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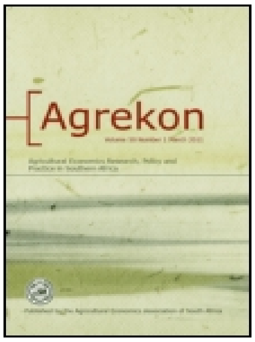

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ESTIMATING THE MAXIMUM VALUE OF CROP HAIL INSURANCE UNDER STOCHASTIC YIELD AND PRICE RISK

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ABSTRACT

The objective of this article is to estimate the maximum value of crop hail insurance according to the financial extent of hail risk's impact on the enterprise in two regions, North West (low hail risk area) and Mpumalanga (high hail risk area). 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 in 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 hail insurance. The results indicate that hail does have a negative impact on the financial position of the farms in North West and Mpumalanga. The effect of hail risk in Mpumalanga is, however, more severe. The calculated maximum benefit (UWRP) from the elimination of hail damage in two regions is R83.50/hectare in North West and R708.70/hectare in Mpumalanga. The conclusion can thus be made that decision makers in both regions will be willing to pay for crop hail insurance, but much more so in Mpumalanga than in North West.

Keywords: risk, insurance, simulation model, SERF, certainty equivalent, utility weighted risk premium

JEL Codes: D81, C15, Q12

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1. INTRODUCTION

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 minimise losses, for the insurer to create products that helps to cover these risks, and for the government that considers risk management among its policy objectives.

A farmer's decision to adopt crop insurance, or the willingness to pay for crop insurance, is influenced by various factors. Some of these factors were identified in studies by authors such as Rydant (1979), Fraser (1992), Coble, Knight, Pope and Williams (1996), Velandia, Rejesus, Knight & Sherrick (2009), Sadati, Ghobadi, Sadati, Mohamadi, Sharifi and Asakereh (2010) and Santeramo, Goodwin, Adinolfi and Capitanio (2013), and include factors such as owned hectares, off-farm income levels, education, age, the level of coverage of the insurance policy, yield and price variability, level of risk aversion of the decision maker and the effectiveness of previous insurance policies. The frequency of the risk and the perception of the riskiness of a specific region as factors that influence the decision to adopt crop insurance were only mentioned in two of the studies (Rydant, 1979; Santeramo *et al.*, 2013). The above-mentioned factors show that the decision to adopt crop insurance is very seldom based on the influence of a specific risk on the enterprise, but rather on the combined effect of different factors. In the event where Multi Peril Crop Insurance (MPCI) is used, all the factors that may influence the enterprise are certainly of importance, but in the event of Specified Peril Insurance (SPI), for instance Hail Insurance, the most important factor to consider must certainly be the influence of that specific peril on the enterprise.

The worldwide participation in crop insurance is relatively low and is evident from the market penetration of selected countries in Table 1. Apart from the relative low overall participation, it is also clear that Hail Insurance is utilised more than MPCI in some of the countries. The statistics in Table 1 indicate that the influence of hail is large enough to attract participation in Hail Insurance. Hail occurrence can, however, differ widely in a specific country, depending on the geographic location of a specific farm (Le Roux and Olivier, 1996).

Table 1: Market penetration of crop insurance in different countries in 2012

Country	MPCI * [Million Euro]	Hail [Million Euro]	Total [Million Euro]	Market Penetration [%]		
				Total	MPCI*	Hail
France	160	170	330	87	48	52
USA	5401	486	5887	80	92	8
Australia	0	104	104	80	0	100
Austria	20	68	88	79	23	77
Korea	56	0	56	72	100	0
Germany	5	159	164	61	3	97
Canada	1038	193	1231	60	84	16
Spain	430	0	430	55	100	0
Argentina	3	116	119	45	3	97
South Africa	21	72	93	33	23	77
China	1019	0	1019	25	100	0
Italy	165	115	280	20	59	41
India	182	0	182	20	100	0
Brazil	142	39	182	12	78	21
Russia	217	0	217	10	100	0
Mexico	114	0	114	8	100	0
Turkey	43	3	46	5	93	7
Total	9016	1525	10541			

Source: Melville (2012)
** Multi Peril Crop Insurance*

The high participation in crop hail insurance of a specific country does not indicate that the whole country is vulnerable to hail storms and the influence of hail on a specific geographic location must be analysed to determine the impact of hail damage and the need for crop hail insurance in that region.

The objective of this article is to estimate the maximum monetary value that a decision maker can derive by mitigating the risk of hail damage through crop hail 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 the monetary value of removing 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 hail insurance.

The procedures that were used for this article will be discussed next and consist of the farm financial simulation model, which was developed to run the analyses, the quantification of the risk variables (price, yield and hail), which was used in the analyses, and the SERF analyses to calculate the maximum willingness to pay. The results of the study will be discussed on the basis of two scenarios (*Base* and *No Hail*) that were tested with the model over a period of 23 years for two regions: North West as a low hail risk region and Mpumalanga as a high hail risk region. 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. The last part of the article draws a conclusion on the findings of the study.

2. PROCEDURES

2.1 The 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 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 with the only loan facility utilised being a bank overdraft. Due to the fact that the debt levels of the different farms are unknown, other debt was not included in the model. In the event where debt levels are known, it can be easily incorporated in the model by including the amount of debt, interest rate and term of the loan through a repayment function. The model is set up for a continuous maize farm and calculates the margin after interest and tax for each production season. In each area, 100 iterations were used and the NPV of the margin after interest and tax for each of the iterations were calculated at a 5 % discount rate as the average real interest rate for South Africa was 4.8% over the last 15 years (World Bank, 2015). The NPV data is used in the analyses of the results. The margin after interest and tax, which is the main objective of the model, is calculated as:

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

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)

The data used to calculate M_i consist of a variety of data sources that includes yields, prices, costs, hail damage, interest and tax that was used to calculate each of the variables in equation (1). The source and application of each data set will be discussed with the equation of each of the variables.

The total income of the model is equal to the production income (PI_i) and is a function of the production of maize according to the production area, price, yield and hail damage. Three different yield types are included in the analyses to enable the model to capture the effect of hail damage separately. Target yield is the yield that is planned for at the beginning of the season and the area dependent costs are calculated accordingly. The target yield that was used is 3t/ha for North West and 5t/ha for Mpumalanga as it is the average long-term yield for the two areas (Grain SA, 2012). 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 or lower than the target yield. The Realised Yield (RY_i) includes the influence of hail and is the yield that is harvested. The yield dependent costs are calculated according to the .

The production income (PI_i) is calculated as:

$$PI_i = A_i \times RY_i \times \tilde{P}_i \tag{2}$$

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)

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

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

where

$\tilde{Y}_i$ Empirically distributed expected yield for year i (t/ha)
$(\widetilde{HD}_i)$ Empirically distributed hail damage for year i (%)

The production income is highly variable as a result of the inherent variability of crop production, prices and the occurrence and impact of hail. As a result, these variables were included as stochastic variables in the model. Section 2.2 provides a more detailed description of the quantification of these risk variables.

The total cost (TC_i) of the enterprise basically consists of three different variables; Area dependent cost, Yield dependent cost and Fixed cost. The total cost of the enterprise is calculated as:

$$TC_i = (AC_i \times A_i) + YC_i + FC_i \tag{4}$$

where

AC_i Area dependant cost for year *i* (R/ha)
A_i Area planted in year *i* (ha)
YC_i Total Yield dependent cost for year *i* (R)
FC_i Total Fixed cost for year *i* (R)

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

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

where

EYC_i Expected yield dependant cost for year *i* (R/ha)
TY_i Target yield for year *i* (ton/ha)

The production cost used in the simulation model is based on the 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, the costs were recalculated. The recalculated costs for both regions are presented in Table 2.

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

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 realised yield and includes the harvest, as well as the transport cost of the realised crop. The costs in Table 2 are based on target yields of 3t/ha for the North West province and 5t/ha for the Mpumalanga province, as these are the long-term average yields for the two areas (Grain SA, 2012). The production cost for Mpumalanga is almost double that of North West and is ascribed to the higher yield possibilities.

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

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

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:

$$TI_i = PI_i - TC_i + (INR_i - INP_i) \tag{7}$$

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:

$$OB_i = \begin{cases} CB_{i-1} \;\; if \;\; OB_{i\neq 1} \\ IB \;\; if \;\; OB_{i=1} \end{cases} \tag{8}$$

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:

$$CB_i = OB_i + M_i \tag{9}$$

2.2 Quantification of risk variables

The risk variables that needed to be simulated for the model were the expected yield ($\tilde{Y}_i$), price ($\tilde{P}_i$) and hail damage ($\widetilde{HD}_i$). The first reason for the simulation of yield and price variables is to overcome the problem of inconsistent data series lengths. The second reason is that 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 characterise risk (Grové, 2007). 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).

Table 3: Real price and yield data for maize for 2001/2002 – 2011/2012

Production Season	Price (May Futures R/ton)	Yield (Provincial Average t/ha)	
	(Average: 1 Dec – Contract End)	North West	Mpumalanga
2001/02	1 074	2.6	3.9
2002/03	1 767	2.2	3.5
2003/04	2 215	2.7	4.0
2004/05	2 112	3.2	5.1
2005/06	2 401	3.3	4.9
2006/07	2 285	1.9	3.3
2007/08	2 301	3.5	5.5
2008/09	2 603	3.6	6.0
2009/10	2 458	3.7	5.9
2010/11	1 999	3.6	5.0
2011/12	2 242	3.4	5.7

Source: SAFEX (2012) and GSA (2012)

The 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 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 procedure that was used to simulate multivariate probability distributions for the stochastic variables follows the procedure developed by Richardson, Klose and Gray (2000). The intra-temporal correlations between the different yield and price variables that were used in the simulation of the random variables are presented in Table 4, 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.

Table 4: Intra-temporal correlation coefficients for yield and price

	Price	Yield North West	Yield Mpumalanga
Price	1	0.0689	0.2305
Yield North West	0	1	0.9024
Yield Mpumalanga	0	0	1

Table 5: Inter-temporal correlation coefficients for yield and price

	Price	Price t-1	Yield NW	Yield NW t-1	Yield MP	Yield MP t-1
Price	1	0.375	0	0	0	0
Yield North West	0	0	1	-0.264	0	0
Yield Mpumalanga	0	0	0	0	1	-0.115

The hail risk for both areas was determined using hail damage 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 than “insured farms” is because 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 only information that was received from Santam was the amount (percentage) of hail damage for each policy in the different years. The premiums, total sum insured and other information regarding the policies are thus unknown.

The original data set for the North West area contained 1 101 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 characterised 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 evident 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.

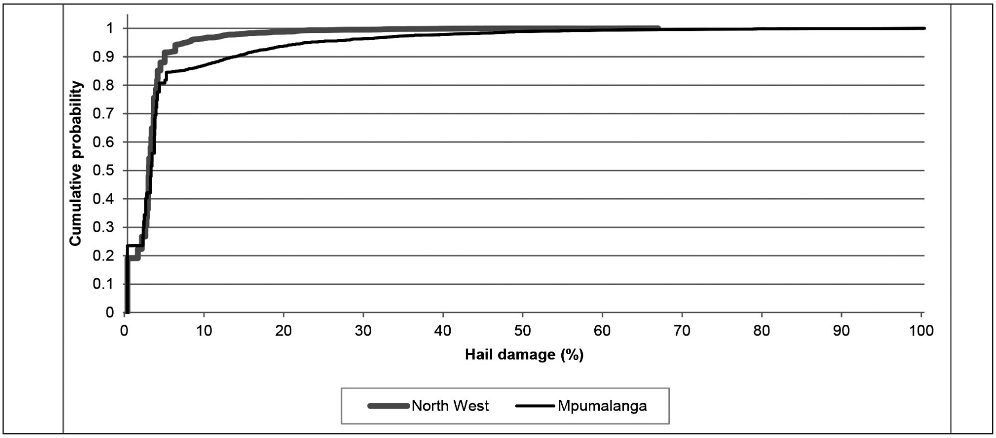

Figure 1: Cumulative probability distributions of hail damage for the North West and Mpumalanga regions

2.3 Calculating the monetary value of crop hail insurance

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, Huirne, Anderson and Lien, 2004). The advantage of SERF is that the *CEs* 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 influence of hail damage on the enterprise, the NPV of the margins after interest and tax of each of the scenarios has 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).

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):

$$CE\big(x, r_a(x)\big) = ln\left\{\left(\frac{1}{n}\sum_i^n \exp(-r_a(x)x_i)\right)^{-1/r_a(x)}\right\} \quad (10)$$

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 (10) over $r_a(x)$ range of 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 and Oosthuizen (2010) 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 $r_s = 25$. 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.

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):

$$UWRP_{PS,BS,r_a} = CE_{PS,r_a(x)} - CE_{BS,r_a(x)} \quad (11)$$

The *Base* scenario for the calculation of the *UWRP* is the scenario where hail occurred. The *UWRP* for the *No Hail* scenario thus indicates the monetary benefit for the decision-maker to move from the *Base* scenario to *No Hail* and sets the upper limit for the cost of crop hail insurance.

3. RESULTS

The results will first focus on the amount of hail damage in both the North West and Mpumalanga regions in order to determine the financial impact brought about by hail in each region. The second part of the results will indicate the maximum value of crop hail insurance in each of the regions according to different risk aversion levels of the decision maker.

3.1 Financial impact of hail damage

An agricultural enterprise must be exposed to a certain risk in order to justify insurance against that risk. In order to quantify the exposure to hail risk in the two regions, the cumulative probabilities of the NPV are calculated for two scenarios: the *Base* scenario where the farm experience all the risk (price, yield and hail) and the *No Hail* scenario where the farm still deals with price and yield risk, but no hail risk is present. Figure 2 and Figure 3 present the cumulative probabilities of the NPV for North West and Mpumalanga, respectively. Although the effect of hail damage is evident in both regions, as there is a shift in the NPVs, the effect is much larger in the Mpumalanga region.

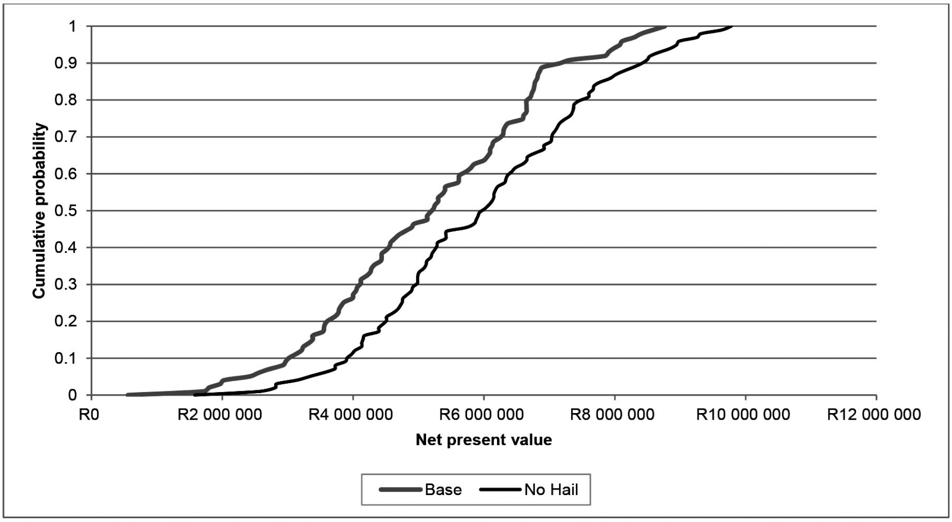

Figure 2: Cumulative probability distributions of the Net Present Value for the scenarios Base and No Hail in North West

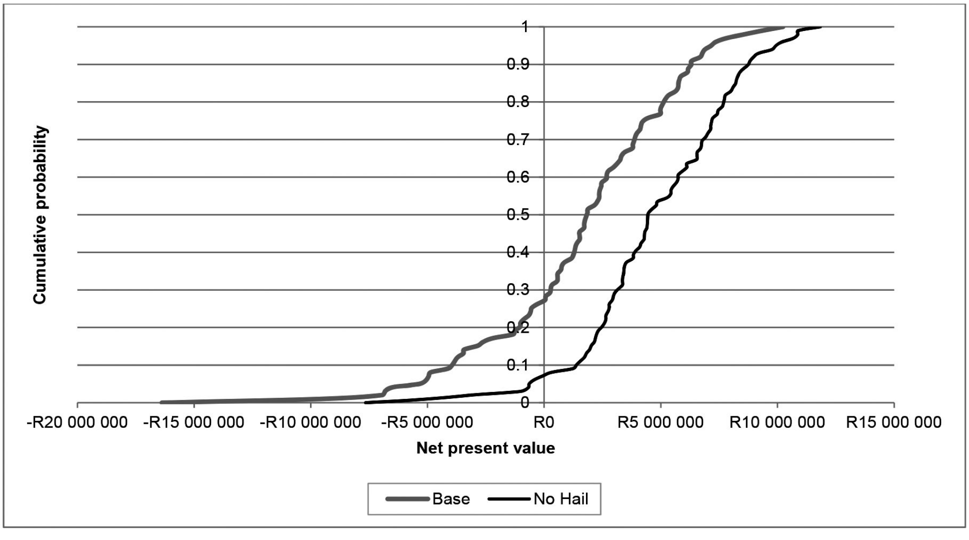

Figure 3: Cumulative probability distributions of the Net Present Value for the scenarios Base and No Hail in Mpumalanga

In North West, 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, indicating that the influence of hail damage over the range of NPVs is relatively 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.

The impact of hail in Mpumalanga 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 Mpumalanga 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.

3.2 Maximum value of crop hail insurance

The SERF analysis calculates the maximum benefit in terms of the UWRP that the farm will receive if the impact of hail is removed completely. The UWRP thus sets the upper limit for the cost of crop hail insurance in the specified region.

Figure 4 represents the UWRP or maximum benefit, at different levels of risk aversion, which a decision-maker will receive through the elimination of hail in North West and Mpumalanga. In North West, the decision-maker will receive a maximum 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 North West (Figure 2). 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.

The maximum benefit calculation for Mpumalanga 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.

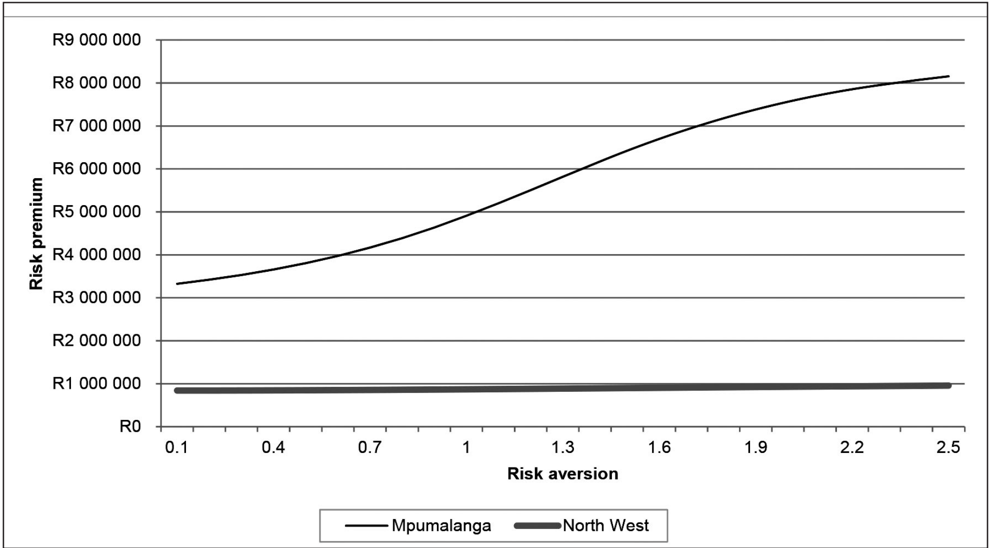

Figure 4: Utility weighted risk premium for the scenarios Base and No Hail in North West and Mpumalanga

According to the results, the cumulative probability distributions of the NPVs in North West and Mpumalanga confirmed that hail does have a negative impact on the financial position of the farms. The effect of hail risk in Mpumalanga 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 Mpumalanga. Although the elimination of hail in North West will hold a benefit for the decision-maker, it is very low in comparison with that of Mpumalanga. The conclusion can thus be made that decision-makers in both regions will be willing to pay for crop hail insurance, but much more so in Mpumalanga than in North West.

4. CONCLUSION

The objective of this article was to estimate the maximum monetary value of mitigating hail risk through crop hail insurance. The achievement of the objective sets the upper limit on the amount of money a decision-maker should pay for crop hail insurance. The procedures that were used for this article consisted of the farm financial simulation model, which was developed to run the analyses, the quantification of the risk variables (price, yield and hail) and the SERF analyses to calculate the maximum willingness to pay.

In order to improve the participation of farmers in crop hail insurance, it is important to know the monetary maximum benefit of mitigating crop hail risk. The applied procedure used in this article proves to be able to calculate and illustrate both the effect that a hail risk has on the financial situation of the farm and the maximum benefit that the decision maker will receive if this risk is mitigated through crop hail insurance. The maximum benefit received from the removal of the risk also sets the upper limit for the cost of insurance and thus indicate the maximum willingness to pay for the insurance product.

A logical extension of this research will be to compare the current crop hail insurance premiums in the regions with the maximum benefit brought about by the reduction of risk through the crop hail insurance product. The current premiums paid by individual insured parties are, however, not readily available and the data should be gathered using structured questionnaires. The findings of such research can shed light on the relationship between the actual premiums in the market place, the maximum amount a crop farmer is willing to pay for hail insurance, the minimum amount an insurance company is willing to receive for crop hail insurance as well as the value of the reduction in hail risk that was identified in this article. The different limits of the premium that can be identified in this procedure will then set the ground for a suggested premium that is beneficial for both the insurer and insured party.

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