# Comparing hail risk management strategies through whole-farm multi-period stochastic budgeting for avocado production in South Africa

by

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# Declaration

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# Abstract

This dissertation compares hail risk management strategies for avocado production in South Africa. Avocado producers in South Africa aim to produce fruit of high quality suited for the export market to earn a price premium. To manage abiotic stress factors, which are seen as production risks, producers implement risk management strategies. The main abiotic stress factor investigated in this study is hail damage. Three strategies that can be used by producers are evaluated and compared from an economic point of view. The three strategies are: erecting a fixed shade netting construction over orchards, purchasing hail insurance, and self-insurance. The self-insurance strategy consists of producers carrying the risk within their enterprise and not implementing any risk management strategy. Shade netting alters the microclimate and can lead to secondary benefits, such as increased quality of fruit. To evaluate the risk management strategies, a whole-farm multi-period stochastic budget model is used to represent a typical avocado farm. The key output variables (KOVs) used in the stochastic budget model are yield, quality, price, hail insurance premiums and hail risk. These KOVs are used as they have been identified as the variables that will most likely influence the financial performance of the avocado farm system when choosing a risk management strategy. Empirical data and methods proposed by Richardson (2000) are used to simulate multivariate empirical probability distributions for the KOVs. Hail risk is an exception and is modelled by using a Bernoulli discrete probability distribution in combination with a triangular probability distribution. The stochastic budget model runs 500 iterations of net present values (NPVs) for each risk management strategy using Simetar. The 500 NPVs of the three risk management strategies are then converted into cumulative distribution functions (CDFs). Stochastic dominance is used to compare each strategy.

The results of this study indicate that, as a risk management strategy only, shade nets are not economically viable and hail insurance is seen as the less risky strategy compared to self-insurance. Using the empirical data of a typical producer with an expected yield of 13.6 ton per hectare (average yield potential), shade nets will not be justifiable, even with an increase in the quality of the fruit. Self-insurance and hail insurance are stochastically dominant of first order over shade nets for all scenarios. Furthermore, self-insurance does not dominate hail insurance in terms of first- or second-order stochastic dominance in any scenario, meaning that it is a riskier management strategy.

The simulated results based on empirical data from a top producer with an expected yield of 18.4 ton per hectare (high yield potential) show that shade nets are stochastically dominant (of first order) over all other strategies when there is an increased quality of fruit without a decline in yield. If there is no increase in quality of fruit cultivated under shade nets, hail insurance and self-insurance will have first-degree stochastic dominance over the shade net strategy. As with the typical producer, there is no scenario where self-insurance is stochastically dominant (of first or second order) over hail insurance. It is possible for hail insurance to have second-degree stochastic dominance over self-insurance.

# Opsomming

Hierdie proefskrif vergelyk risikobestuur strategieë vir avokado produksie in Suid-Afrika. Avokado produsente in Suid-Afrika streef daarna om vrugte van hoë gehalte te lewer wat geskik is vir die uitvoermark om 'n pryspremie te verdien. Produsente implementeer risikobestuur strategieë om abiotiese stresfaktore, wat as produksie risiko's beskou word, te bestuur. Die belangrikste abiotiese stres faktor wat in hierdie studie ondersoek word, is haelskade. Drie strategieë wat produsente kan gebruik word vanuit 'n ekonomiese oogpunt geëvalueer en vergelyk. Die drie strategieë is: die oprigting van 'n vaste skadu net struktuur oor boorde, die aankoop van haelversekering by 'n finansiële instelling, en selfversekering. Die selfversekering strategie bestaan uit produsente wat die risiko binne hulle onderneming dra en geen risikobestuur strategie implementeer nie. Skadu nette verander die mikroklimaat en kan lei tot sekondêre voordele, soos verhoogde vrug kwaliteit. Om die risikobestuur strategieë te evalueer, word 'n geheel plaas meerjarige stogastiese begroting gebruik om 'n tipiese avokado plaas te verteenwoordig. Die kern uitset veranderlikes (KUVs) wat in die begrotings model gebruik word, is opbrengs, kwaliteit, prys, haelversekering premies en hael risiko. Hierdie KUVs word gebruik aangesien dit geïdentifiseer is as die veranderlikes met die grootste kans om die finansiële prestasie van die avokado-boerderystelsel te beïnvloed en in lyn is met die navorsingsvraag. Empiriese data en metodes wat deur Richardson (2000) voorgestel word, word gebruik om die waarskynlikheidsverdeling vir die KUVs te simuleer. Hael risiko is die enigste uitsondering en word gesimuleer deur ’n Bernoulli waarskynlikheidsverdeling in kombinasie met ’n “GRKS” driehoekige verdeling. Die stogastiese begrotings model het 500 iterasies netto teenwoordige waardes (NTWs) vir elke risikobestuur strategie met behulp van Simetar rekenaarsagteware gedoen. Die 500 NPV's van die drie risikobestuur strategieë is omgeskakel in kumulatiewe verspreidings funksies (KVFs). Stogastiese dominansie is gebruik om elke strategie te vergelyk.

Die resultate van hierdie studie dui daarop dat skadu nette nie slegs as 'n risikobestuur strategie ekonomies lewensvatbaar is nie. Vir 'n tipiese produsent met 'n verwagte opbrengs van 13,6 ton per hektaar (gemiddelde opbrengspotensiaal), is skadunet nie regverdigbaar nie, selfs nie met 'n toename in vrug kwaliteit nie. Die enigste situasie waar skadunet geregverdig kan word, is by top kwekers met 'n verwagte opbrengs van 18,4 ton per hektaar (hoë opbrengspotensiaal) en verhoogde vrug kwaliteit sonder 'n afname in opbrengs. Gevolglik is

skadunet nie slegs as 'n risikobestuur strategie verantwoordbaar nie. Daar is geen scenario waar die selfversekerings strategie stogastiese dominansie van eerste of tweede rang vertoon oor hael versekering nie. Daar is wel gevalle waar hael versekering stogasties dominant (van eerste en tweede orde) oor selfversekering is.

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# Chapter 1

# Introduction

## 1.1 Background and motivation

South Africa produces an average of 125 thousand tons of avocadoes each year, of which about 55% is exported, earning a total of 1.1 billion rand (R) of foreign exchange (DAFF, 2018; South African Avocado Growers' Association [SAAGA], 2018). Exported avocados are not only an important earner of foreign exchange, but also earn farmers a price premium compared to fruit sold in the domestic market. However, to be able to compete in the international arena, farmers have to deliver top-quality avocados with no defects caused by sun, hail, insect or wind damage (Winter & Bester, 2018). A South African avocado farm is a long-term investment, and famers must cope with volatile product markets, political uncertainty, fluctuations in yield quality and quantity, and a host of other uncertainties. Therefore, the production of avocadoes, like most other agricultural crops, is a risky venture in which risk management strategies play an important role in mitigating the risk associated with investment, financing or production decisions (Hardaker *et al.*, 2015).

A fundamental aspect of farm management is that the decision makers must make choices regarding resource allocation in a manner that is in line with both the monetary and nonmonetary goals of the enterprise. In addition, good decision-making requires information about the context of the decision, the different options available, the possible future, risks involved, goals, beliefs and preferences (Hardaker *et al.*, 2015). As there is no certainty about the future and the effects of unpredictable variables, it is inevitable that risk will be imbedded in agricultural decision-making. The agricultural sector is a volatile and highly dynamic environment and, therefore, risk and uncertainty are inherently part of the decision-making process. The complexity of decision-making under risk and uncertainty arises from the objective of maximising several, often competing, objectives (e.g. maximise profits, minimise risks, etc.). Hence, risk management strategies are used to overcome the uncertainty of future outcomes (Mare, 2014). Kay *et al*. (2016) argue that the constant and prompt development of agricultural technologies and business strategies forces agricultural decision makers to stay informed and adopt the necessary technologies and management styles to stay competitive.

On the other hand, adapting a risky and/or unproven technology or management style can cause financial stress in the enterprise.

Hail damage to avocados is one of the main production risks faced by farmers, since it affects both the quantity on fruit produced, as well as the exportability thereof. At present, hail insurance is the most commonly implemented strategy by which South African farmers manage the resulting production risk. Alternatively, farmers could also opt to self-insure, which means they do not implement any risk management strategy and thus carry the risk within their enterprise. However, of late, farmers also have the option of avoiding hail risk altogether through the installation of hail nets. Hail nets are not widely used by avocado farmers and have not been the subject of economic study (Stones *et al.*, 2017). According to Blakey *et al.* (2015a), there is a global trend in high-intensity horticulture to include high-density plantings, the use of superior cultivars, greater plant manipulation, and protected cultivation. However, they add that the avocado industry has been slow to adopt such innovations.

The use of shade nets as a means to mitigate abiotic risk in avocados has been tested in South Africa. In 2013, Westfalia Technological Services, in collaboration with the South African Avocado Growers Association (SAAGA), started a research project to test the suitability of shade nets to manage environmental or abiotic stress so as to increase avocado yield and fruit quality and to reduce production risk or/and increase profitability (Blakey *et al., 2014)*. Upon completion of the study, the researchers concluded that shade nets can be used as a successful management strategy to manage abiotic stress factors in avocado production (Stones *et al.*, 2017). However, the economic benefits of shade nets and the risk-reducing effect were not dealt with sufficiently in the research project. In addition, similar studies by Gandorfer *et al.* (2016) found that little research has been done on the risk-reducing effect of shade nets from an economic point of view. Shade nets alter the microclimate and intensity of biotic and abiotic factors within an avocado orchard; the changes can be positive and negative. The aforementioned factors will influence the economic feasibility of avocado cultivation, as there is a direct influence on the quality and quantity of fruit (Tinyane *et al.*, 2017).

## 1.2 Primary objective

As new types of risk management strategies enter the market, producers are uncertain about which strategy will be the most successful in terms of the enterprise's needs. The primary objective of this study was to compare the risk management effectiveness of shade nets versus hail or self-insurance as hail risk management strategies for avocado producers in South Africa. As hail insurance is the most utilised method of managing hail damage risk, this study provides additional information to producers considering the adoption of self-insurance or protected cultivation to manage risk.

## 1.3 Significance of study

Hail insurance is the most widely used means of managing hail risk in South Africa. The use of shade nets is the latest horticultural trend to manage abiotic stress factors like hail. However, avocado producers in South Africa are not adopting the use of shade nets to manage abiotic stress factors because of economic uncertainty. According to Gandorfer *et al.* (2015), very little research has been done on the risk-reducing effect of shade nets from an economic point of view. Most of the studies have dealt with the physical effects of shade nets on fruit, and not from a financial point of view; previous studies have focused on the increase in the quality of fruit that has been cultivated, but not on the economic benefit that these increases in fruit quality can have, and at what extra cost it comes, i.e. considering the cost of reduced yields and the construction of shade nets.

According to Louw *et al*. (2013), it can be assumed that, if producers are rational, their goal will be to maximise profits on a risk-adjusted basis over the long run. Furthermore, producers will not only choose outcomes based on their expected outcomes, but rather on their expected utility; expected utility and prospect theory underline this decision-making process. By using a stochastic dominance approach to analyse the results, it will be possible for decision makers to choose a risk management strategy based on their preferences for risk.

This study provides additional information to producers considering the adoption of protected cultivation in their production processes to manage hail risk. Furthermore, banks and institutions wanting to finance shade nets can gain insight into the feasibility of the transaction.

## 1.4 Research method

Nuthall (2011) explains that, in any situation in which a decision has to be made, there must be a choice and, to make a choice, there has to be a method assisting the decision maker to choose the alternative that maximises all objectives.

This study compares the conventional risk management strategy of hail or self-insurance to the unconventional risk management strategy of anti-hail shade nets to manage hail damage effectively, within the capacity of the producer to withstand adverse outcomes. A literature review covers and compares hail insurance and shade nets as hail risk management strategies to give the reader background and insight. Furthermore, the literature review covers production risks in avocado production. The literature review also discusses how strategic decisions at farm level are made when uncertainty is involved.

A whole-farm multi-period budget model for a typical, representative avocado farm was constructed. The comprehensive budget model allows the study to put different scenarios or decisions made by a decision maker into perspective. One of the main decisions or scenarios in the study is a decision maker considering a risk management strategy to manage hail risk. The available options are: the construction of fixed anti-hail/shade nets over avocado orchards, purchasing hail insurance, and self-insurance. The budget model was used to put the financial and risk position of the producer into perspective, and to evaluate each from an economic perspective, as the three strategies have different physical and financial characteristics. To incorporate risk the budget model was made stochastic.

The comparison was done by quantifying the expected monetary value of the hail-risk management strategies over a period of 20 years. This was accomplished by including all the relevant costs in relation to the eventual value of fruit production, which will lead to the future expected cash flows. The risk of hail damage is incorporated into the expected cash flows. The adjusted expected future cash flows are discounted to get a net present values (NPVs) to compare the risk management efficiency of the three strategies. The stochastic dominance criteria were used to compare the NPVs iterations of each strategy displayed by cumulative distribution functions (CDFs).

## 1.5 Data used in the study

The data used for the construction of the whole-farm budget consists mainly of secondary data obtained from the various role players in the avocado production value chain. The data for the key output variables (KOVs) (except hail insurance premiums) used in the empirical probability distribution was provided by Juan Winter of SOURCE, an agricultural consulting company doing benchmark analysis in the South African agricultural industry (Winter, 2019); hail insurance premiums were obtained from Santam Insurance (Scheepers, Personal Communication, 2019). The costs and assumptions of shade netting in the budget were extrapolated from a study done by Brown (2018).

## 1.6 Assumptions

In this study, a typical avocado farm was simulated as a whole-farm multi-period budget model. The unit of simulation was a "typical farm", which does not exist, but is rather representative of the typical farm in the regions studied. The construction of a typical farm requires numerous assumptions, all of which were made as objectively as possible by consulting the avocado literature and industry experts and adopting norms and indicators from other simulation studies.

In this study it is assumed that all the producers have access to export markets. Furthermore, producers know what impact a hailstorm will have on their crop. Hail insurance is assumed to be the conventional method used by producers to manage the risk of hail damage. Although shade net structures are not necessarily constructed to manage hail risk, it is assumed in this study that this is the main purpose of the nets, whilst fruit quality increases are considered secondary benefits. It is thus assumed that hail risk avoidance is the primary motivation for a producer to erect shade nets. Furthermore, it is assumed that the producer is risk averse and wants to consider options to manage the risk associated with hail damage.

Spatial diversification of a producer's portfolio will not be included in the study, although it is recognised as a highly effective production risk management strategy when the demographic areas' weather patterns are not correlated positively. It is assumed that hail insurance and shade nets are the only available risk management strategies. Therefore, hail insurance and anti-hail shade nets are considered as the only risk management strategies available to the producer. Although there are other strategies to diversify farming practices, as mentioned above, these will not be considered and are deemed to be beyond the scope of this study. In the model there is an extra option for self-insurance, in terms of which the decision maker does not implement any risk management strategy.

Furthermore, the decision maker in this study has a financial reality; this means that the decision maker uses external capital to finance the venture and typically has a high debt-to-asset ratio. Hence, if shade nets are considered, external finance will have to be used to finance them.

In the whole-farm simulation model, only avocado production was considered, and crop and cultivar diversification were not considered. A typical farm will have two, three or four different operating branches to diversify the risk. Furthermore, the typical farm modelled in this study produces a portfolio of cultivars, the average of which is considered, and no distinction is made between different avocado cultivars. In practice, a typical farm will have more than one cultivar of a specific crop. This model does not account for the production and market risk because of cultivar selection.

## 1.7 Outline

Chapter 2 provides an overview of the relevant literature, and Chapter 3 puts into perspective the multi-period whole-farm budget model of the representative avocado farm used in this study. Chapter 4 explains the methods and steps that were used to make the key output variables (KOVs) of the model stochastic. Chapter 5 presents the stochastic simulation results of the farm budget as cumulative distribution functions (CDF), which are interpreted through a stochastic dominance approach. Chapter 6 provides an overview of the study, synthesises the results and makes recommendations for further study.

# Chapter 2

# Literature review

The literature summarised and discussed in this chapter contextualises the South African avocado industry, together with the farm planning and modelling techniques that were applied in this study. Farm modelling and its different components and methods are discussed to gather more insight. A basic introduction to stochastic simulation is given, as this is an important tool to analyse risk in farming systems. Finally, an overview and comparison of the risk management strategies being compared in this research is provided.

## 2.1 The South African avocado industry

According to the South African Avocado Growers' Association (SAAGA) (2018), South Africa produced an average of 118 thousand tons of avocados from 2013 to 2017. There was an above normal harvest in 2018, with total production being estimated at 170 thousand tons. This was produced on 18.5 thousand hectares, with the area expected to expand by an additional thousand hectares every year (SAAGA, 2018). Currently, this means South Africa is the twelfth-largest avocado producer in the world, with Mexico leading the way, followed by the Dominican Republic and Peru (Binard, 2019). At present, 55% of South African avocado production is export oriented, and thus the local market also offers opportunities for producers (SAAGA, 2018). Of the exported fruit, 95% is destined for Europe and the United Kingdom, but substantial efforts are currently spearheaded by SAAGA to diversify South African exports into markets such as China and the United States (SAAGA, 2018).

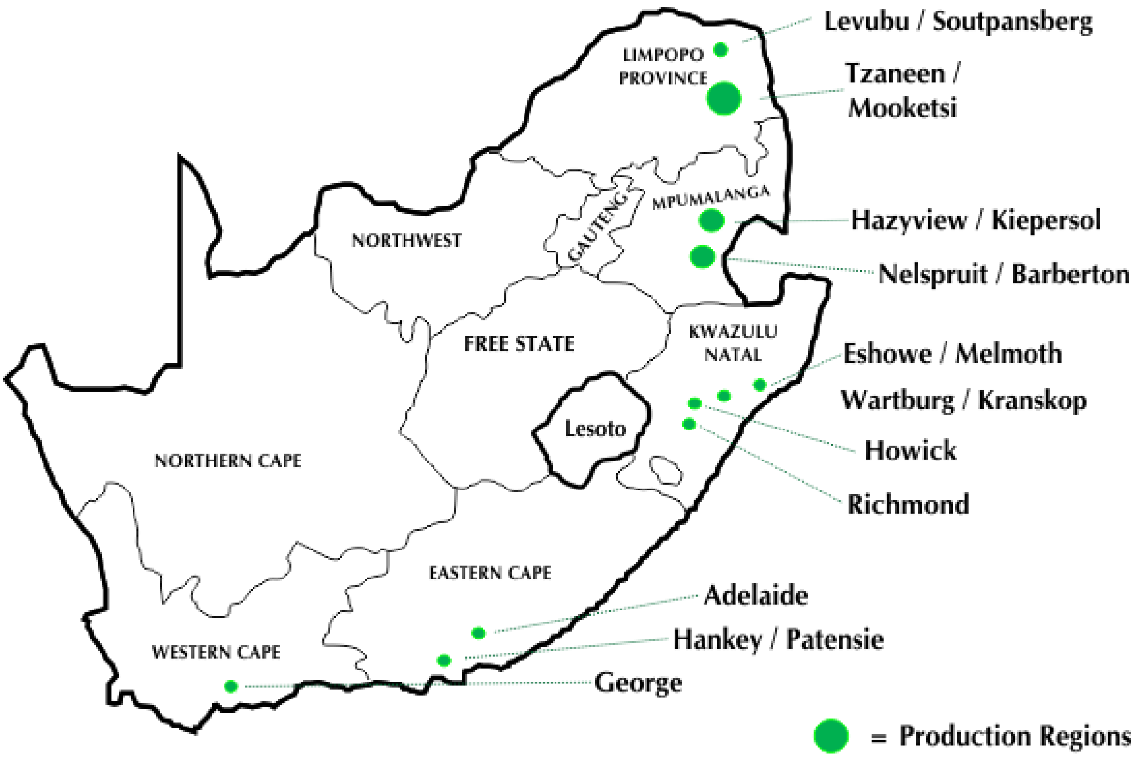


*Figure 2.1: The major avocado production areas in South Africa*

*Source: SAAGA (2018)*

Avocados prefers a warm or moderately cool subtropical climate with high rainfall and healthy and well-drained soils. In South Africa, the north-eastern part of the country provides a suitable climate to produce avocados and is the largest production area, as seen in Figure 2.1. The Southern and Western Cape are not traditional avocado-producing areas, but because of fruit entering the marketing window early and in the late season, these have brought new opportunities for producers. In 2017, the Limpopo province of South Africa – the largest production area, was responsible for ± 60% or 70 thousand tons of avocados. In second place was Mpumalanga, which produced ± 29% or 33 thousand tons of fruit. Lastly KwaZulu-Natal (KZN) produced ± 9% or 10 thousand tons of the total South African harvest, with the Southern and Western Cape producing ± 2% or two thousand tons.

Global avocado prices have showed a steady increase of 20% per year between 2013 and 2018, with avocado prices showing a 150% increase in 2016 alone (Binard, 2019). While the latter was partially the result of a weather-related supply disruption, the demand for avocadoes has shown a structural increase for several years (Binard, 2019). In the USA, for example, per capita consumption increased from 3,5 to 6,9 pounds per person per year between 2006 and 2015. This is driven partially by the associated health benefits and high versatility of avocados. A similar trend is also revealing itself in Europe, where consumption doubled to 365 thousand tons during the five-year period that ended in 2016 (Binard, 2019). The growing global demand thus provides opportunities for South African farmers.

South African avocado producers are positive about the prospects of the industry over the long term. The confidence in the industry is reflected by the number of avocado trees sold annually, as shown in Figure 2.2. Tree sales from registered nurseries showed a steady increase, from just over 84 thousand in 2000/2001, to peak at just under 274 thousand in 2011/2012, after which it levelled off at around 250 thousand. However, plantings are expected to jump to an all-time high of 377 thousand in 2018/2019 (SAAGA, 2018).

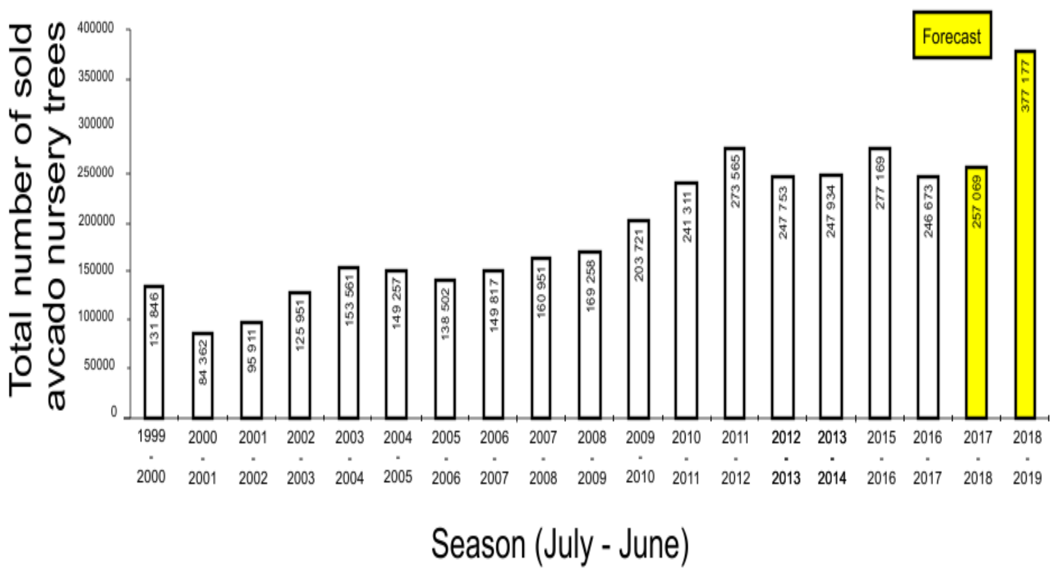


*Figure 2.2: Total number of avocado nursery trees sold: 1999 to 2019*

*Source:* SAAGA (2018)

## 2.2 Strategic farm planning

According to Kay *et al*. (2016), the process of strategic planning determines the long-term direction of a farming enterprise. Decisions in farm systems can be divided into two broad groups. First are the decisions dealing with short-term operational issues. These decisions are aimed to take advantage of opportunities or reduce the impacts of adverse conditions arising within a strategic farm plan. Second are the long-term decisions determined by the long-term goals of an enterprise. Strategic farm planning deals with the long-term decisions that bring about structural changes within an enterprise. Hence, the research question was considered to be part of strategic farm planning.

Farm planning involves futuristic thinking and planning and is critical for an industry or enterprise to stay competitive within the global economy. It will allow an industry or enterprise to be financially sustainable in the long run, and participants in the industry will realise economic profits and create value (Van Reenen & Davel, 1987). Roux and Hichert (2010) define value creation as:

> The ability to innovate and to implement innovative solutions before, and faster than anybody else. The challenge, then, is to learn from change and complexity, to understand it, value it, manage it effectively and, indeed, to embrace it as an agent of rebirth and growth. A precondition for meeting this challenge is the acquisition of knowledge about the future – about those things, patterns and relationships shaping the future (in both a positive and negative way).

### 2.1.1 Farm systems

Agricultural systems are viewed as complex systems that are inherently risky because of the nature of abiotic and biotic factors that affect the production process. Avocado production systems, like most other agricultural systems, are mostly carried out in uncontrollable environments and involve biological processes. Bicknell *et al.* (2015) define an agricultural system as "… an assemblage of components which are united by some form of interaction and interdependence and which operate within a prescribed boundary to achieve a specified agricultural objective on behalf of the beneficiaries of the system".

One of the main reasons why researchers and agricultural economists study farm systems is because the information gained from the modelled systems can be used to inform and improve decision-making (Strauss *et al.*, 2008). According to Nuthall (2011), a successful farm system analysis should incorporate all possible conditions and background factors in which the system operates. Considering the problem at hand, it is also relevant to include all possible conditions and background factors that will have an economic influence on the farm system. To do this, typical and representative farms of the specific industry are 'built' from scratch and studied, with the results used to improve decision-making.

Given that farm systems are complex and inherently risky, a multidisciplinary approach that integrates specialised knowledge and bridges the gap between different parts and perspectives of the system is required. In research, a systems approach can be used to study these complex farm systems. A systems approach allows the researcher to analyse the conditions and background under which a specific farm, typical farm or case study operates. This allows the researcher to quantify the decision environment and determine the impact of changing variables on the entire system. The use of a systems approach for decision-making is best explained by Nuthall (2011):

> … an alternative approach that can be used for making recommendations. This is the construction and analysis of proposed systems using basic technical information. A simple budgeting study on a farm is an example of this approach. That is, rather than simply compare systems that are currently in existence, all possible alternative methods of using the available resources are examined to select the best system.

This study evaluates shade nets and hail insurance as risk management strategies. Each strategy will depend on and influence the farm system. The notion of complexity is due to the compilation of systems from objects, with a series of interrelationships that function in some or another structure to achieve a common goal. In this instance, it involves a farm system consisting of various components that are interdependent of other components and/or the whole farm's performance. A change in one of the components invariably influences other components, and often in unexpected ways. Therefore, a method is needed that integrates these interdependent components and does not ignore the relationships. By definition, the complexity will also create a certain multifaceted nature, and thus alternative perspectives are essential in understanding these 'unexpected' effects of a system. For this purpose, experts in the field of avocado pear production are included in this research project.

The study follows a quantitative and positive approach, meaning that reality needs to be simulated as closely as possible when modelling a farm system. A systems approach allows a holistic analysis of the research question. The risk management strategies in this study are assessed in terms of the risk-reducing effect from an economic point of view. The factors that influence the economic performance and production risks need to be included in the study of the system. The systems approach follows an emergentist approach which sees a holistic system which is more than the sum of the properties of the system's parts. The systems approach allows a decision maker to make better decisions whilst taking risk and uncertainty into account.

### 2.1.2 Typical farms

According to Nuthall (2011), when farming systems are developed and studied there must be a study unit. He recommends that a typical farm should be selected as a study unit, as it will be a representative farm with similar characteristic to a large number of farms. The typical farm theory research method complements the farm systems approach and is seen as a research tool for different farm systems. The use of typical farms is also rooted in economic analysis through the use of representative firms (Feuz & Skold, 1992). According to Strauss et al. (2008), using a typical farm as unit of analysis is done by decision makers because analysing each individual farm is not practically feasible. Furthermore, modelling typical, representative farms is generally used as a base for farm-level planning and decision-making (Feuz & Skold, 1992).

The typical farm defines the most important production and non-production factors, as a holistic view of the farm system must be visible to the interpreter. According to De la Porte (2019), farm size, market access, profitability, farming practices, ownership and yield expectations are some of the most important aspects that a typical farm must represent. There are different ways to approach the construction of typical farms. Köbrich *et al.* (2003), for example, are of the opinion that typical farming systems should be constructed using qualitative criteria based on subjective assessments and ad hoc considerations. Other authors argue that quantitative methods, like principle component and cluster analysis, can be used to construct typical farms (Köbrich *et al*., 2003; Strauss *et al*., 2008). Within this context, it is important to mention that a typical farm does not refer to the average farm in the industry, but rather to the mode of the industry. The typical farm is constructed as representative for the region in which the study is conducted, as production activities and conditions may differ in different regions.

### 2.1.3 Farm budgets

According to Nuthall (2011), farm budgets are one of the simplest analytical tools through which farmers can improve decision-making. Farm budgets are a form of quantitative research that is based on historical data, experience, assumptions and forecast, and are widely used in financial planning (Van Reenen & Davel, 1987). Considering shade nets as a risk management strategy is a typical farm management decision and, according to Louw *et al*. (2013), farm budgets provide a basis and a basic source of information for making these decisions. Furthermore, Louw *et al*. (2013) define budgeting by farming enterprises as follows:

> Budgeting is concerned with the coordination of resources, production and expenditures. A Budget is a written plan for future action, expressed in physical and financial quantities. Budgets are constructed to estimate the outcomes of activities in the future, as opposed to records, which are summaries of past outcomes. Budgeting allows for estimates to be made on paper, before the commitment of funds or resources to an activity, allowing for the anticipation and avoidance of problems that will likely be encountered based on historical information.

According to Kay *et al*. (2016), a wide variety of budgets are available to decision makers. The budgets that are used most often are: enterprise budgets, partial budgets, break-even budgets, cash flow budgets, capital budgets, financing budgets and whole-farm budgets.

The reason why farm budgets comprise a relevant research method for this study is because the main objectives of budgets correspond to the problems being addressed. The objectives of budgets, according to Louw *et al*. (2013), and the problems at hand can be summarised in four points:

1. To purposefully plan the impact that shade nets will have on a farming system and all its subdivisions.
2. To compare the most common hail risk-hedging mechanism, hail insurance, to shade nets.
3. To determine the capital requirements needed for shade nets and to make an investment decision, as shade nets are a long-term, capital-intensive investment.
4. To make cash flow and business health estimates in order to access credit for financing shade nets, which require large capital outlays.

Farm budgets provide an appropriate research method for this research problem. A more in-depth analysis of whole-farm multi-period and stochastic budgets will follow in this section, as they are the most relevant to the study.

**Whole-farm budgeting models**

According to Hoffmann (2010), whole-farm budget models are ultimately used to simulate a specific farm in financial and physical terms. These models are constructed in spreadsheet programs like Microsoft Excel. A time dimension can also be included into a whole-farm budget, moving it from a single year to a longer term as a multi-period farm budget (Louw *et al*., 2013). As shade nets have a lifetime longer than one year, a multi-period whole-farm budget was used.

The whole-farm budget can be used to evaluate profitability measurements such as net farm income and cash flow. Capital budgets are used to calculate the internal rate of return (IRR) on capital investment and/or net present value (NPV), although some adjustments are made to the whole-farm multi-period budget to allow for this (Hoffmann, 2010; Louw *et al*., 2013).

According to Hoffmann (2010), a budget is typically dictated by the question that it tries to address, i.e. the impact of labour-saving technology, considering the expansion of the farming enterprise or making use of external capital. Budgets are defined as a method of simulation modelling. The sophistication of budgets in a spreadsheet environment lies in the number of variables that can be interconnected through a series of simple equations. Mathematical simulation models rely more on the sophistication of the mathematical equation itself.

**Capital budgets**

Capital budgeting implies longer term panning in a dynamic and everchanging agricultural environment. The goal of planning for longer periods is to explore the expected outcome of options measured on specific criteria within the whole farming system as opposed to predicting the exact future of events. The whole-farm multi-period budget model is easily adapted to create a capital budget (Hoffmann, 2010).

**Stochastic farm budgets**

Multi-period whole-farm budgets can take two forms with regard to key output variables (KOVs). These variables will typically include yields, prices and cost of operations, and these output variables are chosen as they are seen as values that are likely to have a significant effect on the budget. These variables that can have fixed or variable values. If the KOVs are fixed, the budget is said to be deterministic. If the KOVs are variable and are adjusted continuously, the budget is said to be stochastic. As mentioned before, the values of stochastic KOVs are determined by probability distributions.

After the KOVs have been simulated the results are represented by probability distributions, and the probability distributions can also be transformed into cumulative distribution functions. To analyse, compare and quantify the risks associated with different scenarios and decisions, probability and cumulative probability functions are used. Hence, stochastic budgets are a frequently used research method to incorporate risk into a budget.

## 2.2 Stochastic simulation

### 2.2.1 Introduction to stochastic simulation

In essence simulation models are built by researchers to create a digital prototype of a physical system and utilised in various specific situations in agriculture, such as crop growth modelling, yield models, crop response models, livestock growth models and livestock replacements models *etc.* (Hoffmann, 2010). A simulation model is said to be stochastic when the variables of the model are not constant with fluctuations of variables being based on probability distributions (Strauss, 2005). Stochastic simulation models are explained by Hardaker *et al.* (2015) as:

> … a mathematical model whereby the real system is represented in the form of a set of equations and parameters. Such simulation models are commonly used to analyse so-called 'what-if' questions about a real system. Such a model typically represents the relationships between the inputs and outputs of the real system and allows for the effects of changing control or decision variables to be explored. The method is sufficiently flexible to allow the incorporation of complex relationships between variables and hence to mimic aspects of the performance of complex real systems such as exist in agriculture. In stochastic simulation, selected variables or relationships incorporate random or stochastic components (by specifying probability distributions) to reflect important parts of the uncertainty in the real system.

In this study, the real system is represented by the modelled avocado farm. As Hardaker *et al*. (2015) state, the random or stochastic components of the variables are incorporated by using probability distributions. Therefore, choosing the correct probability distribution that reflects the random component of the variable as close as possible is crucial for the success of the simulation model. Probability distributions can take two forms, namely discrete and continuous. If a probability distribution is described by tables or figures that describe the likelihood of events based entirely on empirical data without making any assumptions about the shape of the distribution, it is called an empirical probability distribution.

### 2.2.2 The FINSIM model

For this research project, a whole-farm budget was constructed that can incorporate stochastic variables. The mechanism applied was based on the simulation of multi-variable budgets. The theoretical background is presented briefly.

According to Jansen van Vuuren (2013), the FINSIM model was originally developed by Strauss (2005) as a deterministic farm-level decision-support instrument for grains and livestock. The FINSIM farm-level model uses the methods suggested by Richardson *et al.* (2000) to stochastically simulate the KOVs, it is further explained in Section 4 since it forms the basis of this study. Since developed by Strauss (2005) the FINSIM has evolved, with Strauss and Lombard (2008) altering the model to allow for the stochastic simulation of variables. The farm-level model of Strauss (2005) was also incorporated by the Bureau for Agricultural Policy (BFAP) as part of a partial equilibrium model, and was an addition to the BFAP sector model developed by Meyer and Westhoff (2003). This was done to evaluate the effects that an agricultural policy will have on a sector in the economy (Strauss *et al*., 2008). The farm-level and sector models are linked to each other. Linking the farm- and sector-level models policy makers and/or decision makers has the ability to predict the change at both macro and micro level (farm and sector level) with quantitative analysis in monetary terms (Strauss *et al*., 2008). Hence, the FINSIM model is also known as the BFAP farm-level or BFAP sector-level model. As this thesis does not analyse the effects of policy change on an agricultural sector, only the FINSIM farm-level model is discussed.

> The BFAP Farm Program was established with the main objective of assisting farm businesses with strategic decision-making under changing and uncertain market conditions. This is done by means of advanced quantitative analyses of how different policy options, macroeconomic variables, and volatile commodity market conditions could impact farm businesses in selected production regions in South Africa. The BFAP Farm Program includes economic analysis of the production of grain, oilseed,

livestock, wine, fruit, sugar, and vegetables. As such it is a useful tool for farmers, agribusiness firms and policy makers to strategically plan ahead for potential short falls in income (BFAP, 2011).

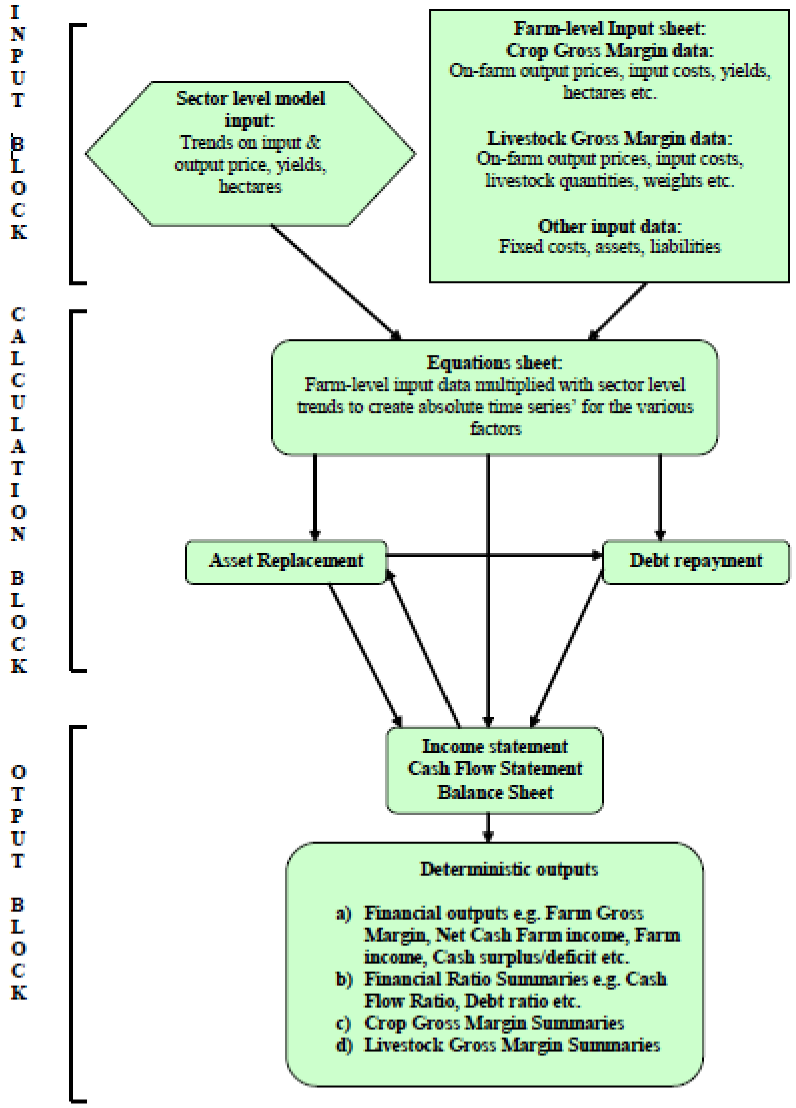


*Figure 2.3: The FINSIM farm-level model*

*Source: Strauss (2005)*

The FINSIM model consists of input, output and calculations blocks, as seen in Figure 2.3. Within the input block there are two sections: the first is the sector-level model input and the other is the farm-level input sheet. The model 'built' in this study follows the same structure as the FINSIM model, but the entire model for this study was uniquely constructed by die author. Furthermore, the study only farm level decisions, therefore the sector level input block is ignored.

The data of a specific farm or typical representative farm is simulated in the calculation block, together with asset replacement and long-, medium- and short-term debt repayments. In the calculation block, tax and other economic factors can be added into the model. Furthermore, if the model is stochastic, the simulation of variables is also done in the calculation block. The mathematical processes behind the stochastic simulation of the model is done by programs like @Risk and SIMETAR. In the BFAP model, the farm-level input variables are multiplied by the sector-level model in the calculation block but, as mentioned before, the sector-level model is not used in this thesis.

The output block of the model can give either deterministic or stochastic outputs, depending of the input data in the input block. The results produced in the output block are financial performance measurements such as net farm income, gross margin, return on equity, etc. Given that several scenarios can be tested, a large number of results can be generated, which requires specialised techniques such as stochastic dominance to make sense thereof.

### 2.2.3 Stochastic dominance

Stochastic dominance is a stochastic efficiency method that can be used to rank different risky scenarios through a pairwise comparison of different alternatives (Hardaker *et al.*, 2015). This is achieved by transforming the probability density functions (PDFs) of the results obtained from stochastically simulating the budget model into cumulative distribution functions (CDF). This allows decision makers to compare the whole distribution of outcomes from the respective scenarios using the CDFs.

This ranking of risk management strategies is done according to their efficiency under consideration of the associated cumulative distribution functions (CDF) and underlying risk attitudes. Stochastic dominance of the first and second order are discussed further. However, in some cases FSD and SSD will not be able to provide a sufficient solution, as there will be too many alternatives in the set; third-degree stochastic dominance can be used, as it has more discriminating power, but is not considered in this study.

**First-degree stochastic dominance (FSD)**

First-degree stochastic dominance (FSD) assumes a positive marginal utility function, which means that the decision maker prefers more over less. An FSD ranking can be done if the CDFs of the respective scenarios have no intersection (do not cross) at any point as seen in Figure

2.4. For example: if given two alternatives A and B, each being defined by CDFs FA(x) and FB(x) respectively, alternative A dominates alternative B in the first-degree, irrespective of the decision maker's underlying risk attitude if:

$$F_A(x) \leq F_B(x) \text{ for all } x$$

*Equation 2.1: Stochastic dominance of first order*

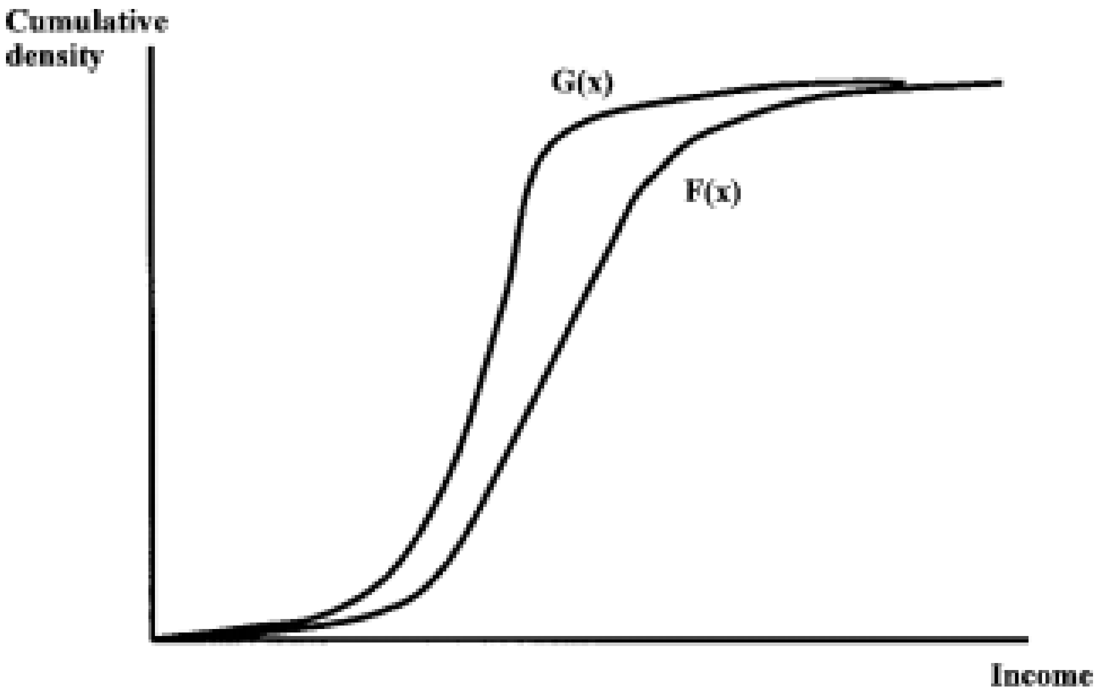


*Figure 2.4: An example of FSD*

*Source:* DeVuyst and Halvorson (2004)

Practically, this means that, if FSD is present, the decision maker will always prefer the CDF of the scenario that is the furthest from the origin.

**Second-degree stochastic dominance (SSD)**

If the CDFs of two or more scenarios intersects at any point, then FSD is not possible and second-degree stochastic dominance (SSD) may be plausible. SSD is only possible for the CDF starting to the right/below the competing CDFs. In Figure 2.5, F(x) starts to the right/below G(x), therefore it is only possible for F(x) to dominate G(x). However, for SSD to be possible, the area before the CDFs' cross must be bigger than after they cross. Equation 2.2 explains in metaethical terms that stochastic variable "a" dominates "b" if:

$$\int_{-\infty}^{x^*} F_A(x)\,dx \leq \int_{-\infty}^{x^*} F_B(x)\,dx, \text{ for all values of } x^*$$

*Equation 2.2: A mathematical equation explaining stochastic dominance of second order*

SSD is more easily explained by graphical illustration, as seen in Figure 2.5. The area before the two functions cross, "area a", is larger than the area after the two functions crossed, "area b". Therefore, F(x) is stochastically dominant of second order over G(x).

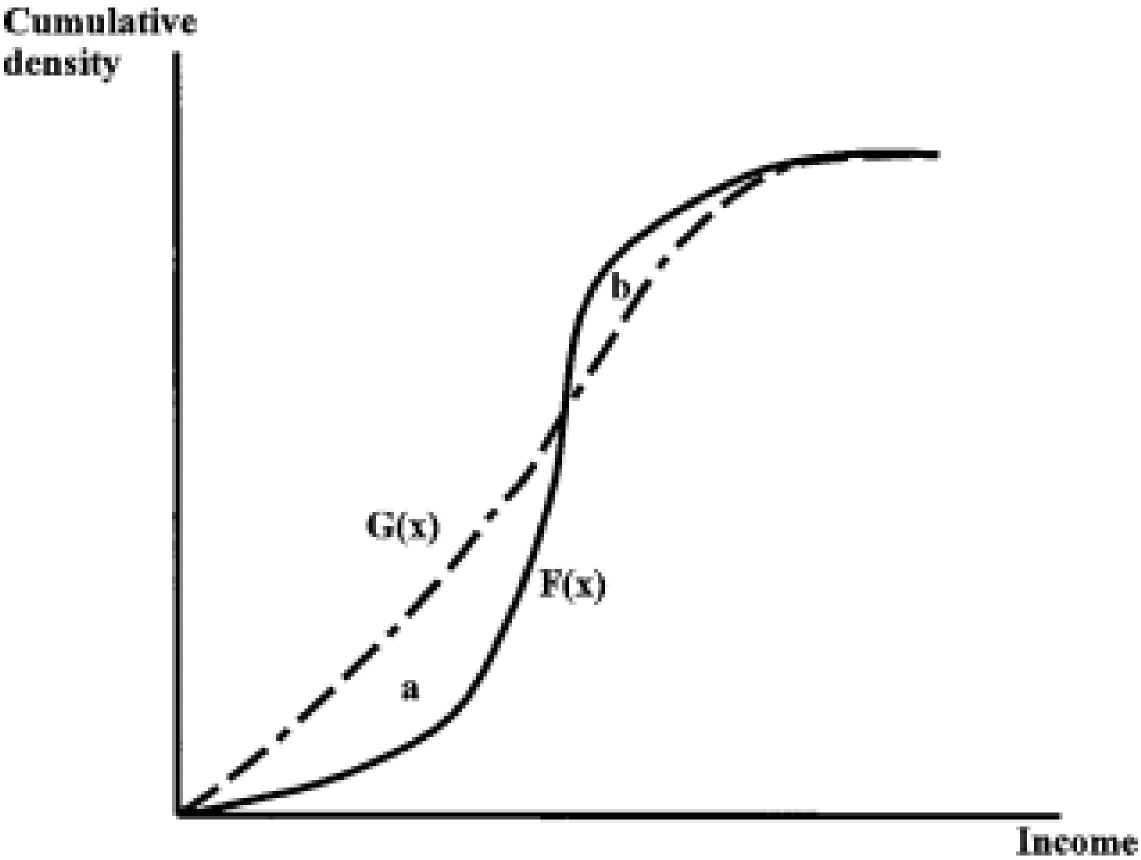


*Figure 2.5: An example of SSD*

*Source:* DeVuyst and Halvorson (2004)

Hence, under this SSD, distributions of outcomes are compared based on areas under their CDFs. The CDFs are only allowed to cross once. SSD assumes a positive but declining marginal utility curve, which means that the decision maker is risk averse. Having stochastic dominance, it does not mean that will be better off in all cases you, since there is still a probability that the worst-case scenario might happen, or extreme events occur, after which you might be worse off.

### 2.2.4 The importance of accounting for risk and uncertainty

Risk and uncertainty are inherent in agriculture processes and mostly emerge from unpredictable and uncontrollable future events (Van Reenen & Davel, 1987). By using available information, participants in an industry try to build up predictions and future scenarios based on subjective possibilities. Avocado producers must cope with numerous risk factors that lead to a high variability in farm income, causing complexity within the farm's economy. According to Loughrey *et al.* (2015), risk management can lead to greater productivity by relaxing financial constraints. The increase in productivity is caused by a higher likelihood of access to finance, which is then used to finance productivity-enhancing investments.

### 2.2.5 Production risk in avocado production systems

Avocado farming is directly exposed to the natural elements. It is carried out in open systems subject to various factors, such as the climate, topography and pedological features (Fleisher, 1992). Having limited control over the complex system elements often leads to risks for the producer. The risks are associated with adverse weather conditions, like fierce winds, drought, heat, hail and floods. Hardaker *et al*. (2015) classify the specific risk related to unpredictable weather and uncertainty about the performance of crops as production risk. In farming, as in business, no risk means no reward – as the profit is the incentive for risk-bearing (Hardaker *et al.*, 2015).

According to Louw (2013), production risk mostly occurs from agriculture being exposed to uncontrollable weather events, including extreme temperatures, hail and strong winds. The type of production risk posed by hail exposure is a decrease in fruit quality and quantity. A fruit farmer will typically refer to pack-out percentage when talking about the export grade percentage, with Class 1 being export grade. A rational producer will strive to maximise the pack-out percentage and yields in order to maximise profit (Blakey & Wolstenholme, 2014). The grading standard for export fruit is determined by the Perishable Products Export Control Board (PPECB) quality certifications (PPECB, 2017). Products approved for export carry the "passed for export" stamp (PPECB, 2017).

Amongst the production risks for avocado production are sunburn, wind damage, spots and hail. According to De Villiers (2010), sunburn is caused when direct, intense sunrays fall onto fruit without sufficient protective leaf cover. Sunburn damage on the avocados skin starts as yellowish green due to discolouration of the green pigment (chlorophyll) in the skin, as illustrated in Figure 2.7 (Tinyane *et al.*, 2017). This is especially a problem in west-facing trees (see Figure 2.6) (Schaffer *et al.*, 2013). It is believed that anti-hail shade nets prevent an overdose of radiation from the sun and thereby reduce sunburn (Knittex, 2017).

*Figure 2.6: Exposed fruit has the potential to contract sunburn*

*Source: Tinyane* et al. *(2017)*


*Figure 2.7: A typical sunburn mark that decreases fruit quality*

*Source: Blakey* et al. *(2015)*

Wind damage to avocado is illustrated in Figure 2.8. This physical damage of the skin of the fruit happens when fruit are still in the youth stage of development after fruit set (De Villiers, 2010). This damage is caused by wind forcing the fruit to move while hanging on the tree, and then either rubbing on nearby branches or on other fruit (De Villiers, 2010).


*Figure 2.8: Wind damage marks on avocado skin*

*Source: Blakey* et al*. (2015)*

Mark or spots on avocados, as illustrated in Figure 2.9 are also a major defect. This is caused by trauma, e.g. insects or fruit flies, or physical damage after fruit set, either during harvest or from hail. De Villiers (2010) states that hail marks on avocados may downgrade fruit to oil factory (class 3) or informal trade. In extreme storms, the condition of the trees may be affected, with leaves, branches and bark being hit off by hail (Blakey *et al*., 2015a).

According to the South African short-term insurer, Santam (2015), hail is a highly sporadic event. This makes it difficult to predict the possibility of hail at an exact point in time for a certain geographical location. Using historical data of hailstorms, financial institutions can predict the prevalence of hail, the time of the year and the average intensity, with specific reference to maximum intensity. With statistical analysis, a financial institution can thus quantify the risk in the specific production location. This mechanism is how insurance premium rates are determined. However, producers do not have access to this data and must make more subjective decisions. Hailstorms can range from small storms, which hardly affect production, to catastrophic events with the whole harvest being destroyed. Figure 2.9 illustrates what physical damage hail can cause to fruit, causing a downgrade in fruit quality.

> Hail, as in any fruit growing venture, can be catastrophic and is highly undesirable, particularly where fruit are sold in quality conscious, discriminating markets in temperate zone countries. Production in subtropics 'hail belts', with a known greater frequency of hailstorms, should be avoided (Schaffer *et al*., 2013).

*Figure 2.9: Effect of hail on avocado fruit*

*Source: De Villliers & Joubert (2011)*

**SAAGA industry loss benchmark**

Recently, SAAGA conducted research on the factors that cause 'losses' in the avocado production process (Winter & Bester, 2018). The term losses can be described as fruit that is rejected on the sorting line in the packhouse. The data used in the study was from 2014, 2015 and 2016, and was collected from the main packhouses in the Limpopo, Mpumalanga and KwaZulu-Natal production regions.

The study found that wind/carapace skin and sun damage were the two main factors causing rejection of fruit. The other three prominent factors that caused fruit rejection were insect damage, hail damage and undersized fruit.

### 2.2.6 Risk and uncertainty of adoption of new technologies

Shade nets and other forms of protected cultivation technology are widely implemented in other horticultural industries, like citrus, stone and pome fruit and other exotic fruit. The avocado industry has not yet implemented these technologies to the extent of other industries (Blakey *et al.*, 2015b). The slow adoption of this technology can be attributed to uncertainties arising from the feasibility, profitability and additional risk that comes with the adoption of a new technology. For the successful adoption of technologies, managers also need to upgrade the necessary information and skills (Torkamani, 2005). Furthermore, asset fixity and path dependence, which form part of the farm problem, also explain the reason for the risk associated with implementing shade nets as a risk management technique, as it is a large capital-intensive investment. Stochastic simulation is a tool for decision makers to investigate new technologies before they are s adopted.

## 2.3 Production risk management strategies in agriculture

### 2.3.1 Crop insurance

Hail insurance is an indemnity insurance based on a contract and can only be purchased after fruit set (Santam, 2015). Insurance is taken out against the agreed insured amount, which is normally in line with the expected income of the producer. The expected income is based on expected yield and market prices and can lead to under- or over-insurance. Hail insurance will cover the monetary yield and quality losses as a percentage of the agreed insured amount (Gandorfer *et al.*, 2018).

The cost of hail insurance is called the premium and is expressed as a percentage. The cost is calculated as the percentage of the premium to the insured amount. The insurance company determines the premiums by statistics and mathematical calculations, based on historical records and payments for a geographical region (Santam, 2015). The higher the risk of hail, the higher the premium will be. In the main avocado production areas of South Africa, the insurance premium is between five and nine percent of the insured value of the item in the policy.

Natural weather cycles, like the El Nina/Nino weather phenomena, can be determined scientifically by ocean temperatures (NOAA, 2017). According to Tack and Ubilava (2012), the effect of climate on insurance in this case can be determined. In the research they found that the ENSO (El Nino-Southern Oscillations) impacts had an economically meaningful effect on crop insurance premium rates (Tack & Ubilava, 2012). The frequency and intensity of hail in specific geographical areas will influence the premium rates (Santam, 2015).

Radar and satellite technology can determine the build-up and movements of hail storms accurately (Santam, 2015). However, this technology has limitations, especially in relation to agricultural crops. The advance warning is limited to short periods of time, ranging from a few minutes to two hours for very strong storms. These short-term notifications can be valuable to moveable assets like vehicles or livestock, but will be of no use for annual and perennial crops or unmoveable assets (Santam, 2015).

### 2.3.2 Shade nets as production risk management instrument

Producers constantly seek improved efficiency and optimised output in production methods with the help of innovation, technology and research (see Figure 2.10). According to Blakey *et al.* (2015b), the avocado industry is lagging behind the wider horticulture industry in the adoption of new, advanced and protected cultivation techniques; the reasons for slow adoption are explained later in this section. Shade nets are a form of protected cultivation. Shade nets are a physical structure erected over orchards. The structures can be erected at the onset, when a new orchard is established or over existing orchards. Shade nets differ from drape nets by being a permanent structure over the orchard. Drape nets are unsupported netting placed directly on the tree after fruit set and completely removed for harvesting the fruit and in the flowering period. This study focuses only on permanent shade net structures.

*Figure 2.10: Innovative techniques for constructing anti-hail shade nets.*

*Source: Knittex (2017)*

There are two main companies manufacturing hail nets in South Africa, namely Knittex and Allnet, with the former being the largest manufacturer. Knittex has a specific net called SpectraNet, which is the most common product used on avocado farms for anti-hail nets. According to the company, "The brand name SpectraNet aptly describes the products ability to manipulate and alter the quantity, quality and relationship of blue, green, red and far-red wavelength energies absorbed by plants" (Knittex, 2017).

The main function of SpectraNet is climate control and light-wave manipulation in the agricultural and horticultural industries (Knittex, 2017). According to Winter and Bester (2018), wind and sunburn damage account for 28% and 27% respectively of the loss of export fruit. SpectraNet is designed specifically to provide plant and crop protection against extreme weather conditions and damage caused by hail, wind, insects, birds, drought and sunburn (see Figure 2.11 and Figure 2.12) (Knittex, 2017). According to Knittex (2017), a well-constructed shade house using SpectraNet fabrics will enable the producer to modify or create an ideal, protected microclimate in which to produce high-quality fruit and thereby increase pack-out percentage.

*Figure 2.11: Anti-hail shade net.*

*Source: Knittex (2017)*

*Figure 2.12: Anti-hail shade net.*

*Source: Knittex (2017)*

A study conducted by Tanny and Cohen (2003) determined the effects that shade nets over and within a citrus orchard had on wind and selected boundary layer parameters. The conclusion was that the shade net could reduce wind speed in the foliage by 40% regarding the wind speed measured in the canopy of the orchard when unshaded (Tanny & Cohen, 2003). According to Smit (2007), shade netting over an orchard controls the microclimate in the production area, causing a more suitable environment for the production of quality fruit and reducing imperfections. Fewer imperfections can lead to an increased pack-out percentage, leading to increased profit (Smit, 2007).

A study by Tinyane *et al*. (2017) found that photo-selective shade nets significantly reduce sun damage. Tinyane *et al*. (2017) also found that photo-selective shade netting had no influence on producing larger fruit. However, under white nets, there was a shift towards the medium-sized fruits preferred by commercial markets (Tinyane *et al*., 2017). Figure 2.13 illustrates the benefits emanating from nets in general. Furthermore, Malapana (2016) found that shade netting with a 20% shade factor caused an 18% reduction in solar irradiance. The reduction of solar irradiance had a positive effect on soil water availability because of a decrease in evapotranspiration. There is conclusive evidence in the studies of Malapana (2016) and Tinyane *et al*. (2017) that covering avocado orchards with shade netting will reduce abiotic stress factors and improve fruit quality. However, both studies found that yield may be lower under shade netting in comparison to open fields.

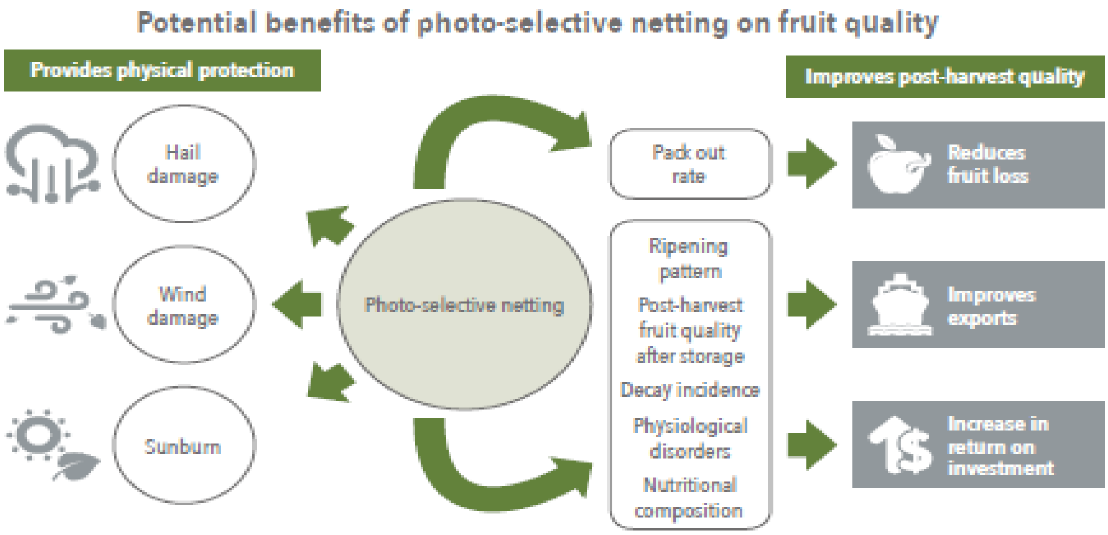


*Figure 2.13: Potential benefits arising from anti-hail shade nets.*

*Source: Tinyane* et al. *(2017)*

In the trials conducted by Westfalia (Blakey *et al*., 2014), shade net structures were erected over established orchards at the start of the 2013/2014 season. The trail sites were situated at Schagen in Mpumalanga, Mooketsi in Limpopo and Karkloof in KwaZulu-Natal. Each trial site consisted of a block covered with shade netting and a block in the same orchard that was not covered. The trial blocks were in the same orchard; hence the trees were the same age and received the same inputs, with shade net cover being the only variable. The overall results of the trials were that there is a definite increase in fruit quality. With regard to yield, conclusive results were not obtained, although there were positive results of an increasing yield for blocks grown under shade nets when compared to open fields.

When comparing all the results of yield and quality from studies conducted on avocados grown under shade net, the conclusion is as follows: Studies conducted by Blakey *et al.*, (2014), Malapana (2016) and Sivakumar (2017) agree that increases in the quality of fruit are caused by a decrease in abiotic stress factors. However, there is no conclusive evidence that yield is increased or decreased, as there are contradicting results. Honeybees are the main pollinator of avocado flowers and shade netting may influence the effectiveness of the bees. Therefore, it is assumed that shade nets only improve fruit quality and do not influence yield.

**Challenges with using shade nets as a production risk management strategy in avocado production**

It is assumed that firms want to maximise profit on a risk-adjusted basis, therefore protected cultivation in horticulture crop production can be justified. Research by Blakey *et al.* (2015b) found that the delayed use of anti-hail nets in avocado in comparison to its frequency of use in deciduous fruit and citrus is attributed to the following challenges:

- Established orchard trees grow to tall trees together with large inter-row spacing. This makes the construction of nets difficult.
- Avocado trees are vigorous, vegetative growers, complicating pruning practices. Furthermore, the avocado industry does not have a dwarf rootstock that will inhibit vigorous vegetative growth (De Villiers & Joubert, 2011).
- The main pollinator of the flowers in avocado orchards is bees and shade nets can block their natural route to the flowers. Lower bee activity in orchards causes a decline in fruit set, leading to a reduction in yields. This is the reason why the stochastic simulation model used in this study does not assume that yield does not improve under shade netting.

- Planting high-density orchards with the latest technologies like ultra-low-flow drip irrigation and ridging are only a recent trend. The yields per hectare are higher than those of conventional cultivation methods.

## 2.4 Comparing shade nets and crop insurance

A major difference between anti-hail nets and hail insurance is that establishing an anti-hail net requires a long-term investment, while the decision to insure against hail is made annually. The two instruments manage hail risk in different ways. While hail insurance covers (ex-post) the monetary yield and quality loss, the anti-hail net prevents (ex-ante) yield and quality damage. Alternatively, one can argue that hail insurance transfers the risk to a third party at an annual cost, whilst hail nets avoid the risk altogether through a once-off investment, which can have longer term financial effects.

A study by Gandorfer *et al*. (2015) compared shade nets and hail insurance as risk management strategies. Gandorfer *et al*. (2015) state that the two methods have differences in the following aspects:

1. Risk management mechanism

Hail insurance is a financial product bought from a financial service provider. Insurance works as a written contract between two parties and is subject to certain conditions. The hedging mechanism is an ex-post mechanism, with damage only taken care of after the damage has occurred.

Shade-netting works on an ex-ante manner. The shade netting works as a physical barrier and hail cannot penetrate the structure. With an ex-ante hedging mechanism, it makes the forward contracting or direct marketing of fruit more viable. The forward contracting/direct marketing of fruit can become risky if an ex-post risk management strategy is followed and the product cannot be delivered. Another difference is that shade netting influences the microclimate, yield and quality of the fruit directly, while hail insurance has no influence on the fruit.

2. Remaining risk

In theory, shade nets should provide complete cover in the case of hailstorms. However, there is a possibility of extreme weather events causing damage to the shade nets and fruit. The remaining risks with hail insurance are disagreements in the contract, inappropriate insured amount (being over- or underinsured). As hail insurance can only be bought after fruit set, there is also a remaining risk that the flowers can be damaged by hail before fruit set, which will reduce yield.

3. Flexibility

Shade nets are permanent structures constructed over orchards. If the decision is made to implement shade netting as a risk management strategy, the nets will be present in the orchard for a period of at least ten years. Shade nets therefore enforce path dependence. Shade nets are a large, capital-intensive long-term investment and a typical producer will require external finance; hail insurance will be more flexible (not path dependent), and more suitable for farms with a high debt-to-asset ratio.

4. Annual risk management cost per hectare

The annual risk management cost of shade netting per hectare will firstly depend on the type of structure, as this will influence the construction cost. In South Africa, the hail insurance premiums for the main avocado production areas range between 5% and 11% (Scheepers, Personal Communication, 2019) of the insured amount (depending on expected yield and price) per hectare, as illustrated in Figure 2.14. The insured amount will be a subjective expectation. The yield expectations are based on the amount of fruit set, as insurance can only be bought after fruit set. Therefore, hail insurance hedging costs per hectare are positively correlated with annual revenues per hectare.

The difference with shade netting is that the risk reduction cost per hectare is constant over time and independent of the annual income per hectare. Hail insurance has an advantage over shade netting in years with low expected revenues; in years of low revenue expectations, caused by low yields and/or prices, the insured amount can be adapted by the decision maker(s).

Figure 2.14 illustrates that, with regard to site-specific hail risk, the risk reduction cost per hectare for hail insurance is directly correlated with the possibility or risk of hail. If the risk of hail increases, the premium paid per insured amount will also increase. Thus, the cost of the hail insurance hedging strategy is directly correlated with site-specific hail risk. According to Figure 2.14, it can be assumed that, for orchards with a high expected revenue and high site-specific hail risk, shade nets would become a viable hail risk management strategy. The viability will depend on the expected annual revenue and the construction cost of the shade net structure.

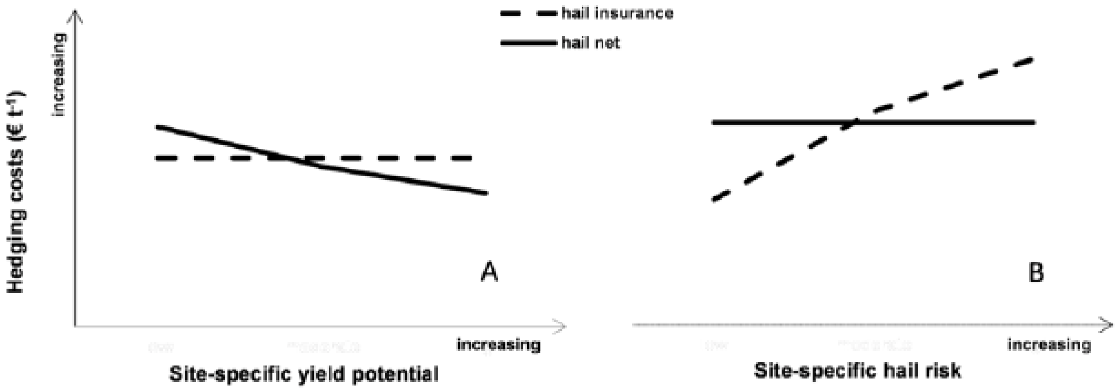


*Figure 2.14: Hedging cost per ton of fruit for a) yield potential and b) hail risk.*

*Source: Gandorfer* et al. (2015)

# Chapter 3

## Model development of a typical avocado farm

The unit of analysis of this study is a typical farm, as discussed in Chapter 2. The typical avocado whole-farm multi-period budget model developed by this study is constructed on the same theoretical basis as the FINSIM model discussed in Chapter 2. The budget model is essentially a simulation model based on accounting principles. The objective of this chapter is to explain how the typical farm and budgeting model that were discussed in Chapter 2 were developed.

### 3.1 Introduction to the Lowveld ecoregional area

The Lowveld production region was chosen for the purpose of this study, given that the region represents 90% of the South African avocado crop (SAAGA, 2018). This is important, since Strauss *et al*. (2008) argue that a presentative farm has to be region specific, given that each has its own unique characteristics that affect the farming system. The greater Lowveld agroecological region consist of the Barberton, Nelspruit, Kiepersol, Hazyview, Letaba and Levubu sub-regions, given their respective microclimates. It was decided to expand the construction of the typical farm to the Lowveld region to ensure that the results are sufficiently generalisable for most avocado farmers.

Kleynhans *et al.* (2005) identified the Lowveld region as seen in Figure 3.1 which illustrates the Lowveld area on a map of South Africa. The Lowveld covers parts of Mpumalanga, Limpopo and eSwatini. According to Engelbrecht *et al.* (2011), the Lowveld region has a subtropical climate and is 700 metres above sea level on average. The region is predominantly a summer rainfall area, with annual rainfall ranging on average from 500 to 800 mm. Apart from avocados, a wide variety of agricultural products are cultivated in the area, with citrus, macadamia nuts and other subtropical fruit being the most prominent crops.

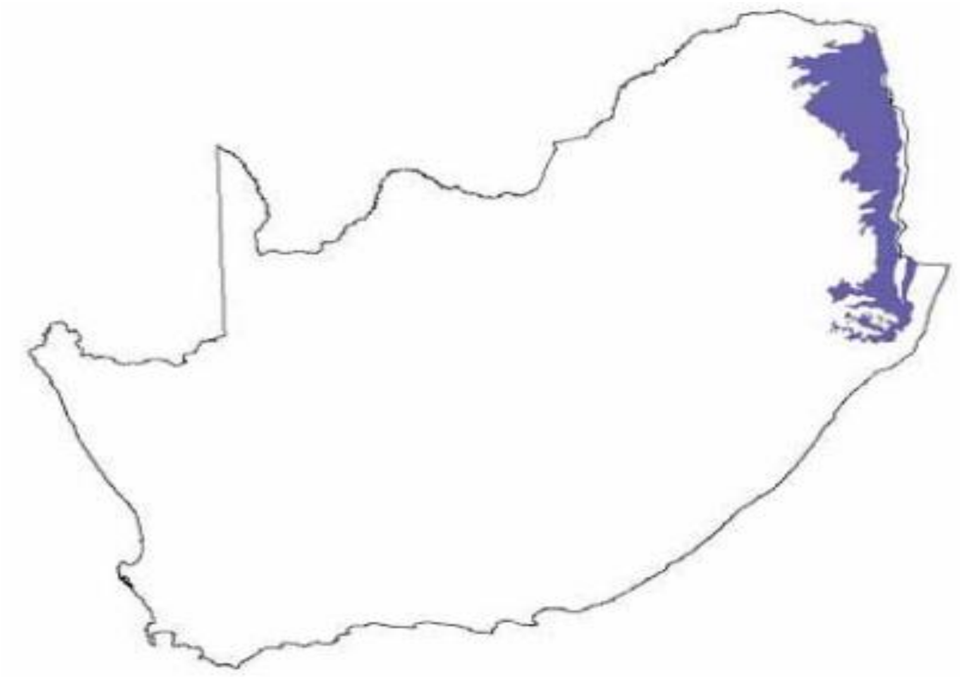

*Figure 3.1: A map illustrating the greater Lowveld area of South Africa*

*Source: Kleynhans* et al. *(2005)*

Within the Lowveld geographical area there are important production areas with different soils and microclimates, and therefore different variables to consider. There are different subregions within the greater Lowveld area, but the typical farm model should be relatively representative throughout the region, although it can be adjusted if necessary.

## 3.2 Identification and validation

The construction and validation of the typical farm model were done in consultation with SAAGA and various avocado producers in the Nelspruit and Letaba regions. With respect to the assumptions regarding the use of shade nets in avocado orchards, studies and trials conducted by Westfalia served as an invaluable source. The following persons were consulted:

- Wilna Stones and Zelda van Rooyen – Westfalia Technological Services.
- Andries Bester – South African Avocado Growers Association (SAAGA).
- Mr Hans Nel and Mr Willie du Plessis – both Schagen, South Africa. These two growers use shade nets as a production risk management strategy.

- Avocado growers in the Nelspruit area: Mr Henry de Predunes (Alkmaar, South Africa), Mr Ettiene du Toit (Sterkspruit, South Africa), and Mr Mark Baker (HLH Hall and Sons, South Africa).
- Juan Winter – Source Bi (Tzaneen, South Africa).

### 3.2.1 Data used in the model

The model is just as good as the data. For the construction of the whole-farm budget, this study relied on the benchmarking data collected by SOURCE in collaboration with SAAGA. SOURCE is an agricultural consulting company that specialises in conducting benchmarking analysis and other services in the South African agricultural industry (Winter, 2019).

Previous studies done by Westfalia Technological Services (WTS) (Stones *et al*., 2017) provide comprehensive data of the additional management costs, construction costs and changes in tree phenology. The costs and assumptions of constructing shade netting in the budget were informed by a study done by Brown (2018) on citrus orchards. Hail insurance premiums were obtained from Santam Insurance upon request (Scheepers, Personal Communication, 2019).

## 3.3 Description of a typical avocado farm

### 3.3.1 Time frame

The whole-farm budget in this study is also multi-period – a budget that is drawn up over more than one year. The reason for selecting a multi-period budget is because of the long-term investment that has to be made if the decision maker adopts shade netting as a hail damage risk management strategy. The time frame of the budget is twenty years and runs from 2019 until 2038. An investment is made in the year 2019, as it is the start of the budget. The empirical data of the KOVs used in simulating the MVE probability distribution is from the previous five years, 2014 until 2018.

### 3.3.2 Physical dimensions

The size of the farm is expressed in hectares and the total area of land is divided into three categories: arable, non-arable and area earmarked for fixed improvements. The arable area of the farm is fully utilised for the production of avocados and is also assumed to be under permanent irrigation. Non-arable land represents areas not suitable for the cultivation of avocados because of rocks, wetlands or poor soil. These areas of land are usually left bare, but they still have value and need to be included. Area for fixed improvements such as infrastructure is necessary for the functioning of the farm. These items include sheds, houses, irrigation dams and roads, to name a few.

The monetary value of the arable land is dependent on various economic and biological factors. An important aspect of the arable land is water rights. The rule of thumb for this area is that one hectare of water rights will be sufficient for three hectares of full-bearing avocado orchards. The arable land has sufficient water rights to irrigate all orchards, and the price of water rights is included in the value per hectare. An irrigation dam is also standard infrastructure on most avocado farms and acts as a buffer for water reserves, as the water rights are normally from a river or public dam. The monetary value of arable land is more than that of non-arable land. The prices used for land were chosen to be as close as possible to market-related prices. The important consideration of unproductive land is that it contributes to the investment requirement but make no contribution to income. The income from the cultivated area thus needs to be spread thinner.

*Table 3.1: Summary of the land distribution and value of land*

| | Ha | Year planted | Trees/ha | Total trees | Value/ha (R) | Total value (R) |
|---|---|---|---|---|---|---|
| Avocado orchards | 30 | 2009 | 408 | 12245 | 500 000 | 15 000 000 |
| Non-arable land | 20 | | | | 50 000 | 1 000 000 |
| Total | 50 | | | | | 16 000 000 |

### 3.3.3 Ownership

The ownership of the typical farm was assumed to be mostly in sole proprietorships, or a family-run business. The owner will typically be involved in financing of capital, management and operations. This specific business model was chosen because of its popularity and the large number of farms structured in this way. There is also a chance that the owner is or was involved in other businesses in his/her lifetime. It is assumed that the farmer is a *bona fide* farmer and the farm enterprise is the only source of income for the farmer. Therefore, the farmer depends on the income from the farm.

### 3.3.4 Access to markets

The typical avocado farm in this study is assumed to have free access to international and local markets. Packing of the fruit is not done on the farm but is outsourced to a packhouse close to the farm. For the farm to have access to international markets, the farm must have full GLOBALG.A.P. accreditation. A GLOBALG.A.P. accreditation is a worldwide standard for good agricultural practices that a farming enterprise must adhere to in order to get the accreditation and allow products to be exported (GLOBALG.A.P, 2019). The local markets are used to sell lower quality (Class 2) fruit. The lowest quality fruit (Class 3) are delivered to avocado-processing factories.

### 3.3.5 Capital requirements

To better reflect reality, it is assumed that the typical farmer uses both own and borrowed capital for long-term financing of the farm. In South Africa, this is normally done by a mortgage loan on the land from a commercial bank or the Land Bank. The interest rate depends on the amount of risk you are exposed to or your repayment capability. When an enterprise uses external capital, the leverage factor also has an influence on the general risk of the business. In the farm model it is assumed that 50% of own capital is used to finance the total capital requirement, and this is known as equity.

*Table 3.2: The total capital requirement for the typical avocado farm model*

| | |
|---|---|
| Land | R 16 000 000 |
| Fixed improvements | R 1 427 200 |
| Farm-related fixed improvements | R 336 000 |
| Vehicles | R 511 867 |
| Tractors | R 799 222 |
| Implements/tools/equipment | R 219 967 |
| Total | R 19 294 256 |

### 3.3.6 Orchard description

For the financial evaluation of shade nets as a risk management strategy, it is assumed that the typical farm will only cultivate avocados. It is also assumed that all trees on the farm are of the same age and cultivar. The model allows for selecting a specific age or cultivar as point of departure. Tree spacing plays an important role in the farm model. The example in Table 3.3 illustrates tree spacing of seven metres between rows and 3,5 metres in the row, and a total number of trees per hectare of 408. The age of the trees indicates the age since they were planted in the orchard. A well-pruned and well-managed avocado tree can remain productive for 30 years. Furthermore, the age determines the yield potential, as it only reaches its full potential after seven years. The assumption is made that the average fruit weighs 250 grams (this is a base assumption but can be changed according to each cultivar).

*Table 3.3: Orchard specifications and fruit-bearing capability (7 x 3.5 m, 408 trees/ha)*

| Age of tree in years | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| Fruit per tree | | 5 | 26 | 120 | 155 | 175 | 180 |
| Yield per tree/kg | | 1,25 | 6,50 | 30,00 | 38,75 | 43,75 | 45 |
| Yield per hectare/kg | | 510 | 2 653,1 | 12 244,9 | 15 816,3 | 17 857,1 | 18 367 |
| Yield per hectare/ton | 0,0 | 0,5 | 2,7 | 12,2 | 15,8 | 17,9 | 18 |
| % of full yield | 0% | 3% | 14% | 67% | 86% | 97% | 100% |

A typical avocado farm will most likely consist of more than one orchard, multiple cultivars with different planting dates, and varying tree spacing. For simplicity, and to focus on the core issue at hand, the typical farm model developed in this thesis will not distinguish between different orchards on the farm. The orchard can be adapted to suit a specific cultivar, as only the prices, yields and quality/pack-out percentage need to be adjusted.

### 3.3.7 Inflation

Inflation is a general phenomenon in an economy and is associated with the sustained increase in the general price level of goods and services in an economy over a period of time. It is important to mention that inflation is not taken into account in the budget model.

## 3.4 Assets

### 3.4.1 Current assets

The model does not account for current assets, as these do not have a significant effect on the model. The reason is that current assets are consumables and include items such as fuel, fertilisers, chemicals and market-ready produce. All these items are typically used in the normal production cycle of one financial year. In the budget model over the longer term, these assets are thus accounted for as inputs and outputs.

### 3.4.2 Medium-term assets

**Implements, tools and equipment**

Mechanical equipment utilised on an avocado farm can differ according to the preferences of and situations that the farm manager faces. However, every farm will have similarities in basic equipment requirements. All the basic equipment, like weed-eaters, pruning equipment and general farm equipment, was also accounted for. The implements accounted for are displayed in Table 3.4.

*Table 3.4: Implements, tools and equipment inventory list*

| Item | Amount | Value/per item (R) | Year model |
|---|---|---|---|
| 2-ton trailer | 2 | 29 167 | 2013 |
| Grader | 1 | 12 500 | 2013 |
| Slasher 1,5 meter | 1 | 10 000 | 2007 |
| Slasher 1,2 meter | 1 | 5 000 | 2016 |
| Mulcher | 1 | 80 000 | 2013 |
| Tower sprayer | 1 | 50 000 | 2015 |
| Chainsaw | 2 | 1 250 | 2017 |
| Ladder | 1 | 400 | 2007 |
| Three-point 400 litre sprayer | 1 | 16 000 | 2015 |
| Disc plough | 1 | 8 000 | 2013 |
| Pruning equipment | 4 | 400 | 2013 |
| Backpack sprayer | 4 | 300 | 2007 |
| General tools | 1 | 2 200 | 2007 |
| Weed eater | 4 | 2 800 | 2015 |
| Bins for harvesting | 30 | 700 | 2005 |
| Firefighting pump with tank | 1 | 1 250 | 2005 |
| Total | | 219 967 | |

**Tractors**

Tractor requirements on the farm are expressed and distinguished in kilowatts, open or closed cabin, orchard vs. normal tractor and four-wheel vs. two-wheel drive. The typical fleet identified for this exercise consists of several specific items: a 53 Kw two-wheel drive closed cabin orchard tractor used mainly for spraying agrochemicals; a 70 Kw four-wheel drive open cabin tractor used for slashing and mulching, but which can also be used for fertigation; and two other tractors that are relatively small and are used for general work, like weed control and transport of materials. The total capital required for tractors is R 799 222.

**Vehicles**

The fleet of vehicles consists of two pickup trucks used for general farm management, two off-road motorcycles used on the farm, and a 10-ton truck used for deliveries and collections.

### 3.4.3 Fixed assets

Fixed assets are assets with a lifespan typically lasting longer than ten years. The fixed assets are divided into two groups: fixed improvements and farm-related fixed improvements. Fixed improvements are not directly 'used' in the production process, while farm-related fixed improvements will have a direct role to play in the production process. Land is also seen as a fixed asset and is explained in Section 3.3.2. Both fixed assets that are farm related and non-farm related were described and identified with assistance from the participating farmers.

**Fixed improvements**

Fixed improvements in the model consist only of housing. There is a large farmhouse where the owner stays and two blocks of accommodation for labourers.

**Farm-related fixed improvements**

Farm-related fixed improvements consist of an irrigation dam, general storeroom, workshop, chemical storeroom, pump station and an office.

### 3.4.4 Asset replacement

According to Strauss (2005), assets are replaced when funds are available, when the condition of the asset necessitates replacement and because of technological 'ageing' of the asset, which means that the farmer has to improve technologically in order to remain productive and therefore competitive. For simplicity, all assets are replaced when their book value reaches zero. The book value falling to zero is caused by depreciation. All depreciation in the model is calculated using the straight-line method.

## 3.5 Liabilities

### 3.5.1 Current liabilities

The model does not account for current liabilities, as these do not have a significant economic influence. As was the case with current assets, current liabilities are those that need to be paid within one financial year. These will thus reflect as part of inputs within the long-term budget.

### 3.5.2 Medium-term liabilities

Medium-term liabilities are debt obligations that must be repaid within one to ten years. A typical avocado farm makes use of medium-term liabilities for financing the replacements of movable assets. For simplicity, the constructed model assumes all financing is done through long-term financing. However, it is assumed that shade nets are financed over a period of 10 years and they are considered a medium-term liability in this study. The interest rate for financing shade netting is 8%, which is 1% higher than the interest rate on long-term liabilities, which is 7%. A higher debt-to- equity ratio is the reason for the interest rate being higher.

### 3.5.3 Long-term liabilities

Long-term liabilities are debt obligations that are repaid over a period longer than ten years. As mentioned in the previous section, al financing is done with long-term loans. An amortization table is used to calculate the principal, instalment and rent. These are cost arising from using external capital. The real interest rate is 7% for long-term liabilities.

## 3.6 Costs

The construction of the budget model was done based on standard accounting principles, which lends validity to the method and requires specific cost-allocation principles.

For accounting purposes, the different costs within the whole-farm model are separated into various components, which will be introduced briefly.

### 3.6.1 Fixed costs

Fixed costs are costs that are constant and continue even if production activities are at a standstill. Fixed costs are typically not influenced by either scale or intensity of production.

Table 3.5 shows the fixed cost for a typical avocado pear farm as indicated by information from the study group (Winter, 2019).

*Table 3.5: The fixed costs involved in a typical avocado farm.*

| Expense | Per month (R) | Per year (R) |
|---|---|---|
| Maintenance | 6 837 | 82 045 |
| Bank costs | 33 | 400 |
| Depreciation | 21 773 | 261 273 |
| Licences | 617 | 7 400 |
| Insurance | 6 695 | 80 337 |
| Bookkeeper | 1 000 | 12 000 |
| Internet and phone | 2 500 | 30 000 |
| Entrepreneur reward | 33 333 | 400 000 |
| Water general | 3 000 | 36 000 |
| Electricity | 1 667 | 20 000 |
| General diesel, fuel and oil | 400 | 4 800 |
| Total | 51 015 | 612 182 |

### 3.6.2 Variable costs

**Non-directly allocable variable cost**

There is no non-directly allocable variable cost in the budget model. The reason for this is that there is only one farming division, so all costs are either directly allocable variable or fixed costs.

**Directly allocable variable cost**

Direct allocable costs can be linked directly to production activities. The cost of each risk management strategy can be allocated as a direct allocable variable cost. The cost of the risk management strategy depends on the strategy and is explained in Section 3.6.3. When implementing shade nets as risk management strategy, the assumption is made that an additional cost of R10 000 per hectare is allocated to pollination, additional pruning and maintenance.

*Table 3.6: Directly allocable variable costs per hectare*

| Item | Total R/ha |
|---|---|
| Pests and diseases | 7 780 |
| Nutrition | 8 120 |
| Irrigation | 3 000 |
| Fuel oil; fuel; diesel | 6 000 |
| Harvest cost | 13 600 |
| Labour | 17 000 |
| Risk management strategy | **** |
| Total | 55 500 |

**** (Depends on strategy)

Christie (2017) found that, on the farm level, a permanent worker and a seasonal worker are employed for every 2.6 hectares of production on an avocado farm. The seasonal workers are employed for harvesting fruit and pruning trees. The labour used for harvesting varies according to the total yield and is subsequently accounted for in the model. The harvesting cost also accounts for classing the fruit according to quality. The data in Table 3.6 shows the directly allocable variable cost for a farm harvesting 18 tons per hectare; this assumption influences the harvesting cost per hectare.

### 3.6.3 Risk management strategies

1. Shade nets

Data on the construction cost of shade net structures was extrapolated from research on citrus orchards (Brown, 2018). The research was based on citrus orchards but is still relevant to this study and can be used as an accurate assumption. The avocado industry uses the same physical structures as the citrus industry for permanent shade net structures.

When shade nets are used as a risk management strategy, additional costs will arise apart from the normal financing costs. These extra costs are assigned to the general maintenance of the structure and the hiring of extra bees for pollination. In this study, it is assumed that the total cost for the construction of shade nets is R300 000 per hectare, and the maintenance and additional costs, like pollination and extra pruning, are R10 000 per hectare per year.

2. Hail insurance

The insurance premium rates of different areas were obtained from a leading short-term insurance company, Santam. Limited information was made available and, also in light of simplicity, a standard insurance product is used in the model. The following are points describing the specific insurance obtained from Santam:

- The rate is per 10% co-payment option. The average rate differs to the extent that different insurers' rates may differ within a district area.
- The insured value per kg gives the average yield per tree that is insured. It may vary as trees grow older, or new plants are added.
- Insurance cost per tree is a value expressed by the rate, the yield, and the value per kilogram per tree.
- Trees per policy is a value, but only on the basis of the number of trees per farm unit. The insurance is done per farm, so an insured person with three farms can own three policies.

3. Self-insurance strategy

The decision maker can decide not to insure and thus carry the risk on the balance sheet. Employing the self-insurance strategy thus means that the farmer is exposed to hail damage risk but is of the opinion that the enterprise can carry it. The benefit of having a self-insurance strategy is that no extra costs have to be paid as with insurance or shade netting. There are three reason why a decision maker would normally implement a self-insurance strategy:

- Being attracted to risk or underestimating the peril
- Subjective beliefs that assign a low likelihood to the possibility of hail
- The cost of insurance
- The strength of the operation’s balance sheet

### 3.6.4 External factor costs

It is assumed that the farm makes use of external finance to cover 50% of the total capital required, as explained in Section 3.3.4. Using external finance has a cost implication in the form of interest that must be paid. In addition, the principal amount also needs to be repaid;

the principal amount is repaid in instalments. The sum of the interest and the principal payment is known as the instalment. The instalment is calculated based on the loan amount, the period over which the loan needs to be repaid, and the interest rate. The capital budget in this study is for a period of twenty years; the period of the long-term liability is also calculated to be repaid in twenty years in the model. The interest rate used in the model is 7%. The 7% interest rate is the real interest rate and thus adapted for inflation. Medium-term finance is used for financing shade net structures and the interest rate is 8%.

## 3.7 Gross margin

The gross margin is simply the gross production value minus all directly and non-directly allocable variable costs and is calculate for each enterprise. The benefits of shade nets will reflect in the gross production value due to less damage or higher packing-out percentages.

*Table 3.7: Calculation of the gross margin per hectare*

| |
|---|
| Gross value of production |
| Yield ton/ha |
| *Class 1 % x Back on farm price Class 1* |
| *Class 2 % x Back on farm price Class 2* |
| *Class 3 % x Back on farm price Class 3* |
| Average price |
| **Total gross value of production = yield x average price** |
| Direct allocable variable cost per hectare |
| Direct allocable variable production cost |
| Other: maintenance, pollination, etc. (only shade nets) |
| Risk management strategy costs |
| **Direct allocable variable cost** |
| Gross margin = Gross value of production - direct allocable variable cost per hectare |

## 3.8 The financial profitability criteria

### 3.8.1 Net present value (NPV)

The decision maker is faced with a multi-period investment decision under conditions of uncertainty. The uncertainty is accommodated in the model by allocating key performance indicators' or key output variables' stochastic values. To appraise the investment decision, the net present values of the total capital flows over the investment period are used to compare the risk management strategies.

The net present value (NPV) method is based on the time value of money, which means the value of future benefits and decline in costs over time (Van Reenen & Davel, 1987). Therefore, large negative outflows in the beginning of a period will have a greater negative influence on the net present value than the same outflow later in the investment period. The NPV calculation is therefore useful to capture the timing and size of capital investments and different capital flows to determine the profitability of an investment. The later use of NPV as an economic performance indicator is thus in accordance with comparing hail risk management strategies in avocado production systems.

To do these calculations, the net capital flows of the investment period are used. After the net capital flows of the investment period have been determined, these capital flows can be discounted into present values and the internal rate of return can be determined.

*Table 3.8: Calculation to determine NPV of whole-farm multi-period budget*

| | | Year 1 | Year 2 | Year t | Year 20 |
|---|---|---|---|---|---|
| Gross margin | **A** | | | | |
| Fixed costs + not directly allocable variable | **B** | | | | |
| External factor cost | **C** | | | | |
| Total capital | **D** | | | | |
| Liquidation of investment (Year 20) | **E** | | | | |
| Net capital flow | **A-B-C-D+E** | | | | |

The total capital requirements component (D) in Table 3.8 calculates the capital investments that flows into the whole-farm model. In year 1 it is assumed that the entire farm is bought, therefore there will be a large capital outflow that year, followed by a series of capital flows in the investment horizon of 20 years. This simply simulates the capital investment requirement, or the money invested in the farm, and serves as basis for the calculation of the NPV.

$$NPV = IV_0 + \frac{CF_1}{(1+r)^1} + \frac{CF_2}{(1+r)^2} + \ldots + \frac{CF_n}{(1+r)^n} + \frac{CF_{20}}{(1+r)^{20}}$$

*Equation 3.1: Discounting capital flows for NPV*

The 20 years of net capital flows are calculated by taking the gross margin (A) minus overheads (B) minus external factor cost (C) minus total capital (D) + liquidation of investment

(E), as displayed in Equation 3.2. The liquidation of the total investment is done only at the end of year 20.

$$gross\ margin\ minus\ overheads\ minus\ external\ factor\ cost\ minus\ total\ capital = Net\ capital\ flow, \text{or } A - B - C - D + E = Net\ capital\ flow$$

*Equation 3.2: Calculation for net capital flow*

### 3.8.2 Discount rate

The discount rate used in the NPV calculation can be subjective according to the decision maker. In this model, a discount rate of 7% was used, as it reflects the most accurate opportunity cost of capital. The discount rate is the same as used for long-term interest rates.

## 3.9 Key output variables (KOVs)

The key output variables (KOVs) are identified within the whole-farm, multi-period budget model. These variables are the most likely to change in a production year and most likely to alter the revenue of the enterprise. The KOV used in the model must be in line with the research question. To account for the risk associated with these variables, they are made stochastic. All the KOVs, except hail damage, are stochastically simulated by creating empirical probability distributions, as described in Chapter 4.

The KOVs that are used are also key performance indicators (KPIs) in a typical avocado farm enterprise. KPIs are basically the same as KOVs. The KPIs of a farming system can indicate the financial performance of an enterprise.

### 3.9.1 Yield

The avocado yield in the model is calculated per hectare and then adjusted to the farm size to return total yield. The total yield does not differentiate between the quality of the fruit, hence it refers to total bearing yield. The total production can be seen as the total harvest per year per hectare. This figure is mostly given in kilograms (kg) or tons (1 000 kg).

### 3.9.2 Price

The prices received depend on two factors; firstly, the quality of the fruit, with export quality fruit usually fetching higher prices, followed by fruit marketed locally and, lastly, fruit used for processing. The second factor is market conditions, which influence the supply and demand. An exception is made with export fruit in that the price also depends on the exchange rate. The prices received for fruit are broken down into classes in the model with associated pack-out percentages.

### 3.9.3 Quality

The total yield, discussed in Section 3.9.1, is divided into three groups in terms of quality of the fruit. The three classes are 1, 2 and 3; Class 1 is export-quality fruit (a fruit producer will typically refer to pack-out percentage when talking about the export grade percentage), Class 2 is marketed locally, and Class 3 is used for processing.

Export markets are lucrative for producers, as exported fruit earn a price premium over fruit sold on the local markets. However, only top-quality avocados with no defects (mostly caused by sun, hail, insect and wind damage) can be classed as export-quality fruit (Winter & Bester, 2018).

### 3.9.4 Hail insurance premium

Hail insurance premiums are discussed in Section 3.6.3.

## 3.10 Model development

With the development of a whole-farm multi-period budget model for a typical avocado farm, it is important to view the enterprise as a complex system with various interrelated components. With the farming system being exposed to and dependent on biotic and abiotic factors, complexity is increased. The model applied for calculating the financial effects of risk management strategies in this study must be able to integrate the interrelatedness of the system. The complexity in terms of risk and the impact thereof on the financial performance of the enterprise must be accommodated. In order to achieve the aforementioned, the typical farm was modelled in Excel spreadsheets. This way of simulation allows the model to link various components through a series of equations, and therefore capture the interrelatedness of the system.

The model consists of fourteen interconnected sheets. Firstly, the physical boundaries of the farm are set, with an overview of the area of cultivated land, non-arable land, age of trees, planting densities and market value of the physical land. On the first sheet, the ownership and sources of capital in terms of internal and external capital are illustrated. The next two sheets consist of the inventory and assets of the farm. All inventory and assets are listed, and calculations such as depreciation, maintenance and current market value are done on this sheet. Following the inventory is the asset-replacement schedule, which calculates when assets and the inventory of the enterprise need to be replaced.

After sheets 1, 2 and 3 have been calculated, it is possible to determine the total external capital requirement of the farm. Sheet 4 consist of an amortisation table to show the repayment schedule. If the decision maker uses shade nets as a risk management strategy, it will also be financed with external capital and an extra amortisation table is included in the sheet.

The next two sheets, sheets 5 and 6, deal with the costs involved in the enterprise. The production costs are calculated on sheet 5. Production costs are directly allocable variable costs. The components of production cost used in the calculation are nutrition, pests, diseases, labour, fuel and harvesting costs. The following sheet calculates the fixed costs. 'Not directly allocable variable costs' are not included in the model. All costs are assumed to be fixed or variable, because there is only one production branch and all variable costs can be allocated to avocado production.

Sheets 7 and 8 are assigned to the stochastic component of the model; making use of empirical probability distributions, the model needs data from which to simulate probability distributions. Sheet 7 is used to store the data of the KOVs used in the stochastic simulation process. On sheet 8, the stochastic simulation of the KOVs is done. Chapter 4 is dedicated to explaining the complete process and steps taken on sheet 8. The last six sheets consist of three capital and gross margin budgets, one for each risk management strategy.

# Chapter 4

# Stochastic simulation of key output variables (KOVs)

## 4.1 Introduction

The previous chapter explained how a typical, representative avocado form can be presented with a budget model. In the model key output variables (KOVs), the variables most relevant to the study and the most likely to change are identified. As mentioned before, in order to incorporate risk, the KOVs will have stochastic values. In this section, the process and methods of the stochastic simulation of the KOVs within the farm budget are explained. To answer the specific research question, the use of the SIMETAR computer program with Microsoft Excel was used to perform the stochastic simulation within the constructed farm model.

In order to account for risk within the model, key output variables (KOVs) were identified and given stochastic values within the model. As mention in Chapter 2, probability distributions are used to incorporate risk (Hardaker *et al*., 2015). When choosing a probability distribution for each KOV to use in the stochastic simulation of the farm model, questions have to be answered about:

- What is the underlying process?
- What data is available?
- Is the model simplicity important?

By asking these questions, the modeller will get an idea of how and/or which probability distribution to use. If data is available and it is relevant, the method of Richardson *et al*. (2000) can be used to estimate a probability distribution based on empirical evidence; it is not always possible to do this, as limited data availability, complex underlying processes and simplicity also play a role.

## 4.2 Defining key output variables (KOVs)

The key output variables (KOVs) used in this model Include those variables that are the most likely to change in any specific year – volatile drivers, as referred to in Section 3:

- Total production/yield
- Pack-out (quality of fruit) (as percentage of total production) (affected by hail damage)

- Export prices (Class 1)
- Local prices (Class 2)
- Fruit processing/factory prices (Class 3); empirical data was not available for Class 3 fruit. It is assumed that the prices of Class 3 fruit follow the same stochastic index as Class 2 fruit
- Hail damage (hail damage will directly affect quality/pack-out of fruit)
- Hail insurance premiums

## 4.3 Simulating the risk of hail damage

Hail risk is the only KOV that does not use empirical data to define the shape of the probability distribution. It was not possible to get enough years of empirical data. Insurance companies that sell hail insurance, like Santam, are not willing to share data of hail insurance claims. The data is not shared by insurance companies since this would undermine their ability to compete.

In this study, hail risk was simulated by multiplying a discrete probability distribution by a continuous probability distribution. A discrete probability distribution can give the probability of an event happening. In this case, the event is a hailstorm. A Bernoulli discrete probability distribution is used in the model to simulate the probability of a hailstorm, as illustrated in Equation 4.1. The formula used in Equation 4.1 is a built-in function of Simetar, which is an Excel plugin. The 0,2 value in the equation indicates that there is a 20% possibility of a hailstorm in any specific year.

$$= BERNOULLI(0{,}2)$$

*Equation 4.1: Bernoulli probability function*

After the Bernoulli discrete probability has randomly simulated the possibility of a hailstorm, a triangular probability distribution is used to simulate the intensity of the hailstorm; the percentages, as shown in Equation 4.2, illustrate the amount of hail damage for a specific year. The “=GRKS( )” is a triangular probability distribution and is also a built-in function of Simetar. The triangular probability distribution has a minimum value of 0%, a most likely of 50%, and a maximum of 100%. The triangular probability distribution is truncated to keep the damage between 0% and 100%.

$$= GRKS(0\%; 50\%; 100\%)$$

*Equation 4.2: A triangular probability distribution*

Table 4.1 provides an illustration of how hail damage is modelled; in this iteration, the model predicted that there would be hailstorms in 2022 and 2024, with the amount of hail damage being 27% and 57% respectively. In all the other years there is no hail damage. With each iteration when simulating the model, there will different scenarios of hail damage. In the specific model, hail damage only affects quality and does not affect yield; this is explained in Table 4.2: in years of no hail damage, the average pack-out percentages are used, which are 58%, 25,8% and 16,6%. If the Bernoulli distribution simulates a hailstorm, which is illustrated by a "1", the "IF" function in Excel is used to look up the intensity of the hailstorm.

*Table 4.1: An Illustration of how hail damage is modelled*

| Year | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 |
|---|---|---|---|---|---|---|---|
| Bernoulli | 0 | 0 | 0 | 1 | 0 | 1 | 0 |
| Triangular | 39% | 64% | 67% | 27% | 58% | 57% | 65% |

Each year of the budget has an independent discrete probability distribution assigned to it. Because hail is sporadic, it cannot be simulated in an empirical way as the other KOVs. The reason for choosing to multiply two probability distributions is that it is simple to explain the form of the distributions to someone who has little knowledge in the field; the form of the multiplied distributions makes sense, and other options that were considered, like the poison distribution, are more complex.

*Table 4.2: An illustration of how hail damage influences quality of fruit*

| Year | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 |
|---|---|---|---|---|---|---|---|
| Hail damage 0 = No 1 = Yes | 0 | 0 | 0 | 1 | 0 | 1 | 0 |
| If yes, how bad | 0% | 0% | 0% | 27% | 0% | 57% | 0% |
| Class 1 | 58% | 58% | 58% | 42% | 58% | 25% | 58% |
| Class 2 | 26% | 26% | 26% | 18,7% | 26% | 11% | 26% |
| Class 3 | 16% | 16% | 16% | 39,5% | 16% | 64,3% | 16% |

## 4.4 Simulation of the MVE probability distributions

In this study, the abovementioned KOVs (except for hail damage risk) are made stochastic by applying the methods proposed by the Richardson *et al*. (2000) model using Simetar computer software to simulate the multivariate empirical probability distributions. The reason for using an MVE probability distribution is because of data limitations; in this case, data is only available from 2014 onwards, and then using standardised probability functions that 'fit' the data the best will not make sense because of too few observations. According to Richardson *et al*. (2000), the use of an MVE probability distribution will not force the data into a specific distribution, but rather will adapt the form of the data. Furthermore, Richardson *et al*. (2000) state that data with less than ten observations provides too small a sample size for the use of standardised probability distributions.

Before the stochastic simulation can be done, the *estimations of parameters* for the probability distribution must first be done. After the parameters have been determined, the stochastic simulation process can be followed.

### 4.4.1 Gather relevant values

As this method uses empirical data to simulate probability distributions, the value must be gathered from all KOVs. In this study, the industry benchmark data obtained from SOURCE (2019) is used as the empirical data for the KOVs.

### 4.4.2 Real values

Deflate monetary values to get the real values

$$Real\ values = Nominal\ values\ /\ GDP\ deflator\ x\ 100$$

*Equation 4.3: The formula used to deflate values affected by inflation*

In the model constructed in this study, empirical data from 2014 until 2018 is used. Therefore, the GDP deflators of these years need to be used. GDP deflator data was obtained from the World Bank (World Bank, 2019).

### 4.4.3 Parameter estimation

1. Trend in adjusted real values

The first step in the estimations of parameters is to separate the random and non-random components of the data used for the stochastic simulation. The objective is to include historic randomness, but the data might be following a trend. The purpose of this step is to remove the trend and only to consider the randomness. A good way to explain a trend is using maize yields, which constantly keep increasing because of improved cultivars and technology.

The dataset has to be tested for a trend by doing a simple regression. The simple regression was done using Simetar, and any t-value bigger that 1,96 is considered as having a trend and has to be adjusted. The adjustment for a trend is done by the following formula:

$$Trend\ adjusted\ real\ values = (real\ values\ /\ (real\ value - residual))\ x\ 100$$

*Equation 4.4: The formula used to adjust value affected by a trend in the data*

If it is found that there is no trend in the data, the real inflation-adjusted values are used. After this, SIMETAR is used to calculate the 'summary statistics', as this data is needed for the next step.

2. Absolute deviations

The absolute deviations (random component) are calculated by subtracting the mean value of the variable from the observed value, and these residuals are used for the simulations.

$$Absolute\ deviations = Trend\ adjusted\ value\ (Trend\ \mathrm{adjusted\ real}\ values) - mean\ value$$

*Equation 4.5: The formula used to get the absolute deviations of the data*

3. Relative deviations

These residuals are converted into fractional deviations about their respective deterministic components by dividing the absolute deviations with the mean.

$$Relative\ deviations = Absolute\ deviation\ /\ mean\ (trend\ column)$$

*Equation 4.6: The formula used to get the relative deviations of the data*

4. Sorting relative deviation and assigning pseudo-minimum and -maximums

For each KOV, the relative deviations are then sorted from the minimum deviation to the maximum deviation. This is done to define the points in the empirical distribution. The minimum and maximum values are given pseudo-values and added additionally, because the probability of simulating the minimum and maximum values is equal to zero, but the fact is that these data have been observed in reality and therefore must allow the simulated distribution to return to these extreme values (Richardson *et al.*, 2000:303).

5. Probabilities

Finally, probabilities are added for each of the relative deviations sorted from minimum to maximum with the added pseudo-values. The pseudo-minimum and -maximum values are 0,0 and 1,0 respectively. As this is an empirical distribution and each value has an equal opportunity to occur, the F(X) value or probability has an equal chance of 1 / N to be observed, as explained in

$$F(X) = \frac{1}{N}$$

*Equation 4.7: Determining the probabilities of each relative deviation sorted from minimum to maximum*

6. Intra-temporal correlation

Simetar was used to construct an M x M intra-temporal correlation matrix using the built-in function and the data of the absolute deviations. The “=RANKCORREL( )” function of Excel was used in this step, which allows for incorporating the correlation between the KOVs.

### 4.4.4 Simulation of the MVE probability distribution

1. ISND

The first step comprises independent standard normal distributions (ISNDs). This is done by using the “=NORM()” Simetar function. No parameter must be inserted into the function, as explained by Richardson, Schumann and Feldman (2008): “The =NORM( ) function defaults to a standard normal deviate (SND) generator when no parameters are provided, as =NORM( ). A SND is a normally distributed random variable with a mean of zero and standard deviation of one.”

2. CUSD

In the second step, the correlated standard normal deviations (CSNDs) are calculated with Simetar, using the "=CUSD()" function. This is usually done in two steps, but with the help of Simetar it is done in one step. The Simetar formula of "= cusd (rank correlation matrix, ISND)" is used; the correlation matrix is used in the function, as well as the independent standard normal distributions. The following steps are used in Excel to complete the CUSD:

- Select all blank cells and type in first cell whilst all are still highlighted – this is done to form an array.
- Fix the correlation matrix – select and fix the entire matrix.
- When selecting the ISND – select the column in the ISND for each year.
- Press Control Shift Enter for the function to work.

3. Means

All the projected future values are prepared in terms of means. This is done to anticipate future movements in KOVs. An example of this is if small avocado trees are not yet fully mature and their yield will increase ever year; in this case, the estimated future growth can be incorporated by using means. In this study, all means remain constant.

4. Simulation

In the fourth step of the simulation, the CSNDs are used again in the Simetar function of "=Empirical()".

$$Stochastic\ index = [means\ +\ means\ x\ empirical\ (\ F(x), F(x)\ 0.05, CUSD)]$$

*Equation 4.8: Formula for calculating the stochastic index*

where:

- Means = the values in step 3 above
- F(x)0.05 are the fractiles
- The specific year of CUSDs in the columns corresponds with the means

*Table 4.3: An illustration of the stochastic index for the KOVs per year*

| Stochastic | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 |
|---|---|---|---|---|---|---|---|---|---|
| (Class 1) export avo prices (4 kg) | 100 | 78 | 122 | 76 | 123 | 115 | 77 | 89 | 76 |
| (Class 2) local avo prices (4 kg) | 100 | 62 | 62 | 80 | 89 | 148 | 94 | 62 | 97 |
| Yield | 100 | 174 | 105 | 174 | 62 | 54 | 122 | 174 | 174 |
| Hail insurance premium | 100 | 107 | 100 | 96 | 96 | 95 | 97 | 99 | 96 |

### 4.4.5 Stochastic values

The stochastic values are then calculated by taking the expected values of the KOVs and multiplying them by the stochastic index divided by one hundred.

$$Stochastic\ values = Expected\ value\ of\ KOV\ x\ (Stochastic\ index/100)$$

*Equation 4.9: The formula used to simulate the stochastic values*

For every year, the expected values of the KOVs remain the same and function as a baseline. The stochastic index changes with every iteration. Hence, the expected value of the KOV used will have a large effect on the stochastic value.

# Chapter 5

# Application of model and results

## 5.1 Introduction

The main research question of this study is to compare shade nets and hail insurance as production risk management strategies in avocado production systems. In this chapter, the results of the stochastic multi-period whole-farm budget are presented using cumulative distribution functions (CDFs). The CDFs of the three production risk management strategies namely shade nets, hail insurance and self-insurance, are compared using stochastic dominance. The self-insurance strategy is when the decision maker chooses not to insure against hail risk or install shade nets. Hail risk is integrated into the stochastic whole-farm multi-period farm budget, with the financial calculations being applied to the capital budget as explained in Chapter 3. The capital budget covers all capital flows over the study period to reflect the financial performance of the typical farm by means of the net present value (NPV).

Since the model is stochastic, a single deterministic net present value will not be given, but instead the distribution of outcomes from a chosen number of iterations within a strategy will be shown, using cumulative distribution functions (CDFs). Each of the 500 iterations represent the possible outcome of a strategy calculated from the stochastic variables selected using Monte Carlo sampling from the predefined distributions, as discussed in Chapter 4. Cumulative distribution functions are derived from the distribution of outcomes within each strategy using the SIMETAR add-in for Microsoft Excel.

This chapter is divided into three sections. The first section explains the structure of how the results are presented and the scenarios introduced in each dataset. The last two sections present the results of the different producers and risk management strategies.

## 5.2 Model and scenario description

In addition to the risk management strategies described in Section 5.1, it was decided to compare the results of both a typical and top producer in the Letaba region to compare the robustness of the results to producer performance. In addition, within the producer types, it was decided to include two additional scenarios that test the robustness of the results to changes in the assumption of the pack-out rate because of hail nets, and the cost of hail insurance. As a result, three scenarios are modelled for the typical and top producer in Letaba.

**Scenario 1, Baseline**

This scenario incorporates the empirical data with respect to pack-out percentages and the cost of hail insurance as reported by SOURCE. It therefore reflects the baseline NPV distributions for the respective risk management strategies.

**Scenario 2, Improved pack-out**

As discussed in Chapter 3, the results of studies on the yield and quality improvements because of hail nets are inconclusive, but some show that it could result in better yields and higher quality fruit. Within this scenario, it is assumed that the pack-out percentages, as a share of exportable fruit in total production, increases to 75% from all the respective baseline levels.

**Scenario 3, Improved pack-out and higher hail insurance cost**

The improved pack-out percentages are assumed as in Scenario 2, but in addition there is an increased hail insurance premium.

## 5.3 Results of the typical Letaba producer

The typical grower in Letaba was constructed using the data from all of the producers who participated in the benchmarking facilitated by SOURCE BI (Winter, 2019). The KOVs are yield, quality, price and hail insurance premium. Hail risk is also a KOV, but empirical data is not used to simulate the probability distribution. The empirical data used in determining the multivariate empirical (MVE) probability distributions of the typical Letaba producer is shown in Table 5.1. All prices are nominal and quoted as delivered in port (DIP), thus packing and marketing costs are included.

*Table 5.1: Empirical data of key output variables (KOVs) of the typical Letaba producer*

| Year | Yield | Pack-out shares | | | Price (R / 4 kg) | | Hail insurance |
|---|---|---|---|---|---|---|---|
| | (ton) | Class 1 | Class 2 | Class 3 | Class 1 | Class 2 | premium Letaba |
| 2014 | 12 | 52% | 19% | 29% | 62 | 64,67 | 5,34% |
| 2015 | 16 | 64% | 17% | 19% | 89,91 | 45,55 | 5,40% |
| 2016 | 14 | 60% | 12% | 28% | 107,61 | 57,88 | 5,26% |
| 2017 | 8 | 65% | 15% | 20% | 120,25 | 74,46 | 5,96% |
| 2018 | 18 | 65% | 20% | 15% | 80,43 | 46,81 | 5,77% |
| **Expected value** | **13,6** | **61%** | **17%** | **22%** | **92,04** | **57,87** | **5,55%** |

The correlation matrix of the KOVs presented in Table 5.1 is shown in Table 5.2, and all prices were converted into nominal values. It shows that there is a small but positive relationship between local and export prices. This relationship is expected, given the transmission between local and international prices. There is a relatively large negative correlation between local prices and yield, but this is to be expected given the supply and demand dynamics and the fact that Letaba is one of the largest production regions in South Africa. Similarly, there is a negative correlation between international prices and yield, albeit less strongly so, as is the case with domestic prices.

*Table 5.2: Correlation matrix for typical grower*

| | Export avo prices 4 kg | Local avo prices 4 kg | Yield | Hail insurance premium |
|---|---|---|---|---|
| Export avo prices 4 kg | 1 | 0,18 | -0,50 | 0,19 |
| Local avo prices 4 kg | | 1 | -0,91 | 0,01 |
| Yield | | | 1 | -0,31 |
| Hail insurance premium | | | | 1 |

### 5.3.1 Scenario 1: Typical Letaba producer: Baseline

Table 5.3 shows the expected values of the KOV used for the stochastic simulation of the respective risk management strategies. As discussed, it is assumed that shade nets do not affect the quality or yield, and the baseline hail insurance premium is assumed.

*Table 5.3: Expected values of KOV used for stochastic simulation*

| **KOVs** | **Yield** | **Pack-out (%)** | | | **Insurance premium (%)** | **Prices (R/kg)** | | | **Hail risk distribution** |
|---|---|---|---|---|---|---|---|---|---|
| | **(Ton)** | **Class 1** | **Class 2** | **Class 3** | | **Class 1** | **Class 2** | **Class 3** | |
| Shade nets | 13,6 | 61% | 17% | 22% | n/a | 92,0 | 57,9 | 10 | Bernoulli (0,2) |
| Self-insure | 13,6 | 61% | 17% | 22% | n/a | 92,0 | 57,9 | 10 | Triangular (0%; 50%; 100%) |
| Hail insure | 13,6 | 61% | 17% | 22% | 5,5% | 92,0 | 57,9 | 10 | |

Figure 5.1 shows the CDFs and Table 5.4 the summary statistics of the model results for the respective strategies given the assumptions of Scenario 1, as discussed. Figure 5.1 shows that the self-insurance and hail-insurance strategies are stochastically dominant to first degree (FSD) over shade netting. FSD is not an option when comparing the self-insurance and hail-insurance strategies, since their respective CDFs intersect. However, hail insurance dominates the self-insurance strategy in terms of second-degree stochastic dominance (SSD), given that the area under the CDF is bigger than the latter (see Figure 5.1). This is also confirmed in Table 5.4, which shows that the hail-insurance strategy carries both a higher expected value (mean) and lower variation in expected values (CV) relative to the self-insurance strategy. Hail nets carry the lowest variation in expected values, given a coefficient of variation of 25%, but this comes with an expected value of -R12.03 million, which rules it out as an option.

*Table 5.4: Summary statistics of Scenario 1 model outputs*

| Variable | NPV Shade-net | NPV Self-insurance | NPV Hail insurance |
|---|---|---|---|
| Mean | -R 12 032 333 | R 1 403 770 | R 2 469 574 |
| Standard deviation | R 2 988 521 | R 3 471 359 | R 2 912 554 |
| Coefficient of variation (CV) | 25% | 247% | 118% |
| Min | -R 20 739 352 | -R 9 089 711 | -R 4 898 132 |
| Max | -R 1 938 009 | R 13 014 765 | R 11 905 182 |

Whilst the hail net strategy avoids hail risk altogether, it substitutes it for an alternative financial risk as the risk incurred by the business because of borrowed capital. One therefore can conclude that the cost of hail nets per hectare is not justifiable, as expected revenue per hectare is not high offset enough by the cost of capital for installing it.

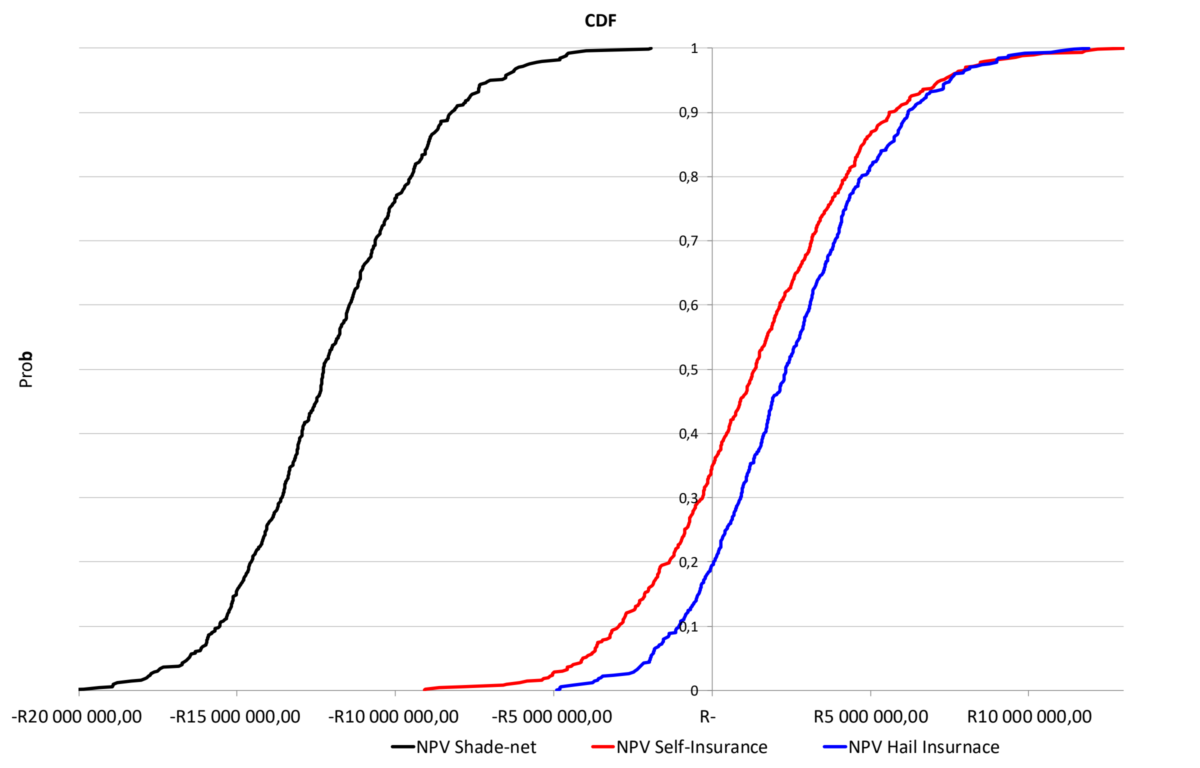


*Figure 5.1: CDFs for typical producer in Scenario 1*

### 5.3.2 Scenario 2: Typical Letaba producer: Improved pack-out under shade nets

Scenario 2 extends Scenario 1 by assuming that hail nets improve fruit quality to the extent that the share of Class 1 increases from 61% to 75%, Class 2 increases from 17% to 20%, and Class 3 declines from 22% to 5%. All other KOVs remain the same, as shown in Table 5.5.

*Table 5.5: A summary of the KOV expected values used in the simulation*

| KOVs | Yield | Pack-out (%) | | | Insurance premium (%) | Prices (R/kg) | | | Hail risk distribution |
|---|---|---|---|---|---|---|---|---|---|
| | (Ton) | Class 1 | Class 2 | Class 3 | | Class 1 | Class 2 | Class 3 | |
| Shade-nets | 13,6 | 75% | 20% | 5% | n/a | 92,0 | 57,9 | 10 | Bernoulli (0,2) |
| Self-insure | 13,6 | 61% | 17% | 22% | n/a | 92,0 | 57,9 | 10 | Triangular (0%; 50%; 100%) |
| Hail insure | 13,6 | 61% | 17% | 22% | 5,5% | 92,0 | 57,9 | 10 | |

The results regarding the hail insurance and self-insurance strategies remain the same, since they are unaffected by the assumptions of Scenario 2 and hence are excluded from Table 5.6. The difference between the NPVs of the hail-net strategies of Scenarios 1 and 2 is striking, with the expect loss decreasing from just over R12 million to R2,4 million (see Table 5.6). The best-case scenario increases from a loss of R1,9 million to a profit of R9,5 million, whilst the worst-case scenario improves from a loss of R20,7 million to a loss of R1,3 million. Hence, the CDF curve of shade netting shifts to the right, as shown in Figure 5.2, but it is still dominated by hail insurance and self-insurance in terms of FSD. In this scenario, ceteris paribus, a rational decision maker will choose to implement hail insurance as a hail risk management strategy over shade netting, even if the pack-out percentages improve.

*Table 5.6: Comparing the shade net strategies of Scenarios 1 and 2 for the typical producer*

| Variable | NPV hail net | |
|---|---|---|
| | Scenario 1 | Scenario 2 |
| Mean | -R 12 032 333 | -R 2 414 812 |
| Standard deviation | R 2 988 521 | R 3 540 026 |
| Coefficient of variation (CV) | 25% | 147% |
| Min | -R 20 739 352 | -R 1 273 0791 |
| Max | -R 1 938 009 | R 9 539 710 |

It is worth noting that the coefficient of variation increases from 25% to 147% from Scenario 1 to 2, which follows from the fact that the standard deviation increases from Scenario 1 to 2, whilst the expected loss (mean) decreases substantially (see Table 5.6). The reason for this is uncertain, but possible because of the increase in the share of Class 1 and 2 fruit at the expense of Class 3 fruit. In accordance with portfolio theory, the volatility of a portfolio is a factor of the share of the stock/enterprise/fruit class and the standard deviation thereof. Hence, if the share of Class 1 and Class 2 is increased at the expense of Class 3, then the weight of their volatility, as their standard deviations of 12,57 and 8,34 respectively, is increased at the expense of the small standard deviation of 2,02 for the latter (see Table 5.7).

*Table 5.7: Simulated real market prices per 4 kg for class*

| | Avo prices R (2010*) / 4 kg | | |
|---|---|---|---|
| | Class 1, export market | Class 2, local market | Class 3, local processed |
| **Mean** | 65,16 | 41,38 | 10,00 |
| **Standard deviation** | 12,57 | 8,34 | 2,02 |
| **Coefficient of variation (CV)** | 19,29 | 20,15 | 20,15 |
| **Min** | 49,34 | 30,20 | 7,30 |
| **Median** | 68,03 | 40,85 | 9,87 |
| **Max** | 80,62 | 51,46 | 12,44 |

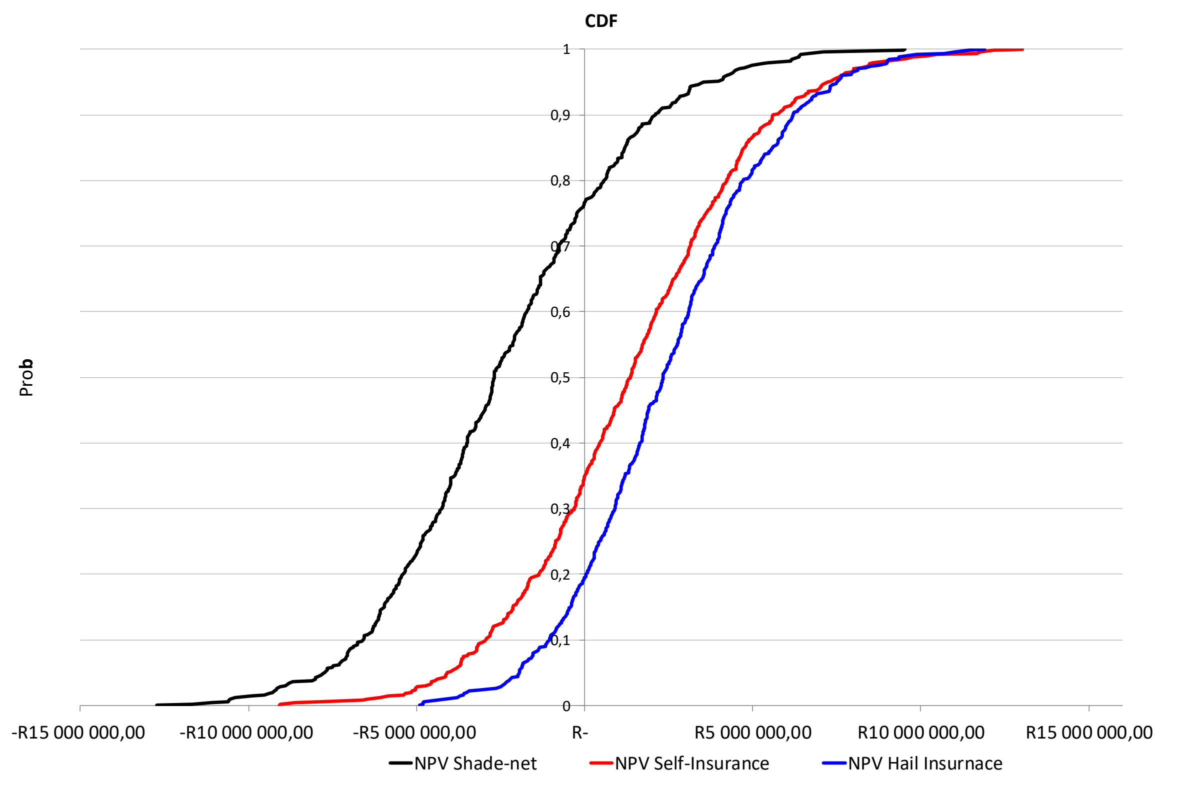


*Figure 5.2: CDFs for typical producer in Scenario 2*

### 5.3.3 Scenario 3: Typical Letaba producer with high hail-insurance premium

Scenario 3 is like Scenario 2, except for the fact that a higher hail-insurance premium is assumed, and hence only the CDF of the hail-insurance strategy will move, as shown in Figure 5.5. A comparison between the CDFs of hail insurance and self-insurance shows that first-degree stochastic dominance is not possible, since their respective CDFs cross.

*Table 5.8: A summary of the KOV expected values used in the simulation*

| **KOVs** | **Yield** | **Pack-out (%)** | | | **Insurance premium (%)** | **Prices (R/kg)** | | | **Hail risk distribution** |
|---|---|---|---|---|---|---|---|---|---|
| | **(Ton)** | **Class 1** | **Class 2** | **Class 3** | | **Class 1** | **Class 2** | **Class 3** | |
| Shade-nets | 13,6 | 75% | 20% | 5% | n/a | 92,0 | 57,9 | 10 | Bernoulli (0,2) |
| Self-insure | 13,6 | 61% | 17% | 22% | n/a | 92,0 | 57,9 | 10 | Triangular (0%; 50%; 100%) |
| Hail insure | 13,6 | 61% | 17% | 22% | 8% | 92,0 | 57,9 | 10 | |

Hail insurance has the possibility to dominate self-insurance with respect to second-degree stochastic dominance, since it has a larger minimum value than hail insurance. However, the area before the respective CDFs cross is smaller than the area after, thus not allowing SSD. It is also worth noting that hail insurance lowers both the downside risk and upside potential, as shown in Table 5.9, since the best, worst and most likely case NPV of self-insurance are greater than that of hail insurance.

*Table 5.9: Summary of Scenario 3 results for typical producer*

| Variable | NPV shade net | NPV self-insurance | NPV hail insurance |
|---|---|---|---|
| Mean | -R 2 414 812 | R 1 403 770 | R 947 682 |
| Standard deviation | R 3 540 026 | R 3 471 359 | R 2 940 514 |
| Coefficient of variation (CV) | 147% | 247% | 310% |
| Min | -R 1 2730 791 | -R 9 089 711 | -R 6 871 288 |
| Max | R 9 539 710 | R 13 014 765 | R 9 690 738 |

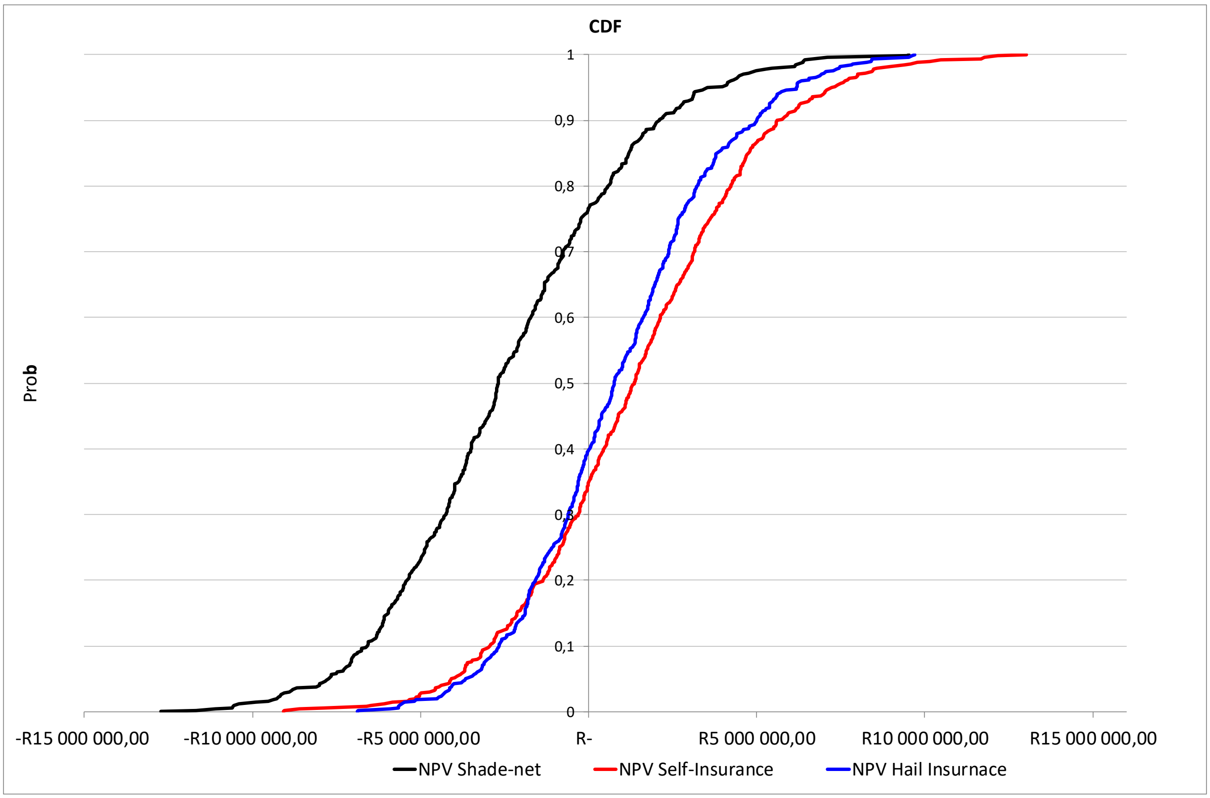


*Figure 5.3: CDFs for typical producer in Scenario 3*

## 5.4 Results of top grower: Letaba

In this section, the model was populated with the KOVs of the top producer in Letaba and follows the structure as in the previous section. The decision to include an analysis of the top producer was driven by the hypothesis that such a producer would be in a better position to afford the hail nets. Table 5.6 summarises the empirical data used for constructing the MVE probability distribution of the top Letaba producer. It is worth noting that 2018 was an exceptionally good growing season in South Africa, whilst the opposite was true for 2017. This supply dynamics is also reflected in the prices received by producers. Producers received record high prices for Class 1 fruit in 2017 and record lows for Class 2 fruit in 2018. All prices shown are nominal and quoted as delivered in port (DIP), therefore packing and marketing costs are included in the model. When comparing the KOVs of the top and typical growers, the variable that stands out is yield. The quality and prices received do not vary significantly, and therefore the difference in financial performance between the two producers is attributed to the high yield potential of the top producer and the average yield potential of the typical producer.

*Table 5.10: Key output variables (KOV) of the top Letaba producer*

| Year | Yield (ton) | Pack-out shares | | | Price (R/4 kg) | | Hail insurance premium Letaba |
|---|---|---|---|---|---|---|---|
| | | Class 1 | Class 2 | Class 3 | Class 1 | Class 2 | |
| 2014 | 17 | 56% | 19% | 25% | 65,89 | 71,89 | 5,34% |
| 2015 | 17 | 48% | 36% | 16% | 94,83 | 45,87 | 5,40% |
| 2016 | 16 | 68% | 12% | 22% | 107,8 | 51,45 | 5,26% |
| 2017 | 10 | 51% | 27% | 22% | 123,3 | 61,01 | 5,96% |
| 2018 | 32 | 65% | 30% | 5% | 79,33 | 36,9 | 5,77% |
| **Expected value** | **18,4** | **58%** | **25%** | **18%** | **94,23** | **53,424** | **5,55%** |

The correlation matrix for the KOVs presented in Table 5.10 is shown in *Table 5.11*. The interpretation of the results is like that discussed in Section 5.3. As discussed previously, there is a large negative relationship between prices and yield, thus if yield increases, prices are expected to decrease.

*Table 5.11: Linear correlation matrix for top producer*

| | Export avo prices 4 kg | Local avo prices 4 kg | Yield | Hail insurance premium |
|---|---|---|---|---|
| Export avo prices 4 kg | 1 | -0,05 | -0,77 | 0,13 |
| Local avo prices 4 kg | | 1 | -0,60 | -0,34 |
| Yield | | | 1 | 0,08 |
| Hail insurance premium | | | | 1 |

### 5.4.1 Scenario 1: Top Letaba producer: Baseline

The KOVs of the top producer in Scenario 1 are presented in Table 5.12, the summary statistics of the simulation are presented in Table 5.13, and the CDFs are visualised in Figure 5.4.

*Table 5.12: A summary of the KOV expected values used in the simulation*

| KOVs | Yield | Pack-out (%) | | | Insurance premium (%) | Prices (R/kg) | | | Hail risk distribution |
|---|---|---|---|---|---|---|---|---|---|
| | (Ton) | Class 1 | Class 2 | Class 3 | | Class 1 | Class 2 | Class 3 | |
| Shade-nets | 18,4 | 58% | 25% | 18% | n/a | 94,2 | 53,4 | 10 | Bernoulli (0,2) |
| Self-insure | 18,4 | 58% | 25% | 18% | n/a | 94,2 | 53,4 | 10 | Triangular (0%; 50%; 100%) |
| Hail insure | 18,4 | 58% | 25% | 18% | 5,5% | 94,2 | 53,4 | 10 | |

The self-insurance and hail-insurance strategies are FSD over shade netting. Furthermore, hail insurance dominates the self-insurance strategy in the sense of second-degree stochastic dominance. A rational decision maker will thus implement the hail-insurance strategy to manage hail risk.

*Table 5.13: Summary of Scenario 1 results for top producer*

| Variable | NPV shade net | NPV self-insurance | NPV hail insurance |
|---|---|---|---|
| Mean | R 4 039 229 | R 9 793 795 | R 12 382 453 |
| Standard deviation | R 4 539 391 | R 5 256 787 | R 4 504 477 |
| Coefficient of variation (CV) | 112% | 54% | 36% |
| Min | -R 10 836 250 | -R 6 580 591 | -R 1 744 963 |
| Max | R 19 941 545 | R 30 522 602 | R 25 715 007 |

A comparison between the top and typical grower with respected to the Scenario 1 CDF results (Figure 5.1 and Figure 5.4) confirms the hypothesis that there is a higher likelihood that the use of shade nets will be a more suitable risk management strategy for the top producer. This is driven primarily by the relatively higher yield of the top grower, of 18,4 ton/ha vs. the 13,6 ton/ha of the typical grower, which lowers the per unit cost of the shade nets. However, hail insurance is still the most suitable risk management strategy for the top grower, even more so than in the case of the typical grower.

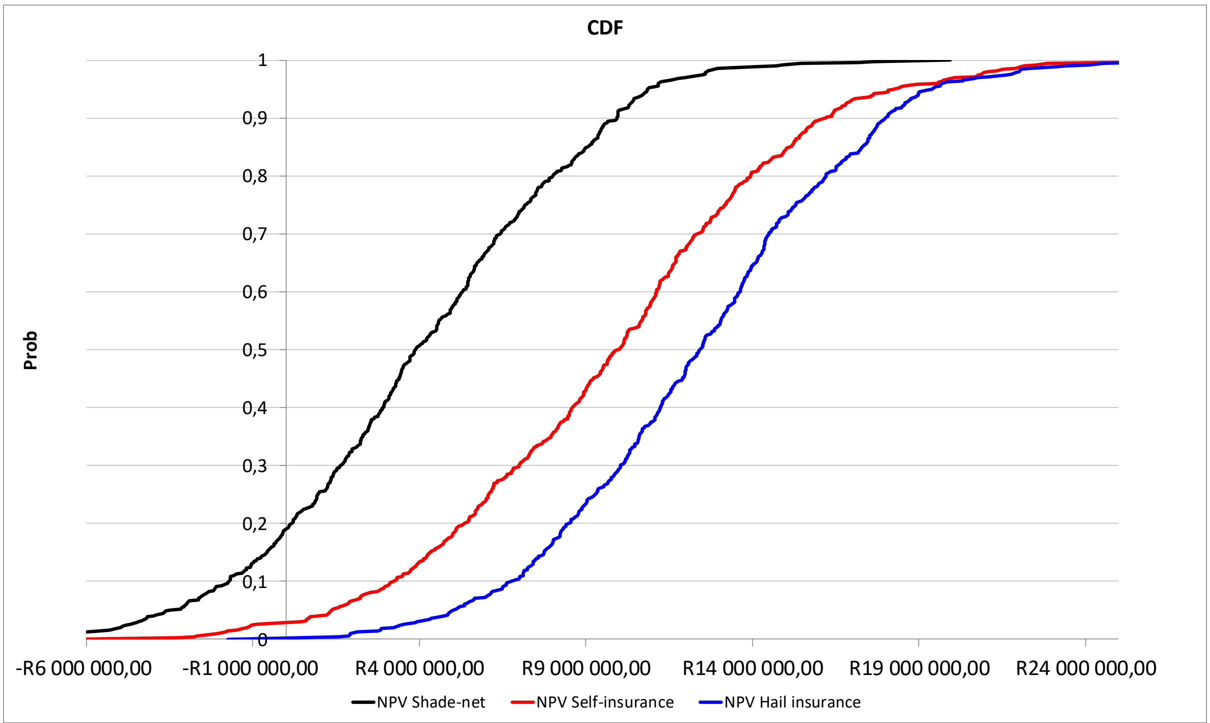


*Figure 5.4: CDFs for top producer in Scenario 1*

### 5.4.2 Scenario 2: Top Letaba producer: Improved pack-out under shade nets

Following the previous results, an assumption is made that there will be an increase in the quality of fruit cultivated under shade netting due to the mitigation of abiotic stress factors. The quality of fruit under shade netting increases to 75%, 20% and 5% for Class 1, 2 and 3 respectively. All other KOVs remain the same, as summarised in Table 5.14.

*Table 5.14: A summary of the expected KOV values used in the simulation*

| **KOVs** | **Yield** | **Pack-out (%)** | | | **Insurance premium (%)** | **Prices (R/kg)** | | | **Hail risk distribution** |
|---|---|---|---|---|---|---|---|---|---|
| | **(Ton)** | **Class 1** | **Class 2** | **Class 3** | | **Class 1** | **Class 2** | **Class 3** | |
| Shade nets | 18,4 | 75% | 20% | 5% | n/a | 94,2 | 53,4 | 10 | Bernoulli (0,2) |
| Self-insure | 18,4 | 58% | 25% | 18% | n/a | 94,2 | 53,4 | 10 | Triangular (0%; 50%; 100%) |
| Hail insure | 18,4 | 58% | 25% | 18% | 5,5% | 94,2 | 53,4 | 10 | |

Figure 5.5 shows the CDFs of the risk management strategies, and Table 5.15 shows the summary statistics. In this scenario, shade netting is stochastically dominant (of first degree) over the self-insurance strategy, but not FSD or SSD over hail insurance because of a greater minimum value of -R 2,176 million versus -R 1,744 million, as shown in Table 5.14 and Table 5.15.

Although the shade net strategy is not FSD or SSD over hail insurance, it will be economically justifiable to implement shade nets as a risk management strategy. The minimum values of shade netting and hail insurance do not differ significantly, as there is a very small probability (1%) that hail insurance will have a bigger NPV than shade netting. An added advantage relative to hail insurance is the relatively lower coefficient of variation, of 33% vs. 36%.

The improved pack-out increases the expected value, from R4,03 million to R16,35 million between Scenario 1 and 2 and decreases the coefficient of variation from 112% to 33%.

*Table 5.15: Comparison of the Scenario 1 and 2 results for top the producer*

| Variable | NPV shade net | |
|---|---|---|
| | Scenario 1 | Scenario 2 |
| Mean | R 4 039 229 | R 16 352 010 |
| Standard deviation | R 4 539 391 | R 5 458 530 |
| Coefficient of variation (CV) | 112% | 33% |
| Min | -R 10 836 250 | -R 2 175 831 |
| Max | R 19 941 545 | R 35 713 678 |

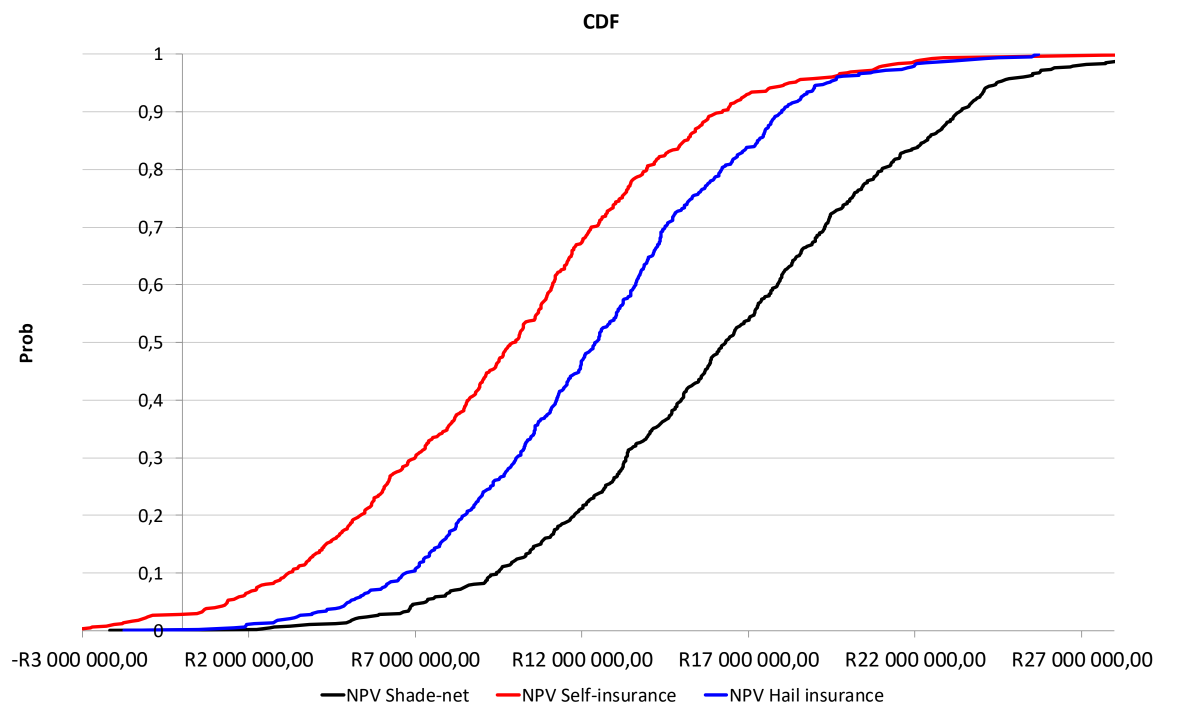


*Figure 5.5: CDFs for typical producer in Scenario 2*

### 5.4.3 Scenario 3.1: Top producer: Scenario 2 plus high hail insurance premium

In this scenario, the hail insurance premium is increased from 5,5% to 8%, whilst all of the other KOVs remain the same.

*Table 5.16: A summary of the expected KOV values used in the simulation*

| KOVs | Yield | Pack-out (%) | | | Insurance premium (%) | Prices (R/kg) | | | Hail risk distribution |
|---|---|---|---|---|---|---|---|---|---|
| | (Ton) | Class 1 | Class 2 | Class 3 | | Class 1 | Class 2 | Class 3 | |
| Shade-nets | 18,4 | 75% | 20% | 5% | n/a | 94,2 | 53,4 | 10 | Bernoulli (0,2) |
| Self-insure | 18,4 | 58% | 25% | 18% | n/a | 94,2 | 53,4 | 10 | Triangular (0%; 50%; 100%) |
| Hail insure | 18,4 | 58% | 25% | 18% | 8% | 94,2 | 53,4 | 10 | |

Shade netting dominates hail insurance and self-insurance in terms of FSD. It is clear that hail insurance is stochastically dominant (of second order) over self-insurance, since the minimum value of hail insurance is greater than that of self-insurance (see Table 5.17), and the area between the two curves is bigger before the intersection.

*Table 5.17: Summary of results of Scenario for top producer*

| Variable | NPV shade net | NPV self-insurance | NPV hail insurance |
|---|---|---|---|
| Mean | R 16 352 010 | R 9 793 795 | R 10 153 750 |
| Standard deviation | R 5 458 530 | R 5 256 787 | R 4 332 489 |
| CV | 33% | 54% | 43% |
| Min | R -2 175 831 | R -6 580 591 | R -3 118 711 |
| Max | R 35 713 678 | R 30 522 602 | R 22 918 823 |

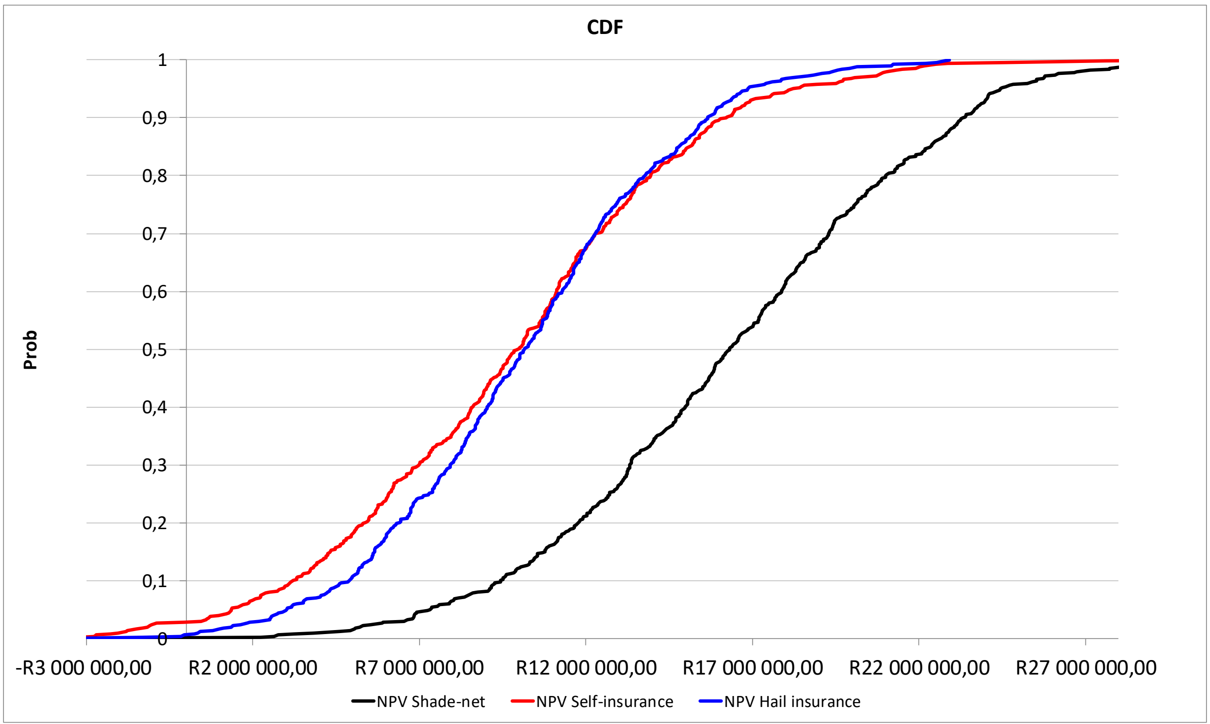


*Figure 5.6: CDFs for typical producer in Scenario 3.1*

### 5.4.4 Scenario 3.2: Top Letaba producer: reduction in hail probability

It was decided to include an additional Scenario 3 just to the illustrate the sensitivity of the results to a decrease in the assumption of the likelihood of hail, from 20% to 17%. The assumption regarding the intensity of the hailstorm, if it occurs, remained unchanged. Hence, it was assumed that the intensity of the hail was still determined by the GRKS distribution with a minimum of 0%, a mode of 50% and a maximum of 100%.

*Table 5.18: A summary of the expected KOV values used in the simulation*

| KOVs | Yield (Ton) | Pack-out (%) | | | Insurance premium (%) | Prices (R/kg) | | | Hail risk distribution |
|---|---|---|---|---|---|---|---|---|---|
| | | Class 1 | Class 2 | Class 3 | | Class 1 | Class 2 | Class 3 | |
| Shade nets | 18,4 | 75% | 20% | 5% | n/a | 94,2 | 53,4 | 10 | Bernoulli (0,17) |
| Self-insure | 18,4 | 58% | 25% | 18% | n/a | 94,2 | 53,4 | 10 | Triangular (0%; 50%; 100%) |
| Hail insure | 18,4 | 58% | 25% | 18% | 8% | 94,2 | 53,4 | 10 | |

Changing the hail risk of the model will only influence the NPVs of the self-insurance and hail-insurance strategies, as it is assumed that shade nets completely protect the fruit from hail damage. However, the change in NPVs of hail insurance is small. Lowering the hail damage risk causes the CDF of self-insurance to shift to the right, and the mean improves from R 9.79 million to R 10.76 million.

Shade netting is still stochastically dominant (of first order) over self-insurance and hail insurance. The difference from Figure 5.6 is that hail insurance is no longer SSD over self-insurance, as the area before the CDFs intersect is smaller than the area after, as seen in Figure 5.7.

*Table 5.19: Summary of Scenario 3.2 results for top producer*

| Variable | NPV shade net | NPV self-insurance | NPV hail insurance |
|---|---|---|---|
| Mean | R 16 352 010 | R 10 759 175 | R 9 996 647 |
| Standard deviation | R 5 458 530 | R 5 204 533 | R 4 263 372 |
| CV | 33% | 48% | 43% |
| Min | -R 2 175 831 | -R 5 832065 | -R 3 104 834 |
| Max | R 35 713 678 | R 30 522 602 | R 22 772 139 |

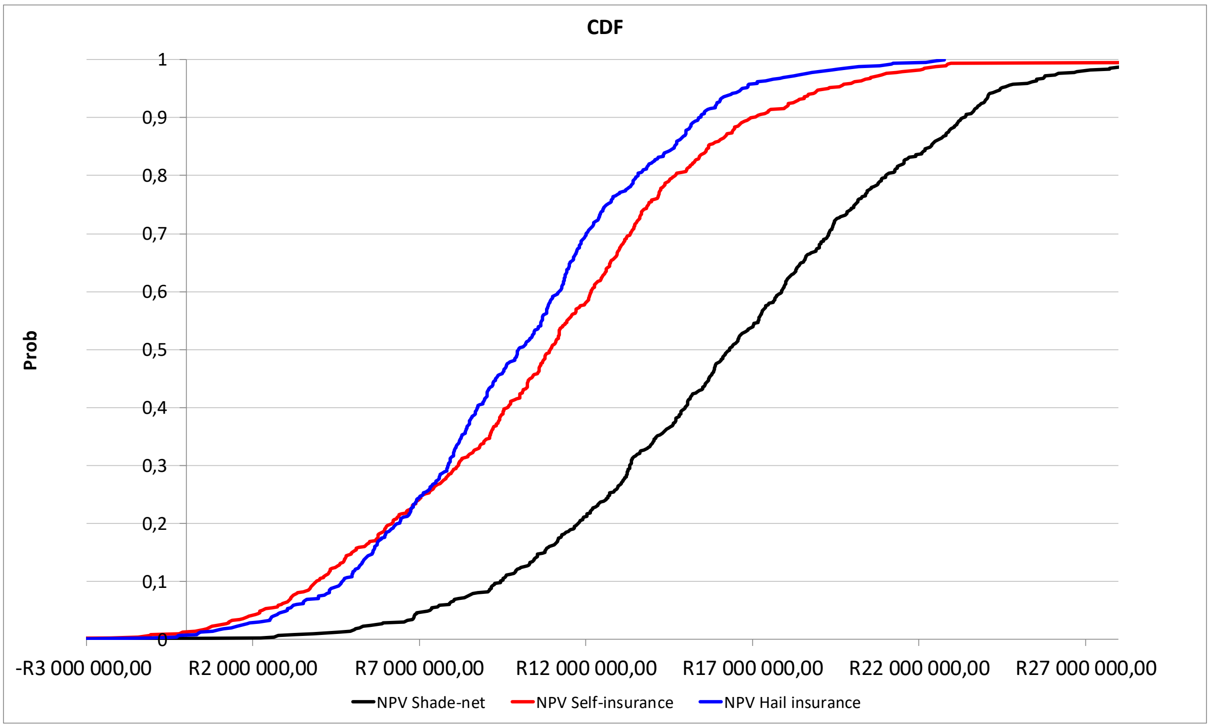


*Figure 5.7: CDFs for typical producer in Scenario 3.2*

The purpose of including a scenario in which the hail damage risk is changed is to show that it has a large effect on the NPV of the self-insurance strategy. Furthermore, this is important, since hail risk is not simulated using empirical data. The accurate simulation of hail risk is deemed to be beyond the scope of this study.

# Chapter 6

# Conclusions, summary, recommendations and programme for further work

## 6.1 Conclusions

The South African avocado industry is export orientated, with roughly 55% of the total annual production being exported. Export markets are more lucrative for producers, as exported fruit earn a price premium over fruit sold on the local markets due to the exchange rate. However, only premium-quality avocados with no defects (mostly caused by sun, hail, insect or wind damage) can be classed and packed as export-quality fruit (Winter & Bester, 2018). Volatile markets, fluctuations in the quality and quantity of yields, and input cost uncertainties make avocado production risky in South Africa. Risk management strategies are widely used and important for investment, financing or production decision-making. Farmers are notoriously risk averse.

Amongst the production risks for avocado farming are: sunburn, wind damage, spots and hail. A key source of production and quality risk in the Limpopo province is that of hail damage. To manage this risk, producers have alternative management options, designed to negate the risk of hail damage. Shade nets are a form of protected cultivation technology widely implemented in horticultural industries like citrus, stone and pome fruit and other exotic fruit. On the other side of the risk management spectrum is conventional, short-term insurance, which is less expensive over the short term, but the running cost over the long term can be significant. Hail insurance is a financial product based on a contract and can only be purchased after fruit set. The insurance company determines the premiums by statistical and mathematical calculations based on historical records and payments for a specific geographical area.

The purpose of this study was to stochastically simulate whole farms for avocado producers in Letaba by constructing multi-period budgets and assessing the financial performance of three risk management strategies. The strategies are shade netting, hail insurance and self-insurance. The self-insurance strategy is where the decision maker does not implement a hail risk management strategy. The self-insurance strategy was included in the results to provide a benchmark for the decision maker to weigh the upside and downside risks of having no hail risk management strategy.

The two active strategies (hail insurance and shade nets) involve either running cost (hail insurance) or capital layout (shade nets), and both these strategies affect the farm in total. Farms are typically complex and multifaceted, and it is important to assess the forms of management in relation to the integrated farming system. For this reason, the systems approach was applied. Systems thinking allows for the integration of the various components and does not ignore the interrelatedness of these components. Often, unexpected effects are found in complex systems that would have been missed were these relationships ignored. The technique employed to adhere to the systems approach concept is that of whole-farm multi-period budget modelling. Budgets are essentially simulation models that are based on standard accounting principles. The sophistication of whole-farm budgets lies in the number of variables that can be interconnected within a spreadsheet environment.

In this study, the real system is represented by the typical avocado farm. The concept of a typical farm was applied to construct the budget model on a farm that is representative, rather than a statistically calculated average. The occurrence of hail and the potential associated financial loss are the key considerations of this study. The random or stochastic components of the variables are incorporated by using probability distributions within the model. A stochastic modelling approach was followed to integrate a probability distribution to the random variables that affect losses to gain insight into the risk. Choosing the correct probability distribution that reflects the random component of the variable as closely as possible is crucial for the success of the simulation model. The baseline model that was developed simulated an avocado farm, with typical farming practices for the area of concern – Letaba.

Multivariate empirical (MVE) probability distributions were used to simulate all KOVs except for hail damage risk. Empirical data of hailstorms was not obtainable from financial institutions, since it is deemed confidential information. As a result, a Bernoulli discrete probability was used to simulate the probability of a hail event, in combination with a GRKS triangular distribution to simulate the intensity of the hailstorm. However, simulating hail damage risk accurately is deemed to be beyond the scope of this study. The accuracy of hail damage risk has a big effect on the economic performance of the self-insurance strategy.

However, the method used to simulate hail damage is easy to understand and successfully illustrates the risk of hail damage. The overall method of stochastic modelling was successful to evaluate the financial impacts of different hail risk management options.

Farm profitability and risk are driven mainly by yield and prices received for produce. Therefore, using yield and price as KOVs in the stochastic budget model successfully incorporates the most important drivers of farm profitability and risk. This principle is effective and useful for any avocado producer, regardless of hail damage risk.

The main results of the study show that, for a typical producer with an expected yield of 13,6 ton per hectare (average yield potential), shade nets will not be justifiable, even with an increase in the quality of the fruit; self-insurance and hail insurance are stochastically dominant of first order over shade nets for all scenarios. Furthermore, self-insurance does not dominate hail insurance in terms of first- or second-order stochastic dominance in any scenario, meaning that it is a riskier management strategy.

The simulated results using the empirical data of a top producer with an expected yield of 18,4 ton per hectare (high yield potential) show that shade nets are stochastically dominant (of first order) over all other strategies when there is increased quality of fruit without a decline in yield. If there is no increase in the quality of fruit cultivated under shade nets, hail insurance and self-insurance will have first-degree stochastic dominance over the shade net strategy. As with the typical producer, there is no scenario in which self-insurance is stochastically dominant (of first or second order) over hail insurance. However, it is possible for hail insurance to have second-degree stochastic dominance over self-insurance.

Decision makers considering implementing a risk management strategy should first examine the individual enterprise's historical data and the individual's goals, risk attitude and financial constraints. In most cases, hail insurance is the safest option, as it limits the extreme downside risk because it does not require a large capital-intensive investment, it is flexible (not path dependent like shade nets), producers are familiar with the method, and it does not influence the biotic or abiotic factors in the avocado production system. Shade nets are not justifiably a risk management strategy only; they can only be economically viable if there is a high expected yield (18 ton/ha) and the quality of the fruit is improved. The self-insurance strategy is highly dependent on the hail risk in the area and is the strategy with the most upside and downside risks.

## 6.2 Summary

A quantitative analysis comparing hail damage risk management strategies for a typical representative avocado farm was done in the form of a stochastic budget model. The stochastic budget model allowed the research to evaluate the financial and risk position of the decision maker when choosing between the different strategies, as these management strategies have different physical and financial characteristics. The three options available to the decision maker are:

- 1) fixed shade net structures that act as a physical barrier against hail damage, but also have secondary benefits such as reduced sunburn and wind damage to fruit;
- 2) self-insurance, which consists of not implementing any risk management strategy and being fully exposed to the peril of hail; and
- 3) purchasing hail insurance from a financial institution.

The evaluation was done by quantifying the expected monetary values of the respective practices in a capital budget over a period of 20 years. This was accomplished by stating all the relevant costs in relation to the eventual value of fruit production, which will lead to the future expected capital flows. The risk of hail damage is incorporated into the expected capital flows. The adjusted expected future cash flows are discounted to get a net present value (NPV). As the budget model is stochastic, a range of NPVs were simulated for each strategy and are presented as a cumulative distribution function (CDF). The stochastic dominance criterion was used to compare the strategies.

Chapter 2 provided a review of the relevant literature on production risk management strategies, risk and uncertainty in farm planning, and the production risks involved in avocado cultivation. Chapter 2 concluded with an overview of previous studies on shade netting and hail insurance from a physical and financial point of view.

Chapter 3 expanded on the theory of constructing a whole-farm multi-period budget model for a typical and representative avocado farm.

Chapter 4 provided an overview of the theory of including stochastic key output variables (KOVs) in the constructed budget model to make it a stochastic model that incorporates risk. The study made use of multivariate empirical probability distributions to incorporate risk, with only hail damage risk being simulated by combining a Bernoulli and GRKS triangular distribution; the stochastic simulation was done with Simetar. The stochastic KOVs included in this model are yield, quality (affected by hail damage), price and insurance premiums.

Chapter 5 presents the results of the simulated stochastic budget model of the respective risk management scenarios, namely self-insurance, hail insurance and shade netting. The model was populated with data from two sets of producers, namely a typical Letaba producer and a top Letaba producer. Three scenarios were tested for each producer – 1) a baseline scenario with the KOVs as is, 2) increased pack-out because of shade nets, and 3) increased pack-out plus increased hail insurance premium. The results of each scenario for the respective producers are presented as CDFs and compared using stochastic dominance.

## 6.3 Recommendations

There is not a 'one-size-fits-all' risk management strategy for producers. Each farming unit will have a tailored solution, as each farm system differs inherently. For a producer to decide which risk management strategy to implement, the potential output of the farming unit has to be known. The variables that need to be studied are yield, quality, prices, area hail risk and hail insurance premiums, as these variables are most likely to influence the financial performance of the enterprise with a given risk management strategy. Furthermore, a decision maker considering shade nets as a risk management strategy has to ensure the technical requirements, as the biotic and abiotic environment changes and traditional cultivation techniques have to be adjusted.

## 6.4 Programme for further work

The main purpose of this study was to do quantitative research to compare the economic qualities of different risk management strategies. The need for this originated from decision makers facing uncertainties when having to choose between risk management strategies. With the stochastic simulation process being based on empirical data to simulate multivariate empirical probability distributions of the KOVs, the results of the simulation become highly dependent on the input values used in Section 4.4.1. Although the method proposed by Richardson *et al*. (2000) allows limited amounts of historical data, having more data will improve the accuracy and explanatory possibilities of the overall model. The accuracy of the model is dependent on the quality and quantity of the data. More data can be used to make the correlations more accurate, etc. The empirical data used in the model may contain anomalies. The model can be improved by making the hail risk simulation more accurate, as the simulation of hail risk was not based on empirical data but on subjective possibilities, as simulating hail risk was deemed beyond the scope of this study.

To solve the abovementioned problem, the MVE probability distributions can be replaced by assigning subjective probability distributions to the KOVs. An example of this is to use triangular probability distributions, which only require a minimum, expected and maximum value to describe an event. The triangular distribution can be helpful when study groups are used to gather subjective probabilities, as it is easily understood. In addition, the normal probability distribution can then be used if there is data about the mean and standard deviation of the KOVs. When probability distributions are subjectively assigned, it is important to still take correlation into account when there are multiple variables.

The typical farm model and the empirical data used for the MVE probability distributions can easily be adapted for a specific farm or case study. Hence, the model can be used as a tool to assist decision-making on farm-level for a specific farm.

Further research is required regarding the long-term impact of shade nets on yield, fruit quality and management practices. It should incorporate the monetary effect of improved microclimate, less evapotranspiration and reduced abiotic stress factors on increased pack-out rates, production costs and yield. For an industry to remain competitive in the long run, innovation that increases efficiency and inherently also profitability is essential for sustainability.

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# Addenda

**Annexure A: Example of a Capital budget iteration for shade-nets as risk management strategy**

| Year | | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Gross Margin | **A** | 3332277 | 1565296 | 2318717 | 2865770 | 306581 | 2700842 | 1656392 | 881749 | 565351 | 3548486 |
| | | | | | | | | | | | |
| Overheads | **B** | **612182** | **612182** | **612182** | **612182** | **612182** | **612182** | **612182** | **612182** | **612182** | **612182** |
| | | 612182 | 612182 | 612182 | 612182 | 612182 | 612182 | 612182 | 612182 | 612182 | 612182 |
| | | | | | | | | | | | |
| External factor cost | **C** | **910621** | **910621** | **910621** | **910621** | **910621** | **910621** | **910621** | **910621** | **910621** | **910621** |
| | | | | | | | | | | | |
| Total Capital | **D** | **19294256** | **0** | **0** | **22000** | **0** | **443000** | **300000** | **0** | **2306000** | **0** |
| Fixed Improvements | | 1427200 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1990000 | 0 |
| Farm fixed improvements | | 336000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 30000 | 0 |
| Vehicles | | 511867 | 0 | 0 | 0 | 0 | 48000 | 300000 | 0 | 0 | 0 |
| Tractors | | 799222 | 0 | 0 | 0 | 0 | 380000 | 0 | 0 | 250000 | 0 |
| Implements/tools/equipment | | 219967 | 0 | 0 | 22000 | 0 | 15000 | 0 | 0 | 36000 | 0 |
| Land | | 16000000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | | | | | | | | | |
| Liquidation of investment (year 20) | **E** | | | | | | | | | | |
| Net Capital flow | **A-B-C-D+E** | -17484780 | 42494 | 795915 | 1320968 | -1216221 | 735040 | -166411 | -641053 | -3263451 | 2025684 |

| Year | | 2029 | 2030 | 2031 | 2032 | 2033 | 2034 | 2035 | 2036 | 2037 | 2038 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Gross Margin | A | 2672927 | 1720883 | -206823 | 2524782 | 611540 | 189028 | 1019152 | -220145 | 2492826 | 711805 |
| | | | | | | | | | | | |
| Overheads | B | **612182** | **612182** | **612182** | **612182** | **612182** | **612182** | **612182** | **612182** | **612182** | **612182** |
| | | 612182 | 612182 | 612182 | 612182 | 612182 | 612182 | 612182 | 612182 | 612182 | 612182 |
| | | | | | | | | | | | |
| External factor cost | C | **910621** | **910621** | **910621** | **910621** | **910621** | **910621** | **910621** | **910621** | **910621** | **910621** |
| | | | | | | | | | | | |
| Total Capital | D | **337750** | **1167000** | **100000** | **10000** | **75000** | **0** | **0** | **100000** | **120000** | **0** |
| Fixed Improvements | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Farm fixed improvements | | 75000 | 0 | 100000 | 0 | 75000 | 0 | 0 | 100000 | 120000 | 0 |
| Vehicles | | 0 | 300000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Tractors | | 0 | 515000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Implements/tools/equipment | | 262750 | 352000 | 0 | 10000 | 0 | 0 | 0 | 0 | 0 | 0 |
| Land | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | | | | | | | | | |
| Liquidation of investment (year 20) | E | | | | | | | | | | **18141266** |
| Net Capital flow | A-B-C-D+E | 812375 | -968919 | -1829625 | 991979 | -986262 | -1333774 | -503650 | -1842947 | 850024 | 17330269 |

## Annexure B: Example of a gross margin budget iteration with hail insurance as risk management strategy

| Year | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 |
|---|---|---|---|---|---|---|---|---|---|---|
| Hail damage 0-no 1-Yes | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 |
| If yes how bad | 0% | 0% | 0% | 0% | 0% | 20% | 0% | 84% | 0% | 0% |
| Class 1 | 61% | 61% | 61% | 61% | 61% | 49% | 61% | 10% | 61% | 61% |
| Class 2 | 17% | 17% | 17% | 17% | 17% | 13% | 17% | 3% | 17% | 17% |
| Class 3 | 22% | 22% | 22% | 22% | 22% | 38% | 22% | 88% | 22% | 22% |
| Price Class 1 | R12,80 | R13,18 | R12,85 | R12,69 | R19,20 | R14,76 | R12,69 | R20,74 | R19,62 | R18,11 |
| Price Class 2 | R7,94 | R12,28 | R8,54 | R7,73 | R7,28 | R12,21 | R12,03 | R12,25 | R8,32 | R12,40 |
| Price Class 3 | R1,91 | R1,97 | R1,92 | R1,89 | R2,86 | R2,20 | R1,89 | R3,09 | R2,93 | R2,70 |
| **Average price** | **R9,575** | **R10,540** | **R9,708** | **R9,470** | **R13,592** | **R9,652** | **R10,183** | **R5,062** | **R14,037** | **R13,743** |
| Year | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 |
| Gross Margin | Block Nr | Ha | Year planed | Trees/ha | Cultivar | Total trees | Lifetime | age | | |
| Avo | 1 | 30 | 2009 | 408 | Hass | 12245 | 30 | 9 | | |
| Age | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
| Expexted Yield/ha | 17,27 | 12,57 | 16,86 | 18,00 | 18,00 | 11,03 | 16,07 | 8,00 | 13,85 | 8,00 |
| Price/ton | 9575,34 | 10539,55 | 9708,05 | 9469,78 | 13592,13 | 9651,58 | 10183,06 | 5062,14 | 14036,59 | 13742,88 |
| | | | | | | | | | | |
| Total value of production/ha | 165402 | 132439 | 163720 | 170456 | 244658 | 106494 | 163691 | 40495 | 194373 | 109938 |
| Direct allocatable PC/ha | 55500 | 55500 | 55500 | 55500 | 55500 | 55500 | 55500 | 55500 | 55500 | 55500 |
| Insurnace/ha | 14423 | 10072 | 13518 | 14376 | 14389 | 9300 | 12820 | 6929 | 12042 | 6929 |
| Payouts | 0 | 0 | 0 | 0 | 0 | 17067 | 0 | 88809 | 0 | 0 |
| Gross margin/ha | 95479 | 66867 | 94702 | 100580 | 174769 | 58761 | 95371 | 66875 | 126831 | 47509 |
| **Gross Margin Total** | **2864360** | **2006000** | **2841056** | **3017398** | **5243075** | **1762835** | **2861127** | **2006264** | **3804919** | **1425276** |
| Insurance payouts | | | | | | | | | | |
| Rate | 5,57% | 5,34% | 5,34% | 5,32% | 5,33% | 5,62% | 5,32% | 5,77% | 5,80% | 5,77% |
| Insured yield ton/ha | 17,27 | 12,57 | 16,86 | 18,00 | 18,00 | 11,03 | 16,07 | 8,00 | 13,85 | 8,00 |
| Insurance cover amount | 259106 | 188489 | 252965 | 270000 | 270000 | 165508 | 241123 | 119992 | 207714 | 119994 |
| Insurance premium/ha | R14 423,29 | R10 072,49 | R13 517,98 | R14 376,11 | R14 389,16 | R9 299,60 | R12 820,21 | R6 928,55 | R12 042,22 | R6 928,67 |
| Hail damage | 0% | 0% | 0% | 0% | 0% | 20% | 0% | 84% | 0% | 0% |
| Payment | | | | | | | | | | |
| Damage Rand/Ha | R - | R - | R - | R - | R - | R 33 617 | R - | R 100 809 | R - | R - |
| Excess payment (10%) | R - | R - | R - | R - | R - | R 16 551 | R - | R 11 999 | R - | R - |
| Payment (Income)/ ha | R - | R - | R - | R - | R - | R 17 067 | R - | R 88 809 | R - | R - |

| Year | 2029 | 2030 | 2031 | 2032 | 2033 | 2034 | 2035 | 2036 | 2037 | 2038 |
|---|---|---|---|---|---|---|---|---|---|---|
| Hail damage 0-no 1-Yes | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| If yes how bad | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 29% |
| Class 1 | 61% | 61% | 61% | 61% | 61% | 61% | 61% | 61% | 61% | 43% |
| Class 2 | 17% | 17% | 17% | 17% | 17% | 17% | 17% | 17% | 17% | 12% |
| Class 3 | 22% | 22% | 22% | 22% | 22% | 22% | 22% | 22% | 22% | 45% |
| Price Class 1 | R20,74 | R20,74 | R12,69 | R19,97 | R18,59 | R19,44 | R14,93 | R17,22 | R18,65 | R20,74 |
| Price Class 2 | R9,41 | R7,28 | R7,74 | R7,37 | R12,17 | R12,40 | R9,02 | R7,86 | R12,15 | R12,40 |
| Price Class 3 | R3,09 | R3,09 | R1,89 | R2,98 | R2,77 | R2,90 | R2,23 | R2,57 | R2,78 | R3,09 |
| **Average price** | **R14,939** | **R14,584** | **R9,471** | **R14,104** | **R14,015** | **R14,596** | **R11,131** | **R12,417** | **R14,051** | **R11,849** |
| Year | 2029 | 2030 | 2031 | 2032 | 2033 | 2034 | 2035 | 2036 | 2037 | 2038 |
| Gross Margin | | | | | | | | | | |
| Avo | | | | | | | | | | |
| Age | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 |
| Expexted Yield/ha | 14,40 | 17,95 | 18,00 | 16,77 | 11,56 | 8,00 | 16,66 | 16,70 | 9,33 | 8,00 |
| Price/ton | 14938,63 | 14584,38 | 9470,80 | 14103,89 | 14014,56 | 14596,43 | 11131,33 | 12417,44 | 14050,77 | 11848,96 |
| | | | | | | | | | | |
| Total value of production/ha | 215190 | 261723 | 170474 | 236483 | 162028 | 116766 | 185482 | 207322 | 131030 | 94777 |
| Direct allocatable PC/ha | 55500 | 55500 | 55500 | 55500 | 55500 | 55500 | 55500 | 55500 | 55500 | 55500 |
| Insurnace/ha | 11442 | 15246 | 14462 | 13526 | 9267 | 6831 | 13236 | 13445 | 8077 | 6779 |
| Payouts | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 22860 |
| Gross margin/ha | 148247 | 190977 | 100513 | 167457 | 97261 | 54435 | 116746 | 138376 | 67453 | 55358 |
| **Gross Margin Total** | **4447420** | **5729300** | **3015382** | **5023705** | **2917819** | **1633062** | **3502392** | **4151288** | **2023583** | **1660734** |
| Insurance payouts | | | | | | | | | | |
| Rate | 5,30% | 5,66% | 5,36% | 5,38% | 5,34% | 5,69% | 5,30% | 5,37% | 5,77% | 5,65% |
| Insured yield ton/ha | 14,40 | 17,95 | 18,00 | 16,77 | 11,56 | 8,00 | 16,66 | 16,70 | 9,33 | 8,00 |
| Insurance cover amount | 216074 | 269181 | 270000 | 251508 | 173421 | 119995 | 249946 | 250440 | 139882 | 119981 |
| Insurance premium/ha | R11 442,28 | R15 245,95 | R14 461,62 | R13 525,72 | R9 267,36 | R6 831,03 | R13 235,75 | R13 445,40 | R8 077,00 | R6 779,44 |
| Hail damage | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 29% |
| Payment | | | | | | | | | | |
| Damage Rand/Ha | R - | R - | R - | R - | R - | R - | R - | R - | R - | R 34 858 |
| Excess payment (10%) | R - | R - | R - | R - | R - | R - | R - | R - | R - | R 11 998 |
| Payment (Income)/ ha | R - | R - | R - | R - | R - | R - | R - | R - | R - | R 22 860 |

## Annexure C: Direct allocable variable cost

| Item | No. of actions/year | Unit | units/ha | R/unit | R/Ha |
|---|---|---|---|---|---|
| Pest And disease | | | | | |
| Fruitflies | 2 | L | 1 | R 300,00 | R 600,00 |
| Heart-shaped scale | 3 | L | 0,75 | 1000 | R 2 250,00 |
| Avocado bug | 1 | L | 1 | 1000 | R 1 000,00 |
| Coconut bug | 3 | L | 1 | 500 | R 1 500,00 |
| Thrips | 4 | L | 1 | 150 | R 600,00 |
| Weed spraying-roundup | 3 | L | 2 | 200 | R 1 200,00 |
| Root rot treatment | 3 | L | 7 | 30 | R 630,00 |
| **Total** | | | | | **R 7 780,00** |
| | | | | | |
| Nutrition | | | | | |
| Leaf analysis | 1 | sample | 1 | R 80,00 | R 80,00 |
| Soil analysis | 1 | sample | 0,5 | R 80,00 | R 40,00 |
| Firtilizer | 1 | kg | 400 | R 10,00 | R 4 000,00 |
| Adjusting soil chemistry | 1 | kg | 2000 | R 1,00 | R 2 000,00 |
| Ferigation | 1 | ha | 1 | R 2 000,00 | R 2 000,00 |
| Mulching | 2 | ton | 1 | 500 | R 1 000,00 |
| **Total** | | | | | **R 8 120,00** |
| | | | | | |
| Irrigation | | | | | |
| Irrigation-Electricity | | | | | R 3 000,00 |
| **Total** | | | | | **R 3 000,00** |
| | | | | | |
| Fuel oil; Fuel; Diesel | | | | | |
| **Total** | | | | | **R 6 000,00** |
| | | | | | |
| Harvest cost | | | | | |
| Harvest cost | 1 | Ton | 13,6 | R 1 000,00 | R 13 600,00 |
| **Total** | | | | | **R 13 600,00** |
| | | | | | |
| Labour | | | | | |
| Permanent | 1 | hr | 1 | R 14 000,00 | R 14 000,00 |
| Seasonal | 1 | hr | 1 | R 3 000,00 | R 3 000,00 |
| **Total** | | | | | **R 17 000,00** |
| | | | | | |
| **Direct allocable production cost/ha** | | | | | **R 55 500,00** |