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Evaluating Alternative Risk Transfer as a Crop Insurance Policy under Stochastic Yields and Prices

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The purpose is to evaluate Alternative Risk Transfer (ART) against Short-term Crop Hail Insurance (SCHI) to provide cost effective and constant cover against hail risk under stochastic yields and prices. A farm financial simulation model was developed to simulate the influence of hail damage and the different crop insurance policies on a maize farm with variable levels of yields and prices. The yield and price data were simulated with the procedure for estimating and simulating multivariate empirical (MVE) probability distributions. The risk efficiency was analysed with stochastic efficiency with respect to a function (SERF). The insurance options with the largest net benefit to the enterprise were ART in the low hail risk area and SCHI in the high hail risk area. It was found that both SCHI and ART might be effective measures for the mitigation of hail damage, depending on the amount of hail risk present in certain area.

Keywords: Risk, Insurance, Alternative Risk Transfer, Simulation Model, SERF, Certainty Equivalent, Utility Weighted Risk Premium

1. Introduction and background

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 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 to ensure that it is efficient.

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). The three major groups of insurance products can also be subdivided, and for the purpose of this research it necessary to define *Damage-based indemnity insurance* (named peril crop insurance), of which Short-term Crop Hail Insurance (SCHI) is an example, and *Alternative Risk Transfer* (ART).

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).

Alternative Risk Transfer (ART) or Self-insurance is a newer form of risk protection and according to Banks (2004) 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 builds 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.

The purpose of this research is to evaluate Alternative Risk Transfer (ART) against Short-term Crop Hail Insurance (SCHI) to provide cost effective and constant cover against hail risks under stochastic yields and prices. 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. Stochastic efficiency with respect to a function (SERF) analysis ranks 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, or Utility Weighted Risk Premium (UWRP), of the preferred option. 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 SCHI will be compared.

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, 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 subsidize 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 programs 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.

The farm financial simulation model that was build to run the analyses will be discussed next, before the risk simulation and risk efficiency analysis that was used will be discussed. 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 provinces in South Africa; North West (low hail risk area) and Mpumalanga (high hail risk area). In each area, 100 iterations with individual farm hail data 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. 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. The results will first focus on the cost effectiveness of the different crop hail insurance options before the ability of the different insurance options to provide continuous cover will be discussed. The last part of the paper draws a conclusion on the findings of the study.

2. Farm Financial Simulation Model

The purpose of the model is to calculate the margin after interest and tax for the farming enterprise. The model was develop to run the hail risk data under stochastic yields and prices with various insurance options and was developed in Microsoft Excel®. The model operates under the assumption that all income and costs associated with the enterprise under analysis are cash based, although the debt levels of different farms can be incorporated easily into the model. The only loan facility that is utilized is a bank overdraft. The model is set up for a continuous maize farm and calculates the margin after interest and tax for each production season. The layout of the model is presented in Table 1. Section A of the model calculates the margin after interest and tax while Section B deals with insurance calculations of Short-term Crop Hail Insurance (SCHI), as well as Alternative Risk Transfer (ART) Insurance.

The shaded areas in the model are the variables that can be changed according to the specific scenario that must be analyzed, while the rest are formulas that are calculated according to the specified variables. The model is designed so that either SCHI or ART can be used as an insurance option. The example of the model in Table 1 uses SCHI to calculate the margin, but the calculations of the ART policy is illustrated in the second part of the model.

It is important to keep in mind that SCHI 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. The premium used for the SCHI 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 SCHI 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 SCHI. 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. In this example the administration cost of each new contribution is 6 %, interest received on the experience account is 4 % per year and the insured party receives an extra 20 % cover on the funds available in the experience account.

2.1. *Margin Calculation*

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:

$$\boldsymbol{M_i = PI_i + OI_i - TC_i + (INR_i - IPN_i) - T_i} \quad (1)$$

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)

2.2. *Income Calculations*

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. Target yield (TY_i) is the yield that is planned for at the beginning of the season and the area dependent costs are calculated accordingly. Expected 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 expected yield can thus be either higher of lower than the target yield. The Realized yield (RY_i) includes the influence of hail and is the yield that is harvested. The yield dependent costs are calculated according to the RY_i.

The production income (PI_i) is calculated as:

$$\boldsymbol{PI_i = A_i \times RY_i \times \tilde{P}_i} \quad (2)$$

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)

Realized yield (RY_i), as a function of hail damage is calculated as:

$$\boldsymbol{RY_i = \tilde{Y}_i \times (1 - \widetilde{HD}_i)} \quad (3)$$

where

$\tilde{Y}_i$	Expected Yield: Empirically distributed subjective yields for year i (t/Ha)
$\widetilde{HD}_i$	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 the section *Income From Crop Hail Insurance* as it is calculated in the second part of the model.

2.3. *Cost Calculations*

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 SCHI premium or the ART contribution is used at a time. The total cost of the enterprise is calculated as:

$$\boldsymbol{TC_i = (AC_i \times A_i) + STC_i + ARTC_i + YC_i + FC_i} \quad (4)$$

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	Total Yield dependent cost for year i (R)
FC_i	Total Fixed cost for year i (R)

The insurance cost for Short-term Crop Hail Insurance and ART are discussed in section *2.5. Cost Of Crop Hail Insurance*.

The Yield dependent cost (YC_i) is a function of the Realized yield (RY_i). As the expected yield dependant cost is the monetary amount if the Target yield is realized, it is necessary to calculate it according to the Realized yield, as the YC_i will decrease with a lower RY_i. The Yield dependent cost is thus calculated as:

$$\boldsymbol{YC_i = (EYC_i / TY_i) \times RY_i \times A_i} \quad (5)$$

where

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

TY_i Target yield for year i (ton/ha)

2.4. *Tax Calculations*

The income tax (T_i) for the model is calculated as:

$$\boldsymbol{T_i} = \begin{vmatrix} \boldsymbol{TI_i} \times \boldsymbol{TR} \quad if \quad TI_i > 0 \; and \; TI_{i-1} \geq 0 \\ (\boldsymbol{TI_i} + \boldsymbol{TI_{i-1}}) \times \boldsymbol{TR} \quad if \quad TI_i > 0 \; and \; TI_{i-1} < 0 \\ \boldsymbol{0} \quad if \quad TI_i < 0 \end{vmatrix} \quad (6)$$

where

TI_i Taxable income for year i (R)
TR Marginal tax rate (40%)

Equation 6 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 forward to the next year. The taxable income is calculated as:

$$\boldsymbol{TI_i} = \boldsymbol{PI_i} + \boldsymbol{OI_i} - \boldsymbol{TC_i} + (\boldsymbol{INR_i} - \boldsymbol{INP_i}) \quad (7)$$

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 funds between years for tax and interest purposes. The opening and closing bank balances is calculated as:

$$\boldsymbol{OB_i} = \begin{vmatrix} \boldsymbol{CB_{i-1}} \quad if \quad OB_{i \neq 1} \\ \boldsymbol{IB} \quad if \quad OB_{i=1} \end{vmatrix} \quad (8)$$

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:

$$\boldsymbol{CB_i} = \boldsymbol{OB_i} + \boldsymbol{M_i} \quad (9)$$

2.5. *Costs of Crop Hail Insurance Calculations*

The cost calculations of both Short-term Crop Hail Insurance and ART are discussed in this section. The Short-term Crop Hail Insurance cost is calculated as:

$$\boldsymbol{STC_i} = \left(\boldsymbol{A_i} \times \boldsymbol{IY_i} \times \boldsymbol{\widetilde{IP}_i}\right) \times \boldsymbol{STP_i} \quad if \quad ARTC_i = 0 \tag{10}$$

where

IY_i	Insured yield for year i (t/ha)
$\widetilde{IP}_i$	Insured price for year i (R/ton) as the forward contract price at harvest time
STP_i	Short-term insurance premium for year i (%)

The SCHI 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:

$$\boldsymbol{STP_i} = \left| \begin{array}{l} \boldsymbol{\lambda} \;\; if \;\; STP_{i=1} \; or \; if \; STC_{i-1} = 0 \; or \; if \; STR_{i-1} > 0 \\ \\ (\boldsymbol{STP_{i-1}} \times \boldsymbol{0.9}) \;\; if \;\; STC_{i-1} > 0, \; STR_{i-1} = 0 \\ \qquad and \; STP_{i-1} > 0.015 \end{array} \right. \tag{11}$$

where

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

The insured party only insures enough of the yield to cover the cost of the enterprise. 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:

$$\boldsymbol{IY_i} = \left| \begin{array}{l} \left(\boldsymbol{AC_i} + \boldsymbol{EYC_i} + (\boldsymbol{FC_i}/\boldsymbol{A_i})\right)/\boldsymbol{\widetilde{IP}_i} \;\; if \;\; IY_i < EY_i \\ \\ \qquad \boldsymbol{EY_i} \;\; if \;\; IY_i > EY_i \end{array} \right. \tag{12}$$

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 run with premiums of 25 % and 50 % of the gross margin and a premium equal to the premium of SCHI that would have been paid in the event where SCHI would have been used.

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

$$\boldsymbol{ARTC_i} = \left| \begin{array}{l} \boldsymbol{ARTP} \times (\boldsymbol{PI_i} - (\boldsymbol{AC_i} \times \boldsymbol{A_i}) - \boldsymbol{YC_i} - \boldsymbol{FC_i}) \;\; if \\ \quad ARTOB_i < \left((AC_i \times A_i) - YC_i - FC_i\right) > 0 \\ \\ \qquad \boldsymbol{0} \;\; if \;\; ARTCC_i > 0 \end{array} \right. \tag{13}$$

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

$$\boldsymbol{ARTOB_i} = \begin{vmatrix} \boldsymbol{ARTCB_{i-1}} \\ \boldsymbol{IC} \quad if \quad ARTOB_{i=1} \end{vmatrix} \tag{14}$$

where

$ARTCB_i$	ART fund closing balance for year i (R)
IC	Initial cash at fund start-up (R)

and

$$\boldsymbol{ARTCC_i = TC_i - PI_i} \quad if \quad RY_i < \tilde{Y}_i \; and \; TC_i > PI_i \tag{15}$$

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 had grown that specific year ($ARTY_i$) and is calculated as:

$$\boldsymbol{ARTY_i} = \begin{vmatrix} \boldsymbol{ARTC_i - ARTA_i + ARTI_i - ARTAF_i} \quad if \quad ARTY_i > 0 \\ \\ \boldsymbol{0} \quad if \quad ARTY_i < 0 \end{vmatrix} \tag{16}$$

2.6. *Income from Crop Hail Insurance Calculations*

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:

$$\boldsymbol{OI_i} = \begin{vmatrix} \boldsymbol{STR_i} \quad if \quad ARTC_{All\,i} = 0 \; and \; HD_i > 5\% \\ \boldsymbol{ARTR_i} \quad if \quad STC_{All\,i} = 0 \; and \; HD_i > 5\% \end{vmatrix} \tag{17}$$

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:

$$\boldsymbol{STR_i} = \begin{vmatrix} \boldsymbol{0} \quad if \quad HD_i \leq EX_i \\ (\boldsymbol{HD_i} - \boldsymbol{EX_i}) \times (\boldsymbol{A_i} \times \boldsymbol{IY_i} \times \boldsymbol{I\widetilde{P}_i}) \quad if \quad HD_i > EX_i \end{vmatrix} \tag{18}$$

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:

$$\boldsymbol{ARTR_i} = \begin{vmatrix} \boldsymbol{ARTCC_i} \quad if \quad ARTCC_i \leq TART_i \\ \boldsymbol{TART_i} \quad if \quad TART_i < ARTCC_i \end{vmatrix} \tag{19}$$

where

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

while

$$\boldsymbol{TART_i} = \boldsymbol{ARTCB_i} \times \boldsymbol{1.2} \tag{20}$$

and

$$\boldsymbol{ARTCB_i} = \boldsymbol{ARTOB_i} + \boldsymbol{ARTC_i} - \boldsymbol{ARTA_i} + \boldsymbol{ARTI_i} \tag{21}$$

where

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

while

$$\boldsymbol{ARTA_i} = \boldsymbol{ARTC_i} \times \boldsymbol{0.06} \tag{22}$$

and

$$\boldsymbol{ARTI_i} = \boldsymbol{ARTOB_i} \times \boldsymbol{0.04} \tag{23}$$

2.7. *Model Application*

The production cost used in the simulation model is based on the commercial production cost for two provinces in South Africa, North West (as a low hail risk area) and Mpumalanga (as a high hail risk area), 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 2.

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 dependent cost is a function of the realized yield and includes the harvest, as well as the transport cost of the realized crop. The costs in Table 2 are based on yields of 3 t/ha for the North West province and 5 t/ha for the Mpumalanga province, as these are average yields for the two areas. The production cost for Mpumalanga is almost double that of North West and is ascribed to the higher yield possibilities.

3. Risk Simulations

The risk variables that needed to be simulated for the model were the expected yield ($\tilde{Y}_i$), price ($\tilde{P}_i$), insured price ($\widetilde{IP}_i$) and hail damage ($\widetilde{HD}_i$). The first reason for the simulation of yield and price variables are to overcome the problem of inconsistent data series lengths. 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 impact 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 characterize risk (Grové, 2007). The procedure that was used to simulate multivariate probability distributions for the stochastic yield and price variables follows the procedure developed by Richardson *et al.* (2000). The data that was used to simulate the maize price and yield for the model consisted of data from 11 maize production seasons. The real price data in Table 3 is the contract price at constant 2011/2012 prices 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).

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 realized 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 realized and therefore the average price for the period is used. It is important to note that the prices used in the model is lower than the SAFEX price due to the transport differential of R204/ton for North West and R236/ton for Mpumalanga that is subtracted from the SAFEX price.

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 4 below, while the inter-temporal correlation coefficients are illustrated in Table 5. 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 one year lagged relationship within a variable.

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 North West area contained 1101 different insurance policies for the 23 years while the Mpumalanga area contained 866 policies. After the data was cleaned, the number of policies that existed for all 23 years was 118 for North West and 112 for Mpumalanga of which 100 policies were randomly selected for each province. The data included the damage (in percentage) that hail caused to the maize crop in each of the 23 years for every policy.

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 event 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 characterized by the probability distribution function (PDF) of the triangle distribution function, with the minimum, maximum and most probable (mode) values as 1%, 5% and 2.5% respectively (Hardaker, Huirne & Anderson, 1997).

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 1. From the cumulative distribution, it is clear to see that there is a higher probability of high impact hail damage occurrences in Mpumalanga than in North West. The production risk brought about by hail is thus higher in the Mpumalanga region than in the North West region.

4. Risk Efficiency Analysis

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.

Stochastic efficiency with respect to a function (SERF), as the most recent advance in ranking risky alternatives, orders alternatives in terms of certainty equivalents (*CE*) (Hardaker *et al*., 2004). 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).

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 analyzed. 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).

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 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):

$$\boldsymbol{CE\big(x, r_a(x)\big) = ln\left\{\left(\frac{1}{n}\sum_i^n \mathbf{exp}\,(-r_a(x)x_i)\right)^{-1/r_a(x)}\right\}} \qquad (24)$$

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 (24) 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) standardized 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.

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):

$$\boldsymbol{UWRP_{PS,BS,r_a} = CE_{PS,r_a(x)} - CE_{BS,r_a(x)}} \qquad (25)$$

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.

5. Results

The results of the study will be discussed on the cost effectiveness of the different crop hail insurance options for the North West province (low hail risk area) and the Mpumalanga province (high hail risk area) respectively. The last part of the results deals with the ability of SCHI and ART to provide continuous risk cover in the same areas.

5.1. Cost Effectiveness 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. 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, *ART* depends on a contribution determined by the decision maker. Although the *ART* contributions in this study were kept at constant percentages or contributions, the contribution 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 impact of the different crop insurance options on the firm, the cumulative probability distributions of the NPVs after interest and tax can be analyzed. 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. 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 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.

5.1.1. North West Province as a Low Hail Risk Area

Figure 2 shows the SERF analysis for all the insurance options in North West. At very low levels of risk aversion ($r_s = 0.1$) the decision maker is risk neutral and the results for the five scenarios are 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 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 risk neutral decision maker will not receive any benefit to move away from the *Base* scenario and will thus not be willing to pay a premium for any of the crop hail insurance options. 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.

High levels of risk aversion ($r_s = 2.5$) for North West 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. For risk averse decision makers *Insurance* now has a higher CE than *ART 50*, but the difference is still relatively small. Figure 3 shows the Utility Weighted Risk Premium (*UWRP*) or maximum benefit for all the insurance options in North West. The risk averse decision maker will receive a maximum benefit (*UWRP*) 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.

The only option of crop hail insurance that will provide a financial advantage for the decision maker in North West 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 given the hail damage risk. 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. The results show 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 North West.

5.1.2. Mpumalanga Province as a High Hail Risk Area

Figure 4 shows the SERF analysis for all the insurance products in Mpumalanga. The influence of the risk aversion level is greater in Mpumalanga than in North West, as the difference in CEs between the alternatives increase more as the risk aversion level increases.

At low levels of risk aversion ($r_s = 0.1$), the difference in CEs between the alternatives are very small but the risk neutral 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. Figure 5 shows the Utility Weighted Risk Premium (*UWRP*) or maximum benefit for all the insurance options in Mpumalanga. The maximum benefit (*UWRP*) that the different insurance options offer at low risk aversion levels 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 (*UWRP*) that the risk averse 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 Mpumalanga 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 Mpumalanga may be one of the reasons leading to this distinct preference of only two options. The high occurrence of hail damage in Mpumalanga 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. Mpumalanga's variable production cost, excluding insurance, is approximately 30 % per expected ton of yield more than that of North West. The influence of the high production cost is evident in the fact that the enterprise has a probability of realizing 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 Mpumalanga, however, forces the insurance product to deliver more benefits in the form of claims, while it is not the case in North West 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 analyzed carefully to enable the decision maker to choose the product that will offer the best financial advantage.

5.2. Ability of Different Crop Hail Insurance Options to Provide Continuous 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 be 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 6. The year number in the table indicates the specific year in which the differences occur. 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 6 shows that for Mpumalanga, 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.

For North West, the probability of the *ART PC* pay-out being less than *Insurance* is lower than in Mpumalanga. In North West 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 Mpumalanga is more severe than in North West. The *ART PC* scenario in Mpumalanga 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 North West, 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 Mpumalanga, 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 North West 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.

6. Conclusion

The purpose of this research was to evaluate Alternative Risk Transfer (ART) against Short-term Crop Hail Insurance (SCHI) to provide cost effective and constant cover against hail risks under stochastic yields and prices.

The cost and benefit structures of the different crop hail insurance options differ from one to another. Although it is easy to realize that the cost and benefit structures of SCHI and ART will be different, the difference applies to the different ART contributions as well. While SCHI 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 the North West province (low hail risk area) and SCHI is the preferable option in the Mpumalanga province (high hail risk area). All these variables must be considered and analyzed 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 SCHI 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 North West, and the second preferred one in Mpumalanga, the product does not include the ability to deliver continuous cover against hail risk. In Mpumalanga, 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 North West, 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 Mpumalanga. While it can be concluded that ART is ineffective in Mpumalanga, owing to its inability to provide continuous cover and the large differences in pay-outs, the same conclusion cannot necessarily be made for North West. The differences in pay-outs in North West 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.

7. References

Banks, E. 2004. *Alternative Risk Transfer: Integrated Risk Management through Insurance, Reinsurance, and the Capital Markets*. West Sussex, England: John Wiley & Sons.

Boehlje, M.D. & Eidman, V.R. 1984. *Farm Management*. Canada: John Wiley & Sons.

Corporate Guarantee. 2013. *Unpacking our concept of "risk"*. Available: "http://www.corporateguarantee.co.za/product/"_[2013, July 27].

Grain SA (GSA). 2012. *Production costs for summer grain*. Available: "http://www.grainsa.co.za/pages/industry-reports/production-reports" [2013, March 25].

Grové, B. 2007. *Stochastic efficiency optimisation analysis of alternative agricultural water use strategies in Vaalharts over the long- and short-run*. Dissertation submitted for the degree Philosophiae Doctor in the Department of Agricultural Economics, Faculty of Natural and Agricultural Sciences, University of the Free State.

Hardaker, J.B., Huirne, R.B.M. & Anderson, J.R. 1997. *Coping with risk in Agriculture*. Wallingford, Oxon, UK.

Hardaker, J.B., Richardson, J.W., Lien, G. & Schumann, K.D. 2004. "Stochastic efficiency analysis with risk aversion bounds: a simplified approach". *Australian Journal of Agricultural and Resource Economics* 48(2). pp. 253-270.

Kurosaki, T. & Fafchamps, M. 2002. "Insurance market efficiency and crop choices in Pakistan". *Journal of Development Economics* 67. pp. 419-453.

Richardson, J.W., Klose, S.L. & Gray, A.W. 2000. "An applied procedure for estimating and simulating Multivariate Empirical (MVE) probability distributions in farm-level risk assessment and policy analysis". *Journal of Agricultural and Applied Economics* 32(2). pp. 299-315.

Roberts, R.A.J. 2005. "Insurance of crops in developing countries". *FAO Agricultural Services Bulletin* 159.

Roumasset, J.A. 1978. "The case against crop insurance in developing countries". *The Philippine Review of Business and Economics* March issue. pp. 87–107.

SAFEX. 2012. *Price history on grain products*. South African Futures Exchange. Available: "http://www.jse.co.za/Markets/Commodity-Derivatives-Market/Commodity-Derivatives-Price-History.aspx#spot". [2013, March 25].

Shaik, S. 2013. "Crop Insurance Adjusted Panel Data Envelopment Analysis Efficiency Measures". *American Journal of Agricultural Economics* 95(5). pp. 1155-1177.

World Bank. 2011. *Weather index insurance for agriculture: Guidance for development practitioners*. Agriculture and Rural Development discussion paper 50. The World Bank, Washington, DC 20433.

Yang, R., Wang, L. & Xian, Z. 2010. "Evaluation on the Efficiency of Crop Insurance in China's Major Grain-Producing Area". *Agriculture and Agricultural Science Procedia* 1. pp. 90-99.

8. Tables

Table 1: Layout of the farm financial model

	Math sign	Unit	Year (i)			
			1	2	$i_{3\text{-}22}$	23
Section A						
PRODUCTION INCOME						
Area planted	A_i	Ha	500	500		500
Target yield	TY_i	ton/ha	3.0	3.0		3.0
Expected yield	$\tilde{Y}_i$	ton/ha	3.0	3.0		3.0
Hail Damage	$\tilde{HD}_i$	%	0.0	0.0		0.0
Realised yield	RY_i	ton/ha	3.0	3.0		3.0
Price	$\tilde{P}_i$	R/ton	2 038	2 038		2 038
TOTAL PRODUCTION INCOME	PI_i	R	3 057 000	3 057 000		3 057 000
OTHER INCOME						
ST claim received	STR_i	R	0	0		0
ART claim received	$ARTR_i$	R	0	0		0
TOTAL OTHER INCOME	OI_i	R	0	0		0
TOTAL INCOME			3 057 000	3 057 000		3 057 000
VARIABLE COST						
Area dependant cost	AC_i	R/ha	2 824	2 824		2 824
Total area dependant cost		R	1 412 000	1 412 000		1 412 000
ST Insurance premium	STC_i	R	91 660	82 494		34 373
ART Insurance contribution	$ARTC_i$	R	0	0		0
Expected yield dependant cost	EYC_i	R/ha	572	572		572
Total yield dependant cost	YC_i	R	286 000	286 000		286 000
FIXED COST	FC_i	R	593 500	593 500		593 500
TOTAL COST	TC_i	R	2 383 160	2 373 994		2 325 873
MARGIN BEFORE INTEREST AND TAX		R	673 840	691 092		731 128
INTEREST PAID (8.5%)	INP_i	R	0	0		0
INTEREST RECEIVED (2.0%)	INR_i	R	0	8 086		268 618
INCOME TAX (40.0%)	T_i	R	269 536	276 437		399 898
MARGIN AFTER INTEREST AND TAX	M_i	R	404 304	422 741		599 848
Bank opening balance	OB_i	R	0	404 304		13 430 897
Bank bank closing balance	CB_i	R	404 304	827 045		14 030 745
Section B						
ST INSURANCE POLICY						
Insured yield	IY_i	ton/ha	2.3	2.3		2.3
Insured price	$I\tilde{P}i$	R/ton	1 976	1 976		1 976
Premium	STP_i	%	4.0	3.6		1.5
Excess	EX_i	%	5.0	5.0		5.0
Cost	STC_i	R	91 660	82 494		34 373
Claim received	STR_i	R	0	0		0
ART INSURANCE POLICY						
Opening Balance	$ARTOB_i$	R	0	179 893		3 734 859
Premium	$ARTP$	%	25.0	25.0		25.0
Contribution	$ARTC_i$	R	191 375	191 375		0
Administration fee (6.0%)	$ARTA_i$	R	11 483	11 483		0
Interest (4.0%)	$ARTI_i$	R	0	7 196		149 394
Claim claimed	$ARTCC_i$	R	0	0		0
Claim received	$ARTR_i$	R	0	0		0
Portion from accumulated funds	$ARTAF$	R	0	0		0
Portion from cover funds	$ARTCF$	R	0	0		0
Closing Balance	$ARTCB_i$	R	179 893	366 981		3 884 254
Total cover (120.0%)	$TART_i$	R	215 871	440 377		4 661 105
Total contribution for the year	$ARTY_i$	R	179 893	187 088		149 394

Table 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

Table 3: Real price and yield data for 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	929	1 074	2.6	3.9
2002/03	2 924	1 767	2.2	3.5
2003/04	1 805	2 215	2.7	4.0
2004/05	3 100	2 112	3.2	5.1
2005/06	2 186	2 401	3.3	4.9
2006/07	1 953	2 285	1.9	3.3
2007/08	2 034	2 301	3.5	5.5
2008/09	2 750	2 603	3.6	6.0
2009/10	3 145	2 458	3.7	5.9
2010/11	1 790	1 999	3.6	5.0
2011/12*	2 180	2 242	3.4	5.7

Source: SAFEX (2012) and GSA (2012)

Table 4: Intra-temporal correlation coefficients 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 5: 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

Table 6: Probabilities of *Insurance* pay-outs being more than that of *ART PC* for Mpumalanga and North West

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

9. Figures

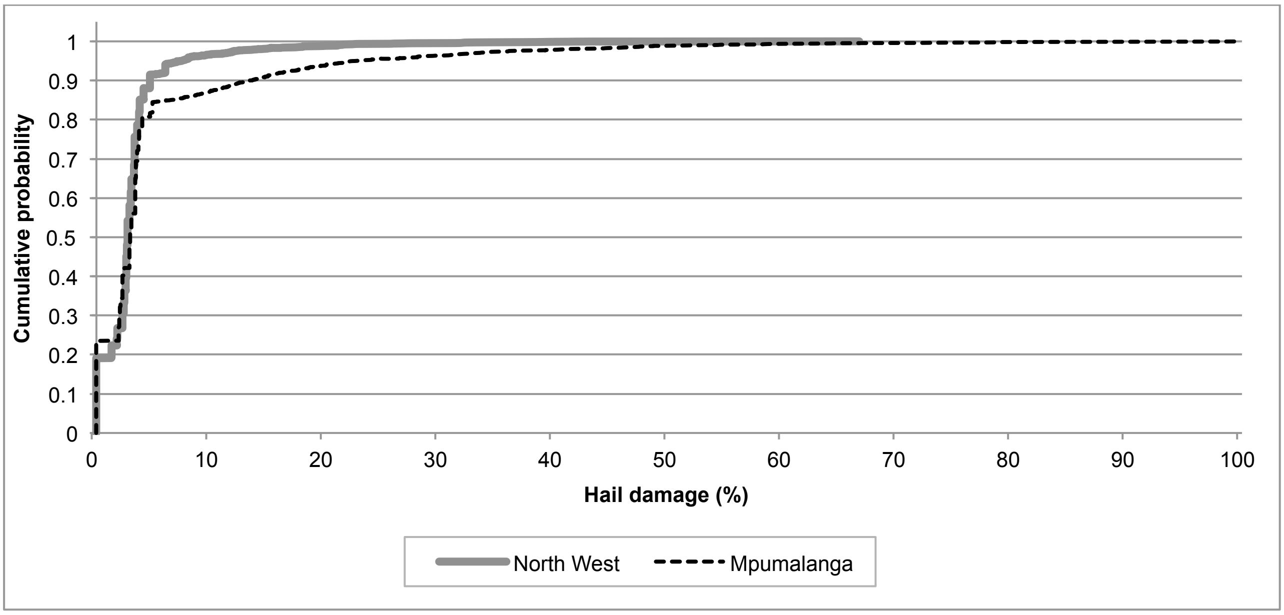

Figure 1: Cumulative probability distributions of hail damage for the North West and Mpumalanga regions

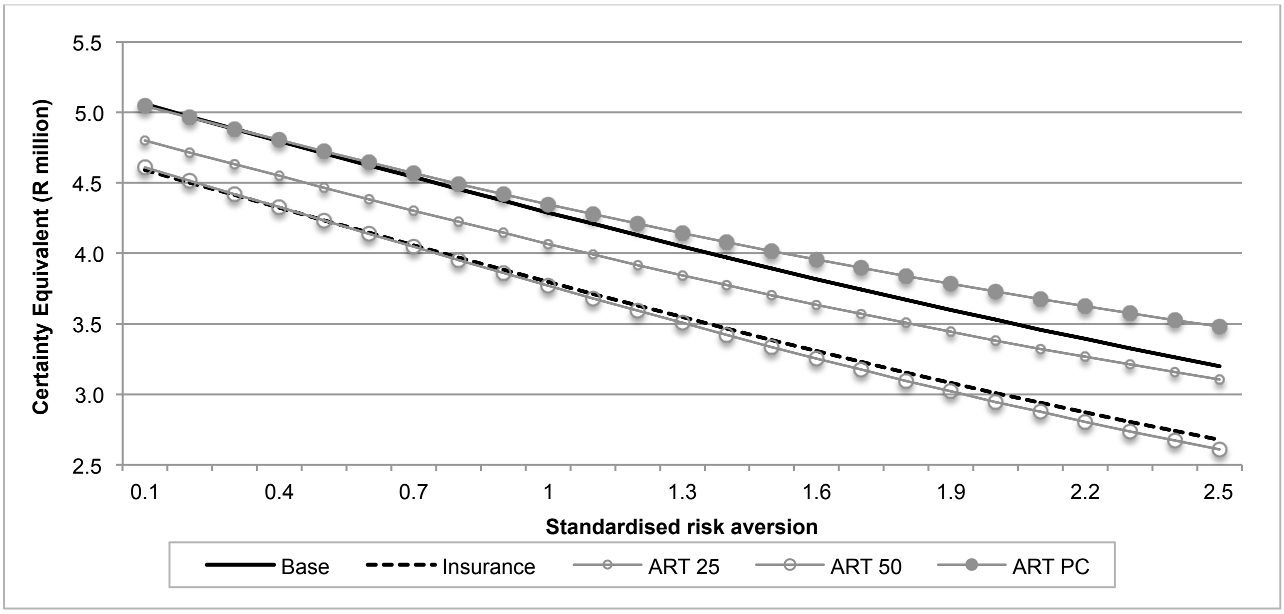

Figure 2: SERF analyses for all the insurance scenarios in North West

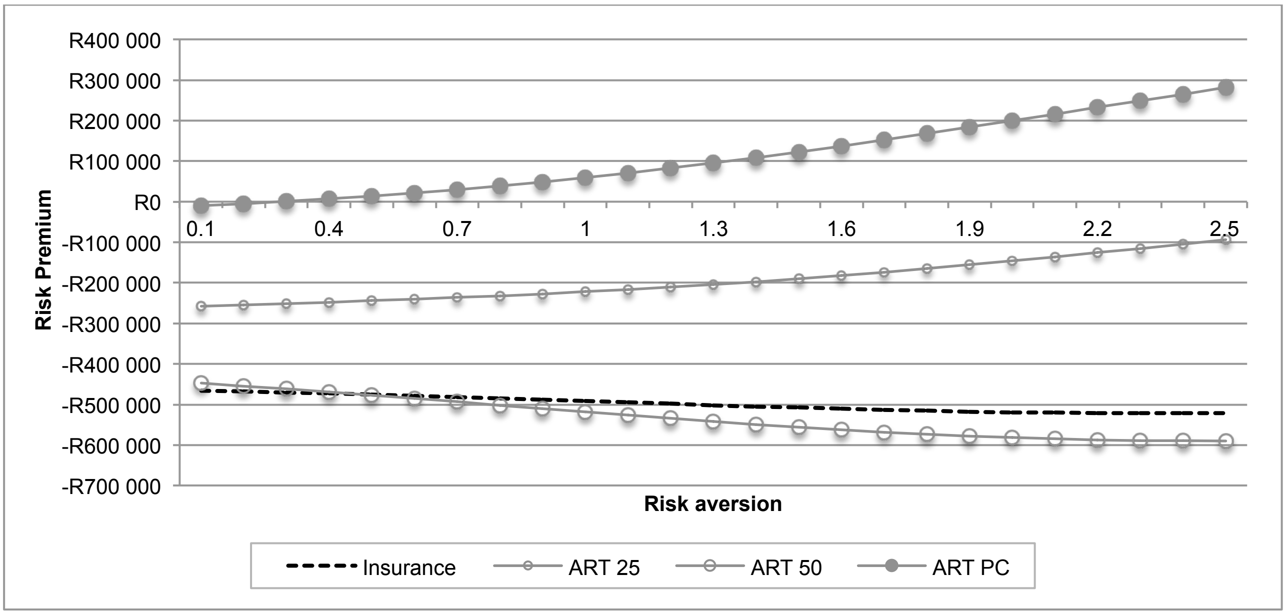

Figure 3: Utility weighted risk premium for all the insurance scenarios in North West

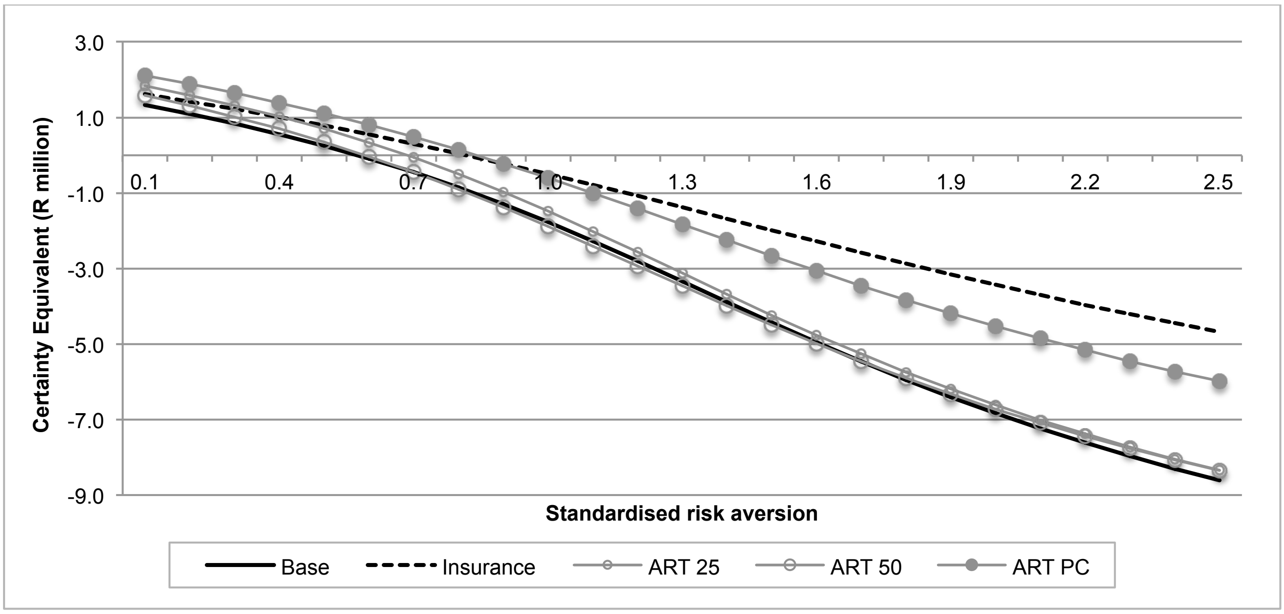

Figure 4: SERF analyses for all the insurance scenarios in Mpumalanga

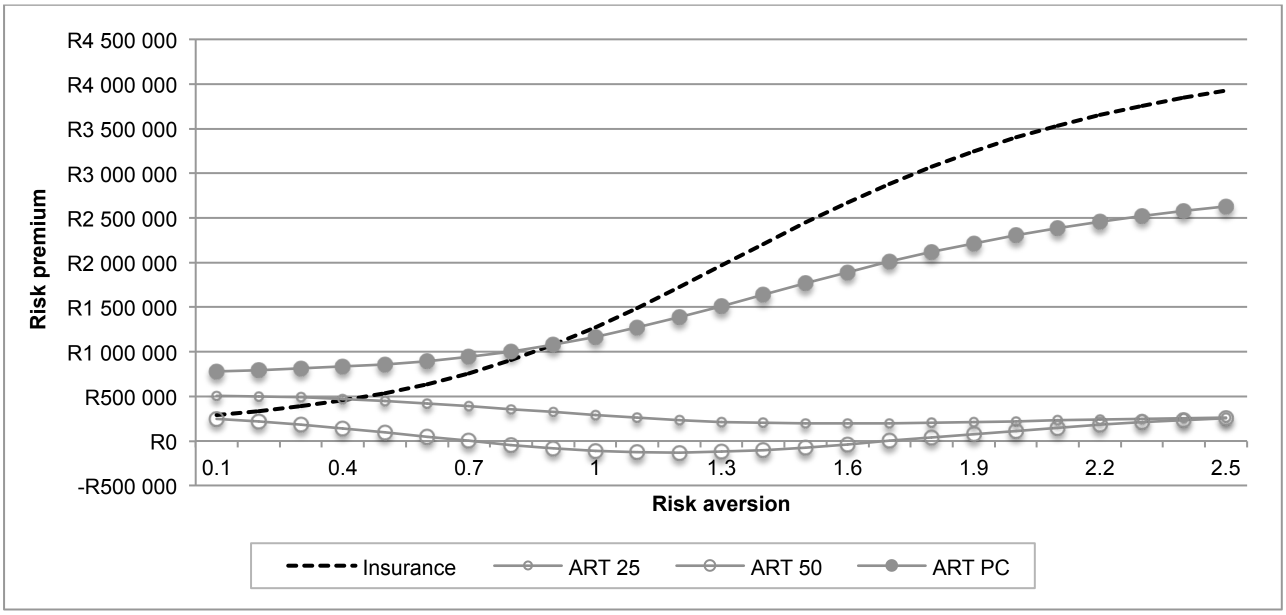

Figure 5: Utility weighted risk premium for all the insurance scenarios in Mpumalanga