically. Various authors in the past have classified agricultural risk. The classification of the risks in each case differs as the authors have grouped the risks into more broad or narrow classes. None of the classifications can be considered wrong, as each situation where it was classified differs, but to classify the risks affecting agriculture as comprehensively and accurately as possible, a combination of the work from different authors is used.

Huirne, Meuwissen, Hardaker and Anderson (2000), as well as Hardaker *et al.* (2004), divided agricultural risks into five different classes. *Production risks* involve all the unpredictable elements, such as the weather, and the uncertainty about the performance of crops and livestock. *Production risk* is thus all the unforeseen circumstances of a natural origin that can alter the production performance of the crop.

Personal risks, also described as *human risks,* are all the risks brought about by the people who operate the farm. A crisis in the life of the owner or any other human operator on the farm can influence production and increase costs, threatening the existence of the business.

The prices of farm inputs and outputs are not known for certain at the time the farmer must decide what product to produce. This uncertainty about the potential costs and benefits of the chosen product may result in *market* or *price risks* if the costs of the operation are larger than the benefits derived from it.

The way in which the farm is financed also poses a risk. Farmers usually make use of financial leverage to finance production activities. Financial leverage involves the borrowing of money from a financial institution at a specified cost (interest) and using it together with own financing to finance the production activities. The *financial risk* of the enterprise originates in the possible incapability of the farm to service the debt. The greater the proportion of borrowed capital is to own capital, the greater the *financial risk* of the enterprise becomes.

Institutional risks include all the risks that are caused by the actions of various institutions. These institutions include the government and foreign governments, as well as business partners and trading institutions. Changes in laws governing agriculture or changes in certain trade policies to foreign countries may have significant impacts on the farming enterprise.

The risks classification of authors, such as Moschini and Hennessey (2001), Musser and Patrick (2001) and Holzmann and Jorgensen (2001), have different names, such as Production uncertainty, Natural risks, Human resource risks, Health risks, Environmental risks, Technological uncertainty, Price uncertainty, Economic risks, Legal risks, Policy uncertainty and Political risks. In order to classify the risks, all of them can be related to the five risks classes as identified by Huirne *et al.* (2000) and Hardaker *et al.* (2004). To simplify the risk classification and reduce the number of risks classes even further, the risks can be divided into four broad classes, namely *Production Risks, Market/Price Risks, Financial Risks* and *Institutional/Legal Risks*. *Personal risks, Human resource risks* or *Health risks* are included under production risks, as these factors will mainly influence the production on the farm.

The sources of agricultural risks indicate where each risk originates from, but equally important as the knowledge on the sources of risks, is knowledge on their frequency, intensity and degree of covariance (Holzmann & Jorgensen, 2001). Holzmann and Jorgensen (2001) identify three degrees of covariance that explain the idiosyncratic/systemic characteristics of each risk. The combination of the different risks classes (sources of risk) and the degree of covariance explain how big the effect of each risk will be on either geographical spread or over time. Table 2.1 below combines the four broad risk classes with the degree of covariance and gives practical examples for some agricultural risks.

The degree of covariance in Table 2.1 ranges from idiosyncratic (micro), to regional covariant (meso), to nation-wide covariant (macro) or systemic events. It is important to recognise the degree of covariance of each risk, as it determines how the specific risk will be addressed. Idiosyncratic and covariant risks are usually addressed by informal methods or market-based risk management strategies. These strategies, however, tend to break down if the risk is more systemic in nature and this is usually where the state plays a role, especially in events where the risk can be classified as catastrophic (systemic with low-frequency but high-welfare effects). The focus of this study thus rather falls on idiosyncratic and covariant risks that are insurable.

Table 2.1: Agricultural risks sources and degree of covariance

Type of risk	**Micro (Idiosyncratic)** Risk affecting an individual or household	**Meso (Covariant)** Risk affecting groups of households or communities	**Macro (Systemic)** Risk affecting regions or nations
Production	Hail, frost, non-contagious diseases, personal hazards (illness, death), assets risks	Rainfall, landslides, pollution	Floods, droughts, pests, contagious diseases, technology
Market/Prices		Changes in price of land, new requirements from food industry	Changes in input/output prices due to shocks, trade policy, new markets, endogenous variability
Financial	Changes in non-farm income sources		Changes in interest rates / value of financial assets / access to credit
Institutional/Legal	Liability risk	Changes in local policy or regulations	Changes in regional or national policy and regulations, environmental law, agricultural payments

Source: Antón (2009), adapted from Harwood *et al.* (1999) and Holzmann & Jorgenson (2001).

2.2.4 Risk management strategies in agriculture

Since the outcomes of a risky event on a farming enterprise usually influence the income of the enterprise negatively, it is important to investigate how the business will respond to risks. Previously, when little farm debt was used, as most resources were produced on the farm, the impact of a risky event was first absorbed by the family consumption, then by the liquidation of assets, and finally by borrowing (Barry & Fraser, 1976). Today, family consumption levels have increased to a point where more than farm resources are required. The increased levels make the family consumption less sensitive to changes in farm income, as it cannot be used to absorb a risky event. Debt capital is used more as resources are purchased and capital investments increase (Barry & Fraser, 1976).

Farmers use various methods to manage the different risks they are faced with. Eidman (1990) identified four different methods to manage risks. First are *production responses* that include risk reducing inputs, information and control and diversification. Second are *marketing responses* that include commodities with a low price risk, forward contracting, hedging and market information. Third, and most important, are *financial responses,* as these have to counter for all other failed methods. The *financial responses* include holding assets for sale to meet cash demands, maintaining liquid credit reserves, managing the pace of investments and withdrawals, formal insurance, leasing assets, and resource providing contracts. Last mentioned are *public methods* which include farm commodity programmes, subsidised credit and subsidised water.

Harwood *et al.* (1999) identified twelve different risk management measures that farmers can use to manage or reduce their risk. *Enterprise Diversification* is one of the most frequently used risk management strategies that entails the producer participating in more than one activity. The returns from different types of enterprises do not follow each other on the same cycle, so when one enterprise has low returns, the other will probably have higher returns. *Vertical Integration* means that a firm retains ownership control of a commodity across two or more levels of activity. *Production Contracts* are used where the grower (producer) produces the required crops under contract for the contractor. The contractor supplies the grower with the inputs and specifies the quantity and quality of the commodity, for which the grower then receives a return for growing the commodity. *Marketing Contracts* are agreements between a producer and buyer that set a price and/or outlet for the commodity before harvest. *Hedging in Futures* provides farmers with a method of reducing their risks by shifting the risk from themselves (the hedger) to a party who is willing to accept the risk in exchange for a profit (the speculator). A futures contract is an agreement, priced and entered on a commodities exchange market, to trade at a specified future time a commodity or other asset with specified attributes. *Futures Options Contracts* give the holder of the contract the right to take a future position at a specified price before a specified date. If the future price increases, the option holder can make a profit by either exercising the option or selling it for a higher price.

Maintaining Financial Reserves and Leveraging refers to the ability of the farmer to make use of debt (financial leverage) to finance the operations. The increase in the farm's leverage increases its ability to expand the business, but it also increases the risk that in years of low farm returns the farmer may not be able to meet his or her financial obligations. *Liquidity* is one of the most important financial risk management aspects. It refers to the ability of the farmer to generate cash quickly and efficiently in order to service financial obligations. *Leasing Inputs and Hiring Custom Work* enables the farmer to increase his farming operation without committing to long-term payments, such as bond repayments. *Insuring Crop Yields and Crop Revenues* is often used by crop producers to mitigate yield and/or revenue risk through a third party (insurance company). *Off-Farm Employment and Other Types of Off-Farm Income* is another strategy that farmers may use to mitigate effects of agricultural risk on farm family household income, while it may also supply a more reliable stream of income than farming returns. *Other Ways of Managing Risk* include strategies such as adjusting inputs and outputs, cultural practices and excess machine capacity (Harwood *et al.*, 1999).

Holzmann and Jorgensen (2001) and Antón (2009) indicate three main categories of risk management strategies. The first category is *prevention strategies* that reduce the probability of a downside risk. By applying methods that may prevent a risk, the farmer's expected income is increased and the income variance is reduced, which in turn increases the wealth of the farmer. The second category is to decrease the potential impact of a future downside risk and is called *mitigation strategies*. These strategies are also implemented before the risk occurs, but instead of preventing it, the impact of the risk is reduced. Mitigation strategies include portfolio diversification, informal and formal insurance mechanisms, and hedging. The last set of strategies are *coping strategies* and are used to relieve the impact of the risk once it has occurred. In this case, there are no implementation measures before the risk occurs and the farmer thus deals with the consequences of the risk's impact.

Farmers usually make use of prevention strategies as far as possible to reduce the probability of risk, but these prevention measures cannot nullify all possible risks. The problem comes in when a risk, for which there was no prevention, or the prevention strategy was not strong enough, occurs on the farm. The farmer then either has to have mitigation strategies in place or has to fall back on coping strategies. The most-used strategy of risk mitigation comes at a price in the form of insurance. The relative high cost of insurance policies then discourages the farmer from making use of it. Farmers then tend to rely heavily on coping strategies, but the influence of the coping strategy on the financials of the business may be fatal. The increase in farm debt levels and the reduction of liquidity makes it more difficult to cope with risks, especially when the impact of the risk is severe.

2.3 Available crop insurance products

Agricultural crop insurance products can broadly be classified into three major groups: indemnity-based insurance, index insurance, and alternative risk transfer (World Bank, 2011; Banks, 2004).

Indemnity-based insurance consists of two main products. *Damage-based indemnity insurance* (also called peril crop insurance) is crop insurance in which the insurance claim is calculated by measuring the percentage damage in the field soon after the damage occurs. The agreed sum insured is based on production cost or expected revenue, less a deductible (co-payment or excess). If the damage cannot be measured accurately immediately after the loss, the damage assessment may be postponed until later in the cropping season. The most common damage-based indemnity insurance is for hail, but it is also used for other named perils, such as fire, frost and excessive rainfall (World Bank, 2011).

Yield-based crop insurance (or Multi-Peril Crop Insurance, MPCI), as the other indemnity-based insurance product, is coverage in which an insured yield (ton/ha) is established as a percentage of the farmer's historical average yield. If the realised yield is then less than the insured yield, the insurer will pay an indemnity equal to the difference between the actual yield and the insured yield, multiplied by a pre-agreed value (crop price). MPCI usually covers almost all causes of yield loss, unless it was caused by negligence of the farmer or poor farming practices (World Bank, 2011).

Index-based crop insurance currently also has two types of products. *Area yield index insurance* is where the indemnity is based on the realised average yield of a certain area (country or district) and not the actual yield of the insured party. The insured yield is calculated as a percentage of the average yield of the area and not the yield of the policyholder. It is important to realise that reliable historic yield data for the area is needed in order to establish an area yield index insurance scheme (World Bank, 2011).

Weather Index Insurance (WII) is the other form of index-based crop insurance and here the indemnity is based on realisations of a specific weather parameter measured over a specified period of time at a particular weather station. The insurance is then structured to protect the insured party against index realisations that are either too low or too high for optimal crop production. The policyholder can thus be insured against too little or too much rain. An indemnity is paid when the realised value of the index is higher or lower than the specified thresholds. The indemnity payment is calculated on a pre-agreed sum insured per unit of the index (World Bank, 2011).

Alternative Risk Transfer (ART) or Self-insurance is a newer form of risk protection and can be described as the "*combined risk management marketplace for innovative insurance and capital market solutions"*. Although ART is not really a specific crop insurance product, it emerges as a viable, flexible and cost-efficient option for protection against risks in various industries (Banks, 2004). With ART, the policyholder build up his or her own insurance policy. The policyholder contributes premiums to the experience account at his or her own pace. The built up funds then accumulate interest (no-claim bonus) and in the event of a claim, the claim is paid from the account. Although the specific principles vary between ART insurers, the policyholder usually receives additional cover as a percentage of the funds in the experience account. In the event where a claim is then more than the accumulated funds, the agreed percentage of extra cover will also be paid out (Corporate Guarantee, 2013). It is important to note that, even though ART may be seen as a type of savings plan, it is a registered insurance product and the premium contribution is thus also tax deductible as in the case of Short-term Crop Insurance.

2.4 Factors affecting the adoption of crop insurance

Certain factors affect a farmer's willingness to adopt crop insurance as a method to mitigate the production risk of the enterprise. Various authors have carried out research on the willingness to adopt or pay for crop insurance, whether it be hail, multi-peril, index or any other type of crop insurance.

Fraser (1992) developed a model to measure a producer's willingness-to-pay for crop insurance in the Australian wheat market by measuring the impact of insurance on the expected income and variance of income. The model featured both price and yield uncertainty, as well as risk aversion on the part of the producer. It was found that that the willingness-to-pay for crop insurance is a function of the levels of coverage, price and yield uncertainty and the attitude to risk of the producer. Willingness-to-pay was positively related to the level of coverage and the level of yield variability, while it was insensitive to the level of price variability and the specific form of the utility function.

The low participation in the Federal Multiple Peril Crop Insurance programme of the USA during the 1990s was the basis for research by Coble, Knight, Pope and Williams (1996) to determine the factors that influence the demand for the Federal MPCI programme. A random-effects, binomial probit model was applied to data for a panel of Kansas wheat farms to examine the demand. It was found that for a farm with given expected indemnity, a large variance of indemnity reflects relatively low probability of a small loss but some nontrivial probability of a large loss. The findings suggest that producers who expect to receive smaller but more frequent indemnities are more likely to insure than are producers for whom indemnities are rare but potentially large.

In a study analysing the factors affecting the adoption of crop insurance, forward contracting and spreading sales, it was found that risk management decisions are correlated and that one risk management tool is thus not independent from other risk management tools (Velandia, Rejesus, Knight & Sherrick, 2009). Using multivariate and multinomial probit approaches that account for simultaneous adoption and/or correlation among the risk management adoption decisions, it was further found that the decision to adopt one risk management tool positively influences the decision to adopt the other tools. According to the results, corn and soybean farmers in Illinois, Iowa and Indiana consider the proportion of owned acres, off-farm income levels, education, age and level of business risks as important factors in their decision to adopt crop insurance, forward contracting and spreading sales as risk management tools (Velandia *et al.*, 2009).

Rydant (1979) argues that most of the studies that examined the effects of farm acreage and income on the hazard adjustment process have isolated these factors as if they were unrelated, when, in fact, one is likely to depend on the other. In Rydant's study, regression analysis was used to examine the relationship between the dependent variable, insurance adoption, and the independent variables, acreage and income, for Illinois corn and soybean farmers. The results indicated that the insurance adopter is a repeat buyer, with a higher income and generally greater awareness of hail hazard than farmers who do not adopt crop-hail insurance. The buyer expresses general satisfaction with insurance company operations and appreciates the worth of crop-hail insurance. Rydant (1979) furthermore suggests the need to examine other variables, such as total crop liability, the frequency of hail damage, deductible clauses, adjustment procedures, premium rates, other aspects of insurance policies, status of farm management and personalities of insurance agents.

In a study by Sadati, Ghobadi, Sadati, Mohamadi, Sharifi and Asakereh (2010) on effective factors on adoption of crop insurance in the Behbahan County, Iran, using data that was collected by a survey and analysed with multiple regression analysis, it was found that younger farmers had a higher adoption rate of crop insurance. It was further found that the adoption of crop insurance correlated positively with the level of literacy and income of the farmers. In addition, the demand for crop insurance was in positive correlation with the amount of agricultural land held and the amount of satisfaction with insurance in previous years. In total, the amount of dry lands, participation in extension courses, income of farmers and amount of satisfaction with previous insurance explained about 54 % of the model of adoption of insurance (Sadati *et al.*, 2010).

Santeramo, Goodwin, Adinolfi and Capitanio (2013) found in a very recent study that the adoption rate of crop insurance adoption increases in capital intensive and risky agricultural regions in the Italian market. Apart from the factors influencing the adoption of insurance, it was found that the entry and exit from the insurance market was inhibited by high premiums and loss ratios. The most likely farms to enter the insurance market are the large farms and the farms in marginal areas.

2.5 Risk simulation

In order to test the effect of previously recorded incidents on expected incidents, simulation models can be used. The various risk programming models that are available cannot always solve problems where changes in inputs, probability distributions, changes over time, risk and uncertainty and linearity occur (Louw, 1979). According to Groenewald (1967), it is where the aforementioned problems come in that simulation can be used to obtain optimal, near optimal or satisfactory solutions, by means of divided experimentation with the model of a real world situation. Louw (1979) did a comprehensive review on simulation and quoted various definitions of simulation from other authors. One of these definitions, by Hardaker (1967), is: "*Simulation consists of building a model of reality which can be used to evaluate the consequences of different policies under varying conditions.*"

The number of simulation models for various problems in agriculture and other fields of research are basically infinite. Some of the reasons why so many simulation models are used in research are (Naylor & Finger, 1967, as cited by Louw, 1979):

- It is difficult and expensive to monitor the situation in practice, especially for problems where data does not exist on a problem under different circumstances. Simulation can be an effective method to generate information under different circumstances.
- The system used in the research may be too complex to be described by a mathematical model as an analytical solution and this negates an attempt to make a single value forecast. Most of the decisions in agriculture form part of this category.

Simulation, except for the above-mentioned factors, is also the most user-friendly and applicable technique to handle multiple objectives and consecutive decisions within the planning period (Louw, 1979). The multiple factors that may influence a specific outcome in agricultural problems should be analysed simultaneously for many iterations of variable combinations of these factors. This may be one of the reasons why simulation techniques are used widely in the research of agricultural problems. Some of the simulation models that have been developed for farm-level analysis in South Africa in the past include the models of Louw (1979), Meiring (1994), Strauss, Meyer and Kirsten (2008), and Malan, Louw and Blignaut (2010).

Louw (1979) developed a simulation model of the decision-making process in farm firms to determine the effects of different growth strategies on firm growth. Net worth and living standards were the criteria for success and these were determined under dynamic circumstances that included risk and uncertainty. Meiring (1994) developed a short-term, stochastic whole-farm simulation model that can take account of risk. This model employs cumulative distribution functions of key variables to generate distribution functions of various important economic criteria by means of Monte Carlo simulation. A linked system of models was used by Strauss *et al.* (2008) to analyse the likely effects of changes in policies and markets. A deterministic farm-level model was developed to link to an existing partial equilibrium sector-level model of the grain and livestock sectors. Malan *et al.* (2010) developed a simulated dairy management model that can be used as a farm management tool. Normal distributions were used to simulate the movement of maize prices under different scenarios.

Some of the special problems (which are of importance to this study) facing simulation modellers are (Richardson, Klose & Gray, 2000):

- non-normally distributed random yields and prices,
- and intra- and inter-temporal correlation of output prices.

These simulation problems can be overcome by a procedure for generating appropriately correlated random numbers in firm simulation models. The phrase “appropriately correlated” is used and it means that whatever procedure is used to simulate random variables, it must ensure that the historical relationship between all variables is maintained in the simulated variables (Richardson *et al.*, 2000). Richardson *et al.* (2000) describe an applied procedure for estimating and simulating multivariate empirical (MVE) probability distributions in farm-level risk assessment.

2.6 Risk efficiency analyses

The decision to choose between alternative risk outcomes, or the assessment of the choices, means that the decision maker should come to grips with both probabilities and preferences for outcomes. The decision maker’s relative preference for different outcomes must be known in order to evaluate and compare the chances of good versus bad outcomes.

Different models have been developed to evaluate or assess risky alternatives by different authors. Anderson, Dillon and Hardaker (1977) explain the subjective expected utility (SEU) model where the decision maker’s utility function is needed to assess the risk. This method was, however, criticised because many people do not act consistently with theory in risky choice situations and because people do not regard small gains and losses as changes in wealth (Allais, 1984; Rabin, 2000; Rabin & Thaler, 2001). The unconvincing results of SEU when put to work in the analysis of risky alternatives in agriculture have led to the need for developing a procedure that avoids the need to elicit a specific, single-valued utility function (King & Robison, 1984; Anderson & Hardaker, 2003). The result was stochastic dominance or efficiency criteria which is a decision rule that provides a partial ordering of risky alternatives for decision makers whose preferences conform to specified conditions about their utility functions (preferences for consequences) (Hardaker *et al.*, 2004).

Concepts of first-degree stochastic dominance (FSD) and second-degree stochastic dominance (SSD) were presented by Hadar and Russell (1969) and Hanoch and Levy (1969). FSD makes it possible to order alternatives for decision makers who prefer more wealth to less and have absolute risk aversion with respect to wealth, $r_a(w)$, between the bounds $-\infty < r_a(w) < +\infty$ (King & Robison, 1984). For SSD, it is assumed that decision makers are not risk preferring, that is, that absolute risk aversion bounds are $0 < r_a(w) < +\infty$. This means that even in instances were the absolute risk aversion parameter of a decision maker is so large that the utility of a small difference at the lowest observation is extraordinarily important, SSD still accounts for it (Hardaker *et al.*, 2004).

Another type of stochastic dominance was introduced by Meyer (1977) and allows for tighter restrictions on risk aversion. For stochastic dominance with respect to a function (SDRF), the absolute risk aversion bounds are reduced to $r_L(w) \leq r_a(w) \leq r_U(w)$, and ranking of risky scenarios is defined for all decision makers whose absolute risk aversion function lies anywhere between lower and upper bounds $r_L(w)$ and $r_U(w)$, respectively (Hardaker *et al.*, 2004). Owing to the trickiness of computing SDRF and the limited understanding that users have of the function, even with the available software to compute it, Hardaker *et al.* (2004) came up with a more transparent and discriminating SDRF method which is called stochastic efficiency with respect to a function (SERF).

SERF, as the most recent advance in ranking risky alternatives, orders alternatives in terms of certainty equivalents (CE). The advantage of SERF is that the CE's are expressed in monetary values that make the interpretation easier than in the case of expected utilities. CE is defined as the sure sum with the same utility as the expected utility of the risky prospect (Hardaker *et al.*, 2004). The decision-maker will thus be indifferent to both the CE and the risky prospect (Grové, 2007). The alternatives are ranked based on CE whereby the alternative with the highest CE is preferred, given the specific level of risk aversion. The vertical distance between two alternatives at a specified risk aversion level yields a utility weighted risk premium ($UWRP$), which is defined as the minimum sure amount that has to be paid to a decision-maker to justify a switch between a preferred and a less preferred alternative (Grové, 2007).

Since the development of SERF, it has been used in numerous studies, in South Africa and internationally, to rank the order of alternatives. Some of the South African studies applying SERF analysis include work done by Venter, Strydom and Grové (2013), Grové and Oosthuizen(2010), Strydom, Grové, Kruger and Willemse (2010), Grové (2007) and Grové, Nel and Maluleke (2006). Venter *et al.* (2013) used SERF analysis to rank different routine grain marketing strategies for different crops. Grové and Oosthuizen (2010) did a stochastic efficiency analysis of deficit irrigation with standard risk aversion. SERF was used to rank the two water supply conditions for two irrigation strategies. The efficiency of different maize marketing strategies was the focus of the research by Strydom *et al.* (2010) and the SERF analysis was used to rank these alternatives in order of preference. Grové *et al.* (2006) used the SERF analysis to rank preference for deficit irrigation by decision makers with varying levels of risk aversion.

2.7 Conclusion

Risk and uncertainty has been a research problem for many authors in the past. These authors all used different definitions for the concepts. No single definition can be declared as right or wrong as the definition for the term depends on the problem it was used for. After reviewing the work of various authors, it was found that, for the purpose of this study, the most applicable definition for *uncertainty* is "*a decision or action of which the outcomes are not definitely known and the magnitude of the different outcomes cannot be measured*." *Risk* will refer to "*the negative, measureable outcomes of the decision or action that alter the economic position of the risk taker*."

The conclusion that can be made from the reviewed literature on risk and uncertainty is that risk in agriculture does matter as it influences the financial position of the farm. Risk research in agriculture is thus typically concerned with estimating the risk in terms of a monetary outcome. As risk characteristics are measurable or observable, they can be used to assign risks to different groups in a risk classification system. According to characteristics and classification of risks, hail can be characterised as an *Idiosyncratic* risk and classified under *Production* risks.

The literature indicated that crop insurance is certainly the most used risk mitigation strategy for crop farming and although it comes at a price, it reduces the impact of risks on the enterprise. A wide range of crop insurance products is available on the market, of which the most common is named peril crop insurance (Damage-based Indemnity Insurance). The most used named peril crop insurance is Short-term Crop Hail Insurance, but it may also be used for other named perils, such as fire, frost and excessive rainfall. One of the newer forms of insurance is Alternative Risk Transfer (ART) or Self-insurance. Although it was not designed as a crop hail insurance product, it is a viable, flexible and cost-efficient option that may be used for protection against risks in various industries. Various factors may influence the decision maker's decision to adopt crop insurance. Some of the identified factors that are relevant to this study are the level of coverage of the insurance policy, yield and price variability, level of risk aversion of the decision maker, the occurrence and impact of damage, the effectiveness of previous insurance policies, and the risk level of the region where the farm is situated.

The literature provides a clear path to follow in terms of the needed procedures for analysing the data. Simulation models can be used for various problems in agriculture and other fields of research. The fact that real life situations involving various variables can be simulated through simulation models offers the solution for this study. As the variables consist of prices, yields, hail risks and different insurance options the simulation model will allow for all these variables to be applied simultaneously in order to generate results. Although sufficient historical hail damage data exist for this study, the available price and yield data only covers a part of the time series of the hail data. The procedure for estimating and simulating multivariate empirical (MVE) probability distributions will allow the deriving of multivariate distribution functions from the available data, while the historical relationship between the variables is maintained in the simulated variables. The risk efficiency of the different crop insurance options can be analysed with stochastic efficiency with respect to a function (SERF). The fact that SERF expresses the certainty equivalents in monetary values does not only make the interpretation of the results easy, but it also enables one to calculate the utility weighted risk premium that will justify the switch between two alternatives for the decision maker.

CHAPTER 3
PROCEDURES

3.1 Introduction

In this chapter the procedures and data that are used to perform the various analyses of the study are described. The procedures consist of the farm financial simulation model, risk simulation and risk efficiency analyses.

3.2 Farm financial simulation model

The model that is used for the analysis was developed in Microsoft Excel and operates under the assumption that all income and costs associated with the enterprise under analysis are cash based, as the debt levels of different farms are unknown. The only loan facility that is utilised is a bank overdraft. The model consists of only one enterprise (maize) and calculates the margin after interest and tax for each production season. The schematic presentation of the model is presented in Table 3.1 below. The first part of the model calculates the margin while the second part deals with insurance calculations of Short-term Crop Hail Insurance, as well as Alternative Risk Transfer (ART) Insurance. The variables used for the example in Table 3.1 are kept constant for all the years in order to simplify the explanation of the calculations.

The shaded areas in the model are the variables that can be changed according to the specific scenario that must be analysed, while the rest are formulas that are calculated according to the specified variables. The model is designed so that either Short-term Crop Hail Insurance or ART can be used as an insurance option. The example of the model in Table 3.1 below uses Short-term Crop Hail Insurance to calculate the margin, but the working of the ART policy is illustrated in the second part of the model.

In order to explain the working of the model in more detail, it is necessary to discuss each section, and the calculations thereof, on its own. The model can be divided in five different sections: Income, Costs, Margin, Short-term Crop Hail Insurance and ART.

It is important to keep in mind that Short-term Crop Hail Insurance is the traditional form of crop insurance where the crops are insured at a specified price and yield at a certain premium. There is also an excess (only damage more than the specified excess can be claimed) involved and the premium decreases over time if the insured party did not claim the previous year. In the case of hail damage, the policy will thus pay out the amount of damage (minus the excess) at the insured price and yield.

Table 3.1: Schematic presentation of the farm financial model

	Math sign	Measure	Year (i) 1	2	i_{3-22}	23
PRODUCTION INCOME						
Area planted	A_i	Ha	500.00	500.00		500.00
Expected yield	EY_i	ton/ha	3.00	3.00		3.00
True yield	$\tilde{Y}_i$	ton/ha	3.00	3.00		3.00
Hail Damage	HD_i	%	0.00%	0.00%		0.00%
Realised yield	RY_i	%	3.00	3.00		3.00
Price	$\tilde{P}_i$	R/ton	R2 038	R2 038		R2 038
TOTAL PRODUCTION INCOME	PI_i		R3 057 000	R3 057 000		R3 057 000
OTHER INCOME						
ST claim received	STR_i		R0	R0		R0
ART claim received	$ARTR_i$		R0	R0		R0
TOTAL OTHER INCOME	OI_i		R0	R0		R0
TOTAL INCOME			R3 057 000	R3 057 000		R3 057 000
VARIABLE COST						
Area dependant cost	AC_i	R/ha	R2 824	R2 824		R2 824
Total area dependant cost			R1 412 000	R1 412 000		R1 412 000
ST Insurance premium	STC_i		R91 660	R82 494		R34 373
ART Insurance contribution	$ARTC_i$		R0	R0		R0
Expected yield dependant cost	EYC_i	R/ha	R572	R572		R572
Total yield dependant cost	YC_i		R286 000	R286 000		R286 000
FIXED COST	FC_i		R593 500	R593 500		R593 500
TOTAL COST	TC_i		R2 383 160	R2 373 994		R2 325 873
MARGIN BEFORE INTEREST AND TAX			R673 840	R691 092		R731 128
INTEREST PAID	INP_i	8.50%	R0	R0		R0
INTEREST RECEIVED	INR_i	2.00%	R0	R8 086		R268 618
INCOME TAX	T_i	40.00%	R269 536	R276 437		R399 898
MARGIN AFTER INTEREST AND TAX	M_i		R404 304	R422 741		R599 848
Bank opening balance	OB_i		R0	R404 304		R13 430 897
Bank bank closing balance	CB_i		R404 304	R827 045		R14 030 745

	Math sign	Measure	Year (i) 1	2	i_{3-22}	23
ST INSURANCE POLICY						
Insured yield	IY_i	ton/ha	2.32	2.32		2.32
Insured price	$I\tilde{P}i$	R/ton	R1 976	R1 976		R1 976
Premium	STP_i	%	4.00%	3.60%		1.50%
Excess	EX_i	%	5.00%	5.00%		5.00%
Cost	STC_i	R	R91 660	R82 494		R34 373
Claim received	STR_i		R0	R0		R0
ART INSURANCE POLICY						
Opening Balance	$ARTOB_i$		R0	R179 893		R3 734 859
Premium	$ARTP$	25.00%	25.00%	25.00%		25.00%
Contribution	$ARTC_i$		R191 375	R191 375		R0
Administration fee	$ARTA_i$	6.00%	R11 483	R11 483		R0
Interest	$ARTI_i$	4.00%	R0	R7 196		R149 394
Claim claimed	$ARTCC_i$		R0	R0		R0
Claim received	$ARTR_i$		R0	R0		R0
Portion from accumulated funds	$ARTAF$		R0	R0		R0
Portion from cover funds	$ARTCF$		R0	R0		R0
Closing Balance	$ARTCB_i$		R179 893	R366 981		R3 884 254
Total cover	$TART_i$	120.00%	R215 871	R440 377		R4 661 105
Total contribution for the year	$ARTY_i$		R179 893	R187 088		R149 394

The premium used for the Short-term Crop Hail Insurance policy is 4 % per year. The premium is kept constant and only decreases over time if there were no claims the previous year (no-claim bonus). In the event of a claim, the premium for the next year will return to 4 %. The fact that Short-term Crop Hail Insurance does not depend on indexes of the yield and rain of previous years, makes the premium more stable than that of Multi-peril Crop Insurance.

When ART insurance, on the other hand is used as a type of self-insurance, then the insured party decides how much of his or her margin at the end of the year must be placed in the policy to provide cover for other years. As this decision will vary between farmers, the premium amount for the calculation was fixed at either 25 % or 50 % of the gross margin. Another contribution that was used is where the contribution to the ART policy is equal to the premium that would have been spent on the Short-term Crop Hail Insurance. The contributions to the ART policy, as a registered insurance product, are also tax deductible as in the case of Short-term Crop Insurance premiums.

3.2.1 Income

The total income of the model is derived from two sources; production income (PI_i) and other income (OI_i). The production income is a function of the production of maize according to the production area, price, yield and hail damage. Other income consists only of pay-outs from one of the insurance policies and is specifically separated from the rest of the income calculations owing to the specific insurance focus of the model.

Three different yield types are included in this section. Expected yield (EY_i) is the yield that is expected at the beginning of the season and the different costs are calculated accordingly. True yield ($\tilde{Y}_i$) is the yield that will actually be realised after the influence of external factors (except hail), such as rain, played a role. The true yield can thus be either higher of lower than the expected yield. The Realised yield (RY_i) includes the influence of hail and is the actual yield that is harvested.

The production income (PI_i) is calculated as:

$$\boldsymbol{PI_i = A_i \times RY_i \times \tilde{P}_i} \tag{3.1}$$

where

A_i	Area planted for year i (Ha)
RY_i	Realised yield for year i (t/Ha)
$\tilde{P}_i$	Empirically distributed deflated price for year i (R/ton)

Realised yield, as a function of hail damage is calculated as:

$$\boldsymbol{RY_i = \tilde{Y}_i \times (1 - HD_i)} \tag{3.2}$$

where

$\tilde{Y}_i$	True Yield: Empirically distributed subjective yields for year i (t/Ha)
HD_i	Hail damage for year i (%)

The other income (OI_i) for the enterprise stems solely from the claims that were paid out by the insurance policies. The different variables used in the calculation of Other Income will be discussed in section 3.2.5 as it is calculated in the second part of the model.

3.2.2 Costs

The total cost (TC_i) of the enterprise basically consists of five different variables, as the payments for insurance policies are kept as separate entities in the model. It is important to note that although both forms part of the equation, only the Short-term crop insurance cost or the ART contribution is used at a time. The total cost of the enterprise is calculated as:

$$\boldsymbol{TC_i = (AC_i \times A_i) + STC_i + ARTC_i + YC_i + FC_i} \quad (3.3)$$

where

AC_i	Area dependant cost for year i (R/ha)
A_i	Area planted in year i (ha)
STC_i	Short-term Crop Insurance premium for year i (R)
$ARTC_i$	ART Insurance contribution for year i (R)
YC_i	Yield dependant cost for year i (R)
FC_i	Fixed cost for year i (R)

The insurance cost for Short-term Crop Hail Insurance and ART are discussed in section 3.2.4.

The Yield dependent cost (YC_i) is a function Realised yield. As the expected yield dependant cost is the monetary amount, if the expected yield is realised, it is necessary to calculate it according to the Realised yield. The Yield dependent cost is thus calculated as:

$$\boldsymbol{YC_i = (EYC_i \times A_i)/EY_i \times RY_i} \quad (3.4)$$

where

EYC_i	Expected yield dependant cost for year i (R/ha)
EY_i	Expected yield for year i (ton/ha)

The production cost used in the simulation model is based on the production cost for the two provinces, North West and Mpumalanga, for the 2011/2012 production season as supplied by Grain SA (2012). For the model the variable cost must be divided between area dependent and yield dependent costs, while fixed cost is a separate entity. Owing to the above reason, and the fact that some of the cost, such as insurance, must be excluded from the figures of Grain South Africa (GSA), the costs were recalculated. The recalculated costs for both regions are presented in Table 3.2 below.

Table 3.2: Production cost for both regions for the 2011/2012 production season

Cost	North West (3 t/ha)	Mpumalanga (5 t/ha)
Variable (Total 500 ha)	R1 698 500	R3 699 500
Area dependant (R/ha)	R2 825	R6 446
Yield dependant (R/ha)	R572	R953
Fixed (Total 500 ha)	R593 500	R593 500
Total (500 ha)	**R2 292 000**	**R4 293 000**

Source: Grain SA (2012) and own calculations

Area cost of a maize enterprise depends on the yield the producer aims to achieve and includes all costs up to the stage where the crop is harvested. Yield dependant cost is a function of the realised yield and includes the harvest, as well as the transport cost of the realised crop. The costs in Table 3.2 above are based on yields of 3 t/ha for the Lichtenburg area and 5 t/ha for the Standerton area, as these are average yields for the two areas. The production cost for the Standerton (Mpumalanga) is almost double that of Lichtenburg (North West) and is ascribed to the higher yield possibilities.

3.2.3 Margin

The purpose of the model is to calculate the margin after interest and tax. The margin after interest and tax for each year will be used to calculate the Net Present Value (NPV) over 23 years at a discount rate of 5%. The results of each scenario are used to compare the different scenarios with one another. The margin after interest and tax is calculated as:

$$\boldsymbol{M_i = PI_i + OI_i - TC_i + (INR_i - IPN_i) - T_i} \qquad (3.5)$$

where

M_i Margin for year i (R)

PI_i Production income for year i (R)

OI_i Other income for year i (R)

TC_i Total cost for year i (R)

INR_i Interest received for year i (R)

INP_i Interest paid for year i (R)

T_i Income tax paid for year i (R)

The income and cost calculations of the model are explained in the previous sections. The income tax (T_i) for the model is calculated as:

$$\boldsymbol{T_i} = \begin{cases} \boldsymbol{TI_i \times TR} \quad if \quad TI_i > 0 \; and \; TI_{i-1} \geq 0 \\ (\boldsymbol{TI_i + TI_{i-1}}) \times \boldsymbol{TR} \quad if \quad TI_i > 0 \; and \; TI_{i-1} < 0 \\ \boldsymbol{0} \quad if \quad TI_i < 0 \end{cases} \qquad (3.6)$$

where

TI_i Taxable income for year i (R)

TR Marginal tax rate (40%)

Equation 3.6 above shows that the income tax calculation depends on the amount of taxable income generated in the specific year. If the taxable income is negative it will be carried over to the next year. The taxable income is calculated as:

$$\boldsymbol{TI_i = PI_i + OI_i - TC_i + (INR_i - INP_i)} \quad (3.7)$$

The bank opening and closing balances that form part of the model are there to monitor the cash flow from one year to another. Although each year is treated as a separate account to calculate the margin after interest and tax, it is necessary to do the flow of reserve surplus/shortage of funds between years for tax and interest purposes.

The opening and closing bank balances is calculated as:

$$\boldsymbol{OB_i} = \left| \begin{array}{l} \boldsymbol{CB_{i-1}} \;\; if \;\; OB_{i\neq 1} \\ \boldsymbol{IB} \;\; if \;\; OB_{i=1} \end{array} \right. \quad (3.8)$$

where:

OB_i Opening bank balance for year i (R)

CB_i Closing bank balance for year i (R)

IB Initial balance of cash at business start-up (R)

while:

$$\boldsymbol{CB_i = OB_i + M_i} \quad (3.9)$$

3.2.4 Cost of crop hail insurance

The Short-term Crop Hail Insurance cost is calculated as:

$$\boldsymbol{STC_i} = (\boldsymbol{A_i} \times \boldsymbol{IY_i} \times \boldsymbol{I\widetilde{P}_i}) \times \boldsymbol{STP_i} \quad if \quad ARTC_i = 0 \quad (3.10)$$

where

IY_i Insured yield for year i (t/ha)

$I\tilde{P}_i$ Insured price for year i (R/ton)

STP_i Short-term insurance premium for year i (%)

The Short-term Crop Hail Insurance premium (STP_i) in the example is a set percentage (4 %) of the total value that is insured and is determined by the insurer. The premium declines with a set percentage per year (10 % in this case) if there were no claims the previous year until it reaches a certain minimum (1.5 % in this case). The premium for the short-term insurance policy is calculated as:

$$\boldsymbol{STP_i} = \left| \begin{array}{l} \boldsymbol{y} \;\; if \;\; STP_{i=1} \; or \; STC_{i-1} = 0 \; or \; STR_{i-1} > 0 \\ (\boldsymbol{STP_{i-1}} \times \boldsymbol{0.9}) \;\; if \;\; STC_{i-1} > 0 \; and \; STR_{i-1} = 0 \\ \qquad and \; STP_{i-1} > 0.015 \end{array} \right. \quad (3.11)$$

where

y Premium as determined by insurer (4.00 % in example)

The insured party only insures enough of the yield to cover the cost in the event of hail occurrence. While the whole area is thus insured at a certain price, the yield at which the crops are insured are calculated according to the expected cost. The insured yield (IY_i) is calculated as:

$$\boldsymbol{IY_i} = \begin{vmatrix} \left(\boldsymbol{AC_i} + \boldsymbol{EYC_i} + (\boldsymbol{FC_i}/\boldsymbol{A_i})\right)/\boldsymbol{I\tilde{P}_i} \quad if \quad IY_i < EY_i \\ \\ \boldsymbol{EY_i} \quad if \quad IY_i > EY_i \end{vmatrix} \tag{3.12}$$

where

$I\tilde{P}_i$ Insured price for year i (R) is the forward contract price at harvest time

The ART insurance premium ($ARTP$) is expressed in the study as a fixed percentage of the difference between the production income and production costs (excluding insurance cost). The insured party decides how much money must be placed in the fund to insure the business against future losses and although the amount (as a percentage) may change every year, it is kept fixed in the study. To show the effect of different contributions, the model is calculated with premiums of 25 % and 50 % of the gross margin and a premium equal to the premium of Short-term Crop Insurance that would have been paid in the event where Short-term Crop Insurance would have been used.

The contribution ($ARTC_i$) to the ART fund is calculated as:

$$\boldsymbol{ARTC_i} = \begin{vmatrix} \boldsymbol{ARTP} \times (\boldsymbol{PI_i} - (\boldsymbol{AC_i} \times \boldsymbol{A_i}) - \boldsymbol{YC_i} - \boldsymbol{FC_i}) \quad if \\ ARTOB_i < \left((AC_i \times A_i) - YC_i - FC_i\right) > 0 \\ \\ \boldsymbol{0} \quad if \quad ARTCC_i > 0 \end{vmatrix} \tag{3.13}$$

where

$ARTP$ ART insurance premium (%)

$ARTOB_i$ ART fund opening balance for year i (R)

$ARTCC_i$ Claim against ART fund for year i (R)

while

$$\boldsymbol{ARTOB_i} = \begin{vmatrix} \boldsymbol{ARTCB_{i-1}} \\ \boldsymbol{IC} \quad if \quad ARTOB_{i=1} \end{vmatrix} \tag{3.14}$$

where

$ARTCB_i$ ART fund closing balance for year i (R)

IC Initial cash at fund start-up (R)

and

$$\boldsymbol{ARTCC_i} = \boldsymbol{TC_i} - \boldsymbol{PI_i} \quad if \quad RY_i < \tilde{Y}_i \; and \; TC_i > PI_i \tag{3.15}$$

The administration fee of 6 % of the contribution is payable on all the contributions that are made to the fund. The interest that is received on the funding can also be described as the no-claim bonus and amounts to 4 % per year of the total value of accumulated funds. The 4 % interest of the ART policy will vary according to interest rates, but as interest rates are fixed in the study, it remains the same.

The last line of the model indicates the total amount with which the ART fund has to grow that specific year ($ARTY_i$) and is calculated as:

$$\boldsymbol{ARTY_i} = \begin{vmatrix} \boldsymbol{ARTC_i - ARTA_i + ARTI_i - ARTAF_i} \ \ if \ \ ARTY_i > 0 \\ \boldsymbol{0} \ \ if \ \ ARTY_i < 0 \end{vmatrix} \quad (3.16)$$

3.2.5 Income from crop hail insurance

The other income (OI_i) for the enterprise stems solely from the claims that were paid out by the insurance policies. As one of two policies can be used the other income is calculated as:

$$\boldsymbol{OI_i} = \begin{vmatrix} \boldsymbol{STR_i} \ \ if \ \ ARTC_{All\,i} = 0 \ and \ HD_i > 5\% \\ \boldsymbol{ARTR_i} \ \ if \ \ STC_{All\,i} = 0 \ and \ HD_i > 5\% \end{vmatrix} \quad (3.17)$$

where

STR_i Short-term claim received for year i (R)

$ARTR_i$ ART claim received for year i (R)

STC_i Short-term insurance cost for year i (R)

$ARTC_i$ ART insurance contribution for year i (R)

In the event of Short-term Crop hail Insurance, the claim (STR_i) that will be paid out by the insurer in the event of hail damage is calculated as:

$$\boldsymbol{STR_i} = \begin{vmatrix} \boldsymbol{0} \ \ if \ \ HD_i \leq EX_i \\ \boldsymbol{(HD_i - EX_i) \times (A_i \times IY_i \times I\widetilde{P}_i)} \ \ if \ \ HD_i > EX_i \end{vmatrix} \quad (3.18)$$

where

EX_i Excess for year i (%)

In the event of ART the claim that is received from the fund in the event of hail may in some years be less than the amount that was claimed from the fund. The reason for this is that the fund takes time to grow and with large losses in the first few years the accumulated funds may not be enough to cover for the loss. The amount that will be paid out in the event of a claim consists of the insured party's accumulated funds, as well as an extra amount of cover (20 % of accumulated funds in this case) from the insurance company. The claim that is received ($ARTR_i$) can thus either consist of accumulated funds ($ARTAF$) or accumulated and cover funds ($ARTCF$) and is calculated as:

$$\boldsymbol{ARTR_i} = \begin{vmatrix} \boldsymbol{ARTCC_i} \ \ if \ \ ARTCC_i \leq TART_i \\ \boldsymbol{TART_i} \ \ if \ \ TART_i < ARTCC_i \end{vmatrix} \quad (3.19)$$

where

$TART_i$ Total cover of ART fund at year i (R)

while

$$\boldsymbol{TART_i = ARTCB_i \times 1.2} \quad (3.20)$$

and

$$\boldsymbol{ARTCB_i = ARTOB_i + ARTC_i - ARTA_i + ARTI_i} \quad (3.21)$$

where

$ARTA_i$	ART administration fee for year i (R)
$ARTI_i$	ART interest received for year i (R)

while

$$\boldsymbol{ARTA_i = ARTC_i \times 0.06} \quad (3.22)$$

and

$$\boldsymbol{ARTI_i = ARTOB_i \times 0.04} \quad (3.23)$$

3.3 Risk simulations

The risk variables that needed to be simulated for the model were the true yield ($\tilde{Y}_i$), price ($\tilde{P}_i$) and insured price ($I\tilde{P}_i$). The first reason for the simulation of these variables is because of the fact that the time series of the data for the yields and prices was shorter than the time series for the hail risk data. The second reason is that, although it may be argued that the insurance products in the study only cover the influence of hail, it is important to include the variability of price and yield in the model. Hail damage is expressed as a percentage loss of the physical crop while the influence of the damage on the financial position of the farm is calculated with the price and yield of the specific season. The financial influence of 20 % hail damage to the crop will be much different in a season with high prices and low yields than in a season with low prices and high yields. The yield and price data should thus be simulated to account for the different variations of yields and prices according to their historical relationships with one another.

Risk simulation is concerned with random draws from a specified distribution that is used to characterise risk (Grové, 2007). The procedure that was used to simulate multivariate probability distributions for the stochastic variables follows the procedure developed by Richardson *et al.* (2000).

3.3.1 Correlating random numbers for simulation

The procedure generates appropriately correlated random numbers which means that it ensures that the historical relationship between all variables is maintained in the simulated variables. In this study the empirical distribution is used to characterise risk. The correlated uniformly distributed values ($CUD' s$) with respect to long run analyses are generated using the independent standard normal deviates ($ISND$), the intra-temporal correlation matrix factored by the square root procedure and the inter-temporal correlation matrix also factored by the square root procedure. After $ISND' s$ equal to the number of random iterations for each of the risk parameters are generated, the $ISND' s$ are correlated through multiplication of the deviates with the square root factored correlation matrix to get correlated standard normal deviates ($CSND$) (Richardson *et al.*, 2000). Grové (2007) used the Cholesky matrix, as described by Dagpunar

(1988), as the factored correlation matrix. The procedure to calculate the Cholesky matrix can be written as:

$$\boldsymbol{c_{ii}} = \sqrt{(\boldsymbol{V_{ii}} - \textstyle\sum_{m=1}^{i-1} \boldsymbol{c_{im}^2})}$$
$$\boldsymbol{c_{ij}} = (\boldsymbol{V_{ij}} - \textstyle\sum_{m=1}^{i-1} \boldsymbol{c_{im}}\, \boldsymbol{c_{jm}})/\boldsymbol{c_{ii}} \quad for \quad j > i \tag{3.24}$$

The $CSND' \ s$ are then adjusted by multiplying it with the Cholesky matrix of the inter-temporal correlation matrix to calculate the adjusted correlated standard normal deviates ($ACSND$). The inter-temporal correlation matrix is constructed by calculating a one-year lagged correlation coefficient and then assuming no higher order autocorrelation. The inter-temporal correlation matrix for variable X_{it}'s correlation to X_{it-1} is given by:

$$\boldsymbol{\rho_{i(t,t-1)}} = \begin{bmatrix} \boldsymbol{1} & \boldsymbol{\rho}_{(\hat{e}_{it},\hat{e}_{it-1})} & \boldsymbol{0} \\ & \boldsymbol{1} & \boldsymbol{\rho}_{(\hat{e}_{jt},\hat{e}_{jt-1})} \\ & & \boldsymbol{1} \end{bmatrix} \tag{3.25}$$

where

ê	Unsorted error terms from a time trend regression
i, j	Variable
t	Time (year)

The final step of the procedure is to transform the $ACSND' \ s$ to $CUD' \ s$. This is done by returning the normal cumulative distribution function, with a mean of 0 (zero) and a standard deviation of 1 (one), for each of the values. Because the $ACSND' \ s$ is appropriately correlated, the output is a vector of correlated deviates distributed uniform zero-one (Richardson *et al.*, 2000). The procedure described above was modelled in Microsoft Excel while SIMETAR© by Richardson, Schumann and Feldman (2004) was used to simulate the random variables.

The intra-temporal correlations between the different yield and price variables that must be kept in the simulation of the random variables are presented in Table 3.3 below, while the inter-temporal correlation coefficients are illustrated in Table 3.4 below. The Intra-temporal correlation coefficients between the variables indicate the relationship between the different variables over time, while the Inter-temporal correlation coefficients indicate the relationship within a variable for different years.

Table 3.3: Intra-temporal correlation matrix for yield and price

	Price Insured	**Price Realised**	**Yield North West**	**Yield Mpumalanga**
Price Insured	1	0.5538	0.1684	0.3509
Price Realised	0	1	0.0689	0.2305
Yield North West	0	0	1	0.9024
Yield Mpumalanga	0	0	0	1

Table 3.4: Inter-temporal correlation coefficients for yield and price

	Price Insu-red	Price Ins. t-1	Price Reali-sed	Price Real t-1	Yield NW	Yield NW t-1	Yield MP	Yield MP t-1
Price Insured	1	-0.442	0	0	0	0	0	0
Price Realised	0	0	1	0.375	0	0	0	0
Yield North West	0	0	0	0	1	-0.264	0	0
Yield Mpumalanga	0	0	0	0	0	0	1	-0.115

3.3.2 Characterisation of price and yield risk

Grové (2007) used the same procedure as Richardson *et al.* (2000) and explained that the empirical function distribution has no fixed function for the cumulative probability distribution, $F(x)$, and is characterised as discrete points on a cumulative probability function. A continuous function of $F(x)$ can be found through interpolation with the following formula:

$$\boldsymbol{F(x)} = \frac{(x-x_i)}{(x_{i+1}-x_i)}(\boldsymbol{p_{i+1}} - \boldsymbol{p_i}) + \boldsymbol{p_i} \quad with \quad x_i \leq x < x_{i+1} \tag{3.26}$$

where

x Empirical values

p Cumulative probability of occurrence

i Lower bound for interpolation of x

$i+1$ Upper bound for interpolation of x

The empirical values (x) and the corresponding calculate values of the cumulative probability of occurrence (p) should be arranged from small to large. Each of the empirical values have an equal probability to be observed in the past, but in a standard empirical distribution the probability of simulating the minimum and maximum points of the data is zero. The problem is corrected by adding a Pseudo-minimum and Pseudo-maximum value that are very close to the observed minimum and maximum but cause the simulated distribution to return to the extreme values with approximately the same value as in the past. The Pseudo values are assigned one half of the probability assigned to the other intervals (Richardson *et al.*, 2000).

According to Grové (2007), the inverse transformed continuous empirical function, which is used to draw stochastic variables from an empirical function, can be written as:

$$\boldsymbol{x} = \frac{(\boldsymbol{u}-\boldsymbol{p_i})(\boldsymbol{x_{i+1}}-\boldsymbol{x_i})}{(\boldsymbol{p_{i+1}}-\boldsymbol{p_i})} + \boldsymbol{x_i} \quad with \quad p_i \leq u < p_{i+1} \tag{3.27}$$

where

u Correlated uniformly distributed value (CUD)

The data that was used to simulate the maize price and yield for the model consisted of data from 11 maize production seasons. The price data in Table 3.5 below is the contract price of May futures on the SAFEX market for each of the production seasons, while the yield data for the two provinces, North West and Mpumalanga, are the average yield for the province for the specific production season as supplied by Grain South Africa (GSA) (2012).

Table 3.5: Price and yield data on maize for 2001/2002 – 2011/2012

Production Season	Prices (May Futures R/ton)		Yield (Provincial Average t/ha)	
	Insured (1 Dec)	Realised (Average: 1 Dec – Contract End)	North West	Mpumalanga
2001/02	R697	R806	2.6	3.9
2002/03	R1 961	R1 185	2.2	3.5
2003/04	R976	R1 198	2.7	4.0
2004/05	R926	R631	3.2	5.1
2005/06	R991	R1 089	3.3	4.9
2006/07	R1 355	R1 585	1.9	3.3
2007/08	R1 500	R1 697	3.5	5.5
2008/09	R1 760	R1 666	3.6	6.0
2009/10	R1 615	R1 262	3.7	5.9
2010/11	R1 374	R1 534	3.6	5.0
2011/12	R2 180	R2 242	3.4	5.7

Source: SAFEX (2012) and GSA (2012)

The insured price is the May futures price on 1 December (or the first business day in December) for the specific season. The price at which the producer insures the crop is the expected price at the time of harvest. The future price at harvest time is thus used as the insured price at planting time. The realised price is the average daily price of the May futures contract for the period from the first business day of December until the day that the contract closes in May. As the farmer can decide to sell his or her crop on the futures market at any time during this period, any of the daily prices of the futures contract have the same probability to be realised and therefore the average price for the period is used. It is important to note that the prices used in the model are lower than the SAFEX price due to the transport differential of R204/ton for Lichtenburg and R236/ton for Standerton that is subtracted from the SAFEX price.

3.3.3 Hail risk

The data that was used for the occurrence of hail damage only shows the exact level of damage for damage percentages higher than the excess percentage of the policy. In the case of a hail occurrence lower than the excess, it was only indicated that hail did occur but the exact percentage of damage is not indicated. As the excess for the data is 5 %, it means that all hail occurrences that cause less than 5 % damage to the crop are only indicated as an occurrence and not as an exact percentage. The hail occurrences of less than 5 % were characterised by the probability distribution function (PDF) of the triangle distribution function, as specified by the following equation (Hardaker, Huirne & Anderson, 1997):

$$\boldsymbol{F(x)} = \begin{vmatrix} \boldsymbol{2(x-a)/(b-a)(m-a)} & if \quad x \leq m \\ \boldsymbol{2(b-x)/(b-a)(b-m)} & if \quad x > m \end{vmatrix} \qquad (3.28)$$

where

a Minimum value (1%)

b Maximum value (5%)

m Most probable value (mode) (2.5%)

To facilitate simulation of risk through inverse transformation, the following equations are used for the triangular distribution (Grové, 2007):

$$\boldsymbol{x} = \begin{vmatrix} \boldsymbol{a} + (\boldsymbol{u}(\boldsymbol{b}-\boldsymbol{a})(\boldsymbol{m}-\boldsymbol{a}))^{\mathbf{0.5}} \quad if \quad 0 \le u \le (m-a)/(b-a) \\ \boldsymbol{a} - \left((\mathbf{1}-\boldsymbol{u})(\boldsymbol{b}-\boldsymbol{a})(\boldsymbol{b}-\boldsymbol{m})\right)^{\mathbf{0.5}} \quad if \quad (m-a)/(b-a) < u \le 1 \end{vmatrix} \tag{3.29}$$

where

u Random value

By substituting random values between 0 (zero) and 1 (one) for u into equation (3.29) above, it is possible to simulate random entities from the triangle probability distribution used to characterise risk.

The hail risk for both areas was determined using insurance data that was supplied by Santam Crop Insurance. The data includes all the hail insurance policies for the period 1990 to 2012. All the policies were, however, not insured for all the years and only the policies that were insured for the whole period were selected. The reason for using the words 'insured policies' rather 'insured farms' is due to the reason that the crop on one farm can be insured through more than one insurance policy, as the different lands on one farm may be owned or rented by different farmers.

The original data set for the Lichtenburg area contained 1101 different insurance policies for the 23 years while the Standerton area contained 866 policies. After the data was cleaned, the number of policies that existed for all 23 years was 118 for Lichtenburg and 112 for Standerton. The data included the damage (in percentage) that hail caused to the maize crop in each of the 23 years for every policy.

In order to give a better presentation of the occurrence of hail damage in the two regions, the cumulative probability distributions of hail damage is presented in Figure 3.1 below. From the cumulative distribution, it is clear to see that there is a higher probability of high impact hail damage occurrences in Standerton than in Lichtenburg. The production risk brought about by hail is thus higher in the Standerton than in the Lichtenburg region.

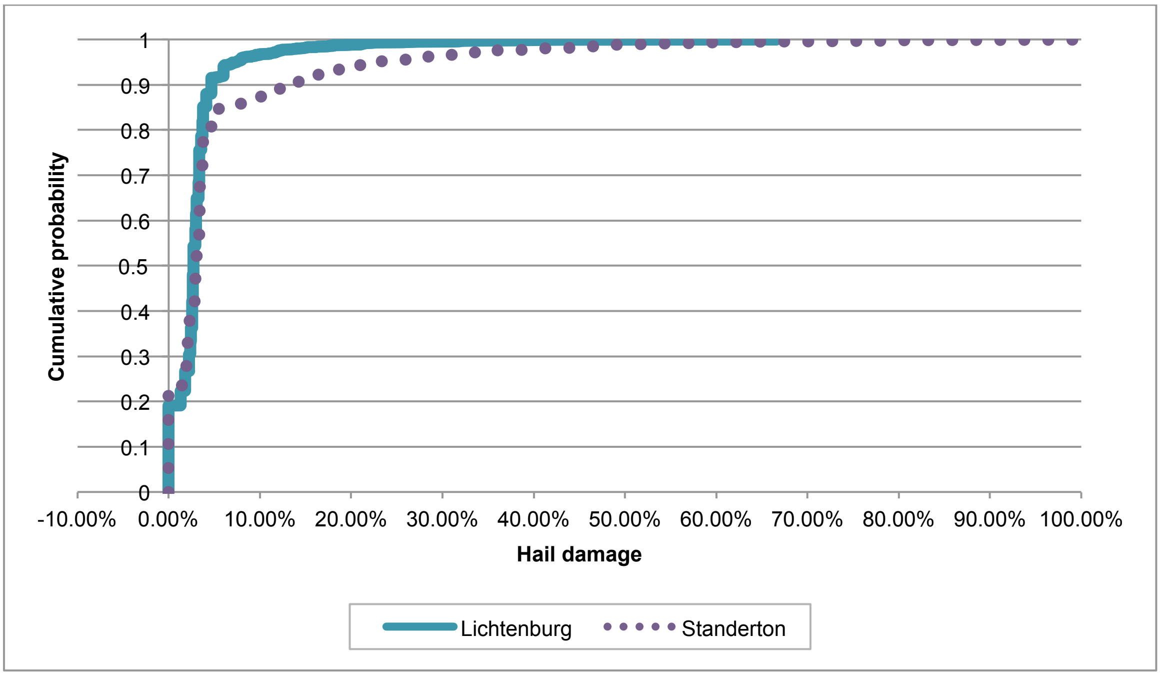

Figure 3.1: Cumulative probability distributions of hail damage for the Lichtenburg and Standerton regions

3.4 Risk efficiency analysis

In order to determine the efficiency of the different insurance products, the NPV of the margins after interest and tax of each of the scenarios have to be analysed. The analysis enables the decision maker to rank the different scenarios in order of preference. The SERF analysis is used to rank the outcome of the different risky alternatives. Although the SERF analysis can be done easily with specialised software, such as SIMETAR©, it is possible to do the analysis in Excel© with the procedure as described by Hardaker *et al.* (2004).

3.4.1 Certainty Equivalents (CE)

A Certainty Equivalent (CE) is the certain amount of value that a decision maker is willing to accept in order to be indifferent between the accepted amount of value and the chance to receive a possibly higher, but uncertain, amount (Boehlje & Eidman, 1984). As the risk aversion level of decision makers differ, the CE of the different decision makers will also differ accordingly. The expected return (ER) from a risky venture is the probability-weighted sum of the possible outcomes.

The difference between the ER and CE is also known as the risk premium (RP). The RP is the amount that the decision maker must receive in order to take risk. The RP of a risk-averse decision maker is always positive, as the decision maker will rather be willing to accept a lower certain outcomes than to experience risk. In the case of a risk seeking decision maker, the RP is always negative, as the decision maker will be willing to pay for the chance to obtain more from the risky venture rather than accepting the $ER.$ To render the risk-seeking decision maker indifferent, the CE thus has to be more than the $ER.$ The RP of a risk-neutral decision maker is equal to zero. A risk-neutral decision maker will thus be satisfied with an amount equal to the average or expected return of the venture.

The form of the utility function specified determines the calculation of the CE, as the CE is calculated as the inverse of the utility function. Assuming an exponential utility function and a discrete distribution of risky alternative x, the estimated CE is calculated as (Hardaker *et al.*, 2004):

$$\boldsymbol{CE\big(x, r_a(x)\big) = ln\left\{\left(\frac{1}{n}\sum_i^n \exp\left(-r_a(x)x_i\right)\right)^{-1/r_a(x)}\right\}} \quad (3.30)$$

where

$r_a(x)$	Level of absolute risk aversion
n	Size of the random sample of risky alternative x
x_i	Net present value (NPV) after interest and tax

The relationship between risk aversion and CE is determined by evaluating equation (3.30) above over a range of $r_a(x)$ values. Repeating for different risky alternatives yields the relationship for several alternatives, which are best compared by means of graphing the results (Grové, 2007).

Grové (2007) standardised the level of absolute risk aversion ($r_a(x)$) and determined that the maximum standardised level of risk aversion ($r_s(x)$) is equal to $r_s = 2.5$. The risk aversion coefficient is thus calculated using $0 < r_s < 2.5$ and the $CE's$ can then be graphically expressed according to the standard levels of risk aversion.

3.4.2 Utility Weighted Risk Premium (UWRP)

The utility weighted risk premium ($UWRP$) is the minimum sure amount that a decision maker will be willing to pay to move from the base scenario (BS) to a more preferred scenario (PS). The vertical distance between the $CE'\ s$ of the different alternatives is equal to the $UWRP$ and it is calculated as (Hardaker *et al.*, 2004):

$$\boldsymbol{UWRP_{PS,BS,r_a} = CE_{PS,r_a(x)} - CE_{BS,r_a(x)}} \quad (3.31)$$

The *Base* scenario for the calculation of the $UWRP$ is the scenario where no insurance is used. The $UWRP$ for each of the other scenarios thus indicates how much the decision maker is willing to pay to move from the *Base* scenario to a scenario with a certain type of crop hail insurance. In the event of a negative $UWRP$, the decision maker will thus not be willing to move to suggested crop hail insurance.

CHAPTER 4
RESULTS

4.1 Introduction

The results of the study will be discussed on the basis of five scenarios that were tested with the model over a period of 23 years for two regions; Lichtenburg and Standerton. In each area, 100 iterations were used and the Net Present Values (NPV) of the margin after interest and tax for each of the iterations were calculated at a 5 % discount rate. In the case of the different ART policies, the balance of the policy at the end of the 23 years is also discounted and added to the NPV of the margin after interest and tax. The NPV data is used in the analyses of the results[1]. The first scenario is the *Base* scenario where no crop hail insurance product is used. The second one is the *Insurance* scenario that makes use of Short-Term Crop Hail insurance. The third and fourth scenarios are *ART 25* and *ART 50,* which make use of ART insurance at respective policy contributions of 25 % and 50 % of the gross margin (before interest and tax). The last scenario is *ART PC* where ART insurance is also used, but the contribution to the fund is equal to the premium that would have been paid for the Short-term Crop Hail Insurance policy.

4.2 The financial extent of hail risk's impact

The financial extent of hail risk's impact is illustrated using the cumulative probability of the NPVs of the *Base* and *No Hail* scenarios. In the *Base* scenario the farm experienced all the risks (hail, yield and price) that are incorporated into the model, but no insurance option is used to provide cover against the influence of hail. *No Hail,* on the other hand, means that the farm still has to deal with yield and price risks, but no hail occurred over the period and no crop hail insurance policy was used. To determine the maximum amount the decision maker should be willing to pay to remove the risk of hail damage to the crops, the SERF analyses are used to calculate the maximum benefit brought about through the elimination of hail.

Figure 4.1 below and Figure 4.2 below present the cumulative probabilities of the NPV for Lichtenburg and Standerton, respectively. Although the effect of hail damage can be seen in both regions, as there is a shift in the NPVs of both regions, the effect is much larger in the Standerton region.

In Lichtenburg, the influence of hail causes the maximum and minimum NPV to be lower. The minimum NPV is approximately R1,02 million lower and the maximum NPV decreases with approximately R1,07 million. The difference between the two scenarios is almost parallel,

[1] The graphical presentations of the cumulative distribution functions of the NPVs are presented in Appendix A, Figures A1 – A6.

indicating that the influence of hail damage over the range of NPVs is relative constant. Although the NPV never becomes negative for either one of the scenarios, the influence of the hail damage may cause financial concerns, especially in the iterations with lower NPVs.

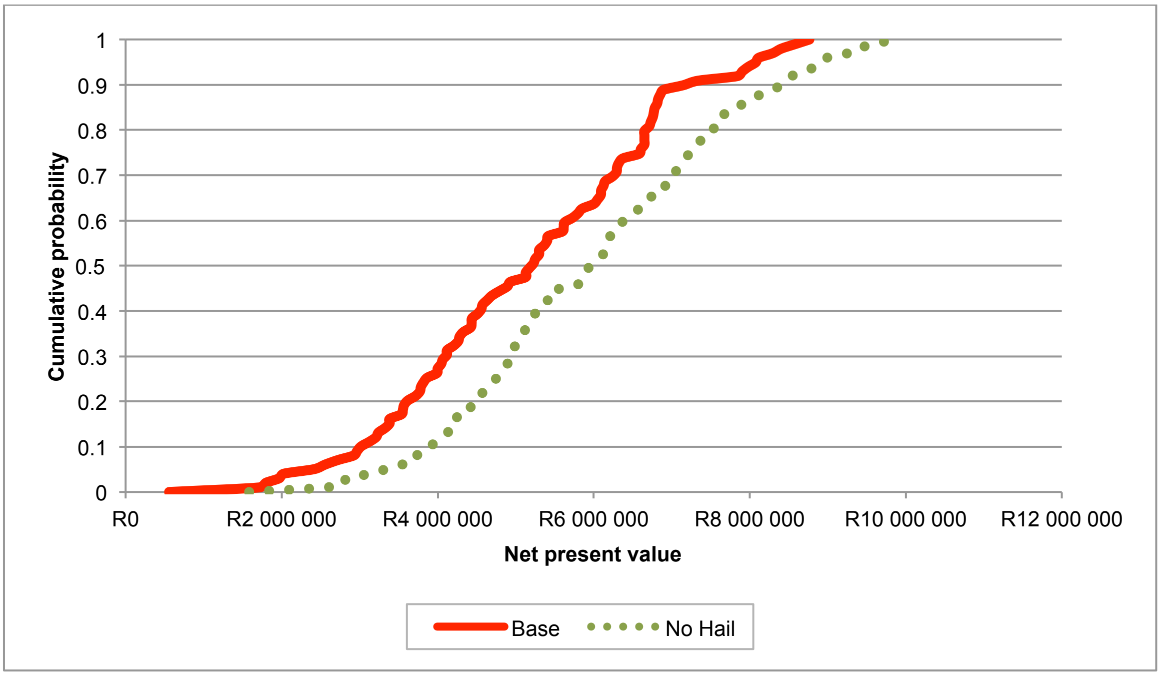

Figure 4.1: Cumulative probability distributions of the Net Present Value for the scenarios *Base* and *No Hail* in Lichtenburg

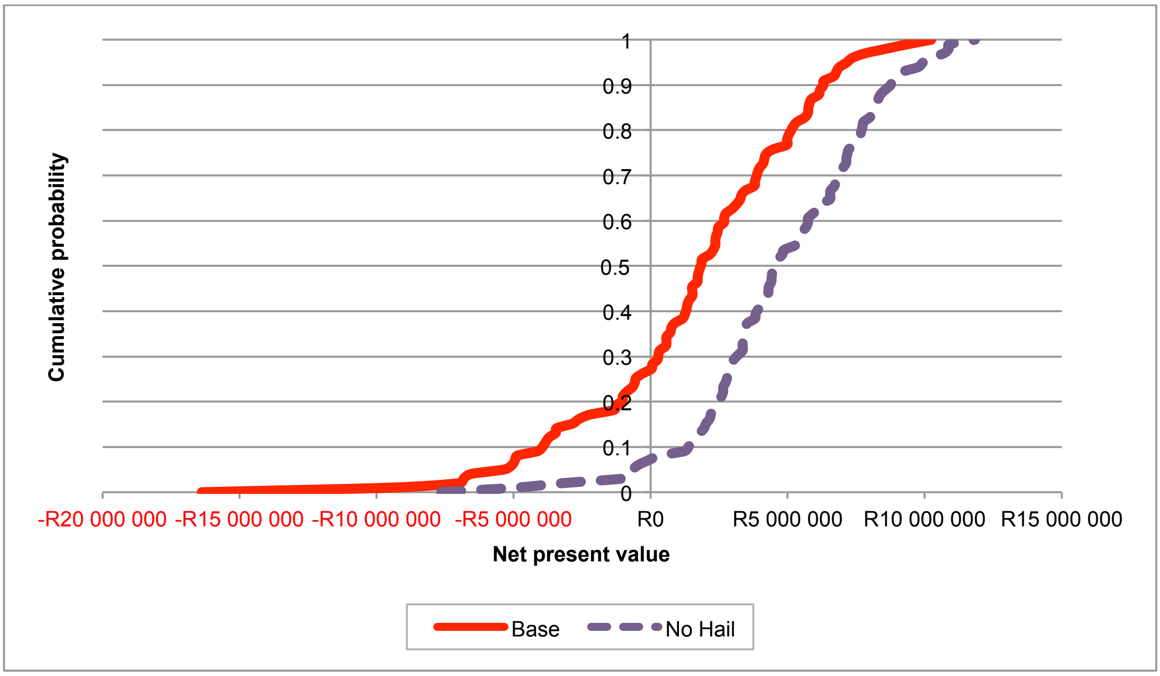

Figure 4.2: Cumulative probability distributions of the Net Present Value for the scenarios *Base* and *No Hail* in Standerton

The impact of hail in Standerton is very severe and may lead to enormous financial implications. The first alarming factor is the increase in the probability of realising negative NPVs. Hail increases the chance of negative NPVs by 19,2 percentage points from 7 % without hail, to 26,2% with hail. Hail damage decreases the maximum NPV by approximately R1,60 million, but causes the minimum NPV, that is already negative without hail, to decrease further by approximately R8,73 million. The fact that the influence of hail damage has a larger influence on the iterations with low NPVs than on the iterations with high NPVs is also of importance. The longer tail of the NPVs for the *Base* scenario in Standerton is important when it comes to the calculation of the maximum benefit of the elimination of hail as the risk aversion of the decision maker has an influence on the calculation. Risk-averse decision makers weigh the lower tail of the NPV heavier when calculating the CE.

Figure 4.3 below represents the utility weighted risk premium ($UWRP$) or maximum benefit, at different levels of risk aversion, which a decision maker will receive through the elimination of hail in Lichtenburg and Standerton. In Lichtenburg, the decision maker will receive a benefit of approximately R840 000 at low risk aversion levels ($r_s = 0.1$) and a maximum benefit of approximately R960 000 at high levels of risk aversion ($r_s = 2.5$). The small difference between the minimum and maximum level is due to the parallel shift in the NPV for Lichtenburg (Figure 4.1 above). The calculated benefit represents the NPV of the benefit over 23 years and for 500 hectares. The benefit that a risk-averse decision maker will receive in the first year is thus R83.50/hectare.

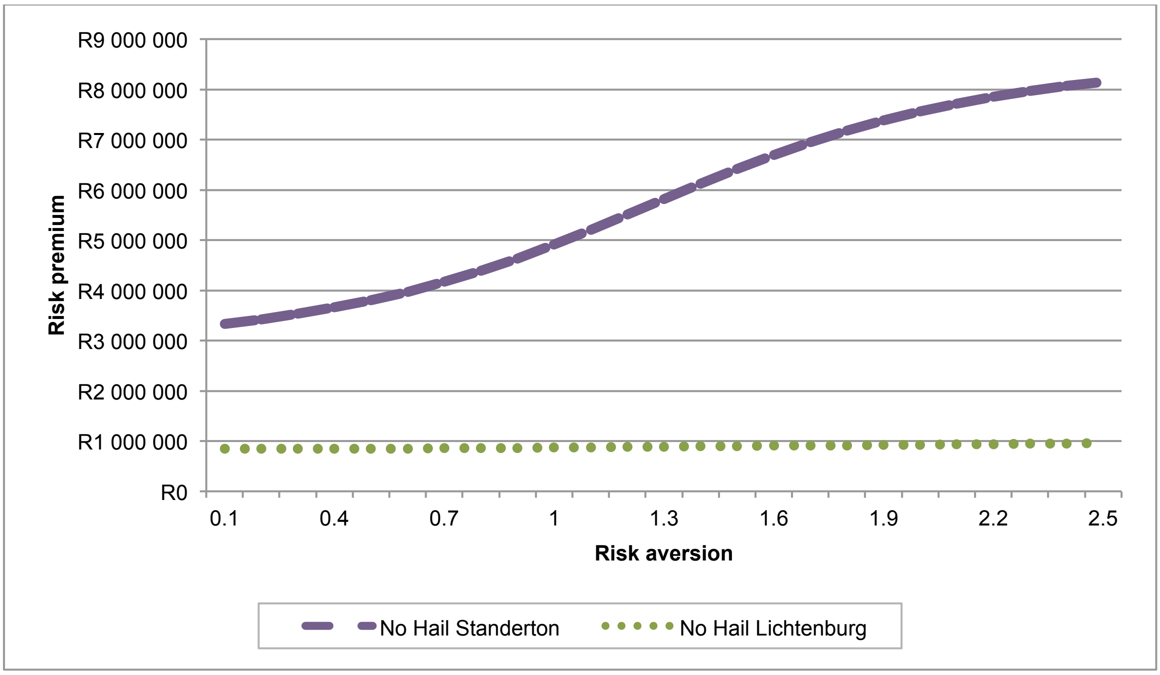

Figure 4.3: Utility weighted risk premium for the scenarios *Base* and *No Hail* in Lichtenburg and Standerton

The maximum benefit calculation for Standerton indicates that at low levels of risk aversion the NPV benefit of having no hail damage is approximately R3,32 million over 23 years, while the NPV benefit at high risk aversion levels is equal to approximately R8,15 million for the same time period. The influence of the long tail in the NPV for the *Base* scenario can thus be clearly seen here. The risk averse decision maker will thus receive a yearly benefit of R708,70 / hectare.

The cumulative probability distributions of the NPVs in Lichtenburg and Standerton confirmed that hail does have a negative impact on the financial position of the farm. The effect of hail risk in Standerton is, however, more severe, especially for the iterations with lower NPVs. The difference in the calculated maximum benefit that the elimination of hail damage will cause in the two regions also confirms the large impact of hail in Standerton. Although the elimination of hail in Lichtenburg will hold a benefit for the decision maker, it is very low in comparison with that of Standerton. The conclusion can thus be made that decision makers in both regions will be willing to pay for crop insurance, but much more so in Standerton than in Lichtenburg.

4.3 The financial advantage of different crop hail insurance options

The four different crop hail insurance options, *Insurance, ART 25, ART 50* and *ART PC*, all have different cost and benefit structures. The largest difference is definitely between *Insurance* and the different *ART* options, but there are some differences among the *ART* options as well. If one compares the cost of the different options, it is found that while *Insurance* has a specified premium based on a percentage of the crop's value, whereas *ART* depends on a contribution determined by the decision maker. Although the *ART* contributions in this study were kept at constant percentages or contributions as well, the percentage of each option differs from the other. On the benefit side, the *Insurance* option will always pay out the full amount of damage less the excess, while the *ART* options will only cover the claim fully if the there is sufficient funds in the account.

The differences in the cost and benefit structures of the different crop insurance options will affect the financial position of the enterprise in a corresponding way. The crop insurance option with the largest benefit will be the preferred option as it improves the financial position of the enterprise. In order to determine the financial influence of the different crop insurance options on the firm, the cumulative probability distributions of the NPVs after interest and tax can be analysed[2]. Although a shift in NPVs indicates whether an insurance option has an influence on the financial position of the enterprise, it is not easy to choose the most preferred option from these graphs. In the case of first-degree stochastic dominant (FSD) NPVs, a preferred option can be selected, as the NPVs are almost parallel and never cross one another. As soon as the NPVs start to cross one another, other methods of analysis have to be applied.

The stochastic efficiency with respect to a function (SERF) analysis was used to rank the outcomes of the different insurance options in order of preference, according to the decision maker's risk aversion level and correlated certainty equivalent (CE). The scenario with the highest

[2] The graphical presentations of the cumulative distribution functions of the NPV's are presented in Appendix A, Figures A1 – A6.

CE at a specific risk aversion level will be the most preferred scenario, while the one with the lowest CE will be the least preferred. The most preferred scenario is also the one with highest net benefit in terms of its cost and benefit structures and will thus influence the financial position of the enterprise the most positively.

Figure 4.4 below shows that in Lichtenburg, at very low levels of risk aversion ($r_s = 0.1$), the results for the five scenarios is quite close together. The decision maker will prefer the *Base* scenario and then *ART PC* (these two are almost equal) as they result in the highest certainty equivalent (CE) while *ART 25* will be in the third place and *ART 50* and *Insurance* in the fourth and fifth places, but also almost equal. A decision maker with a low level of risk aversion will not receive any benefit to move away from the *Base* scenario and will thus not be willing to pay a $UWRP$ for any of the crop hail insurance options.[3] The cost of using insurance thus exceeds the benefit that the product provides and the decision maker will be better off by taking the risk of hail damage, rather than the cost of insurance.

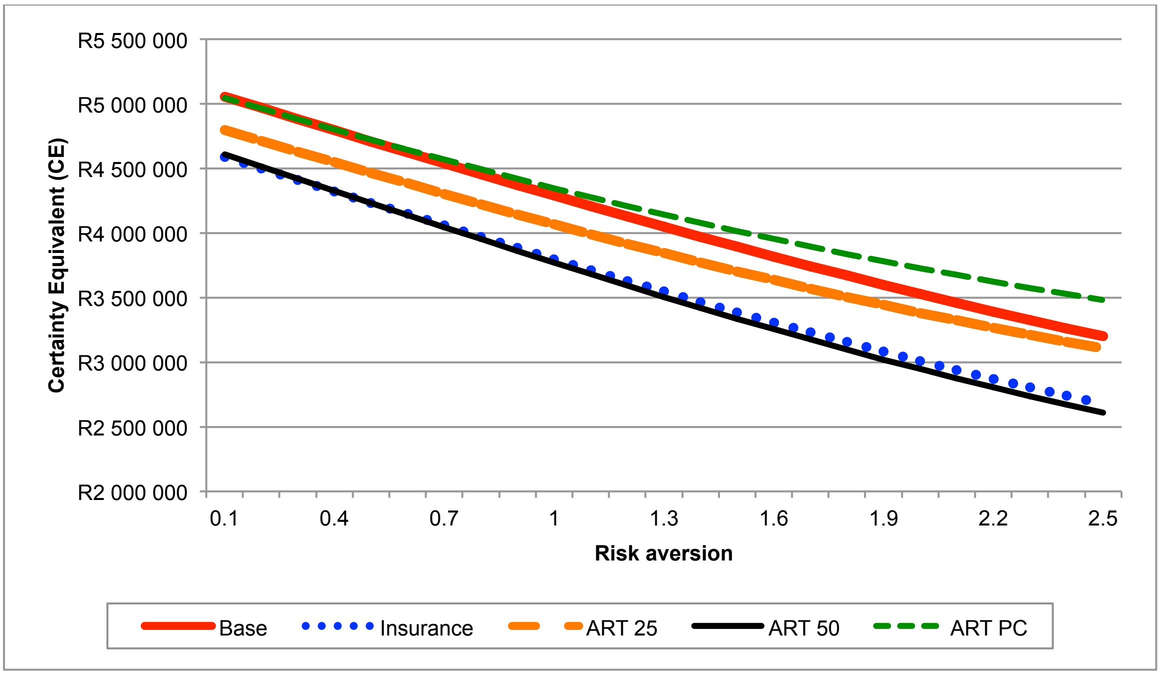

Figure 4.4: SERF analyses for all the insurance scenarios in Lichtenburg

High levels of risk aversion ($r_s = 2.5$) in Lichtenburg change the order of preference and the decision maker will now definitely prefer *ART PC* to the *Base*. *ART 25* is still in the third place, but the difference in CE's between *ART 25* and the *Base* are now smaller. At this high level of risk aversion, *Insurance* now has a higher CE than *ART 50*, but the difference is still relatively small. The risk-averse decision maker will receive a maximum benefit of approximately R282 000 to move from the *Base* to *ART PC*. The yearly benefit of *ART PC* results in R24,50/ha. The cost of *ART PC* is thus less than the benefits for the risk-averse decision maker.

[3] The graphical presentations of the utility weighted risk premiums are presented in Appendix A, Figures A7 – A8.

The only option of crop hail insurance that will provide a financial advantage for the decision maker in Lichtenburg is *ART PC*. The very low preference that the decision maker shows in *Insurance* is a clear indication that cost for this option is too high. One of the problems with the ART options is that the decision maker does not know how big the contribution to the fund must be in order to be able to cover the hail risks. From the results, it can be seen that the *ART 50* contribution may be too large as the $UWRP$ (maximum benefit) decreases with an increase in the risk aversion level, as is the case of *Insurance*. The premium contributed to the *ART 50* fund is thus more than the amount of claims being paid out. The contributions for *ART25* also seem to be a bit too high, but less so as the preference for his product increases a bit as the level of risk aversion increase. The sharp increase in the preference for *ART PC* and the maximum benefit thereof show that this contribution may be just about right. The much smaller contribution to the *ART PC* fund than to the other *ART* options seems to be just enough for the relatively low levels of hail risk in Lichtenburg.

Figure 4.5 below for Standerton shows that the influence of the risk aversion level is greater here than in Lichtenburg, as the difference in CEs between the alternatives increase more as the risk aversion level increases.

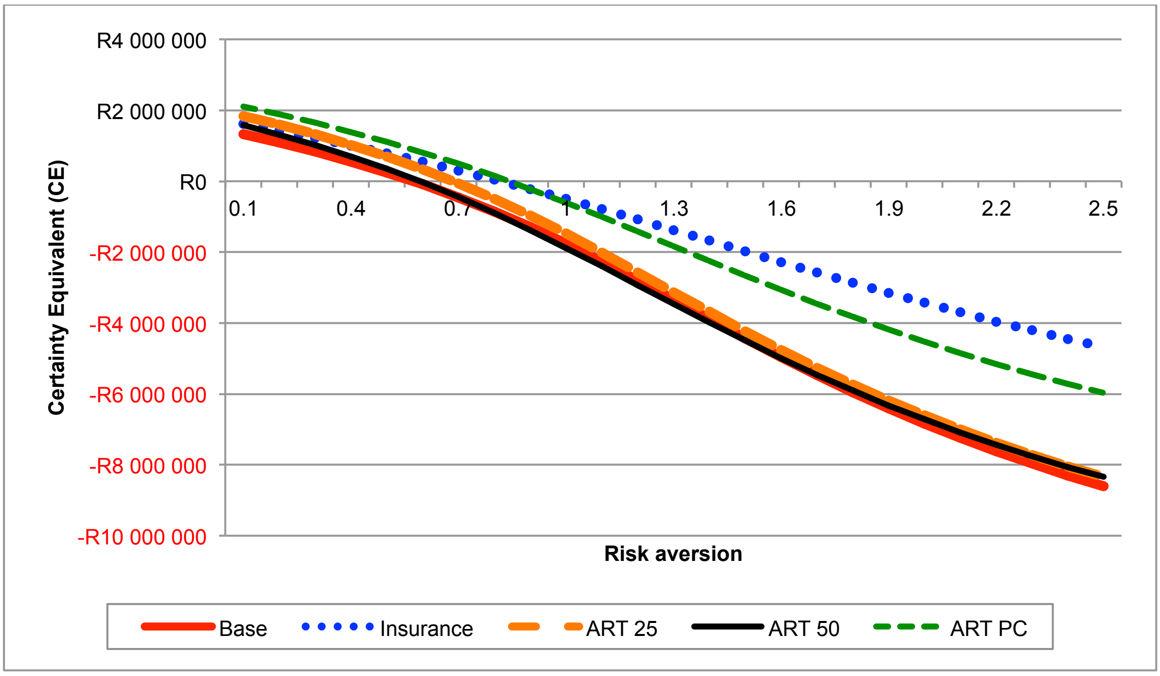

Figure 4.5: SERF analyses for all the insurance scenarios in Standerton

At low levels of risk aversion ($r_s = 0.1$), the difference in CEs between the alternatives are very small but the decision maker will prefer *ART PC* to *ART 25, Insurance, ART 50* and the *Base*, in that particular order. The decision maker will receive a benefit to move from the *Base* to any of the other options. The cost of all the insurance options is thus lower than the benefits resulting in a net benefit. The maximum benefit that the different insurance options offer are approximately

R780 000 for *ART PC*, R510 000 for *ART 25*, R291 000 for *Insurance* and R251 000 for *ART 50.* *ART PC* will result in the highest yearly benefit at low risk aversion levels amounting to R67,80/ha.

As the level of risk aversion increases, the *Insurance* and *ART PC* becomes more preferred, while the difference in CEs between the other three scenarios decrease further. At high levels of risk aversion ($r_s = 2.5$), *Insurance* is preferred to *ART PC* that is again preferred to *ART 25, ART 50* and the *Base,* in that particular order. The maximum benefits that the decision maker will receive to move from *Base* to the other options are approximately R3,93 million for *Insurance*, R2,63 million for *ART PC*, R262 000 for *ART 25* and R258 000 for *ART 50.* These figures indicate that for a risk-averse decision maker, the benefit of having insurance increases further. The two options that resulted in the highest maximum benefit will provide the decision maker with a yearly benefit of R341,70/ha for *Insurance* and R228,70/ha for *ART PC*.

Although all the scenarios in Standerton are preferred to the *Base* scenario, the *Insurance* and *ART PC* scenarios really stood out in order of preference and maximum benefit. The high risk of hail in Standerton may be one of the reasons leading to this distinct preference of only two options. The high occurrence of hail damage in Standerton causes the value and frequency of claims to be high. This high frequency, and expensive, claims drain the *ART 25* and *ART 50* policies faster than the fund could be build up. But, why does the *ART PC* do so much better then? The reason for the *ART PC* policy performing better is also the other reason for the weak performance of the *ART 25* and *ART 50* policies. Standerton's variable production cost, excluding insurance, is approximately 30 % per expected ton of yield more than that of Lichtenburg. The influence of the high production cost can be seen in the fact that the enterprise has a probability of realising negative NPVs, even without the occurrence of hail. The contributions to the *ART 25* and *ART 50* policies are only made in years when the gross margin is positive. During the years with negative gross margins, the *ART* cannot grow. In the case of *ART PC,* a contribution equal to the amount that should have been paid for the premium of *Insurance* is contributed to the fund, regardless of the outcomes of the gross margin. The *ART PC* thus has a better ability to offer protection, as the contributions to the fund are constant.

These results indicate that although all the insurance options have an influence on the financial position of the enterprise, the influence is not always positive. The cost of some of the insurance options definitely outnumbers the benefits and thus actually holds a disadvantage for the financial position of the enterprise. The risk aversion level of the decision maker plays a large role in the choice of crop insurance. As the decision maker becomes more risk averse, preference levels of almost all the insurance options increases, together with the maximum benefit the decision maker can get by adopting one of the options. Another factor that influences the benefits that the insurance product can offer is the amount of hail risk in a certain region. The cost of *Insurance* is the same in both regions, as a percentage of the crop's value. The higher occurrence of risk in

Standerton, however, forces the insurance product to deliver more benefits in the form of claims, while it is not the case in Lichtenburg with its lower claims history. Both Short-term Crop Hail Insurance and ART can offer the enterprise a financial advantage if the right product is applied in the right region. The risk aversion of the decision maker, the impact of hail in the specific area and the cost of the available insurance options must be analysed carefully to enable the decision maker to choose the product that will offer the best financial advantage.

4.4 The ability of different crop hail insurance policies to provide continuous hail risk cover

One of the most important measures in the effectiveness of a crop hail insurance policy is its ability to provide continuous hail risk cover. A positive NPV discounted over 23 years does not mean that the net margin of every year will be positive. Concern is especially raised on the ability of ART policies to provide continuous hail risk cover. Short-term Crop Hail Insurance provides the decision maker with full cover, less the excess, in exchange for a premium based on the value of the insured crop. ART, on the other hand, only provides as much cover as there is money in the built up fund, plus the percentage of additional cover according to the policy. In the event of a hail damage claim being more than the available ART cover, the policy will only pay out what is available and the rest of the loss has to carried by the decision maker.

In order to determine if ART has the ability to provide continuous hail risk cover, the claim pay-outs of ART must be compared with the claim pay-outs of Short-term Crop Hail Insurance. By subtracting the ART pay-out from the Short-term Crop Hail Insurance pay-out, it is possible to calculate the amount of loss due to hail damage that must be carried by the decision maker. *ART PC* is the only ART policy that provides the decision maker with a net benefit. The pay-outs of *ART PC* is thus compared with the pay-outs of insurance in Table 4.1 below. The year number in the table indicates the specific year in which the differences occur, with year 1 as the first year and year 23 as the last year. The probability, in percentage, indicates the chance that an *ART PC* pay-out will be less than that of an *Insurance* pay-out in that specific year. The maximum, minimum and average indicate the actual calculated differences between the pay-outs, while the standard deviation of the differences are also calculated.

Table 4.1 below shows that for Standerton, some of the pay-outs from *ART PC* will be less than that of *Insurance* in 11 of the 23 years. The highest probabilities of the pay-outs being less occur in year 1, 3, 6, 7 and 9. The maximum amount with which *Insurance* pay-outs will be more than that of *ART PC* is R2 716 921 and the minimum is R727.

Table 4.1: Probabilities of *Insurance* pay-outs being more than that of *ART PC* for Standerton and Lichtenburg

	Year										
	1	**2**	**3**	**4**	**5**	**6**	**7**	**9**	**10**	**13**	**14**
	Standerton										
Probability	12%	2%	11%	3%	4%	17%	14%	10%	1%	3%	2%
Maximum	R 1 413 770	R 835 782	R 1 536 566	R 1 072 066	R 1 413 214	R 1 843 967	R 1 926 758	R 2 716 921	R 189 344	R 1 272 509	R 622 785
Minimum	R 36 561	R 10 592	R 27 103	R 131 432	R 335 406	R 727	R 102 142	R 19 023	R 189 344	R 281 340	R 587 931
Average	R 362 822	R 423 187	R 446 900	R 750 474	R 894 199	R 638 569	R 618 782	R 933 927	R 189 344	R 867 631	R 605 358
Stdev	R 368 319	R 412 595	R 513 016	R 437 840	R 381 790	R 591 347	R 477 339	R 922 597	R -	R 424 490	R 17 427
	Lichtenburg										
Probability	9%	2%	0%	0%	0%	0%	5%	0%	1%	0%	0%
Maximum	R 528 057	R 640 551	R -	R -	R -	R -	R 338 020	R -	R 615 889	R -	R -
Minimum	R 15 027	R 89 973	R -	R -	R -	R -	R 58 481	R -	R 615 889	R -	R -
Average	R 172 584	R 365 262	R -	R -	R -	R -	R 165 341	R -	R 615 889	R -	R -
Stdev	R 155 434	R 275 289	R -	R -	R -	R -	R 98 423	R -	R -	R -	R -

For Lichtenburg, the probability of the *ART PC* pay-out being less than *Insurance* is lower than in Standerton. In Lichtenburg some of the *ART PC* pay-outs is only less than that of *Insurance* in 4 of the 23 years. The highest probabilities of the pay-outs being less occur in year 1, and 5. The maximum amount with which *Insurance* pay-outs will be more than that of *ART PC* is R640 551 and the minimum is R15 027.

The differences in pay-outs for the two regions once again show that the influence of hail damage in Standerton is more severe than in Lichtenburg. The *ART PC* scenario in Standerton needs 7 years before it can accumulate enough funds to provide full risk cover for a year, while it can only provide continuous full risk cover for the last nine years of time series. In Lichtenburg, on the other hand, the fund only needs two years to accumulate enough funds to provide full risk cover for next four years, while it provides continuous full risk cover for the last eleven years of the time series.

The results show that even though *ART PC* is preferred to the *Base* scenario in Standerton, it remains very risky and will not be able to provide the same level of hail risk cover as the *Insurance* scenario, owing to the high differences in pay-outs. Although *ART PC* may seem relative risky in Lichtenburg as well, as the pay-out of the *ART PC* may be as much as R640 551 less than that of *Insurance*, the *ART PC* scenario remains the best option as it will provide the decision maker with the most benefits of all the available options. ART thus certainly does not have the same ability as Short-term Crop Hail Insurance to provide continuous hail risk cover and it proves that ART is less effective. These findings, however, do not suggest that ART must not be used as a crop hail insurance measure, as it certainly can provide benefits to certain decision makers, depending on the impact of hail risk in the area in which it is used and on the risk aversion level of the decision maker.

4.5 Conclusion

The objective of the study was to evaluate the effectiveness of ART against Short-term Crop Hail Insurance as risk management strategies for hail damage. In order to determine the need for crop hail insurance in the chosen areas, it was necessary to determine the financial extent of hail risk's impact. The leftward shift indicated a negative impact on the financial position of the enterprise. The difference between the two regions, however, comes in at the impact of hail on the iterations with low NPVs. In Lichtenburg the shift of the NPV was almost parallel, indicating that iterations with low and high NPVs suffer the same amount of financial impact due to hail. In Standerton, however, the effect of hail had a much higher impact on the iterations with low NPVs than on those with high NPVs. This high impact on the lower NPVs caused the tail of the cumulative probability distribution of the NPVs to be much longer. The maximum benefit that the elimination of hail provides was calculated by determining the $UWRP$ with the SERF analysis. The maximum benefit that the elimination of hail provides also indicated the lower impact of hail in Lichtenburg, as decision makers with a high level of risk aversion will only receive a maximum yearly benefit of approximately R83,50/ha, while decision makers with the same level of risk aversion will receive a yearly maximum benefit of R708,70/ha. Hail damage does have an impact on the financial position in both regions, but the extent of the impact in Standerton is much more severe than in Lichtenburg.

The cost and benefit structures of the different crop hail insurance options differ from one to another. Although it is easy to realise that the cost and benefit structures of Short-term Crop Hail Insurance and ART will be different, the difference applies to the different ART contributions as well. While Short-term Crop Hail insurance has a fixed premium (cost) as percentage of the crop's value and covers all claims (benefit) fully, less the excess, the premium (cost) of ART is determined by the amount the decision maker decides on and the claims (benefit) can only be as much as the accumulated funds, plus the extra percentage cover from the insurer. The difference between the costs and benefits of a crop hail insurance policy determines the net advantage (or disadvantage) that it will bring to the financial position of the enterprise. The results indicated that although all the insurance options did influence the financial position of the enterprise, it was not always positive. The costs of some of the crop hail insurance options definitely outnumbered the benefits, resulting in a negative financial impact for the enterprise. It was found that the impact of hail risk in a specific region, the cost of the insurance option, the variable production cost of the crop and the level of risk aversion of the decision maker all play a vital role in the calculation of the net advantage a crop hail insurance option will provide to the enterprise. Owing to these factors, an ART product is the most preferred option in Lichtenburg and Short-term Crop hail insurance is the preferable option in Standerton. All these variables must be considered and analysed carefully in order for the decision maker to make an informed decision on the crop hail insurance option that will be used.

The last test for effectiveness of the different crop hail insurance options was the ability of the different options to provide continuous cover against hail risk. Although the financial impact of a product may seem positive over the long term, it cannot be concluded that the product will be able to provide sufficient cover each year. The concern is especially with regard to ART, where the level of cover depends on the accumulated funds in the policy. The difference between the claim pay-outs of Short-term Crop Hail Insurance and ART indicates not only the instances where ART could not provide full cover, but also the amount of risk that will now have to be carried by the decision maker. The results show that although one of the ART products was the most preferred option in Lichtenburg, and the second preferred one in Standerton, the product does not include the ability to deliver continuous cover against hail risk. In Standerton, the risk of using ART is especially high, as the product is unable to cover all losses in 11 of the 23 years. The shortage in the pay-out of ART can amount to values of up to R2,70 million and the probability of the decision maker being able to carry these losses is very low. In Lichtenburg, the ART policy is also not always able to provide continuous protection, but the probability of the instances when it does happen and the size in difference between pay-outs are much smaller than in Standerton. While it can be concluded that ART is ineffective in Standerton, owing to its inability to provide continuous cover and the large differences in pay-outs, the same conclusion cannot necessarily be made for Lichtenburg. The differences in pay-outs in Lichtenburg are small enough to be counter for by the decision maker. The enterprise in Lichtenburg never returns a negative NPV, even without insurance, while the financial impact on the enterprise and the maximum benefit of the ART policy provides a total financial advantage for the enterprise.

CHAPTER 5
SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

This chapter provides a summary of the study, together with a conclusion. The final section is devoted to giving recommendations regarding the findings of the study.

5.2 Summary

Decision makers are uncertain about the type of crop insurance that will be the most effective in terms of their enterprise's needs. The uncertainty stems from a lack of information on the risks that have an influence on the farm and the crop insurance products that can be used to mitigate the risks. Owing to this problem, the primary objective of the study was to evaluate the effectiveness of ART against Short-term Crop Hail Insurance as risk management strategies in two regions: Standerton as a high hail risk area and Lichtenburg as a low hail risk area.

5.2.1 Literature review

The reviewed literature indicated that risk in agriculture matters as it has an influence on the financial position of the farm. Risk research in agriculture is thus typically concerned with estimating the influence of a risk in terms of a monetary outcome. Agricultural risks can further be characterised, in terms of its occurrence, predictability and in relation to other risks, and classified, in terms of the cost of the event and the source of the risk. Hail risk, for example, is characterised as an Idiosyncratic risk and classified under Production risks.

According to the literature, crop insurance is certainly the most used risk mitigation strategy for crop farming. A wide range of crop insurance products are available, of which the most used named (single) peril crop insurance is Short-term Crop Hail Insurance. Alternative Risk Transfer (ART) is one of the newer forms of insurance and although it was not originally designed as a crop insurance product, it may be used for it. Different authors have identified various factors influencing the adoption of or willingness to pay for crop insurance. Some of these factors that were of importance to this study are the level of coverage of the insurance policy, yield and price variability, level of risk aversion of the decision maker, the occurrence and impact of damage, the effectiveness of previous insurance policies, and the risk level of the region where the farm is situated.

5.2.2 Procedures

Agricultural risks and the influence thereof was analysed in the past by various techniques. The procedures that were applied in this study basically consisted of three different types of analysis. The first procedure was the development of a farm financial model. Simulation models are ideal for analysis where the real life situation involving various variables must be simulated. The model was developed in Microsoft Excel and calculates the margin after interest and tax for each season over a 23-year period, according to variable levels of hail risk, yields, prices and different insurance options.

The available historic yield and price data for maize did not match the time series of the available hail data. This raised the need for the second procedure where multivariate empirical (MVE) probability distributions were estimated and simulated for the stochastic variables. MVE allows for the deriving of multivariate distribution functions from the available data, while the historical relationship between the variables is maintained in the simulated variables.

The third and last procedure was stochastic efficiency with respect to a function (SERF) that was used to perform the risk efficiency analysis. SERF is the most recent advance in ranking risky alternatives and orders the certainty equivalents (CE) in monetary terms. The monetary expressed CEs do not only make interpretation easier, but allow the researcher to calculate the utility weighted risk premium (UWRP) between alternatives.

5.2.3 Results

The results were interpreted on the basis of five scenarios that were simulated with a simulation model. The first scenario was the *Base* scenario where no crop hail insurance product was used. The second one was the *Insurance* scenario that made use of Short-Term Crop Hail insurance. The third and fourth scenarios were *ART 25* and *ART 50* which made use of ART insurance at respective policy contributions of 25 % and 50 % of the gross margin (before interest and tax). The last scenario was *ART PC* where ART insurance was also used, but the contribution to the fund is equal to the premium that would have been paid for the Short-term Crop Hail Insurance policy.

The first secondary objective was to determine the financial extent of hail risk's impact in order to determine the need for crop hail insurance in the specific area. The difference between the cumulative probability distributions of the Net Present Values (NPV), after interest and tax, between a scenario with hail risk (but no insurance in place) and a scenario without any hail risks, indicated that hail risk influences the financial position of the enterprises in both the Standerton and Lichtenburg areas. The impact of hail risk in Standerton was, however, much more severe and increased the probability to return negative NPVs, while it also had a larger effect on the iterations with low NPVs than on those with high NPVs. The large effect on the iterations with low NPVs causes the tail of the graph to be longer. The maximum benefit (UWRP) that the decision maker will receive through the elimination of hail shows that the decision makers in both areas are willing to pay for crop hail insurance, but more so in Standerton than in Lichtenburg. The maximum benefit for decision makers in Lichtenburg are relatively constant and do not change much as the level of risk aversion of the decision maker increases. In Standerton, the level of risk aversion, however, plays a large role, owing to the longer tail of the NPVs, and causes the maximum benefit of a decision maker with high levels of risk aversion to be more than double that of a decision maker with a low risk aversion level.

The second sub-objective was to determine the financial advantage of the different crop insurance strategies. The cost and benefit structures of crop insurance products differ and thus influence the financial position of the enterprise differently. The difference between the costs and benefits of a certain product provides the enterprise with a net advantage (or disadvantage) and the option with the largest net financial advantage is the one that will be used by the decision maker. The SERF analysis indicated that in Lichtenburg, only the *ART PC* options provided the enterprise with a financial advantage, while that was the case with all the crop insurance in Standerton. However, the only crop insurance options in Standerton that have a significant advantage were Short-term Crop Insurance and *ART PC*. These results are a bit contradictory with those indicating that the decision maker is willing to pay for crop insurance in both regions. The reason for this may be that costs of the other crop insurance options were more than the benefits and thus too expensive for the decision maker. The high cost of the least preferred options are easily observable, as the UWRP for these options decreases as the level of risk aversion increases, while it is the other way around for the preferred options. From the results, it can further be concluded that the impact of hail risk in a specific region, the cost of the insurance option, the variable production cost of the crop and the level of risk aversion of the decision maker play a vital role in determining which crop insurance product will provide the decision maker with the largest net benefit.

The third, and last, sub-objective was to determine the ability of the different crop hail insurance policies to provide continuous risk cover. In order for a crop hail insurance product to be effective, it must include the ability to provide continuous risk cover. The ability of ART to provide continuous risk cover is especially of concern, as the product consists of a fund that is built up over time and the level of coverage thus depends on the size of the fund. The comparison between the claim pay-outs of Short-term Crop Hail Insurance and the *ART PC* product in both regions indicates that the ART product does not have the ability to provide continuous risk cover. This, however, does not necessarily brand the ART product as ineffective, as it still delivers the best returns of all the crop insurance products in Lichtenburg, while the differences in claim pay-outs may be covered by the enterprise with liquid reserves. In Standerton, although the second preferred option, ART is ineffective as the probability of claim pay-outs being to less than that of Short-term Crop Insurance is higher than in Lichtenburg, while the size of the differences in pay-outs are also too large to be covered by liquid reserves.

5.3 Conclusion

Alternative Risk Transfer (ART) as an insurance option seems viable in both the Lichtenburg and Standerton regions, but the concern remains regarding the constant risk cover that it provides. Decision makers thus carefully have to analyse the probabilities of the ART pay-out being less than the damage incurred. Some of the differences may be small enough to be covered by liquid reserves, but in instances of large losses the difference may be so large that it may lead to solvency problems. Another problem of ART that must be kept in mind is the requirements of financial institutions for the provision of production credit. One of these requirements is usually that the producer must have multi-peril crop insurance in place. In the event where the accumulated ART policy is smaller than the required amount of production credit, the financial institutions may not be able to provide the needed credit. The precise amount that must be contributed to the policy in order to reap the most benefits must still be determined. Of the three different contribution levels that were used, it is clear that *ART PC* provided the best cover. It however remains an open question what the optimal contribution amount is?

Short-term Crop Hail insurance is a product that has been used by producers for the protection of their crops against hail damage for centuries. The largest advantage of Short-term Crop Hail insurance is that the producer is always certain of full cover, less the excess, in the event of hail damage. The cost of this product may, however, be too high in areas with low occurrences of hail damage. In order to determine if this product will result in a net benefit for the enterprise, the cost and benefits of the product must be carefully evaluated in terms of the occurrence of hail, the risk aversion level of the decision maker and the production cost of the crops. In areas with high occurrences of hail damage, there seems not to be a better alternative for crop hail insurance cover and Short-term Crop Hail Insurance is more of a necessity than anything else.

In final conclusion, it was found that both Short-term Crop Hail Insurance and ART might be effective measures for the mitigation of hail damage, as long as these products are implemented according to findings of proper research into the option that will provide the enterprise with the largest net benefit.

5.4 Recommendations

It is recommended that further research should be done to expand on the findings of this study. The first suggestion will be to repeat the study in other maize production areas in order to determine the influence of insurance at additional levels of hail damage. The study can further be expanded to other crops, such as soybeans, that are influenced by hail, or to other perils, such as frost. Further research regarding the size of the ART contribution is also suggested so that a more precise and reliable formula can be used to determine the optimal contribution. Since the model can easily be adapted to be applied on not only other field crops but horticultural crops with different types of risk perils as well, it is suggested that the model should be applied to other sectors of agriculture to test the effectiveness of insurance on these sectors. ART might be more effective against risks types of which low impact occurrence can be prevented and where the ART fund is only used for events where the prevention methods are not enough to cover the full impact of the risk.

Farmers are advised to obtain as much information on the risks they are faced with and the costs and benefits of different insurance products before a certain type of insurance is chosen. By doing some research and comparing the net benefit that each of the different insurance products may bring to the table, the decision maker will be able to choose the insurance product with the highest net benefit.

It is recommended that insurers apply the study to their different products and insured areas. The results of each area can then be used as a marketing tool to indicate the net benefit that the specific product may bring to the enterprise. The findings of such comparisons will also enable the insurer to re-evaluate the premium of the different insurance products and adjust it to a level where both the insurer and insured will benefit from the insurance product.

Lastly, it is recommended that the results be used as an argument for policy regarding government subsidies for insurance. The results not only show the impact of hail on the maize enterprise of farmers, but also the influence of the costs and benefits of the crop insurance products. A subsidised insurance scheme may increase the adoption of crop insurance in South Africa, resulting in a more secure environment for farmers practising the high risk occupation of farming.

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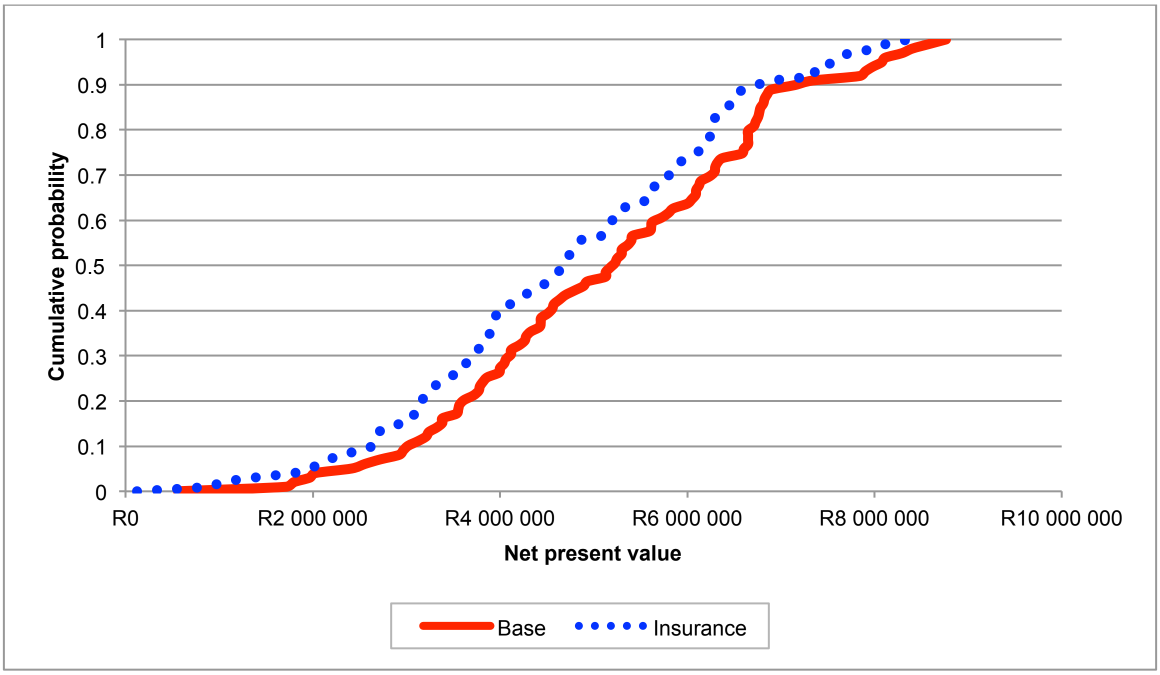

Figure A1: Cumulative probability distributions of the NPV for the scenarios *Base* and *Insurance* in Lichtenburg

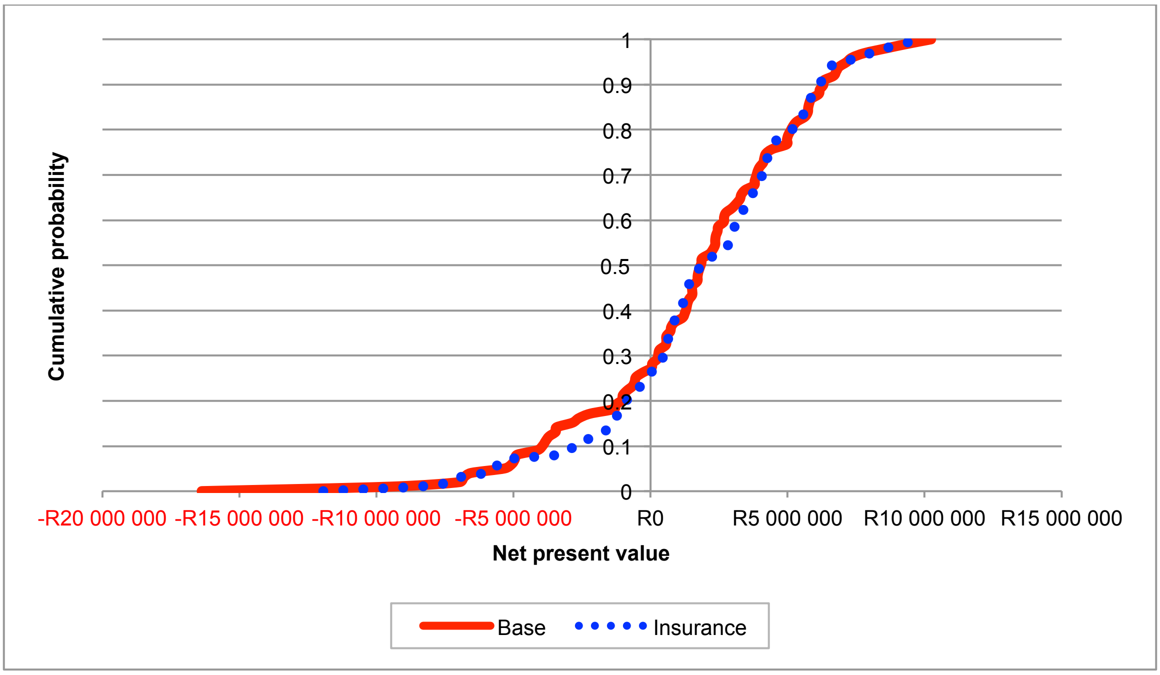

Figure A2: Cumulative probability distributions of the NPV for the scenarios *Base* and *Insurance* in Standerton

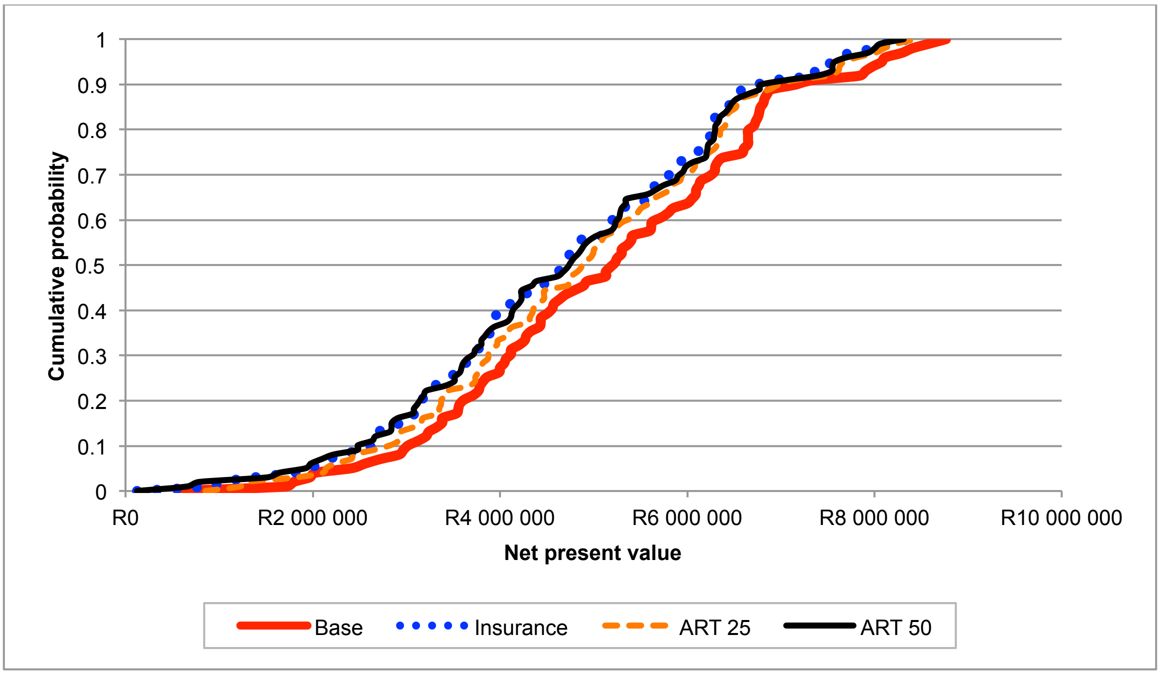

Figure A3: Cumulative probability distributions of the NPV for the scenarios *Base*, *Insurance, ART 25* and *ART 50* in Lichtenburg

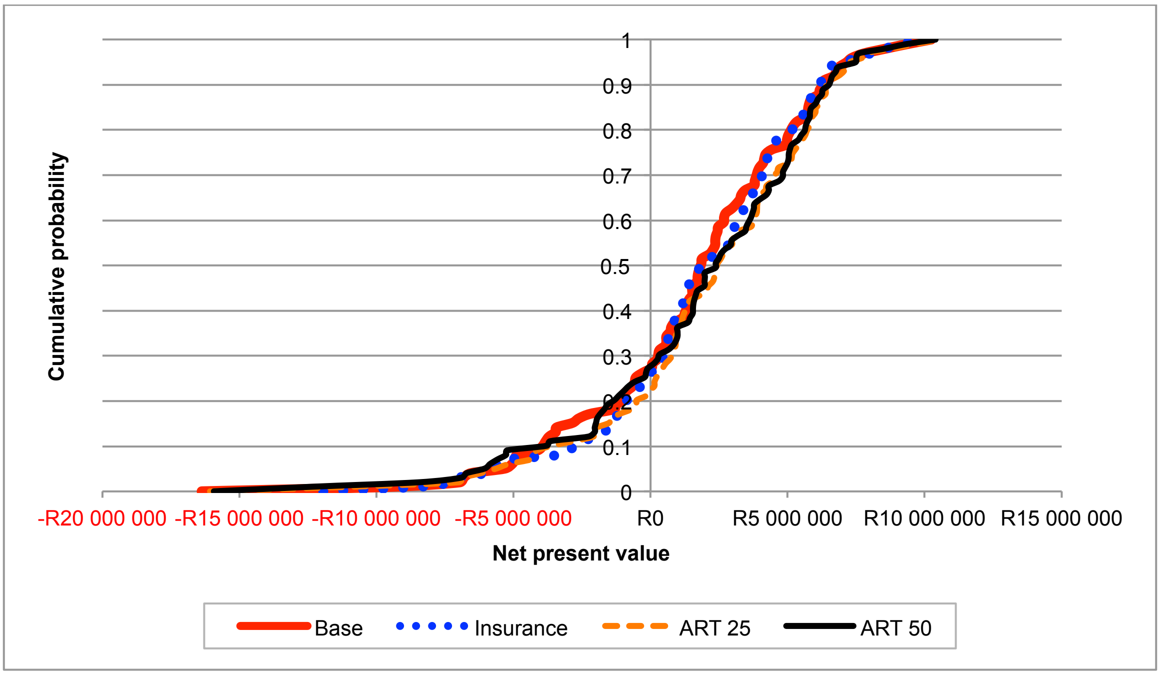

Figure A4: Cumulative probability distributions of the NPV for the scenarios *Base*, *Insurance, ART 25* and *ART 50* in Standerton

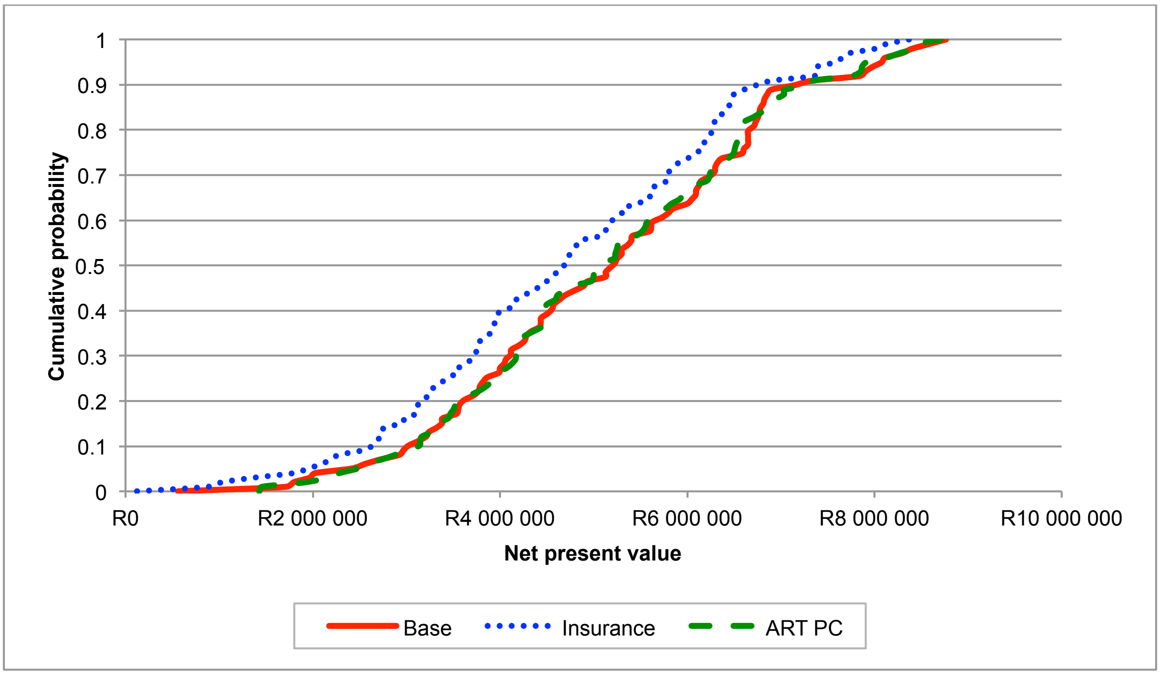

Figure A5: Cumulative probability distributions of the NPV for the scenarios *Base*, *Insurance* and *ART PC* in Lichtenburg

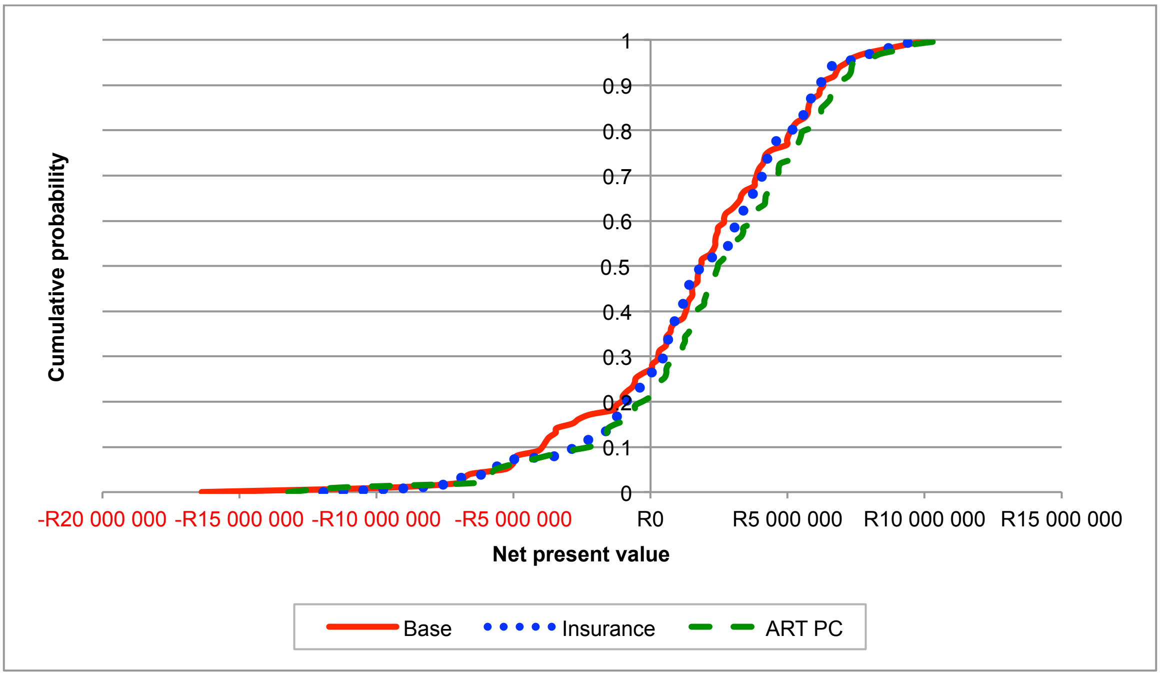

Figure A6: Cumulative probability distributions of the NPV for the scenarios *Base*, *Insurance* and *ART PC* in Standerton

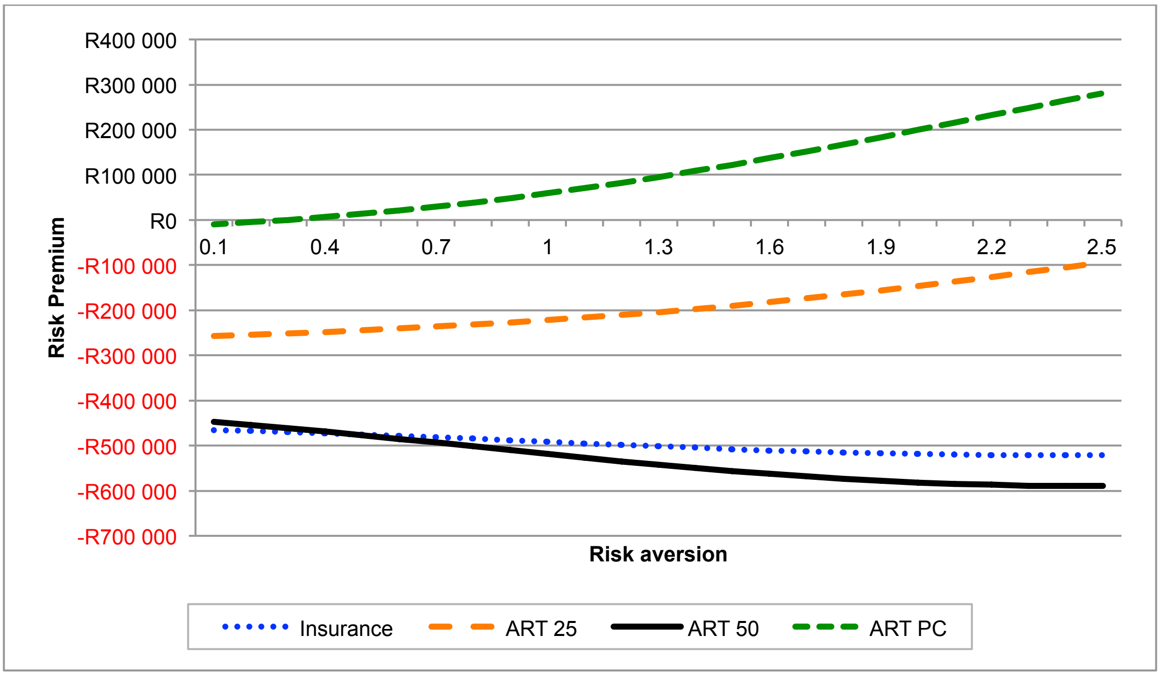

Figure A7: Utility weighted risk premium for all the insurance scenarios in Lichtenburg

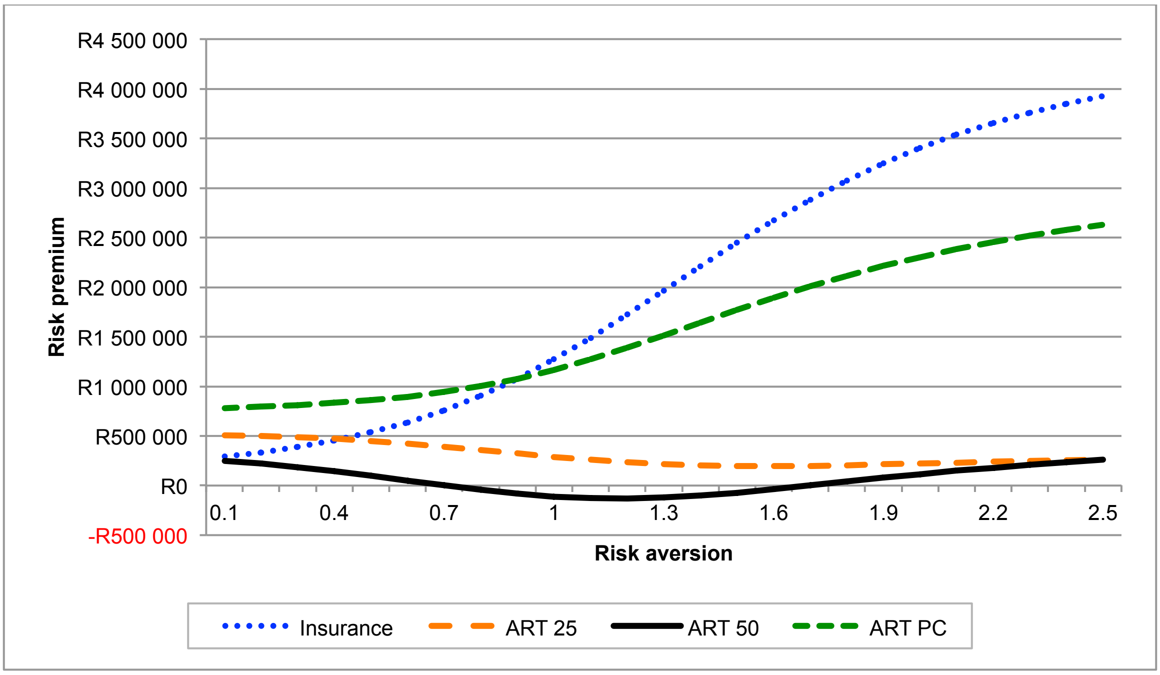

Figure A8: Utility weighted risk premium for all the insurance scenarios in Standerton