Development of a Decision Support System for Assessing Alternative Agriculture Land Uses: A Case Study of the Stellenbosch Wine Region

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March 2018

Declaration

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March 2018

ABSTRACT

The South African wine industry is one of the oldest wine industries in the world apart from Europe and the Mediterranean. The wine industry, according to SAWIS (2015), is one of the biggest agriculture exporters and was responsible for 1.2% of the national GDP in 2013. Of the total contribution of R36.1 billion to the GDP, almost R20 billion (53%) was created in the Western Cape. By volume, South Africa is the eighth-largest national wine producer in the world (SAWIS, 2015a).

According to SAWIS (2015) increased production costs and an increased number of competitors have placed mounting pressure on the profitability margins of the South African wine industry. The current drought coupled with the increasing pressure on profitability margins, requires wine estates to re-evaluate their business strategies to ensure economic sustainability. Therefore, many wine estates are investigating diversification opportunities. It is however a complex task to undertake and many wine farmers do not have the adequate experience outside of the wine industry. Thus, there exists an opportunity to develop a decision support system (DSS) that will aid farmers with the decision-making process regarding alternative selection.

This study focussed on providing agricultural decision-makers, who are considering to adopt an agricultural diversification strategy, with a set of considerations to evaluate land use alternatives in a particular area by making use of a decision support system (DSS). Agriculture diversification refers to farms that are participating in diversification of agricultural activities where income is generated from more than one agricultural enterprise. This study specifically focussed on crop alternatives (thus excluding other opportunities such as livestock).

A set of considerations that agricultural decision makers can use to guide them during the decision-making process had to be identified. It was crucial that it should be a holistic set that includes aspects regarding the whole farming operation and not just one aspect such as climate when evaluating the suitability of crops for a specific region. The identified considerations are not bound to a specific area and are therefore applicable to all regions. The identified considerations together with design requirements that had to be developed were incorporated into the design of the DSS model. Both the set of identified considerations and the design requirements had to be in accordance with literature and inputs from experts to ensure that the best possible DSS could be designed.

The developed DSS uses user inputs to compare different land use alternative types with one another per consideration. The Stellenbosch area was used as a case study scenario for the application of the developed DSS.

An internal validation was performed by creating different scenarios to test the logical workings and coding of the developed DSS. Subject matter experts were consulted thereafter to validate the developed DSS and to evaluate and thus incorporate reliability and credibility into the DSS.

OPSOMMING

Die Suid-Afrikaanse wynindustrie is een van die oudste wynindustrieë in die wêreld uitsluitend Europa en die Meditereense lande. Volgens SAWIS (2015) is die Suid-Afrikaanse wynindustrie een van die grootste landbou uitvoerders en was dit verantwoordelik vir 1.2% van die nasionale Bruto Binnelandse Produk (BBP) in 2013. Amper R20 miljard (53%) van die totale bydrae van R36.1 miljard tot die BBP was gegenereer in die Wes-Kaap. Suid-Afrika is in terme van volume die agtste grootste wynprodusent in die wêreld (SAWIS, 2015a).

Volgens SAWIS (2015) plaas stygende produksiekoste en toenemende kompetisie geleidelik meer druk op die winsmarges van die Suid-Afrikaanse wynindustrie. Die droogte wat tans ervaar word tesame met die toenemende druk op winsmarges, vereis dat wynplase hul besigheidstrategieë herevalueer om ekonomiese volhoubaarheid te verseker. Dit het tot gevolg dat baie wynplase diversifiserings geleenthede ondersoek. Dit is egter ‘n komplekse taak om te onderneem en baie wynplase het nie genoegsame ondervinding buite die wynbedryf nie. Daar bestaan dus ‘n geleentheid om ‘n besluit steun stelsel (BSS) te ontwikkel. Dié stelsel sal boere ondersteun in die besluitnemingproses ten opsigte van alternatiewe opsies.

Dié studie se fokus is om aan lanbou besluitnemers wat landbou diversifikasie oorweeg, ‘n stel inagnemings te verskaf om alternatiewe te evalueer deur gebruik te maak van ‘n ondersteuningstelsel vir besluitneming. Landboudiversifikasie verwys na plase wat deelneem aan diversifikasie van landbou aktiwiteite, waar inkomste gegenereer word van uit meer as net een landbou onderneming. Hierdie studie fokus slegs op gewas alternatiewe, dus sal ander opsies soos veëboerdery uitgesluit word.

‘n Stel inagnemings wat landbou besluitnemers kan gebruik om hulle leiding te gee tydens die besluitnemingsproses, moes geïdentifiseer word. Dit was noodsaaklik dat die stel inagnemings holisties moes wees. Dit moet dus aspekte van die hele boerdery insluit en nie net fokus op seker aspekte soos klimaat, om die geskiktheid van gewasse vir ‘n gebied te bepaal nie. Die geïdentifiseerde inagnemings is nie beperk tot ‘n spesifieke gebied nie en is dus geskik vir alle streke. Hierdie kriteria asook die ontwerpvereistes wat ontwikkel moes word, was ingesluit in die ontwerp van die BSS model. Om te verseker dat die bes moontlike BSS ontwerp word, moes beide die stel geïdentifiseerde kriteria asook die ontwerpvereistes ooreenstem met die literatuur en insette van kenners.

Die ontwikkelde BSS maak gebruik van gebruikers insette om verskillende grondgebruik alternatiewe per inagneming te vergelyk. Die Stellenbosch area is gebruik vir gevallestudie scenario doeleindes vir die toepassing van die ontwikkelde BSS.

‘n Interne validasie is gedoen deur verskeie scenarios te ontwikkel om die logiese werking en kodering van die ontwikkelde BSS te toets. Vakkundiges is daarna geraadpleeg om die ontwikkelde BSS te valideer en om dit te evalueer om sodoende betroubaarheid en geloofwaardigheid daaraan te gee.

ACKNOWLEDGEMENTS

Everything grand is made from a series of ugly little moments. Everything worthwhile by hours of self-doubt and days of drudgery. All the works by people you and I admire sit atop a foundation of failures.

Pierce Brown

There was plenty of times during the course of writing this thesis where I doubted myself, where the people that encouraged me lifted me up and gave me strength, for that I am infinitely grateful.

The completion of this thesis would not have been possible without the endless encouragements, love, support and motivation from my mother, father and brother- you are truly my pillars. Late nights and phone calls of despair were always met with a hug, smile or word of encouragement. It meant the world.

To my supervisors for the endless inputs and revisions. I will never be able to thank you enough.

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And finally, to my heavenly Father, whom gives me strength and guidance through the best and darkest of times. He is and always will be my rock and foundation.

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ABBREVIATIONS

Decision Support System	**DSS**
Decision Support Systems	**DSSs**
Besluit Steun Stelsel	**BSS**
Besluit Steun Stelsels	**BSSs**
Gross Domestic Product	**GDP**
Bruto binnelandse produk	**BBP**
PricewaterhouseCoopers	**PwC**
Visual Basics for Application	**VBA**
Agriculture Research Council	**ARC**
Five Forces Framework	**FFF**
Research and Development	**R&D**
Decision Support Tool	**DST**
Mean Variance	**E-V**
Fuzzy Knowledge and Inference Systems	**FISs**
Intuitionistic Fuzzy Sets	**IFSs**
Interval-Valued Intuitionistic Fuzzy Sets	**IVIFSs**
Multi-objective Optimization by Ratio Analysis plus Full Multiplicative Form	**MULTIMOORA**
Mix Integer Nonlinear Programming	**MINLP**
General Algebraic Modelling System	**GAMS**
Key Performance Indicator	**KPI**
Hectares	**ha**
Wine Industry Strategic Exercise	**WISE**
Consumer Price Index	**CPI**
Production Price Index	**PPI**
Best In Class	**BIC**
Square meter	**m^2**
Kilolitre	**kl**
Megalitre	**ML**
Gross National Product	**GNP**

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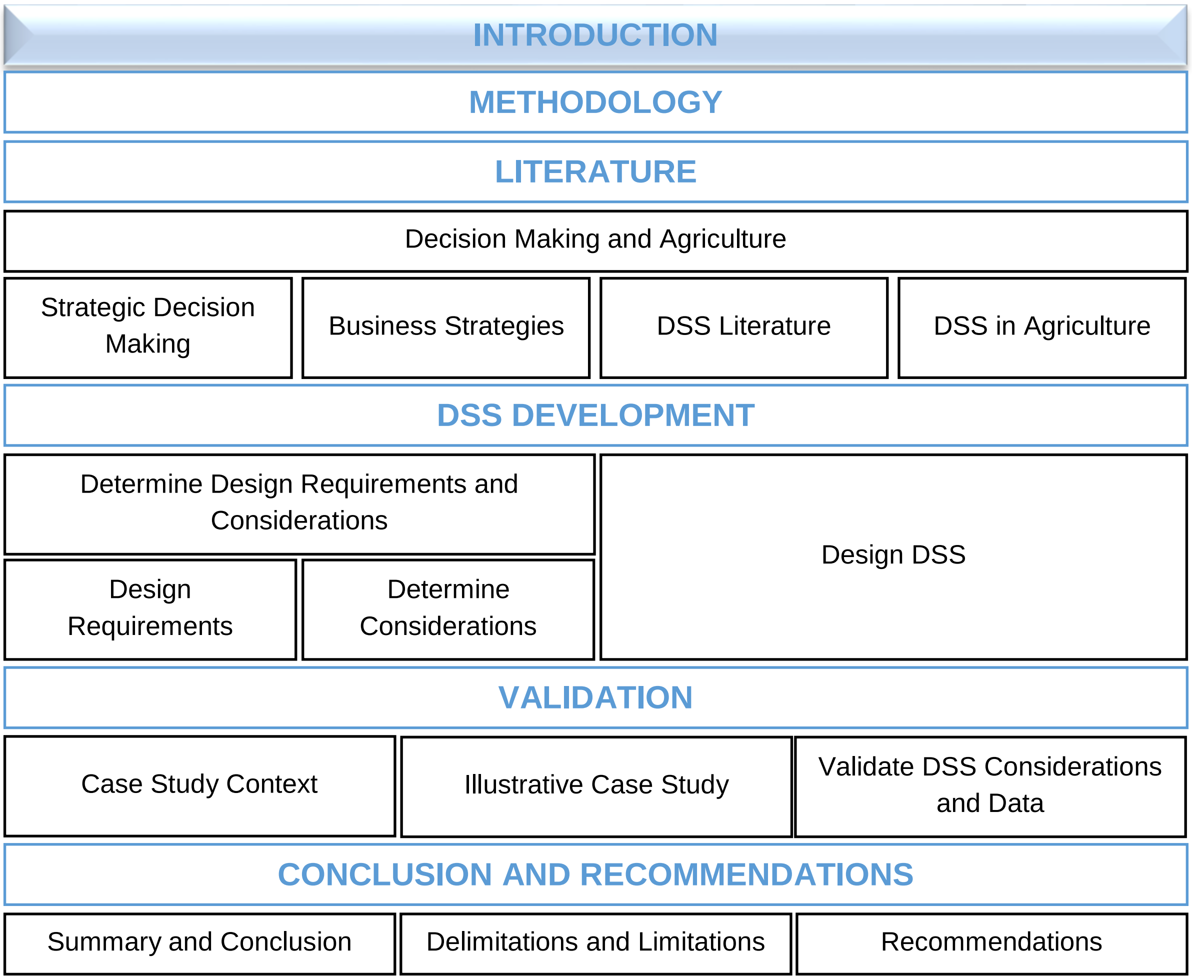
INTRODUCTION

1. INTRODUCTION

Chapter 1 introduces the reader to the research. An overview of the project is provided in Section 1.1. This is followed by the problem statement (Section 1.2), aim of the research (Section 1.3), as well as the research objectives (Section 1.4). The expected contribution of the research (Section 1.5) and the scoping of the study (Section 1.6) is then discussed. Chapter 1 concludes with the chapter layout of the project (Section 1.7). This serves to inform the reader what can be expected from each of the following chapters. The figure below provides a high-level overview of the document and is used as a roadmap to guide the reader throughout the study.



1.1. OVERVIEW

The South African wine industry is one of the oldest wine industries in the world apart from Europe and the Mediterranean (Marais, 2015), dating back to 1655 when the first governor of the Cape, Jan van Riebeeck, planted a vine (Wines of South Africa, 2015). Wine was produced from this vine four years later in 1659 and an industry was born (Wines of South Africa, 2015). According to the 2014 PwC report it takes South African vines three years, after the vines were planted, to come into full production, and in general vines stop delivering a harvest that bears commercially worthwhile capacities after 20-25 years of age (PwC, 2014).

In 2016 there existed over 3232 farmers that cultivate approximately 98 597 hectares of vineyard in South Africa (WOSA, 2016a). The term wine farm, which is known as a winery outside of South Africa, refers to a place where grapes are grown, fermented, blended and the wine that is produced from the grapes is bottled (WINESA, 2015). The South African wine industry continues to contribute to the country's Gross Domestic Product (GDP) and provide job opportunities. The wine industry, according to SAWIS (2015), is one of the biggest agriculture exporters and was responsible for 1.2% of the national GDP in 2013. The wine industry, including wine tourism, supported 300 000 jobs (direct and indirect employment) and contributed R36.1 billion to the economy in 2013 (SAWIS, 2015a). Of the total contribution of R36.1 billion to the GDP, almost R20 billion (53%) was created in the Western Cape. By volume South Africa is the eighth-largest national wine producer in the world (SAWIS, 2015a).

Operating a successful wine business encompasses the anticipation of trends, possible opportunities and apprehensions within the industry, as well as taking into account the views of peers (PwC, 2014). Constant improvements, and thus changes to a current business strategy are of the utmost importance to keep up with the latest trends and to ensure economic sustainability and revenue growth of wine estates. According to data from a 2014 PwC report, only 2% of respondents were not confident about revenue growth over the next 12 to 36 months, when considering their organisations in 2013. This percentage however increased to 20% in 2014 (PwC, 2014).

The historical town of Stellenbosch is synonymous with a winemaking tradition that goes back as far as the end of the 17th century (WOSA, 2016b). The Stellenbosch viticulture area, with its mountainous terrain, good rainfall, deep well-drained soils and diversity of terroirs are a highly sought after area for viticulture activities (WOSA, 2016b). At present there are approximately 150 wine estates and producers in the area (WOSA, 2016b).

The drought that the Western Cape experienced in 2016 together with the growing pressure on profitability margins of the South African wine industry (SAWIS, 2015a) requires wine estates to re-evaluate their business strategies. Thus, there exists an opportunity to develop a decision support system (DSS) that will take into account a set of considerations to provide farmers with support when they are assessing possible land use alternatives. This study thus develops a DSS to aid farmers who are seeking to adopt a diversification business strategy and are therefore looking for a set of considerations that they need to evaluate, when considering an alternative land use option. A literature review, which formed the foundation of this study, was done to define strategic decision-making and to determine whether decision support tools are applicable in the field of agriculture, to solve the specific problem at hand. Moreover, literature was consulted to determine what different types of DSS for agriculture currently exist. Considerations that form part of the DSS as well as design requirements that are needed to develop the DSS were reviewed prior to developing the proposed DSS. The proposed DSS, which allows an end-user to provide tailored inputs for each of the developed considerations, compares and evaluates different selected land use alternatives. The DSS was then applied to an illustrative case study. Finally, the considerations as well as the functionality of the DSS was validated.

1.2. PROBLEM STATEMENT

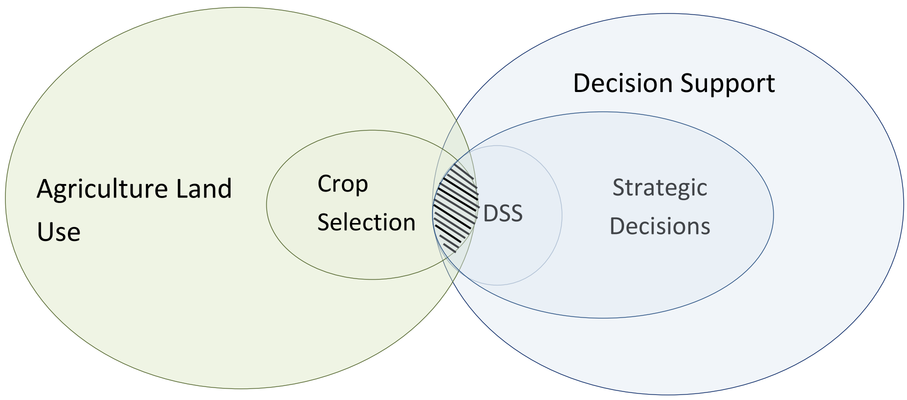


Figure 1: Research Domain

South Africa is classified as a dry country and most of its water sources are under strain (Pretorius, 2009). The far lower than average rainfall received in the Western Cape during 2016/2017 was reflected in the lower dam levels (City of Cape Town, 2017). Poor winter rainfall in the Western Cape during 2016, low dam levels, and a hot dry summer that was forecasted for 2016, were all contributing factors that led to the Western Cape Government implementing water restrictions as of 1 November 2016 (Western Cape Government, 2016). According to BBC News (2017) the Western Cape faces its worst water shortage in 113 years, which led to the province being declared a drought disaster zone in May 2017.

According to SAWIS (2015) there was mounting pressure on the profitability of the South African wine industry. This was due to the increased rate in production costs that had considerably surpassed the growth in income derived from grape production, as well as an increase of competition (SAWIS, 2015a).

The current drought which limits the litres per annum per hectare that can be supplied to vineyards coupled with the increasing pressure on profitability margins, creates an opportunity for wine estates to re-evaluate their business strategies to ensure that they stay sustainable. Thus, a lot of wine estates have recently been investigating diversification opportunities. It is however a complex task to undertake and a lot of wine farmers do not have a vast amount of experience outside of the wine industry.

This study focussed on farm estates in the Stellenbosch region that were considering to adopt a diversification strategy, and were therefore seeking a set of considerations that needs to be considered when thinking about implementing possible land use alternatives in this region. Specific considerations that can be used to evaluate different possible land use alternatives and subsequently provide decision assistance to farmers formed part of the developed DSS. It is crucial that a farmer evaluates the developed considerations when considering any of the possible land use alternatives. Therefore there exists a need for such a tool to assist farmers in the Stellenbosch region with the decision-making process regarding the possible land use alternatives that they can employ as well as highlighting the considerations that need to be evaluated, for them to stay economically sustainable.

1.3. RESEARCH AIM

To identify and validate a set of considerations that are used to develop a Decision Support System that can be used to assess available land use alternatives in a region with the aim of ensuring financial success and economic sustainability.

1.4. RESEARCH OBJECTIVES

The research objectives are set out for each of the different chapters as illustrated in Table 1. The research objectives are reviewed in each chapter and their outcomes will be specified at the end of each chapter. This illustrates how the research objectives are met throughout the study.

Table 1: Research Objectives

Methodology	**Chapter 2** 1. Define a methodology that will ensure that the research aim is fulfilled.
Decision-making and Agriculture	**Chapter 3** 1. Review the key concepts in strategic decision-making. 2. Establish a relationship between strategic decision-making and land use alternative decision-making. 3. Determine strategic decision-making characteristics. 4. Identify the core concepts that influence the strategic decision-making process. 5. Review the literature to understand what is meant with the term decision support system (DSS) and what it can be used for. 6. Understand how a DSS can be used in this study. 7. Review the literature to establish what the applicability of decision support tools in the agriculture sector is. 8. Understand what is meant by the term business strategy and which strategy this study will focus on.
Determine Considerations and Design Requirements	**Chapter 4** 1. Develop a set of considerations that needs to be considered when any land use alternative is reviewed. 2. Develop design requirements for the proposed DSS.

Design DSS	**Chapter 5** 1. Develop a DSS to compare selected land use alternatives per consideration in accordance with the different design requirements. 2. Develop process flow diagrams to illustrate: • The overall inputs and outputs of the DSS and its extension. • How the Visual Basic for Applications (VBA) code of the DSS works. • The different components of the DSS and how the different components relate to one another.
Case Study Context	**Chapter 6** 1. Identify the specific problems that wine estates in the Stellenbosch region are currently experiencing. 2. Determine a specific business sector from which land use alternatives will be selected. 3. Determine the climate pattern of the Stellenbosch region.
Illustrative Case Study	**Chapter 7** 1. Identify possible land use alternatives for the Stellenbosch region. 2. Select specific land use alternative types that the case study will focus on. 3. Compare the different selected land use alternatives. 4. Apply the developed DSS to the Stellenbosch case study.
DSS Validation	**Chapter 8** 1. Perform an internal validation of the DSS. 2. Validate the DSS by consulting different experts from the agriculture sector in the Stellenbosch region.

1.5. CONTRIBUTIONS

- The student developed a list of considerations which needs to be considered whenever a decision maker considers adopting an alternative agriculture land use option.
- A decision support system (DSS) was developed which incorporates the abovementioned considerations.
- An illustrative case study was conducted where information was collected to be able to populate the proposed DSS and to compare the different land use alternatives per consideration.
- This study reviews literature to attempt to find a holistic set of considerations to provide farmers in the Stellenbosch region with considerations to aid them with decision-making.

1.6. SCOPING

The purpose of scoping a research study is to identify the important issues that need to be addressed during the study and to highlight the boundaries of the research. The limitations – factors that the researcher has no control over – will be pointed out in Section 9.2 of the final chapter of the research study. The delimitations – factors that the researcher has control over to scope the research study are as follows:

1. A DSS that can be used to improve the management of resources on farms will be developed.
2. The case study will be conducted in the Western Cape – specifically the Stellenbosch region. The researcher is based in this region, thus simplifying the data collection process and interviewing process with subject matter experts.
3. The agriculture sector is the only sector that will be considered when identifying possible land use alternatives for the proposed DSS. Land use alternatives from other sectors such as the mining and quarrying sectors, manufacturing and construction sectors, and service industry will thus be excluded due to various reasons. Section 6.2 provides an explanation regarding the exclusion of these sectors. This DSS will solely include and focus on alternative land use options that will use the available land optimally in the agriculture sector.
4. For the illustrative case study, research will be conducted to identify different land use alternatives that wine estates in the Stellenbosch region can possibly implement.
5. A list of considerations will be developed that needs to be taken into consideration when any land use alternative is reviewed as a viable option for the case study, or any other area.
6. Supply chains and logistics will not be considered in this study. The focus of the study is to develop a list of considerations that can be used in conjunction with a DSS to evaluate different land use alternatives. Supply chain and logistics forms part of a different field of study. These aspects were thus excluded in order to narrow the study.

7. The possible land use alternatives used in the case study was limited to a specific sample. Due to the amount of possible land use alternatives that could be implemented in the Stellenbosch region, the researcher used a selection process to determine which land use alternatives to include in the case study application (Section 7.2) A sample size of land use alternatives was deemed to be sufficient to evaluate the DSS and the developed list of considerations.
8. The DSS will be validated by interviewing decision makers from the Stellenbosch region.
9. The study will solely focus on diversification strategies, thus excluding discussions of other strategies.
10. The study will focus solely on agriculture and not business diversification to narrow the study as well as to keep the developed list of considerations as generic as possible.

1.7. DOCUMENT STRUCTURE

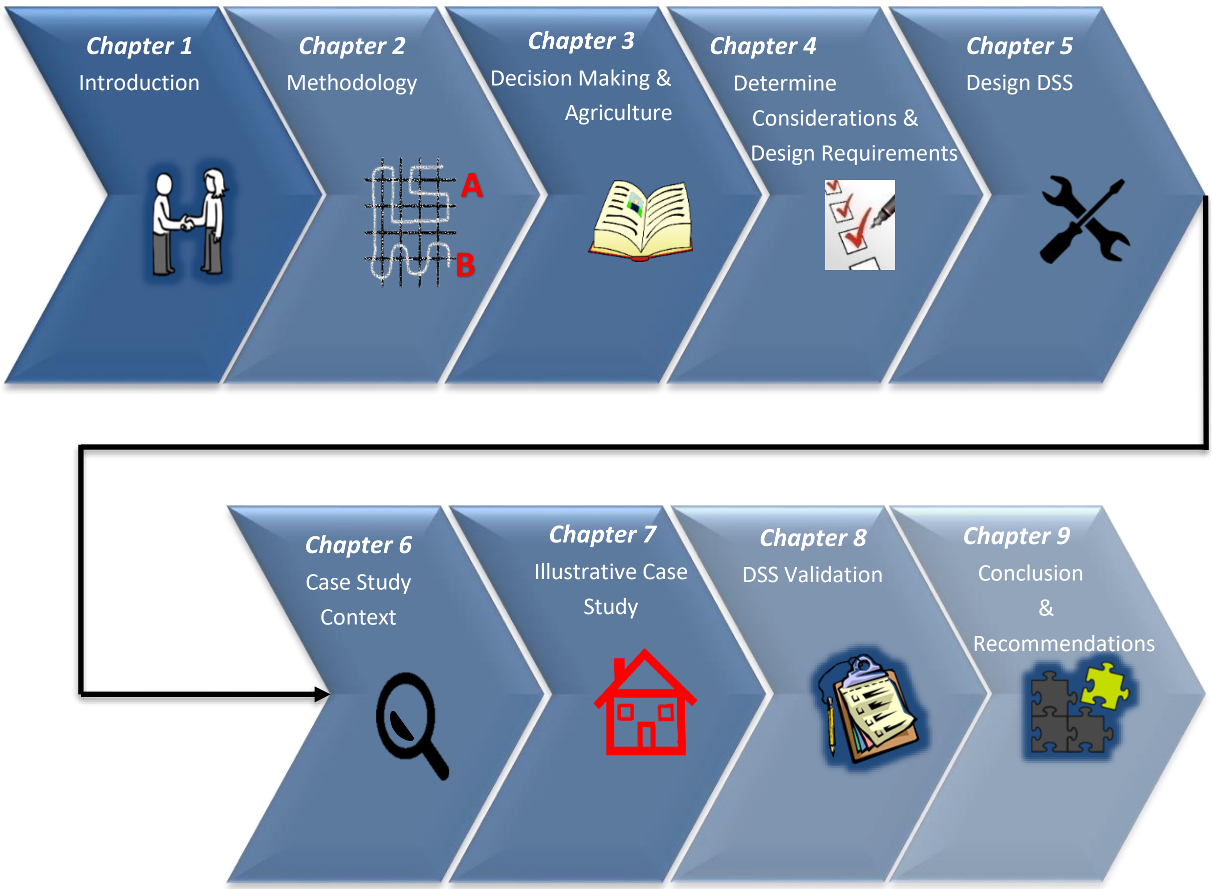
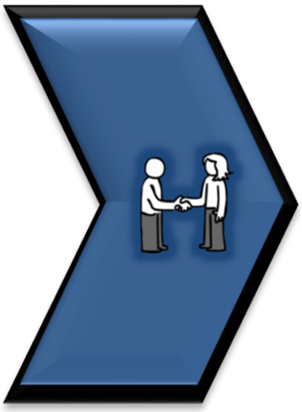


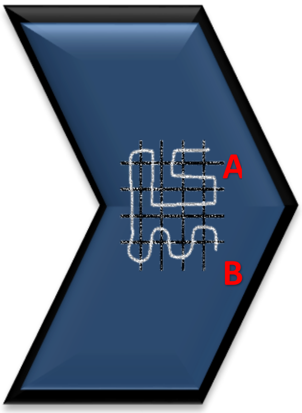
Figure 2: Project layout

Figure 2 provides an overview of the thesis structure. The following descriptions expand further on the content of each of the chapters.



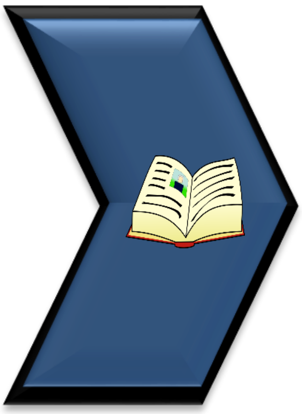
Chapter 1: Introduction

Chapter 1 is an introduction to the research study. It includes an overview of the research study, which is followed by a detailed description of the research problem. The research aim, objectives of the project, the expected contribution that the researcher will make and the scoping of the study will be formulated. The chapter will conclude with the document structure.



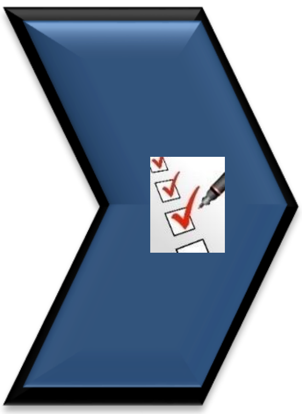
Chapter 2: Methodology

The second chapter of this project is a short chapter that highlights the procedure that was followed to execute this project successfully. The project methodology informs the reader of all the steps that were taken to ensure that the project objectives and research aim were executed successfully.



Chapter 3: Decision-making & Agriculture

Chapter 3 contains the literature analysis. This chapter places specific emphases on strategic decision-making and a review of business strategies. The research then focuses on decision support systems and narrows down to review what the purpose and benefit of these systems are. The chapter concludes by evaluating the applicability of decision support tools in agriculture.



Chapter 4: Determine Considerations & Design Requirements

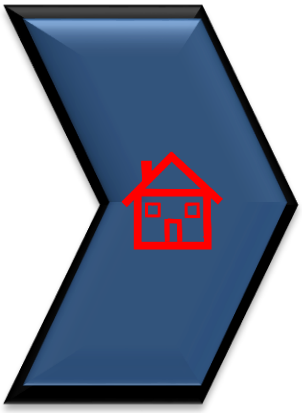
Particular considerations that will be incorporated into the proposed DSS and the design requirements that are needed to create the proposed DSS are developed and explained in this chapter.

Chapter 5: Design DSS

The proposed DSS is developed in Chapter 5 in accordance with the stipulated design requirements. The logic of the DSS is also explained through process flow diagrams.

Chapter 6: Case Study: Context

Chapter 6, which forms the context of the illustrative case study chapter, discusses specific problems that are currently experienced in the wine industry, indicating why it is important to re-evaluate business strategies of wine estates in the Stellenbosch region. A specific business sector from which land use alternatives for the Stellenbosch region will be chosen, is also selected. A weather profile of the Stellenbosch region which is used in this study concludes this chapter.



Chapter 7: Illustrative Case Study:

The DSS is applied in chapter 7 through an illustrative case study. Chapter 7 follows a stepwise process, which begins by identifying the possible land use alternatives. It then narrows down to select land use alternatives by means of a filtering process. Data are collected for each of the considerations of the selected land use alternatives and the DSS is ultimately applied. Each of these intermediate steps of the process are thoroughly explained and executed, which contribute to achieving the specified research objectives of this chapter.

Chapter 8: DSS Validation

The DSS was validated firstly by conducting an internal validation which was followed by an external validation where different experts in the agriculture industry, that were situated in the Stellenbosch region, were consulted to evaluate the reliability and quality of the proposed DSS.

Chapter 9: Conclusion and Recommendations

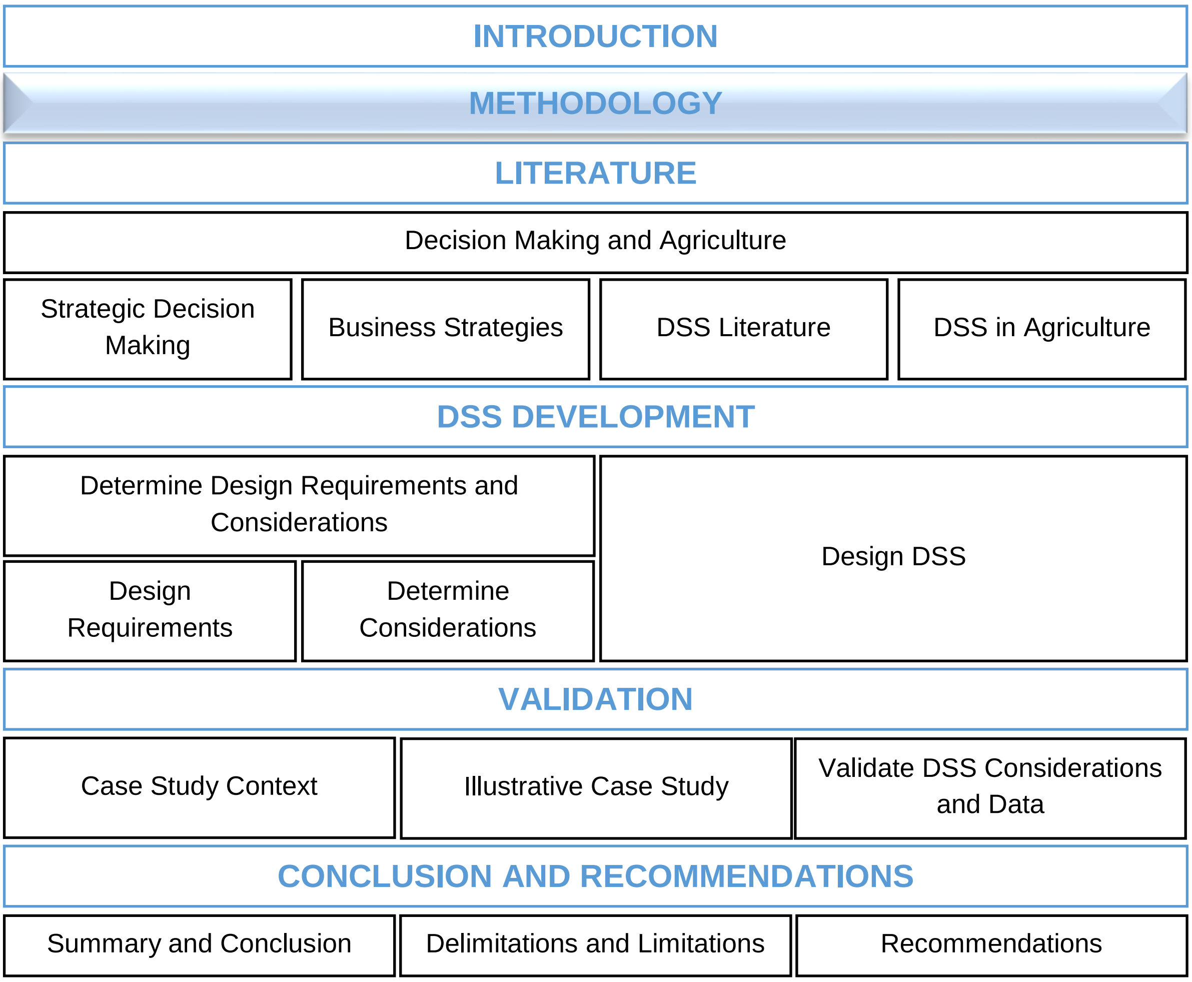
Chapter 9 concludes the study by providing the closing remarks, delimitations and limitations, and recommendations for this research field. Limitations and recommendations are outlined to make possible improvements to this study and for possible research purposes.

2

METHODOLOGY

2. METHODOLOGY

Kothari (2004) states that the research methodology is a systematic process that is followed to solve the research problem, where research methods include all the different methods that are used to conduct the research. The research design and methodology is a guiding process that helps the researcher with the planning of a project so that the project is executed successfully. The methodology of a project tells all parties concerned where the research to answer the research questions comes from, and why the research is conducted in a specific way (Rautak Ltd, 2015). The purpose of this chapter is to provide the reader with an overview of the research process that is followed during the execution of the study process, and to indicate in which sections the results of the various steps are presented.



It is crucial to outline the research process prior to commencing the research methodology and the associated research methods. The research process that was followed in this research study is depicted in Figure 3.

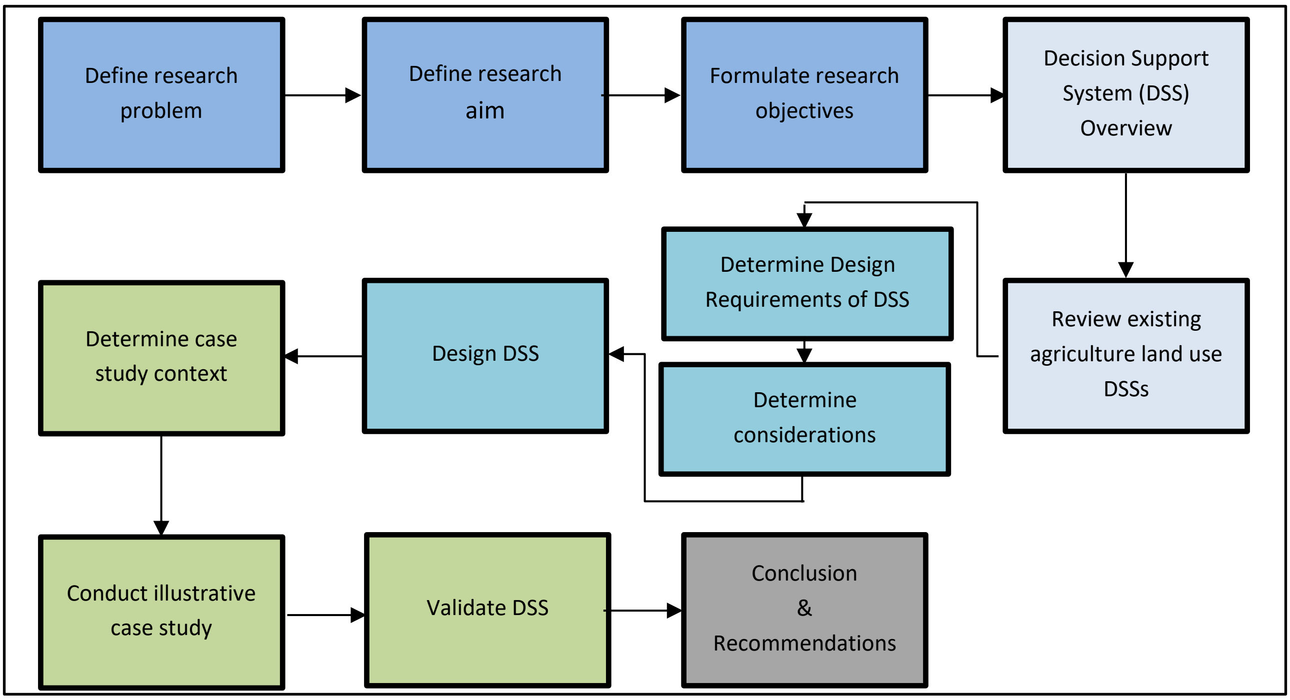


Figure 3: Research Process Flow Diagram

Five main stages can be identified and are grouped according to different colours in Figure 3. The study context was defined, after which an extensive literature review was done to identify and establish areas of importance within the applicable study fields. The information from the literature review was then utilised to determine considerations and design requirements, by reviewing existing decision support systems (DSSs) to develop a proposed DSS that can be used to satisfy the research aim of this study. The fourth stage involved conducting research to provide context to the illustrative case study as well as applying the developed DSS by means of an illustrative case study. Validating the proposed DSS, firstly through performing an internal validation, and secondly by conducting interviews with experts and getting further inputs from these experts through interview questionnaires concluded the fourth stage. The research that gave context to the case study and the illustrative case study itself formed part of the validation process. Consequently, these two parts were grouped together into one stage with the validation of the DSS and the set of considerations. The study conclusion formed the fifth and final stage.

Jabareen (2011) defines a conceptual framework as ‘a network, or a “plane”, of interlinked concepts that together provide a comprehensive understanding of a phenomenon or phenomena.’ He further argues that the components that make up a conceptual framework support one another, express all their phenomena, and create a philosophy that is specific to the framework (Jabareen, 2011). It is an iterative process which means that it ‘requires a steady movement between concept and data, as well as comparative, requiring a constant comparison across types of evidence to control the conceptual level and scope of the emerging theory’ (Jabareen, 2011). A constant interaction between analysis and the collection of data is required in this technique. The framework procedure constitutes of the following core steps or phases: mapping the selective data source, extensive reading and categorizing of the selected data, identifying and naming concepts, integrating concepts, synthesise and resynthesise to let it all make sense, validating, and rethinking.

The conceptual framework as proposed by Jabareen (2011) evaluates interlinked concepts. The steps of this framework were used as a foundation for the information gathering process of this thesis.

Stage 1: Study Context

The first focus of this study, to identify and describe the problem, is presented in Section 1.2. It is important to draw a clear picture of the problem to be able to follow a logical approach to solving the problem at hand, as well as to draft the research objectives of the study to ensure the successful execution of the research aim. The aim of the identification and description of the problem is to outline the current situation. The research aim, which informs the reader what the overall objective of the project is, was formulated in Section 1.3. The different research objectives were formulated per chapter in Section 1.4.

Stage 2: Literature Review

The literature study follows a systematic top down approach. Therefore, the first section of the literature study focuses on strategic decision-making, Section 3.1, which is followed by a discussion regarding business strategies, with specific focus on farm diversification (Section 3.2). Decision support systems in general (Section 3.3) is considered next. The literature review concludes with Section 3.4 where different types of DSSs that can be used in the agriculture sector are reviewed. The search engine Scopus was used to search and perform applicable research. Key words that were used to narrow down the search, include ‘crop selection’, ‘decision support’, ‘agriculture’, ‘farming’, ‘considerations’, and ‘framework’. The literature was grouped and stored accordingly. The aim of the literature study was to establish what a decision support system is, what the relevancy of such a DSS is, what design requirements define a well-functioning DSS, and to support the development of the set of considerations that can be used to assess possible land use alternatives. Moreover, the review study was used as a foundation to be able to develop a applicable decision support system. The literature study also determined what types of DSSs are in existence, how these DSSs can be applied in the agriculture sector, and whether there exists a gap in the literature that this particular study can aim at to contribute to the successful execution of the study.

Stage 3: DSS Development

The appropriate information from the aforementioned study fields were merged and used to develop the proposed DSS. The ten-step iterative process as proposed by Jakeman et al. (2006) (refer to Section 3.3) was used as the foundation during the development process of the DSS.

Firstly, design requirements for the DSS and a set of considerations that will provide assistance to farmers had to be established before attempting to develop the proposed DSS. These requirements and considerations will be used when decision makers consider adopting any of the possible land use alternative types. After the design requirements were determined in Section 4.1, a holistic list of considerations were established in Section 4.2. The design requirements were establish in accordance to what literature deemed a successful DSS should consist of. The literature that was reviewed in Chapter 3 was used. The set of considerations was developed in Chapter 4, Section 4.2. The researcher followed a systematic process, literature was initially reviewed to established what considerations are deemed important to assess possible land use alternatives for a specified region after which experts were consulted. Valuable inputs were obtained from experts which enhanced the completeness of the set of developed considerations. Each of the identified generic considerations were described accordingly. The list of developed considerations was used to compare the different possible land use alternatives with one another. Research regarding each of the selected land use alternatives was done (see Appendix C) to identify and establish the considerations. The literature that has been reviewed in Section 3.1 was also used to support the importance of some of the identified considerations. Chapter 5 followed, where the proposed DSS was developed according to the established design requirements. The researcher constructed different process flow diagrams (Sections 5.1 and Section 5.3) to explain the logic behind the developed DSS. A discussion of how the proposed DSS adheres to a particular design requirement is provided in the section where the development process of the DSS is described (Section 5.4).

Stage 4: Validation

The validation of the research process comprises of three subsections which subsequently forms three chapters in this document, namely Chapter 6, the case study context; Chapter 7, an illustrative case study, and Chapter 8, DSS Validation. The first of the three subsections, the case study context, contains the research that was done and information that was gathered to provide context to the illustrative case study. Firstly this chapter identify and evaluate information regarding the problems that wine estates in the Stellenbosch region are currently experiencing, thus justifying the reason why business strategies of wine estates in this region should change. Specific problems that wine estates in the Stellenbosch region are experiencing and why strategic re-evaluation is required were addressed in Section 6.1. Research continued, to identify a specific business sector that this study focused on and from which viable land use alternatives for the Stellenbosch region were identified. The research to identify an appropriate business sector is presented in Section 6.2. By including the business sector selection section, it ensured an appreciation why certain land use alternatives, which are not from the agriculture business sector, were excluded from this study as viable land use alternatives. To be able to provide an overview of each of the land use alternatives as well as specific considerations that should be adhered to in order to make each alternative a viable option for an identified region, research is presented in Appendix C: Selected Land Use Alternatives Theory. Conducting this research made it possible for the researcher to compare each of the alternatives' climatic requirements to Stellenbosch's climate profile to evaluate the suitability of each alternative for this region.

The second section, Chapter 7, an illustrative case study, involved gathering applicable data regarding the considerations that were identified in Section 4.2 to populate the developed DSS that was described in Chapter 5. A stepwise process was followed to ensure that all required information was captured to be able to populate and thus apply the DSS in a particular region:

Step 1: Identifying land use alternatives

Research was done to identify different land use alternatives that wine estates in the Stellenbosch region can follow to ensure economic sustainability (Section 7.1). An initial web search was conducted to establish the different types of farming activities that could be found in South Africa. The researcher used keywords to search for applicable data using the university's search engine. Articles relating to a specific land use alternative were grouped together in one folder for later use. These grouped articles were used in Appendix C: Selected Land Use Alternatives Theory as well as in Chapter 4.

Step 2: Filtering of initial land use alternative

The second step of the stepwise process is concerned with filtering the land use alternatives that were identified in the first step. The identified land use alternatives where filtered, based on the climate suitability of the specified region and on expert opinions.

Climate suitability was the first consideration that was evaluated when considering a land use alternative for a region. Opinions from experts in applicable fields also played a key role in the filtering process. The researcher initially contacted an expert that's associated with the Agriculture Research Council (ARC)-Infrutec/Nietvoorbij situated in Stellenbosch. This expert provided a list of names with contact details of other experts in different agricultural fields, including a contact person from whom data concerning the weather patterns of Stellenbosch could be obtained. It was important to get data of the relevant weather patterns of the Stellenbosch region to be able to compare each of the filtered land use alternatives' climatic requirements. This was determined from the research that was done as part of giving context to the case study to evaluate whether the climate of the region in Stellenbosch is suitable for a particular alternative. Secondly, the researcher contacted different experts to get information and opinions to further filter the initial identified land use alternatives. The filtering process was done in Section 7.2. The filtering process narrowed down the number of land use alternatives that this research study will include in the proposed DSS. A second important aspect that the filtering process achieved was to force the researcher to keep within the scope of this project. The project scope stipulated that this project will use the Stellenbosch region as a case study with filtering based on climatic requirements restricting the possible land use alternatives to this region.

Step 3: Develop specific considerations for each land use alternative

The generic considerations that have been developed in Section 4.2 were applied to each of the selected land use alternatives and tailored accordingly. For each of the selected land use alternatives, information was gathered from experts as well as from conducting research where needed, to populate the considerations for each of the selected land use alternatives. The considerations with accompanying information, can be found in Section 7.3. The purpose of these case studies is to compare the different selected land use alternatives per consideration.

Step 4: Apply the developed DSS

The last part of the stepwise process revolves around the application of the developed DSS in the Stellenbosch region. Once specific land use alternatives were identified and selected, and the developed considerations were populated for each of the selected land use alternatives, the information was used to populate and apply the developed DSS in the Stellenbosch region. The researcher created a data sheet in Excel, containing data for each of the selected land use alternatives per consideration, which the DSS used.

Stage 5: Validating the DSS and Conclusion

The last section of stage four (Chapter 8) entails the validation of the developed DSS and considerations. The aim of this stage was to validate the functionality of the developed DSS as well as consulting experts, to validate the developed considerations. The researcher firstly conducted an internal validation to validate the functionality and logic of the developed DSS. Secondly, an external validation was done which involved consulting experts. The DSS and its extension, as well as the stepwise process (Figure 37), were both presented to four different experts. This allowed the experts to evaluate the quality, applicability, and completeness of the developed considerations as well as the functionality of the DSS. Validating the different considerations and the functionality of the DSS conveys the reliability of the developed considerations and that of the DSS. The internal and external validations were done in Chapter 8.

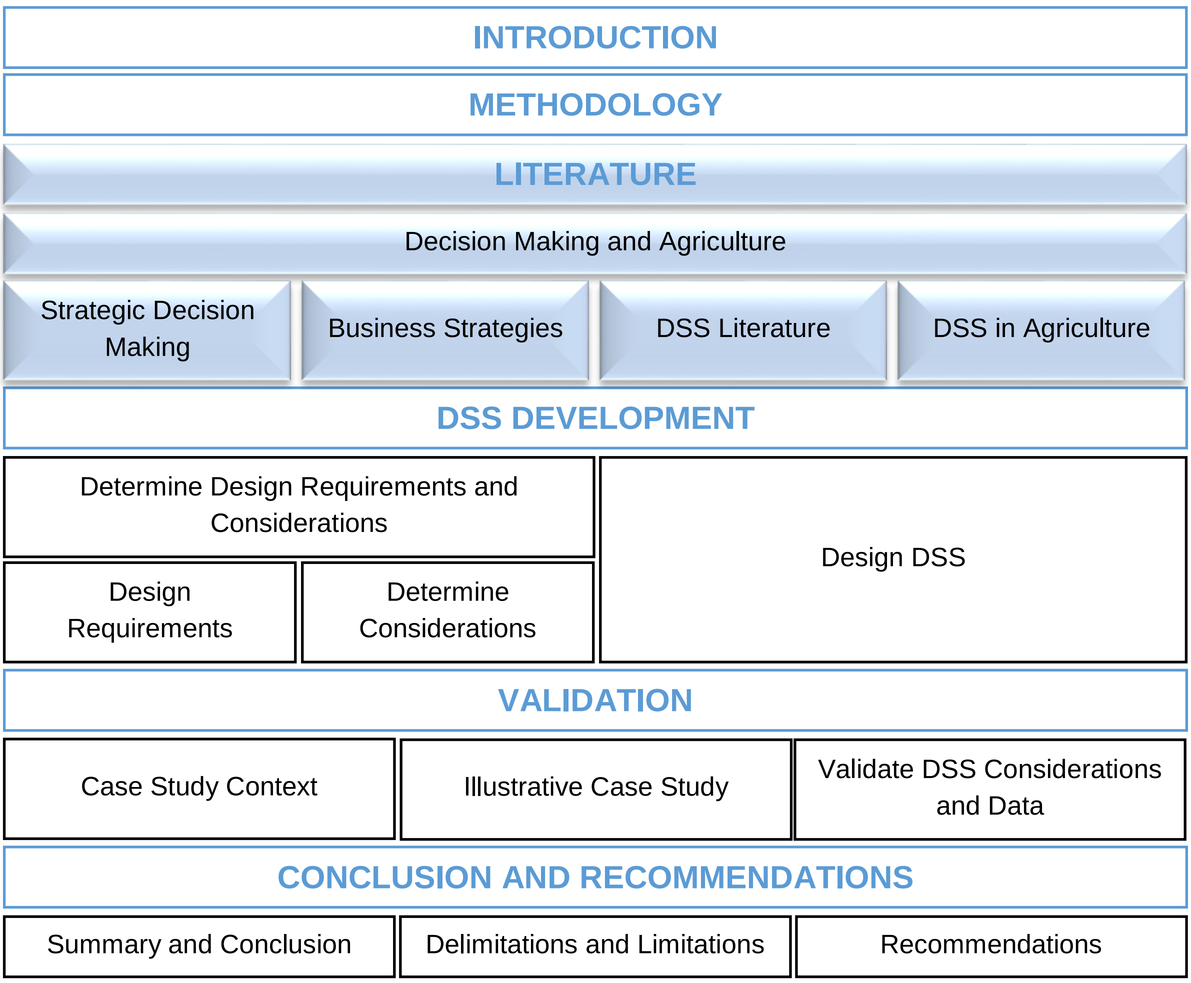
The last focus area and consequently stage, the concluding chapter of the study, Chapter 9, will provide a summary and draw conclusions as well as provide the limitations and delimitations for the study. Recommendations for future research will also be provided in this concluding chapter.

3

DECISION-MAKING AND AGRICULTURE

3. DECISION-MAKING AND AGRICULTURE

This chapter aims to provide a detailed summary of the literature regarding decision-making within the context of agriculture, thereby identifying particular core concepts within this domain, regarding the development of a set of considerations to assess land use alternatives for an identified region. The strategic decision-making concept is discussed in detail, focussing on the various key characteristics that affect the strategic decision-making process, and expands on the different features of these characteristics. The aforementioned characteristics include decision-specific characteristics (Section 3.1.1), the characteristics of the decision makers (Section 3.1.2), and external environmental characteristics (Section 3.1.3). A discussion of business strategies follows, specifically highlighting the particular business strategy that this study focusses on (Section 3.2). Literature concerning decision support systems are also reviewed and discussed (Section 3.3). The literature chapter concludes with Section 3.4 where different types of DSSs are discussed. The aforementioned sections pave the way for the development of a decision support systems which could be applied in the agriculture sector.



3.1. STRATEGIC DECISION-MAKING

According to Tzionas, Ioannidou, & Paraskevopoulos (2004) 'a decision theory is an axiomatic theory that are used for making choices in uncertain conditions'. The strategic decision-making process together with the accompanying factors that influence the process, allows for a better understanding of the business itself and the business environment. This resulted in it being one of the most active areas of management research at the time (Schwenk, 1995). Management choices can be greatly affected through strategic decisions. Moreover, strategic decisions of an investment nature, that is decisions that require significant commitment of resources, greatly influence the long term performance of an enterprise (Papadakis, Lioukas, & Chambers, 1998). Nooraie (2008) describes these strategic decisions as highly unstructured, complex, and inherently risky. Grant (1996) argues that an enterprise's efficiency is usually linked to using rules, routines, and other incorporated methods to the fullest, which will economise on the transfer of communication and knowledge, and result in teams utilising decisions-making and problem-solving techniques to dissolve complicated, unique, and important tasks. He further states that relevant knowledge influences the quality of the decisions that are made. The prosperity of the South African agriculture sector plays a vital role in the country's achievement of important development and economic goals. In recent years increased economic, social, political, technological, and environmental variability has however become prominent in this sector. Decision-making in terms of selecting business strategies is encumbered due to uncertainty, which results from high and elevated levels of variability (Strauss, Meyer, & Kirsten, 2008). Therefore, based on the characteristics of strategic decisions, these decisions can be utilised in the agriculture sector, specifically in aiding decision makers to review and select land use alternatives.

It is however essential to define the strategy by which the business is governed, to be able to comprehend the concepts behind strategic decision-making. Andrews (1997) states that the goals, objectives, and purposes of a company can be determined by a pattern of decisions which, as a result, determine the main policies that are required to attain the specified goals, as well as the type of company that the enterprise strives to be. Moreover, according to Andrews (1997), corporate strategy applies to the whole enterprise, regardless of its size or diversity, whereas business strategy is less comprehensive and refers to the choice of product or service of individual businesses within the enterprise. Managers launch themselves as well as their company into the future, by creating a road to get them from a position where they are now, to one where they want to be in the future, when they create a strategy. Luehrman (1998) further states that there is almost always a sequence of main decision-making involved when executing a strategy. The approaches and the competitive decisions that the executives of an enterprise make to gain and satisfy customers, enhance overall growth of the company, support operation performance, and finally help the enterprise to reach its performance goals and objectives which are influenced by the corporate strategy of the company (Gamble & Thompson Jr, 2014).

Strategic decision-making can thus be defined as incremental and interdependent because the procedure is mainly steered by a variety of contextual influences, that not only originate from current circumstances, but from past and prospective future events (M Nooraie, 2012). Wernerfelt & Karnani (1987) argue that strategy has to do with the future. Consequently strategic management decisions are always made with uncertainty. Any of the following four sources: demand, supply (exogenous or endogenous), externalities, and competitive factors, can bring forth uncertainty (Wernerfelt & Karnani, 1987). A variety of factors influence the process by which those decisions are made when strategic decision-making is concerned. Elbanna (2006), Mahmood Nooraie (2012), and Papadakis et al. (1998) propose that the influencing factors of the strategic decision-making process can be divided into three groups:

1. Decision-specific characteristics
2. Decision-making team's characteristics
3. External environmental characteristics

Each of the above-mentioned factors as well as their effect on the decision-making process is considered in the remainder of Section 3.1.

3.1.1. DECISION-SPECIFIC CHARACTERISTICS

Elbanna (2006) and Papadakis et al. (1998) suggested that very little research has been conducted and is available that illustrates the impact of decision-specific characteristics on the decision-making process. Dean & Sharfman (1993) and Dutton (1993) however argue that the same external and internal factors concerning the decision can be interpreted differently by different managers within different businesses as well as the same business. Different decision makers that are responsible for managing the farm will therefore interpret these internal and external factors that relate to a decision, differently. Papadakis et al. (1998) suggest that the business's response time to the decision is greatly influenced by categorising and classifying the decision early in the decision-making process. Decisions that are classified as being a crises are managed and handled very differently from those that are classified as being an opportunity. It is claimed that there exists a relationship between the frequency and the familiarity of the process by which the decision is made, and the decision itself (M Nooraie, 2012). It is further suggested that the extent of the impact of the decision also has a substantial effect on the decision-making process. The riskiness and the complexity of the decision have a further impact on the decision-making process. Schilit & Paine (1987) found a correlation between the level of risk involved in the decision and the time involved to make a decision – the higher the level, the longer the duration. Even though a few decision-specific characteristics have been pointed out, there exists limited literature that highlights the understanding of the influence of these characteristics on the decision-making process in any business.

Managing an agriculture enterprise, like any other business, requires decision-making. Specific decisions play a role in the degree of success or failure when undertaking a new land use alternative. The decision-specific characteristics that are discussed in Section 3.1 can thus be applied in the agriculture section, and more specifically when a decision maker considers adopting a new land use alternative.

3.1.2. DECISION-MAKING TEAM’S CHARACTERISTICS

The role that the top management of an enterprise, the decision makers, has on the decision-making process are highlighted in this section. The top management are therefore the individuals that are responsible for making the different decisions on the farm. The risk inclination of the decision makers is the first factor that affects the strategic decision-making process. Wally & Baum (1994) argue that the completion of the strategic decision-making process is encouraged by a strong inclination and high tolerance for risk. Hitt & Tyler (1991) however contradict the aforementioned by arguing that the decision makers’ inclination did not have a noteworthy influence on the objective considerations or the strategic decision.

The educational level of the decision maker, therefore the farm manager or owner, is yet another important factor to take into consideration. Nooraie (2012) proposes that it is not the type but rather the frequency of the education of the decision maker that has a positive influence on the innovation of the strategic decision-making process. In addition, he states that longer durations of management service has a negative influence on the innovation level of the decision-making process. In the agriculture sector a negative influence on the innovation level of the decision-making process can thus be expected in the case where a farm is owned by generations of the same family.

The cognitive diversity of the decision makers has a further influence on the strategic decision-making process. Wally & Baum (1994) established a positive connection on the pace and creativity of the decision-making process when there exist individual differences among members of the decision-making team. Decision makers are portrayed as being rational and utility maximising, in a study conducted by Masomi & Ghayekhloo (2011). This study argues that the decision-making process is influenced by two principle cognitive factors which are attributed to the characteristics of the decision-making team: prospect theory factors and heuristic factors. Prospect theory factors refer to a more detailed framework, where the individual’s way of making a decision in a risky uncertain environment is described. Whereas making a decision in a risky or uncertain environment by using more common practices or rules of thumb, is known as heuristic factors. Although the impacts differ in degree and depends on each individual study, this study aligns with the improvement of decisions where the decision is influenced by individual behavioural factors of the farm owner or manager(s).

According to Bashir et al. (2013) age as well as gender have a considerable impact on both the decision-making process and the risk tolerance. Based on their findings, it could be expected that older farmers will take less risks compared to younger farmers. Relative risk is yet another aspect that influences the decision-making process and the risk tolerance of the farm owner or manager. For example, the decision-making process will differ for a farmer whose livelihood solely depends on the income from a single wine farm, versus a farmer that owns a gold mine and a wine farm and can experiment with alternative land use options on his or her wine farm without being totally reliant on the outcome. Furthermore, individuals that are part of the decision-making team, may not always display rational thinking and when they are placed in the position of making a risky and uncertain decision, they might be subjected to emotional as well as cognitive errors.

The decision-making process, according to the reviewed study, is furthermore affected by the business image or self-image factor. An individual, thus the decision maker of the farm, will make a decision based on whether it can advance or improve her/his own self-image and/or that of the farm that he/she works for. Considering all the factors that can affect and bias decisions, the need for tools such as DSSs to improve decision making becomes clear.

3.1.3. EXTERNAL ENVIRONMENTAL CHARACTERISTICS

Nooraie (2012) states that strategic decisions and the strategic decision-making process should adjust to possible opportunities, constraints, potential threats and other environmental characteristics within the functioning domain of the enterprise. There are various environmental factors that have a considerable effect on the strategic decision-making process. One such factor is the dynamism of the environment, which describes the rate of change and unpredictability of the environment (Papadakis et al., 1998). Both Mahmood Nooraie (2011) and Priem, Rasheed, & Kotulic (1995) state that rationality has a positive correlation to the outcome of the decision-making process. It is thus proposed that a rational decision-making process is used.

Threats and opportunities within a business, such as competition from related enterprises in the same or even other industries, is another environmental factor. The competitive value of the activities within an enterprise can only be established comparative to some other company or companies that deliver a specific set of services and/or products to specified customers (Porter, 1991). Hostility is yet another environmental factor that is associated with competition. Environmental hostility is the situation where a business is confronted with competition in terms of service/product price, production and distributions, as well as unfavourable customer demand, supply resource shortage, and regulatory restrictions (M Nooraie, 2012).

Porter (1991) introduced the Five Forces Framework (FFF) to identify an enterprise's weaknesses and strengths to be able to develop and improve the enterprise's structure as well as its corporate strategy. This framework not only advanced strategic management to become a prominent focus point in business management, but it is also one of the most widely used analytic frameworks in today's strategic management environment (Grundy, 2006; Narayanan & Fahey, 2005).The analysis of the level of rivalry within the enterprise and the business strategy development, determines the FFF through assessment of the opportunities, risks, and profitability based on five key factors. The five key factors will be reviewed later in this section.

Firstly, Porter (2008) suggests that for an enterprise to be successful, it has to achieve a competitive position or series of competitive positions that lead to sustainable and greater financial performance, compared to that of other enterprises. Thus, farmers need to establish such a degree of competitiveness among competing farms that their farms are sustainable and able to outperform rival farms financially. Secondly, the alignment of the sets of internal aims and policies of the enterprise, and that of the external opportunities and threats, further influence the success of an organisation. Lastly, the strategy of an organisation should focus on creating and exploiting its particular competencies that make them unique and rate them above that of competing organisations. Farms therefore need to have a unique value proposition that allows them to stand out amongst competing farms. As such, the FFF method can be used to identify sources of value for a business (the farm) through evaluating not only the profit potential of the business, but also the attractiveness level of functioning in that particular industry. It is thus important to identify possible sources where value can be added within a business, before the factors that determine the competitive success of a business can be reviewed.

Drake (2010) states that six principle sources of value adding exist within a business. The first one, economies of scale, is a cost advantage that is obtained when a given production, market and/or distribution growth produces a less than proportionate increase in the correlated cost. Economies of scale can be found more often in large enterprises with large scale operations and outputs, where the cost per unit commonly decreases with an increase in demand. Because the fixed cost related to the production can be extended over a large area, the cost generally decreases. It might therefore be expected that a larger farming enterprise will consequently be able to provide a product at a lower cost per unit than a farm that operates on a small scale. Secondly, economies of scope is a cost advantage that is obtained from a decrease in average cost, due to the company increasing the number of different products produced. Farms that produce a variety of products will accordingly be able to be at an advantage, due to the decrease in average cost of producing the different products. The economies of scope is thus the efficiencies acquired when an investment is able to uphold more than one activity. Thirdly, established organisations within a specific industry might experience cost advantages, such as access to raw supplies, that are not available to organisations that are not established in the industry. Reputable well-established farms will thus have cost benefits over newly established farms, regarding the acquisition of necessary raw materials, to drive success. Product differentiation is another value adding source. Companies can invest in the development or inclusion of attributes of products that are seen as different and attractive to the target market. Established industry organisations may gain a competitive advantage by having access to current, well-developed distribution channels. A distribution channel refers to the path through which goods and/or services move from the vendor to the customer, or the path of payment for those specified goods and/or services from the customer to the vendor (Szopa & Pękała, 2012). As mentioned before, the competitive success of an organisation can be analysed after the potential sources of value added within an industry have been identified.

Porter (1991) developed a framework to measure the success in distinct businesses (see Figure 4). Porter made a distinction between the two problems of strategy: 'linking firm characteristics to market outcomes' (the cross-sectional problem) and 'the dynamic processes by which markets are created' (the longitudinal problem of strategy). Porter argues that a complete theory of strategy focus on both of these dimensions. The framework is built around five competitive forces that deteriorate lasting industry average profitability. The framework can be applied at any industry level, strategic group, or even individual organisation. The ultimate function of this framework is to explain the sustainability of profits against direct and indirect competition, as well as against bargaining. In the agriculture sector, Porter's FFF can be used to quantify the success of a farming operation. A farm can use the tool to understand the competitiveness of the agriculture sector, and to identify the strategy they are following for potential profitability. A farm owner can therefore adjust the strategy he or she is following when he or she understands the forces in the agriculture environment that can influence profitability. A farmer can therefore take advantage of a strong position or improve a weak position, and also prevent taking the wrong steps in the future.

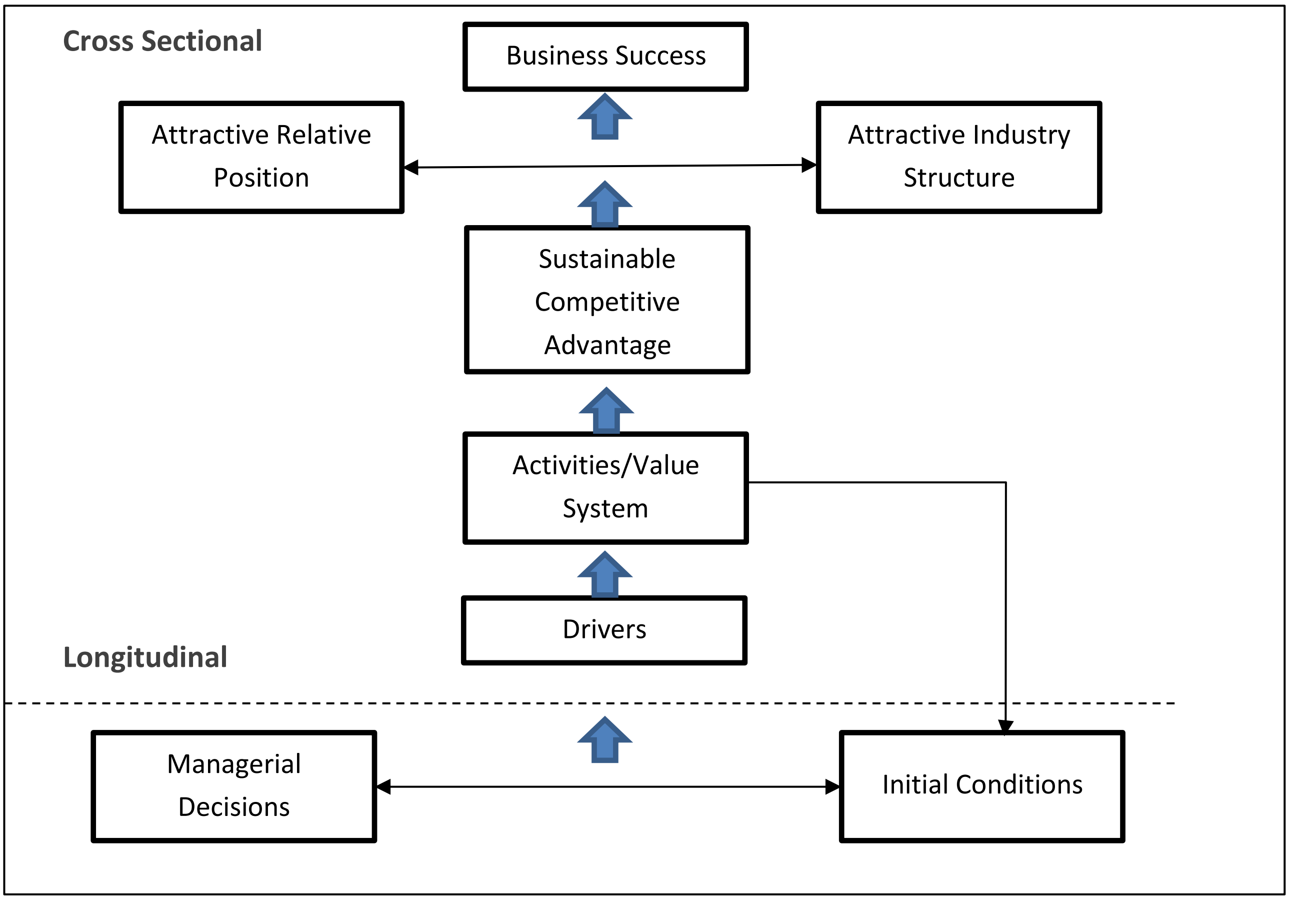


Figure 4: Determents of success in distinct business based on Porter (1991)

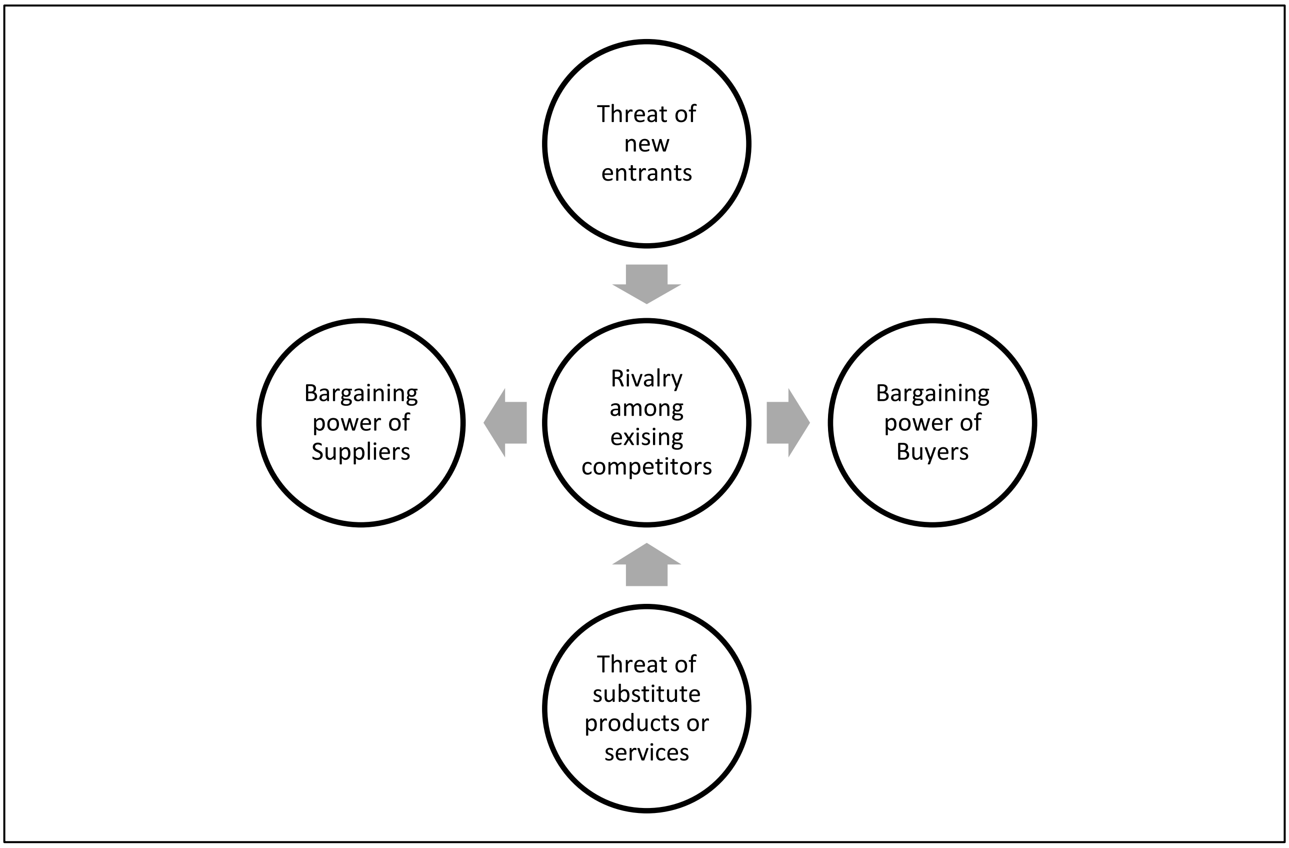


Figure 5: Five Forces: Summary of key Drivers based on Porter (1991)

Part of the structure of a business is exogenous while the other part depends on organisational actions. Thus, Porter (1991) is of the opinion that firm position interrelates with structure eventually.

Managers often make the mistake of defining competition too narrowly as being dependent on only direct competitors; competition for profits however goes further than mere industry rivals to include the other four forces as well, as illustrated in Figure 5. The four forces include customers, suppliers, potential entrants, and substitute products. The structure of the organisation is defined and the nature of the competitive interaction within an organisation is shaped by the extended rivalry which results from previously mentioned five forces. As such, Porter (2008) argues that the origin of an organisation's actual profitability, while supplying a framework to anticipate and perhaps influence rivals, can be revealed by understanding the competitive forces and their fundamental causes.

Therefore, as this study is primarily focused on providing a list of considerations which will aid decision makers regarding land use options, it is crucial that decision makers study the provided list and the possible land use option on the enterprises profitability, as well as on rival enterprises. Ideally the decision maker will choose the decision that will increase profitability, financial performance as well as competitive advantage. As a result there exists a need to discuss each of the elements of the FFF and to identify the sources of each of the individual competitive forces in the FFF.

3.1.3.1. Element one: Competitive rivalry within the industry

Price discounting, advertising campaigns, new product introductions, and service improvements are the different variety of familiar forms that rivalry among existing competitors in the industry takes according to Dälken (2014).

The profitability of an organisation is limited by high competitive rivalry between existing organisations. The degree to which the rivalry impacts the profitability negatively, depends on the intensity of the rivalry and the manner in which organisational rivalry between competing enterprises takes place. The competition between rival organisations within a particular industry is at its greatest when rival organisations are approximately the same size. Opportunities for new business of rivals are limited when an industry is saturated. Additionally, the competition for market share among industry rivals is high when the industry growth rate is low. Furthermore, some enterprises within an industry have objectives that are not purely based on economic performance, for example, certain state owned enterprises value not only economic performance, but prestige and employment as well, where economic performance is deemed as less important.

According to Porter (1991) the basis as well as the intensity of competition is reflected by the rivalry among existing organisation. Because price competition between competitors is responsible for the direct transfer of industry profits to its customers, an enterprise's profitability is negatively affected, especially by purely price based rivalry. Several rounds of retaliations are expected to take place, because price reductions are easy for competitors to see and oppose. As a consequence of continuous price reductions amid competitors, customers have become accustomed to focus on a product's price or service, rather than on the features and services that that product has to offer.

Competition between rivals that tends to focus on something other than price aspects, such as support services, product features, or brand image, for example, are less probable to deteriorate the profitability of an enterprise, since it improves customer value and can possibly support higher prices (Porter, 2008).

The average profitability of an industry can also be increased if the competition between competitors is a positive sum. The chance for positive sum competition however is more likely to happen in industries with a diversified customer base. Competing enterprises within a particular industry intend to look after the requirements of different customer segments with a different combination of services, prices, features, brand identities, and products. The positive sum rivalry can thus lead to increased profitability as well as possible industry expansion.

To summarise, competitive rivalry within the organisation looks at the number and strengths of one's competitors. Farmers have limited ability to adjust service or price, they can only focus on quality and volume, however the other FFF are very applicable especially economies of scale and the power of buyers. Thus, farmers that are investigating the possibility of adopting a land use alternative, can use Porter's FFF to evaluate what products neighbouring farms are producing, to possibly cultivate and produce a different product to ensure minimal competitive rivalry. Minimal competitive rivalry in turn will most likely lead to great strength in the marketplace and healthy profits. Farmers can then further use the FFF to evaluate the possible viable land use alternatives in a region, that were obtained by applying the proposed DSS.

3.1.3.2. Element two: Threat of new entrants

New industry entrants present new industry capacity and actively seek to gain market share (Porter, 2008). This consequently leads to an increase in industry prices, costs and rate of investments, which are requirements to stay competitive. Furthermore, competition can potentially be stirred up by new entrants that are diversifying from other markets and that are making use of their existing competencies and cash flows. The profitability of an industry is therefore affected negatively by the threat of new entrants. Therefore, to be able to discourage potential new entrants that present a high threat, organisations that are established in a particular industry, have to uphold low prices or increase investment.

According to Heger & Kraft (2008) the level of resistance from established enterprises within an industry, as well as the level of existing entry barriers, influences the scale of threat that a new entrant presents. Entry barriers are defined as the benefits that incumbents possess compared to that of new entrants. The threat of entry is high in cases where the retaliation from established enterprises in an industry is minimum and the entry barriers are low. It can thus be derived from the above discussion that profit potential decrease is a consequence of the threat of entry and not whether entrance into the industry actually takes place (Blees, Kemp, Maas, & Mosselman, 2003).

Blees et al. (2003) identified 36 barriers that cripple the entering of new enterprises into a new industry. Although each of these barriers have their own threats that they present to new entrants, it was recommended by Porter (2008) that related barriers be grouped together – seven main sources were identified accordingly. Farmers can use Porter's FFF to identify the sources of entry barriers to establish which of the possible viable land use options that were obtained after applying the proposed DSS in a particular region, will face the least amount of entry barriers.

1. The advantage of lower unit prices, due to supply side economies of scale, can be experienced by large enterprises which operate on a larger scale and work with large volume production capabilities. As stated before, a lower unit cost is a consequence of the ability of these companies to spread the fixed cost concerned in the production activities, over a broad unit base. Another advantage is that these enterprises can require more effective technologies and better terms from suppliers because of large scale operations and profits. Supply-side economies of scale thus discourage new entrants as they force entrance to enter on a large scale, to be able to compete established enterprises in the industry (Sheperd & Sheperd, 2004).

2. Demand side economies of scale or network effects, which describe the increase of willingness of the consumer to pay for a product or service, as the number of users of that product or service increases, is another important source of entry barrier that Werden (2011) reviews. The products or service therefore becomes more valuable when the number of customers that are using it increase. As such, new entrants are discouraged into the industry, due to the limiting importance placed by the customers on a new product and/or service. Furthermore, even though the quality of the new product must remain high, the price of the new product must be considerably lower to be able to acquire a large enough customer base to compete with existing products or services in the industry.

3. One of the most difficult entry barriers to overcome for a newcomer is to secure sufficient capital to enter into an industry according to Porter (2008). Blees et al. (2003) state that this entry barrier is especially high and therefore difficult to overcome, if the newcomer is to enter into a capital intensive industry such as a refinery, pharmaceuticals, automotive, or oil refinery, or if the capital investment required is for unrecoverable expenses, like upfront advertising and research and development (R&D). The amount of competitors are thus limited by the substantial capital investment that newcomers need, to enter certain industries. Tenure advantages are not always dependent on the size of the enterprise. As such, Kaiser, Christensen, Foust, & Davidian (2011) state that some tenures, despite of their size, can present customers with better quality and cost advantages that are not available to possible rivals. Experience that let an enterprise improve their production effectiveness, gain access to better raw materials, have favourable geographic locations, and establish brand identity, are some of the sources where these advantages can stem from. Decision makers in the agriculture sector can use the proposed DSS to establish the expenses related to adopting a possible land use alternative.

4. According to Porter (2008) and Kaiser et al. (2011) access to adequate distribution channels is another barrier that can deter the entrance of a newcomer into an industry. When a business or individual enter into e.g. an agriculture industry, they are required to secure distribution channels for the procurement of raw materials to be able to produce their goods and or services. It is however more likely that limited channels such as retail channels, are more likely tied up with existing farmers, which deters newcomers from entering the agriculture industry. Due to limited access it is sometimes required that newcomers bypass the established distribution channels to be able to create their own. Decision makers in the agriculture sector can use Porter's FFF to establish if there is a market for a particular product, to overcome problems with access to adequate distribution channels.

5. Restrictive government policies can either help or restrict the entrance of newcomers into an industry (Blees et al., 2003).The entry barriers can be either strengthened or annulled by these policies. In some instances policies which is a consequence of licensing requirements on foreign investment and restrictions can limit or even entirely block entry into some industries.

6. The entry barriers for a possible newcomer are also raised by expansive patenting rules that protect a brand from being copied and imitated and environmental restrictions and safety regulations (Porter, 2008).

7. Other than the aforementioned sources that have been discussed, the historical reaction of established organisations towards newcomers will also play a role when a new enterprise decides whether or not to take the risk to enter a specific industry.

3.1.3.3. Element three: Power of suppliers

De Swaan Arons & Waalewijn (1999) state that by either charging higher prices, outsourcing costs to industry participants, or by limiting the quality of the product or the service that they provide, dominant suppliers within an industry have the power to seize more of the power for themselves. As large amount of raw materials in the form of components, labour, and other supplies have to be supplied in the agriculture and producing industries. Buyer-supplier relationships between the industry and the enterprise are consequently formed. As aforementioned, if specific suppliers to an industry is dominant and thus they have the power to charge higher prices for the required raw materials, lower profitability for the industry follows. Therefore, a supplier group is powerful when the industry in which it competes and operates is more concentrated than the industry it supplies goods and/or services to. Decision makers in the agriculture sector can use this source of entry barrier to establish the degree of power the suppliers of raw materials have for a specific land use alternative. By establishing dominant suppliers, farmers can evaluate whether these suppliers are increasing the cost of the raw materials that the farmer need, to implement a possible land use alternative themselves.

Furthermore, a supplier group is also powerful when it supplies products or services to a number of different industries. It is therefore not dependent on one specific industry for its profit. Kaiser et al. (2011) state that in such situations it is not unusual for the suppliers to obtain the minimum profits from each of the different industries they supply to.

High cost of changing from one supplier to another is yet another factor that contributes to the power of the supplier group. Usually, it is enterprises or industries where highly specialised processes and equipment are necessary to produce their goods or services, or when the supplier group presents products that are differentiated, that are usually patent protected according to Porter (2008). Moreover, Cox (2001) argues that powerful supplier groups are those that provide unique products and services that cannot be acquired from any other supplier.

Finally, Porter (1980) states that if the industry which the buyer occupies is more profitable, the supplier group can credibly threaten to integrate into the industry, allowing suppliers to be encouraged to enter the market.

3.1.3.4. Element four: Power of buyers

Buyer power is defined as the circumstances in which the demand in the industry is concentrated to such an extent that the buyers can exercise market power over the sellers in that particular industry (Noll, 2005). Under such market conditions, powerful customers are therefore able to seize more value, by forcing down prices below what the products would normally retail for, while demanding more service or better quality. Farmers should use the FFF to establish if there are few customers for a particular product before they decide to adopt a land use alternative. The FFF can be used in conjunction with the proposed DSS to establish the demand of the possible viable options that the DSS produced.

Generally strong buyer power are concerned with what economists call a monopsony – a state of the market where only one buyer exists, but numerous suppliers, or an oligapsony – a state of the market where only a few buyers exist, but numerous sellers. Buyers have power and are therefore powerful if they possess negotiation leverage, compared to other organisations that are in the same industry.

Porter (2008) suggests that the high risk for large volume buyers that are associated with industries that have fixed costs on the products that they provide, introduce buyer power into the industry. This happens specifically if large volumes are bought by those buyers from a single vendor. Furthermore, rival enterprises are forced to maintain capacity by continuous discounting of their products and or/services in industries where there are high fixed costs, due to the pressure that are caused by low marginal costs.

Undifferentiated products or standardised products are another factor that contributes to buying power as proposed by Kaiser et al. (2011). The buyer has the option to look for an alternative company that sells the desired products or services on more favourable terms if the seller produces products or services that are undifferentiated or standard. Similarly, it is easy for buyers to change from one supplier to another if the quality of the products and/or services of the buyer is mostly unaffected by the supplier industry’s product.

Buyers also have the power to exercise pressure on suppliers by threating to switch to another, if the cost related to switching from one supplier to another is minimal. Likewise, buyers are more likely to look for the cheapest option if the products bought from the supplier represent a substantial part of the buyer’s purchasing budget and cost structure. This is usually caused by procurement budget restraints, low cash flow, or low profit margins.

Finally, Porter (2008) states that the buyer power is high if the buyer organisation can credibly threaten to integrate backwards by either buying the company that supplies the products, by buying a rival company, or by producing the procured product themselves.

3.1.3.5. Element five: Threat of substitutes

A substitute product or service is one that functions the same as the original product or service, but in a different way (Cheng, 2013). Substitute products influence a product's price elasticity – the more substitute products there are available to choose from, the more elastic the demand becomes. A high substitute has a negative influence on an industry's profitability by placing a cap on retail prices.

Enterprises can differentiate themselves from substitute enterprises within an industry by either selling products with superior performance, marketing or some other property, to prevent probable suffering in terms of profit potential, or even, in some instances, growth potential. Farmers should use the FFF to establish if the market is flooded for a particular product before they decide to adopt a land use alternative.

According to Kaiser et al. (2011) the treat of substitution is high when a particular enterprise presents an attractive price to performance trade-off, related to that of the product presented by the industry in which it competes. Furthermore, the threat of substitute is high when the correlating cost to switching from the existing product to the substitute product is minimal. These substitute products are not bound to a specific industry, but can exist in a different industry or in the same industry in which the current buyer competes.

Porter (1991) defines a successful business as a business with an attractive relative position and that therefore has a competitive advantage over that of its industry competitors.

As this study specifically deals with the identification of a list of considerations which may aid a decision maker to evaluate different land use alternatives for a particular region, it is of the utmost importance that the decision maker review the influence of the decision on all of the aforementioned competitive forces, thus establishing the effect on the competitive advantage of the enterprise. Ideally the decision to replace an existing land use option with a different land use alternative, should result in the option that is more favourable to the enterprise. Consequently, the decision that increases the competitive advantage of the enterprise, is the most favourable one. By assessing both the list of identified considerations that can aid a decision maker when evaluating different land use alternatives for a specified region and the influence of the FFF, the decision maker can determine which decision will lead to an increased competitive advantage, which in turn leads to sustainable and superior financial performance.

3.2. BUSINESS STRATEGIES

Michael Porter in his article 'What is Strategy'(1996), argues that 'Strategy is the creation of a unique and valuable position, involving a different set of activities.' He further states that, 'The essence of strategic positioning is to choose activities that are different from rivals' (Porter, 1996). Anthony Ulwick gave a more straightforward definition of strategy (Ulwick, 2005):

> *A strategy is often perceived as being intangible, as there is nothing to touch and feel - there are no physical attributes associated with a strategy. A strategy is simply a plan - a plan that describes what an organisation proposes to do to achieve a stated mission.*

It is important to define something to be able to properly understand it. Formal strategic planning models like those that are used for big enterprises are usually used as a guide when most farm level studies of strategic management are conducted. Even though strategy is often considered to be a formal empirical process, the process might follow a more entrepreneurial mode at the farm level, because it is informal and unstructured and executed naturally or instinctively (McLeay, Martin, & Zwart, 1996). According to McLeay et al. (1996) not much is known about the strategic management processes of farmers, specifically the strategic decisions they make, the strategic alternatives that are available for farmers to use, and the strategic results that come from it.

Farmers are more likely to employ and evolve their distinctive capabilities in a specific strategic area where they feel confident. The strategy that is best fit for a specific farm business is likely to be the one that aligns capabilities, natural resources and environmental business objectives, opportunities and threats (McLeay et al., 1996).

Farm diversification is an adaption strategy that has been employed since the 1960s, and is gaining popularity (Poláková, Moulis, Koláčková, & Tichá, 2016). Lange, Piorr, Siebert, & Zasada (2013) define farm diversification as, 'the extension of on-farm business activities into other sectors to enhance the continuation of agricultural activity, to broaden the income base, and to enable steady farm development'. De Vries (1993) defines farm diversification simply as farms that are more flexible, and that can therefore respond better to future consumer demands to maximise profits. Barnes, Hansson, Manevska-Tasevska, Shrestha, & Thomson (2015) discriminate between the following two diversification types, namely, farm diversification and agriculture diversification. Farm diversification, according to Barnes et al. (2015) refers to 'a farm business is considered diversified if it uses any of its farm resources to produce income from activities outside conventional agriculture', whereas agriculture diversification refers to farms that are participating in diversification of the agricultural activities, where income is generated from more than one agricultural enterprise.

During periods where farms are experiencing crisis and profit squeeze, diversification has been used as an economic adaption strategy. The main aim of this strategy is to generate additional income. It is perceived as a survival strategy, especially for small and marginal farm holdings (Barnes et al., 2015). According to Poláková et al. (2016) the 'generation of additional income, the continuance of farming, and the enhancement of life quality', are some of the most important goals of diversification. A study done by Barnes et al. (2015) found that diversification strategies offer a trajectory toward viability, because income is generated from multiple sources which can account for business cycle variations and variation of seasonal income.

The topic of diversification to generate additional income is one that came up frequently while talking to agriculture experts in the Stellenbosch region. For this reason diversification strategies are the only strategy that will be discussed in this study. In this study, diversification is primarily considered as agriculture diversification that is engaged in the cultivation of various crops. This definition excludes farm strategies aiming to relocate and recombine farm resources away from their original farming activities to generate an additional form of income. This study focusses on farmers adopting a diversification agriculture strategy to stay economically sustainable and viable, and thereby reviewing the possible agricultural land use alternatives that are available for farmers in the Stellenbosch region.

3.3. DECISION SUPPORT SYSTEMS

As humans, we would like to think that rational thought forms the basis of our choices, whether our decisions are individual or collective in nature. The term 'rationality', which may be difficult to define accurately, has a long and complicated history in Western philosophy. Brown, Hall, Snook, & Garvin (2010) state that it 'describes a style of thinking and ordering of our actions vis-à-vis our environment'. Rational choice theory, which believes that decisions are made, based on gathering data about alternatives, and then selecting the alternative or set of alternatives associated with the highest utility or usefulness, is believed to be the foundation of modern economics, and to some extent, of decision-making. But, regardless of what we want to believe, research done over the last two centuries revealed common patterns, which indicated that we assess information in a way that are far from rational (Hall, 2010). Thus, a set of processes and analytical tools that aid systematic and structural thinking when difficult choices are involved, were required. This set of processes and analytical tools, which are referred to as decision analysis, provides a method where a decision problem can be formed by separating the uncertainties, determining the subjective beliefs of the participants regarding those uncertainties, and then finally building a quantitative decision model (Hall, 2010).

Anticipating trends, possible opportunities and apprehensions within an industry, as well as being concerned with the views of one's peers, is of the utmost importance to the success of any business. Operating a successful wine business is no different (PwC, 2014). Therefore, incorporating constant improvements, and ensuring that a business keeps up with the latest trends in its industry by re-evaluating its business strategy, will ensure sustainability and revenue growth of wine estates.

According to SAWIS (2015) there is mounting pressure on the profitability of the South African wine industry. Therefore, a lot of wine estates are investigating agriculture diversification opportunities. It is however a complex task to undertake, and many wine farmers do not have much experience outside of the wine industry. These opportunities are dependent on informed decision-making.

The implementation of these land use alternative opportunities requires what McNie (2007) refers to as 'useful information'. Useful information according to McNie (2007) is information that 'improve environmental decision-making by expanding alternatives, clarifying choice and enabling decision makers to achieve desired outcomes'. Decision support systems (DSSs) and other modelling tools can help with this process (Junier & Mostert, 2014).

The last part of the twentieth century and early period of the twenty-first century, have had environmental as well as social challenges that are innately complex and intricate. These challenges are not confined to a specific region, but are rather global in extent. Consumption patterns, the production process, resource management methods, and the importance that we attach to other species, are required to change to respond to such present-day environmental and social challenges. Therefore, scientific logic emerged globally as an important factor in environmental policy and management.

Decision Support Systems, which is technology that aid in the comparative assessment and selection of possibilities which can promote change, can be used, due to modern driving forces of environmental change which has prompted things to be done differently. Turban & Aronson (2001) defines a DSSs as an 'interactive, computer-based systems, which help decision makers use data and models to solve unstructured problems'. The idea of a DSS was developed by Gorry and Morton in 1971 by expanding on Herbert Simon's work of 1960.

Organisational decision-making formed the basis of Simon's work. He discriminated between three key organisational decision phases: (1) the gathering of 'intelligence' to identify the need for change, (2) 'design' or the development of alternative strategies, plans or options which will be used to solve the problem(s) that was identified during the first phase, and (3) the process of assessing and then selecting the alternatives (McIntosh et al., 2011). DSSs support the analysis of current statuses or they can give future predictions, or both. They can furthermore assist discussions, store data and models, stimulate learning, and advance internal capacity building. The research study and consequently the proposed DSS, will incorporate all three key decision phases. The first phase, the gathering of intelligence, however, is limited by the scope of this study, due to the region (Stellenbosch) of the illustrative case study, and by implication the proposed DSS, is applied.

More effective decisions can be made by using decision support tools (DST), by leading the user through specific decision stages and portraying the different possible outcomes from various alternatives.

Porter (1991) defined a decision support framework, which is a specific DST, as follows: a tool that can be used to identify applicable variables and the questions that the user needs to answer to be able to build conclusions that are unique to an industry. The chosen variables, the interactions between the variables, and the organisation of these variables in the framework, determine the theory represented in the framework. The framework tries to assist the analyst to understand the environment by thinking through the problem better and defining and choosing among the available alternatives (Porter, 1991).

These DST can be dynamic software tools where user inputs dictate output recommendations. Some dynamic software tools may even propose an optimal decision path. Farmers and farm managers can use these tools to efficiently facilitate farm management, by providing different alternative recommendations based on evidence (Rose et al., 2016). Different crop management options and crops must be selected by farmers, which then allocate them to a specific field. These selections are critical, because they influence the productivity and short- and long-term profitability of the farm. Decision support systems can assist farmers to allocate resources more efficiently (Dury, Schaller, Garcia, Reynaud, & Bergez, 2012).

The one notion that exists is that complex problems can be solved by using modelling tools, or more precisely DSSs. The other notion is that DSSs have limitations regarding their use. Examples of authors that are of the latter opinion, include Borowski & Hare (2007); de Kok & Wind (2003); Gourbesville (2008); McIntosh et al. (2011). A number of reasons provided in the literature concerning the limitations of DSSs have been summarised by van Delden et al (2011) as follows: 'a lack of transparency, inflexibility and a focus on technical capabilities rather than on real planning systems' (Van Delden, Seppelt, White, & Jakeman, 2011). They furthermore state that a decision support system should agree with 'the perceptions, experiences and operational procedures of the policy makers' (Van Delden et al., 2011).

Three components are fundamental for the success of a DSS: the instrument's efficiency (ease of use, fit for purpose), the model's knowledge base (how well does the model replicate reality), and availability of data for processing purposes (Junier & Mostert, 2014). Jakeman, Letcher, & Norton (2006) suggested an iterative process that consists of ten steps to develop and evaluate such a DSS, as shown in Figure 6**.**

Trust in the outcomes of the tool is another important aspect of a DSS that should be included according to Junier & Mostert (2014). McNie (2007) refers to credibility as information that is accurate, valid and of high quality, as a consideration for useful information. Trust in the outcome of the DSS as well as the accuracy, validity, and quality of the information is incorporated into the DSS by consulting decision makers in the agriculture sector, thus validating the model (Section 8). The technical elements, the environment (or context), strategy for implementation purposes which includes the process of developing the tool, user characteristics, and user behaviour, all play a role in the quality of the performance of a DSS (Junier & Mostert, 2014).

The ten-step iterative process

Certain general steps must be considered to ensure that credible results and knowledge acquisition for the model, as well as for the community in the long run are obtained, regardless of the type of modelling problem. Jakeman, Letcher, & Norton (2006) state that some of the steps outlined in Figure 6 might involve the end user as well as the modeller. Moreover, the steps delineated are not always clearly distinguishable. Because model structure are partially distinct by the structural parameters, it is a matter of preference where model structure selection ends and parameter estimation begins (Jakeman et al., 2006). The ten-step iterative process was used as a foundation to develop the proposed DSS. Because it only served as a guideline during the design and building process of the proposed DSS, some of the steps of the ten-step iterative process will be omitted. A brief discussion of each of the ten steps follow Figure 6.

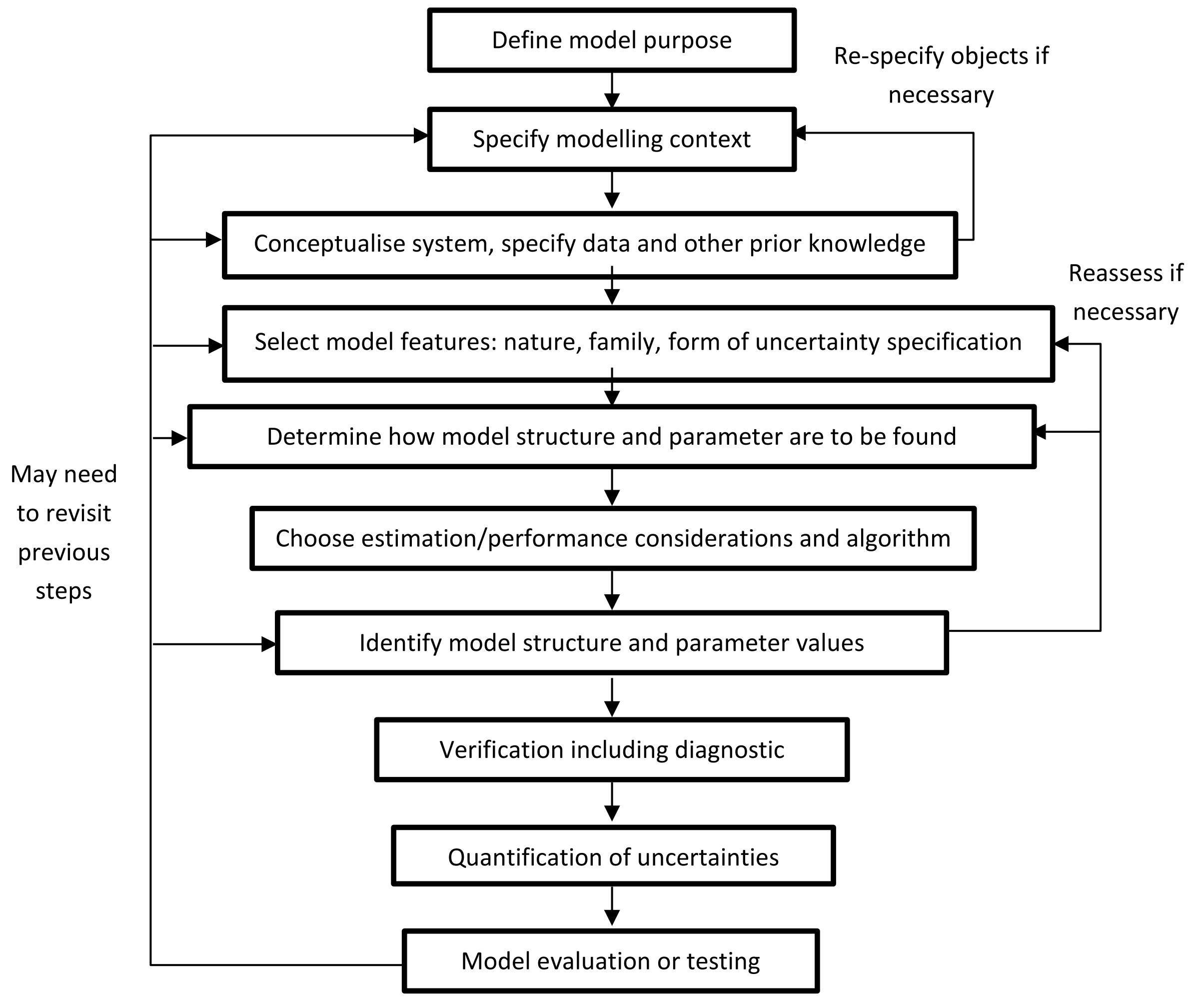


Figure 6: Iterative process between model building steps (Jakeman et al., 2006)

Step 1: Definition of the purposes of modelling

Defining the purpose is not always an easy task; different stakeholders will have different degrees of interest in the potential purpose of the model. Better defining and understanding the problem and possible solutions are beneficial to all parties involved, to evaluate how much trust could be placed in the model. Even if the final model is unsatisfactory, it is important to realize that some purposes, with specific regard to an increased understanding of the system and data, might be executed well. For example, an erroneous model can still give insight as to how an environmental system works. Some of the purposes of modelling include the following: better understanding of the system in a qualitative manner; data reduction; prediction; assessment of data; discovering limitations, inconsistencies, and coverage; providing a clear focus point for discussion of a problem; giving guidance for management and decision-making. It is the responsibility of the modeller to establish the purpose and priorities within the provided list, even though the listed motives are not mutually exclusive, but they influence decisions in later stages (Jakeman et al., 2006).

Scoping the research study ensure that the research stays within specified boundaries. Specifying the research problem (Section 1.2), the research aim (Section 1.3), and the research objectives of the study (Section 1.4,) define the purpose of the research study, and to a certain extent the purpose of the proposed DSS. The first step of the 10-step iterative process will further be used to formulate the design requirements of the proposed DSS, thus clarifying the purpose of the proposed model which will benefit both the researcher and the reader. Formulating a clear purpose for the suggested model will further lead to data reduction, thus applying this step will help the researcher to focus on gathering only necessary data that will be incorporated into the proposed model.

Step 2: Specifications of the modelling context: scope and resources

The second step establishes the following: exact questions and issues that the model focuses on; the parties involved which include the clients or end users; the required outputs of the model; the forcing variables (drivers); the expected accuracy, the spatial and temporal scope, scale, and resolve; timeframe of completion of the model; available resources for operating and modelling the model; and flexibility. Determining the boundaries of the model is an important step. Flexibility and required resources to operate the model can be a concern.

The second step of the process are closely linked and builds upon the first step of the process. Formulating the purpose of the proposed model (step 1) informs all parties involved what the model aims to achieve. Thus the design requirements should address the questions and issues (the research problem statement) to satisfy the purpose of the model. The second step indicates that it is important to provide the limitations and delimitations of the research study and the model, to determine the boundaries thereof. The design requirements need to be framed to provide an accurate description of the outputs of the proposed DSS.

Step 3: Conceptualisation of the system, specification, data and other prior knowledge

According to Jakeman et al. (2006) conceptualisation refers to 'basic premises about the working of the system being modelled'. It can help the thought process by using influential diagrams, linguistic model, block diagram or bond graph, which indicate how the drivers of the model are connected to the internal (state) variables and outputs (observed responses). Conceptualisation can be very basic at first, until the results of obtained knowledge and data analysis could be used. Even if a new model is not designed from the start, the conceptualisation step is still very important, due to time and money constrictions which limit one to utilise a 'canned' model. The conceptualisation step, which is mostly a qualitative step, defines data, prior knowledge, and assumptions that were made about processes. The third step changes from qualitative to quantitative when decisions are made regarding what needs to be included and what can be excluded. The degree of detail required in the outputs, form the first part of this step. The next part is to follow up the implications which Jakeman et al. (2006) formulate as 'the internal resolution of the mode must be sufficient to produce outputs at the required resolution, and the time and spatial intervals throughout the model must be compatible with the range of rates of change of the variables'.

Mapping the logic of the proposed DSS will help with conceptualising how the DSS will function once it has been designed. This step can therefore be used to ensure that the logic behind the proposed model is sound and complete, to guide the researcher during the design process and to provide the reader with an outline of the logic of the proposed DSS.

Step 4: Selection of model features and families

The system and data requirements as outlined in the previous three steps determine the model features for selection. Relationships between the components and processes of systems are specified by the structure of the model, which include data structure, measures used to indicate relationships, or the functional form of connections. Selection of the features of a model should be flexible and ready for revision, depending on the assessment of the practicality of initial beliefs.

Features of the model needs to be adequate to adhere to the purpose of the model, but still simplistic enough to promote user acceptance.

Step 5: Choice of how model structure and parameter values are to be found

The type of relationship between variables can sometimes be suggested by means of adequate prior science-based theoretical knowledge. Such knowledge makes it easier to find the structure of the model. The structure of a model may, in some cases, be found on the basis of trial and error, which is based on the credibility of the behaviour of the model. The parameters can be adjusted according to the observed outputs. Data availability, as well as how informative the data is, plays a role in how the model is going to be compiled.

Relevant data that needs to be gathered through research and interviews with experts, the sample size of the land use alternatives to be included in the model, and the relationships between the different considerations and each of the land use alternatives that are included, will influence the model structure and parameter values of the proposed DSS.

Step 6: Choice of estimation performance considerations and technique

Step 6, which is barely ever a consideration on its own, display the desired properties of the estimates. For example, robustness to outliers, unbiasedness and statistical effectiveness, as well as acceptable prediction regarding the performance of a set of data that are used for calibration purposes, might be sought. The parameter estimation method should be kept as simple as possible computationally, to decrease the number of possible coding errors.

Step 7: Identification of model structure and parameters

This step involves finding a model structure and parameter values that are suitable. In many cases this entails evaluating which parameters should be added or which may be dropped.

Step seven can evaluate the relevancy of each of the identified considerations. Some of the initial identified considerations can be excluded from the design, due to, for example, scope.

Step 8: Conditional verification including diagnostic checking

The model needs to be 'conditionally' verified and tested after it has been identified, to make sure that it is robust enough. It is also necessary to ensure that the interactions and outcomes of the model are appropriate and aligned with the objectives of the model. Quantitative and qualitative considerations are involved in this step. Quantitative verification is seldom undertaken against a wide array of considerations. Qualitative verification, on the other hand, includes people who can supply valuable knowledge, or that can use the model without being modellers. If the model does not act feasibly, the previous steps need to be re-evaluated (Jakeman et al., 2006).

To apply this step to the proposed DSS, an internal validation should be conducted to test that the interactions and outcomes of the model are appropriate and in line with the objectives and requirements of the DSS.

Step 9: Quantification of uncertainty

It is important to consider uncertainty when developing any model, specifically when designing a big integrated model. Incomplete system understanding, infrequent data and measurements, uncertainty regarding the baseline inputs and the environment where the model runs take place, are some of the reasons listed for uncertainty in models. Uncertainty is also associated with the definition of the problem. The process in this step is just as important as the technical aspects of the step, since it is a reflective process. The uncertainty of a model must be seen in relation to its purpose.

Step 10: Model evaluation or testing (other models, algorithms, comparisons with alternatives)

The final step of the iterative process that Jakeman et al. (2006) propose, states that the model is required to be evaluated in terms of its objectives. In simpler models this relate to the validation of the model. Therefore, confirmation area, seen as the performance of the model, is evaluated against data that was not used to build the model. Large integrated models can rarely use this method, since it is rarely feasible or applicable for models of such a nature. The reason why the model has been built, needs to be assessed in more detail; the considerations must rather be fitted for purpose and transparency of the process.

The last step of the ten-step iterative process can be applied in this study by validating the developed DSS externally, by having industry experts validate the developed DSS and its logic.

3.4. DSSs IN AGRICULTURE

After establishing that there exists a need for a DSS that can provide support to farmers who are considering an agricultural diversification strategy, and who want to evaluate possible land use alternatives that they can employ to stay viable, the researcher had to review current literature to determine whether such a DSS already exists. This section will review the current available literature regarding decision support models in agriculture. A Scopus search with keywords 'crop selection', 'decision support' and 'considerations' was used to aid this research task. Using those specified keywords, narrowed down the search to 29 search results.

Decision support systems (DSSs) are a well-established tool that are utilised in agriculture with the aim of providing assistance regarding crop planning. Hartati & Sitanggang (2010) argue that it is not only preferable to apply a DSS for efficient land suitability evaluation and crop selectin problems, but also important. Moreover, the DSS assists the decision makers in comprehending the decision problem as well as the effect that their choices have on the enterprise, by allowing them to continuously exchange information between the system and themselves (Mallach, 2000; P. N. Smith, 1992; Wei, Liang, & Wang, 2007). The complexity of these systems varies greatly.

Model based land use studies should be used to inform debate on development pathways and get an understanding regarding future agriculture development opportunities (de Wit, van Keulen, Seligman, & Spharim, 1988) to help both the formulation of strategy policy objectives (Dogliotti, Van Ittersum, & Rossing, 2005), as well as strategic planning by farmers, by using trade-offs between economic and environmental objectives (Castelán-Ortega, Fawcett, Arriaga-Jordán, & Herrero, 2003; Pacini, Wossink, Giesen, & Huirne, 2004; Ten Berge et al., 2000; Vatn, Bakken, Botterweg, & Romstad, 1999; Wossink, de Koeijer, & Renkema, 1992; Zander & Kächele, 1999). Selecting the 'right' crop for a specific area is one of the most important decisions that farmers are faced with. Potential crop farmers should know the risks involved as well as the suitability of the crops which will allow a potential grower to select a crop that is tailored to his or her specific need. Risks can be managed by adopting diversification strategies. Table 2 illustrates decision support systems that have been developed for crop selection. The author, the focus area of each of the developed DSSs, the consideration that each DSS takes into account, as well as what theory or work a particular DSS is based on, can also be seen in Table 2. A discussion of each of the depicted DSSs will follow after Table 2.

Table 2: Decision Support Systems (DSSs) for crop selection

Author/Source	Based on	Focus area	Consideration
Rădulescu & Rădulescu (2012)	Portfolio Theory	Financial risk	↓ Climate risk ↓ Market risk
Collender (1989)	Mean variance analysis	Risk estimation	Mean variance characteristics
Salleh (2012)	Fuzzy Modelling	Crop selection	Uncertainties during the development of the agriculture DSSs
Hartati & Sitanggang (2010)	Fuzzy Modelling	Evaluate land suitability	Land characteristics
Balezentiene, Streimikiene, & Balezentis (2013)	Fuzzy MULTIMOORA method	Sustainable energy	Climatic suitability, ↓ Environmental pressure
Nevo & Amir (1991)	Rule-based expert system	Crop suitability	Severe uncertainties
Rossing, Jansma, De Ruijter, & Schans (1997) van Ittersum, Rabbinge, & van Latesteijn (1998) Makowski, Hendrix, van Ittersum, & Rossing (2000) Ten Berge et al. (2000) Dogliotti, Van Ittersum, & Rossing (2005)	Multi goal linear programming	Soil	↓ Erosion, ↑ Organic matter ↑ Rate of change
Annetts & Audsley (2002); Dogliotti, Van Ittersum, & Rossing (2005); Bartolini, Bazzani, Gallerani, Raggi, & Viaggi (2007); Sarker & Ray (2009); Louhichi et al. (2010)	Multi-objective optimization problems Process-based simulation model Empirical data	Profit	↑ Gross margin ↑ Annual profit ↑ Income ↑ Net benefit

Author/Source	Based on	Focus area	Consideration
Dogliotti et al. (2005); Bartolini et al. (2007)	Process-based simulation model Empirical data	Labour	↓ Total labour ↓ Casual labour ↓ Cost
Annetts & Audsley (2002); Dogliotti et al. (2005)	Multiple objective linear programming Process-based simulation model Empirical data	Pesticides	↓ Herbicide use ↓ Losses ↓ Pesticide exposures

Each of the different methods that the DSSs (illustrated in Table 2) are based on, will be reviewed and discussed accordingly.

3.4.1. PORTFOLIO THEORY

Rădulescu & Rădulescu (2012) developed a minimum risk decision support tool for crop planning based on portfolio theory. The developed portfolio selection model takes market and climatic risk into account. The model assigns a crop to land, based on the risk profile of that crop. The model was solved using MINLP solver from GAMS. The construction of the input data collection and the user parameters are facilitated by the user interface. User input data such as historical data of land productivities for different crops and soil types were used. Numerical results obtained from this model can be analysed. Because this model selects crops based on market and climatic risks only, it falls short with regards to producing a holistic set of considerations that can be used to evaluate the suitability of crop selection for a specific region.

3.4.2. MEAN-VARIANCE ANALYSIS

Mean variance analysis is a way to allocate assets in a world of risk and return (Goodman, 2009). An *n*-component vector (portfolio) *X* is called feasible in mean-variance analysis if it satisfies:

$$AX = b$$
$$X \geq 0$$

Where A is an m x n matrix of constraint coefficients, and b an m-component constant vector. If for some feasible portfolio

$$E = \mu^T X$$
$$V = X^t C X$$

a mean variance (E-V) combination is labelled feasible. Where E is the expected return of the portfolio, V the variance of the portfolio, μ the vector of expected returns on securities, and C a positive semidefinite covariance matrix of returns among securities (Markowitz, 1989).

Only suboptimal portfolios can be identified. A universal optimal portfolio, however, cannot be identified (Goodman, 2009). A feasible E-V combination is called inefficient if some other feasible combination has either less V and no less E, or else greater E and no greater V (Markowitz, 1989). In other words, if the variance can be decreased without decreasing the expected return, or if the expected return can be increased without increasing the variance, a portfolio is labelled as inefficient (Goodman, 2009). A portfolio is called efficient if it is not inefficient. A feasible portfolio X is efficient or inefficient according to whether its E-V combination meets the one definition or the other (Markowitz, 1989). Depending on whether a feasible portfolio X's E-V combination meets either of the definitions, determines if portfolio X is efficient or inefficient.

Collender (1989) studied different models to allocate resources in agriculture, based on specific risks, using mean variance analysis.

3.4.3. FUZZY MODELLING

Uncertainty in practice are dealt with by different frameworks. Liu & Forrest (2011) categorised such frameworks: (1) probability and statistics and (2) grey system theory and fuzzy set theory. Decision-making problems are widely solved by making use of fuzzy set theory, which was introduced by Zadeh (1965). Thus, according to Zavadskas, Antucheviciene, Razavi Hajiagha, & Hashemi (2015) a fuzzy set theory is 'a generalization of ordinal sets, where a membership degree is assigned to each element of a set'. Unique characteristics are subscribed to each type of uncertainty and each type of uncertainty is suitable for special cases. Fuzzy sets are concerned with gradual concepts and describe their boundaries, while probability deals with the occurrence of well-defined events (Pedrycz & Gomide, 1998). In effect, the fuzzy set theory is suitable for recognition-based uncertainty (Zavadskas et al., 2015).

Studies were done where decision support systems were developed for crop selection by making use of the fuzzy modelling approach. Fuzzy knowledge and inference systems (FISs) form part of the artificial intelligence techniques. According to Coulon-Leroy, Charnomordic, Thiollet-Scholtus, & Guillaume (2013) 'fuzzy logic is used as an interference between the linguistic space, the one of human reasoning, and the space of numerical computation'. Salleh (2012) developed a decision support system using fuzzy logic for crop selection in Malaysia. The fuzzy logic approach was used to overcome the uncertainties during the development of the agriculture DSSs. Hartati & Sitanggang (2010) developed a DSS, based on land characteristics using the fuzzy logic approach, that can determine the land suitability class for agricultural purposes.

3.4.4. FUZZY MULTIMOORA METHOD

The uncertain environment in recent years has led to multiple decision-making methods receiving different extensions (Zavadskas et al., 2015). Building from Fuzzy modelling (discussed in Section 3.4.3), Krassimir Atanassov (1986) introduced the concept of intuitionistic fuzzy sets (IFSs) as an addition to ordinal fuzzy sets. IFS assigns a degree of non-membership to each element on top of a membership degree of each element. The interval-valued intuitionistic fuzzy sets (IVIFSs), where membership and non-membership degrees are stated as closed intervals, were extended at a later stage by Atanassov & Gargov (1989). When it became clear that the type one fuzzy sets were not always adequate for multi-attribute decision-making under uncertain environments, fuzzy sets that involved interval-valued as well as intuitionistic fuzzy sets (type 2 fuzzy sets), were suggested. Thus, by using either generalized interval-valued trapezoidal fuzzy numbers (Baležentis & Zeng, 2013) or intuitionistic fuzzy numbers (Melorose, Perroy, & Careas, 2015), the MULTIMOORA (Multi-objective Optimization by Ratio Analysis plus Full Multiplicative Form) method was rationalized as a result. Economic, management, or technological decisions have been made successfully by using this method (Zavadskas et al., 2015). The MULTIMOORA method aggregates the decisions of multi[le decision makers. A matrix is therefore required. The method further requires the consideration weights to be completely known, which can be difficult and subjective because of the increasing complexity of decision-making circumstances (Tian, Wang, Wang, & Zhang, 2016). This method was not used in this study, because this the MULTIMOORA method relies on opinions from multiple decision makers and weighted averages.

Balezentiene, Streimikiene, & Balezentis (2013) developed a DSS based on fuzzy MULTIMOORA method which focuses only on climatic suitability and low environmental pressure exhibited by a crop. This study only considered these two factors (climatic suitability and low environmental pressure presented by a crop) when selecting crops for a specific region. Alternative factors were therefore excluded, thus not using a comprehensive set of considerations during the crop selection process.

3.4.5. RULE-BASED EXPERT SYSTEM

Research in the field of artificial intelligence brought forth this technology. Gaultney, Strickland, & Poe (1985) defines an expert system as a computer program which consists of the following characteristics:

1. Reason by symbol manipulation.
2. Problems with a high degree of complexity or difficulty can be solved by it.
3. High level rules, the avoidance of blind search, and high performance exemplifies expertise.
4. Arrive at an answer by making use of heuristics or ‘rule of thumb’.

5. Transforms the problem from non-professional terminology into a form that can be used by expert rule application.
6. Uses a knowledge base that is well-structured, appropriate for problems within a rather narrow area.
7. Gives answers to questions about its knowledge and explanations of its method of reasoning.
8. Integrates new knowledge incrementally without damaging affective previous knowledge or control strategies.

Nevo & Amir (1991) developed a rule-based expert system called CROPLOT which determines the suitability of crops to specified plots, usually under severe uncertainties. CROPLOT is used in the plot allocation process when planning the production of field crops only. Because CROPLOT specified that only field crop allocation are considered, the considerations that were incorporated might not be suitable or complete for say horticulture crop allocation. The knowledge base that was used for CROPLOT was derived for conditions and practises in the Jezreel Valley in Israel. Because of this, the considerations that are assessed might differ significantly from considerations that are derived for a location in South Africa. CROPLOT needs the inference program of the shell 'Rabbi' to run, which farmers in South Africa don't necessary have.

3.4.6. EMPIRICAL DATA

Empirical data is information we gather about something specific that is grounded on experience. Therefore information that scientists gather by means of observation and experimentation, is labelled as empirical data (Roundy, 2016). It is therefore important to get inputs from experts with experience when identifying the set of considerations that will be used in this study.

Annetts & Audsley (2002), Dogliotti, Van Ittersum, & Rossing (2005); Bartolini, Bazzani, Gallerani, Raggi, & Viaggi (2007); Sarker & Ray (2009); Louhichi et al. (2010), Bartolini et al. (2007) all made use of empirical data in the various models that they developed that were applied in the agriculture sector. The frequent and extensive use of empirical data in these studies, emphasise the importance of using empirical data in this research study.

3.4.7. MULTI-OBJECTIVE OPTIMIZATION PROBLEMS

A choice between various alternative solutions optimising the objective function is usually what a decision maker that is utilising mathematical programming optimisation models are dealing with. Secondary, tertiary or higher order objectives can form the foundation of the decision (Wilamowsky, Epstein, & Dickman, 1990). Dogliotti et al. (2005) developed a model based on multi goal linear programming that allocates production activities to a farm with land units differing in soil quality, irrigation level, mechanical level, and crop protection type used. Where production activities consist of current practices as well as prospective activities that are new to the area. This study highlights the importance of including soil type as a consideration during the crop selection process. The considerations that were used in this study however are based on data derived for vegetable crop selection in South Uruguay. The study furthermore does not consider other important factors such as temperature or required infrastructure.

3.4.8. MULTI-OBJECTIVE LINEAR PROGRAMMING

Multi-objective linear programming allows a decision maker to achieve his aims optimally by arriving at the best overall decision (Kulej, 2011). A multiple objective linear programming problem can formally be described as:

$$
\begin{aligned}
f_1(x) &= c_{11}x_1 + c_{12}x_2 + \cdots + c_{1n}x_n \rightarrow maximize \\
f_2(x) &= c_{21}x_1 + c_{22}x_2 + \cdots + c_{2n}x_n \rightarrow maximize \\
&\ddots \qquad \vdots \\
f_q(x) &= c_{q1}x_1 + c_{q2}x_2 + \cdots + c_{qn}x_n \rightarrow maximize
\end{aligned}
$$

Subject to:

$$
X \begin{cases}
a_{11}x_1 + a_{12}x_2 + \cdots + a_{1n}x_n = b_1 \\
a_{21}x_1 + a_{22}x_2 + \cdots + a_{2n}x_n = b_2 \\
\vdots \\
\vdots \\
a_{m1}x_1 + a_{m2}x_2 + \cdots + a_{mn}x_n = b_m \\
x_j \geq 0, j = 1, \ldots, n.
\end{cases}
$$

The set of feasible solutions $\mathbb{X} \in \mathbb{R}^n$ is defined by the set of m constraints (inequalities or equations) for the problem and the nonnegativity constraints. Each feasible solution $x = (x_1, \ldots, x_n) \in \mathbb{X}$ (which is an n-dimensional vector of decision variables in the so called decision space $\mathbb{R}^n$) implies a value for each objective function $f_1(x)$, i = 1, . . . ,*q*. . Hence, each x ∈ X corresponds to a vector y = (y1, y2, . . . , yq) ∈ ℝ *q* , where y = (y1, y2, . . . , y*q*) = (f1(x), f2(x), . . . , f*q*(x)) (Kulej, 2011).

The studies done by De Wit et al. (1988); Van Ittersum et al. (1998); Wossink et al. (1992); Rossing et al. 1997; Vatn et al. (1999); Zander & Kachele (1999); Ten Berge et al. (2000); Castelan-Ortega et al. (2003); & Pacini et al. (2004) used mulita-objective linear programing as the integrating framework. Judgment from experts determined the number of land use alternatives that were provided to the linear programming algorithm in each of the above mentioned studies. Dogliotti et al. (2005) argue that this makes the transfer to new conditions difficult, which forms an undesirable potential bias as a result. Thus the importance of using a systematic approach to identify agriculture alternatives, and to not solely rely on expert opinions are pointed out.

Section 3.4 evaluated and reviewed what the literature had to offer regarding crop selection decision support systems. As illustrated in Table 2, there exist many different DSSs that focus on different aspects in the agriculture field. The aim of this study, however, is to develop a set of considerations as part of a DSS that can provide assistance to decision makers when they are considering adopting a land use alternative. The DSSs discussed in this section focused on a few aspects only, thus not taking the whole farming operation into consideration. The set of considerations that is developed in this study is also applicable on the whole farming operation, and not just on a specific sector such as land consideration or climate. The set of considerations in conjunction with data gathered, will then be used to develop the model to assess possible land use alternatives according to specified user input.

3.5. CHAPTER CONCLUSION

To summarise the chapter, Chapter 3 firstly describes the strategic decision-making landscape. Specific strategic decision-making attributes are discussed and compared to the decisions that decision maker are faced with when they need to evaluate an alternative land use alternative type. Subsequently, because of the comparison, land use alternative decisions are categorised as strategic decisions. The factors that have an effect on strategic decision-making are examined and grouped according to three principle categories: decision-specific characteristics, decision-making team characteristics, and external company characteristics.

Each of the decision-making team's characteristics discussed in Section 3.1.2, has an effect on the decision-making process according to the findings of the reviewed research study. This is because the proposed DSS is not just applicable to one specified farm and therefore not one specified team of decision maker. The decision-making members that form a team will thus change from one farm to the other, which means that their cognitive diversity, age, gender, and what each member regards as promotion of the business-image/their self-image, will differ. As such, only two of these decision-making team's characteristics, the education level of the decision maker and to a lesser extent the risk inclination of the decision maker, will be addressed in this study. The other factors: cognitive diversity, age and gender, and business image/self-image of the decision maker will be excluded. These factors will be omitted to keep the proposed DSS as generic as possible.

A detailed review of the factors that influence the business environment of the enterprise are included in the external company characteristics category. The influence of competition on the decision-making process are emphasised. A discussion of business strategies, focusing on what is meant by a business strategy, and specifically agriculture diversification strategies, followed the strategic decision-making review.

Literature regarding decision support systems were then reviewed (Section 3.3). More specifically, the purpose and usefulness of a DSS was highlighted. To address the limitation of a lack of transparency that concerns the usefulness of a DSS as stipulated in Section 3.3, it is important that a literature review is conducted, valid sources are used with regards to data collection, and that the proposed DSS is validated to ensure transparency. The methods that are used to select land use alternatives for the proposed DSS, need to be clearly stated to provide more transparency. The proposed DSS needs to be designed in such a manner that flexibility is incorporated into it to address the limitation of inflexibility that was mentioned in Section 3.3. Validation is also important to assess whether the data and outcomes obtained by using the proposed DSS, align with the agriculture expert. Thus it addresses a further limitation that was set out in Section 3.3 of the literature study.

After reviewing literature concerning the ten-step iterative process (Section 3.3), it came to light that it is important to know what the purpose of the model is to ensure that the design requirements and the purpose of the proposed DSS are aligned, and to understand what data needs to be gathered and incorporated into the model to reduce data redundancy. The ten-step iterative process further indicated the importance of providing the logic of the proposed DSS to conceptualise how it will work after it has been designed. Thus the logic of the DSS needs to be mapped before designing the proposed DSS. Furthermore, step four pointed out that it is important to include adequate model features into the design of the proposed DSS. Features that can promote user acceptance and ease of use, can for example, include a button. It is important to review each of the identified considerations prior to developing the proposed DSS to establish whether some can be excluded due to factors such as scope, practicality, or maintaining a generic form. The eighth step of the ten-step iterative process should be incorporated into the proposed DSS to evaluate whether the interactions and outcomes of the developed model are appropriate and in line with its objectives and requirements. The ten-step iterative process points out the importance of quantifying uncertainties. This will be addressed by outlining the scope – both the limitations and delimitations – of the research study. The last step of the ten-step iteration process that needs to be included in the research study, is concerned with evaluating and/or testing the developed DSS. The research outlines that data that was not used during the development process – external data – needs to be used to validate the developed model during this process.

Furthermore, the chapter also highlighted where DSSs are used in agriculture and concluded with a section that revolves around different types of DSSs that can be found in the agriculture section. It was found after reviewing literature regarding DSSs in agriculture (Section 3.4) that these DSSs only focussed on certain aspects and not the farm practice as a whole, when considering which crops should be selected. These DSSs will, for example, focus on climate, but exclude manpower aspects. The purpose of the proposed model is to take into account different aspects when determining which crops would be best for a specified environment. Thus, a holistic set of considerations that will evaluate land use alternatives needs to be developed and incorporated into the model.

This chapter thus contributes to achieving the following research objectives as illustrated in Table 3.

Table 3: Chapter three research objectives and outcomes

Research objective	Section	Outcome
Review the key concepts in strategic decision-making	Section 3.1	The key concepts of strategic decision-making were reviewed.
Determine strategic decision-making characteristics	Section 3.1	The key characteristics have been determined.
Establish a relationship between strategic decision-making and land use alternative decision-making.	Section 3.1	A correlation between strategic decision-making and the choice regarding which land use alternative should be adopted, were established.
Identify the core factors that influence the strategic decision-making process.	Section 3.1	Core factors that form part of the strategic decision-making characteristic were identified.
Review the literature to understand what is meant by the term decision support system and what it can be used for.	Section 3.2	Research was done and literature reviewed to establish what is meant by referring to a DSS and to establish what the purpose of a DSS is.
Understand what is meant by the term business strategy and which strategy this study will focus on.	Section 3.2	Research was done to determine what is meant by the term business strategy, specifically with the term agricultural diversification which is subsequently the business strategy that this study will focus on.
Understand how a DSS can be used in this study	Section 3.4	Literature was reviewed to get a clear understanding of what the purpose of a DSS is and how it can be utilised in the agriculture sector. Furthermore, it was found that a DSS can be used to allocate resources efficiently and that it can thus be used in this study to provide guidance in a strategic manner to decision makers when they are considering adopting a land use alternative.

Research objective	Section	Outcome
Review the literature to establish what the applicability of decision support tools in the agriculture sector is.	Section 3.4	Literature was reviewed to establish how DSSs can be used in the agriculture sector.

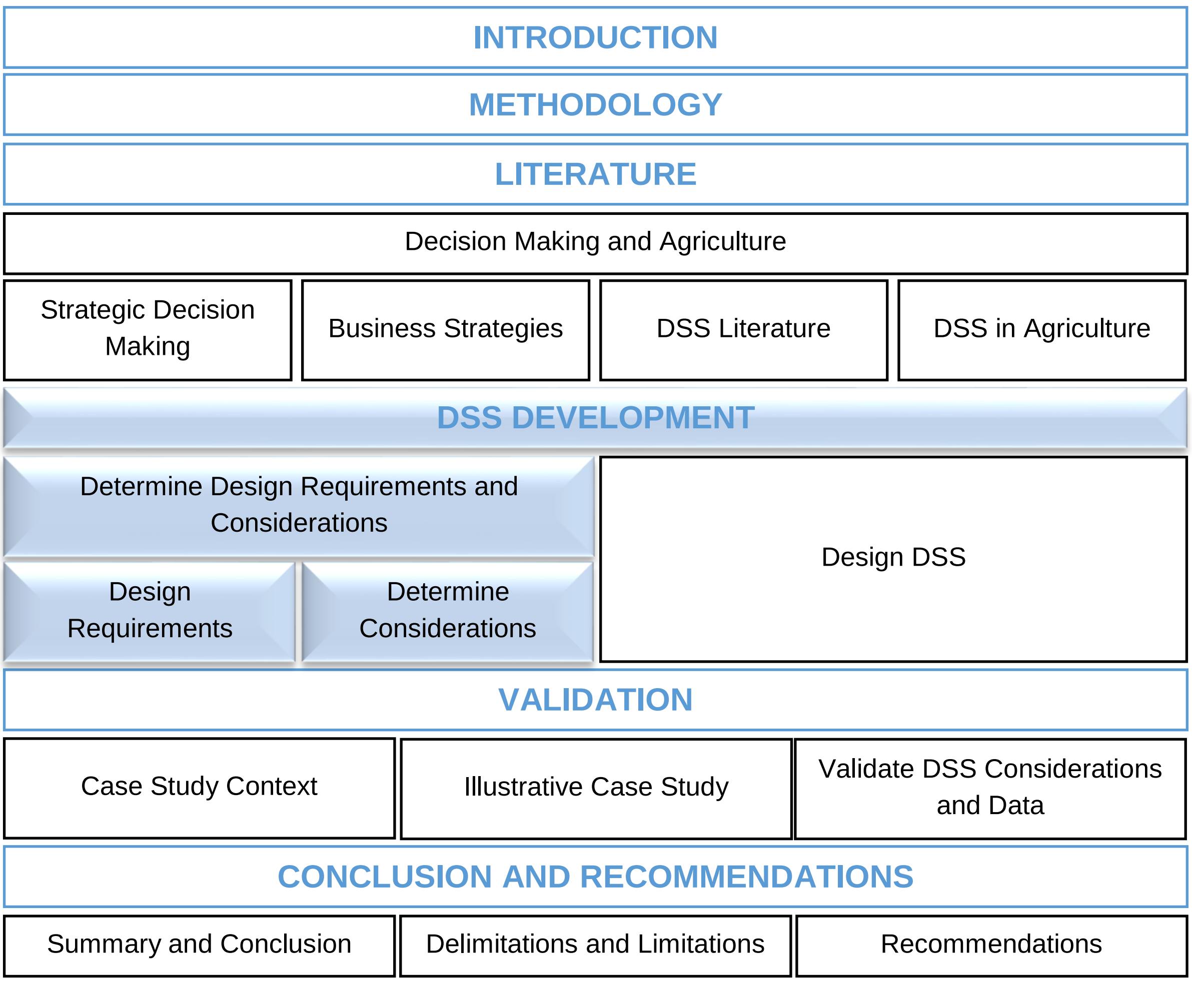
4

DETERMINE CONSIDERATIONS & DESIGN REQUIREMENTS

4. DETERMINE DESIGN REQUIREMENTS AND CONSIDERATIONS

The aim of this chapter is to develop design requirements to identify a set of considerations. The different design requirements that will be developed and highlighted need to be included in the proposed DSS. After reviewing literature in Chapter 3, it was found that it is important that the developed set of considerations is holistic – to take the whole farming operation into consideration and not just focus on one or two aspects. The considerations, as mentioned before, will be used to assist decision makers when deciding which land use alternatives are best suited for a specified region.

Design requirements that the proposed DSS needs to adhere to are outlined in Section 4.1. The considerations that will be used to evaluate different land use alternatives and therefore lend support to decision makers, are developed in Section 4.2. Section 4.3 will conclude this chapter.



4.1. DESIGN REQUIREMENTS

A design requirement is a functional need that a specific design, product, or process, requires to be able to perform its intended function. According to Dieter & Schmidt (2013) it is essential that a list of requirements are compiled to be able to establish the needs and wants of the product that are being designed. It is therefore important to know which design requirements are essential to a design – in this case the proposed DSS – to be able to incorporate the predefined design requirements in the design. Product development begins by determining what the needs are that a product must have – what the end user wants from the product. Dieter & Schmidt (2013) define a customer or end user as 'anyone who receives or uses what an individual or organisation produces'. Furthermore, from a design point of view, the design requirements include product performance, time to market, cost, and quality. The four design requirements are described as follows:

- Performance is concerned with what the design or product should do after completion and while in operation.
- The time dimension deals with time related aspects of the design. For many products, the first enterprise to market a great product, captures the market.
- Cost relates to all the monetary aspects of the design. This is a crucial aspect that needs to be considered. When similar products have similar requirements associated with them, the cost of a product or service influences most customers' decisions as to which product or service they are going to purchase.
- Quality, from a design point of view can be defined as 'the totality of features and characteristics of a product or a service that bear on its ability to satisfy stated or implied needs'.

Hartati & Sitanggang (2010) state that a DSS should be efficient, flexible, and effective because of the diversity and complexity of the selection considerations, their interrelationship, and the volume of information. The first step of the ten-step iterative proposes, refers to Section 3.3 of the literature review, which entails clarifying the purpose of the proposed mode, and the second step of this process is concerned with setting boundaries for the proposed model. The purpose of the DSS that will be developed in this study can be defined as: to help the decision maker to choose suitable crops in a flexible and user-friendly manner, by allowing the user to provide specified input values to fully explore the relationship between the considerations and the land use alternatives. The design requirements set out in this section therefore need to ensure that the purpose of the model is met and provide an accurate portrayal of the outputs of the proposed DSS. According to Rose et al. (2016), ease of use, performance (the tool usefulness and whether it works well), the cost associated with the DSS, trust (whether or not the tool is evidence based), IT education (whether the tool requires good IT skills to use), and habit (whether the tool matches closely with existing farming habits), are important factors that play a vital role when considering whether or not an end user will ultimately use a DSS. Furthermore, research has highlighted the importance of perceived usefulness, profitability, ease of use, updated information, and credibility (D. Kerr, 2004; McCown, 2002). Junier & Mostert (2014) have also emphasised that the instrument's efficiency (ease of use, fit for purpose) is critical to the success of a DSS.

The design requirements for the proposed DSS for this particular study, taking the above mentioned aspects into consideration, can thus be developed as follows:

1. The proposed DSS is required to inform the end user which possible land alternatives are viable, given specified input values.
2. The proposed DSS needs to tell the end user which of the alternatives he or she could possibly invest in.
3. Land availability: The proposed DSS should be able to evaluate whether there is enough land available for a particular land use alternative to be viable.
4. Practicality: The proposed DSS should be user-friendly and inexpensive. Furthermore, it should be accessible to a range of different farmers.
5. The proposed DSS should include a combination of viable factors (economic, environmental, labour related, pests/diseases) to evaluate the suitability of a land use alternative for a specified region.
6. The prospective DSS should be flexible, thus addressing the limitation regarding the use of DSSs, that was discussed in Section 3.3 of the literature study. It should also be efficient and effective.
7. Trust: the planned DSS should make use of accurate trustworthy data.
8. The risk associated with the different alternatives should be assessed.

4.2. IDENTIFYING SET OF CONSIDERATIONS FOR EVALUATING LAND USE ALTERNATIVES

The first step in the developing process of the proposed DSS as described in Chapter 2, is to identify a set of considerations that will provide assistance to farmers when they are considering adopting any of the possible land use alternative types. The set of developed considerations is not just confined to one aspect of the farming operation, such as land suitability or climate suitability, but it rather takes the farming business as a whole into account. Research done about each of the selected land use alternatives (Appendix C) was used to identify and establish the considerations. Inputs from experts (Refer to Appendix A: Experts for a description of the relevant expert) have also been used in some cases. The literature that was reviewed in Section 3.1 was used to support the importance of some of the identified set of considerations. The decision-making team's characteristic – risk inclination of the decision maker – that was found to influence strategic decision-making as discussed in Section 3.1.2 of the literature study, is incorporated into the DSS with the considerations 'markets' and 'diseases & pests'.

Figure 7 illustrates the considerations that were identified and established. Each of the identified considerations will be discussed, and references from literature will be provided to establish the relevance of each. To establish the considerations, relevant literature were firstly reviewed and analysed after which the researcher inductively identified considerations that were consider frequently. Subject matter experts were then consultant to further refine these conductive identified considerations to establish the final set of considerations as shown in Figure 7. The established considerations are used in the remainder of the DSS development procedure to compare the different selected land use options with one another per consideration.

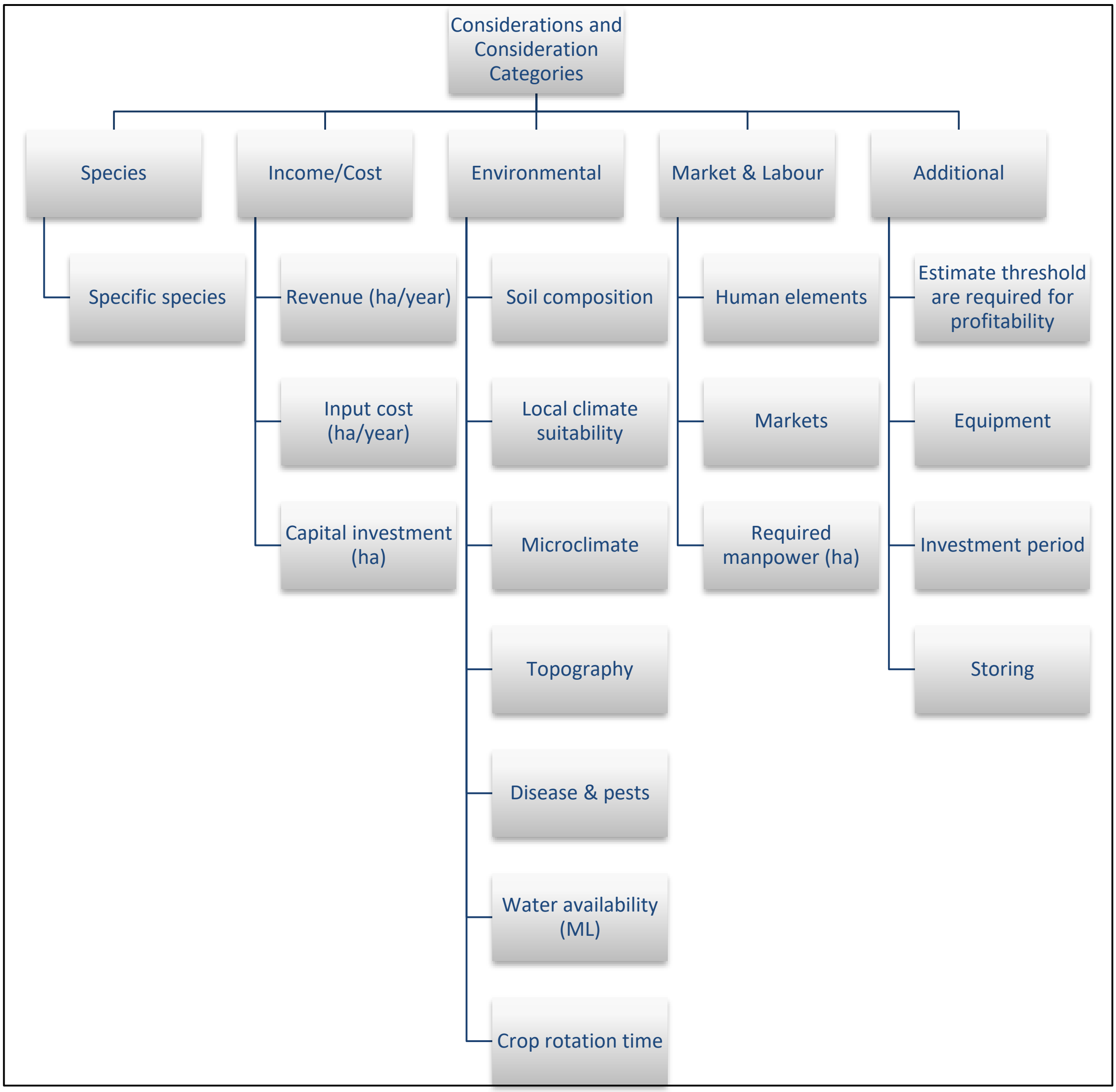


Figure 7: Identified Considerations and main Consideration Categories

The different identified considerations play a vital role in the viability of each of the various land use alternatives and are therefore important to review, prior to implementing any alternative in an intended region. Table 4 illustrates each of the established considerations, an accompanied explanation as well as justification from literature or an expert, showing why this specific consideration is deemed important.

Table 4: Considerations, Accompanying Explanation and Reference

Considerations	Explanation	Relevance /References
Specific species	Consider the specific species and which one would perform best in the intended region.	1. Wine composition p.15 (Bisson, 2001). 2. Factors influencing berry development and maturation p. 36 (Bisson, 2001). 3. Agronomic Principles: Soil Type and Management (YARA, 2016). 4. Dury, Schaller, Garcia, Reynaud, & Bergez (2012) argue that choosing the correct alternative is the primary land use decision in farming.
Revenue **(per ha per year)**	The amount of revenue this species will make per hectare per year.	1. Revenue is an important Key Performance Indicator (KPI) to evaluate the growth or decline of the business (PwC, 2007). 2. Revenue is crucial to assess whether the business operation is profitable or not (du Toit, 2016) 3. Dury, Schaller, Garcia, Reynaud, & Bergez (2012) argue in their article 'Models to support cropping plan and crop rotation decisions. A review', that it is generally commonly accepted that 'cropping systems must generate incomes for farmers'. 4. Thomas & Evanson (1987) argue that financial performance is the driving force behind profitability and efficiency of an operation.
Capital Investment	The amount of money invested to acquire capital or fixed assets such as machinery.	1. To make sure that the capital invested are allocated in the most effective manner to warrant that the best possible return is obtained (Capital Investment, 2016).
Input Cost **(per hectare per year)**	What is the total input cost per hectare per year?	1. Important to know the input cost, to evaluate whether the specific endeavour is worthwhile or not (du Toit, 2016).

Considerations	Explanation	Relevance /References
Soil Composition	Evaluate the soil composition, e.g. the acidity levels to determine whether the soil is adequate for the specific strategy type.	1. The concept of terroir and wine quality p.10. (Bisson, 2001). 2. Wine composition p.15 (Bisson, 2001) 3. Grapevine Performance p.29 (Bisson, 2001). 4. Chapter 3: Soil and Cultural practices p.36 (Dugo & Di Giacomo, 2015). 5. Agronomic Principles: Soil Type and Management (YARA, 2016). 6. Expert HE1 (2016) believes soil composition plays an important role when evaluating the suitability of a species for a specific region. 7. It is important that a thorough study should be made of the soil conditions when establishing a vineyard (WOSA, 2016b).
Local climate suitability	Whether this specific type of alternative will flourish in the climate type of the region, e.g. taking the temperature, rainfall, and sunlight into consideration.	1. The concept of terroir and wine quality p.10. (Bisson, 2001). 2. Wine composition p.15 (Bisson, 2001). 3. Grapevine Biology p.21 (Bisson, 2001). 4. Grapevine Performance p.29 (Bisson, 2001). 5. Factors influencing berry development and maturation p. 36 (Bisson, 2001). 6. Agronomic Principles: Climatic Zone (YARA, 2016). 7. Protea: Climatic and soil requirements (Department of Agriculture Forestry and Fisheries, 2008b). 8. The climate of a region, per expert HE1 (2016), is the most important factor to consider when investigating the viability of a species for a region. 9. It is important that a thorough study be made of the climatic conditions when establishing a vineyard (WOSA, 2016b).
Microclimate	Considering the micro climate of the area where the specific species will be planted.	1. Wine composition p.15 (Bisson, 2001). 2. Grapevine Performance p.29 (Bisson, 2001).
Topography	Evaluating and taking into account the valley floor and hillsides where the specific type of species will grow.	1. The concept of terroir and wine quality p.10. (Bisson, 2001). 2. Grapevine Performance p.29 (Bisson, 2001).

Considerations	Explanation	Relevance /References
Disease & Pests	What disease and pests are known to attack the specific type of species and what can be done to prevent these diseases and attacks?	1. Wine composition p.15 (Bisson, 2001). 2. Grapevine Biology p.21 (Bisson, 2001). 3. Grapevine Performance p.29 (Bisson, 2001). 4. Chapter 4: Pests and Diseases p.49 (Dugo & Di Giacomo, 2015). 5. Agronomic Principles: Crop Protection (YARA, 2016). 6. Nooraie (2012) states that strategic decisions and the strategic decision-making process should adjust to possible potential threats and other environmental characteristics within the functioning domain of the enterprise.
Water Availability (kilolitre per hectare per year)	How much water does this specific type of alternative require to survive?	1. Grapevine Biology p.21 (Bisson, 2001). 2. Chapter 3: Soil and Cultural practices p.43 (Dugo & Di Giacomo, 2015). 3. Agronomic Principles: Water Management (YARA, 2016). 4. Protea: Climatic and soil requirements (Department of Agriculture Forestry and Fisheries, 2008b). 5. Nooraie (2012) states that strategic decisions and the strategic decision-making process should adjust to possible constraints and other environmental characteristics within the functioning domain of the enterprise – water availability being a possible constraint.
Human Element	What amount of training/skill does the workers require to be able to perform their duties? This will be evaluated on a scale of: • **Low Skilled Staff** No or very little knowledge. • **Medium Skilled Staff** Some skills/training required for workers to perform their duties. • **High Skilled Staff** Workers require a lot of training/skills to be able to perform their duties.	1. Grapevine Performance p.29 (Bisson, 2001). 2. Chapter 3: Soil and Cultural practices p.45 (Dugo & Di Giacomo, 2015).

Considerations	Explanation	Relevance /References
Markets	Who is the target market? How stable is the land use option in terms of price and production quantities?	1. Chapter 23: The market of citrus oils around the world p. 532 (Dugo & Di Giacomo, 2015). 2. It is important to know who your target market is, and whether there exists a need to produce a specific product, prior to considering the product for cultivating purposes (van den Berg, 2016).
Required manpower (per ha)	The number of employees required to successfully complete the work.	1. Decision to Harvest p. 61 (Bisson, 2001).
Estimated threshold area required for profitability	What is the minimum number of hectare required for this specific strategy type to be profitable?	It is important to know what amount of land is required for the operation to be profitable. This is the minimum amount required to make a profit when the land use option is the only source of income. There is a minimum to sustain certain overheads related to a species themselves. Thus, if specific equipment is required for a particular species, the species need to cover the complete cost for that overhead. Furthermore, there is a portion of the farm overheads that needs to be covered. For this one can for example attribute 30% of the overheads if the specific species uses 30% of the available hectares.
Equipment	The extent to which mechanisation is used. This will be evaluated based on the following categories: • No equipment, manpower only • 20% equipment, 80% manpower • 40% equipment, 60% manpower • 50% equipment, 50% manpower • 60% equipment, 40% manpower • 80% equipment, 20% manpower • 100% equipment, no manpower – business is 100% mechanised	1. Harvesting Options p.66 (Bisson, 2001).

Considerations	Explanation	Relevance /References
Investment Period	How much time is required before the species can be harvested for the first time?	1. Chapter 23: The market of citrus oils around the world p. 532 (Dugo & Di Giacomo, 2015).
Storing	How will the product be stored? What facilities will be needed to store the product?	1. Decision to Harvest p. 60 (Bisson, 2001).
Crop rotation time	How often (in years) should a different crop be planted in the same field?	1. Crop rotation lead to greater overall production (Thierfelder & Wall, 2011). 2. Effective disease management tool (Monsanto, 2014). 3. Used to reduce pests (Thierfelder & Wall, 2011). 4. Increase soil fertility ("Why crop rotation is important," 2012). 5. Dury et al. (2012) state that concerning crop rotation, 'decisions are critical because they modify farm productivity and profitability'.

4.3. CHAPTER CONCLUSION

Each of the design requirements that has been developed and highlighted in Section 4.1 will be merged into the proposed DSS in the design chapter, Chapter 5. The set of considerations that were identified in the second part of this chapter, Section 4.2, will be used throughout the DSS. The considerations that have been developed in this chapter can provide support to farmers in the decision-making process when a land use alternative is considered.

Ensuring that the design requirements that were developed in Section 4.1 align with the purpose of DSS, satisfy the first step of the ten-step iterative proposes, as discussed in Section 3.3 of the literature review. The first, second, and sixth design requirement (Section 4.1) comply to the second step of the ten-step iterative process (refer to Section 3.3). This step of the process is concerned with portraying the outputs of the DSS, setting boundaries and incorporating flexibility into the model.

Formulating design requirement six, ensures that flexibility is incorporated into the prospective DSS. This was an important aspect to include after reviewing literature regarding possible limitations concerning the use of DSSs (Section 3.3).

The research that was done as part of the literature study in Section 3.3 confirmed selecting and including features into the model. The fourth design requirement that ensures that the proposed DSS is designed in a practical and user-friendly manner, follows the fourth step of the ten-step iterative process.

In addition, the considerations are not just tailored for the Stellenbosch region, and can therefore be used in other regions as well. This chapter therefore contributes in achieving the following research objectives as illustrated in Table 5 and outlined in Section 1.4.

Table 5: Chapter four research objectives and outcomes

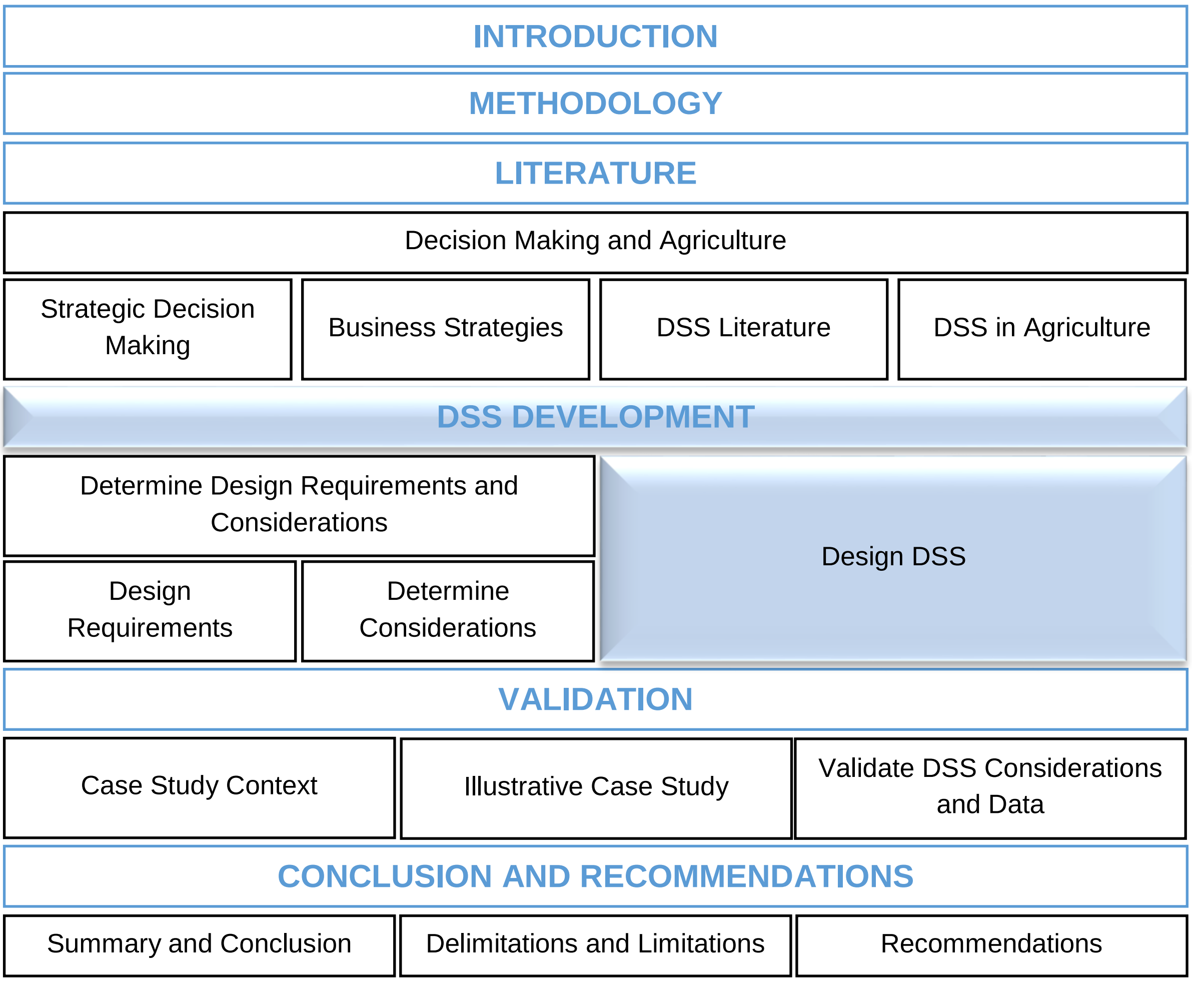
Research Objective	Section	Outcome
1. Develop the design requirements of the proposed DSS	Section 4.1	Design requirements were developed after reviewing literature regarding what are important factors to be included in a DSS to warrant its success.
2. Develop a set of considerations that needs to be considered when any land use alternative type is reviewed	Section 4.2	Inputs from experts as well as literature were used to develop a set of considerations to provide support to a farmer when a land use alternative type is considered.

5

DESIGN DECISION SUPPORT SYSTEM

5. DESIGN DECISION SUPPORT SYSTEM

This chapter employs the literature discussed in Chapter 3 as a foundation to design the proposed DSS in accordance with the design requirements as outlined in Chapter 4. Each of the design requirements are reviewed to ensure that they are incorporated into the proposed DSS. Firstly, the logic of the DSS as well as that of the VBA code are explained in Section 5.1. This is done by making use of process flow diagrams. The data requirements of the DSS and the DSS extension model is provided in Section 5.2. Section 5.3 serves to inform the user of how the overall components of the DSS fit together. A process flow diagram is once again used. After the logic and overview of how the components of the proposed DSS have been outlined, the DSS is developed in Section 5.4. The DSS is described and an explanation of how each of the various design requirements are addressed, is be provided.



5.1. DSS LOGIC

The aim of this section is to clarify the logical pattern behind the DSS, thus informing the reader how the DSS works. After reviewing literature it was established that this is an important step to follow to conceptualise how the proposed DSS will function – refer to the third step of the ten-step iterative process that was described in Section 3.3 of the literature study. The logic of the DSS is described by utilising process flow diagrams with accompanying explanations. The first process flow diagram, Figure 8, provides an overall picture of how the DSS works. It illustrates which information is used and what the DSS accomplishes.

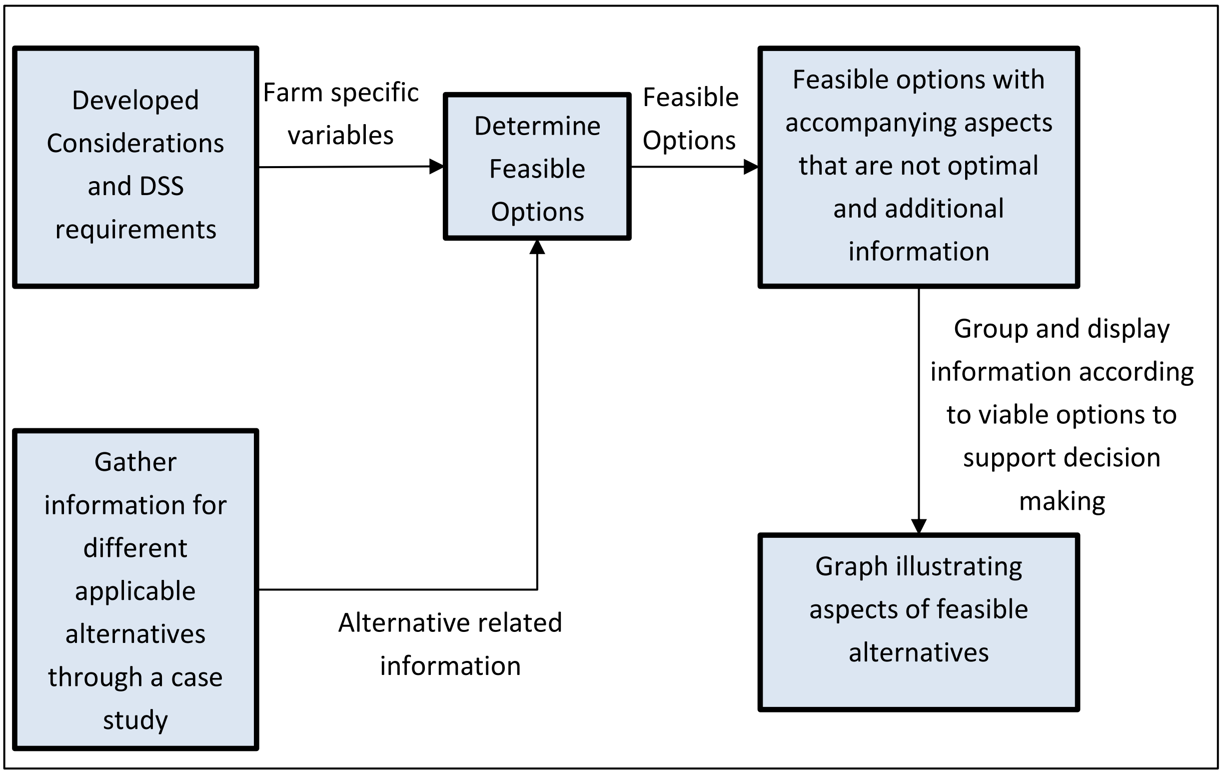


Figure 8: Overall process flow of DSS

Figure 9 illustrates the process flow of the extended model. The extended model utilises the viable options obtained from the DSS as illustrated in Figure 8 together with specified user input. The user can provide the amount of land he or she wants for each of the viable options. Estimate threshold area required for profitability was not taken into account in the extended model as it is a combination of alternatives that will generate multiple revenue streams. Corresponding values of each of the other relative input values are then determined, based on the required provided hectares. A decision maker can thus determine the implications, e.g. cost, for specified hectares, as well as the total of a selected combination of options that he/she wants. The excel formulas that the extension of the DSS model use to populate data, is illustrated in Appendix H: Extension of DSS.

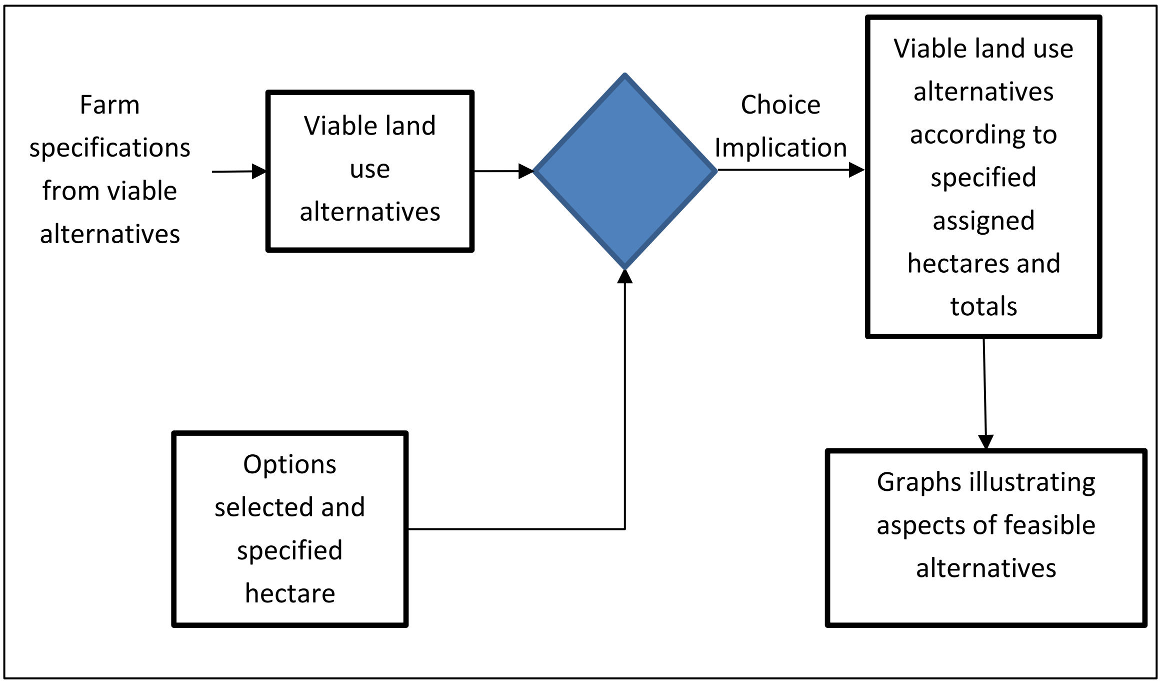
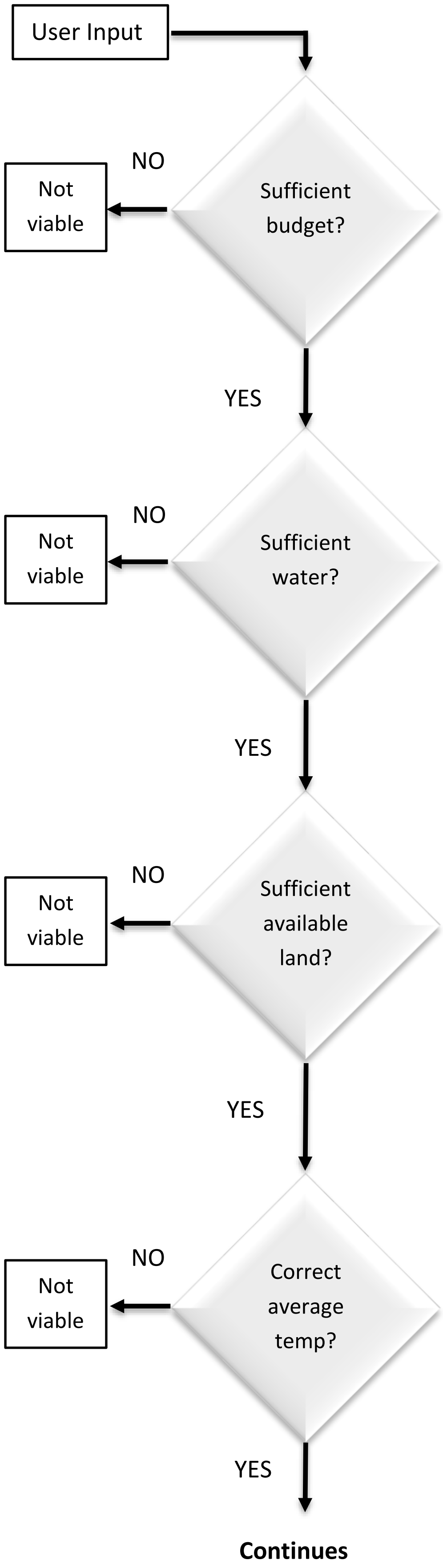


Figure 9: DSS extension process flow

The main purpose of the first developed model is to give a decision maker viable land use alternatives that could be adopted according to the user's input data. The information that the researcher gathered to populate the data sheet, together with the set of developed considerations of Section 4.2 will form part of the design of the model. The decision maker is required to provide and fill in data for each of the developed consideration. The DSS will be designed in such a way that there would be a well-marked space where a decision maker needs to fill in the data. In doing so, the user will tailor the model and as a result the possible viable options that the model provide, according to the provided input data. The extended model's purpose is to evaluate how the parameters will change when a decision maker change the hectares assigned to each of the possible land use alternatives that the first model generated. Thus, providing the decision maker with a combined profile of the possible alternatives. Because it is a choice that the user needs to make, the user will have to assign the number of hectares to each of the viable options obtained from the first model. Therefore, for the extended mode, the only data that the user needs to provide is the assigned hectares.

The two process flow diagrams that follow, explain in detail how the DSS evaluated each of the determined considerations. These process flow diagrams explain each input consideration in a systematic way.

Process Flow Diagram



Description

Check for first critical consideration. Is the total budget provided by the user sufficient to cover the total input cost and capital investment required for a specific land use alternative. The code also takes the required land that an alternative requires into account to determine whether sufficient funds are available, based on one unit of required land.

VBA code responsible:

```
If userInput(1) < (criteria(i, 1) + criteria(i, 3)) * criteria(i, 8) Then
```

Check remaining viable alternatives for second critical consideration. Is the total amount of water available in a specific area, as provided by the end user, sufficient for a particular land use alternative.

VBA code responsible:

```
ElseIf userInput(4) < criteria(i, 6) Then 'water requirement checked for remaining viable options'
    criteria(i, 22) = 2  'not viable'
```

Check remaining viable alternatives for third critical consideration. Is the amount of land available in a specific area, as provided by the end user, sufficient for a particular land use alternative. This is the minimum amount of land that an alternative requires for it to be viable. Based on one unit of required land.

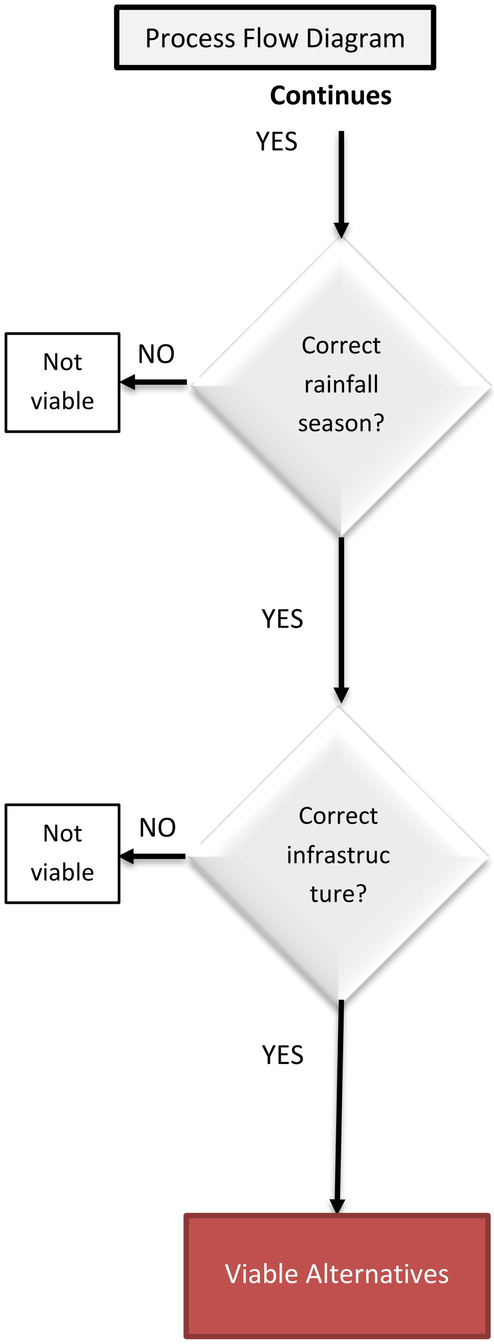
VBA code responsible:

```
ElseIf userInput(6) < criteria(i, 8) Then 'land requirement checked for remaining viable options'
    criteria(i, 22) = 2 'not viable'
```

Check remaining viable alternatives for fourth critical consideration. To assess whether the coldest month of a particular area has a sufficient average minimum temperature. This is only valid for citrus cultivars. The VBA code thus firstly see whether a citrus alternative is a viable option at this stage and then whether or not the user input adhere to the requirements.

VBA code responsible:

```
For i = 2 To 4
  If criteria(i, 22) = 1 Then 'only check if still a viable option'
    If criteria(i, 4) > userInput(2) Then
      criteria(i, 22) = 2 'not viable'
```



Description

Check remaining viable alternatives for fifth critical consideration. To assess whether a particular farm lies in the correct rainfall season for a particular land use alternative. This is only valid for the grape cultivar. The VBA thus first determines whether the grape cultivar alternative is still a valid option before assessing whether the user input adheres to the requirements.

VBA code responsible:

```
If userInput(9) <> criteria(1, 11) Then
```

Check remaining viable alternatives for sixth critical consideration. To determine if the end user has access to required infrastructures, e.g. packing stores or a wine cellar. The code once again sees whether relevant alternatives are still viable before measuring the user input against the requirements.

VBA code responsible:

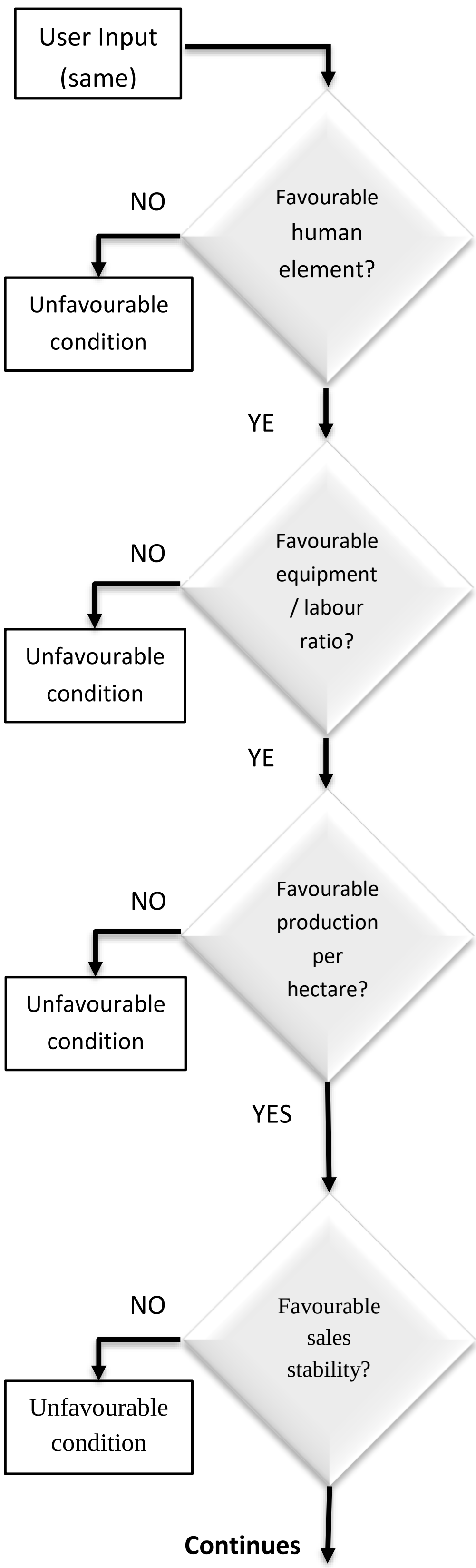
```
    ElseIf userInput(12) <> criteria(1, 15) Then
        criteria(1, 22) = 2 'not viable'
For i = 2 To 6
    If criteria(i, 22) = 1 Then 'only check if still a viable option'
        If userInput(11) <> criteria(i, 14) Then
            criteria(i, 22) = 2 'not viable'
```

Viable land use alternatives that adhere to all the critical considerations have been determined. These alternatives will be displayed, but the VBA program will also first check for favourable condition considerations before alternatives are displayed.

The above process flow diagram deals with all the critical considerations that have been discussed in Section 5.1. The following process flow diagram deals with the favourable condition considerations. The VBA program will not discard an alternative if the alternative does not adhere to a favourable condition consideration, because circumstances can be manipulated so that an alternative is still viable in an intended region. However, these considerations are still important to consider. Manipulation of circumstances requires extra inputs such as knowledge and it may be expensive. The process flow diagram that regards the favourable condition considerations is a continuous build up from the previous process flow diagram that dealt with the critical considerations.

It thus takes into consideration the alternatives that's still viable after the user inputs for the critical considerations have been compared to the requirements of the alternatives.

Process Flow Diagram



Description

VBA considers only the viable alternatives (following the process as shown in previous process flow diagram) using the same input data as before.

To determine whether the human element consideration is a favourable or unfavourable condition for a specified alternative.

VBA code responsible:

If userInput(5) < criteria(i, 7) Then *'Human requirement'*

unfav(i) = unfav(i) + 1

To determine whether the correct equipment/labour ratio consideration is a favourable or unfavourable condition for a specific alternative.

VBA code responsible:

If userInput(8) < criteria(i, 10) Then *'equipment requirement'*

unfav(i) = unfav(i) + 1

To determine whether the specified production per hectare is a favourable or unfavourable consideration condition for a specific alternative.

VBA code responsible:

If userInput(10) = 1 And criteria(i, 12) > 4 Then *'production per hectare requirement given and option in lower half of stability ranking'*

unfav(i) = unfav(i) + 1

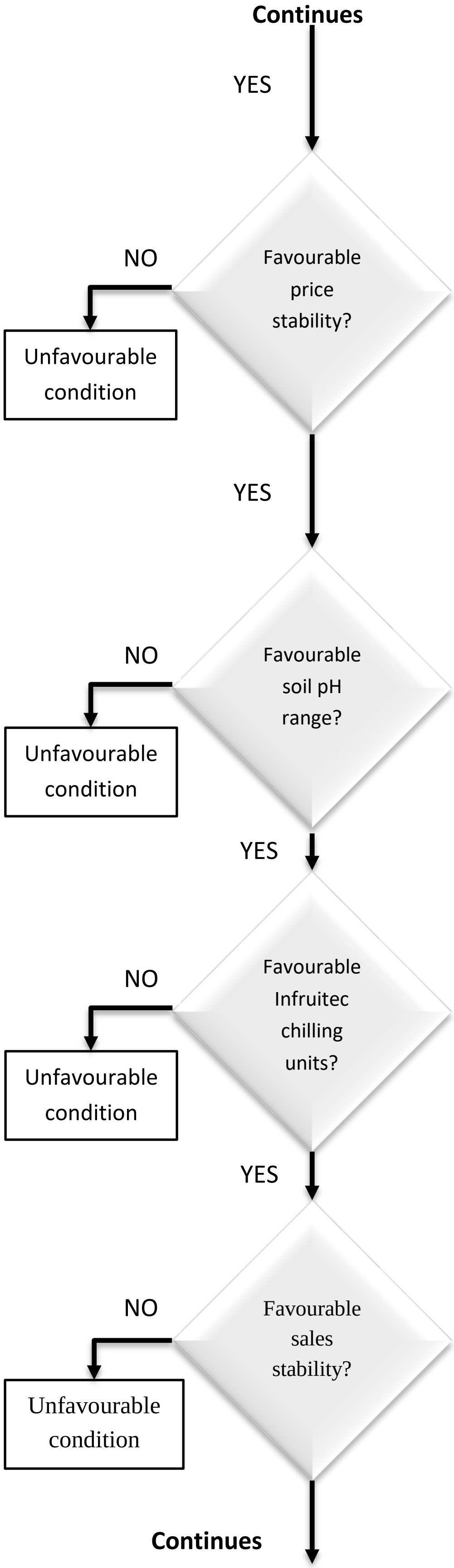
To determine whether the sales requirement consideration is a favourable or unfavourable condition according to the user input for a specific alternative.

VBA code responsible:

If userInput(17) = 1 And criteriaAdditional(i, 1) > 4 Then *'sales stability requirement givenand option in lower half of stability ranking'*

unfav(i) = unfav(i) + 1

Process Flow Diagram



Description

To determine whether the price requirement consideration is a favourable or unfavourable condition according to the user input for a specific alternative.

VBA code responsible:

If userInput(18) = 1 And criteriaAdditional(i, 2) > 3 Then *'price stability requirement given and option in lower two-thirds of stability ranking'*

    unfav(i) = unfav(i) + 1

ElseIf userInput(18) = 2 And criteriaAdditional(i, 2) > 5 Then *'price stability requirement given and option in lower third of stability ranking'*

    unfav(i) = unfav(i) + 1

To determine whether the specified soil pH range is a favourable or unfavourable consideration condition for a specific alternative.

VBA code responsible:

If userInput(13) < criteria(i, 16) Or userInput(14) > criteria(i, 17) Then *'soil pH range required'*

    unfav(i) = unfav(i) + 1

To determine whether a region has an adequate number of Infruitec chilling units for relevant viable alternatives.

VBA code responsible:

If userInput(3) < criteria(i, 5) Then

    unfav(i) = unfav(i) + 1

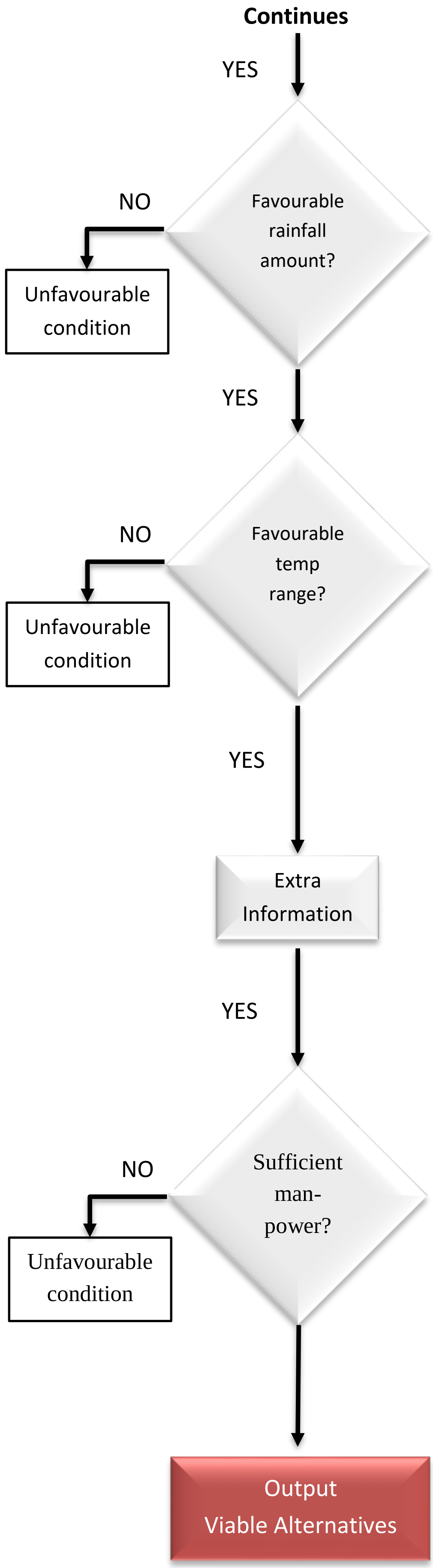
To determine whether the sales requirement consideration is a favourable or unfavourable condition according to the user input for a specific alternative.

VBA code responsible:

If userInput(17) = 1 And criteriaAdditional(i, 1) > 4 Then *'sales stability requirement givenand option in lower half of stability ranking'*

    unfav(i) = unfav(i) + 1

Process Flow Diagram



Description

To determine whether a region receives a favourable or unfavourable amount of rainfall per season for relevant viable alternatives.

VBA code responsible:

```
If userInput(14) < criteria(i, 18) Or userInput(14) > criteria(i, 19) Then
        unfav(i) = unfav(i) + 1
If userInput(14) < criteria(i, 18) Or userInput(14) > criteria(i, 19) Then
```

To determine whether a region's temperature range is favourable or unfavourable for appropriate viable alternatives.

VBA code responsible:

```
If userInput(15) < criteria(i, 20) Then 'lower limit breached'
        unfav(i) = unfav(i) + 1
End If
If userInput(16) > criteria(i, 21) Then 'upper limit breached'
        unfav(i) = unfav(i) + 1
```

Add extra informative information for each of the viable alternatives. Extra information is information that the user has no control over which includes the gross income, minimum investment period, harvest month, crop rotation time, main risks, known fungi/diseases, and the known pests. The VBA program reads the relative information for the additional information directly from the data sheet and prints it in its appropriate place.

Is the total amount of manpower available, as provided by the end user, sufficient for a particular land use alternative. The code once again takes the required land that an alternative requires into account to determine whether sufficient manpower is available, based on one unit of required land.

VBA code responsible:

```
If userInput(5) < criteria(i, 7) Then 'Human requirement
        unfav(i) = unfav(i) + 1
        unfavConditions(i, unfav(i)) =
Worksheets("User_Interface").Cells(8, "B").Value
    End If
```

Display viable options with appropriate extra information.

The viable land use alternatives are displayed next to one another with appropriate information for each of the considerations. Each possible viable alternative are compared to the provided user input. Thus if multiple viable alternatives are obtained, it does not mean the provided user input is adequate to cover all of them, but rather for each alternative respectively. For example, if two viable alternatives are obtained, it is not to say that the end user has enough funds (budget) available to implement both alternatives, but it does mean that the end user's budget covers each alternative separately.

The developed DSS can be used when a farmer wants to choose between different land use options and he has to understand which of the options are viable for a specified region. Some decision makers might prioritise certain non-critical (unfavourable condition considerations) over others, thus choosing a land use alternative for an intended region, even though the alternative has one or more unfavourable condition considerations attached to it. A decision maker might for example, choose to invest in plums even when the number of infruitec chilling hours in the intended region are too few for the specific species of plums, because this unfavourable condition can be manipulated.

5.2. DSS AND DSS EXTENSION DATA INPUT REQUIREMENTS

The developed DSS and DSS extension makes use of data to provide possible land use alternatives. The purpose of this subsection is to clearly outline the data inputs that the researcher provide and which data the end user of the model provides.

5.2.1. DEVELOPED DSS DATA REQUIREMENTS:

For this study the researcher conducted research and held interviews with experts in the agriculture field to populate the data tables that the DSS requires to function. The researcher used a step wise selection process to select a sample of land use alternatives for this study. The research and interviews with experts allowed the researcher to populate the data tables for each of the selected land use alternatives. The researcher also provided the annual local sales/exports, annual production, and price data for each of the land use alternatives that were selected for this study. The researcher further developed and provided the set of developed considerations, keys with accompanying meaning, and additional informative information which was included in the DSS.

The end user of the DSS has to provide specific user inputs for each of the considerations that are built into the developed DSS. It is important that the decision maker supplies this data so that the developed DSS can be tailored to that decision maker's farm/area.

5.2.2. DSS EXTENSION DATA REQUIREMENTS

The extended model developed in this study, depends on the developed DSS. The model uses the outputs and by implication the data of the DSS. However, the end user is required to provide the assigned hectares per possible displayed land use alternative that he or she wish. After the end user assigned hectares of his or her choice to each of the alternatives, the DSS extension is programmed to automatically provide the rest of the outputs and generate graphs that are in accordance to the user assigned hectares. The extended model gives the user a choice to manipulate the assigned hectares to realize the implication of doing so. For this reason it is important that it is the end user that assign the hectares to each of the possible displayed land use alternatives and not the researcher.

5.3. THE PROCESS FLOW OF THE DSS

The process flow of the model components is depicted in Figure 10. Each of the different components was discussed accordingly in Section 5.1. Figure 10 also provides a summary of the different components, and illustrates their interconnectivity with one another.

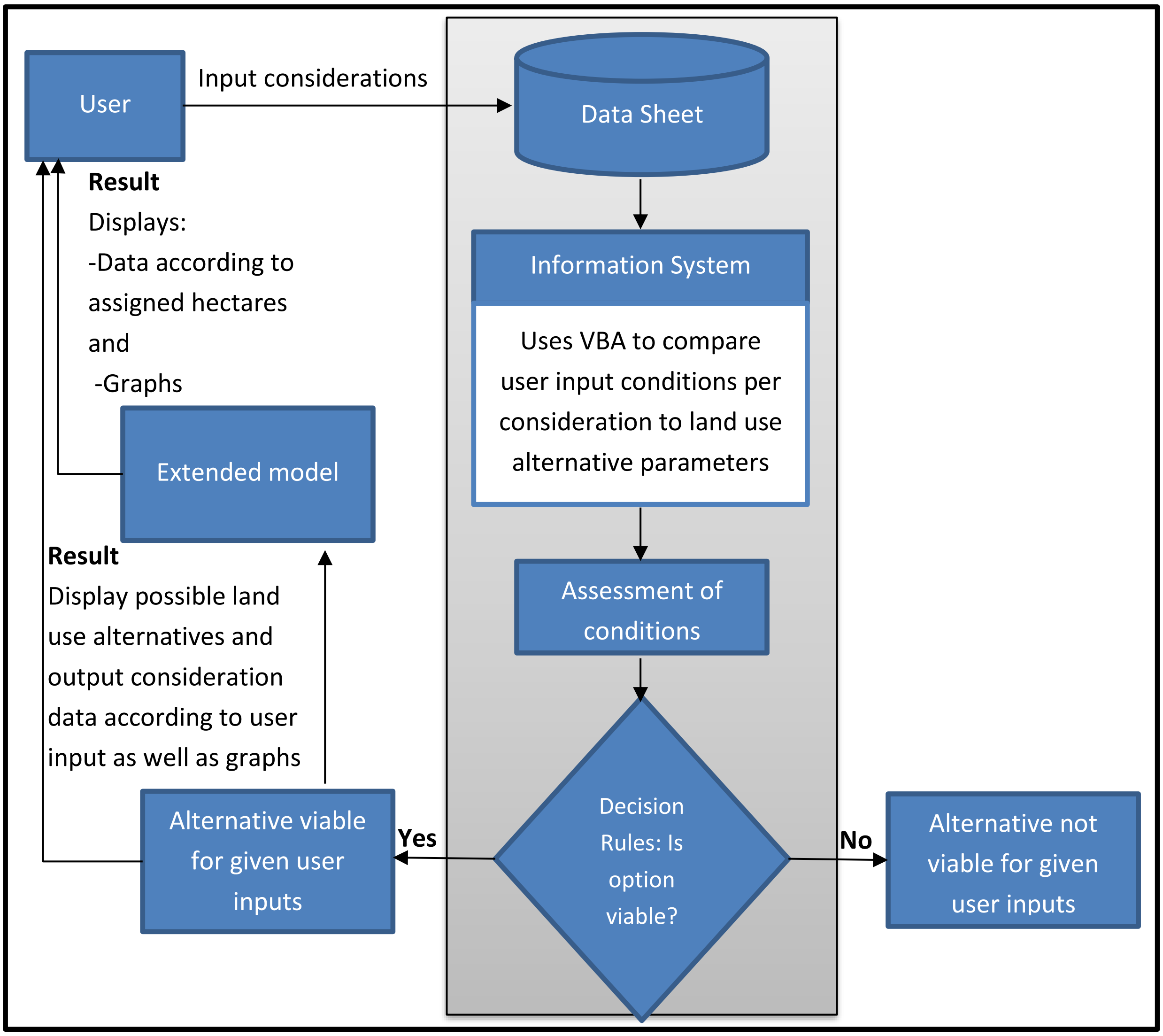


Figure 10: Process flow of components of DSS

5.4. DESIGNING THE PROPOSED DSS ACCORDING TO THE DESIGN REQUIREMENTS

As aforementioned, each of the design requirements that was identified in Section 4.1 will be addressed in this chapter. A recapitulation of each of the design requirements that was identified in Section 4.1 are illustrated in Table 6. The DSS is designed according to each of these identified requirements. An explanation of how each particular design requirement is addressed in the proposed DSS is provided.

Table 6: Design Requirement Number and Description identified in Chapter 4

Design Requirement Number	Description
One	The proposed DSS is required to inform the end user which possible land alternatives are viable – given specified input values, it should help evaluate the different options. It is important to state the purpose of the proposed DSS from the start (Jakeman et al., 2006).
Two	The proposed DSS needs to tell the end user which of the alternatives he or she could possibly invest in. Throughout the literature study arguments indicated how a DSS can support decision-makers with the decision-making process. The purpose of the DSS should be clearly defined (Jakeman et al., 2006). Financial performance is a key indicator when making a decision according to Thomas & Evanson (1987).
Three	Land availability: The proposed DSS should be able to evaluate whether there is enough land available for a particular land use alternative to be viable. An inductive requirement.
Four	Practicality: The proposed DSS should be user-friendly and inexpensive. Furthermore, it should be accessible to a range of different farmers. Junier & Mostert (2014) and Jakeman et al. (2006) argue that ease of use of the DSS is a fundamental compenent (Section 3.3).
Five	The proposed DSS should include a combination of viable factors (economic, environmental, labour related, pests/diseases) to evaluate the suitability of a land use alternative for a specified region (Jakeman et al.,2006).

Design Requirement Number	Description
Six	The prospective DSS should be flexible, efficient, and effective. Junier & Mostert (2014) and Jakeman et al. (2006) states that flexibility, efficiency, and effectiveness are critical components that need to be incorporated into the developed DSS.
Seven	Trust: the planned DSS should make use of accurate trustworthy data. Junier & Mostert (2014) and McNie (2007) argue that trust in the outcome of the tool is an important factor (Section 3.3).
Eight	The risk associated with the different alternatives should be assessed. Wally & Baum (1994) and Masomi & Ghayekhloo (2011) indicated the effect of risk on the decision making process (Section 3.1.2).

5.4.1. DESIGN REQUIREMENT ONE

Firstly, a matrix was created which used the considerations in combination with the different land use alternative types to generate a data sheet as shown in Figure 11. To adhere to this requirement, the researcher will gather information regarding each of the identified considerations of Section 4.2. The information will be used to populate the data sheet illustrated in Figure 11. A VBA program will compare the gathered information with specified user input per consideration to evaluate whether or not a land use alternative is viable. Information for each agricultural crop that will be included in the proposed DSS, will be displayed in the different columns in Figure 11.

		Crop Alternative A	Crop Alternative B	Crop Alternative C	Crop Alternative D	Crop Alternative E
Land Use Alternative	Category					
	Type					
	Cultivar					
>=	Capital Investment (per hectare)					
	Input Cost (per hectare)					
	Average min temp of coldest month					
	Required minimum Infruitec Chilling units (hours)					
	Water Availability (kL/ha/year)					
	Human Element					
	Estimate threshold required for profitability (ha)					
	Required Manpower (per hectare)					
	Equipment					
<=	Rainfall Season Region (1 = winter, 2 = no					
	Markets-Production (Ranking in terms of stability)					
=	Packing store (1 required, 0 not)					
	Cellar					
Ranges	Soil Composition-pH level (lower boundary)					
	Soil Composition-pH level (upper boundary)					
	Local Climate Suitability-Rain (lower boundary)(mm)					
	Local Climate Suitability-Rain (upper boundary)(mm)					
	Local Climate Suitability-Temp (Lower boundary)(°C)					
	Local Climate Suitability Temp (Upper boundary)(°C)					
Extra info	Gross Income (per season per hectare)					
	Minimum investment period (years)					
	Harvest month (start)					
	Crop Rotation time					
	Main risks					
	Known diseases/fungi					
	Known pests					
	Harvest length (months)					
<=	Sales stability					
	Price stability					

Figure 11: Data sheet

5.4.2. DESIGN REQUIREMENT TWO

Thomas & Evanson (1987) state that financial performance is the driving force behind profitability and efficiency of an operation and this design requirements entail the DSS to inform the end user which of the alternatives he or she could possibly invest in. Therefore, input costs per hectare and capital investment per hectare vs gross income per hectare are evaluated for each of the land use alternatives and incorporated into the DSS model.

5.4.3. DESIGN REQUIREMENT THREE

Given this design requirement, one of the user input requirements that the user should provide, is the amount of available land that he or she has. This land availability is then compared to the consideration, 'estimate threshold area required for profitability', of each of the land use alternatives to determine whether or not there is enough land available for a land use alternative. 'Estimate threshold are required for profitability', refers to the minimum area required to make an alternative type viable.

5.4.4. DESIGN REQUIREMENT FOUR

To adhere to this design requirement, the proposed DSS was designed in excel to minimise cost associated with the design. A user interface, where a farmer can give desired inputs for certain of the considerations, also had to be created to ensure that the DSS is user-friendly, thereby using the fourth step of the ten-step iterative process as discussed in Section 3.3 of the literature review. It was thus important to divide the considerations that were developed in Section 4.2 into different categories. The considerations were divided based on whether a logical input from the user for the consideration could be given or not. The considerations for which a user could provide an input as well as the accompanying input keys can be seen in Figure 12. Two buttons, namely *Clear options* and *Determine viable options* were also added to the user interface to enhance practicality and user-friendliness of the DSS.

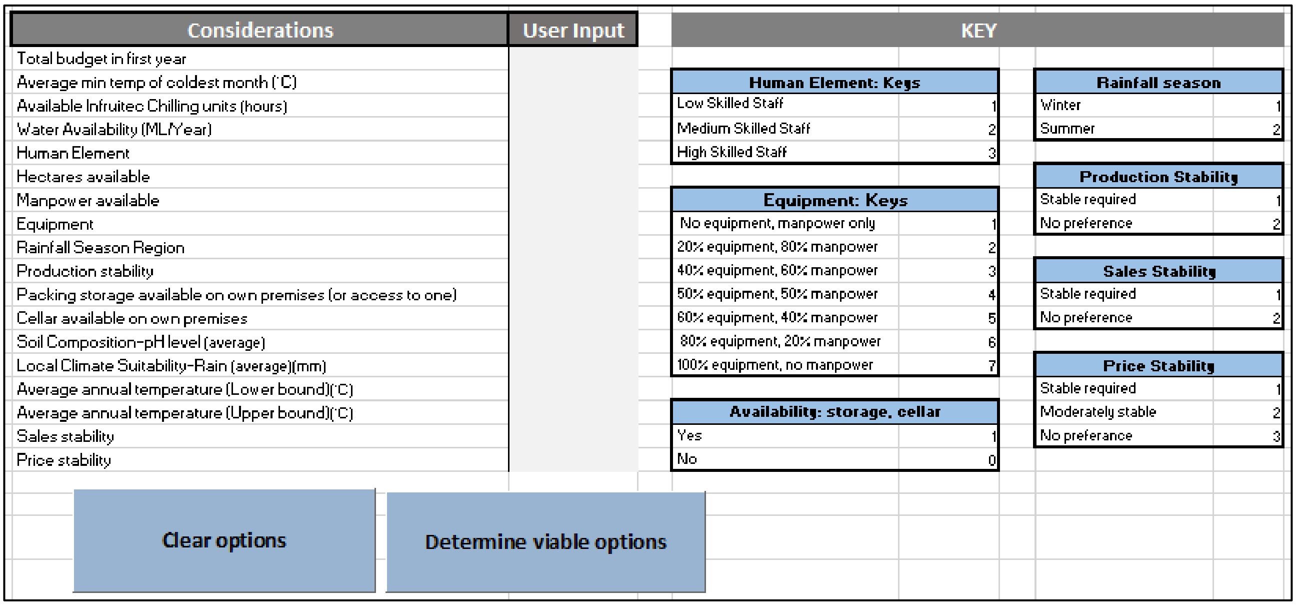


Figure 12: Considerations where user gives an input (left) accompanying user input keys (right)

The consideration '*Total budget in first year' = [the total input cost (per hectare/year) + Capital investment (per hectare)] times the '*estimate threshold area required for profitability'*. This consideration is the only consideration which is a combination of two previously identified considerations.*

5.4.5. DESIGN REQUIREMENT FIVE

Considerations of different factors including economic (gross income per hectare, input cost per hectare, capital investment per hectare), environmental (local climate suitability, soil composition, water availability), labour related (required manpower per hectare, human element), diseases and pests, as well as other factors such as markets, were included in the DSS. The different aforementioned considerations can be seen in Figure 11 and/or Figure 12. Note that some of the considerations seen in Figure 11 are phrased differently than in Figure 12. This is done on purpose to increase the user-practicality. For example the consideration *Required manpower per hectare* changed to *Manpower available*.

5.4.6. DESIGN REQUIREMENT SIX

To incorporate flexibility into the proposed DSS, the considerations were classified as critical or unfavourable. Furthermore some of the considerations were simply provided as additional information. A thorough description of each of the different types of considerations will follow. An extension of the DSS where the end user can manipulate and assign hectares to each of the viable options, was also developed to increase the flexibility. The VBA program is also efficient and effective in that after the user input has been provided, the user can simply press a well-marked button, illustrated in Figure 12, which will then in turn generate the different viable land use alternatives according to the specified information. When the user press the button, the VBA program is executed. The program reads and loops through the data and provides outputs according to the parameters that are built into the program. The decision-making team's characteristic – risk inclination of the decision maker – was found to influence strategic decision-making as discussed in Section 3.1.2 of the literature study and was incorporated into the DSS with the consideration *diseases & pests* and *markets* which is explained in Section 5.4.6.1. From the logical explanation of the detail workings of the DSS (Section 5.1), it can be seen that the DSS adhere to the sixth design requirement.

5.4.6.1. Critical considerations, unfavourable conditions, and extra information

The developed model used Visual Basic for Application (VBA) to search through the data sheet to compare the land use alternatives per consideration, according to input provided by the user. Certain of the considerations were classified as critical, which meant that a land use alternative was immediately discarded as a possible option if the user input violated the constrains of the consideration. An example of such a consideration is *Water Availability.* This consideration asks the user to provide the amount of water that he/she has available. If that amount is less than what a land use alternative requires, the alternative is discarded. The specific land use alternative type determines whether a consideration is classified as critical or not.

The considerations that were not classified as critical were labelled as unfavourable conditions, which means that the input provided by the user can violate the constrains of the considerations, but the VBA program would not discard the alternative type. The land use alternative types are not discarded for these cases, because not adhering to these constraints, does not mean that the alternative type is not suited for the region, but it simply means that the region does not provide optimal conditions. The type of land use alternative determined whether a consideration was classified as an 'unfavourable condition' consideration.

Considerations that the user had no control over such as the known diseases/fungi and pests that attack a certain alternative type, were simply given as supplementary information. Figure 13 illustrates the list of considerations that was given as additional information. These considerations are, however, still important to evaluate when considering any of the land use alternative types.

Figure 13: Considerations that were given as additional information in the model

Additional flexibility was built into the DSS with the consideration labelled as *markets*, seeing as this consideration has four different components that need to be evaluated. The four different components are: target market, sales stability, production per hectare, and price stability. The end-user has a choice regarding the latter three components. Since markets are classified as an unfavourable condition consideration, the VBA program will not discard an alternative type if the specified user input violates the constraints. The logic behind the DSS and thus the VBA program, as well as a scenario where a user would use the DSS, was explained in Section 5.1.

Target Market

The target market of each of the different land use alternative types is established firstly to be able to calculate the respective sales, production, and price stability. The target market of each of the alternative types was established during the illustrative case study in Chapter 7.

Sales Stability

A matrix was created which took into consideration each of the land use alternative types and annual local sales/exports over a specified time period. The data for each of alternatives that will be used in this matrix, depends on whether the target market is local or international. Only export data will be used if the target market is international, and only local sales data will be used if the target market is local. The annual local sales/exports matrix can be seen in Figure 14.

Crop information		Annual local sales/exports (in tons)					
Category	Type	2009	2010	2011	2012	2013	2014

Figure 14: Annual local sales/exports matrix

The average and standard deviation of each of the land use alternatives was calculated as shown in Figure 15, which will be used to calculate the sales stability of each in Chapter 7. If the standard deviation differed 10% or less from the average of the alternative, the researcher deemed the alternative as stable in terms of sales. The alternatives will also be ranked, based on their sale stability. This is done by dividing the standard deviation of each by its average value as shown in Figure 15. The smaller the calculated value obtained when dividing an alternative's standard deviation by its average value, the more stable an alternative. The sales stability will be incorporated into the DSS by asking the user whether he/she requires sales stability for the intended possible land use alternatives. If the user specifies that sales stability is required, the top half land alternatives based on their rank, will be considered as stable, while the bottom 50% will be considered as unstable.

Crop information		Stats			Rank	Stable
Category	Type	Average	Std Dev	Std Dev/Average	1 = most stable To 8 = least stable	<10%

Figure 15: Sales/export Stats, Rank, & Stability Matrix

Production per Hectare

Another matrix was created to establish production trends. This matrix combined each of the land use alternative types and annual production over a specified time period. The data for each of the alternatives that will be used in this matrix, – obtained from reports published by the Department of Agriculture Forestry and Fisheries and SAWIS – represents the total amounts produced per year.

Crop information		Annual production (in tons)					
Category	Type	2009	2010	2011	2012	2013	2014

Figure 16: Production Matrix

The production per hectare of each of the alternatives will be calculated using the same method as with sales stability. If the standard deviation deviated from the average of the alternative with 10% or less, the alternative will be considered as stable, in terms of production. The alternatives will also be ranked, based on their production per hectare (standard deviation divided by average). The production per hectare will once again be incorporated into the DSS using the same method as with sales stability.

Crop information		Stats			Rank	Stable
Category	Type	Average	Std Dev	Std Dev/Average	1 = most stable To 8 = least stable	<10%

Figure 17: Production Stats, Rank, & Stability Matrix

Price Stability

A last matrix was created to establish price trends by combining each of the land use alternative types and the annual price data over a specified time period. The data for each of the alternatives that will be used in this matrix, depends on whether the target market is local or international. Only export data will be used if the target market is international, and only local sales data will be used if the target market is local. Years were chosen for which relevant data could be obtained for all the selected land use alternatives.

Crop information			Average price (in R/ton)					
Category	Type	Local/Export	2009	2010	2011	2012	2013	2014

Figure 18: Price Matrix

The average and standard deviations for each alternative type will once again be calculated to be able to determine the price stability. If the standard deviations deviated less than 10% from the average value of an alternative type, the researcher considered that type as stable. For price stability another category will be added, namely, moderately stable. The researcher considered an alternative type, moderately stable, if the standard deviation deviated less than 25% from the average value of the alternative type. If the standard deviation deviated more than 25% from an alternative type's average value, the researcher classified the alternative type as unstable. The price stability rank, which is the standard deviation divided by the average of each of the alternative types, will also be calculated. Price stability will be incorporated into the DSS using the same method as with sales and production per hectare, just with an added option of 'moderate stability required'. The smaller the calculated value obtained when dividing an alternative's standard deviation by its average value, the more stable an alternative will be seen in terms of price. The price, stats, rank and stability matrix is illustrated in Figure 19. The data that will be used to populate the table will be obtained from reports published over various years by the Department of Agriculture, Forestry and Fisheries and SAWIS.

Crop information		Stats			Rank	Stable	Moderate	Unstable
Category	Type	Average	Std Dev	StdDev/Avg	1 = most stable To 8 = least stable	<10%	<25%	>25%

Figure 19: Price Stats, Rank & Stability Matrix

5.4.6.2. Extension of DSS model

The extended DSS model allows a user to assign a specified amount of hectares to each of the viable alternatives that the DSS provide. This gives the end user the freedom to combine alternatives according to his or her need. The extended model provides information for each of the viable alternatives according to the number of hectares assigned to each of the viable options, as well as the total number of the combinations. Furthermore, the model will specify when the combination of assigned hectares results in exceeding the specified user inputs for a particular consideration. For example, if the total cost, in the first year of the combination of viable alternatives according to the assigned hectares in the extended DSS model, results in the specified budget being exceeded, it will be indicated. A graph will also be provided that indicates the total cost in the first year of the combination of viable alternatives. Also, the specified budget will be indicated on the graph to easily evaluate whether the total cost in the first year of the combination of the viable alternatives per assigned hectares, exceeds the budget value. Figure 20 illustrates the unpopulated extension of the DSS. The extension uses excel formulas and not a VBA code to populate data.

Considerations	VIABLE LAND USE ALTERNATIVES		
Land-use alternative			
Hectares Assigned			
Hectares Remaining			
Annual Gross Income			
Capital Investment in first year			
Input Cost per year			
Total Cost in first year			
Remaining budget			
Manpower required			
Manpower remaining			
Water required (ML/year)			
Water remaining (ML/year)			
	TOTALS		
Hectares Assigned	0 ha		
Hectares Remaining	0 ha		
Annual Gross Income	R 0.00		
Capital Investment in first year	R 0.00		
Input Cost per year	R 0.00		
Total Cost in first year	R 0.00		
Remaining budget	R 0.00		
Manpower required	0 workers		
Manpower remaining	0 workers		
Water required (ML/year)	0 ML/year		
Water remaining (ML/year)	0 ML/year		

Figure 20: DSS extension

5.4.7. DESIGN REQUIREMENT SEVEN

This design requirement will be achieved by gathering information from different farmers or reliable institutes to ensure that the data that are used in the DSS are accurate and reliable. Farmers who farm with selected land use alternatives, need to be contacted and real time data has to be collected from them to populate the proposed DSS. Institutions that gather data regarding selected land use alternatives, can also be contacted if need be to populate the developed DSS. Contact information for such institutions and/or most commercialised farms can be obtained on the internet. Furthermore, interviews will be conducted with relevant parties to obtain information that will also be used to populate the matrices that have been described.

5.4.8. DESIGN REQUIREMENT EIGHT

A risk assessment of the alternatives will firstly be done to adhere to this design requirement. The developed model utilises quantitative data to compare the different considerations for each of the land use alternatives. The information related to the risk consideration is qualitative data which needs to be quantifiable to be able to make accurate comparisons. Likelihood and impact scores are used to quantify data that are predominantly qualitative, into measurable quantitative indicators. A risk quantification matrix, as illustrated in Figure 21, is used to quantify the information into risk and impact scores. The horizontal axis indicates the perceived likelihood that a given identifiable risk would occur, while the vertical access represents the impact of that specific risk if it should occur (where 5 is the maximum and 1 is the minimum, for both axes). The risk or impact score of each case will be determined by the combination of the perceived likelihood of occurrence and relevance of occurrence. To illustrate this concept, say the likelihood of incident X occurring, is perceived to be moderate, which corresponds to a quantitative value of 3, and the impact of occurrence that incident X will have are perceived to be minor or in quantitative terms 2, then the overall risk score of incident X will be 4. If however, the impact of occurrence of incident X is perceived to be major (quantitative value of 4), then the overall risk score will be 6.

Impact					
Severe	5	6	7	8	9
Major	4	5	6	7	8
Moderate	3	4	5	6	7
Minor	2	3	4	5	6
Insignificant	1	2	3	4	5
	Rare	Unlikely	Moderate	Likely	Almost Certain
	Likelihood				

Figure 21: Quantification risk matrix

The education level of the decision maker, a characteristic of the decision-making team, according to literature that was reviewed in Section 3.1.2, is incorporated into this study with the consideration *skillset of a farmer*. Due to the difficulty related to the quantifiability of this consideration, the researcher attempted to categorise the level of the decision maker with this consideration. This consideration, *skillset of the farmer*, was not included in the developed set of considerations of Section 4.2, but is nonetheless important to evaluate. A farmer with a vast amount of experience will most likely enjoy more success than a farmer with little or no experience. This is an important consideration to take into account when considering a possible alternative type. The type of information required for this consideration is personal and should be completed by the farmers themselves. Thus due to the self-reflective nature of this consideration, this consideration was excluded from the developed DSS, but incorporated into the research study as a post-risk analysis, after the DSS was developed.

A high order risk analysis, which focuses on the missing consideration was done. To evaluate the consideration, *skillset of the farmer*, the researcher combined inputs obtained from the experts and inputs gathered from talking to an agricultural economist from ABSA bank, who provides loans to farmers based on specific considerations. The aspects that the experts who validated the considerations regarded as important and necessary to be reviewed to evaluate the skillset of the farmer, can be reviewed in Table 7.

Table 7: Aspects that need to be reviewed to evaluate the skill of the farmer

Aspect	Explanation
Geography	Has the farmer farmed in the intended region before? Is the region and its climatic requirements known to him/her? *Example:* It is not a foregone conclusion that a successful farmer based in the Karoo district is going to make a success of a farming operation in the Western Cape, where the climate differs significantly.
Product	Is the farmer familiar with the intended product that he/she is planning to farm with? *Example* It is not guaranteed that a successful crop farmer with no knowledge of livestock, who has farmed with a variety of crops for much of his life, is going to be successful when adopting a livestock land use alternative. The risk associated in adopting an alternative that differs significantly, is much higher than adopting an alternative that's similar to an existing farming activity.
Knowledge/Experience	How much knowledge or experience does the farmer have? *Example* A farmer with a vast array of knowledge and experience will most likely be more successful than a farmer with little or no knowledge and

Aspect	Explanation
	experience. Knowledge and experience and risk are thus inversely proportional. As such, a farmer with knowledge and experience has a lower risk than a farmer with little or no knowledge or experience.

The interviewed agricultural economist provided the researcher with a list of considerations that they (ABSA bank) evaluate when receiving an agricultural application to determine the risk involved with issuing a bank loan to the individual. The researcher is only concerned with the considerations on the list which can evaluate the skillset of the farmer. Therefore, only the considerations on the provided list that will aid with classifying the skill of the farmer will be included in this study. The following are aspects that the bank use (with sub-questions) regarding the skillset of the farmer:

1. Type of farming

- Where is the farm located?
- How long has the farmer been in the farming industry?

The location of the farm, as pointed out before, is an important aspect to review. It is not guaranteed that a farmer that is knowledgeable about one area, automatically have the knowledge to undertake a new venture in another unfamiliar location. The second sub question of this aspect relates to the amount of knowledge or experience the farmer has.

2. Management

- Who manages the farm?
- What is the farmer's qualification and what knowledge does he/she have of the industry?
- Does the farmer have other interests that he needs to take care of and if so, who farms in his absence?
- What, if any, is his success/failure record?
- What knowledge does he buy in by employing an individual that has a specific required skill set?
- Does he plan?
- Does the farmer budget? If he does, is someone doing the budget for him?

This aspect indicates the knowledge or experience of a farmer.

3. Managing Information Systems

- Are proper records kept?
- Are managing information up to date and regularly available?

- Are the history records of the previous yields available?

This aspect indicates how organised a farmer is.

4. Credit Record

- Has the farmer been bankrupt before?
- Is the farmer honest about his previous bankruptcy?
- What does his credit record look like – does he exceed the limit regularly?

A good credit score reflects reliability and making payments on time. It thus indicates that good business decisions were made which indicates experience.

Four aspects can therefore be identified which encompass all the aspects that were obtained from the expert as well as described by the agricultural economist. The four aspects are:

- Knowledge/Experience
- Product/Farming type
- Location/Geography
- Organisational skills

Each of the four aspects will be used to construct a high order diagram that classifies the consideration 'skill of the farmer', in terms of risks. The bubble sizes indicate the risk associated with that aspect. An aspect with an associated high risk will have a big bubble size. Thus, for example, a farmer with extensive experience, who possesses organisational skills, plans to start farming with a product that he has moderate knowledge of, in a new location that he has never farmed before, will have the following risk profile as illustrated in Figure 22.

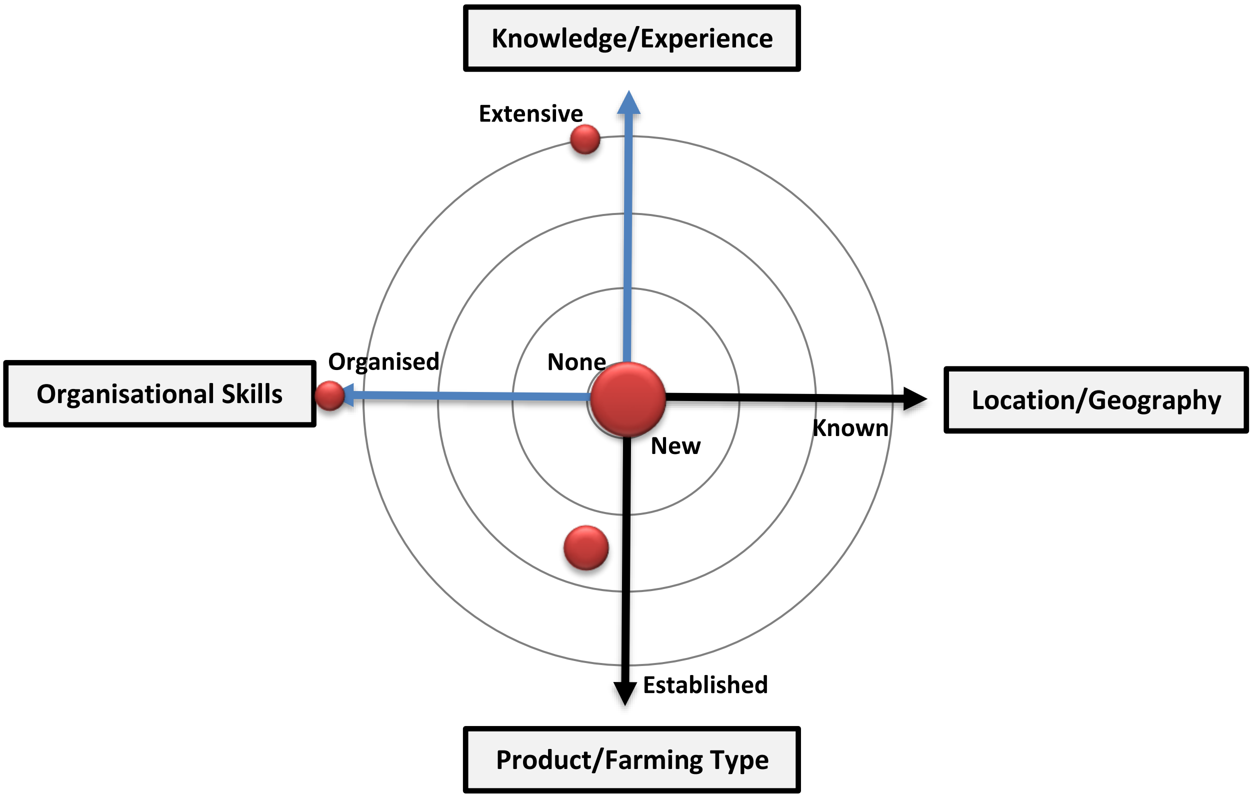


Figure 22: Evaluating the risk associated with the skill of the farmer

Figure 22 indicates that there are little risks involved with the aspects related to the organisational skills and knowledge/experience of the farmer, but that the new location that the farmer is planning to start his new venture in, increases the risk profile of the farmer.

5.5. CHAPTER CONCLUSION

After an introduction that provided the reader with an overview of the chapter, the DSS was developed according to the specified design requirements of the previous chapter, explaining how each of the design requirements will be addressed in the DSS. As stated before, the DSS is designed to guide the end-user to choose the right type of land use alternative in a flexible and user-friendly way by letting the decision maker specify input values to express his or her requirements. This was followed by explaining the logic of the DSS by means of process flow diagrams. The process flow diagrams explain the overall inputs and outputs of the DSS as well as that of the extended model. The purpose of the process flow diagrams was to show the logic of how the proposed model will function. The third step of the ten-step iterative process (refer to Section 3.3 of the literature review) indicated the importance of providing the logic of the proposed model. The VBA code of the DSS was explained by means of process diagrams (Section 5.1). Section 5.2 indicated the data input requirements of the developed DSS and the DSS extension. This section served to inform the reader whom will supply the required data of the DSS and the extension model. A process flow diagram depicting the components of the DSS and how they work together (Section 5.3) followed. The proposed DSS was designed according to the outlined requirements of Section 4.1 in Section 5.4.,which concluded this chapter. The DSS that was developed in this chapter will be used in Chapter 7 where an illustrated case study will be done. The objectives of this chapter, as set out in Section 1.4, have all been met as illustrated in Table 8.

Table 8: Chapter 5 research objectives and outcomes

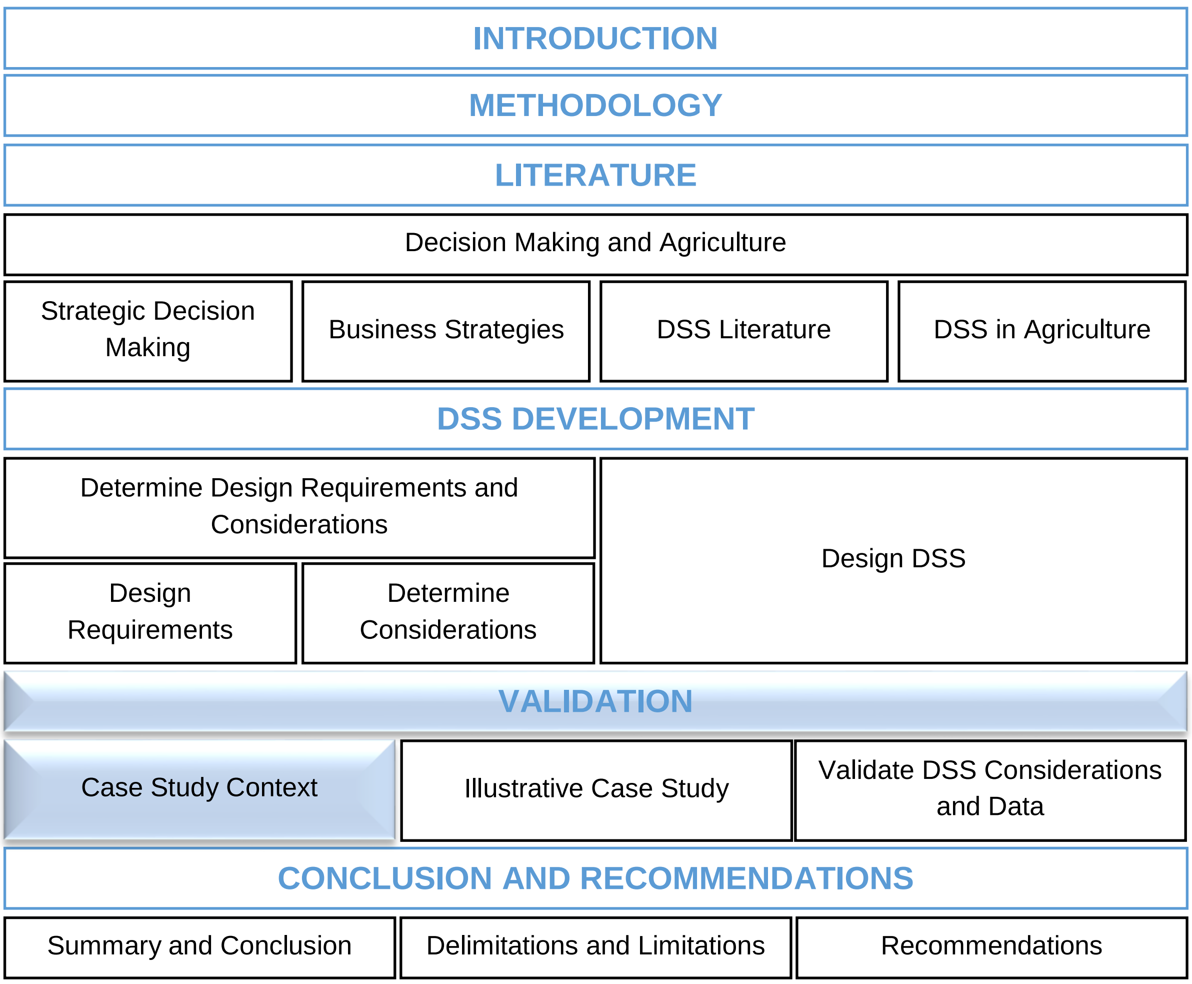
Research Objective	Section	Outcome
1. Develop process flow diagrams to illustrate: • The overall inputs and outputs of the DSS and its extension. • How the VBA code of the DSS works. • The different components of the DSS and how the different components relate to one another.	Section 5.1 Section 5.3	Different process flow diagrams were developed to show the logic of the DSS and that of its extension, how the VBA code works, as well as illustrating the various components and the relationship of the different components.
2. Develop a DSS to compare selected land use alternatives per consideration in accordance with the different design requirements.	Section 5.4	A DSS that utilises the set of considerations from Section 4.2 was designed according to the prescribed designed requirements of Section 4.1.

6

CASE STUDY CONTEXT

6. CASE STUDY CONTEXT

The sixth chapter of this study contains information that will assist the development of the case study presented in the following chapter. Research in Section 6.1 will be conducted to identify specific problems that wine estates in the Stellenbosch area are experiencing. It is because of these problems that wine estates need to re-evaluate their business strategies to be able to stay sustainable. This study will focus on farms that are considering a diversification business strategy, as discussed in Section 3.2. and Section 6.2 will identify a specific business sector from which possible land use alternatives can be identified, while Section 6.3 will look at Stellenbosch's weather patterns. New facts regarding the selected possible land use alternatives will be established (Appendix C: Selected Land Use Alternatives Theory). This chapter forms the first subsection of the validation stage in this study.



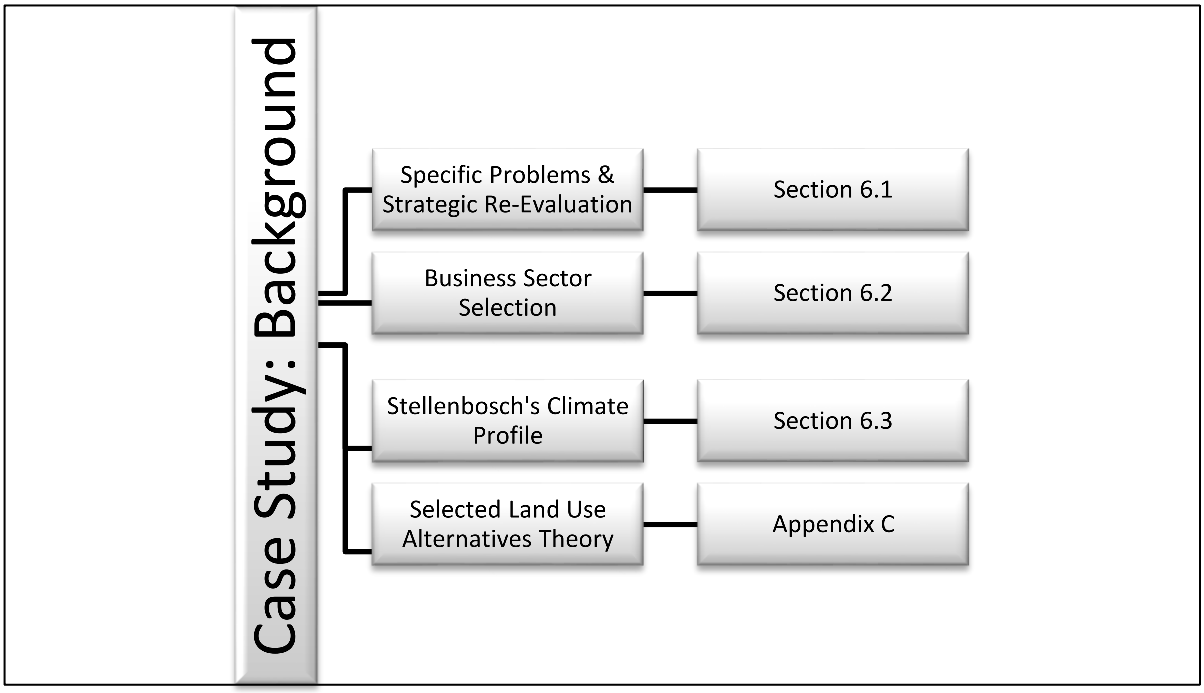


Figure 23: Chapter 6 Layout

6.1. SPECIFIC PROBLEMS & STRATEGIC RE-EVALUATION

According to SAWIS (2015) there is mounting pressure regarding the profitability of the South African wine industry. This is due to the increased rate in production costs that has considerably surpassed the growth in income, emanating from grape production, as well as an increase in competition (SAWIS, 2015a). South Africa is currently in the grip of one of the worst droughts of the last 20 years. The Western Cape is experiencing a lower than average rainfall when compared to previous years (PwC, 2015). The lower than average rainfall is reflected in the low dam levels.

There are various problems that the wine estates in the Stellenbosch region are experiencing. This section of the chapter will be dedicated to indicate specific problems and thus give the reasons why wine estates in the Stellenbosch region are required to re-evaluate their business strategy to stay prosperous and sustainable.

The South African Industry Insight Survey

A yearly survey, the South African industry insight survey, conducted by Price Waterhouse Cooper (PwC), explores some of the financial and economic problems in the local wine industry. In this survey, inputs from key role players and decision makers in the wine industry are gathered (PwC, 2015). Three categories from the reports were focused on: general economic and industry perspective; competitiveness index for producing cellars; and Wine Industry Strategic Exercise (WISE). This study was dedicated to indicate some of the problems that are currently being experienced in the wine industry. Each problem will be categorised and discussed.

1. Profitability Pressure

Economic and industry perspective

This category will look at the confidence level of participants regarding revenue growth, and the pressure on the profitability in the wine industry.

➢ Confidence level regarding revenue growth

Figure 24 indicates the confidence level of experts that participated in the study regarding revenue growth when considering the organisation's prospects.

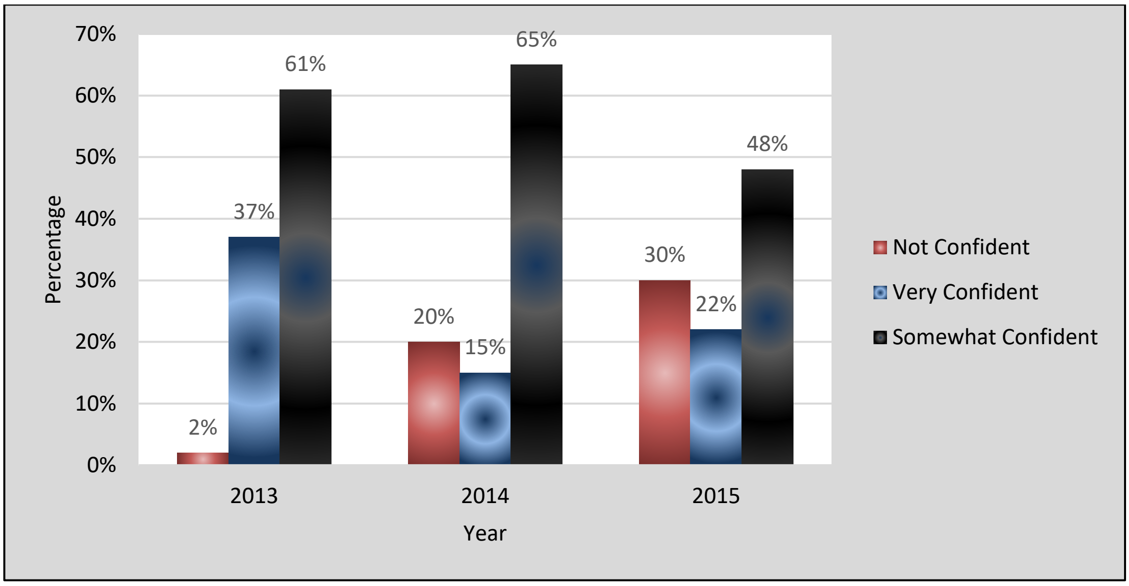


Figure 24: Revenue growth confidence over next 12-36 months (PwC, 2015)

Figure 24 indicates the percentage of participants that are not confident about revenue growth at all when the organisation's prospects were considered to grow from 2% in 2013 to 20% in 2014 to 30% in 2015. This is another indication that the wine industry's financial margins are shrinking.

➢ Profitability Pressure in the Wine Industry

The latest report on the South African wine industry's macro-economic impact on the country's economy, indicates the effects of persistent cost pressures in the wine industry. The pressures or constraints can be categorized accordingly:

- A relatively constant wine consumption demand from South Africans in the long-term. Locally packed wine sales, for example increase with a mere ± 0.7% from 1997 (366, 891 million litres) to 2013 (369, 407 million litres) (SAWIS, 2015a).
- Cost acceleration in exuberance of the overall inflation rate (SAWIS, 2015a). The average inflation rate for the period 2008–2013 were 6.37 % (Trading Economics, 2016).
  - Packaged costs (e.g. rand per litre) increased from 2008 to 2013 by 146%.

- Bulk costs increased by 46% from 2008 to 2013.
- For the same period the National Production Price Index (PPI) increased by 29%.
- From 2008 to 2013 the average production costs increased by 52%, while net income per ton of grapes produced during this period, increased by only 38.2%

The cost acceleration in exuberance of the overall inflation rate percentage increases, are shown in Figure 25. The red bars on the graph highlight the difference between the percentage increase of the average production costs, and the net income per ton of grapes produced.

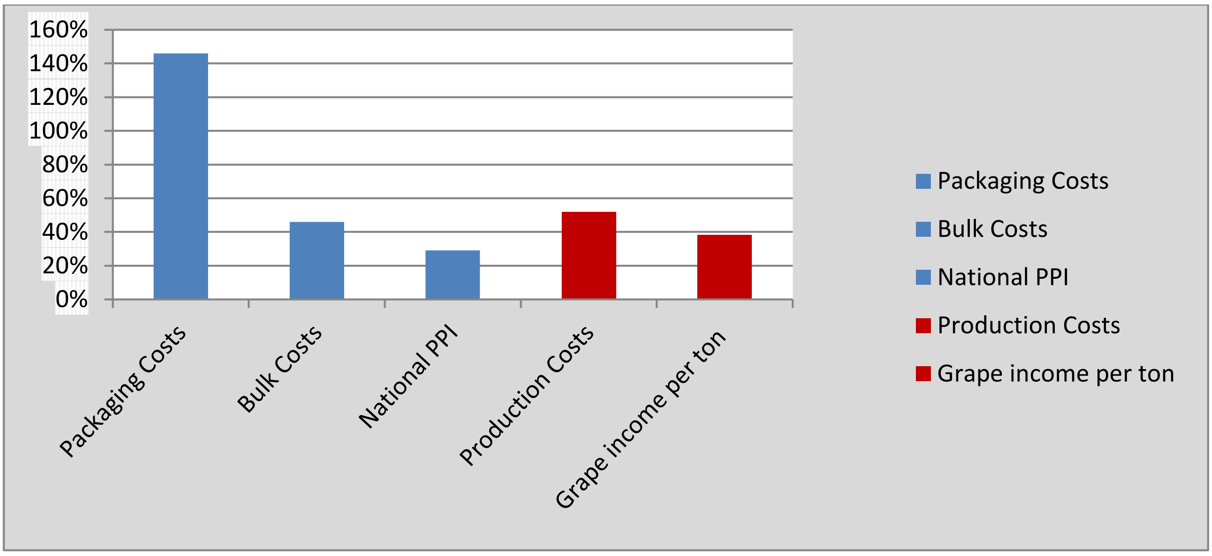


Figure 25: Cost escalation from 2008-2013

Figure 26 illustrates how the average production cost in the wine industry increased from 2005 to 2014 (VinPro, 2015).

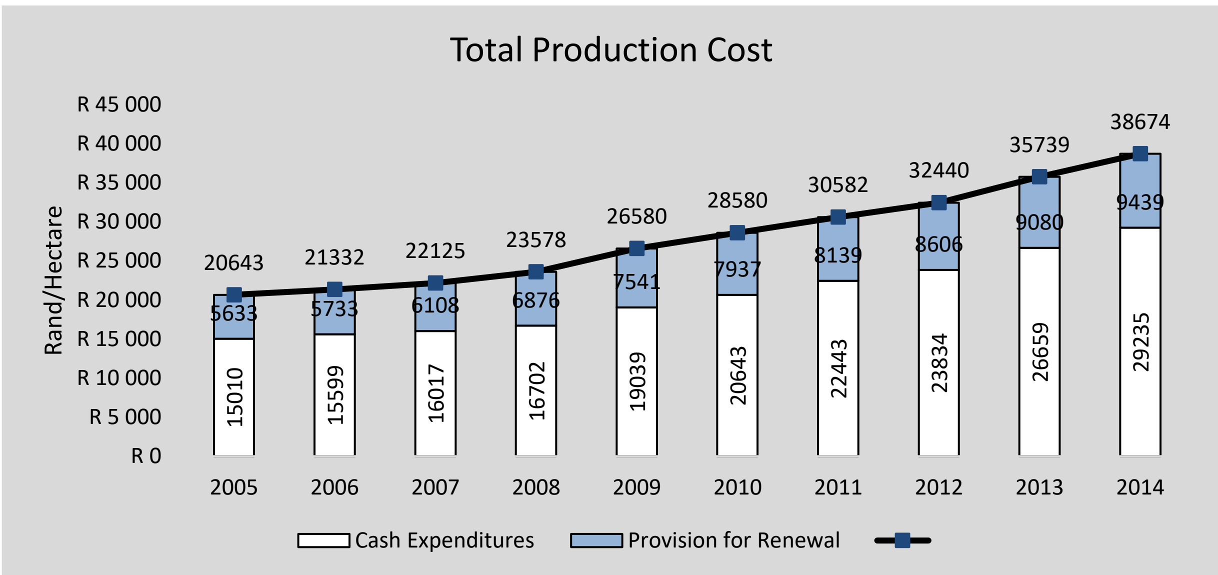


Figure 26: Total production cost (VinPro, 2015)

Shift from Bulk wine

Pressure on profitability margins of the South African wine industry effects the form of wine exports as well. In order to increase profitabilirt planned targets include a shift away from bulk wine towards packaged wine.

Wine Industry Strategic Exercise (WISE)

The South African wine and brandy industry developed a strategic exercise to assist it to reach goals by 2025. The goal of this exercise is to drive competitiveness and increase profitability and sustainability. One of the targets that WISE aims to reach, is decreasing the amount of bulk wine that is exported, and increasing the amount of packaged wine that is exported (PwC, 2015). Research conducted by WISE indicates that China, followed by Africa, are the countries/continents where the greatest growth opportunities lie for South Africa (PwC, 2015). A shortened list of WISE's growth goals can be viewed in Table 9.

Table 9: Shortened list of WISE goals (PwC, 2015)

2015	Target	2025
60:40	Exports bulk: packaged	40:60
1%:2%:5%	Export markets USA:China:Africa	7%:7%:10%

The survey also asked CEOs where they think the greatest possibility for growth regarding product composition lies (bulk or packaged wine). The results can be seen in Figure 27. There is a clear shift away from bulk wine from 2014 to 2015, which is aligned with the target goals of WISE (Table 9).

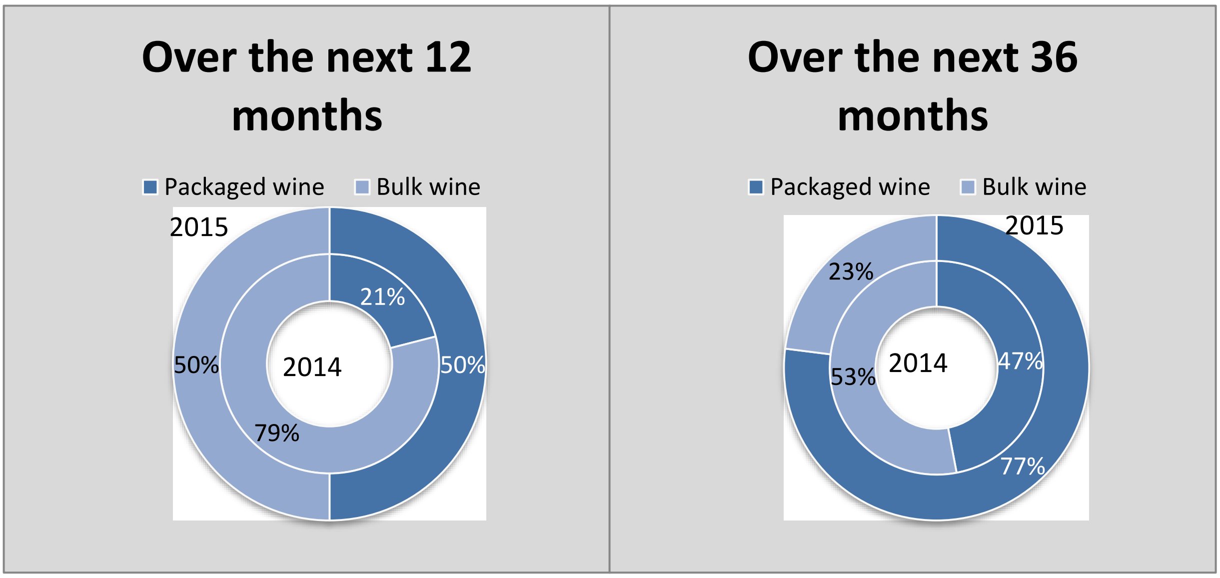


Figure 27: Growth opportunities regarding product composition (PwC, 2015)

One of the reasons why the wine industry want to move away from exporting bulk wine, is because of the very little control that the industry have regarding the final product. Winemakers lose control of a crucial part of the production process when wine is bottled outside of South Africa. The wine that is exported, can be mixed with a lower quality blend wine and branded as South African wine, which would damage the South African brand and reputation. Job opportunities in South Africa are also lost when exporting bulk wine. Since 2010 two bottling plants have closed in the Stellenbosch region, costing people their jobs. Bottling wine locally, will thus create more jobs (SULAIMAN, 2013).

Figure 28 illustrates how the total amount of wine exported in bulk, decreased with 28.31% from 2013 to 2015. On behalf of the wine industry, the executive manager of the South African Wine Industry Information and Systems (SAWIS), Yvette van der Merwe said the following (SAWIS, 2015a):

> *Although bulk exports account for 66% of volumes sold outside South Africa in 2013, that figure is reversing, and as the performance of packaged wines continues to strengthen, we are seeing an increase in the contribution of the wine industry to the national coffers. From 2016, we can also look forward to the impact of the new EU Trade Agreement, which will raise the EU's duty-free quota for South African wines from the present 50 million litres to 110 million litres a year.*

This trade agreement allows an increase of 60 million litres of packaged wine that can be exported without paying tax on it.

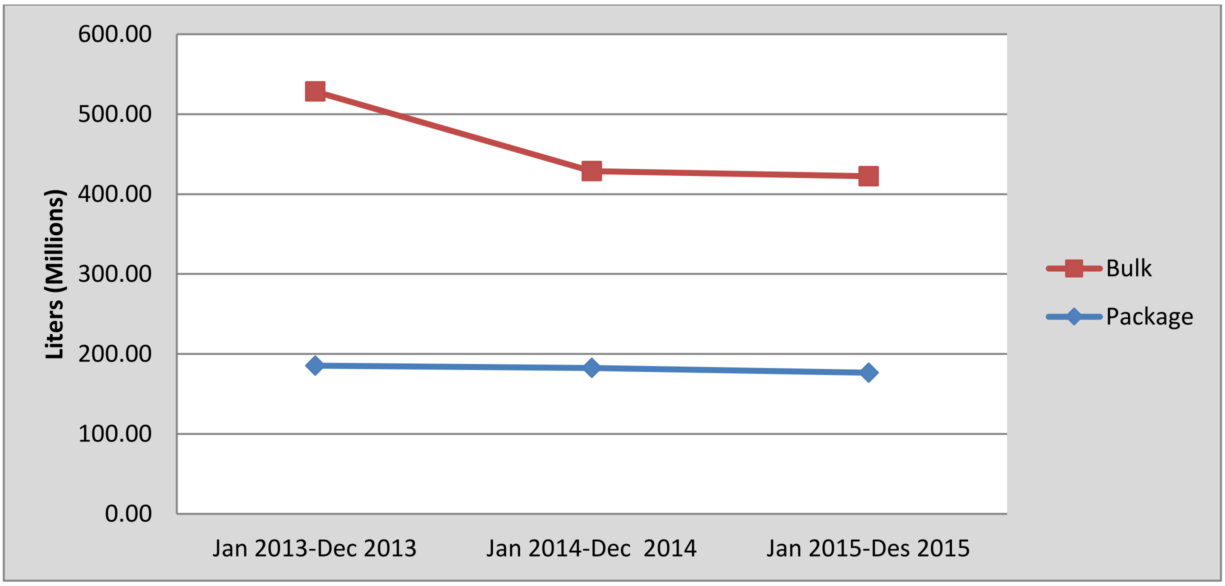


Figure 28: Bulk and Package Wine Exports (VinPro, 2014, 2016)

2. Vineyard Age

In South Africa, it is unusual to find vines that are older than 25 years that are still able to produce on a commercial level. It is however, common to find older vines in other geographical areas (PwC, 2015). A benchmark study was performed during the South African industry insight survey. The benchmarks that were used are typically those that wine estates can concentrate on to ensure durability and sustainability of their business. It is important for any enterprise to know the industry trend and whether it deviates from it. A vine of 10 years was used as a benchmark vine, because it is seen as the right combination between established vineyards that can produce reliability year after year, and younger vines that can meet the output requirements over time (PwC, 2015). Results from the study indicate that neither the bottom 25% that the industry average, nor the Best In Class (BIC) group of participants, were able to record results equal to that of the benchmark study (refer to Figure 29).

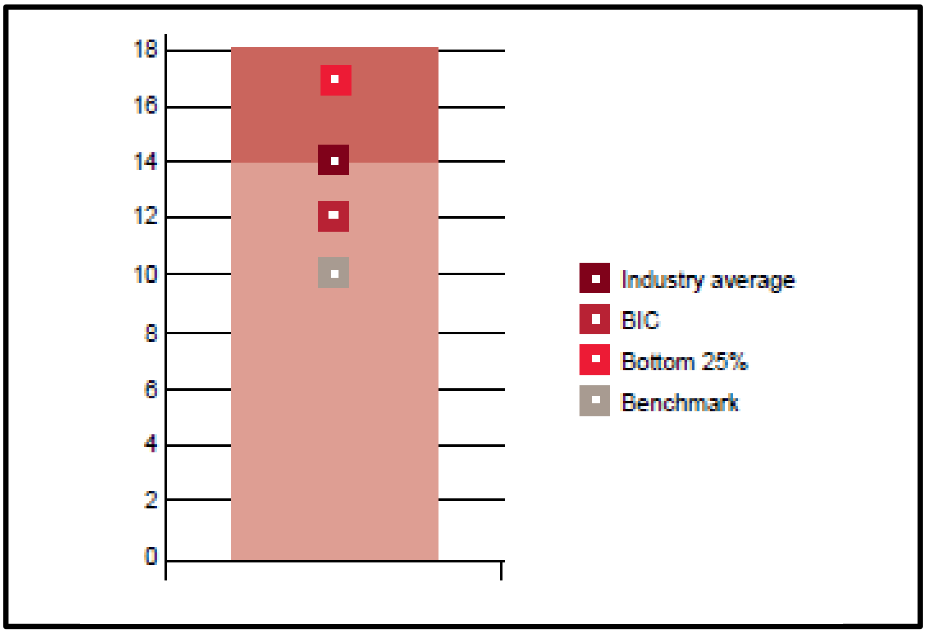


Figure 29: Average age of vineyards (years) (PwC, 2015)

3. Drought

A report published by the City of Cape Town (2017) recorded the dam levels of the major dams in the Western Cape. The major dams contribute 99.6% towards the Western Cape Water Supply System, whereas the minor dams make up the remainder 0.4%. The major dams comprise of: Berg River, Steenbras Lower, Steenbras Upper, Theewaterskloof, Voëlvlei, and Wemmershoek. The contribution that each of these major dams make towards the total Western Cape Supply System from 2013 till 2017 can be seen in Figure 30. The total amount of combined water available, expressed as a percentage for each of the years, are also indicated. Contributions of the smaller dams towards the Western Cape Water Supply, have been excluded from Figure 30, due to the minor collective contribution of these dams. The steady decline in dam levels from 2014 to 2017 is clearly visible in Figure 30, with a decline of 25.9% from 2016 to 2017. All figures indicated are for 7 August of the respective years. This steady decline reflects the drought that is currently experienced in the Western Cape. A further concern is that the useable water in the dam is approximately 10% less than the indicated dam level, since it is a challenge to use the last 10% of a dam's water.

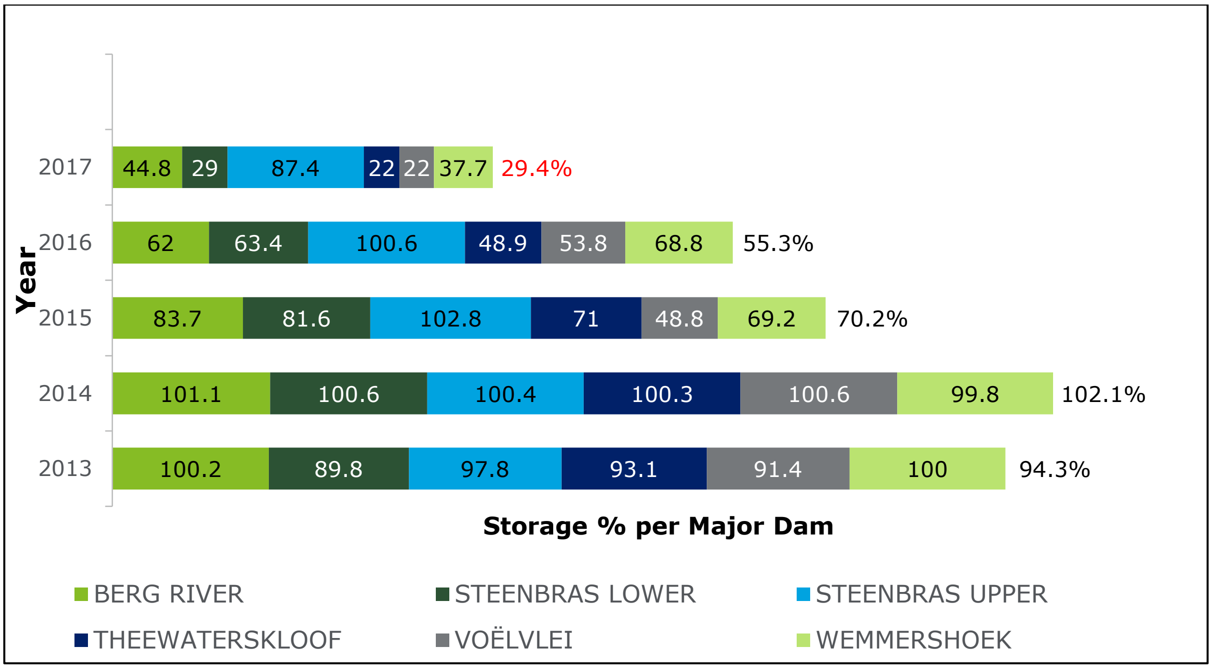


Figure 30: Dam levels (%) of the major dams in the Western Cape for 7 August 2013-2017 (City of Cape Town, 2017)

4. Decline of grape crop yield

Figure 31 shows the total grape crop yield per harvesting season from 2006 to 2014 and the crop yields shown for Aug 2015, Nov 2015, Jan 2016 and Feb 2016 are projected amounts for each of the consecutive months. The linear trend line in Figure 31 indicates that the grape crop yield in the Stellenbosch region is slowly declining. This could be due to the drought that is currently being experienced in the region, or it could be the age of the vineyard. According to (SAWIS, 2016b) the continuous drought conditions that the Stellenbosch area are experiencing, might have an even more dramatic negative affect on the 2016 wine grape harvest than was estimated. The drought will have a further negative impact on the 2017 harvest, due to retention in the vineyards from the hardship they suffered in 2016. During the harvest estimate in the second week of February, this was indeed confirmed. The total of the 2016 South African harvest amounted to 1 294 475 tons, which is 12.4% lower than the 2015 harvest, and it is also 35% lower than the predicted amount for January 2016 (SAWIS, 2016b). It is estimated that an even further decline can be expected for most regions, but it is expected that the Stellenbosch region will have the smallest wine grape harvest in more than 10 years. Due to the drought, water sources are rapidly becoming limited or even depleted, which cause the decrease in the harvest estimates (SAWIS, 2016b).

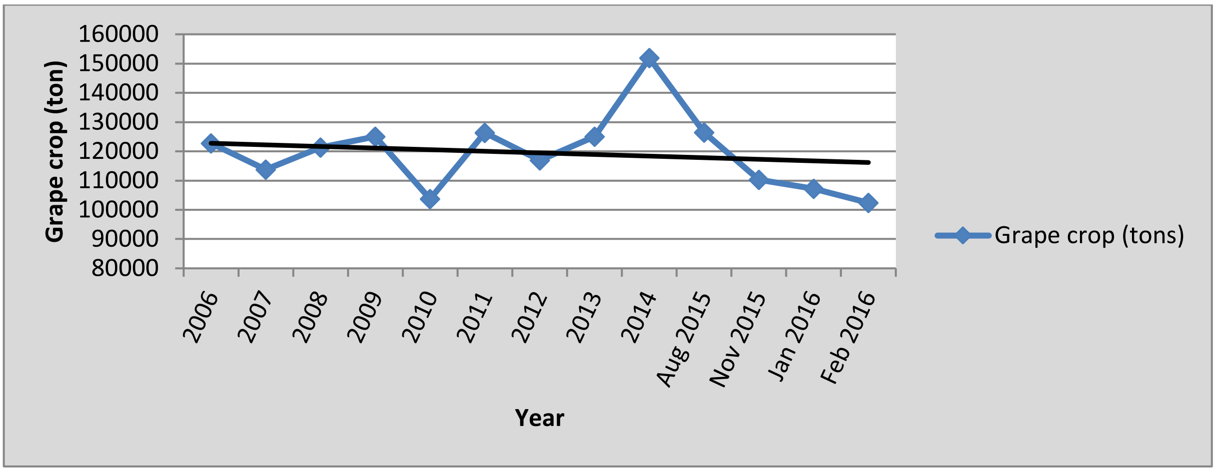


Figure 31: Grape and Wine Crop (SAWIS, 2016a)

Figure 32 provides a summary of the specific problems that have been discussed.

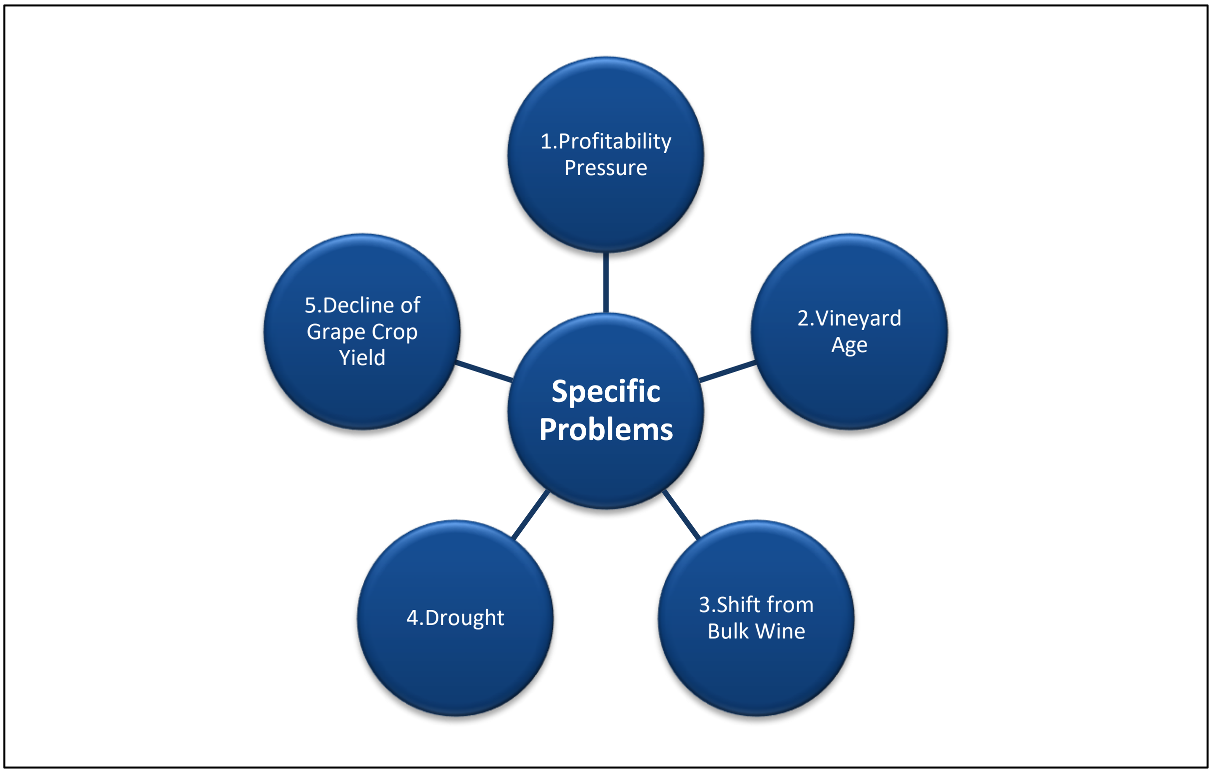


Figure 32: Specific Problems that wine estates in the Stellenbosch area are experiencing

6.2. BUSINESS SECTOR SELECTION

Economists divide economic activities that contribute to the Cape Gross Domestic Product (GDP) into two broad categories namely, goods produced and services delivered. The first category includes the agriculture, mining and quarrying, manufacturing, and construction sectors. The second sector, the service sector, includes all industries that deliver a service to people: wholesale, retail, banking, consumer services, transport, finance, government services, etc. Figure 33 illustrates the different sectors in South Africa. The bubble sizes in Figure 33 represent the contribution made by each sector towards the Western Cape GDP during 2014. The agriculture, forestry and fishing sector contributed 4.2% towards the Western Cape's GDP during 2014, but only 2.6% towards South Africa's GDP. Figure 33 indicates that the agriculture, forestry and fisheries sector employ more people, percentage wise, in the Western Cape (8.4%) than in South Africa (5.4%) (Western Cape Government Provincial Treasury, 2015). The Western Cape contributed 13.7% towards the South African GDP in 2015 (South Africa.info, 2015).

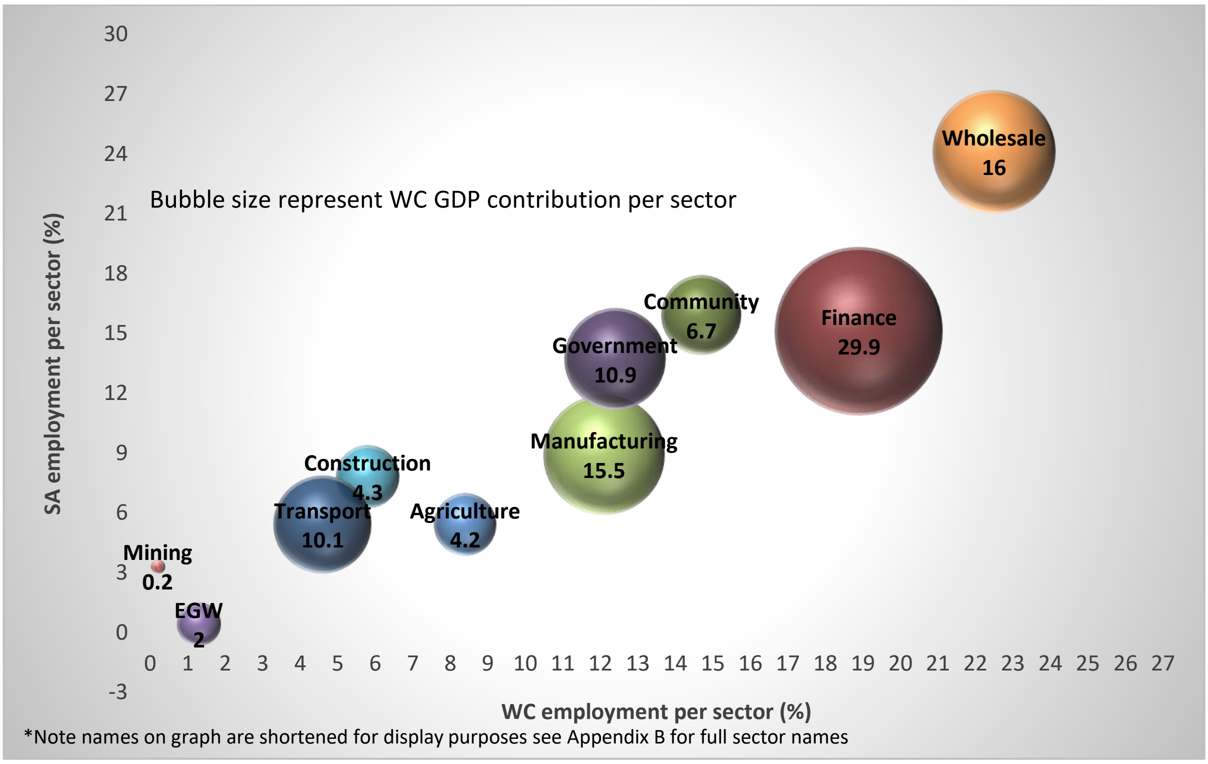


Figure 33: National GDP and national and Western Cape employment contribution per economic sector (Western Cape Government Provincial Treasury, 2015)

This study will only focus on the Agriculture sector to find possible land use alternatives and thus excluding the other sectors. Reasons for exclusion of the other business sectors:

1. **Mining and Quarrying Sector**

   Specific minerals need to be excavated, therefore the mining and quarrying sectors will not be considered.

2. **Manufacturing and Construction Sectors**

   The manufacturing sector are defined as the branch of manufacturing and trade that is based on the fabrication, processing, or preparation of products from raw materials and commodities (Sustainable Development Indicator Group, 1996). Diversification strategies, which include identifying possible land use alternatives, need to be assessed, which would ensure the sustainability of farms in the Stellenbosch region. This paper will not look at the whole value chain of the product and therefore this sector is excluded. The construction sector refers to activities involving construction, alteration, and/or repair. Residential construction also falls under this sector. Before construction activities can commence, permits need to be acquired, government regulations need to be adhered to, and external experts such as contractors need to be hired (Republic of South Africa, 2014). This paper will not attempt to look for diversification strategies from this sector, due to time constraints.

3. **Service Industry**

   The tertiary sector does not include manufacturing activities, but rather focus on providing various services to people. The sectors included in the service industry are the wholesale and retail trade; catering and accommodation sector; general government services sector; finance, insurance, real estate and business services sector; community, social and personal services sector; and the transport sector (Department of Environmental Affairs, 2008). The electricity, gas and water sector provides electricity, gas or water to people, which is a service, and thus it also falls under the service industry. These sectors will therefore be excluded, because this study attempts to find land use alternatives that can be utilised to improve profit margins. The service sector will be excluded, even though it may generate additional revenue for farmers in the region, because it is not conceptually possible to deploy all the vineyard land for this sector. This DSS will thus only include and focus on alternative land use options that will use the available land optimally in the agriculture sector.

6.3. STELLENBOSCH CLIMATE PROFILE

The climate of a region greatly influences the choice of agriculture activity. According to ARC infruitec-nietvoorbij scientist expert HE7, climate is the most determining factor when it comes to deciding which crops to plant in a specific region.

To ascertain whether or not a specific agriculture activity is suited for the Stellenbosch region based on its climatic requirements, a climate profile of the region needs to be established. Data was acquired from the AgroClimatology Department of the Agriculture Research Council. Helderfontein weather station, situated in the Stellenbosch region (Latitude -33.9233, Longitude 18.87331, Altitude 133) (see Figure 34) is the weather station used by the department.

Figure 34: Helderfontein Weather Station (Google Earth, 2016)

The in-between seasons of autumn and spring are regarded as very short seasons throughout South Africa. For climate analysis January is accepted as mid-summer and July as mid-winter (South African Weather Service, 2016).

The average monthly temperatures as well as the maximum and minimum average monthly temperatures for the Stellenbosch region are shown in Figure 35.

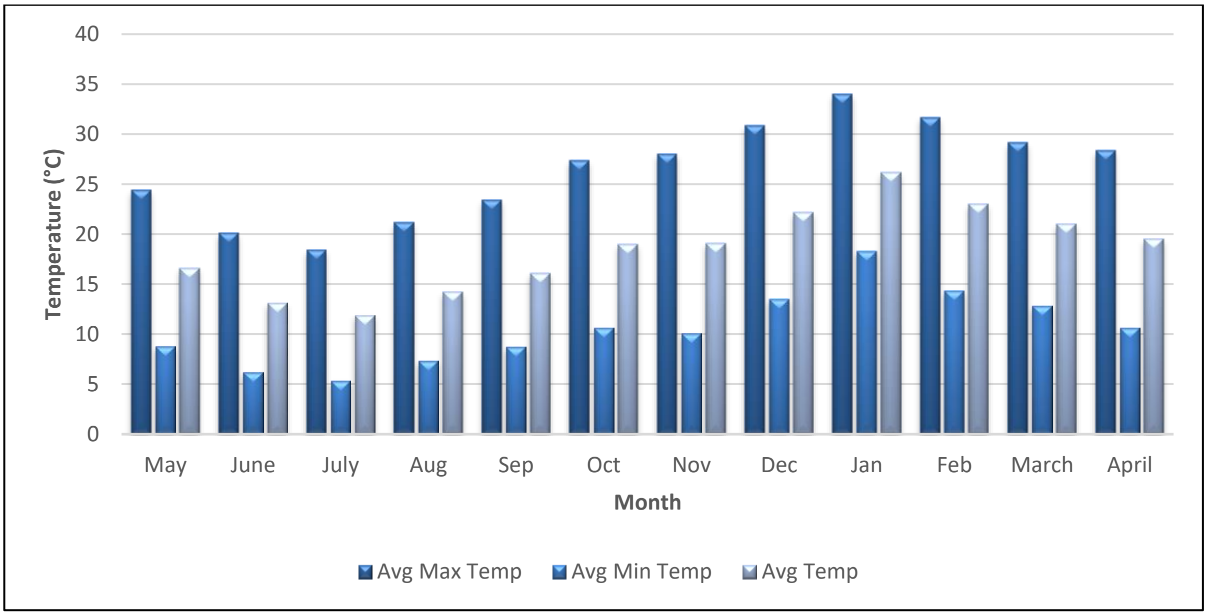


Figure 35 Monthly Temperatures (AgroClimatology, 2016)

Figure 36 illustrates the average total rainfall per month for the Stellenbosch region. The exact temperature and rainfall per month can be seen in Table 36 and Table 37.

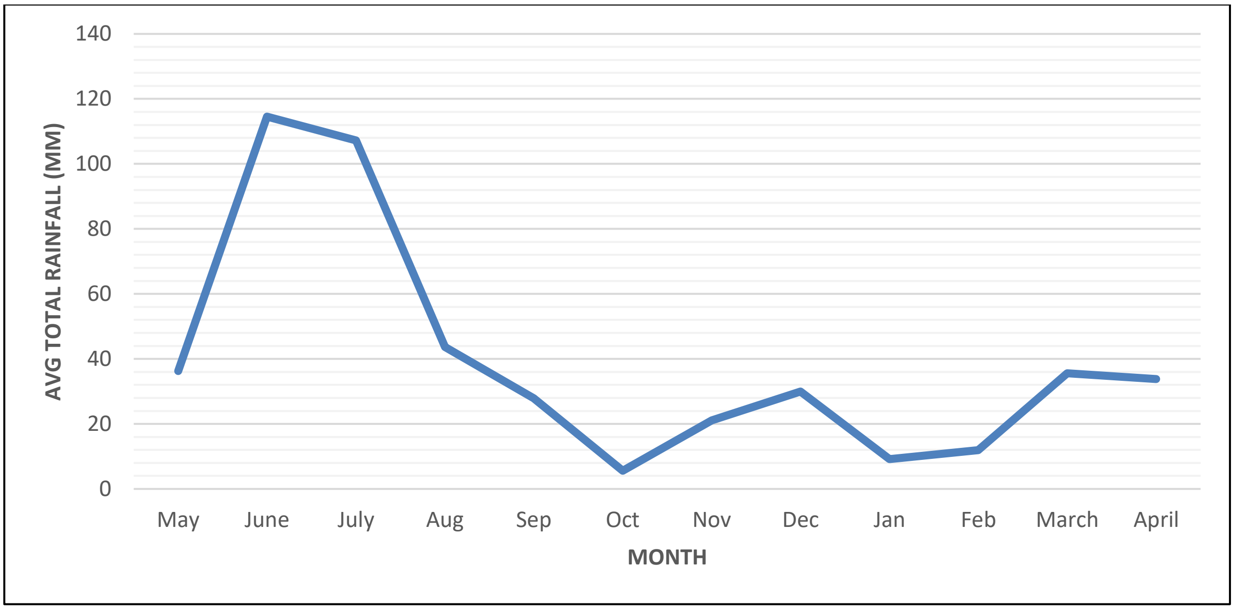


Figure 36: Average Monthly Rainfall (AgroClimatology, 2016)

The Stellenbosch region has a Mediterranean climate, because it receives most of its rain during the winter months as can be seen in Figure 35 and Figure 36 (SA Explorer, 2014). During 2015 this region received 413.77 mm rain and had an average maximum and minimum temperature of 26.34 °C and 10.03 °C respectively (Table 36) (AgroClimatology, 2016). This region is characterised by cool, mild winters and very dry, hot summers (Cloete & Olivier, 2010).

6.4. CHAPTER CONCLUSION

The information reviewed and discussed in this chapter, will serve as a foundation for the following chapter. The objectives of his chapter, as set out in Section 1.4, have all been met, as can be seen in Table 10. The research that was conducted in this chapter, will be used throughout the study to meet the research aim of the project successfully. Theory regarding each of the selected land use alternatives can be found in Appendix C: Selected Land Use Alternatives Theory.

Table 10: Chapter 5 research objectives and outcomes

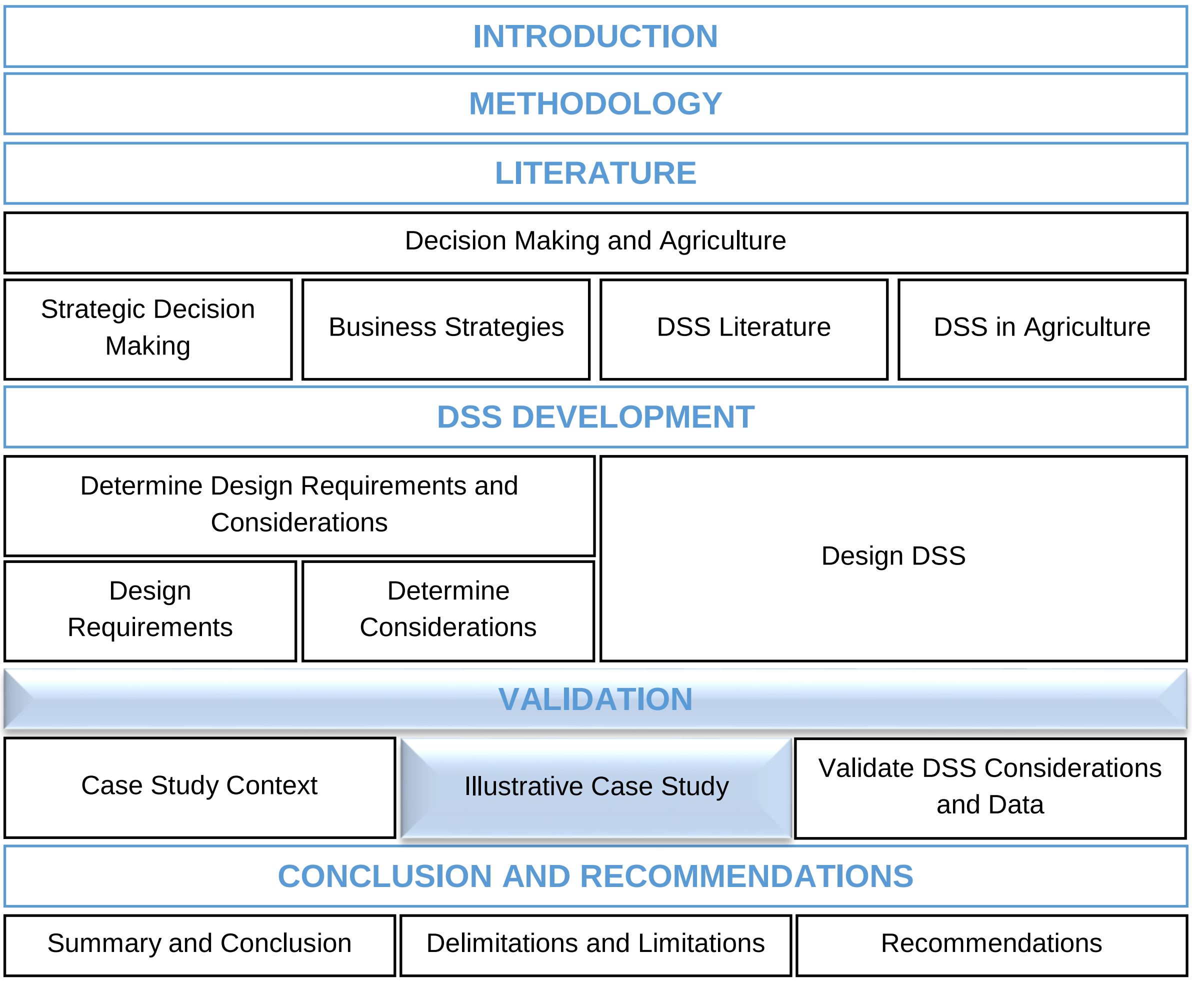
Research objective	Section	Outcome
1. Conduct research to identify the specific problems that wine estates in the Stellenbosch region are currently experiencing.	Section 6.1	The problems in the wine industry are identified and each of them is discussed.
2. Determine a specific business sector from which land use alternatives will be selected.	Section 6.2	The agriculture sector was identified as the business sector from which land use alternatives will be selected.
3. Determining the climate pattern of the Stellenbosch region.	Section 6.3	Data was collected to compile a profile of Stellenbosch's climate.

7

ILLUSTRATIVE CASE STUDY

7. ILLUSTRATIVE CASE STUDY

The purpose of this chapter is to apply the DSS that was developed in Chapter 5. The application of the DSS will be restricted to the Stellenbosch region, due to scope limitations. The data regarding Stellenbosch's weather patterns (refer to Section 6.3) as well as the research that has been conducted in Appendix C: Selected Land Use Alternatives Theory, will be used throughout this chapter. Due to the sensitive nature of some of the information obtained from experts, codes will be used when referring to certain experts to ensure that anonymity is maintained. The field of expertise, a short description, as well as a job title (where anonymity is not violated) of each of the experts can be found in Appendix A, on page 173.



A stepwise process is followed in this chapter to ultimately apply the developed DSS. The process is to ensure that land use alternatives that are selected to be incorporated into the DSS for a specified region are viable in that particular region. Furthermore the process will also ensure that data is collected from relevant parties to make sure that the data used in the DSS are reliable and trustworthy. An illustration of the process can be seen in Figure 37. Each of the process steps will be executed sequentially in this chapter and an explanation of the importance or relevance of each of the steps will be provided.

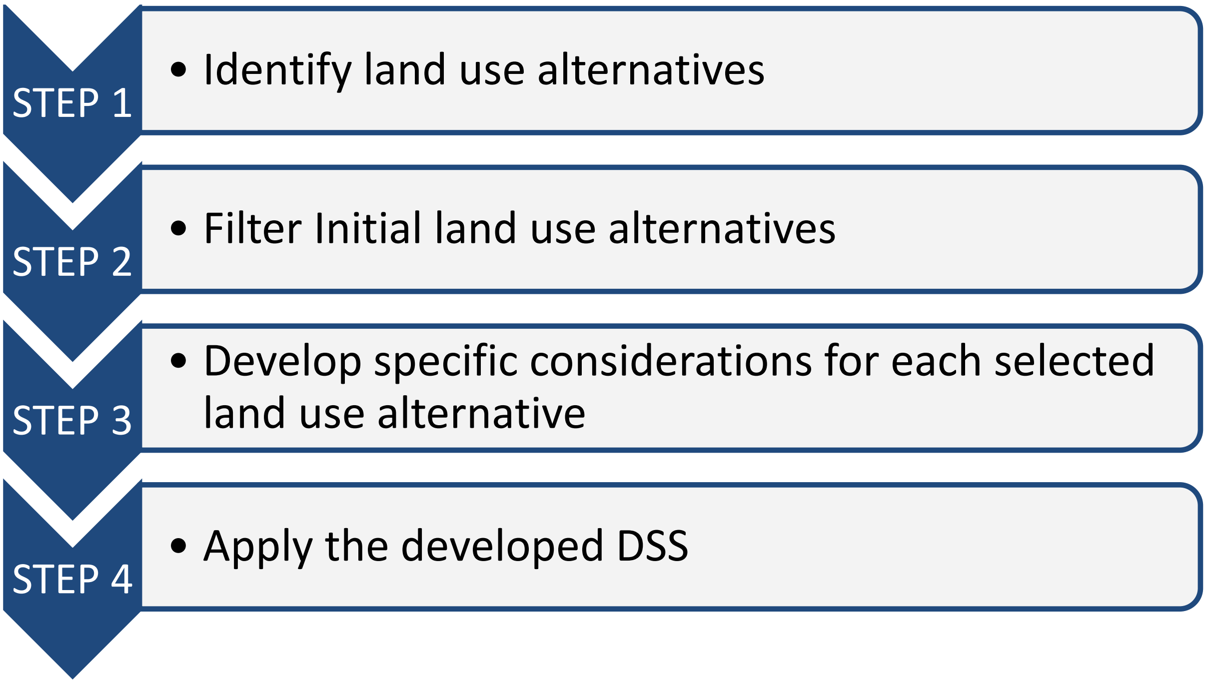


Figure 37: Proposed DSS stepwise application process

7.1. IDENTIFY LAND USE ALTERNATIVES

Once considerations which will ultimately be used to measure the success or failure of a land use alternative type were established, different possible land use alternatives that could be considered for a specific region had to be identified. Specific land use alternatives could be selected from the agriculture sector after this sector was identified as the business sector, which this study will focus on. Land use alternatives that take place in South Africa will be identified and considered as a starting point. Identifying and selecting specific alternatives that are suitable for the Stellenbosch region, is an iterative process. The alternatives will be filtered in the next step to adhere to the project scope, which stipulates that the project will focus on the Stellenbosch region, a region in South Africa.

The South African Department of Agriculture, Forestry and Fisheries divided the key agriculture activities that take place in South Africa into three broad categories, namely field crops, horticulture, and livestock (Department of Agriculture Foresrty and Fisheries, 2015). Field crops are crops, other than vegetables and fruits, that are grown on a large scale for agricultural purposes, while horticulture is defined as 'the study and practice of growing flowers, fruit, and vegetables' (Collins Cobuild, 1988). Livestock refers to animals that are kept in an agricultural environment with the purpose of producing commodities (Collins Cobuild, 1988). The main agriculture activities according to the Department of Agriculture, Forestry and Fisheries of South Africa (2016) can be seen in Table 11.

Table 11: Key Farming activities in South Africa (Department of Agriculture Foresrty and Fisheries, 2015; Department of Agriculture Forestry and Fisheries, 2016)

	CATEGORIES		
	FIELD CROPS	HORTICULTURE	LIVESTOCK
Main Agriculture Activity	***Grains*** Maize Wheat Barley Sorghum Oats Lucerne Cowpeas Lentils Chicory	***Viticulture***	***Dairy Farming***
	Oilseed Groundnuts Sunflower Seed Soya Beans Canola	***Citrus Fruit*** Oranges Lemons and Limes Grapefruit Naartjies	***Beef Cattle Farming***
	Sugar Sugar Cane	***Subtropical Crops*** Pineapples Avocado Mangoes Bananas Litchis Guavas Papayas Granadillas Pecan Nuts Macadamia Nuts	***Small Stock (Sheep and Goat)***
	Cotton	***Deciduous Fruit*** Apples Pears Apricots Peaches Nectarines Plums	***Hunting and Wildlife Sector***

CATEGORIES		
FIELD CROPS	HORTICULTURE	LIVESTOCK
	Grapes Olives Figs Cherries	
Tobacco	***Vegetables*** Potatoes Tomatoes Onions Cabbage Dry Beans Pumpkin Green Mealies Sweet Potato Green Peas	***Pig and Poultry Farming***
	Tea Honey bush tea Rooibos tea	***Aquaculture***
	Fynbos Industry	
	Strawberries and other Berries	

7.2. FILTERING OF INITIAL LAND USE ALTERNATIVES

After identifying possible land use alternatives that take place in South Africa, a filtering process can now commence to select land use alternatives that this study will focus on. The selected land use alternatives, as stipulated in the scope, must be viable for the Stellenbosch region. The aim of this study is to identify considerations as part of a DSS that needs to be evaluated, to assist wine farmers in the Stellenbosch region with the decision-making process regarding possible land use alternatives. Moreover, wine grapes are classified as a crop. As such, this study will only include crop land use alternatives, thus excluding possible livestock alternatives.

Figure 38 shows the most important agriculture enterprises in South Africa per district (Cloete & Olivier, 2010). The Stellenbosch region lies on the boundary of a *diverse* and *fruit* region (refer to Figure 38), making it an ideal region to implement crop land use alternatives.

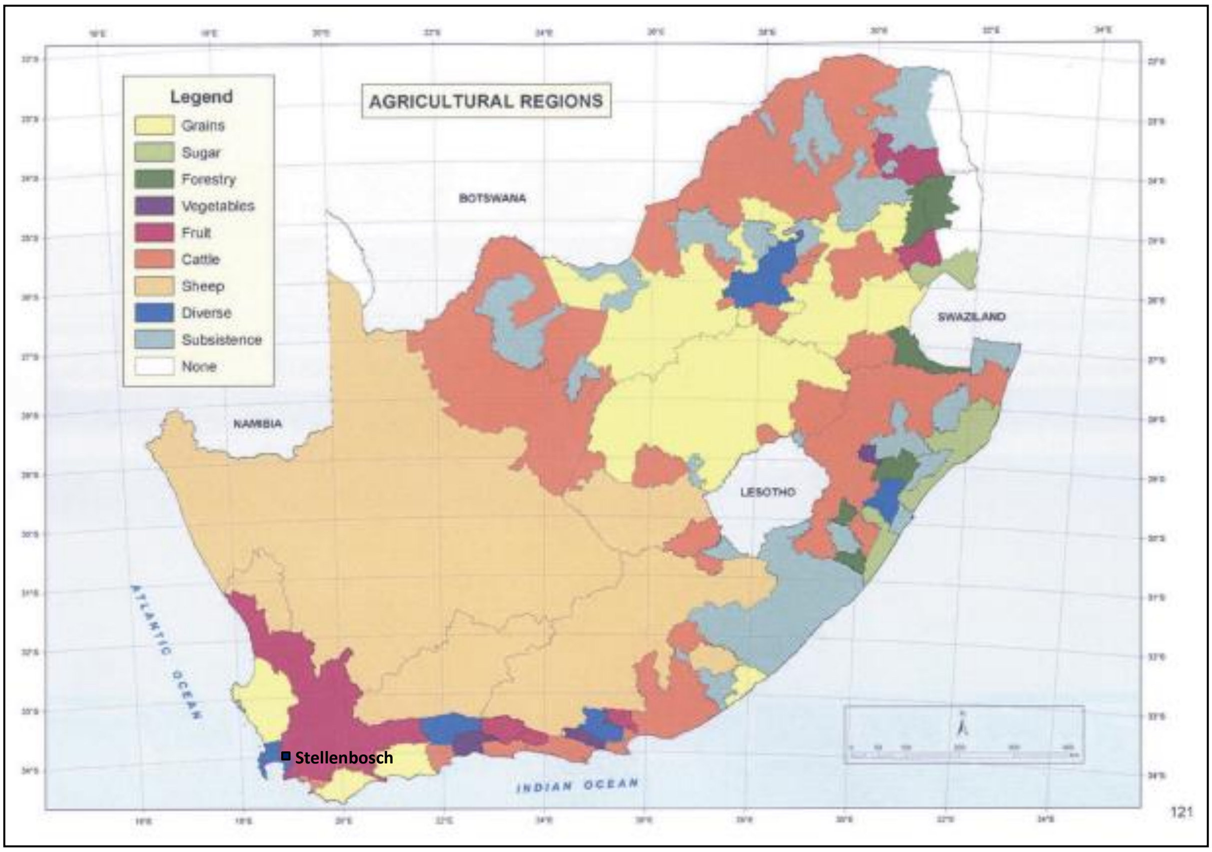


Figure 38: Most important agriculture enterprises in South Africa (Cloete & Olivier, 2010)

Agriculture activities that will serve as possible land use alternatives that can be followed will be selected from Table 11 by means of a filtering process. Filtering and ultimately selection of the agriculture activities will be based on:

- Suitability of the specific agriculture activity for the Stellenbosch climate
- Expert opinions
- Expert opinion but lack of required data

Filtering based on the first consideration, climatic suitability, will be done in Table 12. Research on each of the initial identified agriculture activities listed in Table 11, will be done to evaluate whether an activity is compatible for the Stellenbosch region, based on climatic requirements. A brief explanation regarding a specific activity's climatic requirements will be given, as well as whether the activity has been selected as a possible land use alternative for this study.

Table 12: Agriculture activities filtering based on climate suitability

CLIMATE	EXPLANATION	SELECTED	
		YES	NO
Sunflower Seed	Most prevalent in summer rainfall areas (Department of Agriculture Forestry and Fisheries, 2010c).		✖
Groundnuts	Cultivated in dry warm areas. Can only be planted on the same land every four years (Department of Agriculture, 2008).		✖
Sorghum	Cultivated in drier areas of South Africa. Requires short days, long nights (du Plessis, 2008).		✖
Subtropical Fruit	Thrives in subtropical climate		✖
Sugar Cane	Sugar Cane is considered a tropical plant and thus thrives in hot tropical areas such as KwaZulu-Natal (NETAFIM, n.d.; South Africa.info, 2015).		✖
Soya Beans	Warm temperature, short day plant. Temperatures above 30 °C from November till the end of March damage the plant. No cultivation in the Western Cape (Department of Agriculture Forestry and Fisheries, 2010b).		✖
Cotton	Requires an average summer rainfall of at least 600 mm for reasonable consistent production (Theron, 2015)		✖
Maize	Grown in temperate to tropic regions when the daily mean temperatures are above 15 °C (Water development and Managing unit, 2015) According to Western Cape AgriStats no canola is grown in the Stellenbosch region (Western Cape Department of Agriculture, 2016).		✖
Dry Beans	Thrives in warm climates. Grows optimally at temperatures ranging from 18 °C to 24 °C and is cultivated under rain condition (summer rainfall regions) (Department of Agriculture Forestry and Fisheries, 2010a)		✖

CLIMATE	EXPLANATION	SELECTED	
		YES	NO
Barley	Mostly cultivated on the southern coastal plains of the Western Cape (Department of Agriculture Foresrty and Fisheries, 2015). Barley requires an average of 390–430 mm of rainfall per year for optimal growth (Department of Agriculture Forestry and Fisheries, 2009). The average yearly rainfall for the Stellenbosch region, apart from 2015, is more than this (Table 37**).**		✖
Cowpeas	Requires hot dry temperatures, with the optimum temperature for growth and development being around 30 °C. It also required 400–700 mm rainfall (Department of Agriculture Forestry and Fisheries, 2011). This is therefore a crop that is grown in summer rainfall regions.		✖
Chicory	A summer rainfall vegetable (Agriculture Victoria, 2016). Predominantly cultivated in the Eastern Cape (Bramley & Kok, 2016)		✖

Further filtering based on opinions of experts will be done in Table 13. Agriculture activities from Table 11 that have filtered through the first filtering process will be evaluated. An explanation of each, as well as whether the specified activity has been selected, will once again be stated.

Table 13: Agriculture activities filtering based on Expert Opinions

EXPERT OPINION	EXPLANATION	SELECTED	
		YES	NO
Wheat	The Stellenbosch area is not ideal for any type of grain farming activities according to expert HE7.		✖
Canola	The Stellenbosch area is not ideal for any type of grain farming activities (HE7, 2016). According to Western Cape AgriStats no canola is being produced in the Stellenbosch region (Western Cape Department of Agriculture, 2016).		✖

EXPERT OPINION	EXPLANATION	SELECTED	
		YES	NO
Vegetables	Expert HE1 advised against potatoes, stating that the soil in the Stellenbosch area is not ideal. Tomatoes were also discouraged. The expert recommended evaluating cabbage crops and carrots.	✖	
Citrus Fruit	The Stellenbosch region's climate is suited for the cultivation of citrus fruit. Orange, soft citrus and lemons are well-suited for this region (HE7, 2016).	✖	
Viticulture	Stellenbosch is one of the most well-known wine making regions. Cabernet Sauvignon is particularly well-suited for this region (HE2, 2016).	✖	
Deciduous Fruit	Expert HE7 recommended against apples and pears. Expert HE1 also advised against the cultivation of pomegranates in the Stellenbosch region. Regarding deciduous fruit, expert HE7 suggested evaluating plums and peaches.	✖	
Lucerne, Oats, Lentils, Hay, Tobacco	Expert HE7 advised against the cultivation of any grain type crops in the Stellenbosch region.		✖

There are specific land use alternatives that subject experts recommended, but for which the researcher could not obtain the required information and data. These land use alternatives were thus excluded in this research study. Table 14 shows the land use alternatives that were omitted due to a lack of required data and with an accompanying explanation.

Table 14: Agriculture activities filtering based on Data Availability

LACK OF DATA	EXPLANATION	SELECTED	
		YES	NO
Blue Berries	Blueberries are well-suited for the Stellenbosch climate (HE7, 2016). Information for blueberries could not however be obtained. The researcher contacted various blueberry farmers in the region. The researcher was told that at this point of time the information is deemed as too sensitive and classified. Another blueberry farmer, situated in the George region, informed the researcher that there are plant rights associated with certain species of blueberries – the ones that are specifically cultivated for South Africa. Due to these plant rights, all information about that specific cultivars are considered classified (HE6, 2016).		✖
Fynbos Industry	Protea are well-suited for the Stellenbosch region (HE4, 2016), but due to a lack of data even though the researcher contacted independent protea farmers, this land use alternative will not be selected for the purpose of this thesis.		✖

7.3. DEVELOP SPECIFIC CONSIDERATIONS FOR EACH LAND USE ALTERNATIVE

Information was gathered from experts to be able to compare the selected land use alternatives with one another per consideration. The considerations that were developed in Section 4.2 will be used to assess the land use alternatives that filtered through the filtering process and were therefore selected. Figure 39 illustrates the category, the selected land use alternatives, as well as the alternative types that were selected for this research study. The information that was obtained by means of research and interviews with experts, will be displayed according to the different land use alternative types to populate. See Table 4 for each of the selected land use alternatives.

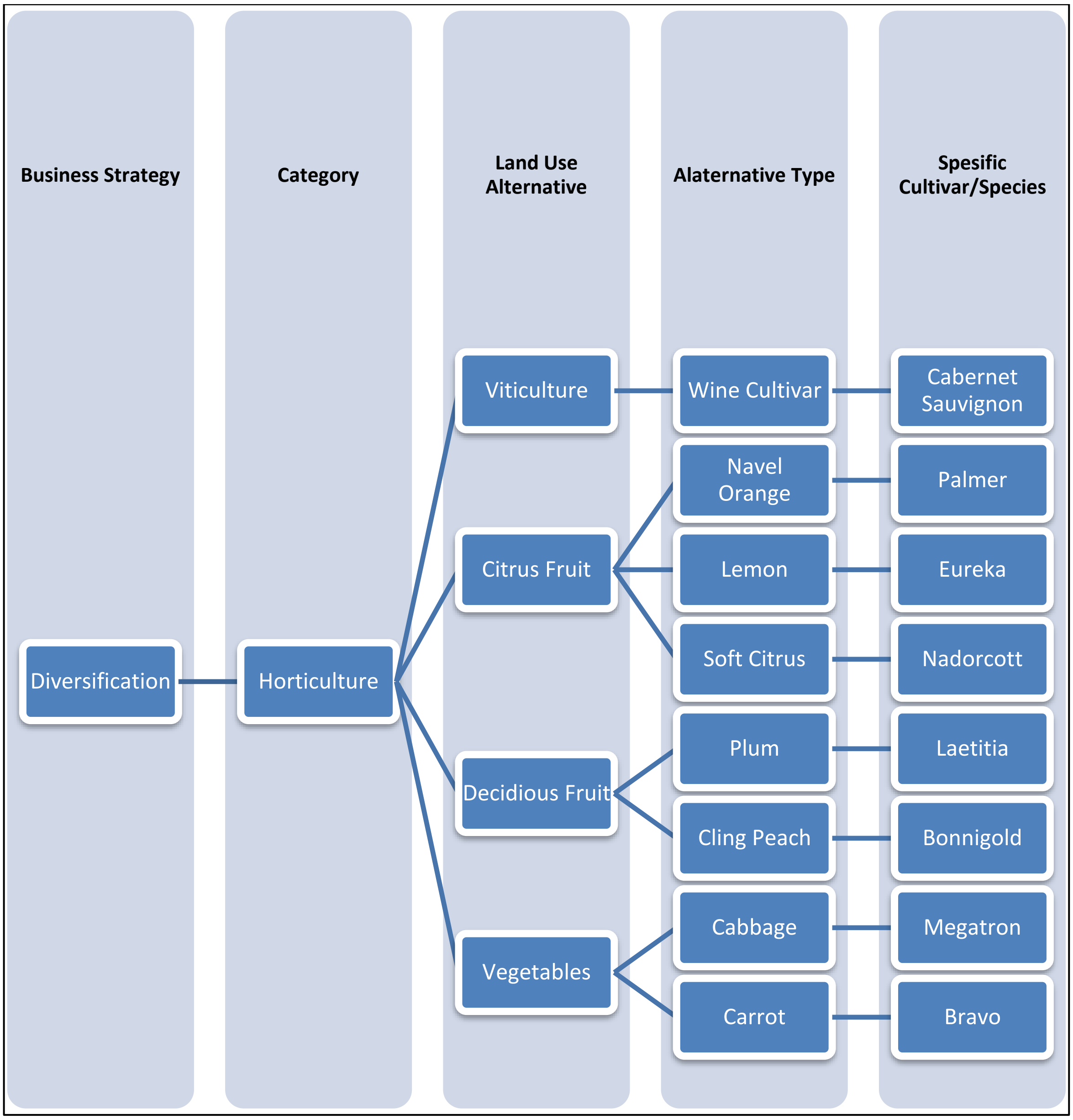


Figure 39: Thesis terminology and connectedness of selected land use alternatives and types

These populated tables can be seen in Appendix D: Populated Specific Considerations Tables.

Thus the process to populate Table 4 is as follows:

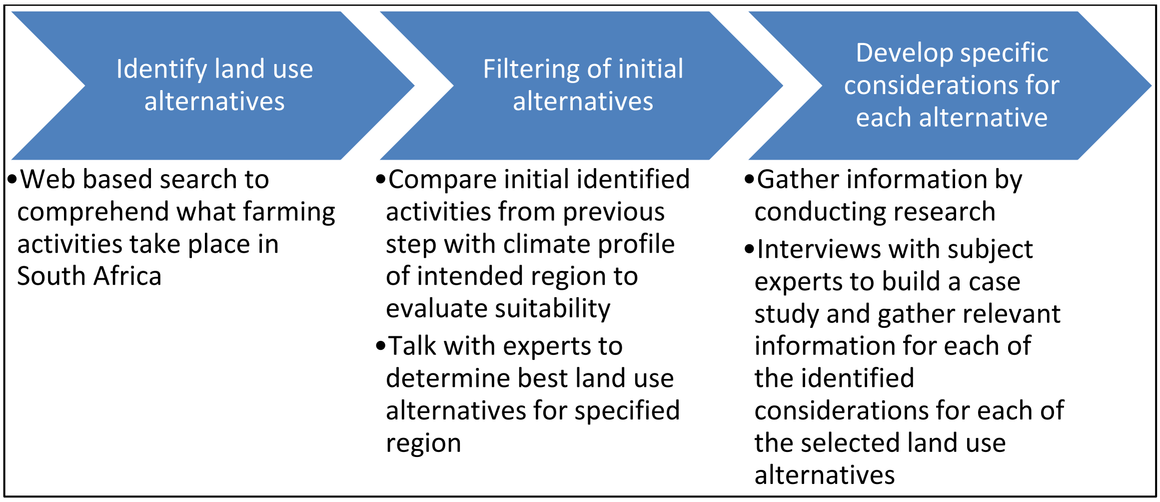


Figure 40: Process to populate Table 4

Figure 40 illustrates the three main processes, each of which was discussed in Sections 7.1, 7.2, and 7.3 respectively. The inputs of each of these processes and what each of the three processes consists of, are also shown in Figure 40.

7.4. APPLY THE DEVELOPED DSS

The last part of the illustrative case study is concerned with using the data collected in this chapter to populate the DSS that was developed in Chapter 5 to compare the selected land use alternatives with one another per consideration.

7.4.1. DATA, USER INPUT & ALTERNATIVES

As aforementioned, the model was built in Microsoft Excel. The different considerations that were developed in Section 4.2 and the data from the case studies of Chapter 7 were used to populate the matrix as shown in Figure 41.

Land Use Alternative	Category	Viticulture	Citrus			Deciduous Fruit		Vegetables	
	Type	Wine Cultivar	Navel Oranges	Lemons	Mandarins	Plums	Cling Peaches	Cabbage	Carrots
	Cultivar	Cabernet Sauvignon	Palmer	Eureka	Clementines	Laetitia	Bonnigold	Megaton	Star 3006
>=	Capital Investment (per	60427.53	186650	186650	186650	172519	118258	65000	75000
	Input Cost (per hectare)	48568.2	166851	215954	194912	281079	261216	22571.71	23466.05
	Average min temp of coldest		2	2	2				
	Required minimum Infruitec Chilling units (hours)					600	400		
	Water Availability (kL/ha/year)	3000	8500	10200	7650	9000	9000	4.5	2
	Human Element	2	2	2	2	1	1	1	2
	Estimate threshold required for	80	30	25	15	20	20	20	48
	Required Manpower (per hectare)	4.58	0.75	1.09	1.05	1.3	1.3	1.5	3.4
	Equipment	3	5	5	5	3	3	1	2
<=	Rainfall Season Region (1 = winter, 2 = no preference)	1	2	2	2	1	1	1	2
	Markets-Production (Ranking in terms of stability)	7	8	6	5	4	2	1	3
=	Packing store (1 required, 0 not)		1	1	1	1	1		
	Cellar	1							
Ranges	Soil Composition-pH level (lower boundary)	6	6	6	6	5.5	6	6.5	6
	Soil Composition-pH level (upper boundary)	6	6.5	6.5	6.5	6.5	6.5	7	6.5
	Local Climate Suitability-Rain (lower boundary)(mm)	500	655	573.5	589.5			380	200
	Local Climate Suitability-Rain (upper boundary)(mm)	800	983	1966.4	884.7			500	240
	Local Climate Suitability-Temp (Lower boundary)(°C)		13	13	10			-3	15
	Local Climate Suitability Temp		38	30	35			20	20
Extra info	Gross Income (per season per hectare)	59895.66	208780	454737	268315	318437.7	383333.3	91124.26	140735.3
	Minimum investment period (years)	4	2	2	2	5	5	0.1	0.1
	Harvest month (start)	4	3	5	4	1	11	9	0
	Crop Rotation time							3	3
	Main risks	Waste outweighs value adding	Markets regulation changes	Markets regulation changes	Markets regulation changes	Not adequate number of Infruitec chilling units	Very sensitive to climate changes, tree develops buttons if not adequate amount of Infruitec chilling	Pests Plague	Flood
		Pests/Diseases	Change of overseas protocalls and regulations	Change of overseas protocalls and regulations	Change of overseas protocalls and regulations	Pests/Diseases	Pests/Disease	Weed	Weed
		Labour strikes	New diseases, specifically Asian Greening	New diseases, specifically Asian Greening	New diseases, specifically Asian Greening	Sunburn	Filed fire if orchard are not kept clean	Hail	Pest/Disease
		Poor quality grape production	Labour related risks	Labour related risks	Labour related risks			Market establishment	
	Known diseases/fungi	Eutypa dieback	Fusarium (secondary fungus)	Botrytis	Alternaria brown spot	Bacterial cancer (latent in all plum cultivars)	Bud mite	Alternaria leaf spot	Bacterial blight
		Powdery mildew	Phytophthora parasitica	Fusarium (secondary fungus)	Fusarium (secondary fungus)				White mould
			Phytophthora citrophthora	Phytophthora parasitica	Phytophthora parasitica				
				Phytophthora citrophthora					
	Known pests	Snails	Red scale	Red scale	Red scale	American budworm	American budworm	Diamond back moth	Nematodes
		Snout Beetle	South African citrus thrips	South African citrus thrips	South African citrus thrips	Snout Beetle	Snout Beetle	Cutworm	Cutworms
		Grape berry	Mediterranean fruit flies	Mediterranean fruit flies	Mediterranean fruit flies			Thrips	Aphids
		Moth	Budworm	Budworm	Budworm			American bollworm	
		Birds	Woolly whitefly	Woolly whitefly	Woolly whitefly			Grey cabbage aphid	
	Harvest length (months)	1	3	5	2.5	2	1	1	1
<=	Sales stability	3	8	7	6	2	5	1	4
	Price stability	1	5	8	7	6	2	4	3

Figure 41: Populated Data Table

As explained in Section 5.4.6.1, the considerations were classified as critical or unfavourable conditioned considerations, depending on the land use alternative type. Table 15 illustrates the considerations that were classified as critical considerations according to the land use alternatives that were selected in Section 7.2.

Table 15: Critical considerations

Critical considerations for all land use alternatives	Critical considerations for specified land use alternatives	
	Land Use Alternative Type	**Considerations**
• Total budget in first year	• Wine Cultivar	• Rainfall Season Region • Cellar available on own premises
• Water Available	• Navel Orange • Lemon • Soft Citrus	• Average min of coldest month
• Hectares Available	• Navel Orange • Lemon • Soft Citrus • Plums • Peaches	• Packing storage available on own premises (or access to one)

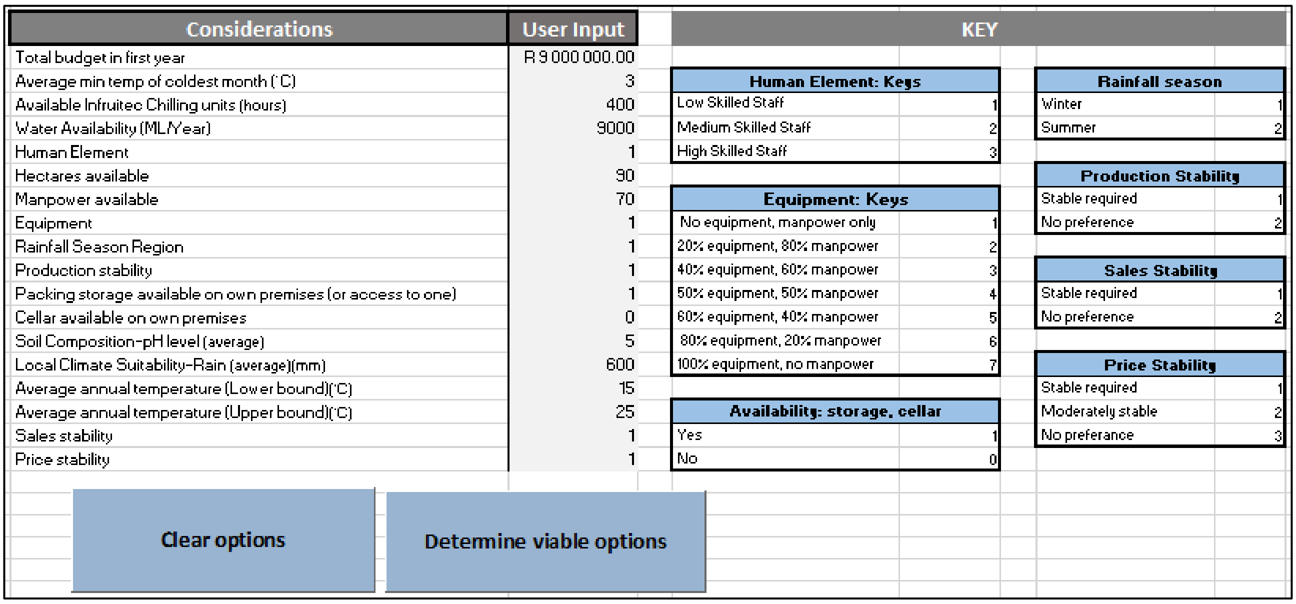
The considerations that were not classified as critical were thus labelled as unfavourable conditions, which, as stated before, means that the input provided by the user can violate the constraints of the considerations, but the program would not discard the alternative type. The land use alternative types are not discarded for these cases, because not adhering to these constraints does not mean that the alternative type is not suited for the region, but it simply means that the region does not provide optimal conditions. In some cases, conditions can be manipulated as in the case with the number of Infruitec chilling hours that are available in a region. Special products can be applied to the deciduous fruit trees when there are not enough Infruitec chilling hours available. Additional costs and knowledge regarding the application and time of application of these products are, however, required according to expert HE7. The following considerations were classified as *unfavourable conditions* according to the land use alternatives that have been selected in Section 7.2.

Table 16: Unfavourable condition considerations

Unfavourable condition considerations for all land use alternatives	Unfavourable condition considerations for specified land use alternatives	
	Land Use Alternative Type	Considerations
• Human Element	• Navel Oranges • Lemons • Soft Citrus • Cabbage	• Optimal temperature range

Unfavourable condition considerations for all land use alternatives	Unfavourable condition considerations for specified land use alternatives	
	Land Use Alternative Type	Considerations
	• Carrots	
• Equipment	• Plums • Peaches	• Chilling units required
• Market fluctuation	• Navel Oranges • Lemons • Soft Citrus • Plums • Peaches • Cabbage • Carrots	• Rainfall season
• Soil pH range level	• Wine Cultivar • Navel Oranges • Lemons • Soft Citrus • Cabbage • Carrots	• Rainfall requirements
• Manpower available		

Specified user values have been added to the user interface that was developed and discussed in Section 5.4.4, as illustrated in Figure 42.



Considerations	User Input
Total budget in first year	R 9 000 000.00
Average min temp of coldest month (°C)	3
Available Infruitec Chilling units (hours)	400
Water Availability (ML/Year)	9000
Human Element	1
Hectares available	90
Manpower available	70
Equipment	1
Rainfall Season Region	1
Production stability	1
Packing storage available on own premises (or access to one)	1
Cellar available on own premises	0
Soil Composition-pH level (average)	5
Local Climate Suitability-Rain (average)(mm)	600
Average annual temperature (Lower bound)(°C)	15
Average annual temperature (Upper bound)(°C)	25
Sales stability	1
Price stability	1

KEY

Human Element: Keys	
Low Skilled Staff	1
Medium Skilled Staff	2
High Skilled Staff	3

Equipment: Keys	
No equipment, manpower only	1
20% equipment, 80% manpower	2
40% equipment, 60% manpower	3
50% equipment, 50% manpower	4
60% equipment, 40% manpower	5
80% equipment, 20% manpower	6
100% equipment, no manpower	7

Availability: storage, cellar	
Yes	1
No	0

Rainfall season	
Winter	1
Summer	2

Production Stability	
Stable required	1
No preference	2

Sales Stability	
Stable required	1
No preference	2

Price Stability	
Stable required	1
Moderately stable	2
No preferance	3

Figure 42: Considerations where user gives an input (left) accompanying user input keys (right)

The consideration '*Total budget in first year' = [the total input cost (per hectare/year) + Capital investment (per hectare)] times the 'estimate threshold area required for profitability'.*

The viable land use alternative types which were obtained for the given user inputs of Figure 42, are illustrated in

VIABLE LAND-USE ALTERNATIVES				
Land-use alternative	**Mandarins**	**Cling Peaches**	**Cabbage**	**Carrots**
Annual Gross Income (Based on hectars required)	**R 4 024 725.00**	**R 7 666 666.00**	**R 1 822 485.20**	**R 6 755 294.40**
Capital Investment in first year (Based on hectars required)	R 2 799 750.00	R 2 365 160.00	R 1 300 000.00	R 3 600 000.00
Input Cost per year (Based on hectars required)	R 2 923 680.00	R 5 224 320.00	R 451 434.20	R 1 126 370.40
Total Cost in first year (Based on hectars required)	**R 5 723 430.00**	**R 7 589 480.00**	**R 1 751 434.20**	**R 4 726 370.40**
Remaining budget	R 3 276 570.00	R 1 410 520.00	R 7 248 565.80	R 4 273 629.60
Hectares required	15	20	20	48
Hectares remaining	75	70	70	42
Investment Period	2	5	0	0
Harvest month (start)	4	11	9	0
Crop rotation time (if required)			3	3
Risks	Markets regulation changes	Very sensitive to climate changes, tree develops buttons if not adequate amount of Infruitec chilling	Pests Plague	Flood
	Change of overseas protocalls and regulations	Pests/Disease	Weed	Weed
	New diseases, specifically Asian Greening	Filed fire if orchard are not kept clean	Hail	Pest/Disease
	Labour related risks		Market establishment	
Known diseases/fungi	Alternaria brown spot	Bud mite	Alternaria leaf spot	Bacterial blight
	Fusarium (secondary fungus)			White mould
	Phytophthora parasitica			
Known pests	Red scale	American budworm	Diamond back moth	Nematodes
	South African citrus thrips	Snout Beetle	Cutworm	Cutworms
	Mediterranean fruit flies		Thrips	Aphids
	Budworm		American bollworm	
	Woolly whitefly		Grey cabbage aphid	
Unfavourable conditions	Human Element	Equipment	Price stability	Manpower available
	Equipment	Sales stability	Average annual temperature (Lower bound)(°C)	Human Element
	Production stability	Average annual temperature (Lower bound)(°C)	Local Climate Suitability-Rain (average)(mm)	Equipment
	Sales stability		Average annual temperature (Upper bound)(°C)	Average annual temperature (Lower bound)(°C)
	Price stability			Local Climate Suitability-Rain (average)(mm)
	Average annual temperature (Lower bound)(°C)			Average annual temperature (Upper bound)(°C)
Harvest length (months)	2.5	1	1	1

Figure 43.

VIABLE LAND-USE ALTERNATIVES				
Land-use alternative	**Mandarins**	**Cling Peaches**	**Cabbage**	**Carrots**
Annual Gross Income (Based on hectars required)	**R 4 024 725.00**	**R 7 666 666.00**	**R 1 822 485.20**	**R 6 755 294.40**
Capital Investment in first year (Based on hectars required)	R 2 799 750.00	R 2 365 160.00	R 1 300 000.00	R 3 600 000.00
Input Cost per year (Based on hectars required)	R 2 923 680.00	R 5 224 320.00	R 451 434.20	R 1 126 370.40
Total Cost in first year (Based on hectars required)	**R 5 723 430.00**	**R 7 589 480.00**	**R 1 751 434.20**	**R 4 726 370.40**
Remaining budget	R 3 276 570.00	R 1 410 520.00	R 7 248 565.80	R 4 273 629.60
Hectares required	15	20	20	48
Hectares remaining	75	70	70	42
Investment Period	2	5	0	0
Harvest month (start)	4	11	9	0
Crop rotation time (if required)			3	3
Risks	Markets regulation changes	Very sensitive to climate changes, tree develops buttons if not adequate amount of Infruitec chilling	Pests Plague	Flood
	Change of overseas protocalls and regulations	Pests/Disease	Weed	Weed
	New diseases, specifically Asian Greening	Filed fire if orchard are not kept clean	Hail	Pest/Disease
	Labour related risks		Market establishment	
Known diseases/fungi	Alternaria brown spot	Bud mite	Alternaria leaf spot	Bacterial blight
	Fusarium (secondary fungus)			White mould
	Phytophthora parasitica			
Known pests	Red scale	American budworm	Diamond back moth	Nematodes
	South African citrus thrips	Snout Beetle	Cutworm	Cutworms
	Mediterranean fruit flies		Thrips	Aphids
	Budworm		American bollworm	
	Woolly whitefly		Grey cabbage aphid	
Unfavourable conditions	Human Element	Equipment	Price stability	Manpower available
	Equipment	Sales stability	Average annual temperature (Lower bound)(°C)	Human Element
	Production stability	Average annual temperature (Lower bound)(°C)	Local Climate Suitability-Rain (average)(mm)	Equipment
	Sales stability		Average annual temperature (Upper bound)(°C)	Average annual temperature (Lower bound)(°C)
	Price stability			Local Climate Suitability-Rain (average)(mm)
	Average annual temperature (Lower bound)(°C)			Average annual temperature (Upper bound)(°C)
Harvest length (months)	2.5	1	1	1

Figure 43: Output with provided user input of Figure 42

The viable land use alternatives that were generated according to the user input of Figure 42 were used to create a graph (Figure 44) that compares the total cost in the first year with the expected gross income per viable alternative. Moreover, the bubble sizes in the graph indicate the required investment period of each viable land use alternative before an alternative is expected to generate income.

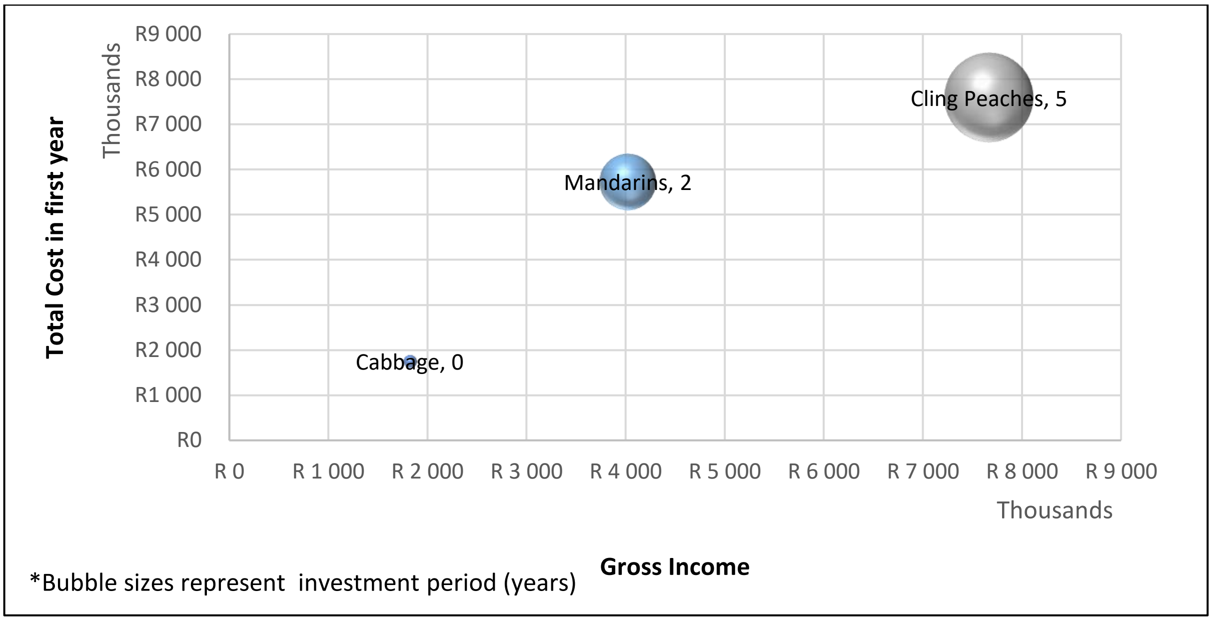


Figure 44: Cost in first year vs annual gross income comparison for user input of Figure 42

7.4.2. MARKETS

7.4.2.1. Target Market

The target market of each of the different land use alternative types was established during the case studies, using inputs from experts in each of the applicable fields. Table 17 shows each of the alternative types' target markets. The sales, production, and price stability of a land use alternative were established while building the model.

Table 17: Land Use Alternative Target Market

Land Use Alternative Type	Target Market
Wine Cultivar	International
Navel Orange	International
Lemon	International
Soft Citrus (Mandarins)	International
Plums	International
Cling Peaches	Local
Cabbage	Local
Carrots	Local

7.4.2.2. Sales Stability

Data to establish sales trends for each of the land use alternative types were gathered for the depicted years as shown in Figure 45. The data shown in Figure 45 for each of alternatives depends on whether the target market was local or international. Only export data was used if the target market was international, and only local sales data was used if the target market was found to be local.

Crop information		Annual local sales/exports (in tons)					
Category	Type	2009	2010	2011	2012	2013	2014
Viticulture	Specific Cultivar	20310.52	20020.6	17399.2	16172.9	19719.1	16997.2
Citrus	Navel Oranges	830431	102431	984116	1069961	1150456	1109148
	Lemons	131101	143203	160962	159831	169190	218354
	Mandarins	100103	114132	107945	116132	126633	149398
Deciduous Fruit	Plums	10017.14	9323.38	10302.6	8860.93	9111.34	8962.67
	Peaches	20100	24460	26200	28050	25002	21200
Vegetables	Cabbage	100210	109810	108009	100084	102401	103503
	Carrots	91369	85062	96405	111526	113355	112623

Figure 45: Sales Data (Analytix Business Intelligence for SAWIS, 2014; Department of Agriculture Forestry and Fisheries, 2015a, 2015b, 2015c, 2015d; SAWIS, 2015c)

The average and standard deviation of each of the land use alternatives were calculated as indicated in Figure 46, which was then used to calculate the sales stability of each. If the standard deviation deviated 10% or less from the average of the alternative, the alternative was deemed as stable in terms of sales. Wine cultivar, plums, and cabbage were found to be stable (refer to Figure 46). The alternatives were also ranked, based on their sale stability. This was done by dividing the standard deviation of each by its average value as shown in Figure 46.

Crop information			Stats			Rank	Stable	
Category	Type	Cultivar	Average	Std Dev	Std Dev/Average	1 = most stable To 8 = least stable	<10%	
Viticulture	Wine Cultivar	Cabernet Sauvignon	18436.6	1785.37	0.096838179	3	1843.66	Exports
Citrus	Navel Oranges	Palmer	874424	394833	0.451534796	8	87442.4	Exports
	Lemons	Eureka	163774	30074.8	0.183636284	7	16377.4	Exports
	Mandarins	Clementine	119057	17283	0.145165729	6	11905.7	Exports
Deciduous Fruit	Plums	Laetitia	9429.68	593.526	0.062942306	2	942.968	Exports
	Peaches	Bonnigold	24168.7	3011.23	0.124592149	5	2416.87	Local
Vegetables	Cabbage	Megaton	104003	4057.86	0.039016812	1	10400.3	Local
	Carrots	Star 3006	101723	12355.5	0.121461465	4	10172.3	Local

Figure 46: Sales/export Stats, Rank, & Stability

7.4.2.3. Production per Hectare

Data to establish production trends for each of the selected land use alternatives was collected for the specified years as shown in Figure 47. The data represents the total annual production amounts.

Crop information		Annual production (in tons)					
Category	Type	2009	2010	2011	2012	2013	2014
Viticulture	Wine Cultivar	18939.42	16591.4	20343.8	26280.4	23188.2	29947.1
Citrus	Navel Oranges	138321	142032	1428027	1518612	1632917	1783663
	Lemons	200132	229946	255496	231881	199444	322132
	Mandarins	139121.6	145122	139540	146132	146270	195293
Deciduous Fruit	Plums	59961	56009	67087	66987	81859	74054
	Peaches	160931	164102	169102	190131	178130	150901
Vegetables	Cabbage	130820	145380	148200	139103	140021	142081
	Carrots	144213	140201	161101	184321	188210	180910

Figure 47: Production Data (Analytix Business Intelligence for SAWIS, 2014; Department of Agriculture Forestry and Fisheries, 2015a, 2015b, 2015c, 2015d; HortGro, 2014; SAWIS, 2009, 2012a, 2015b)

The production per hectare of each of the alternatives was calculated using the same method as with sales stability. If the standard deviation deviated 10% or less from the average of the alternative, the alternative was considered as stable in terms of production. Peaches and cabbage were found to have production per hectare (refer to Figure 48), which correlates with the production per hectare rank average (Standard deviation) which is also shown in Figure 48. Navel oranges were found to be the most unstable in terms of production per hectare.

Crop information		Stats			Rank	Stable
Category	Type	Average	Std Dev	Std Dev/Average	1 = most stable To 8 = least stable	<10%
Viticulture	Specific Cultivar	22548.4	4948.74	0.219471777	7	2254.84
Citrus	Navel Oranges	1107262	758478	0.685003394	8	110726
	Lemons	239839	45578.4	0.190037674	6	23983.9
	Mandarins	151913	21493.8	0.141487677	5	15191.3
Deciduous Fruit	Plums	67659.5	9362.65	0.138379008	4	6765.95
	Peaches	168883	13758.5	0.081467528	2	16888.3
Vegetables	Cabbage	140934	6005.94	0.042615196	1	14093.4
	Carrots	166493	21043.1	0.126390455	3	16649.3

Figure 48: Production Stats, Rank, & Stability

7.4.2.4. Price Stability

To establish price trends for each of the selected land use alternatives, data was collected over the time period as shown in Figure 49. Export or local sales prices are shown in Figure 49, depending on whether the intended market was found to be local or international. The export price shown for the alternative type wine cultivar, is an average combined price for bottled and bulk exports.

Crop information			Average price (in R/ton)					
Category	Type	Local/Export	2009	2010	2011	2012	2013	2014
Viticulture	Wine Cultivar	Exports	24580	25840	24510	25130	23460	-
	Navel Oranges	Exports	3100	4050	4076	4230	5000	5892
	Lemons	Exports	2100	5811	5880	5790	7008	11105
	Mandarins	Exports	4500	5820	5822	7370	8690	9980
Deciduous Fruit	Plums	Exports	7 739	8 112	9 709	10 384	10 861	15 390
	Cling Peaches	Local	7570	7010	8000	8130	9580	8250
Vegetables	Cabbage	Local	1600	1390	1501	1752	2086	2384
	Carrots	Local	2650	3408	2901	2600	3290	3698

Figure 49: Price Data (Analytix Business Intelligence for SAWIS, 2014; Department of Agriculture Forestry and Fisheries, 2015a, 2015b, 2015c, 2015d; HortGro, 2015)

The average and standard deviations for each alternative type was once again calculated to be able to determine the price stability. If the standard deviations deviated less than 10% from the average value for an alternative type, that type was deemed stable. Figure 50 shows only one alternative was found to be stable. Therefore, another category, 'moderately stable' was added. An alternative type was considered moderately stable if the standard deviation deviated less than 25% from the average value of the alternative type. If the standard deviation deviated more than 25% from an alternative type's average value, that alternative type was unstable. The price stability rank, which was calculated as the standard deviation divided by the average of each of the alternative types, can also be seen in Figure 50. Lemons, mandarins (soft citrus), and plums were found to have fluctuating prices, while the alternative type wine cultivar, was found to have the most stable price trends.

Crop information			Stats			Rank	Stable	Moderate	Unstable
Category	Type	Local/Export	Average	Std Dev	StdDev/Avg	1 = most stable To 8 = least stable	<10%	<25%	>25%
Viticulture	Wine Cultivar	Exports	24704	876.4302596	0.035477261	1	2470.4	6176	
	Navel Oranges	Exports	4391.333	952.0492984	0.216801875	5	439.1333	1097.833333	
	Lemons	Exports	6282.333	2894.927886	0.460804566	8	628.2333	1570.583333	
	Mandarins	Exports	7030.333	2044.405211	0.290797764	7	703.0333	1757.583333	
Deciduous Fruit	Plums	Exports	10 366	2753.151606	0.265598676	6	1036.583	2591.458333	
	Cling Peaches	Local	8090	859.3253167	0.106220682	2	809	2022.5	
Vegetables	Cabbage	Local	1785.5	379.8408877	0.212736426	4	178.55	446.375	
	Carrots	Local	3091.167	442.7642337	0.143235316	3	309.1167	772.7916667	

Figure 50: Price Stats, Rank, & Stability

7.4.3. RISKS ASSESSMENT

The risk illustrated in Table 18, unless stated otherwise, has been identified by experts in each of the applicable fields. Each of the experts was also asked the perceived likelihood of the occurrence of that risk, and what the impact of occurrence associated with that risk would be. The overall risk factor for each of the different cases could then be obtained by using the quantification matrix (see Figure 21). A weighted average was calculated for each of the perceived risks. The expert consulted for each case is indicated in Table 18. For a more detailed description of the expert see Table 23.

Table 18: Risk, Likelihood, Relevance & Overall Impact Scores

LAND USE TYPE & CULTIVAR	EXPERT CONSULTED	RISK	LIKELIHOOD	IMPACT	RISK FACTOR	WEIGHTED AVERAGE
WINE CULTIVAR: CABERNET SAUVIGNON	Renier Uys	1. Waste outweighs value adding 2. Pests/Diseases 3. Labour problems 4. Poor quality grape production 5. Veld fires 6. Local market forces 7. Macroeconomic factors	3 4 4 3 2 4 3	3 5 4 3 5 5 4	5 8 7 5 6 8 6	6.43
NAVEL ORANGES: PALMER	Stephan Bruwer	1. Market regulation changes 2. Change of overseas protocols and regulations 3. New diseases filtering into the country – specifically Asian Greening 4. Labour related risks	2 5 3 1	2 3 3 1	3 7 5 1	4
LEMON: EUREKA	Stephan Bruwer	1. Market regulation changes 2. Change of overseas protocols and regulations 3. New diseases filtering into the country – specifically Asian Greening 4. Labour related risks	2 5 3 1	2 3 3 1	3 7 5 1	4
MANDARIN:	Stephan Bruwer	1. Market regulation changes	2	2	3	4

LAND USE TYPE & CULTIVAR	EXPERT CONSULTED	RISK	LIKELIHOOD	IMPACT	RISK FACTOR	WEIGHTED AVERAGE
CLEMENTINE		2. Change of overseas protocols and regulations 3. New diseases filtering through to the country, specifically Asian Greening 4. Labour related risks	5 3 1	3 3 1	5 7 1	
PLUMS: LAETITIA	Expert HE7	1. Sunburn 2. Pests/disease 3. Not adequate number of chilling units	2 1 2	5 5 5	6 5 6	5.67
CLING PEACHES: BONNIGOLD	Expert HE7	1. Bonnigold is very sensitive to climate changes – if there are not enough cold units, trees consequently gets buttons. 2. Disease/Pests 3. Veld fire if orchard is not kept clean	2 5 2	5 5 5	6 9 6	7
CABBAGE: MEGATON	Frans van den Berg	1. Hail 2. Weed 3. Pest Plague 4. Market establishment	1 2 3 4	5 3 4 4	5 4 6 7	5.5
CARROT: STAR 3006	Hugo Burger,	1. Disease/Pests 2. Weed 3. Flood	3 3 1	3 3 4	5 5 4	4.67

Uys (2016) made the following comments regarding risks in the wine industry:

- Waste outweighing benefit is relevant especially in organic grape farming. When nature does not work in harmony with the growth process of vineyards and grapes, some of the negative effects can still be negated with chemicals that would stimulate grape bunch forming, or suppress devastating diseases, for instance.
- Pests and diseases will always be present and farmers must take a preventative approach to pest/disease control.
- Labour problems' impact depends largely on time of year. Labour problems during harvest time will have a much more severe impact. Labour problems are frequent and range from bad discipline, negligence, alcoholism to an antagonistic attitude from workers.
- Poor quality grape production will usually be as a result of poor pest/disease control, unfavourable weather circumstances, or generally bad vineyard and soil planning and management.
- The risk of veld fires is predominantly during the summer months and mostly caused by negligent controlled fire practices or, as of late, due to arson and politically motivated.
- Free market forces of supply and demand have a severe impact on the profitability of grape production. When the market is flooded with grapes, the market prices will be low, causing a loss on the yield.
- Macroeconomic factors such as the exchange rate will have an effect on the foreign demand for domestic goods like wine. During a depreciation of the real exchange rate, there will be an increased demand and grape producers will be able to negotiate higher prices for their grapes. The inverse also holds.

The average weighted risk factor and the distribution of it is similar for all the different options, and due to time and scope constraints, an in-depth risk analysis could not be conducted. As such, the risk factors obtained for the various options, provided no conclusive basis for selection and was therefore not included as a selection consideration itself. However, since risk is a crucial consideration in any new venture, it was incorporated instead, into the framework as a cautionary informative add-on for each alternative. The application of the framework will therefore not only provide the most viable option itself, but also the accompanying risk considerations.

7.4.4. DISEASES/FUNGUS & PESTS

The main diseases/funguses and pests that were identified by experts or from the literature, can be seen in Table 19. A method of control, as well as the expert consulted for each case, is indicated in Table 19. For a more detailed description of the expert see Table 23.

Table 19: Pests, Disease, Fungus & Control Methods

Land Use Type & Cultivar	**Expert Consulted**	**Frequent Disease and Pests**	**Method of Control**
Wine Cultivar: Cabernet Sauvignon	Conrad Schutte	***Disease/Fungus:***	
		Eutypa dieback	Chemically
		Powdery mildew	Chemically
		Pests:	
		Snails	Chemically
		Snout Beetle	Chemically
		Grape berry Moth	Chemically
		Birds	
Navel Orange: Palmer	Hannes Bester	***Diseases/Fungus:***	
		Fusarium (secondary fungus)	Chemical
		Phytophthora parasitica	Chemically
		Phytophthora citrophthora	Chemically
		Pests	
		Red scale	Chemically
		South African citrus thrips	Chemically
		Mediterranean fruit flies	Chemically
		Budworm	Chemically
		Woolly whitefly	Apply toxic bait to leaves
			Chemically
		Ants	
Lemon: Eureka	Hannes Bester	***Diseases/Fungus:***	
		Botrytis-	Chemical
		Fusarium (secondary fungus)	Chemically
		Phytophthora parasitica	Chemically
		Phytophthora citrophthora	Chemically
		Pests	
		Red scale	Chemically
		South African citrus thrips	Apply toxic bait to leaves Chemically

Land Use Type & Cultivar	Expert Consulted	Frequent Disease and Pests	Method of Control
		Mediterranean fruit flies Budworm Woolly whitefly	Chemically Apply toxic bait to leaves
Mandarin: Clementine	Hannes Bester	***Diseases/Fungus:*** Alternaria brown spot Fusarium (secondary fungus) Phytophthora parasitica ***Pests*** Red scale South African citrus thrips Mediterranean fruit flies Budworm Woolly whitefly	 Chemically Chemically Chemically Chemically Chemically Apply toxic bait to leaves Chemically Apply toxic bait to leaves
Plums: Laetitia	Expert HE7	***Disease/Fungus*** Bacterial cancer (latent in all plum cultivars) ***Pests**:* American budworm Snout Beetle	 Chemical control Chemical control
Cling Peaches: Bonnigold	Expert HE7	***Disease/Fungus*** Bud mite ***Pests**:* American budworm Snout Beetle	 Fungicide Chemical control Chemical control
Cabbage: Megaton	Frans van den Berg	***Disease/Fungus*** Alternaria leaf spot ***Pests*** Diamond back moth Cutworm Thrips American bollworm Grey cabbage aphid	 Chemical control. Chemical control Chemical control. Chemical control. Chemical control. Chemical control.

Land Use Type & Cultivar	Expert Consulted	Frequent Disease and Pests	Method of Control
		(Department of Agriculture Forestry and Fisheries, 1998a)	
Carrot: Star 3006	(Department of Agriculture Forestry and Fisheries, 1998b; Starke Ayres, 2016)	***Diseases/Fungus***	
		Bacterial leaf blight	Crop rotation
		Cottony rot	Crop rotation
		Pests	
		Red spider mites	Chemically
		Cutworms	Chemically
		Aphids	Chemically

Since diseases/funguses and risks can be classified as a risk, it is an important consideration in any new agriculture undertaking. It was therefore integrated into the model as additional information for each alternative type. As such, precautionary steps can be taken for pest control.

7.4.5. EXTENDED DSS MODEL

The extended DSS model, which utilises the generated viable options of the DSS model with the user input of Figure 42, are depicted in Figure 51. The values generated for each of the considerations as illustrated in Figure 51 depends on the number of assigned hectares, in this case 20, 15, and 10 hectares, that were assigned to mandarins, cling peaches, and cabbage respectively. The totals thus reflect the total combined amounts of the different viable options when 20, 15, and 10 hectares are assigned to the respective viable alternatives. Figure 51 and Figure 52 show this combination of alternatives with the assigned hectares exceeding the specified budget.

Considerations	VIABLE LAND USE ALTERNATIVES			
Land-use alternative	Mandarins	Cling Peaches	Cabbage	Carrots
Hectares Assigned	20	15	10	0
Hectares Remaining	70	75	80	90
Annual Gross Income	R 5 366 300.00	R 5 749 999.50	R 911 242.60	R 0.00
Capital Investment in first year	R 3 733 000.00	R 1 773 870.00	R 650 000.00	R 0.00
Input Cost per year	R 3 898 240.00	R 3 918 240.00	R 225 717.10	R 0.00
Total Cost in first year	R 7 631 240.00	R 5 692 110.00	R 875 717.10	R 0.00
Remaining budget	R 1 368 760.00	R 3 307 890.00	R 8 124 282.90	R 9 000 000.00
Manpower required	21	19.5	15	0
Manpower remaining	49	50.5	55	70
Water required (ML/year)	153	135	0.045	0
Water remaining (ML/year)	8847	8865	8999.955	9000
	TOTALS			
Hectares Assigned	45 ha			
Hectares Remaining	45 ha			
Annual Gross Income	R 12 027 542.10			
Capital Investment in first year	R 6 156 870.00			
Input Cost per year	R 8 042 197.10			
Total Cost in first year	R 14 199 067.10			
Remaining budget	Insufficient funds. Additional R 5199067.1 required			
Manpower required	56 workers			
Manpower remaining	14 workers			
Water required (ML/year)	288 ML/year			
Water remaining (ML/year)	8712 ML/year			

Figure 51: Populated extended DSS model according to user input of Figure 42

As clearly illustrated in Figure 52, the total cost in the first year of the viable options, according to the assigned hectares, exceeds the specified budget of R9 million (indicated by the horizontal line on the graph). The figure further indicates how much each of the viable options contributes to the total cost in the first year.

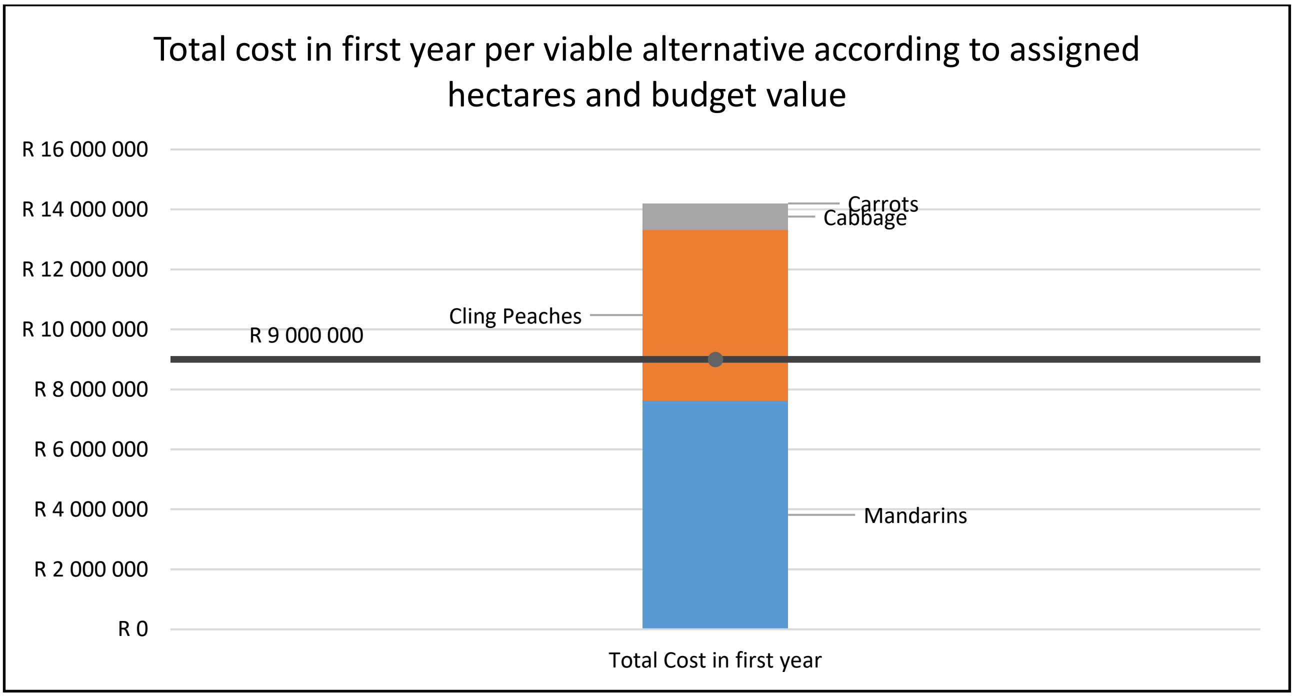


Figure 52: Total cost in first year per viable option according to assigned hectares and budget value

The percentage that each of the alternatives use of the total amount per alternative according to the assigned hectares, are illustrated in Figure 53. This graph is useful to quickly evaluate the different requirements of the viable option and compare the requirements of the different alternatives with each other.

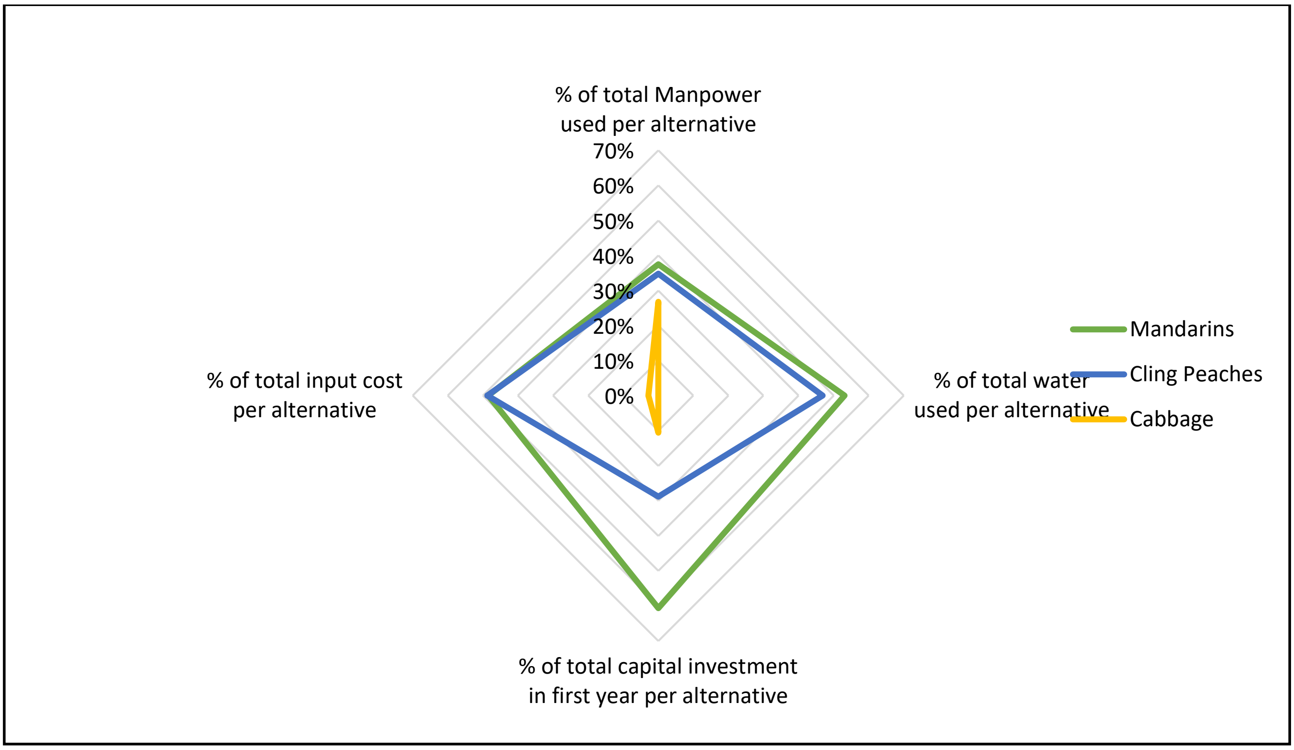


Figure 53: % each consideration use of the total amount per consideration according to assigned hectares

The last graph that was used to evaluate different considerations of the viable options according to the assigned hectares, compares annual expected gross income and input cost per year per viable alternative (see Figure 54).

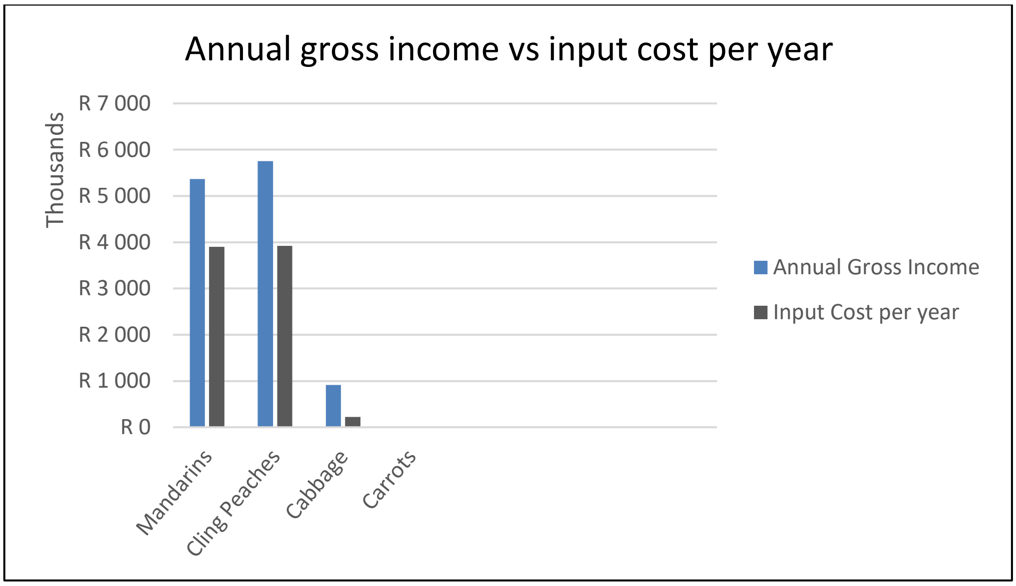


Figure 54: Expected annual gross income vs annual input cost per viable option according to assigned hectares

7.5. CHAPTER CONCLUSION

The aim of this chapter was to collect relevant information by making use of an iterative process, using the set of developed considerations of Section 4.2, which is incorporated into the DSS, and to employ the developed DSS in a specified region – Stellenbosch – as stipulated by the scope of this study. Firstly, the stepwise process which this chapter follows was outlined: identify land use alternatives, filtering initial land use alternatives, develop specific considerations for each land use alternative, and apply the developed DSS. Each of the steps of the process was described and executed sequentially thereafter. The land use alternative types and data collected to populate the DSS were specifically tailored for the Stellenbosch region. Eight different land use alternative types were selected and used in the developed DSS. The chapter's research objectives, as outlined in Section 1.4, have all been met as illustrated in Table 20. The developed DSS and the considerations will be validated in Chapter 8 to ensure that the case study is relevant and applicable.

Table 20: Chapter seven research objectives and outcomes

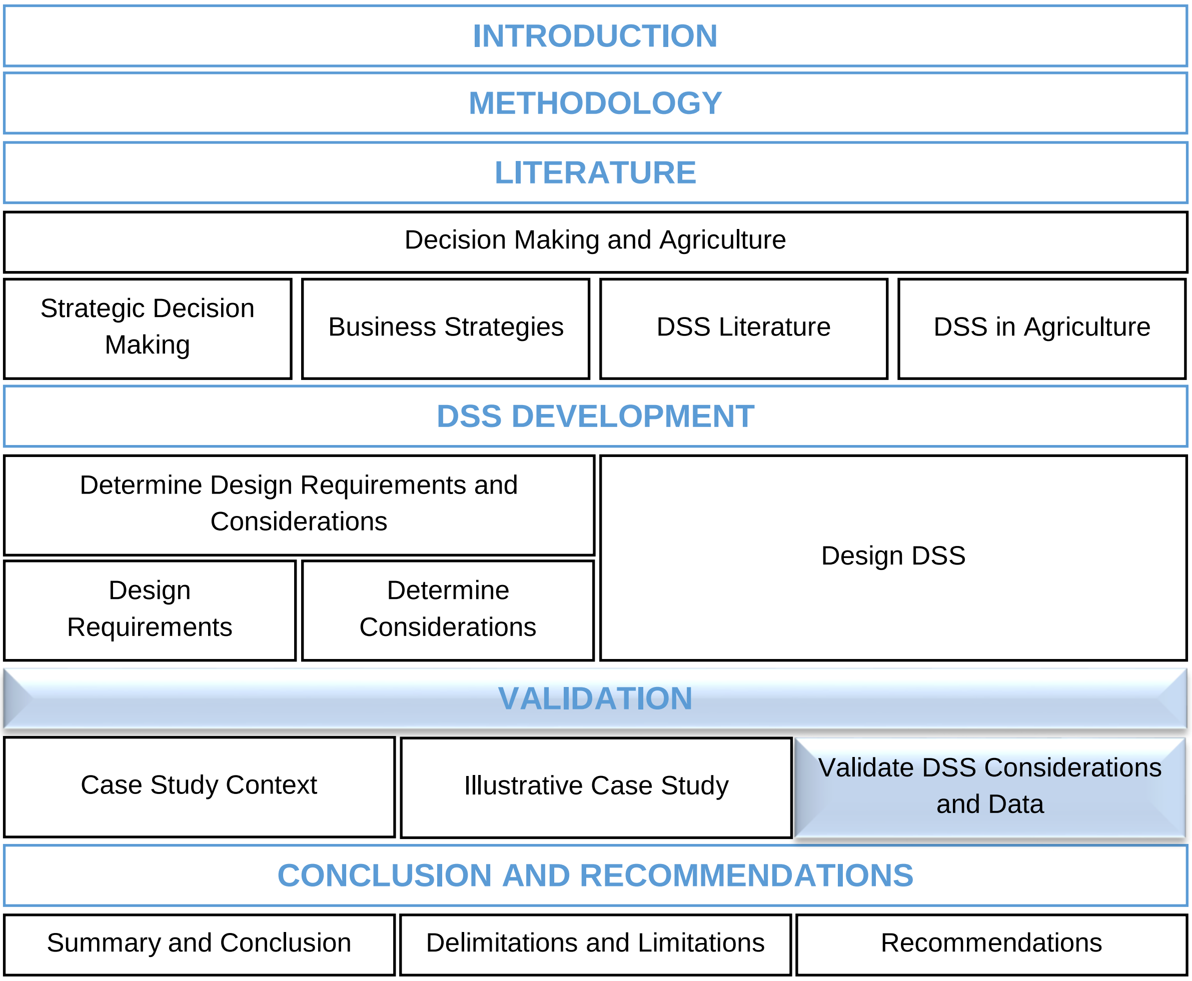
Research Objective	Section	Outcome
1. Identify possible land use alternatives for the Stellenbosch region	Section 7.1 Section 7.2	Main agriculture activities that take place in South Africa were identified in Section 7.1. Alternative types that expert pointed out are worth investigating as viable options for the Stellenbosch region, but for which data could not be obtained, were identified in Section 7.2.
2. Select specific land use alternative types that this study will focus on	Section 7.2	A filtering process based on climatic suitability, inputs from experts, and expert opinion, but lack of data, was used to select specific land use alternative types.
3. Compare the different selected land use alternatives	Appendix D: Populated Specific Considerations Tables	Information about each of the land use alternative types was gathered and presented as a case study which enabled the researcher to compare the different alternative types with one another per consideration.
4. Apply the developed DSS in the Stellenbosch region	Section 7.4	The developed DSS was applied in the Stellenbosch region by means of an illustrative case study. Data was collected from applicable parties to populate the developed DSS.

8

DSS VALIDATION

8. DSS VALIDATION

Junier & Mostert (2014) refer to validity as a model's capability to portray reality accurately. Information should therefore be seen as useful. Thus, it should be fit for the purpose, accessible, and user-friendly. The information therefore, is required to be perceived as valid in turn. Additionally, the perceived validity of a model or a DSS is determined by those who work with it, both the developers and the users (Junier & Mostert, 2014). Validating something therefore, gives credibility to a claim or statement. Therefore, it is important to validate one's work, to incorporate credibility and quality into it. The purpose of this chapter is to validate the considerations that were developed in Section 4.2 and resulting in the DSS that was developed in Chapter 5, to fulfil the research objective of this chapter as outlined in Section 1.4. An internal validation will first be done in Section 8.1 after which subject matter experts will be consulted to be able to conduct an external validation (Section 8.2).



8.1. INTERNAL VALIDATION

The eight step of the ten-step iterative process that was outlined in Section 3.3 of the literature study, indicated the importance of testing whether the interactions and outcomes of the model are appropriate and in line with the objectives and requirements of the developed DSS. To apply this step, an internal validation was conducted by the researcher to determine whether the developed DSS provides the expected outputs. For these scenarios the researcher provided different input values. Since the researcher knew which of the factors influenced the outputs prior to providing the input values, the input values could be manipulated accordingly to generate different possible viable land use alternatives. Thus, input values that generated different possible viable alternatives and therefore tested the logic and functionality of the proposed DSS, were chosen and used. The combination of input values that have been chosen, tests the critical as well as the favourable condition considerations. Creating different scenarios to test and evaluate the DSS, ensures that the researchers are certain that the DSS functions as it should, therefore performing an internal validation of the DSS. Various alternative input values were tested by manipulating crop alternatives values, in order to verify the coding logic. Some of the scenarios that the researcher conducted to perform the logic of the developed DSS are shown in Appendix I: Internal Validation Scenarios.

8.2. EXTERNAL VALIDATION

8.2.1. PROCESS

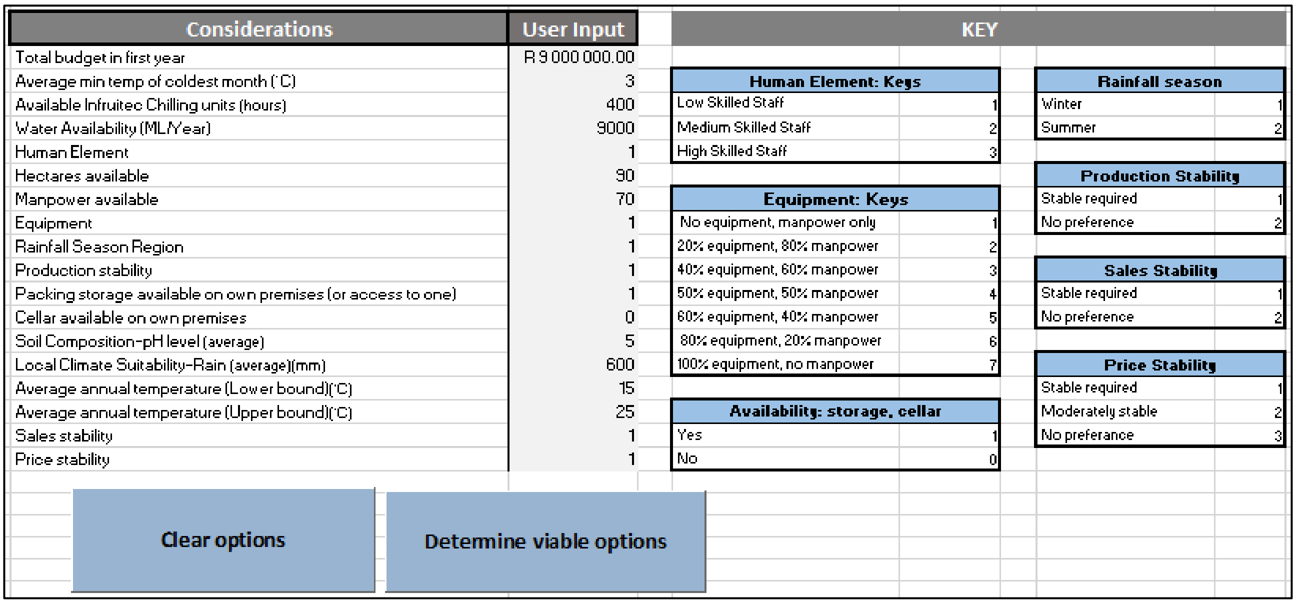
The tenth step of the ten-step iterative process (refer to Section 3.3 of the literature study) states that the model is required to be evaluated in terms of its objectives. This literature specified that data that was not used to develop the model, should be used to validate the developed model in this step, thus conducting an external validation.

The set of considerations developed in Section 4.2 was used for validation purposes. The researcher developed the considerations using inputs from experts and research to determine what is important and needs to be taken into account when a decision maker considers undertaking a new land use alternative. Developing the considerations after conducting a literature study and considering opinions from subject experts, serves as a first validation of the developed set of considerations. The set of developed considerations can provide assistance to farmers that are following or considering a diversification strategy, when they want to assess possible land use alternatives.

The developed considerations had to be validated by a person or persons from the agriculture industry, who is a farm owner, manager, or decision maker, to evaluate the quality and completeness of the set of considerations. The developed considerations were thus validated for a second time, although each of the experts in question was limited to their specified field of expertise.

Four independent candidates who are either a farm owner or farm manager in the Stellenbosch region, were contacted and interviews were set up. The researcher presented the developed DSS from Chapter 5, which incorporates the set of considerations from Section 4.2 and the information/data obtained from the illustrative case study of Chapter 7, to be able to compare the selected land use alternative types with one another per consideration. Furthermore, the stepwise process that was followed to apply the DSS in a particular region (Figure 37, Chapter 7), was also shown and explained to each of the interviewees. The researcher explained the purpose of the study, the aim of the research, and provided the study context for each of the interviewees so that they were able to orientate themselves to understand the research study better. A systematic process was followed where the researcher explained the developed DSS to each of the interviewees.

On each occasion the researcher began by explaining the model to an interviewee. This was followed by showing the relevant interviewee the stepwise process (Figure 37, Section 7) that was used to apply the DSS in the Stellenbosch region. A demonstration to illustrate how the model works was also given. The researcher validated the process that was followed, by showing each interviewee the process flow diagram of the developed DSS (Figure 10, Section 5.3), allowing them to understand how the different components of the DSS link together. Each of the consideration and the different keys (illustrated again in Figure 55) were explained in detail, an overview of how the VBA program works was provided, and the scope of the study was outlined. The researcher validated the input data by explaining to the interviewees how the data that was used in the DSS was obtained; that data was collected from either organisations or experts, and it was used in an illustrative case study to ensure that the data is valid and credible.



Considerations	User Input
Total budget in first year	R 9 000 000.00
Average min temp of coldest month (°C)	3
Available Infruitec Chilling units (hours)	400
Water Availability (ML/Year)	9000
Human Element	1
Hectares available	90
Manpower available	70
Equipment	1
Rainfall Season Region	1
Production stability	1
Packing storage available on own premises (or access to one)	1
Cellar available on own premises	0
Soil Composition-pH level (average)	5
Local Climate Suitability-Rain (average)(mm)	600
Average annual temperature (Lower bound)(°C)	15
Average annual temperature (Upper bound)(°C)	25
Sales stability	1
Price stability	1

KEY

Human Element: Keys	
Low Skilled Staff	1
Medium Skilled Staff	2
High Skilled Staff	3

Equipment: Keys	
No equipment, manpower only	1
20% equipment, 80% manpower	2
40% equipment, 60% manpower	3
50% equipment, 50% manpower	4
60% equipment, 40% manpower	5
80% equipment, 20% manpower	6
100% equipment, no manpower	7

Availability: storage, cellar	
Yes	1
No	0

Rainfall season	
Winter	1
Summer	2

Production Stability	
Stable required	1
No preference	2

Sales Stability	
Stable required	1
No preference	2

Price Stability	
Stable required	1
Moderately stable	2
No preferance	3

Figure 55: Considerations with user input (left) and keys (right)

The researcher asked each interviewee to create a scenario where they had to consider adopting a new land use alternative, and provide data that is applicable to each of their farms. The interviewees then inserted desired inputs into the model for the corresponding viable land use alternative types. Interviewee 1 and 4, used real data that was applicable to their farms, as well as different values, to evaluate and test the input data, to see how the DSS works and to ultimately validate the DSS overall. The other two interviewees were more interested in the developed considerations, thus validating the considerations and as a consequence they only ran the program once after they provided their user inputs. After the model demonstration and each of the interviewees evaluated the considerations, provided desired inputs, and ran the program to obtain corresponding land use alternatives, the researcher gave each of the interviewees an interview questionnaire to complete for validation purposes. Interview 1 and 4 therefore did a more in depth validation of the considerations, as well as the proposed model. Since the model was applied (real user input values were used by creating a scenario where the decision makers considered adopting land use alternatives for their farms), other input values to further test the model were used and only then was the questionnaire completed for validation purposes.

The different validation types that have been discussed in this section, as well as the implementation of the specified validation type, is illustrated in Table 21.

Table 21: Validation Types

Degree of Validation	**Type of validation**	**Method of implementation**
First External Validation	Consideration Validation	Literature study and opinions of experts.
	Input Validation	Gathering data from various subject experts and credible literature.
Second External Validation	Process Validation	Validating the process flow diagram of the developed DSS by subject experts..
	Input data Validation	Validating the input data that was used in the DSS by explaining to each of the interviewed subject experts how the data was obtained, and having a subject expert validate the DSS by using applicable real data.

Degree of Validation	Type of validation	Method of implementation
	Consideration Validation	Secondary consideration validation was ensured by interviewing subject experts to validate the developed considerations.
	DSS Validation	External validation by subject experts to validate the developed DSS.

8.2.2. FEEDBACK

The completed interview questionnaires of the four interviewees are in Appendix F: Validation Questionnaires. A summary of the feedback that was obtained from the completion of the questionnaires, as well as feedback that was given during the interview with the researcher, will be presented in this section.

8.2.2.1. Background contextualization of interviewees

Interviewee 1: Small holdings olive farm owner and acclaimed olive consultant. Has more than a decade of experience growing and processing table olives. Supplier of olives to selected retailers across South Africa. This expert also provides advice and assistance on the processing of table olives which includes process and facility design if required. An honorary life membership of the South African Olive industry was awarded to this expert. This expert has also written a book about olive processing.

Interviewee 2: Olive farm owner in the Stellenbosch region with a background in engineering systems.

Interviewee 3: Manager and winemaker at a well-established boutique wine estate in the Stellenbosch region, with previous exposure and experience to citrus, apple and sheep farming. This expert has over 10 years of experience in the wine industry. The wine estate produce and sells three different wine ranges.

Interviewee 4: Manger and blueberry analyst on a blueberry farm in the Stellenbosch region. BSc Agriculture background. The blueberry farm is one of the largest exporters of blueberries in South Africa.

8.2.2.2. Methodology related questions

Interviewee 1 believed the stepwise process that was followed to apply the developed DSS as well as the method that was used to develop the set of considerations, were very practical and inclusive. Interviewee 2 found the process to be sound, while interviewee 3 seemed more impartial towards the stepwise process, but argued that the method that was used to identify the considerations, was inclusive and complete. Interviewee 3 stated that for him a DSS is a new concept but that it could be useful by following the process. Interviewee 4 agreed with the methodology process and the method that was followed to identify the set of generic considerations.

There was an overall consensus from all four interviewees that the process that was followed to identify the considerations, was logical and correct.

8.2.2.3. DSS related questions

Interviewee 1 believed that the considerations (Section 4.2) identified in the DSS comprise of a comprehensive set for the assessment of alternative land use options. Interviewee 2 stated that it is nearly complete, but he suggested two additional considerations, namely availability of seasonal harvest labour, and the influence of the direction and strength of the wind. Interviewee 3 felt that the set of developed considerations was comprehensive for initial decision-making purposes, but that more considerations, specific to an alternative type, would arise as deeper investigation into that alternative is done. He further stated that the consideration, manpower per hectare, could be added as an informative output consideration. Interviewee 4 agreed with interviewee 3, in that more considerations that are specific to an alternative type will arise with deeper analysis of that specific alternative. However, he did agree that the identified considerations comprise of a good completed set of generic considerations.

All four interviewees agreed that the model is easy to understand, practical, and user-friendly.

The strong points of the proposed DSS to assess possible land use alternatives according to interviewee 1, include its broad base, applicability, and ease of use. Interviewee 2 pointed out the DSS's simplicity as a strong point, while interviewee 3 argued that the model takes climate, soil, and water into account, which he considered as critical considerations. Interviewee 4 argued that the user friendliness of the DSS is one of its strongest attributes. Expert 4 pointed out that the critical generic considerations that the DSS considers are a further strong point of the model.

The DSS could be enhanced by adding more alternative types, according to interviewee 2. Interviewee 1 and 4mdid not indicate any weak points. Interviewee 3 commented that the DSS provides one alternative rather than to give multiple viable options for a specific region, but stated that it is a preference point more than a weak point of the DSS.

It was found that the DSS is applicable according to all four interviewees, after they validated it by providing user inputs that are relevant to their respective farms.

After conducting an external validation by interviewing different subject matter experts, the outcome of each of the validation types, as outlined in Table 21, can be seen in Table 22.

Table 22: Outcomes according to Validation Type

Degree of Validation	Type of validation	Method of implementation
Second External Validation	Process Validation	It was found that the process flow diagram, as described to each subject matter expertise, is valid. Thus the process of developing the DSS for all regions is valid.
	Input data Validation	The subject matter experts all agreed on the method that was used to collect the data for the DSS. They further validated the input data by establishing whether the outputs aligned with what they know, when they provided applicable real data.
	Consideration Validation	The developed set of considerations was found valid according to all interviewed subject matter experts. Additional considerations that could be added to the set of developed considerations were suggested.
	DSS Validation	The interviewed experts all agreed about the usefulness and validity of the DSS.

8.2.2.4. Additional Information

Interviewee 2 stated that during 2015, because of the drought, farmers in their region (the Stellenbosch region) were only allowed to use 80% of their water quota, and that percentage reduced to 70% during 2016. Due to that, he argued that as a potential investor, not only would water availability be a very important consideration when assessing a possible land use alternatives, but he would specifically look for alternatives that can tolerate drought. Another aspect that he would most definitely evaluate when investigating a land use alternative, is farming with a cultivar that ripens out of season, in comparison to other varieties of its type, which would ensure that there is a market for it.

The feedback that was received from the four interviewees was positive overall. A principle indication is the fact that all three interviewees agreed that the DSS is applicable for its intended purpose.

Conducting these interviews with experts from the agricultural sector with exposure to different types of farming practices, introduced trust and reliability into the developed framework. The completeness of the set of considerations was evaluated as well as the relevancy and correctness. Creating a scenario where each of the interviewees was asked to provide user input as if they are considering to adopt land use alternatives, ensured validation of the applicability of the DSS to assess alternative land use options for a particular region. Thus the process of developing the DSS is valid for all regions, whereas the inputs and alternatives are specific for this region. Furthermore, because interviewee 1 and 4 not only used applicable data for the scenarios, but went further and provided different user inputs in order to obtain different associated alternatives, the use of the model was validated. This is reinforced by the fact that the interviewees are all in the agricultural industry, which means they not only have experience and knowledge as to what are important considerations to regard, but they also possess practical knowledge. Interviewing more than one expert from the industry creates further trust regarding the DSS, since ambiguity are reduced and an expert opinion from more than one source and agricultural field was obtained.

8.3. CHAPTER CONCLUSION

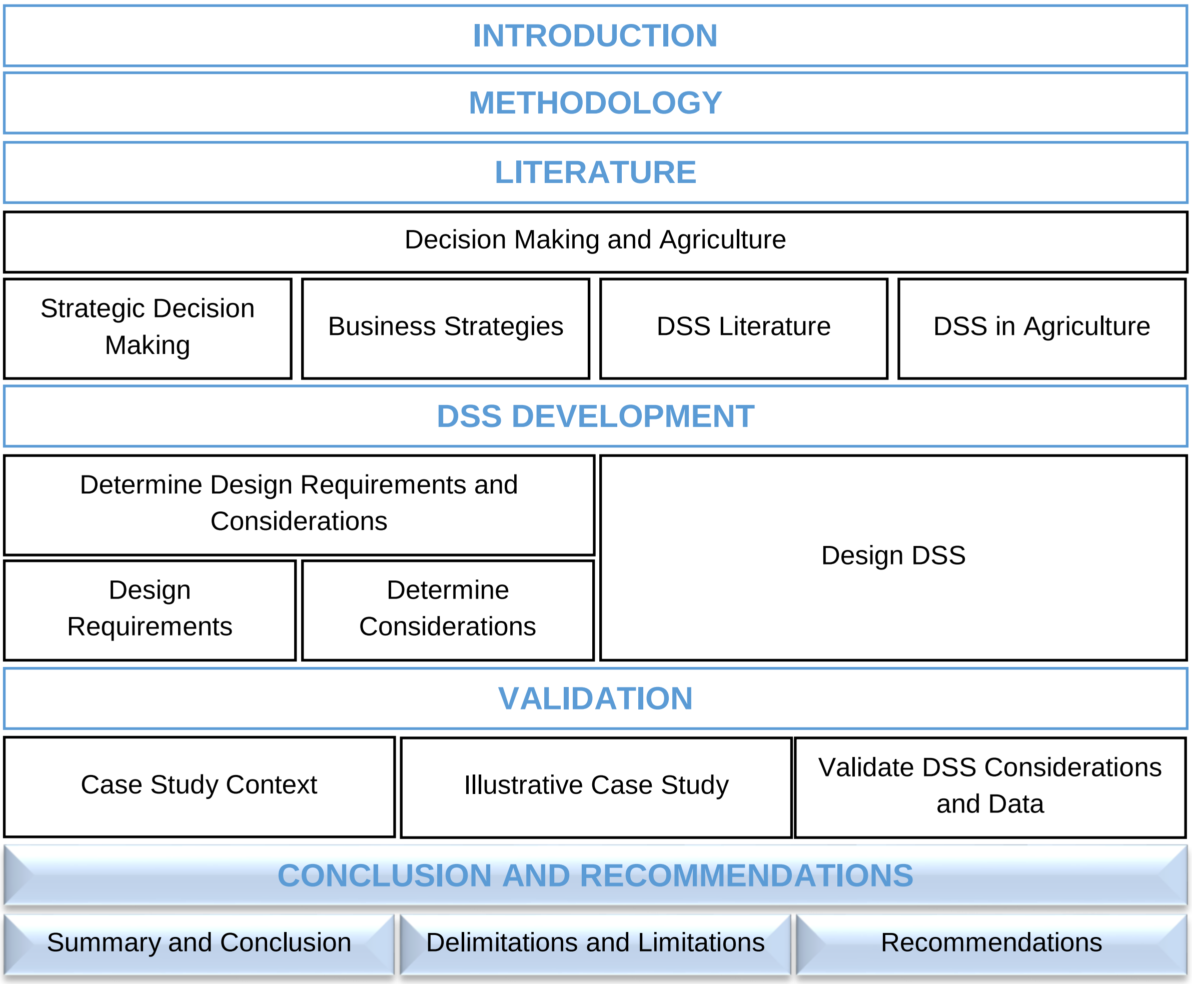
Consulting experts with vast knowledge of different types of farming practices within the agriculture industry ensured that reliability and credibility have been incorporated into the framework. It was important to interview experts with exposure to different types of farming practices wine, olives, citrus, apples, sheep, blueberries to ensure that the data obtained from the case studies could be evaluated accurately. As such, the research objective for this chapter, as set out in Section 1.4, has been met. The internal validation served to validate the coding logic of the developed DSS. Various alternative input values were tested by manipulating crop alternative values, in order to verify the coding logic. The researcher created different scenarios to conduct the internal validation. Subsequently it was found that the DSS behaved as expected. The logic of the DSS was therefore validated during the internal validation process. The application of the proposed DSS to an illustrative case study proved that, the model is easy, understandable, simplistic, and a valuable tool, as further enforced by the feedback gained from experts. Also, validating the developed considerations, indicates the completeness of the set of considerations, and that it can thus provide assistance to decision makers when they are assessing possible land use alternatives with the purpose of adopting a new alternative.

9

CONCLUSION & RECOMMENDATIONS

9. CONCLUSION AND RECOMMENDATIONS

The purpose of this chapter is to provide a holistic overview of the study conducted and to conclude the research study. A brief overview of each of the chapters that form part of this research study will be provided (Section 9.1), followed by the projects, delimitations and limitations that were experienced throughout the course of this project (Section 9.2). The research project will conclude with recommendations of possible future research (Section 9.3).



9.1. SUMMARY AND CONCLUSION

This study focussed on farm estates that are considering a diversification strategy, and are therefore seeking a set of considerations developed as part of a DSS, that will aid them when assessing possible land use alternatives in a specified region.

To properly define, understand, and determine the scope of the study, a project (Chapter 1) assisted the researcher to keep within certain research boudaries. Also, throughout the development of the project, the researcher could refer back to the research objectives that were defined in Section 1.4, to ensure that the research is alligned to achieve the different outcomes of the research project. A project methodology was set out in Chapter 2, that informed the reader but also guided the researcher as to what steps should be followed. The methodology highlighted the procedure that was followed to execute the project successfully, as well as to help in forming a structure for the research study.

A conclusion drawn from the literature analysis (Chapter 3), which placed specific emphases on strategic decisions for landscape alternatives, indicated that land use alternative decisions are categorised as strategic decisions. This conclusion was made after literature about strategic decision-making attributes were discussed and compared to the decisions that decision makers are faced with when they need to evaluate an alternative land use type. The role that top management – the individuals who are responsible for making the different decisions on the farm – play, came to light after reviewing literature in Section 3.1.2. Further research indicated that each of the decision-making team's characteristics has an effect on the decision-making process. It was therefore important to incorporate the decision-making team's applicable characteristics on this research study into the developed DSS . The characteristics that were included in the design of the DSS were: 1) the education level of the decision maker, and to a lesser extent 2) the risk inclination of the decision maker. Other factors that were identified in the literature review were omitted to keep the developed DSS as generic as possible. Literature suggested that strategic decisions and the strategic decision-making process should adjust to possible opportunities, constraints, potential threats and other environmental characteristics within the functioning domain of the enterprise. Factors that affect the business environment of an enterprise, were included in the external company characteristics category (Section 3.1.3). The influence of competition on the decision-making process was emphasised. Porter's Five Forces Framework (FFF) which is used to identify an enterprise's weaknesses and strengths, in order to develop and improve the enterprise's structure, as well as its corporate strategy, were first discussed and then adopted for this research study. Consequently, the following were determined: 1) in order to be sustainable, farmers need to attain a competitive position over opposing farms; thus allowing them to outperform rivals in terms of financial performance; 2) farms need to have a unique value proposition that allow them to stand out amongst competing farms; 3) farmers need two sources of value for their farm – evaluating the profit potential of the farm as well as the attractiveness level of functioning in that particular industry; 4) a larger farming enterprise will consequently be able to provide a product at a lower cost per unit than a farm that operated on small scale; 5) farms that produce a variety of products, according to the principle: economies of scope, are likely to have an advantage, due to the decrease in average cost of producing the different products; and 6) reputable well-established farms will have cost benefits over newly established farms regarding the acquirement of necessary raw materials to drive success.

The literature suggested that diversification strategies offer a trajectory toward viability, because income is generated from multiple sources which can account for business cycle variations and variation of seasonal income. In this study, diversification was primarily considered as agriculture diversification that is engaged in the cultivation of various crops. This definition excludes farm strategies aiming to relocate and recombine farm resources away from their original farming activities to generate an additional form of income.

After reviewing literature about decision support systems (Section 3.3), the importance of conducting a sound literature review, use valid sources from which to collect data, and to perform DSS validation to provide transparency in the designed DSS, was realised. A concern that emerged during the literature review, was the lack of flexibility in a DSS, the literature thus emphasised the importance of incorporating flexibility into the design of the DSS. This was done by creating a specific design requirement to address this concern. The ten-step iterative process (Section 3.3), guided the researcher in the designing process. This process pointed out the importance of including adequate model futures into the design of the proposed DSS to promote user acceptance and ease of use – consequently a design requirement to ensure this was formed.

The ten-step iterative process indicated the importance of providing the logic of the proposed DSS to conceptualise how it will work after it has been designed. Thus the logic of the DSS had to be mapped before the DSS could be designed.

It was found after reviewing literature regarding DSSs in agriculture (Section 3.4) that these DSSs only focussed on certain aspects regarding the suitability of an agricultural crop, and not on the farm practice as a whole, when considering which crops to select. These DSSs will, for example, focus on climate, but exclude manpower aspects. The purpose of the proposed model was to take into account different aspects when determining which crops would be best for a specified environment. Thus, a holistic set of considerations that will evaluate land use alternatives had to be developed and incorporated into the model. A design requirement stipulating that different aspects had to be taken into account during the design of the DSS, was formulated.

A set of considerations was developed and incorporated into the DSS, that are crucial to review before adopting any new land use alternative. The considerations were identified by reviewing literature as to what is important to take into consideration when assessing land use alternatives. Experts were consulted thereafter to enhance the completeness of the set of considerations. The ten-step iterative process indicated the importance of reviewing each of the identified considerations prior to developing the proposed DSS to establish whether some can be excluded, due to factors such as scope, practicality, or maintaining a generic form. This literature thus suggested that it was acceptable for the researcher to omit certain of the initial identified considerations during the design process of the DSS. The DSS was designed in accordance with the specified design requirements, as set out in Chapter 4. Literature indicated the importance of evaluating the education level of a farmer, but that the design requirement that fulfils this, was excluded from the developed DSS. This was due to the difficult nature to quantify this consideration and instead a possible evaluation of the consideration was done.

Problems that the wine industry are facing, such as the persisting drought and mounting pressure on profitability margins of wine estates, came to light after reviewing literature. Specific problems that the wine industry are experiencing, indicated why it is important for wine estates to investigate the possibility of re-evaluation of their agricultural strategies.

After the DSS was designed in accordance to the outlined design requirements, an illustrative case study was used to apply the developed DSS. To ensure that all the required data was obtained, a stepwise process was created that had to be followed during the application of the DSS. In the DSS a desired user input could be given to obtain viable land use alternatives corresponding to the user inputs that were developed in Chapter 5, and which incorporated the information from the case studies as well as the set of developed considerations.

Research further indicated the worth of validating the designed DSS to assess whether the interactions and outcomes of the developed model are appropriate and in line with its objectives and requirements. The researcher thus conducted an internal validation to assess the workings and coding logic of the designed DSS, to assess whether the DSS generates outcomes that were expected when various alternative input values were manipulated. External subject matter experts then further validated the designed DSS. Reviewing literature, indicated that data that was not used during the development process, thus external data, had to be used to validate the developed model. Experts validated the model by using values that were applicable in real life situations. Experts all agreed on the usefulness and applicability of the DSS. Thus the process of developing the DSS is valid for all regions, whereas the inputs and alternatives are specific for this region.

Therefore, farm owners should use the DSS as a guide to understand which considerations are important to regard, and subsequently which crops are best suited for their particular region, when they consider adopting a new agriculture diversification strategy.

It can be concluded that bankers can greatly benefit in using the developed DSS to inform farmers which agriculture strategy would be best to follow when farmers come to the bank to ask for an agriculture loan. The researcher suggests that the best method to populate complete input crop datasets, would be to get consultants to collect significant amounts of data which could then be pooled. Consultants can then use this pool of data as the need arises, to provide advice to farmers, or if a bank contracted the consultants, they could provide the necessary data to the bank regarding appropriate advice to agriculture customers. Consultants can also be used to keep the data pool updated.

The research objectives of each chapter were described, the completion thereof was specified, and the outcome, whether they were met or not, was specified. After the completion of this study, all the research objectives as outlined in Section 1.4, were met. The following proposed research aim of the study as set out in Section 1.3, was reached successfully: To develop a set of considerations as part of a DSS, to assess the available land use alternatives in a specified region, to ensure financial success and economic sustainability of wine estates in a region.

9.2. DELIMITATIONS & LIMITATIONS

As stated earlier, this section specifies the influence of the delimitations outlined by the researcher in Section 1.6 and the limitations that the researcher experienced throughout the research study. Current work could be improved and possible new study fields could be entered by identifying and stipulating these limitations. The impact of the outlined delimitations and limitations that were experienced throughout the course of the development and application of this study are recorded below.

9.2.1. DELIMITATIONS IMPACT

1. A DSS that can be used to possibly improve the management of recourses on a farm was developed. DSSs have innate limitations such as relying on quantifiable data to a certain degree. Consequently, indefinable or intangible data is challenging to analyse. The decision-maker must therefore thoroughly consider the end result, even when the DSS can quantify some of the facets. A decision-maker needs to keep in mind that it is impossible to capture all relevant data mechanically. Whereas some data might be cumbersome to capture, some cannot be recorded at all. A DSS in itself is a supporting tool, the final decision therefore still rests with the decision-maker.
2. The agriculture sector was the only sector that was considered when identifying possible land use alternatives for the proposed DSS. Consequently, there may be land use alternative from other sectors that were not investigated in this study that might prove to be more profitable or advantageous than the ones evaluated.
3. Research was conducted to identify different land use alternatives that wine estates in the Stellenbosch region could possibly implement. Once again, scoping the study to a specific region might've cause the results to be only applicable on this region.
4. Inputs and information from experts in different fields were gathered by means of interviews. Different means of gathering data could've lead to being more compelling and robust than single method studies.

5. Excluding supply chains and logistics from this study means that supply chain and logistics costs and time factors were not included in the results.
6. A full risk analysis was not performed. Consequently, all possible risks associated with a specific land use alternative were not included in the study. Decision-makers can therefore experience unexpected problems.
7. The possible land use alternatives in the proposed DSS were limited to a specific sample. Limiting the possible land use alternatives, might've cause bias towards the land use alternatives that were selected in this study. Increasing the sample size might've provided decision-makers with a wider choice between alternatives.
8. The DSS was validated by interviewing decision makers from the Stellenbosch region. Thus, the DSS might only be validated for the Stellenbosch region and the developed list of considerations might be insufficient for other regions.
9. The study focussed solely on agriculture and not business diversification. Business diversification might prove to be more financially feasible than agriculture diversification.

9.2.2. LIMITATIONS

1. The study focused on identifying land use alternatives from the agriculture sector, specifically for the Stellenbosch region. The results and conclusions might thus only be relevant to wine farms in this region. The list of considerations that were determined, even though the researcher tried to ensure that it was as generic as possible, may not be relevant and/or be incomplete for other regions.
2. Supply chain and logistic aspects were not included in this study. Other business sectors, other than the agriculture sector, were not considered for the identification of land use alternatives.
3. This study only included crop land use alternatives, thus excluding possible livestock alternatives.
4. To support decision-making, this study mainly focussed on financial feasibility – consequently, it did not consider aspects related to social and environmental feasibility.
5. The developed DSS is there to provide support to farmers when considering diversifying and thus undertaking a new land use alternative. Therefore, farmers are still required to evaluate the area that are available to them. Considerations which are specifically tailored to a limited area such as microclimate and typography, were therefore omitted from the model. Excluding certain identified considerations from the proposed DSS during the design phase, are further based on step seven of the ten-step iterative process that was discussed in Section 3.3 of the literature review.
6. The developed model assumes land ownership and does therefore not consider the cost of acquiring land.

7. Due to time and scope constraints, an in-depth risk analysis could not be conducted. Since risk is however a crucial consideration in any new venture, risks that experts identified were included into the DSS as a cautionary informative add-on for each alternative. The application of the DSS will therefore not only provide the most viable option itself, but also its accompanying risk considerations.
8. The model further assumes that an alternative type's estimate threshold area required, is the minimum amount of area that that type requires to be viable – it will thus exclude an alternative type if the area is smaller.
9. Another assumption that the developed DSS makes, is that costs relating to the construction of packing stores are not a contributing factor when considering the economy of scale of an alternative type. The area required to make an alternative type viable is therefore the minimum required area. The economy of scale of an alternative type, would have to increase to cover the construction expenses of a packing store.
10. Due to the self-reflective nature of the consideration *skillset of the farmer*, this consideration was excluded from the developed DSS, but rather incorporated into the research study as a post-risk analysis after the DSS was developed.

9.3. RECOMMENDATIONS FOR FUTURE RESEARCH

Throughout the course of this study, areas of possible improvement were identified.

1. As pointed out, this study focussed on finding land use alternatives for the Stellenbosch region. Future studies can thus take the study further and apply it in other locations, to evaluate whether the considerations, and therefore the framework, is still valid in other regions. If future studies find that additional considerations are required for the framework to be valid in other regions, those can be added to the developed set of considerations in this study.
2. Due to scope and time constraints, a full risk analysis was not performed during this study. Therefore, a full risk analysis which includes multiple inputs from experts per land use alternative type, can be performed as part of future work.
3. The developed DSS is not just applicable to one specified farm and therefore not one specified team of decision makers. The decision-making members in a team, will thus differ from one farm to the next, which, by implication means, that their cognitive diversity, age, gender, and what each member regards as promotion of the business-image/their self-image, will differ. Future research can evaluate how to incorporate these individual/team factors into decision-making.
4. The developed model assumes that an alternative type's estimate threshold area required, is the minimum amount of area required to be viable – it will thus exclude an alternative type

if the area is smaller. This gives the opportunity for further study to adapt the model not to discard an alternative type when the area provided by the user is smaller than the alternative's economy of scale. If this is executed correctly, it will enable a farmer to establish which land use alternative is the most viable option to employ on an additional small piece of acquired land, to his already existing farming venture. The additional acquired land will therefore not be his only revenue stream, and as such, a smaller amount than the identified economy of scale can be implemented and still be economically viable.

5. Different weights could be assigned to different considerations according to their relevancy and importance, which could be incorporated into the developed model.
6. A related field, organic farming, could be investigated. Considerations could be developed that are in accordance and relevant to organic farming, and a case study could be done to evaluate the relevancy and ultimately the validity of the developed considerations for organic farming.
7. Livestock could be incorporated as possible land use alternatives as well. Different considerations would however be required for livestock, such as carrying capacity and fencing.
8. Reflecting on the case study (Chapter 7), it was found that due to the nature of the data, the collection process tends to be tedious and long, which might not be optimal for farmers. To surpass this, it would be recommended that farmers from the same region pool their data. But this once again might not be that viable, which leads to an opportunity for consultants to collect a significant amount of data and pool it. The consultants can then use this pool of data as the need arises, to provide advice to farmers.
9. Banks might be the right group to commercialise a tool like the one which was developed in this research study. Section 5.4.8 was subsequently included in this research study. Thus a future recommendation is to validate the developed considerations and DSS outputs with a banking institution, since the next person the farmer would go to after using the developed DSS, is the bank – to get a loan for the input capital.
10. Improved profit over the long run is the main driving force behind land use alternative decisions. To improve profit, the revenue must be maximised and the cost minimized. Revenue is increased by increasing the production per hectare or increasing the price (quality). This unfortunately normally means increased cost. This is an optimization problem that can be considered in future.
11. The identification of a piece of land that's no longer profitable can also be difficult for some farmers that only look at their total financial situation. Considering all the existing blocks of land on a farm and using a DSS with the aim to optimise profitability of each block and the operation as a whole could further improve the DSS.
12. A further recommendation for future study includes looking at the optimization of available manpower and equipment when considering alternatives.

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REFERENCES

10. REFERENCES

Agriculture Victoria. (2016). *Sowing options for autumn: Cereal varieties and other alternatives*. Retrieved September 5, 2016, from http://agriculture.vic.gov.au/agriculture/dairy/pastures-management/forage-cereals/sowing-options-for-autumn-cereal-varities-and-other-alternatives

AgroClimatology. (2016). Helderfontein Weather Report.

Analytix Business Intelligence for SAWIS. (2014). South African Wine Export Analysis (2008-2013), (April), 124. Retrieved from www.wosa.co.za/knowledge/pkdownloaddocument.aspx?docid=323

Andrews, K. R. (1997). The concept of corporate strategy. In *Resources, firms, and strategies: A reader in the resource-based perspective* (p. 52).

Annetts, J. E., & Audsley, E. (2002). Multiple objective linear programming for environmental farm planning. *Journal of the Operational Research Society*, *53*(9), 933–943. doi:10.1057/palgrave.jors.2601404

ARC. (2013). *Production Guidline for Winter Vegetables*. Retrieved from http://www.arc.agric.za/arc-vopi/Leaflets Library/Production Guideline for Winter Vegetables.pdf

ARC Infruitec-Nietvoorbij. (2014). ARC Variteite.

Atanassov, K. (1986). Intuitionistic fuzzy sets. *International Journal Bioautomation*, *20*(1), 87–96. Retrieved from https://doaj.org/article/08c6e4e7c36d4934bc39ae4afeaf2dff

Atanassov, K., & Gargov, G. (1989). Interval valued intuitionistic fuzzy sets. *Fuzzy Sets and Systems*, *31*(3), 343–349. doi:10.1016/0165-0114(89)90205-4

Atkins, T. (n.d.). A Quick Guide To Chill Unit Calculations, 3–4. Retrieved from http://www.hortplus.com/main/article/chill unit calculations.pdf

Balezentiene, L., Streimikiene, D., & Balezentis, T. (2013). Fuzzy decision support methodology for sustainable energy crop selection. *Renewable and Sustainable Energy Reviews*, *17*, 83–93. doi:10.1016/j.rser.2012.09.016

Baležentis, T., & Zeng, S. (2013). Group multi-criteria decision-making based upon interval-valued fuzzy numbers: An extension of the MULTIMOORA method. *Expert Systems with Applications*, *40*(2), 543–550. doi:10.1016/j.eswa.2012.07.066

Barnes, A. P., Hansson, H., Manevska-Tasevska, G., Shrestha, S. S., & Thomson, S. G. (2015). The influence of diversification on long-term viability of the agricultural sector. *Land Use Policy*, *49*, 404–412. doi:10.1016/j.landusepol.2015.08.023

Bartolini, F., Bazzani, G. M., Gallerani, V., Raggi, M., & Viaggi, D. (2007). The impact of water and agriculture policy scenarios on irrigated farming systems in Italy: An analysis based on farm level multi-attribute linear programming models. *Agricultural Systems*, *93*(1-3), 90–114. doi:10.1016/j.agsy.2006.04.006

Bashir, T., Javed, A., Butt, A. A., Azam, N., Tanveer, A., & Ansar, I. (2013). An assessment study on the factors influencing the individual investor decision making behavior. *Journal of Business and Management*, *9*(5), 37–44. doi:2278-487X

BBC News. (2017, May 22). South Africa's Western Cape declares drought disaster. Retrieved from http://www.bbc.com/news/world-africa-40002770

Bester, H. (2016). Cirus Pests/Diseases.

Bisson, L. (2001). Section 1 - Factors Influencing Wine Quality. Retrieved from http://lfbisson.ucdavis.edu/PDF/VEN124 Section 1.pdf

Blees, J., Kemp, R., Maas, J., & Mosselman, M. (2003). Barriers to entry: differences in barriers to entry for SMEs and large enterprises. *Scientific Analysis of Entrepreneurship and SMEs.*

Borowski, I., & Hare, M. (2007). Exploring the gap between water managers and researchers: Difficulties of model-based tools to support practical water management. *Water Resources Management*, *21*(7), 1049–1074. doi:10.1007/s11269-006-9098-z

Bramley, M., & Kok, L. (2016). *Up close and chicory*. Retrieved September 5, 2016, from http://www.plaastoe.co.za/landbou/item/383-up-close-and-chicory

Brittingham, O. (2013). *Olivia's Wine Adventures*. Retrieved April 6, 2016, from http://oliviamb-wine.blogspot.co.za/2013/02/the-wines-of-south-africa.html

Bruwer, S. (2016). Citrus Risks.

Capital Investment. (2016). *Capital Investment Decisions*. Retrieved September 7, 2016, from http://www.capital-investment.co.uk/capital-investment-decisions.php

Castelán-Ortega, O. A., Fawcett, R. H., Arriaga-Jordán, C., & Herrero, M. (2003). A decision support system for smallholder campesino maize-cattle production systems of the Toluca Valley in Central Mexico. Part II - Emulating the farming system. *Agricultural Systems*, *75*(1), 23–46. doi:10.1016/S0308-521X(01)00110-X

Cheng, D. S. Y. (2013). Analyze the hotel industry in Porter Five Competitive Forces. *The Journal of Global Business Management*, *9*(3), 52–57.

Citrus Research International. (2010). Citrus Varieties (pp. 1–12).

City of Cape Town. (2017). City of Cape Town: Water Dashboard, (August), 7–9. Retrieved from http://resource.capetown.gov.za/documentcentre/Documents/City research reports and review/damlevels.pdf

Cloete, S., & Olivier, J. (2010). South African sheep and wool industries. In D. Cottle (Ed.), *The international sheep and wool handbook*. Manor Farm, Thrumpton, Nottingham NG11 0AX, United Kingdom: Nottingham University Press.

Collender, R. N. (1989). Estimation risk in farm planning under uncertainty. *American Journal of Agricultural Economics*. Retrieved from http://search.ebscohost.com/login.aspx?direct=true&db=bth&AN=4596241&site=ehost-live

Collins Cobuild. (1988). *Collins Cobuild Essential English Dictionary*. (G. Fox, Ed.) (2d ed.). William Collins Sons & Co Ltd.

Cornell University. (2015). *Cornell gardening resources Microclimates*. Retrieved March 15, 2016, from http://www.gardening.cornell.edu/weather/microcli.html

Coulon-Leroy, C., Charnomordic, B., Thiollet-Scholtus, M., & Guillaume, S. (2013). Imperfect knowledge and data-based approach to model a complex agronomic feature - Application to vine vigor. *Computers and Electronics in Agriculture*, *99*, 135–145. doi:10.1016/j.compag.2013.09.010

Cox, A. (2001). Understanding buyer and supplier power: A framework for procurement and supply competence. *Journal of Supply Chain Management*, *37*(1), 8–15. doi:10.1111/j.1745-493X.2001.tb00094.x

Dälken, F. (2014). Are Porter's Five Competitive Forces still Applicable? A Critical Examination concerning the Relevance for Today's Business. *University of Twente*, 10–24. Retrieved from http://essay.utwente.nl/65339/

De Kok, J. L., & Wind, H. G. (2003). Design and application of decision-support systems for integrated water management: lessons to be learnt. *Physics and Chemistry of the Earth, Parts A/B/C*, *28*(14-15), 571–578. doi:10.1016/S1474-7065(03)00103-7

De Swaan Arons, H., & Waalewijn, P. (1999). A Knowledge Base Representing Porter' s Five Forces Model. Retrieved from http://hdl.handle.net/1765/753

De Vries, W. M. (1993). FARMING WITH OTHER GAINFUL ACTIVITIES IN THE NETHERLANDS. *Sociologia Ruralis*, *33*(2), 190–202. doi:10.1111/j.1467-9523.1993.tb00960.x

De Wit, C. T., van Keulen, H., Seligman, N. G., & Spharim, I. (1988). Application of interactive multiple goal programming techniques for analysis and planning of regional agricultural development. *Agricultural Systems*, *26*(3), 211–230. doi:10.1016/0308-521X(88)90012-1

Dean, J., & Sharfman, M. (1993). Procedural rationality in the strategic decision- making process. *Journal of Management Studies*, *30*(4), 587 – 610. doi:10.1111/j.1467-6486.1993.tb00317.x

Department of Agriculture. (2008). *Cultivation of Groundnuts*. doi:10.4103/2229-5070.138534 [doi]\rTP-4-80 [pii]

Department of Agriculture Foresrty and Fisheries. (2015). *Agriculture*. Retrieved from http://www.gcis.gov.za/sites/www.gcis.gov.za/files/docs/resourcecentre/Agriculture2015.pdf

Department of Agriculture Forestry and Fisheries. (1998a). Production guidelines for Cabbage, *1*, 22. doi:10.3389/fphys.2012.00155

Department of Agriculture Forestry and Fisheries. (1998b). Production guidelines for Carrot, *1*, 16. doi:10.3389/fphys.2012.00155

Department of Agriculture Forestry and Fisheries. (2008a). Plums. Retrieved from http://www.nda.agric.za/docs/Brochures/plum.pdf

Department of Agriculture Forestry and Fisheries. (2008b). Protea Brochure. Retrieved from http://www.nda.agric.za/docs/Brochures/proteabrochure.pdf

Department of Agriculture Forestry and Fisheries. (2009). *Barley*. *Statewide Agricultural Land Use Baseline 2015* (Vol. 1). doi:10.1017/CBO9781107415324.004

Department of Agriculture Forestry and Fisheries. (2010a). *Dry beans Production guideline*. Retrieved from http://www.nda.agric.za/docs/Brochures/prodGuideDryBeans.pdf

Department of Agriculture Forestry and Fisheries. (2010b). *Soya Beans - production guideline*. Retrieved from http://www.nda.agric.za/docs/Brochures/Soya-beans.pdf

Department of Agriculture Forestry and Fisheries. (2010c). *Sunflower Production guideline*. *Production Guideline* (Vol. 5). doi:10.1002/0471743984.vse0337

Department of Agriculture Forestry and Fisheries. (2011). *Production guidelines for Cowpeas*. Retrieved September 5, 2016, from http://www.arc.agric.za/arc-gci/Fact Sheets Library/Cowpea - Production guidelines for cowpea.pdf

Department of Agriculture Forestry and Fisheries. (2012a). *A Profile of the South African carrot market value chain*. Retrieved from http://www.nda.agric.za/docs/AMCP/CARROT2012.pdf

Department of Agriculture Forestry and Fisheries. (2012b). Grapes Production Guidline, 2009. doi:doi:10.1201/b11576-25

Department of Agriculture Forestry and Fisheries. (2013). *Abstract of Agricultural Statistics 2013*. Retrieved from www.nda.agric.za/docs/statsinfo/Abstract2013

Department of Agriculture Forestry and Fisheries. (2015a). A profile of the South African cabbage market value chain. *Department of Agriculture Forestry and Fisheries Republic of South Africa*, 1–52.

Department of Agriculture Forestry and Fisheries. (2015b). A profile of the South African carrot market value chain, 1–36.

Department of Agriculture Forestry and Fisheries. (2015c). *A PROFILE OF THE SOUTH AFRICAN CITRUS MARKET VALUE CHAIN*. Retrieved from http://www.nda.agric.za/docs/AMCP/Litchi2012.pdf

Department of Agriculture Forestry and Fisheries. (2015d). A profile of the South African peach market value chain, 1–36. doi:10.1007/s13398-014-0173-7.2

Department of Agriculture Forestry and Fisheries. (2015e). *A profile of the South African plum market value chain*. doi:10.1007/s13398-014-0173-7.2

Department of Agriculture Forestry and Fisheries. (2016). *Abstract of Agricultural statistics* (Vol. 1). doi:10.1017/CBO9781107415324.004

Department of Environmental Affairs. (2008). *Tertiary Sector*. Retrieved August 24, 2016, from http://soer.deat.gov.za/608.html

Dieter, G. E., & Schmidt, L. C. (2013). *Engineering Design* (Fith.). McGraw Hill.

Dogliotti, S., Van Ittersum, M. K., & Rossing, W. A. H. (2005). A method for exploring sustainable development options at farm scale: A case study for vegetable farms in South Uruguay. *Agricultural Systems*, *86*(1), 29–51. doi:10.1016/j.agsy.2004.08.002

Drake, P. P. (2010). Value-added measures of performance and residual income valuation.

Du Plessis, J. (2008). Sorghum production. *Department of Agriculture*, 1–14. Retrieved from http://www.nda.agric.za/docs/Infopaks/FieldCrops_Sorghum.pdf

Du Toit, P. (2016). Buffalo.

Dugo, G., & Di Giacomo, A. (2015). *Citrus: The genus Citrus*. *PhD Proposal* (Vol. 1). London: Taylor & Francis Inc. doi:10.1017/CBO9781107415324.004

Dury, J., Schaller, N., Garcia, F., Reynaud, A., & Bergez, J. E. (2012). Models to support cropping plan and crop rotation decisions. A review. *Agronomy for Sustainable Development*, *32*(2), 567–580. doi:10.1007/s13593-011-0037-x

Dutton, J. E. (1993). Interpretations on automatic: A different view of strategic issue diagnosis*. *Journal of Management Studies*, *30*(3), 339–357. doi:10.1111/j.1467-6486.1993.tb00308.x

Elbanna, S. (2006). Strategic decision-making: Process perspectives. *International Journal of Management Reviews*, *8*(1), 1–20. doi:10.1111/j.1468-2370.2006.00118.x

FAOSTAT. (2016). *Production/Crops*. Retrieved April 13, 2016, from http://faostat3.fao.org/browse/Q/QC/E

Food and Agriculture Organization of the United Nations. (2015). *Crop Water Information: Cabbage*. Retrieved October 23, 2016, from http://www.fao.org/nr/water/cropinfo_cabbage.html

Food and Agriculture Organisation of the United Nations. (1989). *Citrus Juices: Trends and Prospects in World Production and International Trade*. Rome. Retrieved from https://books.google.co.za/books?id=dkqSHEQoayEC&pg=PA11&lpg=PA11&dq=citrus+juice+varieties&source=bl&ots=7GPzOZwqIT&sig=9q2BYi0K7QoO2aSqCZg76n1d8ro&hl=en&sa=X&ved=0ahUKEwj6jq6bqYnMAhXIQBQKHZbWAjsQ6AEIQDAG#v=onepage&q=citrus juice varieties&f=false

Gamble, J., & Thompson Jr, A. (2014). *Essentials of strategic management*. Irwin Mcgraw-Hill.

Gaultney, L. D. (1985). The potential for expert systems in agricultural systems management. *ASAE Paper*, *1*(85-5033).

Goldammer, T. (2016). *Vineyard Site Selection*. Retrieved October 24, 2016, from http://www.wine-grape-growing.com/wine_grape_growing/vineyard_site_selection/vineyard_site_selection_topography.htm

Goodman, J. (2009). Risk and portfolio management with econometrics. *Risk and Portfolio Management with Econometrics*, 1–14. Retrieved from http://www.math.nyu.edu/faculty/goodman/teaching/RPME09/index.html

Google Earth. (2016). Helderfontein Weather Station.

Gourbesville, P. (2008). Integrated river basin management, ICT and DSS: Challenges and needs. *Physics and Chemistry of the Earth*, *33*(5), 312–321. doi:10.1016/j.pce.2008.02.007

Grant, R. M. (1996). Toward a knowledge-based theory of the firm. *Strategic Management Journal*, *17*(May), 109–122. Retrieved from http://www.jstor.org/stable/2486994

Grundy, T. (2006). Rethinking and reinventing Michael Porter's five forces model. *Strategic Change*, *15*(5), 213–229. doi:10.1002/jsc.764

Hacking, A. (2006). An Overview of the South African Low Chill Fruit Industry ., *5*(May), 1–14. Retrieved from http://www.lowchillaustralia.com.au/items/286/Session 5_Hacking SA Low Chill Industry.pdf

Hartati, S., & Sitanggang, I. S. (2010). A Fuzzy Based Decision Support System for Evaluating Land Suitability and Selecting Crops. *Computer Science*, *6*(4), 417–424.

HE2. (2016). Horticulture Expert 2.

HE4. (2016). Horticulture Expert 4.

HE6. (2016). Horticulture Expert 6.

Heger, D., & Kraft, K. (2008). Barriers to entry and profitability. *ZEW - Centre for European Economic Research Discussion Paper*, *No. 08-071*, 68–81. Retrieved from https://ssrn.com/abstract=1268245

Hitt, M. A., & Tyler, B. B. (1991). Strategic decision models: Integrating different perspectives. *Strategic Management Journal*, *12*(5), 327–351. Retrieved from http://www.jstor.org/stable/2486562

HortGro. (2014). *Plums 2014*. Retrieved from http://www.hortgro.co.za/wp-content/uploads/2016/02/Plums-2014.pdf

HortGro. (2015). *Key deciduous fruit statistics 2015*. Paarl. Retrieved from http://www.hortgro.co.za/wp-content/uploads/2016/06/Key-Deciduous-Fruit-Statistics-2015-2.pdf

Hortgro Ltd. (2016). *WELCOME TO HORTGRO*. Retrieved November 4, 2016, from http://www.hortgro.co.za/about/

Indian Agricultural Research Institute. (n.d.). *MANDARIN*. Retrieved October 24, 2016, from http://www.fruitipedia.com/mandarin.htm

Jabareen, Y. (2011). Building a conceptual framework. Philosophy, definition, procedure. *International Journal of Qualitative Methods*, *8*(4), 49–62. doi:10.1177/160940690900800406

Jakeman, A. J., Letcher, R. A., & Norton, J. P. (2006). Ten iterative steps in development and evaluation of environmental models. *Environmental Modelling and Software*, *21*(5), 602–614. doi:10.1016/j.envsoft.2006.01.004

Junier, S., & Mostert, E. (2014). A decision support system for the implementation of the Water Framework Directive in the Netherlands: Process, validity and useful information. *Environmental Science and Policy*, *40*, 49–56. doi:10.1016/j.envsci.2014.04.004

Kaiser, D., Christensen, I., Foust, J., & Davidian, K. (2011). An industry structural analysis and strategy insights for the commercial crew transportation industry. *AIAA*, *Space Conf*. doi:10.2514/6.2011-7288

Kerr, B. (2013, March). Why cabbage should be your first choice. *Farmer's Weekly*. Retrieved from http://www.farmersweekly.co.za/article.aspx?id=10237&h=Why-cabbage-should-be-your-first-choice

Kerr, D. (2004). Factors influencing the development and adoption of knowledge based decision support systems for small, owner-operated rural business. *Artificial Intelligents Review*, 22(2), 127–147. doi.org/10.1007/s10462-004-4305-x

Klein karoo Seed Marketing. (2004). Megaton Technical Release, 2–7. Retrieved from http://www.seedmarketing.co.za/docs/MEGATON2014.pdf

Kothari, C. R. (2004). *Research Methodology: Methods & Techniques*. *New Age International (P) Ltd*. doi:10.1017/CBO9781107415324.004

Kulej, M. (2011). *Business Information Systems*. Wrocław: PRINTPAP Łódź. Retrieved from http://www.ioz.pwr.wroc.pl/pracownicy/kulej/OperRes.pdf

Lange, A., Piorr, A., Siebert, R., & Zasada, I. (2013). Land Use Policy Spatial differentiation of farm diversification : How rural attractiveness and vicinity to cities determine farm households' response to the CAP. *Land Use Policy*, *31*, 136–144. doi:10.1016/j.landusepol.2012.02.010

Liu, S., & Forrest, J. Y. L. (2011). *Grey systems: Theory and applications*. Heidelberg: Springer–Verlag.

Louhichi, K., Kanellopoulos, A., Janssen, S., Flichman, G., Blanco, M., Hengsdijk, H., & Van Ittersum, M. K. (2010). FSSIM, a bio-economic farm model for simulating the response of EU farming systems to agricultural and environmental policies. *Agricultural Systems*, *103*(8), 585–597. doi:10.1016/j.agsy.2010.06.006

Luehrman, T. A. (1998). Strategy as a Portfolio of Real Options. *Harvard Business Review*, (September- October), 89–99.

Makowski, D., Hendrix, E. M. ., Van Ittersum, M. K., & Rossing, W. A. H. (2000). A framework to study nearly optimal solutions of linear programming models developed for agricultural land use exploration. *Ecological Modelling*, *131*(1), 65–77. doi:10.1016/S0304-3800(00)00249-0

Mallach, E. G. (2000). *Decision Support and Data Warehouse Systems*. McGraw-Hill.

Marais, E. (2015). *What Makes South Africa Unique?* Retrieved from http://zar.co.za/world.htm

Marie, J. (2016). *Optimum Conditions for Orange Trees*. Retrieved October 24, 2016, from http://homeguides.sfgate.com/optimum-conditions-orange-trees-50691.html

Markowitz, H. M. (1989). Mean–Variance Analysis. In J. Eatwell, M. Milgate, & P. Newman (Eds.), *Finance* (pp. 194–198). London: Palgrave Macmillan. doi:10.1007/978-1-349-20213-3_21

Masomi, S. R., & Ghayekhloo, S. (2011). Consequences of human behaviors' in Economic: the Effects of Behavioral Factors in Investment decision making at Tehran Stock Exchange. *International Conference on Business and Economics Research*, *1*(1), 234–237.

McCown, R. L. (2002). Changing systems for supporting farmers' decisions: Problems, paradigms, and prospects. *Agricultural Systems,* 74, 179–220. doi:10.1016/S0308-521X(02)00026-4

McIntosh, B. S., Ascough, J. C., Twery, M., Chew, J., Elmahdi, A., Haase, D., & Voinov, A. (2011). Environmental decision support systems (EDSS) development - Challenges and best practices. *Environmental Modelling and Software*, *26*(12), 1389–1402. doi:10.1016/j.envsoft.2011.09.009

McLeay, F., Martin, S., & Zwart, T. (1996). Farm Business Marketing Behavior and Strategic

Groups in Agriculture. *Agribusiness*, *12*(4), 339–351.

McNie, E. C. (2007). Reconciling the supply of scientific information with user demands: an analysis of the problem and review of the literature. *Environmental Science and Policy*, *10*(1), 17–38. doi:10.1016/j.envsci.2006.10.004

Melorose, J., Perroy, R., & Careas, S. (2015). Multimoora-IFN: A MCDM method based on intuituinistic fuzzy number for performance management. *Statewide Agricultural Land Use Baseline 2015*, *1*(Mcdm). doi:10.1017/CBO9781107415324.004

Miksen, C. (n.d.). *Favourable peach tree conditions*. Retrieved October 26, 2016, from http://homeguides.sfgate.com/favorable-peach-tree-conditions-31504.html

Monsanto. (2014). The benefits of crop rotation, 2. Retrieved from http://www.sandsofiowa.com/images/E0240401/CropRotationBenefits91914.pdf

Myburgh, P. (2016). Soil and Water Science.

Narayanan, V. K., & Fahey, L. (2005). The relevance of the institutional underpinnings of porter's five forces framework to emerging economies: An epistemological analysis. *Journal of Management Studies*, *42*(1), 207–223. doi:10.1111/j.1467-6486.2005.00494.x

National Department of Agriculture. (2000). *Cultivating Citrus*. Retrieved September 7, 2016, from http://www.nda.agric.za/docs/Citrus/citrus.htm

NETAFIM. (n.d.). *Climate*. Retrieved August 18, 2016, from http://www.sugarcanecrops.com/climate/

Nevo, A., & Amir, I. (1991). CROPLOT-An expert system for determining the suitability of crops to plots. *Agricultural Systems*, *37*(3), 225–241. doi:10.1016/0308-521X(91)90034-8

Noll, R. G. (2005). "BUYER POWER" and economic policy. *Antitrust Law Journal*, *72*(2), 589–624. Retrieved from http://www.jstor.org/stable/40843636

Nooraie, M. (2008). Decision magnitude of impact and strategic decision-making process output: the mediating impact of rationality of the decision-making process. *Management Decision*, *46*(4), 640–655. doi:10.1108/00251740810865102

Nooraie, M. (2011). Decision's familiarity and strategic decision-making process output: The mediating impact of rationality of the decision-making process. *International Journal of Applied Decision Science*, *4*(4), 385–400. doi:10.1504/IJADS.2011.043306

Nooraie, M. (2012). Factors influencing strategic decision-making processes. *International Journal of Academic Research in Business and Social Sciences*, *2*(7), 405–429.

Pacini, C., Wossink, A., Giesen, G., & Huirne, R. (2004). Ecological-economic modelling to support multi-objective policy making: A farming systems approach implemented for Tuscany. *Agriculture, Ecosystems and Environment*, *102*(3), 349–364. doi:10.1016/j.agee.2003.08.010

Papadakis, V. M., Lioukas, S., & Chambers, D. (1998). Strategic decision-making processes: The role of management and context. *Strategic Management Journal*, *19*(2), 115–147. doi:10.1002/(SICI)1097-0266(199802)19:2<115::AID-SMJ941>3.0.CO;2-5

Pedrycz, W., & Gomide, F. (1998). *An introduction to fuzzy sets: Analysis and design*. Cambridge, UK: MIT Press. Retrieved from https://books.google.co.za/books?hl=en&lr=&id=wzWZVGVdlLIC&oi=fnd&pg=PA3&dq=An+Introduction+to+Fuzzy+Sets:+Analysis+and+Design,&ots=twEoV9etqI&sig=OhnIXtx7QSBpxe3136nu51kUJjE#v=onepage&q=An Introduction to Fuzzy Sets%3A Analysis and Design%2C&f=false

Poláková, J., Moulis, P., Koláčková, G., & Tichá, I. (2016). Determinants of the business model change – A case study of a farm applying diversification strategy. *Procedia - Social and Behavioral Sciences*, *220*, 338–345. doi:10.1016/j.sbspro.2016.05.507

Porter, M. E. (1980). *Competitive strategy: Techniques for analyzing industries and companies*. *New York*. doi:10.1002/smj.4250020110

Porter, M. E. (1991). Towards a dynamic theory of strategy. *Strategic Management Journal*, *12*(Special Issue), 95–117.

Porter, M. E. (1996). What is Strategy? *Harvard Business Review*, (December). Retrieved from http://www.engr.mun.ca/~amyhsiao/strategy.pdf

Porter, M. E. (2008). The five competitive forces that shape strategy. *Harvard Business Review*, *86*(1), 78–93.

Pretorius, E. (2009). Using GIS in the search for suitable sites for the implementation of fog water collection systems in South Africa, 1–8. Retrieved from http://icaci.org/files/documents/ICC_proceedings/ICC2009/html/nonref/5_16.pdf

Priem, R. L., Rasheed, A. M. A., & Kotulic, A. G. (1995). Rationality in strategic decision processes, environmental dynamism, and firm performance. *Journal of Management*, *21*, 913–929.

PwC. (2007). Guide to key performance indicators. *Corporate Reporting*, 1–28. Retrieved from http://www.PwC.com/gx/en/corporate-reporting/assets/pdfs/UK_KPI_guide.pdf

PwC. (2014). The South African wine industry insights survey 2014, (June). Retrieved from http://www.PwC.co.za/en_ZA/za/assets/pdf/wine-insights-survey-2014.pdf

PwC. (2015). *The South African wine industry insights survey 2015*. Retrieved from http://www.PwC.co.za/en/assets/pdf/wine-industry-to-be-uploaded.pdf

Queensland Department of Agriculture and Fisheries. (2012). *Citrus land and climate requirements*. Retrieved September 7, 2016, from https://www.daf.qld.gov.au/plants/fruit-and-vegetables/fruit-and-nuts/citrus/citrus-land-and-climate-requirements

Queensland Department of Agriculture and Fisheries. (2015). *Stonefruit land and climate requirements*. Retrieved October 18, 2016, from https://www.daf.qld.gov.au/plants/fruit-and-vegetables/fruit-and-nuts/stonefruit/land-and-climate-requirements

Rădulescu, C. Z., & Rădulescu, M. (2012). A decision support tool based on a portfolio selection model for crop planning. *Studies in Informatics and Control*, *21*(4), 377 –382.

Rautak Ltd. (2015). *Why do you need a methodology?* Retrieved from http://www.PwC.co.za/en_ZA/za/assets/pdf/wine-insights-survey-2014.pdf

Republic of South Africa. (2014). *Government Gazette*. Retrieved from http://www.labour.gov.za/DOL/downloads/legislation/regulations/occupational-health-and-safety/ConstructionRegulation_2014part1.pdf

Rose, D. C., Sutherland, W. J., Parker, C., Lobley, M., Winter, M., Morris, C., & Dicks, L. V. (2016). Decision support tools for agriculture: Towards effective design and delivery. *Agricultural Systems*, *149*, 165–174. doi:10.1016/j.agsy.2016.09.009

Rossing, W. A. H., Jansma, J. E., De Ruijter, F. J., & Schans, J. (1997). Operationalizing sustainability: Exploring options for environmentally friendly flower bulb production systems. *European Journal of Plant Pathology*, *103*(3), 217–234. doi:10.1023/A:1008609624648

Roundy, L. (2016). *Empirical Data: Definition & Example*. Retrieved May 5, 2017, from http://study.com/academy/lesson/empirical-data-definition-example.html

SA Explorer. (2014). *Stellenbosch Climate*. Retrieved August 25, 2016, from http://www.saexplorer.co.za/south-africa/climate/stellenbosch_climate.asp

SA Geography. (2012). *Africa Climate*. Retrieved April 6, 2016, from http://sageography.myschoolstuff.co.za/wp-content/uploads/sites/2/2012/11/AfClimate.gif

Salleh, M. N. M. (2012). A fuzzy modelling of decision support system for crop selection. *ISIEA 2012 - 2012 IEEE Symposium on Industrial Electronics and Applications*, 17–22. doi:10.1109/ISIEA.2012.6496622

Sarker, R., & Ray, T. (2009). An improved evolutionary algorithm for solving multi-objective crop planning models. *Computers and Electronics in Agriculture*, *68*(2), 191–199. doi:10.1016/j.compag.2009.06.002

SAWIS. (2007). *VineyardStatus_2007* (Vol. 81).

SAWIS. (2008). *VineyardStatus_2008* (Vol. 89).

SAWIS. (2009). *STOCK SITUATION 2009*.

SAWIS. (2010). *VineyardStatus_2010* (Vol. 73).

SAWIS. (2011). *VineyardStatus_2011*.

SAWIS. (2012a). *STOCK SITUATION 2012*.

SAWIS. (2012b). *VineyardStatus_2012*.

SAWIS. (2013). *VineyardStatus_2013* (Vol. 50).

SAWIS. (2014). *VineyardStatus_2014*.

SAWIS. (2015a). *Final Report - Macro- economic Impact of the Wine Industry on the South African Economy (also with reference to the Impacts on the Western Cape)*. Retrieved from http://www.sawis.co.za/info/download/Macro-economic_impact_study_-_Final_Report_Version_4_30Jan2015.pdf

SAWIS. (2015b). *STOCK SITUATION 2015*.

SAWIS. (2015c). *Total Exports*.

SAWIS. (2016a). *ESTIMATED 2016 GRAPE AND WINE CROP*.

SAWIS. (2016b). *SOUTH AFRICAN WINE GRAPE HARVEST 2016: FEBRUARY ESTIMATE*.

Schilit, W. K., & Paine, F. T. (1987). An examination of the underlying dynamics of strategic decisions subject to upward influence activity. *Journal of Management Studies*, *24*(2), 161–187. doi:10.1111/j.1467-6486.1987.tb00942.x

Schwenk, C. R. (1995). Strategic decision making. *Journal of Management Studies*, *21*(3), 471 – 493. doi:10.1016/0149-2063(95)90016-0

Gate, S. F. (2016). *What Climate Does a Lemon Tree Have to Live In?* Retrieved from http://homeguides.sfgate.com/climate-lemon-tree-live-in-61221.html

Sheperd, W. G., & Sheperd, J. M. (2004). *The economics of industrial organization.* (Fith.). Lobg Grove, Illiois: Waveland Press.

Smith, C. (2016). No Title.

Smith, P. N. (1992). Fuzzy evaluation of land-use and transportation options. *Environment and Planning B: Urban Analytics and City Science*, *19*(5), 525 – 544.

South Africa.info. (2015). *South Africa's weather and climate*. Retrieved April 6, 2016, from http://www.southafrica.info/travel/advice/climate.htm#.VwTlX5x96t8

South Africa.info. (2015). *The nine Provinces of South Africa*. Retrieved August 17, 2016, from http://www.southafrica.info/about/geography/provinces.htm#.V7SMsVt96t8

South African Weather Service. (2016). *How are the dates of the four seasons worked out*. Retrieved August 25, 2016, from http://www.weathersa.co.za/learning/weather-questions/82-how-are-the-dates-of-the-four-seasons-worked-out

Starke Ayres. (2016). *STAR 3006 Carrot*. Retrieved from http://www.starkeayres.co.za/com_product_docs/STAR-3006.pdf

STATS SA. (2009). *Statistical release: Consumer Price Index*. Retrieved from www.statssa.gov.za

STATS SA. (2016). *Consumer Price Index*.

Strauss, P., Meyer, F. H., & Kirsten, J. (2008). Facilitating decision-making in agriculture by using a system of models. *Agrekon*, *47*(3), 346–364. doi:10.1080/03031853.2008.9523804

Sulaiman, T. (2013). *Bulk versus bottle dilemma for South African wine*. Retrieved from http://www.reuters.com/article/us-safrica-wine-bulk-idUSBRE92P0FC20130326

Sustainable Development Indicator Group. (1996). *Manufacturing Industry*. Retrieved May 5, 2016, from http://www.hq.nasa.gov/iwgsdi/Manufacturing.html

Szopa, P., & Pękała, W. (2012). Distribution channels and their roles in the enterprise. *Polish Journal of Management Studies*, *6*(1), 143–150.

Taylor, N., & Gush, M. (2009). *The Water Use of Fruit Trees and Orchard Crops in South Africa – A Knowledge Review*. Retrieved from http://fred.csir.co.za/extra/project/fruittrees/deliverables/Deliv1K5_1770KnowledgeReview_Final.pdf

Ten Berge, H. F. M., Van Ittersum, M. K., Rossing, W. A. H., Van De Ven, G. W. J., Schans, J., & Van De Sanden, P. A. C. M. (2000). Farming options for The Netherlands explored by multi-objective modelling. *European Journal of Agronomy*, *13*(2-3), 263–277. doi:10.1016/S1161-

0301(00)00078-2

The World Carrot Museum. (2016). *In Depth Guide to Carrot Cultivation*. Retrieved October 24, 2016, from http://www.carrotmuseum.co.uk/cultivation2.html

Theron, C. G. (2015). *Environmental needs of the Cotton Plant*. Retrieved August 23, 2016, from http://cottonsa.org.za/wp-content/uploads/2015/12/environmental-needs-of-the-cotton-plant.pdf

Thierfelder, C., & Wall, P. C. (2011). The Importance of crop rotations. *The Importance of Crop Rotation*. Retrieved from http://www.fao.org/ag/ca/Training_Materials/Leaflet_Rotations.pdf

Thomas, J., & Evanson, R. V. (1987). An empirical investigation of association between financial ratio use and small business success. *Journal of Business Finance & Accounting*, *14*(4), 555–571. doi:10.1111/j.1468-5957.1987.tb00112.x

Tian, Z.,Wang, J., Wang, J., & Zhang, H. (2016). An improved MULTIMOORA approach for multi-criteria decision-making based on interdependent inputs of simplified neutrosophic linguistic information, *Neural Comput and Applic*. doi:10.1007/s00521-016-2378-5

Trading Economics. (2016). *South African Inflation Rate*. Retrieved March 7, 2016, from http://www.tradingeconomics.com/south-africa/inflation-cpi

Tsvakirai, C. (2014). *An economic evaluation of South Africa's peach and nectarine research*. Retrieved from http://www.arc.agric.za/Economic Impact Assessment Studies/An economic evaluation of South Africa's peach and nectarine research .pdf

Turban, E., & Aronson, J. E. (2001). *Decision support systems and intelligent systems* (6th ed.). New York: Prentice Hall: Upper Saddle River.

Tzionas, P., Ioannidou, I. A., & Paraskevopoulos, S. (2004). A hierarchical fuzzy decision support system for the environmental rehabilitation of Lake Koronia, Greece. *Environmental Management*, *34*(2), 245–260. doi:10.1007/s00267-004-0307-3

Ulwick, A. W. (2005). *Business Strategy Formulation: Theory, Process, and the Intellectual Revolution*. Quorum Books. Retrieved from http://books.google.com/books?id=lDLDHk-GB1gC&pgis=1

Uys, R. (2016). Independent Wine Farmer.

Van Delden, H., Seppelt, R., White, R., & Jakeman, A. J. (2011). A methodology for the design and development of integrated models for policy support. *Environmental Modelling and Software*, *26*(3), 266–279. doi:10.1016/j.envsoft.2010.03.021

Van Den Berg, F. (2016). Cabbage Risks and Pests.

Van Ittersum, M. K., Rabbinge, R., & Van Latesteijn, H. C. (1998). Exploratory land use studies and their role in strategic policy making. *Agricultural Systems*, *58*(3), 309–330. doi:10.1016/S0308-521X(98)00033-X

Vatn, A., Bakken, L., Botterweg, P., & Romstad, E. (1999). ECECMOD: An interdisciplinary modelling system for analyzing nutrient and soil losses from agriculture. *Ecological Economics*, *30*(2), 189–205. doi:10.1016/S0921-8009(98)00116-5

VinPro. (2015). *Vinpro Cost Guide 2015/2016*.

Wally, S., & Baum, J. R. (1994). Personal and structural determinants of the pace of strategic decision making. *Academy of Management Journal*, *37*(4), 932–956. doi:10.2307/256605

Water development and Managing unit. (2015). *Crop Water Information:Maize*. Retrieved August 23, 2016, from http://www.fao.org/nr/water/cropinfo_maize.html

Wei, C.-C., Liang, G.-S., & Wang, M.-J. J. (2007). A comprehensive supply chain management project selection framework under fuzzy environment. *International Journal of Project Management*, *25*(6), 627–636. doi:10.1016/j.ijproman.2007.01.010

Werden, G. J. (2011). Netwok effects and conditions of entry: Lessons from the Microsoft case. *Antitrust Law Journal*, *69*(1), 87–111. Retrieved from http://www.jstor.org/stable/40843512

Wernerfelt, B., & Karnani, A. (1987). Competitive strategy under uncertainty. *Strategic Management Journal*, *8*(2), 187–194. Retrieved from http://www.jstor.org.ez.sun.ac.za/stable/pdf/2485982.pdf

Western Cape Department of Agriculture. (2016). *Western Cape AgriStats*. Retrieved August 23, 2016, from http://www.elsenburg.com/gis/apps/agristats/

Western Cape Government. (2016). *How to manage water restrictions at your home*. Retrieved November 3, 2016, from https://www.westerncape.gov.za/general-publication/how-manage-water-restrictions-your-home

Western Cape Government Provincial Treasury. (2015). *Provincial Economic Review and Outlook 2015*. Retrieved from https://www.westerncape.gov.za/assets/departments/treasury/Documents/2015_pero_final_to_web_15_otober_2015.pdf

Why crop rotation is important. (2012, February). *Farmer's Weekly*. Retrieved from http://www.farmersweekly.co.za/article.aspx?id=14679&h=Why-crop-rotation-is-important

Wilamowsky, Y., Epstein, S., & Dickman, B. (1990). Optimization in multiple-objective linear programming problems with pre-emptive priorities. *The Journal of the Operational Research Society*, *41*(4), 351–356.

Wines of South Africa. (2015). *THREE CENTURIES OF CAPE WINE*. Retrieved from http://www.wosa.co.za/The-Industry/History/Three-Centuries-of-Cape-Wine/

WINESA. (2015). *Wine Farms*. Retrieved from http://www.wine-sa.com/wine-farms/

Wolpert, J. A. (n.d.). Cabernet Sauvignon, 37–39. Retrieved from http://iv.ucdavis.edu/files/24325.pdf

WOSA. (2016a). *Overview*. Retrieved November 14, 2016, from http://www.wosa.co.za/The-Industry/Overview/

WOSA. (2016b). *Winegrowing areas*. Retrieved April 15, 2016, from http://www.wosa.co.za/The-Industry/Winegrowing-Areas/Winelands-of-South-Africa/

Wossink, G. A. A., De Koeijer, T. J., & Renkema, J. A. (1992). Environmental-economic policy assessment: A farm economic approach. *Agricultural Systems*, *39*(4), 421–438.

doi:10.1016/0308-521X(92)90078-3

YARA. (2016). *Agronomic Principles*. Retrieved April 6, 2016, from http://www.yara.us/agriculture/crops/citrus/key-facts/agronomic-principles/

Zadeh, L. A. (1965). Fuzzy sets. *Information and Computation*, *8*(3), 338–353.

Zander, P., & Kächele, H. (1999). Modelling multiple objectives of land use for sustainable development. *Agricultural Systems*, *59*(3), 311–325. doi:10.1016/S0308-521X(99)00017-7

Zavadskas, E. K., Antucheviciene, J., Razavi Hajiagha, S. H., & Hashemi, S. S. (2015). The interval-valued intuitionistic fuzzy MULTIMOORA method for group decision making in engineering. *Mathematical Problems in Engineering*, *2015*(2). doi:10.1155/2015/560690

APPENDIX A: EXPERTS

The different subject matter experts who were consulted are described, in Table 23. These experts were consulted throughout the study, especially during crucial stages such as refining and identifying the final set of considerations that were used in the developed DSS.

Table 23: Expert Description

Expert	Description	Contact Details
Chris Smith **HE7**	Scientist at ARC infruitec-nietvoorbij Job description: Stone fruit evaluation	SmithC@arc.agric.za 021 809 3360
Hugo Burger	Vegetable expert associated with Hygrotech	-
Stephan Bruwer	Managing Director at Unipack fruit Unipack, based in Ashton Western Cape, is one of the leading soft citrus exporters in South Africa. They also grow their own high quality produce citrus fruit. They have an integrated business where they are responsible for the growing, packaging, shipping, and retailing of their products.	jsb@unipack.co.za
Hannes Bester	Citrus expert associated with the Citrus Growers Association	-
Pieter du Toit	Independent farmer with over 20 years of experience Farms in the Karoo district	-
Frans van den Berg	Independent farmer Mixed farming, including cabbage. Farms in Barkly East.	
Irene Joubert	AgroClimatology ARC- Institute for Soil Climate and Water	VGentl@arc.agric.za 021 809 3152

Phillip Myburgh	ARC: Soil and Water Science Irrigation scheduling recommendation for grapevine	myburghp@arc.agric.za
Renier Uys	Independent Wine Farmer in the Stellenbosch region	renieruys@gmail.com
HE1	Department of Agriculture Western Cape Government Senior Scientist	-
HE2	Viticulturist in the Stellenbosch region	--
HE3	Agriculture Economist Associated with VinPro	-
HE4	Independent Protea farmer in the Stellenbosch region	-
HE5	Independent citrus farmer	-
HE6	Independent farmer in the George region Mixed farming which includes blueberries	-

APPENDIX B: SECTOR NAMES

Table 24: Sector shortened and accompanying full name

Shortened Sector Name as display on Figure 33	Full name of sector
Agriculture	Agriculture, Forestry, & Fishing
Mining	Mining & Quarrying
Manufacturing	Manufacturing
EGW	Electricity, Gas, & Water
Construction	Construction
Wholesale	Wholesale & Retail Trade, Catering & Accommodation
Transport	Transport
Finance	Finance, Insurance, Real Estate, & Business services
Community	Community, Social, & Personal Services
Government	General Government Services

APPENDIX C: SELECTED LAND USE ALTERNATIVES THEORY

As previously mentioned, farms in the Stellenbosch region need to find new business strategies to be sustainable and profitable. It has also been pointed out that bulk wine production is the sector of the business which holds little advantage for the farm in terms of profit. At present the profits of the wine estates lie with the sales of premium packaged wine. Wine estates in the Stellenbosch region thus need to move away from bulk wine production and refocus their attention on the production of their premium wines, or find land use alternatives that they can implement. This study will develop a DSS that considers land use alternatives that can be implemented in the Stellenbosch region. Possible land use alternatives will be selected exclusively from the agriculture business sector and not from other business sectors (refer to Section 6.2 for further detail regarding business sector selection). Farmers considering land use alternatives, that are highlighted by the framework developed in this thesis, will thus follow a differentiation business strategy as discussed in Section 3.2. The main concept of this thesis, which attempts to find possible land use alternatives that farmers in the Stellenbosch region can use to ensure sustainability, is illustrated in Figure 56.

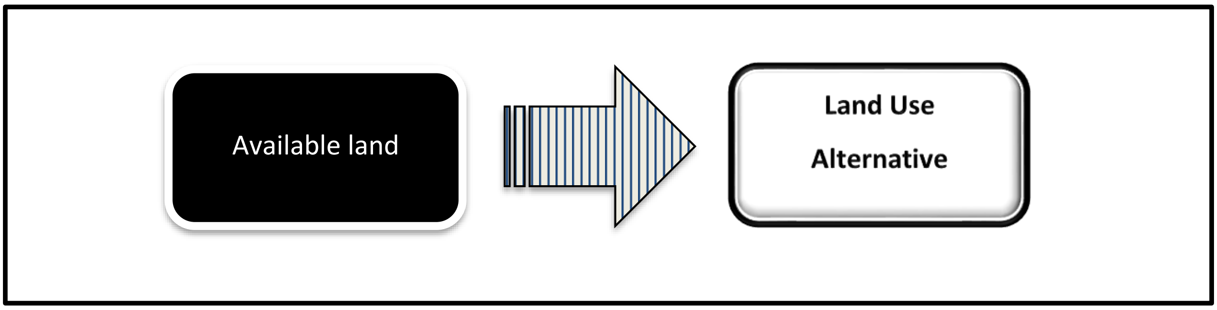


Figure 56: Higher order thesis overview

The different possible land use alternatives are grouped according to horticulture. The Collins Cobuild Essential English Dictionary (1988) defines horticulture as 'the study and practice of growing flowers, fruit, and vegetables'. The land use alternative types, which are illustrated in Figure 39, have been selected based on a filtering process (refer to Section 7.2). The alternative types shown in Figure 39 are only the alternatives that this study will focus on, and are therefore just an extract from the possible land use alternatives that could be applied in the Stellenbosch region.

C.1. HORTICULTURE

Research about each of the selected land use alternatives needs to be done to make it possible to provide an overview of each, as well as to provide specific considerations that should be adhered to, for each alternative to become a viable option for a region. The selection process of the alternatives takes place in Section 7.2. The remainder of Section C.1. Horticulture, will be concerned with establishing requirements that are specific to an alternative type. This information will be used and compared to Stellenbosch's weather profile, to determine whether an alternative type is suitable for the Stellenbosch region, based on its climatic requirements. The requirements of each type will also be used when developing a model as part of the framework to compare the selected land use alternative types with one another per consideration.

C.1.1. VITICULTURE

C.1.1.1. WINE CULTIVAR

Overview

Viticulture includes tasks such as soil preparation, planting and growing of different vine varieties, and fighting of diseases. To achieve the best results, viticulturists are continuously trying to match specific vine varieties with soil and mesoclimates. The soil composition, the location of the vineyard, the type of wine required, and climate conditions of a region, are important factors that play a role in the choice of cultivar that will be planted (WOSA, 2016b).

Considerations

Certain cultivars are better suited in a specific region, depending on the soil composition, the climate, topography, disease/pest pressure and the human element in a region (Bisson, 2001). These factors (Figure 57) all influence the performance of the grapevine:

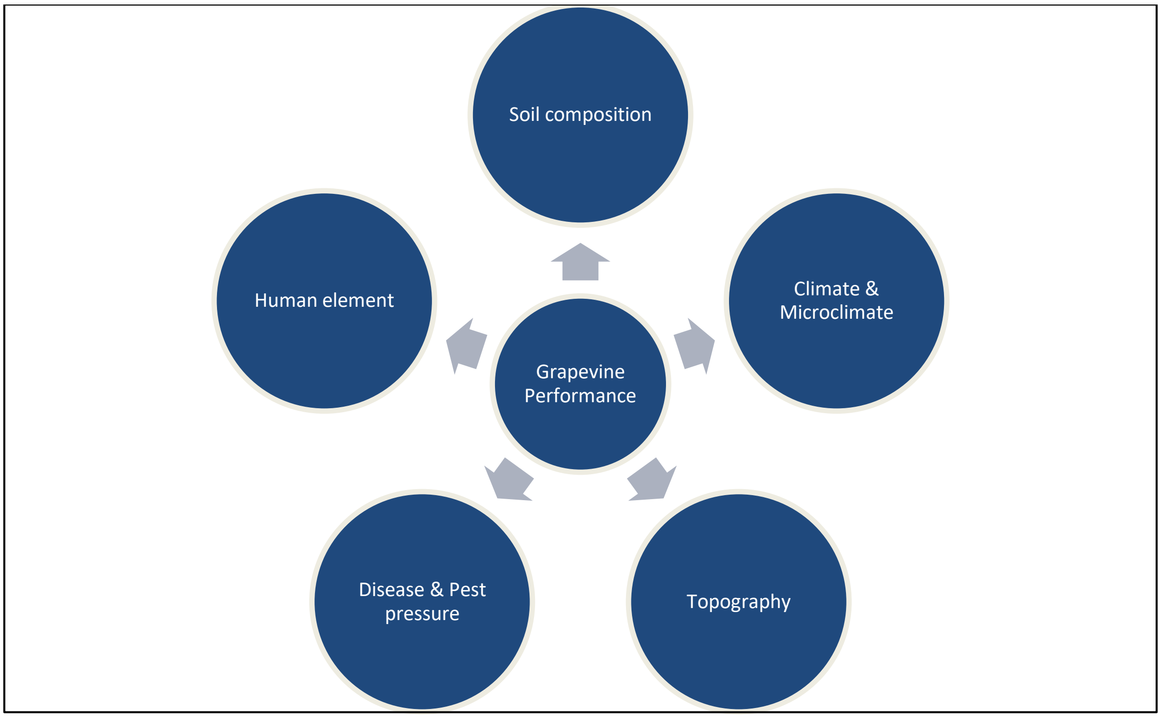


Figure 57: Factors affecting grapevine performance (Bisson, 2001)

Soil composition

Soil is considered as one of the most influential factors when it comes to the performance of the grapevines, because of its capacity to hold water (Bisson, 2001). The plant not only gets its nutrients from the soil, but the soil also regulates the amount of water to the roots of the grapevines, since it is responsible for the amount of water in the soil itself (Bisson, 2001). The nature of the microorganisms that are present, specifically bacteria and fungi, which interact with the root structure of the crop, are also influenced by the composition of the soil. These microorganisms can be beneficial, neutral or harmful to the vine. Grapes grow well in a wide range of soils, but prefer well-drained soils which will aid roots to grow well, as well as soils with a pH level of between 5.5 and 6 (Department of Agriculture Forestry and Fisheries, 2012b).

Climate and Microclimate

The composition of the harvested grapes is greatly influenced by climate. The amount of sunlight that is available to the plant, will affect the sugar quantity of the grapes, since photosynthesis is responsible for the production of sugar in plants. The compositions of the grapes will also be influenced by the temperature, because temperature affects the biochemical and chemical reactions that influence the metabolic activities of plant tissues. The availability of water will also influence the composition of the grape, since water is essential for this process. With higher humidity comes more diseases, especially from fungi, but soil and vines lose less water when the humidity of the region is high. A reduction in the yield of the produce and undesirable changes to the grape chemistry can be caused by clusters of fungal infection (Bisson, 2001). Rainfall can have a positive or negative effect on the grapes, depending on the season of occurrence. The humidity and the soil are affected by rainfall (Bisson, 2001). In general, mature clusters do not require rain, because it promotes mould proliferation. Good wine producing regions receive between 500 mm and 800 mm rainfall a year (Goldammer, 2016). Relentless wind conditions can cause the berry of the grapevines to be smaller with a thicker skin, which might be desired in come cultivars. Wind limits mould growth, because it tends to dry out clusters, but it accelerates evaporation, which increases the amount of vine water lost (Bisson, 2001).

Microclimate is defined as the climate of a specific small area which differs from surrounding areas (Cornell University, 2015). The microclimate of vines refers to (Bisson, 2001):

- Climate of individual vines: heating of vineyard floor
- Climate of individual clusters:
    - Effect of shades
    - Humidity retention

It is also important to note the microclimate which is the climate of a specific section of the vineyard. The composition of the vineyard floor will influence the amount of heat that is retained, which will increase the local temperature of the vines. Clusters that are exposed will have a lower humidity, but may be more prone to sunburn than clusters that are protected (Bisson, 2001). It is important to consider the type of cultivar, as many of these factors are beneficial to some but undesired to other cultivars.

Topography

The valley floor and the hillside where the grapevines are grown are called the topography. Erosion causes the soil to be shallower the steeper the slope gets. The soils that are found in valley floors, in contrast to the soil that is found against steep slopes, are likely to be deep. The composition of the fruit produced in the different scenarios can vary greatly (Bisson, 2001). Gentle slopes are ideal for the production of wine grapes (Goldammer, 2016).

Disease and Pest pressure

The degree and nature of disease and pest pressure can have a critical impact on the vine (Bisson, 2001). Desirable stress can lead to the fruit having more complex characters, but too much pressure almost always lead to a reduction of fruit quality which can even kill the vine (Bisson, 2001). It is important to practice disease control during autumn (June to August) in the Western Cape. This is done by removing all the shoots, except the bearers, as soon as the leaves have fallen (WOSA, 2016b). Cabernet Sauvignon is known to be susceptible to Eutypa dieback, and moderately susceptible to powdery mildew (Wolpert, n.d.)

Human Element

The composition of the grapes that are harvested, will be greatly influenced by the timing and extent of irrigation and fertilisation. The character of the wine or the influence of the microorganisms which is influenced by the grape composition, can be influenced by irrigation and fertilisation practises (Bisson, 2001). The cluster exposure, the chemical composition and the amount of yield per vine will be affected by the nature of the trellising system and the canopy management strategies that are used. Each of these factors needs to be considered and optimised for each of the different cultivars (Bisson, 2001). The vine management techniques that a farm employ, also have an impact on the composition of the fruit and thus the flavour and aroma of the wine. Vine growth by trellising, training and pruning can be managed and used to manipulate the shape and size of the vine (Bisson, 2001). Sugar production in leaves, which is caused by photosynthesis is influenced by the amount of light exposure which is impacted by trellising and training. The size of the vine can also be controlled by means of pruning (Bisson, 2001). The number of grapes yield per vine is controlled by pruning, because pruning determines the amount of dormant buds per vine as well as the number of clusters. A vine can become extremely vigorous if it has too few buds, which causes it to produce grapes of poorer quality (Bisson, 2001). Too many buds however will cause ‘over cropping’, which happens when the vine has too many grapes, but not enough sugar to completely ripen all the grapes. It is crucial to balance the amount of leaves and the amount of grapes to ensure that all the grapes ripen completely (Bisson, 2001). The amount of sunlight exposure on the foliage can be determined by canopy management or trellising.

Growing a Specific Cultivar in the Stellenbosch region

The historical town of Stellenbosch is synonymous with a winemaking tradition that goes back as far as the end of the seventeenth century (WOSA, 2016b). The Stellenbosch viticulture area, with its mountainous terrain, good rainfall, deep well-drained soils and diversity of terroirs, is a highly sought after area for viticulture activities (WOSA, 2016b). At present there are approximately 150 wine estates and producers in the area and this number are growing rapidly (WOSA, 2016b). Figure 58 shows how the total number of hectares planted in the Stellenbosch region (white and red vines) declined, while the total number of grape crops harvested, increased over the indicated years. This can be due to better decision-taking and management of the vineyard. Another factor that might cause this trend, is the type of cultivar that was planted. A cultivar that thrives in a specific environment, will produce a higher yield than a cultivar that is not suited for that environment.

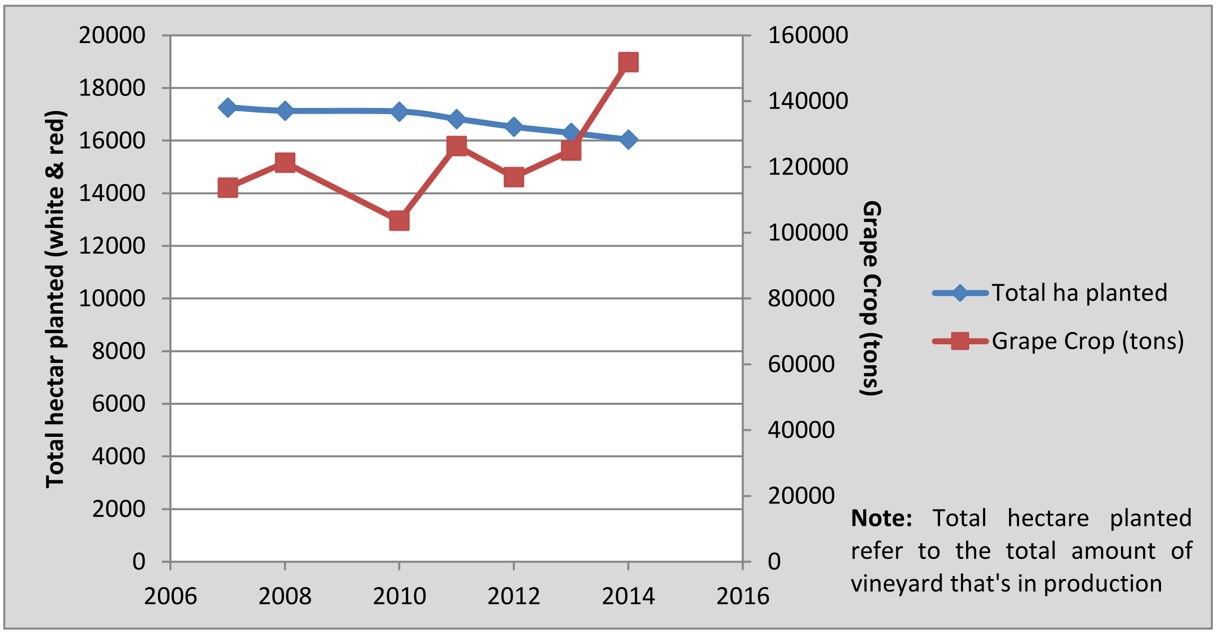


Figure 58: Total vineyard vs Grape crop (SAWIS, 2007, 2008, 2010, 2011, 2012b, 2013, 2014, 2016a)

Cabernet Sauvignon is a cultivar that has been identified by an expert as a cultivar that is especially well-suited for the Stellenbosch region with its Mediterranean climate. Cabernet Sauvignon is a late cultivar that is harvested from the end of March until the end of April. The cultivar requires minimum temperatures of approximately 10°C during winter to enter dormancy, and about 25°C during the fruit ripening period (HE2, 2016).

By adopting this land use alternative, planting a specific well-suited type of vineyard will produce a higher yield per square meter, which allows a farmer to enjoy a higher yield while planting fewer vineyards.

C.1.2. CITRUS FRUIT

The genetic pool of the citrus fruit originally comes from South-Eastern China (Dugo & Di Giacomo, 2015). All the known citrus species of today come from parent species *Citrus maxima* (*C. grandis*), pomelo, which is also believed to be the first ancestor, *Citrus medica*, citron, *Citrus reticulata*, mandarin and similar, and *Citrus halimii*. The shape and colour of the citrus fruit depend on the type of species. Citrus fruit are usually characterised by a spherical shape, although it can be more ellipsoid (like lemons and limes) or flattened (like mandarins). The colour of the fruit can range from a deep orange or reddish, to light orange, yellow or even greenish (Dugo & Di Giacomo, 2015).

The citrus industry is the third largest horticulture industry in South Africa in terms of gross value, by contributing R9.69 billion to the total gross value of South African agricultural production during the 2013/2014 production season. Oranges, easy peelers (soft citrus), lemons and limes, and grapefruit, are the four broad categories that the industry consists of (Department of Agriculture Forestry and Fisheries, 2015c).

Factors Influencing Citrus Growth

Certain factors as shown in Figure 59 need to be considered when planting citrus. This include the type of soil, climate, nutrition and fertilisation, irrigation, pruning and pesticides.

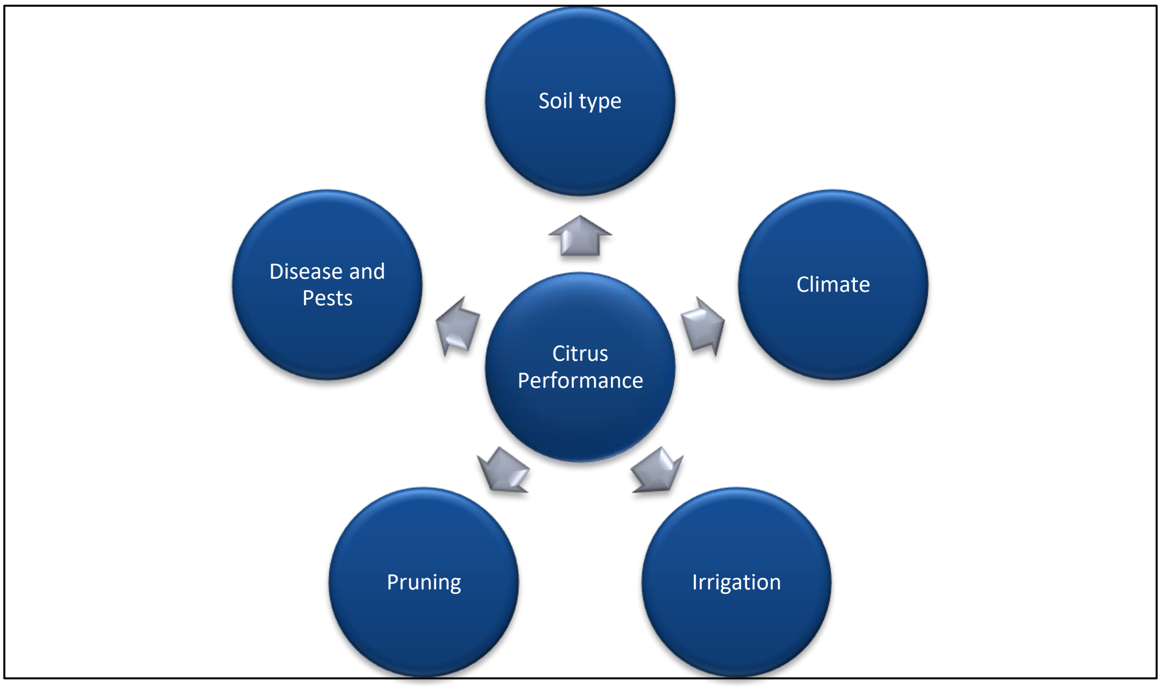


Figure 59: Factors influencing citrus performance (Dugo & Di Giacomo, 2015)

Soil type

Citrus grows on different types of soils ranging from sands to clay with a variety of water holding capacities (YARA, 2016). Citrus trees have a shallow root system, which accumulates under the canopy of the tree. The composition of the soil plays an important part in whether a specific type of citrus species is suited for an environment. According to Dugo & Di Giacomo (2015) the texture of the soil is the first factor that needs to be considered for citriculture (the cultivation of citrus fruits). Soil drainage is the easiest way to establish whether the citrus species is suited for the specific soil in the area. Neither the surface nor the root-explored layers must ever be flooded by water. Sandy soils, although it dries quickly and therefore requires regular watering, are the best to promote water seepage. Soils with high concentration of clay and fine particles called lime, obstruct water percolation and are the worst for citriculture. The best type of soils for citriculture are those which contain roughly the same amount of sand and clay-lime particles. Another factor that should be considered is the soil's pH level (Dugo & Di Giacomo, 2015). Citrus trees prefer well-drained soils with a pH of 6–6.5 (National Department of Agriculture, 2000).

Climate

Citrus grows well in Tropical, Subtropical, Semitropical and Mediterranean climate zones (YARA, 2016).

- **Tropics**

Citrus trees are well-suited to grow in tropical regions. Oranges grow rapidly in this region, but the fruit's skin colour never develop a bright orange colour, but rather stay a pale greenish colour, because of the lower temperature that occurs in this climate zone before harvest (YARA, 2016). It is difficult to identify a mature from an immature fruit, because the orange has a continuous flowering-fruiting cycle. A problem associated with oranges that are grown in the tropics, is the constant fruit drop throughout the season (YARA, 2016).

- **Subtropics**

The subtropics are characterised by hot, humid summers and mild winters. In this region citrus plants produce sweet fruits with high juice content and quality, which is perfect for either processing or fresh consumption (YARA, 2016). Mandarins and oranges are the most prominent and noticeable citrus fruits in the subtropics. Satsuma cultivation is also ideal for cool subtropical climate zones.

- **Semi-tropics and Mediterranean**

Citrus fruits that grow in semitropical and Mediterranean regions, have the brightest skin colour and smoothest skin texture (YARA, 2016). The fruit grown here are ideal for fresh fruit production, because of the optimal sweet and acid balance of the fruit. The cool winters in the Mediterranean are responsible for producing fruit with the best peel colour in this region. Blood oranges, navel oranges and lemons are usually grown in Mediterranean climates (YARA, 2016).

Figure 60: Peel of mature orange in Mediterranean (left) and tropical (right) climates (YARA, 2016)

Irrigation

The root system of citrus trees is superficial, because they are evergreen plants that initially come from areas with humid climates. To support the leaf, stem and fruit development, the citrus plant requires water supply at fixed intervals. In rainy regions watering is usually adequate to make the citrus industry profitable; irrigation is however required in temperate and dry zones where there is a lack of water. The amount of water influences the growth, quality and fruit sets of the plants. A break in irrigation should never be scheduled during early spring or summer, as this will have negative consequences on the size of the fruit (Dugo & Di Giacomo, 2015).

Pruning

It is important to manipulate tree structure to provide active, abundant and well-lit leaves that are evenly spaced to ensure the production of a good citrus crop with evenly sized fruit (YARA, 2016). In general, pruning is not practised or reduced if the fruit of the citrus are used for processing or in countries with a tropical climate (Dugo & Di Giacomo, 2015). Hand pruning is still an important method to control tree growth and bearing in Mediterranean countries. The main reason for citrus pruning is to thin the citrus plants and open the canopy to allow sufficient light to penetrate and to keep the canopy low. The aim of pruning is also to make sure that water and nutrients are available to bear an optimal number of well positioned fruit (YARA, 2016).

Diseases and Pests

Herbicides are used to control weeds that compete for the same resources (such as water, space, nutrients) as citrus plants. Mechanical mowing and cultivation are also used (YARA, 2016). Pests which feed on the roots, trunks, leaves and fruits of citrus plants, include mites, aphides, leaf miners, insects and nematodes (YARA, 2016). Pesticides are used to control these pests. The larva of fruit flies eat the pulp of the fruits, fruits are damaged by citrus bud, rust and spider mites, and the tissue of the fruit are peeled because of scars made by thrips (YARA, 2016). It is important to practice effective pest control to preserve external character qualities of the fruit. Productivity and quality of the citrus trees can be greatly influenced by bacteria, fungi and viruses. Fungal infestations are responsible for most post-harvest decay problems. Major tree loss has been due to viral diseases (YARA, 2016).

Citrus Production in South Africa

The Food and Agriculture Organisation of the United Nations publishes statistics regarding the amount of a specified crop (citrus) that are produced in a specific country (South Africa) over a specified period. Figure 61 illustrates the total amount of citrus produced from 2000–2013 in South Africa. It can be seen in Figure 61 that citrus production in SA grew from 1 730 676 tons in the year 2000 to 2 407 180 tons in 2013 (FAOSTAT, 2016).

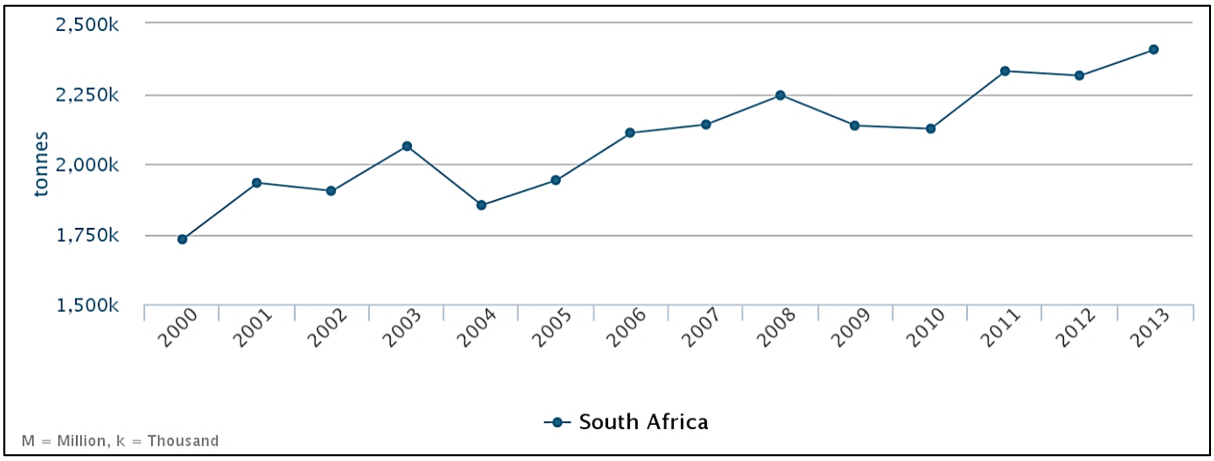


Figure 61: Production of total amount of citrus fruit in SA over time (FAOSTAT, 2016)

Citrus Uses

Figure 62 illustrates the structure of the citrus fruit that can be used for many purposes.

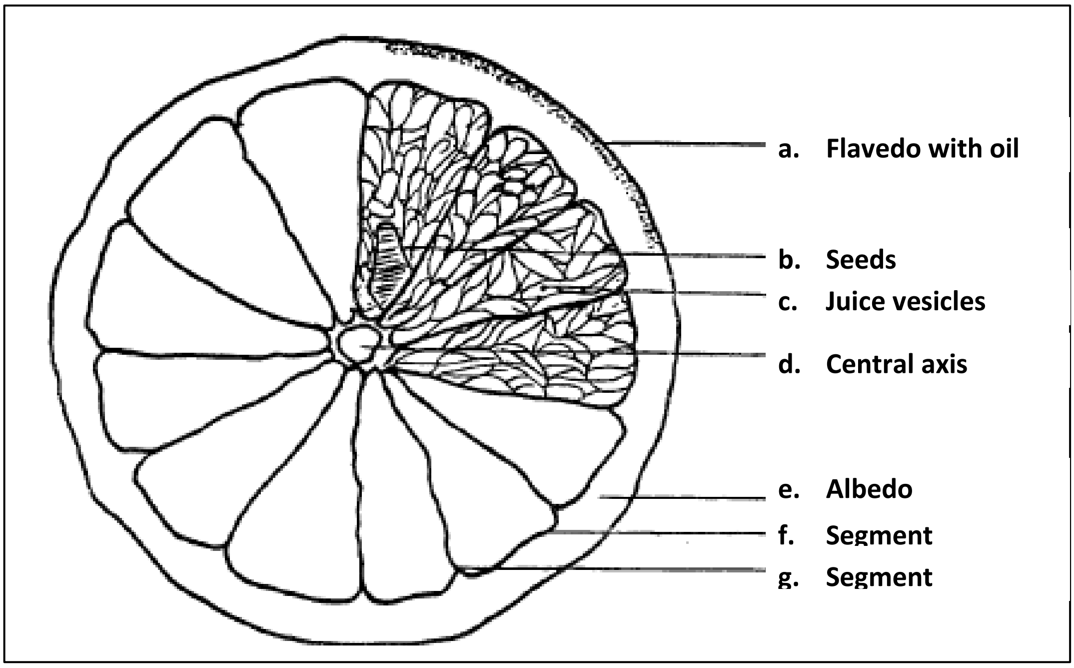


Figure 62: Cross section structure of a citrus fruit (Dugo & Di Giacomo, 2015)

Fruits produced by the citrus trees have the following uses (Dugo & Di Giacomo, 2015):

Raw Fruit

Citrus fruits are eaten raw and they are also high in Vitamin C.

Essential Oils

Citrus fruits have oil glands which contain essential oils that are embedded in the skin, immediately beneath the epidermis of the fruit.

Juices

To manufacture juice from fresh citrus fruit, the content of solids (a sugar/acid ratio that is suitable to the type of citrus fruit used) and the colour, are the most important qualities to take into consideration (Food and Argiculture Organisation of the United Nations, 1989).

Pectin

Pectin can be described as a gelatinous substance in fruit which controls the firmness of fruit.

Flavonoids

Flavonoids are believed to be beneficial because of their cell signalling pathways and antioxidant effects.

Brined Citrus

Brined citrus refers to the preservation of citrus peel by utilising brining techniques.

Other by-products

Other products which are made from citrus, includes marmalade, dried peel (cattle feed), candied peel, syrups, wine, vinegar, alcohol, purees, jams, jellies and lemon seed oil.

Growing citrus in the Stellenbosch region

The Western Cape has a temperate Mediterranean climate with a winter rainfall (South Africa.Info, 2015). Temperate areas refer to areas that have a relative moderate temperature, rather than extreme hot or extreme cold temperatures. The map in Figure 63 illustrates that the Stellenbosch region which is in the Western Cape, has a Mediterranean climate.

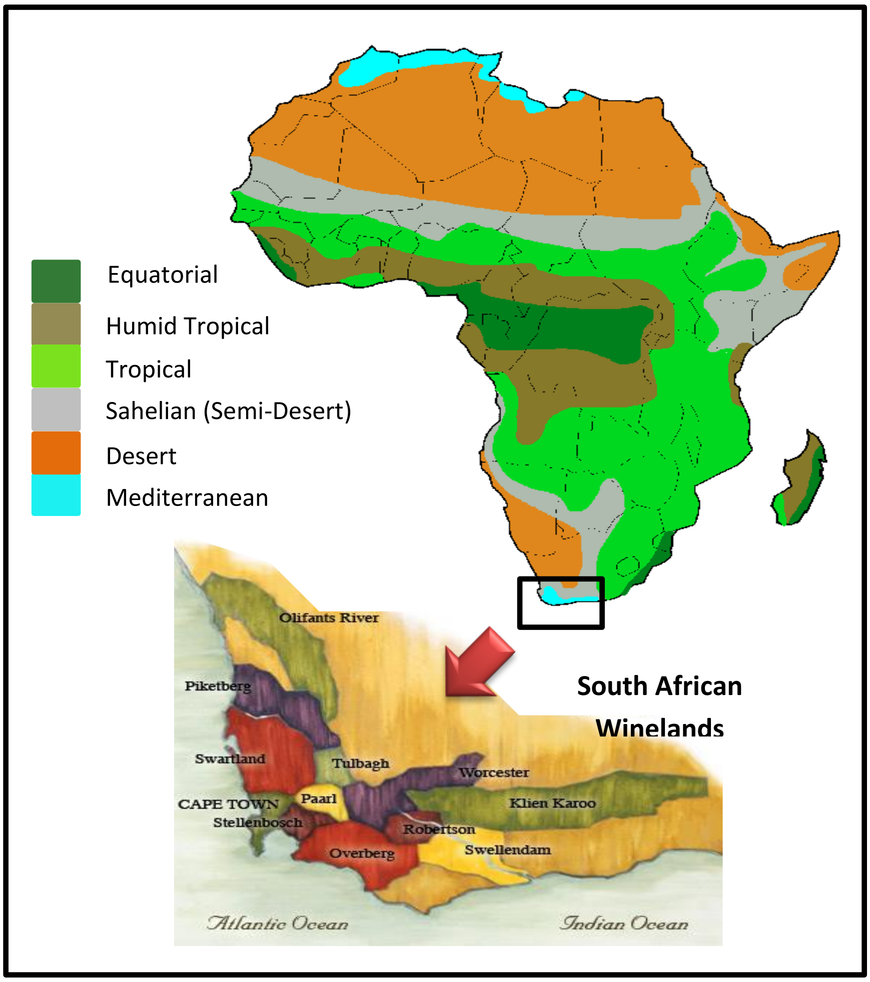


Figure 63: Climate map of Africa (Brittingham, 2013; SA Geography, 2012)

C.1.2.1. ORANGES

The orange is the most wildly grown citrus fruit. It is estimated that at the beginning of the third millennium 50 000 000 ton will be produced globally (Dugo & Di Giacomo, 2015). There are currently 6.51 hectares of oranges planted in the Stellenbosch region (Western Cape Department of Agriculture, 2016).

The Western Cape is considered a cooler citrus producing region and production in these areas are mainly focused on Navel oranges (Department of Agriculture Forestry and Fisheries, 2015c). Navel oranges are medium to large seedless fruit and are easy to peel (Citrus Research International, 2010). Orange trees grow well in regions with a rainfall that is between 655 mm and 983 mm per year (Marie, 2016). Optimum growth temperature for orange trees ranges between 13 °C and 38 °C. The average min temperature for the coldest month should not be below 2 °C to 3 °C (National Department of Agriculture, 2000). The harvest period of the Navel orange begins in March and lasts until June (Citrus Research International, 2010).

C.1.2.2. LEMONS

Another citrus fruit that flourishes in the cooler Western Cape citrus producing region, is the lemon (Department of Agriculture Forestry and Fisheries, 2015c). Lemon trees prefer regions with a rainfall between 574 mm and 1966 mm per year (Marie, 2016). The optimum growing temperature for lemon trees varies between 25 °C to 30 °C, but trees become inactive at temperatures below 12.7 °C (SF GATE, 2016). The coldest month of the region should not have an average minimum temperature of lower than 2 °C to 3 °C if no tree protection is provided (National Department of Agriculture, 2000). Lemon trees bear fruit throughout the year in many regions of South Africa. The Eureka cultivar is a popular cultivar choice with a high acid level and juice content. The production season for the Eureka cultivar ranges from middle March to middle August in cooler areas (Citrus Research International, 2010). There are currently 112.78 hectares of lemons planted in the Stellenbosch region (Department of Agriculture Forestry and Fisheries, 2013).

C.1.2.3. SOFT CITRUS (MANDARINS)

The cooler climate of the Western Cape also allows producers in this region to respond to the consumer demand for easy peelers such as the clementine and satsuma cultivars. The majority of easy peelers in South Africa are produced in the Western cape and Eastern Cape (Department of Agriculture Forestry and Fisheries, 2015c) Soft citrus trees grow well in regions that receive between 589.5 mm and 884.7 mm rain per year and have temperatures that ranges from 10 °C to 35 °C (Indian Agricultural Research Institute, n.d.). As with lemons and oranges, soft citrus should not be planted in regions where the average temperature of the coldest month is lower than 2 °C to 3 °C either (National Department of Agriculture, 2000) The clementine cultivar is the leading mandarin brand. These fruit are seedless when they are grown away from other cross-pollinating varieties and they are easy to peel. They are characterised by their bright orange peel at maturity and their sweet taste and flavour. Harvesting period for this cultivar ranges from mid-April to end June (Citrus Research International, 2010).

C.1.3. DECIDUOUS FRUIT

Plants that lose their leaves periodically at the end of each season or have plant parts such as fruit that fall off the plant, are referred to as deciduous plants. Deciduous fruit are also known as temperate fruit, due to their area of origin in the temperate parts of the world. These trees have good cold hardiness, because they originate from parts that have temperate climates. Chilling is required for good cropping and consistent bud-break. In the Southern hemisphere, the dormant period for trees that require chilling, stretch from autumn until August or September (Taylor & Gush, 2009).

Rain and humidity during the growing period of deciduous trees encourage disease and pest plagues, which make Stellenbosch with its Mediterranean-type climate and winter rainfall, an ideal region for growing deciduous fruit, according to ARC infruitec-nietvoorbij scientist expert HE7.

In South Africa three different methods of measuring chilling units are used. The Richardson model which measures 'Richardson Chill Units', the Infruitec model, measuring 'Infruitec Chilling Units', and the number of hours below 7.2 °C (Hacking, 2006). Deciduous trees require chilling units to be able to leave its dormant stage – the no-growth period of the tree. One Richardson Chill Unit is obtained at a temperature of 4 °C, measured for one hour, which is also the maximum chilling that can take place in one hour. The Units are determined on an hourly basis and accumulated for the winter months (Atkins, n.d.). The only difference between the Richardson and Infruitec models are, that the Infruitec model does not lose chilling units when temperatures exceed 16 °C, once a unit has been 'banked' (Hacking, 2006). Smith (2016) suggested working with the Infruitec model. Hence this paper will work with Infruitec chilling units.

C.1.3.1. PLUMS

South Africa's plum industry is well established. Most of the plums that are produced in South Africa are intended for the export market. Countries that are situated in the northern hemisphere, import South African produced plums during their winter and spring seasons. Plum production contributed R867 million to gross value production, during the 2013/2014 season (Department of Agriculture Forestry and Fisheries, 2015e).

Stellenbosch together with Tulbagh, Wolseley, Paarl, and the Little Karoo are responsible for over half of the plums produced in South Africa. This can mainly be ascribed to the region's Mediterranean-type climate which is characterised by hot dry summers and cold winters (Department of Agriculture Forestry and Fisheries, 2015e). There are currently 807.61 hectares of plums planted in the Stellenbosch region (Western Cape Department of Agriculture, 2016). Plum trees prefer well-drained soil with a pH level between 5,5 and 6,5 (Department of Agriculture Forestry and Fisheries, 2008a).

The plum cultivar, Laetitia, was bred in South Africa and released in 1985. This cultivar, classified as a very good production variety, is in full bloom at the end of September, and has low chilling requirements. This plum cultivar requires at least 600 Infruitec chilling hours according to expert HE7. The fruit of the tree is harvested from middle to late January, has a round-oblong shape, a semi-free stone, has a storage ability for up to four weeks at dual temperature, and is characterised by its bright red skin colour with many white lenticels (ARC Infruitec-Nietvoorbij, 2014). Bacterial cancer is latent in all plum cultivars, including Laetitia. Plums require crosspollination. This cultivar requires two cross-pollinator species, Casselman and Songold that are compatible with Laetitia (C. Smith, 2016). Laetitia is resistant to Xanthomonas spot, but reasonably susceptible to Monilinia laxa, which causes brown rot (ARC Infruitec-Nietvoorbij, 2014).

C.1.3.2. PEACHES

The initial peach and rootstock varieties were brought to South Africa from St Helena in 1655 and later from Holland in 1666. Peaches can be classified into two major classes: clingstone and freestone. The stones or pits of cling peaches are inclined to stick to the fleshy part of the peach. Dessert (freestone) peaches on the other hand have soft flesh and the seeds tend not to stick to the flesh of the fruit (Tsvakirai, 2014). Peaches contributed an estimate of 8.2% which amounts to R0.82 billion to the total gross value of deciduous fruits produced in South Africa for the 2013/2014 season (Department of Agriculture Forestry and Fisheries, 2015d)

Peaches are mainly grown in the Western Cape. One of the key factors to investigate when considering a specific cultivar for a region, is whether the intended region has an adequate number of chilling units available. Drainage is another important factor that needs to be considered. Peach trees, like other deciduous fruit species, like well-drained soils (Queensland Department of Agriculture and Fisheries, 2015). Peach trees prefer light, well-drained somewhat sandy soil with a pH that ranges from 6 to 6,5. Peaches grow well in regions where the average temperature during summer months is approximately 24 °C. Peach trees prefer sunny areas, but can grow in partial shady areas (Miksen, n.d.).

Bonnigold, a cling peach variety, was bred at Roodeplaat in South Africa and became available in 1991. It is classified as a good fruit production tree and is in full bloom during late August. The fruit of this tree is harvested late November. The fruit is characterised by a round yellow shape with yellow flesh and has a good to moderate storage ability (ARC Infruitec-Nietvoorbij, 2014). According to expert HE7, Bonnigold requires a minimum of 400 Infruitec chilling units.

C.1.4. VEGETABLES

C.1.4.1. CABBAGE

It is believed that cabbage evolved from a wild form innate to Europe. Today it is considered as one of the most popular vegetables in South Africa (Department of Agriculture Forestry and Fisheries, 1998a). A crop that is suited for almost all regions and climates grows easily, and that is easy to market locally (B. Kerr, 2013). Although the crop has its advantages, pest control is definitely required throughout its growing cycle. Cabbage (Brassica oleracea) is a cole crop which forms part of the Cruciferae family.

Cabbage is a cool season crop, although new varieties have made it possible to expand the range of the season. New farmers however are advised against cultivating this crop during the hot months when more insects are known to attack the crop. The vegetable can be enjoyed in different ways such as eating it with pap, adding it to stews or fresh salads, or mixing it with meat. Cabbage also contains Vitamin C, folic acid, and calcium, as well as being high in fibre (ARC, 2013). There is currently 42.99 hectares of cabbage being farmed in the Stellenbosch region (Western Cape Department of Agriculture, 2016).

Soil, Water and Climate Requirements

Cabbages can grow in almost all soil types, but prefer well-drained soil with a pH factor of 6.5–7 (ARC, 2013). Depending on the growing season and climate of the region, cabbages require between 380 and 500 mm of water per crop. Cabbage grows best in cool, humid areas as it is a cool season crop (Department of Agriculture Forestry and Fisheries, 1998a). Although, when the right cultivar is planted, it can be grown throughout the year in most regions (ARC, 2013). Preferred temperatures for growth and development of the crop ranges between 15 °C to 20 °C (ARC, 2013).

Uses

The entire plant can be consumed either cooked or raw.

Soil Preparation

It is important to clean the area where the cabbage is intended to be planted eight weeks before the time, and to plough the land deeply, to a depth of 450 mm to 600 mm, right before planting commences (Department of Agriculture Forestry and Fisheries, 1998a).

Planting and Spacing

Cabbage can be planted by direct-seeding or transplanting of seedlings. Approximately 2 kg of seed per hectare will be required if direct-seeding is used.

The spacing between the cabbages depends on the cultivar size. For medium-head sized cultivars 55 000 to 65 000 plants per hectare are recommended while 40 000 to 45 000 plants of the big-headed type per hectare are suggested (Department of Agriculture Forestry and Fisheries, 1998a).

Fertilisation

Cabbage needs between 200 and 250 kg nitrogen per hectare. It is further recommended that a topdressing of 300 kg LAN be applied four weeks after transplanting of seedlings (Department of Agriculture Forestry and Fisheries, 1998a).

Weed Control

Weeds are controlled chemically by administrating registered herbicides, mechanically or by hand. During land preparation, mechanical cultivation is employed.

Pest and Diseases

Frequent pests and diseases that affect cabbage are shown in Table 25.

Table 25: Cabbage pests & diseases/funguses compiled from (Department of Agriculture Forestry and Fisheries, 1998a)

Pest	Disease/Fungus
1. Cabbage aphids	**1.** Damping off
2. Diamond-back moth	**2.** Sclerotonia rot or white mould
3. Bagrada bug	**3.** Black rot
4. Thrips	**4.** Downy mildew
5. Cabbage webworm	
6. Nematodes	
7. Red spider mite	
8. Cutworms	
9. Plusia looper	

Pests and disease/funguses can be controlled chemically or mechanically by means of crop rotation, which includes using pesticides, planting of tolerant cultivars, and treating the seedbed with fungicides (Department of Agriculture Forestry and Fisheries, 1998a).

Megaton hybrid, a winter cultivar that has a good cold tolerance and that is harvested in spring, was suggested for the Stellenbosch region by Hugo Burger, a vegetable specialist associated with Hygrotech. This cultivar takes 110–125 days to reach maturity and is characterised by having a round head shape that is blue-green in colour that weighs between 5 kg and 8 kg. The plant itself is of a large size with a smooth leaf texture. The fresh and hawker markets are its primary target markets (Klein Karoo Seed Marketing, 2004).

C.1.4.2. CARROTS

Carrots (Daucus carota) are a popular root crop in commercial as well as home gardens in South Africa. Carrots usually have an orange, white or red/white blend colour, with orange-red being by far the most widespread colour (Department of Agriculture Forestry and Fisheries, 2012a).The vegetable is grown for its root, which is eaten raw in salads or cooked as part of a meal. Carrots are amid the top ten most economically significant vegetables in the world, regarding production area and market value (Department of Agriculture Forestry and Fisheries, 2012a). Carrots contributed an estimated R56 million to the total gross value production in 2014 (Department of Agriculture Forestry and Fisheries, 2015b).

Stellenbosch is one of the major production areas of carrots in South Africa (Department of Agriculture Forestry and Fisheries, 1998b). It is recommended that carrots are sown from August to end March in the Western Cape region (ARC, 2013). Currently 64.25 hectare of carrots are cultivated in the Stellenbosch area (Western Cape Department of Agriculture, 2016).

Crop Rotation

Crop rotation reduces the amount of soil-borne pests, and it improves the quality of the soil. Cabbage, lettuce, tomatoes, and pumpkin are ideal crop rotating partners for carrots (ARC, 2013).

Climate, Soil requirements and Weed control

Carrots grow well in regions that receive between 200–240 mm rain per year (The World Carrot Museum, 2016) and they prefer temperature that ranges between 15 – 20 °C (ARC, 2013). Carrot plants like deep well-drained sandy loam to sandy soils with a pH level that's between 6–6.6 (ARC, 2013). Weeds should not be allowed to compete with the carrot plants at any time. Soil cultivation between rows is done to control weeds (Department of Agriculture Forestry and Fisheries, 1998b)

Pest and Diseases

Frequent pests and diseases that affect cabbage are shown in Table 26.

Table 26: Carrot pests & diseases/funguses compiled from (Department of Agriculture Forestry and Fisheries, 1998b; Starke Ayres, 2016)

Pest	Disease/Fungus
1. Aphids	1. Bacterial leaf blight
2. Red Spider mite	2. Cottony rot
3. Cutworms	3. Oidium

Cultivar

Hugo Burger suggested the Star 3006, a F1 Nantes hybrid carrot cultivar, for the Stellenbosch region. This variety can be planted throughout the year in the Western Cape. During summer it takes between 95 and 105 days for this cultivar to reach maturity and it takes between 105 and 135 days during the winter months. Mainly produced for the fresh market segment. The plant is characterised by dark green leaves that are medium to long. The root varies from 14 to 18 cm, is cono-cylindrical in shape, has an intense orange colour, and has a relatively smooth texture. This cultivar has a high resistance towards Alternaria (Ad) and Cavity Spot (Ps) and is somewhat resistant towards Oidium. An advantage of Star 3006 is that is requires approximately 30% less Nitrogen than the standard nantes varieties (Starke Ayres, 2016).

C.2. SUMMARY OF ALTERNATIVES THEORY

Research on each of the selected land use alternatives had to be done to be able to compare climatic Considerations of each of the alternative types to that of Stellenbosch, to evaluate whether an alternative type would be suitable for the region. The information in Appendix C: Selected Land Use Alternatives Theory will be compared to Stellenbosch's weather data in Section 7.3. The information will also be used to set parameters when developing a model, that will compare possibilities and use alternatives with each consideration, according to user input.

APPENDIX D: POPULATED SPECIFIC CONSIDERATIONS TABLES

D.1. HORTICULTURE

D.1.1. VITICULTURE

D.1.1.1. Wine Cultivar

The information that is displayed in Table 27, unless stated otherwise, was supplied by an agriculture economist, expert HE3, that is affiliated with VinPro. The information is for the 2015 harvest season.

Table 27: Wine Cultivar Case study

Viticulture Considerations	*Description*	*Case Study*
Viticulture type	Consider the different cultivars and which one would perform best in the intended region.	Cabernet Sauvignon Expert HE2 stated that this wine cultivar is an excellent choice for the Stellenbosch region.
Gross Income (per ha per year)	The amount of revenue this species will make per hectare per year.	R 59 895.66 per hectare per year
Capital Investment (per hectare)	The amount of money invested to acquire capital or fixed assets, such as machinery, or to prepare the land for the land use alternative.	R60 427.53 per hectare

Viticulture Considerations	***Description***	***Case Study***
Input Cost (per hectare per year)	What is the total input cost per hectare per year?	R48 568.2 per hectare per year
		R8670.2
Cost Breakdown Structure	Cellar& Marketing Cost	R39 898
	Production Cost	R41
	Seed	R1056
	Fertiliser	R26
	Organic material	R2023
	Pesticide Control	R1126
	Herbicide Control	R201
	Repair & Binding material	R2062
	Supervision	R8610
	Permanent Labour	R4126
	Seasonal & Contract workers	R2004
	Fuel	R2256
	Repair, Parts, Maintenance	R532
	Licence & Insurance	R248
	Transport hired	R1671
	Electricity	R630
	Water costs	R397
	Land- Property- Municipal taxes	R1947
	Administration	R9410
	Provision for renewal	
Soil composition	Evaluate the soil composition, e.g. the acidity levels to determine whether the soil is adequate for the specific citrus cultivar	Well-drained soils with a pH level of 5.5–6 (Department of Agriculture Forestry and Fisheries, 2012b)

Viticulture Considerations	***Description***	***Case Study***
Local climate suitability	Whether this specific type of alternative will flourish in the climate type of the region, e.g. taking the temperature and rainfall into consideration. With vineyard, an important consideration is whether the region has a winter or summer rainfall.	*Rainfall* Good wine producing regions receive between 500 mm and 800 mm rainfall a year (Goldammer, 2016). Except for 2013 and 2015, Table 37 illustrates that the Stellenbosch rain fall meets these requirements. *Temperature* The cultivar requires a temperature of approximately 10 °C during winter to enter dormancy and 25 °C during the fruit ripening period. Cabernet Sauvignon is a late cultivar that's harvested from the end March till the end of April. This cultivar thrives under Mediterranean climates with a winter rainfall (HE2, 2016). The average temperatures in the Stellenbosch region for Dec, Jan, Feb, and March (the ripening period for the cultivar) are all approximately 25 °C, with the average maximum temperatures for these months above 25 °C (Refer to Table 36).
Topography	Evaluating and taking into account the valley floor and hillsides where the specific type of species will grow.	Gentle slope is ideal. The cultivar requires sun for the berries to ripen (Goldammer, 2016).
Disease & Pests	What disease and pests are known to attack the specific type of cultivar? What can be done to prevent these diseases and attacks?	*Diseases/Fungus* Susceptible to Eutypa dieback; Moderately susceptible to powdery mildew (Wolpert, n.d.) *Pests:* Snails Snout Beetle Grape berry moth Birds Refer to Table 19 for control methods
Water Availability (kilolitre per hectare per year)	How much water does this specific variety require to survive?	3000 Kilolitre/hectare/year (Myburgh, 2016)

Viticulture Considerations	***Description***	***Case Study***
Risks	What are the typical risks associated with this alternative type?	• Waste outweighs value adding • Pest/Diseases • Labour problems • Poor quality grape production • Veld fires • Local market forces • Macroeconomic factors (Uys, 2016)
Human Element	What amount of training/skill does the workers require to be able to perform their duties? This will be evaluated on a scale of: • **Low Skilled Staff** No or very little knowledge. • **Medium Skilled Staff** Some skills/training required for workers to perform their duties. • **High Skilled Staff** Workers require a lot of training/skills to be able to perform their duties.	Medium Skilled Staff
Markets	Who is the target market? How stable is the land use option in terms of sales, price, and production quantities?	*Target Market:* International *Stability:* Sales: Stale Production: Unstable Price: Stable **For market stability refer to Section 7.4.2.**
Required manpower (per ha)	The number of employees required to successfully complete the work.	4.58
Estimate threshold area required for profitability (ha)	What is the minimum number of hectares required for this specific alternative to be profitable?	80 hectares

Viticulture Considerations	***Description***	***Case Study***
Equipment	The extent to which mechanisation is used. This will be evaluated based on the following categories: • No equipment, manpower only • 20% equipment, 80% manpower • 40% equipment, 60% manpower • 50% equipment, 50% manpower • 60% equipment, 40% manpower • 80% equipment, 20% manpower • 100% equipment, no manpower – business is 100% mechanised	40% equipment, 60% manpower
Investment Period	Period required before this cultivar can be harvested?	4 years
Storing	How will the product be stored? What facilities will be needed to store the product?	Cellar: Wine barrels/tanks Pre-cooled to 1–2 °C within six hours of harvest (Department of Agriculture Forestry and Fisheries, 2012b).
Rotation Time	How often (years) should a different crop be planted in the same field?	Not Applicable

D.1.2. CITRUS FRUIT

Expert HE5 was consulted for information regarding citrus production. The monetary values are average values for the region and not values from one specific farm. Average values are used for anonymity and confidentiality reasons. The three-citrus types that were evaluated are oranges, lemons, and soft citrus (mandarins)

D.1.2.1. Navel Oranges

The information displayed in Table 28, unless stated otherwise, has been obtained from expert HE5.

Table 28: Orange Case Study

Citrus Considerations	Description	Case Study
Citrus type and species	Consider the varieties of citrus (grapefruit, sweet orange, lime, kumquat) as well as the specific cultivar and which one would perform best in the intended region.	Navel Orange: Palmer
Revenue/ Gross Income (per ha per year)	The amount of revenue this species will make per hectare per year.	R208 780 per hectare per year
Capital Investment (per hectare)	The amount of money invested to acquire capital or fixed assets, such as machinery or to prepare the land for the species.	R186 650 per hectare
Input Cost (per hectare per year)	What is the total input cost per hectare per year?	R166 851 per hectare per year
		R81 800
Cost Breakdown Structure	Marketing & Package Cost	R85 051
	Production Cost	R16 565
	Fertilisers and Sprays	R31 858
	Wages and Salaries	R5732
	Contract Work/Hiring of equipment	-
	Crop Insurance	R112
	Miscellaneous expenses	R611
	Water	R5926
	Electricity	R6715
	Repairs and Maintenance	R13 683
	Depreciation	R3849
	Admin & Miscellaneous	

Citrus Considerations	Description	Case Study
Soil composition	Evaluate the soil composition, e.g. the acidity levels to determine whether the soil is adequate for the specific citrus cultivar.	Citrus prefer well-drained soils with a pH level of 6 to 6,5 and low salinity (National Department of Agriculture, 2000).
Local climate suitability	Whether this specific type of strategy will flourish in the climate type of the region, e.g. taking the temperature, wind, humidity, rainfall, and amount of sunlight into consideration. With citrus production, it is also important to determine whether the region has a tropical, subtropical, or Mediterranean climate.	Sweet oranges are well-suited to grow in the Stellenbosch region with its Mediterranean climate. The cool winters in the Mediterranean are responsible for producing fruit with the best peel colour in this region (YARA, 2016). Harvest season is from March till June. *Rainfall* Rainfall should be between 655 mm and 983 mm per year (Marie, 2016). Average rainfall in the Stellenbosch region, apart from 2010, 2011 and 2015, falls in this range Table 37. *Temperature* Optimum growth temperature ranges between 13–38 °C. The average min temperature for the coldest month should not be below 2 to 3°C (National Department of Agriculture, 2000). The average min temperature in the Stellenbosch region for the coldest month (July) was 5.35 °C (Table 36).
Topography	Evaluating and taking into account the valley floor and hillsides where the specific type of species will grow.	Slopes of up to 15% are suitable for citrus production, given that the specific farm is designed to minimise soil erosion (Queensland Department of Agriculture and Fisheries, 2012).
Disease & Pests	What disease and pests are known to attack the specific type of species/animal, what can be done to prevent these diseases and attacks, and what is the amount of damage caused by these diseases and pests?	*Diseases/Fungus:* Fusarium (secondary fungus) Phytophthora parasitica Phytophthora citrophthora *Pests* Red scale South African citrus thrips Mediterranean fruit flies Budworm Woolly whitefly Ants (Bester, 2016) Refer to Table 19 for control methods

Citrus Considerations	Description	Case Study
Water Availability (Kilolitre/hectare/year)	The amount of water that's available. How much water does this specific variety of citrus require to survive?	When rainfall is less than 700 mm a year, one hectare of mature trees will require 8000 to 9000 KL of irrigation per year (Queensland Department of Agriculture and Fisheries, 2012). Acid fruit could be a result of a lack of water during October to January (National Department of Agriculture, 2000) The average rainfall in the Stellenbosch region from 2007–2015 (Table 37) being 675.95 mm.
Risks	What are the typical risks associated with this alternative?	• Market regulation changes • Change of overseas protocols and regulations • New diseases filtering to the country, specifically Asian Greening • Labour related risks (Bruwer, 2016)
Human Element	What amount of training/skill does the workers require to be able to perform their duties? This will be evaluated on a scale of: • **Low Skilled Staff** No or very little knowledge. • **Medium Skilled Staff** Some skills/training required for workers to perform their duties. • **High Skilled Staff** Workers require a lot of training/skills to be able to perform their duties.	Medium Skilled Staff
Markets	Who is the target market? How stable is the land use option in terms of sales, price, and production quantities?	*Target Market:* International South Africa was the second biggest exporter of oranges in 2014 (Department of Agriculture Forestry and Fisheries, 2015c). *Stability:* Sales: Unstable Production: Unstable Price: Moderately Stable **For market stability refer to Section 7.4.2.**
Required manpower (per ha)	The number of employees required to successfully complete the work.	0.75 labourers per hectare

Citrus Considerations	Description	Case Study
Estimate threshold area required for profitability (ha)	What is the minimum amount of hectare required for this specific strategy type to be profitable?	30 ha (without a packing store) 100 ha (with a packing store)
Equipment	The extent to which mechanisation is used. This will be evaluated based on the following categories: • No equipment, manpower only • 20% equipment, 80% manpower • 40% equipment, 60% manpower • 50% equipment, 50% manpower • 60% equipment, 40% manpower • 80% equipment, 20% manpower • 100% equipment, no manpower – business is 100% mechanised	60% equipment, 40% manpower
Investment Period	Period required before this cultivar can be harvested?	In the Southern Hemisphere harvest occurs almost entirely during the second year of cultivation of the citrus plant (Dugo & Di Giacomo, 2015)
Storing	How will the product be stored? What facilities will be needed to store the product?	Packing store
Rotation Time	How often (years) should a different crop be planted in the same field?	Not Applicable

D.1.2.2. Lemons

Table 29: Lemon Case Study

Citrus Considerations	Description	Case Study
Citrus type and species	Consider the varieties of citrus (grapefruit, sweet orange, lime, kumquat) as well as the specific cultivar and which one would perform best in the intended region.	Lemons: Eureka

Revenue/ Gross Income (per ha per year)	The amount of revenue this cultivar will make per hectare per year	R454 737 per hectare per year
Capital Investment (per hectare)	The amount of money invested to acquire capital or fixed assets such as machinery or prepare the land for the species.	R186 650 per hectare
Input Cost (per hectare per year) Cost Breakdown Structure	What is the total input cost per hectare per year? Marketing & Package Cost Production Cost Fertilisers and Sprays Wages and Salaries Contract Work/Hiring of equipment Crop Insurance Miscellaneous expenses Water Electricity Repairs and Maintenance Depreciation Admin & Miscellaneous	R215 954 per hectare per year R104 748 R111 206 R16 877 R52 843 R3622 R0 R61 R203 R4736 R14 769 R13 683 R4412
Soil composition	Evaluate the soil composition, e.g. the acidity levels to determine whether the soil is adequate for the specific citrus cultivar.	Citrus prefer well-drained soils with a pH level of 6 to 6,5 and low salinity (National Department of Agriculture, 2000).

Local climate suitability	Whether this specific type of strategy will flourish in the climate type of the region, e.g. taking the temperature, wind, rainfall, and amount of sunlight into consideration. With citrus production, it is also important to determine whether the region has a tropical, subtropical, or Mediterranean climate.	Lemons are well-suited to grow in the Stellenbosch region with its Mediterranean climate. Harvest season is from mid-February till mid-July. *Rainfall* Rainfall should be between 574 mm and 1966 mm per year (Marie, 2016). Average rainfall in the Stellenbosch region, apart from 2010, 2011 and 2015, falls in this range Table 37. *Temperature* The average min temperature for the coldest month should not be below 2– 3 °C (National Department of Agriculture, 2000). Optimum temperature ranges between 25–30 °C. Lemons prefer sunny areas. Trees becomes inactive at temperatures below 12.7 °C (SF GATE, 2016).
Topography	Evaluating and taking into account the valley floor and hillsides where the specific type of species will grow.	Slopes of up to 15% are acceptable, if the farm is designed to minimise soil erosion (Queensland Department of Agriculture and Fisheries, 2012).
Disease & Pests	What disease and pests are known to attack the specific type of species/animal, what can be done to prevent these diseases and attacks, and what is the amount of damage caused by these diseases and pests?	*Diseases/Fungus:* Botrytis- Fusarium (secondary fungus) Phytophthora parasitica Phytophthora citrophthora *Pests* Red scale South African citrus thrips Mediterranean fruit flies Budworm Woolly whitefly (Bester, 2016) Refer to Table 19 for control methods
Water Availability (Kilolitre/hectare/year)	The amount of water that's available. How much water does this specific variety of citrus require to survive?	9600–10 800 KL water per hectare per year

Risks	What are the typical risks associated with this alternative?	• Market regulation changes • Change of overseas protocols and regulations • New diseases filtering to the country, specifically Asian Greening • Labour related risks (Bruwer, 2016)
Human Element	What amount of training/skill does the workers require to be able to perform their duties? This will be evaluated on a scale of: • **Low Skilled Staff** No or very little knowledge. • **Medium Skilled Staff** Some skills/training required for workers to perform their duties. • **High Skilled Staff** Workers require a lot of training/skills to be able to perform their duties.	Medium Skilled Staff
Markets	Who is the target market? How stable is the land use option in terms of sales, price, and production quantities?	*Target Market:* International *Stability:* Sales: Unstable Production: Unstable Price: Unstable **For market stability refer to Section 7.4.2.**
Required manpower (per ha)	The number of employees required to successfully complete the work.	1.09 labourers per hectare
Estimate threshold area required for profitability (ha)	What is the minimum amount of hectare required for this specific strategy type to be profitable?	25 ha (without packing store) 65 ha (with packing store)

Equipment	The extent to which mechanisation is used. This will be evaluated based on the following categories: • No equipment, manpower only • 20% equipment, 80% manpower • 40% equipment, 60% manpower • 50% equipment, 50% manpower • 60% equipment, 40% manpower • 80% equipment, 20% manpower • 100% equipment, no manpower– business is 100% mechanised	60% equipment, 40% manpower
Investment Period	Period required before this cultivar can be harvested?	In the Southern Hemisphere harvest occurs almost entirely during the second year of cultivation of the citrus plant (Dugo & Di Giacomo, 2015)
Storing	How will the product be stored? What facilities will be needed to store the product?	Packing store
Rotation Time	How often (years) should a different crop be planted in the same field?	Not Applicable

D.1.2.3. Soft Citrus (Mandarins)

Table 30: Soft Citrus (Mandarin) Case Study

Citrus Considerations	***Description***	***Case Study***
Citrus type and species	Consider the varieties of citrus (grapefruit, sweet orange, lime, kumquat) as well as the specific cultivar and which one would perform best in the intended region.	Soft Citrus (Mandarins): Clementine
Revenue/ Gross Income (per ha per year)	The amount of revenue this species will make per hectare per year	R268 315 per hectare per year
Capital Investment (per hectare)	The amount of money invested to acquire capital or fixed assets, such as machinery or to prepare the land for the species.	R186 650 per hectare
Input Cost (per hectare per year) Cost Breakdown Structure	What is the total input cost per hectare per year? Marketing & Package Cost Production Cost Fertilisers and Sprays Wages and Salaries Contract Work/Hiring of equipment Crop Insurance Misc. expenses Water Electricity Repairs and Maintenance Depreciation Admin & Misc.	R194 912 per hectare per year R78 521 R116 391 R23 130 R47 712 R4686 - R67 R1617 R7374 R13 316 R13 683 R4806
Soil composition	Evaluate the soil composition, e.g. the acidity levels to determine whether the soil is adequate for the specific citrus cultivar.	Citrus prefer well-drained soils with a pH level of 6 to 6,5 and low salinity (National Department of Agriculture, 2000).

Citrus Considerations	***Description***	***Case Study***
Local climate suitability	Whether this specific type of alternative will flourish in the climate type of the region, e.g. taking the temperature, wind, humidity, rainfall, and amount of sunlight into consideration. With citrus production, it is also important to determine whether the region has a tropical, subtropical, or Mediterranean climate.	Mandarins are well-suited to grow in the Stellenbosch region with its Mediterranean climate. Harvest season is from mid-April till end-June. *Rainfall:* 589.5 – 884.7 mm per year *Temperature:* Optimum growth temperature ranges between 10–35 °C (Indian Agricultural Research Institute, n.d.). The average min temperature for the coldest month should not be below 2–3 °C (National Department of Agriculture, 2000).
Topography	Evaluating and taking into account the valley floor and hillsides where the specific type of species will grow.	Slopes of up to 15% are acceptable, if the farm is designed to minimise soil erosion (Queensland Department of Agriculture and Fisheries, 2012).
Disease & Pests	What disease and pests are known to attack the specific type of species/animal? What can be done to prevent these diseases and attacks?	*Diseases/Fungus:* Alternaria brown spot Fusarium (secondary fungus) Phytophthora parasitica *Pests* Red scale South African citrus thrips Mediterranean fruit flies Budworm Woolly whitefly (Bester, 2016) Refer to Table 19 for control methods
Water Availability (Kilolitre/hectare/year)	The amount of water that's available. How much water does this specific variety of citrus require to survive?	7200–8100 KL water per hectare per year
Risks	What are the typical risks associated with this alternative?	• Market regulation changes • Change of overseas protocols and regulations • New diseases filtering to the country, specifically Asian Greening • Labour related risks (Bruwer, 2016)

Citrus Considerations	***Description***	***Case Study***
Human Element	What amount of training/skill does the workers require to be able to perform their duties? This will be evaluated on a scale of: • **Low Skilled Staff** No or very little knowledge. • **Medium Skilled Staff** Some skills/training required for workers to perform their duties. • **High Skilled Staff** Workers require a lot of training/skills to be able to perform their duties.	Medium Skilled Staff
Markets	Who is the target market? How stable is the land use option in terms of sales, price, and production quantities?	*Target Market:* International 76% of the total production of soft citrus were exported in 2014. Prices recorded for export markets between 2013 and 2014 increased by 17% (Department of Agriculture Forestry and Fisheries, 2015c). *Stability:* Sales: Unstable Production: Unstable Price: Unstable **For market stability refer to Section 7.4.2.**
Required manpower (per ha)	The number of employees required to successfully complete the work.	1.05 labourers per hectare
Estimate threshold area required for profitability (ha)	What is the minimum amount of hectare required for this specific strategy type to be profitable?	15 ha (without packing store) 35 ha (with packing store)

Citrus Considerations	***Description***	***Case Study***
Equipment	The extent to which mechanisation is used. This will be evaluated based on the following categories: • No equipment, manpower only • 20% equipment, 80% manpower • 40% equipment, 60% manpower • 50% equipment, 50% manpower • 60% equipment, 40% manpower • 80% equipment, 20% manpower • 100% equipment, no manpower– business is 100% mechanised	60% equipment, 40% manpower
Investment Period	Period required before this cultivar can be harvested?	In the Southern Hemisphere harvest occurs almost entirely during the second year of cultivation of the citrus plant (Dugo & Di Giacomo, 2015)
Storing	How will the product be stored? What facilities will be needed to store the product?	Packing store Store at 5-8 °C
Rotation Time	How often (years) should a different crop be planted in the same field?	Not Applicable

D.1.3. DECIDUOUS FRUIT

Expert HE7 suggested that the researcher contact Hortgro, a South African based company that focuses on production, research, technology, markets and transformation within the deciduous fruit industry (Hortgro Ltd, 2016). All information unless otherwise stated, have been obtained from them.

D.1.3.1. Plums

Table 31: Plums Case Study

Deciduous Fruit Considerations	***Description***	***Case Study***
Deciduous fruit type and species	Consider the varieties of deciduous fruits as well as the specific cultivar and which one would perform best in the intended region.	Plums: Laetitia
Revenue/Gross Income (per ha per year)	The amount of revenue this cultivar will make per hectare per year	R 318 437 per hectare per year
Capital Investment (per hectare)	The amount of money invested to acquire capital or fixed assets, e.g. machinery, or to prepare the land for the species.	R172 519 per hectare
Input Cost (per hectare per year)	What is the total input cost per hectare per year?	R 281 079 per hectare per year
Cost Breakdown Structure	Marketing & Package Cost	R114 052
	Production Cost	R165 333
	Fertilisers	R10 723
	Herbicides	R1332
	Pesticides	R8 542
	Fungicides	R7 106
	Rest breaking agents	R2 096
	Consultants	R950
	Seasonal Labour	R34 546
	Fixed Labour	R15 643
	Transport rental & Fuel	R28 255
	Repairs and Maintenance	R6 202
	Electricity	
	General	R3 948
	Pollination	R225
	Water costs	R3 480
	Overheads	R2 150
	Interest on loans	R20 835
	Depreciation on orchard	R9 885
		R9 415

Deciduous Fruit Considerations	***Description***	***Case Study***
Soil composition	Evaluate the soil composition, e.g. the acidity levels to determine whether the soil is adequate for the specific cultivar?	Soil should have a pH level of 5,5 –6,5 and be well-drained. (Department of Agriculture Forestry and Fisheries, 2008a)
Local climate suitability	Whether this specific cultivar will flourish in the climate type of the region. It is important to evaluate the number of chilling units available in a certain region before considering a specific cultivar. It is also important to determine whether the region has a tropical, subtropical, or Mediterranean climate.	Well-suited for Stellenbosch with its Mediterranean-type climate. Harvest season is from January till end February. *Chilling Units* The Stellenbosch region has approximately 600 Infruitec Chilling Units. Laetitia requires 600 or more chilling hours (low chilling requirement variety) (C. Smith, 2016).
Topography	Evaluating and taking into account the valley floor and hillsides where the specific type of species will grow.	Sunny areas North-Eastern slopes for early ripening Southern slopes for late ripening (C. Smith, 2016)
Disease & Pests	What disease and pests are known to attack the specific type of species/animal, what can be done to prevent these diseases and attacks?	*Diseases* Bacterial cancer (latent in all plum cultivars) *Pests:* American budworm Snout Beetle Monilinia laxa. (C. Smith, 2016) Refer to Table 19 for control measures
Water Availability (Kilolitre/hectare/year)	The amount of water that's available. How much water does this specific cultivar require to survive?	Approximately 8000 – 10 000 KL per hectare per year
Risks	What are the typical risks associated with this alternative?	• Sunburn • Pests/Diseases • Not adequate number of chilling units (C. Smith, 2016)

Deciduous Fruit Considerations	***Description***	***Case Study***
Human Element	What amount of training/skill does the workers require to be able to perform their duties? This will be evaluated on a scale of: • **Low Skilled Staff** No or very little knowledge. • **Medium Skilled Staff** Some skills/training required for workers to perform their duties. • **High Skilled Staff** Workers require a lot of training/skills to be able to perform their duties.	Differ from the type of work that is required, most of workers fall within the Low Skilled Staff group with some in the Medium Skilled Staff group.
Markets	Who is the target market? How stable is the land use option in terms of sales, price, and production quantities?	*Target market* International. Laetitia is the largest plum export cultivar *Stability:* Sales: Stable Production: Unstable Price: Unstable **For market stability refer to Section 7.4.2.**
Required manpower (per ha)	The number of employees required to successfully complete the work.	1.3 workers/ha/year
Estimate threshold area required for profitability (ha)	What is the minimum amount of hectare required for this specific strategy type to be profitable?	20 hectares

Deciduous Fruit Considerations	***Description***	***Case Study***
Equipment	The extent to which mechanisation is used. This will be evaluated based on the following categories: • No equipment, manpower only • 20% equipment, 80% manpower • 40% equipment, 60% manpower • 50% equipment, 50% manpower • 60% equipment, 40% manpower • 80% equipment, 20% manpower • 100% equipment, no manpower – business is 100% mechanised	Approximately 40% equipment, 60% manpower.
Investment Period	Period required before this cultivar can be harvested?	Full fruit bearing within 5–6 years, but a period of approximately 10 years are required to break even and start making a profit.
Storing	How will the product be stored? What facilities will be needed to store the product?	Packing Store All deciduous fruit have a short shelf life. As soon as is the fruit is picked it should be cooled to -0,5 °C by means of force cooling, to stop the respiration process and to delay the ripening process. Packaging takes place afterwards. The cold chain should not be broken. Cooling facilities are thus required.
Rotation Time	How often (years) should a different crop be planted in the same field?	Not Applicable

D.1.3.2. Cling Peaches

Table 32:Cling Peaches Case Study

Deciduous Fruit Considerations	***Description***	***Case Study***
Deciduous fruit type and species	Consider the varieties of deciduous fruits as well as the specific cultivar and decide which variety would perform best in the intended region.	Cling Peaches: Bonnigold
Revenue/Gross Income (per ha per year)	The amount of revenue this species will make per hectare per year.	R 383 333.3 per hectare per year
Capital Investment (per hectare)	The amount of money invested to acquire capital or fixed assets such as machinery or to prepare the land for the species.	R118 258 per hectare
Input Cost (per hectare per year)	What is the total input cost per hectare per year?	R261 216 per hectare per year
Cost Breakdown Structure	Marketing & Package Cost	R103 875
	Production Cost	R157 341
	Fertilisers	R10 687
	Herbicides	R1 332
	Pesticides	R8 694
	Fungicides	R11 320
	Rest breaking agents	-
	Consultants	R950
	Seasonal Labour	R30 310
	Fixed Labour	R15 643
	Transport rental & Fuel	R27 772
	Repairs and Maintenance	R6 336
	Electricity	R3 689
	General	R225
	Pollination	-
	Water costs	R2 150
	Overheads	R20 835
	Interest on loans	R10 719
	Depreciation on orchard	R6 679
Soil composition	Evaluate the soil composition, e.g. the acidity levels to determine whether the soil is adequate for the specific cultivar	Light, well-drained somewhat sandy soil with a pH level of 6–6,5

Deciduous Fruit Considerations	***Description***	***Case Study***
Local climate suitability	Whether this specific cultivar will flourish in the climate type of the region. It is important to evaluate the number of chilling units available in a certain region before considering a specific cultivar. It is also important to determine whether the region has a tropical, subtropical, or Mediterranean climate.	Well-suited for the Mediterranean climate with its winter rainfall area. Harvest period: Late November *Temperature* Requires at least 400 Infruitec chilling units, which Stellenbosch, with an average of 600 Infruitec chilling units, have (C. Smith, 2016). Peaches grow well in regions where the average temperature during summer months is approximately 24 °C (Miksen, n.d.)..
Topography	Evaluating and taking into account the valley floor and hillsides where the specific type of species will grow.	Sunny areas North-Eastern slopes for early ripening Southern slopes for late ripening (C. Smith, 2016)
Disease & Pests	What disease and pests are known to attack the specific type of species/animal that can be done to prevent these diseases and attacks, and what is the amount of damage caused by these diseases and pests?	*Disease/Fungus* Bud mite *Pests:* American budworm Snout Beetle (C. Smith, 2016) Refer to Table 19 for control measures
Water Availability (Kilolitre/hectare/year)	The amount of water that's available. How much water does this specific cultivar require to survive?	Approximately 8000 – 10 000 KL per hectare per year
Risks	What are the typical risks associated with this alternative?	• Bonnigold is very sensitive to climate changes, if there are not enough cold units, trees consequently get buttons. • Diseases/Pests • Veld fire if orchard is not kept clean (C. Smith, 2016)

Deciduous Fruit Considerations	***Description***	***Case Study***
Human Element	What amount of training/skill does the workers require to be able to perform their duties? This will be evaluated on a scale of: • **Low Skilled Staff** No or very little knowledge. • **Medium Skilled Staff** Some skills/training required for workers to perform their duties. • **High Skilled Staff** Workers require a lot of training/skills to be able to perform their duties.	Differ from the type of work that is required, most the workers fall within the Low Skilled Staff group with some falling in the Medium Skilled Staff group.
Markets	Who is the target market? How stable is the land use option in terms of sales, price, and production quantities?	*Target Market:* Local target market *Stability:* Sales: Unstable Production: Stable Price: Moderately Stable **For market stability refer to Section 7.4.2.**
Required manpower (per ha)	The number of employees required to successfully complete the work.	1.3 workers/ha/year
Estimate threshold area required for profitability (ha)	What is the minimum amount of hectare required for this specific alternative to be profitable?	Approximately 20 hectares

Deciduous Fruit Considerations	***Description***	***Case Study***
Equipment	The extent to which mechanisation is used. This will be evaluated based on the following categories: • No equipment, manpower only • 20% equipment, 80% manpower • 40% equipment, 60% manpower • 50% equipment, 50% manpower • 60% equipment, 40% manpower • 80% equipment, 20% manpower 100% equipment, no manpower– business is 100% mechanised	Approximately 40% equipment, 60% manpower.
Investment Period	Period required before this cultivar can be harvested?	Full fruit bearing within 5–6 years, but a period of approximately 10 years are required to break even and start making a profit.
Storing	How will the product be stored? What facilities will be needed to store the product?	Packing Store All deciduous fruit have a short shelf life. The fruit should be cooled as soon as it is picked to -0,5 °C by means of force cooling to stop the respiration process and to delay the ripening process. Packaging takes place afterwards. The cold chain should not be broken. Cooling facilities are thus required. Moderate to good storage ability.
Rotation Time	How often (years) should a different crop be planted in the same field?	Not Applicable

D.1.4. VEGETABLES

D.1.4.1. Cabbage

Note original data obtain from horticulture expert HE1 was for the year 2008. Data represented in Table 33 has been adjusted based on interest rate conversion, from nominal to real terms. The consumer price index (CPI) for 2008 and 2016 that was use for the conversions were 101,4 and 123,2 respectively (STATS SA, 2009, 2016). All data depicted in Table 33, unless stated otherwise, has been obtained from expert HE1.

Table 33: Cabbage Case Study

Cabbage Considerations	***Description***	***Case Study***
Species	Consider the different cabbage cultivars and which would perform best in the intended region.	Cabbage: Megaton
Gross Income (per ha per year)	The amount of revenue this cultivar will make per hectare per year	R91 124.26 per hectare per year
Capital Investment (per hectare)	The amount of money invested to acquire capital or fixed assets such as machinery or prepare the land for the species.	R55 000 per hectare
Input Cost (per hectare per year)	What is the total input cost per hectare per year?	R22 571.71 per hectare per year
Cost Breakdown Structure	Marketing Cost	R4556.21
	Operating Cost	R18 015.5
	Labour	R2308.48
	Fertilisers Spread-10.5%	R1329.19
	Fertilisers Add: LAN-28%	R793.39
	Fungus Control spray: Benomyl	R145.79
	Pest control spray: Bladbuff	R10.64
	Dedavap (DVP)	R341.89
	Cabbage Seed	R100.22
	Cabbage Plants	R3644.97
	Water-right scheme cost	R706.04
	Weed-control spray: Pree	R65.51
	Fuel	R902.29
	Maintenance & Repair	R611.65
	Packaging Material	R6506.27
	Interest on working capital	R377.42
	Irrigation Cost	R171.70
Soil composition	Evaluate the soil composition, e.g. the acidity levels to determine whether the soil is adequate for the specific cultivar.	Well-drained soils with a pH level of 6.5–7.

Cabbage Considerations	***Description***	***Case Study***
Local climate suitability	Whether this specific type of alternative will flourish in the climate type of the region, e.g. taking the temperature, rainfall, and rainfall season into consideration.	Suitable for Stellenbosch region The Megaton cultivar is a winter cultivar which is harvested in spring (September). Harvesting takes between 1 and 4 weeks. *Rainfall* 380–500 mm per year (Food and Agriculture Organization of the United Nations, 2015). *Temperature* Temperature range during the growth period should be between -3–20°C (June, July, August) (ARC, 2013). The average temperatures for these months in the Stellenbosch region fall within the required range Table 36.
Topography	Evaluating and taking the valley floor and hillsides where the specific type of species will grow, into account.	
Disease & Pests	What disease and pests are known to attack the specific type of species? What can be done to prevent these diseases and attacks, and what is the amount of damage caused by these diseases and pests?	*Disease/Fungus* Alternaria leaf spot *Pests* Diamond back moth Cutworm Thrips American bollworm Grey cabbage aphid (Department of Agriculture Forestry and Fisheries, 1998a; van den Berg, 2016) Refer to Table 19 for control measures
Water Availability (Kilolitre/hectare/year)	The amount of water that's available. How much water does this specific species require to survive?	4.5 KL /ha/year
Risks	What are the typical risks associated with this alternative?	• Hail • Weed • Pests/Plague • Market establishment • Competition (van den Berg, 2016)

Cabbage Considerations	***Description***	***Case Study***
Human Element	What amount of training/skill does the workers require to be able to perform their duties? This will be evaluated on a scale of: • **Low Skilled Staff** No or very little knowledge. • **Medium Skilled Staff** Some skills/training required for workers to perform their duties. • **High Skilled Staff** Workers require a lot of training/skills to be able to perform their duties.	Mostly low skilled staff
Markets	Who is the target market? How stable is the land use option in terms of sales, price, and production quantities?	*Target Market:* Locally Sold locally on the fresh produce markets *Stability:* Sales: Stable Production: Stable Price: Moderately Stable **For market stability refer to Section 7.4.2.**
Required manpower (per ha)	The number of employees required to successfully complete the work.	1.5
Estimate threshold area required for profitability (ha)	What is the minimum amount of hectare required for this specific strategy type to be profitable?	20 hectares

Cabbage Considerations	***Description***	***Case Study***
Equipment	The extent to which mechanisation is used. This will be evaluated based on the following categories: • No equipment, manpower only • 20% equipment, 80% manpower • 40% equipment, 60% manpower • 50% equipment, 50% manpower • 60% equipment, 40% manpower • 80% equipment, 20% manpower • 100% equipment, no manpower– business is 100% mechanised	No equipment, manpower only
Investment Period	Period required before this cultivar can be harvested.	None, harvest same year as plant
Storing	How will the product be stored? What facilities will be needed to store the product?	Cabbage should preferably be stored at 0 °C with a humidity of 90–95% (Department of Agriculture Forestry and Fisheries, 1998a).
Rotation Time	How often (years) should a different crop be planted in the same field?	3-4 Years

D.1.4.2. Carrot

Note original data obtain from horticulture expert HE1 was for the year 2008. Data represented in Table 34 has been adjusted based on interest rate conversion, from nominal to real terms. The consumer price index (CPI) for 2008 and 2016 that was used for the conversions were 101,4 and 123,2 respectively (STATS SA, 2009, 2016). All data depicted in Table 34, unless stated otherwise have been obtained from expert HE1.

Table 34: Carrot Case Study

Carrot Considerations	***Description***	***Case Study***
Species	Consider the different carrot cultivars and which would perform best in the intended region.	Yellow Carrot: Star 3006
Gross Income (per ha per year)	The amount of revenue this species will make per hectare per year	R140 735.3 per hectare per year
Capital Investment (per hectare)	The amount of money invested to acquire capital or fixed assets, e.g. machinery, or prepare the land for the alternative.	R75 000 per hectare
Input Cost (per hectare per year) Cost Breakdown Structure	What is the total input cost per hectare per year? Marketing Cost Operating Cost Labour Fertilisers potassium nitrate Fertilisers spread 2.3.4 (30) Fertilisers Add: LAN-28% Fungus control spray: Apron XL 350 FS Pest control spray: Decis Carrot Seed Water-right scheme cost Weed-control spray: Afalon 450SC/Linagan Fuel Maintenance & Repair Packaging Material Interest on working capital Irrigation Cost	R23 466.05 per hectare per year R7036.76 R16 429.29 R971.99 R1789.68 R1556.71 R952.07 R3510.12 R236.92 R1120.22 R706.04 R277.02 R808.46 R570.03 R3614.60 R217.51 R51.19

Carrot Considerations	***Description***	***Case Study***
Soil composition	Evaluate the soil composition, e.g. the acidity levels to determine whether the soil is adequate for the specific cultivar	Deep well-drained sandy loam to sandy soil Require pH level of 6-6.5 (ARC, 2013)
Local climate suitability	Whether this specific type of alternative will flourish in the climate type of the region, e.g. taking the temperature, rainfall, and rainfall season into consideration.	Harvest period ranges from 1 to 4 weeks. *Rainfall* 200–240 mm per year (The World Carrot Museum, 2016) *Temperature* Optimum temperature for growth ranges between 15 and 20 °C (ARC, 2013) This cultivar carrot can be grown throughout the year in the Western Cape.
Topography	Evaluating and taking the valley floor and hillsides where the specific type of species will grow, into account.	-
Disease & Pests	What disease and pests are known to attack the specific type of species, what can be done to prevent these diseases and attacks?	*Pests* Red spider mites Aphids *Cutworms* *Diseases/Fungus* Bacterial leaf blight Cottony rot Refer to Table 19 for control measures
Water Availability (Kilolitre/hectare/year)	The amount of water that's available. How much water does this specific species require to survive?	2 KL /ha/year
Risks	What are the typical risks associated with this alternative?	• Disease/Pests • Flood • Weed

Carrot Considerations	***Description***	***Case Study***
Human Element	What amount of training/skill does the workers require to be able to perform their duties? This will be evaluated on a scale of: • **Low Skilled Staff** No or very little knowledge. • **Medium Skilled Staff** Some skills/training required for workers to perform their duties. • **High Skilled Staff** Workers require a lot of training/skills to be able to perform their duties.	Mostly medium skilled staff required
Markets	Who is the target market? How stable is the land use option in terms of sales, price, and production quantities?	*Target Market:* Local Fresh market *Stability:* Sales: Unstable Production: Unstable Price: Moderately Stable **For market stability refer to Section 7.4.2.**
Required manpower (per ha)	The number of employees required to successfully complete the work.	3.4
Estimate threshold area required for profitability (ha)	What is the minimum amount of hectare required for this specific strategy type to be profitable?	48 hectares

Carrot Considerations	***Description***	***Case Study***
Equipment	The extent to which mechanisation is used. This will be evaluated based on the following categories: • No equipment, manpower only • 20% equipment, 80% manpower • 40% equipment, 60% manpower • 50% equipment, 50% manpower • 60% equipment, 40% manpower • 80% equipment, 20% manpower • 100% equipment, no manpower– business is 100% mechanised	Approximately 20% equipment, 80% manpower.
Investment Period	Period required before this cultivar can be harvested?	None, harvest same year as plant
Storing	How will the product be stored? What facilities will be needed to store the product?	Can only be stored for a few days. Harvest carrots as required (before consumption or selling). Fresh carrots will keep for 5 days at room temperature and for 7 to 21 days when refrigerated (ARC, 2013).
Rotation Time	How often (years) should a different crop be planted in the same field?	Every 3 years

APPENDIX E: CLIMATE DATA

Table 35: Legend

Element	Description	Unit
T	Average Temperature	°C
T_x	Average Maximum Temperature	°C
T_n	Average Minimum Temperature	°C
Rain	Average Total Rainfall	mm
RH_x	Average Maximum Relative Humidity	%
RH_n	Average Minimum Relative Humidity	%
WS	Average Wind Speed	ms

Table 36: Monthly Weather Data

Year	Month	T_x	T_n.	T	Rain	RH_x	WS
2015	May	24.42	8.8	16.61	36.32	96.6	0.81
2015	June	20.11	6.19	13.15	114.55	95.77	1.02
2015	July	18.46	5.35	11.905	107.19	95.73	1.18
2015	August	21.16	7.31	14.235	43.69	96.85	1.12
2015	September	23.43	8.76	16.095	27.94	92.23	1.52
2015	October	27.37	10.62	18.995	5.59	93.53	1.4
2015	November	28.05	10.1	19.075	21.08	92.34	1.48
2015	December	30.86	13.49	22.175	29.97	94.31	1.45
2016	January	34.03	18.3	26.165	9.14	82.86	2.46
2016	February	31.67	14.35	23.01	11.94	91.75	1.61
2016	March	29.16	12.84	21	35.56	93.61	1.56
2016	April	28.4	10.65	19.525	33.78	96.6	0.94

Table 37: Yearly Weather Data

Year	**T_x**	**T_n**	**T**	**Rain**	**RH_x**	**RH_n**	**WS**
2007	24.62	11.06	17.84	765.8	93.37	44.15	1.69
2008	27.24	11.57	19.405	755.99	94.16	38.73	1.42
2009	25.86	10.38	18.12	682.5	94.15	38.46	1.25
2010	26.31	10.25	18.28	563.12	93.23	35.94	1.37
2011	26.32	10.06	18.19	483.87	93.55	35.69	1.31
2012	25.51	9.84	17.675	774.95	93.56	37.92	1.28
2013	25.61	10.3	17.955	957.07	93.11	37.46	1.39
2014	26.56	10.61	18.585	686.56	93.36	36.83	1.33
2015	26.34	10.03	18.185	413.77	93.59	35.65	1.34

APPENDIX F: VALIDATION QUESTIONNAIRES

INTERVIEW QUESTIONNAIRE 1

Interviewer: Jeanne-Mari de Villiers

Interviewee: Interviewee 1

Date: 15 November 2016

Interviewee background contextualisation

a)

Interviewer: What is your occupation and the industry thereof?

***Interviewee**: Olive Consultant – table olives and oil*

b)

Interviewer: What is your current role in the organisation?

***Interviewee**: Smallholding owner and olive consultant.*

c)

Interviewer: Previous exposure to the farming industry? Please elaborate.

***Interviewee**: Was factory manager of a table olive factory on a 300 Ha farm and produced 600 tonnes of table olives pa. Has more than a decade of experiencing growing and processing table olives. Has a background in Chemistry, Physiology, Pharmacology, and Microbiology. An honorary life membership of the South African Olive Industry Association was awarded to this expert.*

d)

Interviewer: Previous exposure to the field of decision support systems? Please elaborate.

***Interviewee**: No*

Methodology related questions

a)

Interviewer: To what extent do you agree or disagree with the stepwise process that was followed to apply the decision support system for the identification of land use alternatives in a specified region, as visually depicted in Figure 37?

i)

Interviewer: If you do not agree with the methodology what improvements do you propose?

***Interviewee**: N/A*

ii)

Interviewer: Considering the stepwise process that was followed to apply the developed DSS, what is your opinion of the potential of the DSS as guidance to establish land use alternatives for the Stellenbosch region?

***Interviewee**: Very practical inclusion of many many aspects that are not usually taken into account – especially aspects like pests and diseases – I believe too often we embark on projects without being informed of these risks*

b)

Interviewer: To what degree do you agree with the process followed in identifying the various considerations?

***Interviewee**: It seems to be a very logical and comprehensive process*

DSS related questions

a)

Interviewer: Do you believe that the considerations (refer to Figure 42) identified in the DSS comprise a comprehensive set for the assessment of alternative land use options?

Interviewee: I do – it would be a huge advantage to be able to have this information at one's fingertips to support the final decisions

i)

Interviewer: Are there any additional considerations that you feel must be included in the model?

Interviewee: There needs to be this type of ringfencing to make it more widely applicable

b)

Interviewer: Please comment on the following structural aspects of the DSS?

i)

Interviewer: How would you rate the easiness of understanding the DSS?

Interviewee: Very clear and easy

ii)

Interviewer: How would you rate the easiness of use of the model?

Interviewee: Very easy

c)

Interviewer: In your opinion, what are strong points of the proposed DSS to assess possible land use alternatives?

Interviewee: Its broad base, applicability and ease of use d)

Interviewer: In your opinion, what are weak points of the proposed DSS to assess possible land use alternatives?

Interviewee: Don’t see any yet –

e)

Interviewer: In your opinion, how can the DSS be improved?

Interviewee: N/A

f)

Interviewer: Please comment on the applicability and usability of this DSS, from your professional viewpoint, to evaluate possible land use alternatives.

Interviewee: I appreciate the overall applicability of the framework which shows the necessary constraints in scope to make it more widely applicable.

Further comments

Please provide any further comment should you deem it necessary.

Thank you very much for your time and effort in the validation of this research study. It is greatly appreciated.

INTERVIEW QUESTIONNAIRE 2

Interviewer: Jeanne-Mari de Villiers

Interviewee: Interviewee 2

Date: 11 November 2016

Interviewee background contextualisation

a)

Interviewer: What is your occupation and the industry thereof?

***Interviewee**: Retired engineer – Olive farm owner.*

b)

Interviewer: What is your current role in the organisation?

***Interviewee**: Owner – manager.*

c)

Interviewer: Previous exposure to the farming industry? Please elaborate.

***Interviewee**: None*

d)

Interviewer: Previous exposure to the field of decision support systems? Please elaborate.

***Interviewee**: Was IT manager in large organisation. Decision support systems were part of what we did.*

Methodology related questions

a)

To what extent do you agree or disagree with the stepwise process that was followed to apply the decision support system for the identification of land use alternatives in a specified region, as visually depicted in Figure 37?

i)

Interviewer: If you do not agree with the research methodology what improvements do you propose?

***Interviewee**: NA*

ii)

Interviewer: Considering the stepwise process that was followed to apply the developed DSS, what is your opinion of the potential of the DSS as guidance to establish land use alternatives for the Stellenbosch region?

***Interviewee**: SEEMS SOUND*

b)

Interviewer: To what degree do you agree with the process followed in identifying the various considerations?

Interviewee*: LOGICAL AND SYSTEMATIC*

DSS related questions

a)

Interviewer: Do you believe that the considerations (refer to Figure 42) identified in the DSS comprise a comprehensive set for the assessment of alternative land use options?

Interviewee: *MOSTLY YES*

i)

Interviewer: Are there any additional considerations that you feel must be included in the model?

Interviewee*: THE STRENGTH AND DIRECTION OF WIND MAY ALSO BE A FACTOR IN SOME CROPS.*

AVAILABILITY OF SEASONAL HARVEST LABOUR

b)

Please comment on the following structural aspects of the DSS

i)

Interviewer: How would you rate the easiness of understanding the DSS?

Interviewee*: GOOD*

ii)

Interviewer: How would you rate the easiness of use of the model?

Interviewee*: GOOD*

c)

Interviewer: In your opinion, what are strong points of the proposed DSS to assess possible land use alternatives?

Interviewee*: SIMPLICITY*

d)

Interviewer: In your opinion, what are weak points of the proposed DSS to assess possible land use alternatives?

Interviewee*: IT COULD BE ENHANCED TO COVER MORE ALTERNATIVES*

e)

Interviewer: In your opinion, how can the DSS be improved?

Interviewee: *ANSWERED IN PREVIOUS QUESTION* f)

Interviewer: Please comment on the applicability and usability of this DSS, from your professional viewpoint, to evaluate possible land use alternatives.

Interviewee: GOOD

Further comments

Please provide any further comments should you deem in necessary

Thank you very much for your time and effort in the validation of this research study. It is greatly appreciated.

INTERVIEW QUESTIONNAIRE 3

Interviewer: Jeanne-Mari de Villiers

Interviewee: Interviewee 3

Date: 15 November 2016

Interviewee background contextualisation

a)

Interviewer: What is your occupation and the industry thereof?

***Interviewee**: Wine industry*

b)

Interviewer: What is your current role in the organisation?

***Interviewee**: General manager of independent wine farm in the Stellenbosch area*

c)

Interviewer: Previous exposure to the farming industry? Please elaborate.

***Interviewee**: A wine maker. Has previous exposure and knowledge about citrus farming as well as sheep farmer. General manager where I was part of the decision-making team on farms with mix farming practises- citrus, vineyard, apples.*

d)

Interviewer: Previous exposure to the field of decision support systems? Please elaborate.

***Interviewee**: None*

Methodology related questions

a)

Interviewer: To what extent do you agree or disagree with the stepwise process that was followed to apply the decision support system for the identification of land use alternatives in a specified region, as visually depicted in Figure 37?

i)

Interviewer: If you do not agree with the process what improvements do you propose?

***Interviewee**:* NA

ii)

Interviewer: Considering the stepwise process that was followed to apply the developed DSS, what is your opinion of the potential of the DSS as guidance to establish land use alternatives for the Stellenbosch region?

***Interviewee**:* Can be used. A DSS is just a new concept, one that I am not familiar with.

b)

Interviewer: To what degree do you agree with the process followed in identifying the various considerations?

Interviewee: Good method that was followed to determine the set of considerations.

DSS related questions

a)

Interviewer: Do you believe that the considerations (refer to Figure 42) identified in the DSS comprise a comprehensive set for the assessment of alternative land use options?

Interviewee: Sufficient list of considerations for initial decisions. More considerations which will be more specific to a specific alternative will arise as deeper investigation into that alternative is done, there will thus be more points to look at.

i)

Interviewer: Are there any additional considerations that you feel must be included in the model?

Interviewee: Manpower/hectare can be added as an informative consideration.

b)

Interviewer: Please comment on the following structural aspects of the DSS?

i)

Interviewer: How would you rate the easiness of understanding the DSS?

Interviewee: Easy

ii)

Interviewer: How would you rate the easiness of use of the model?

Interviewee: Easy

c)

Interviewer: In your opinion, what are strong points of the proposed DSS to assess possible land use alternatives?

Interviewee: DSS takes climate, soil, water considerations into account which are critical considerations.

d)

Interviewer: In your opinion, what are weak points of the proposed DSS to assess possible land use alternatives?

Interviewee: *Not specific a weak point, rather a preference. It can be more specific for example citrus to plums transfer, not give different options but rather focus on one specific alternative as a viable option.*

e)

Interviewer: In your opinion, how can the DSS be improved?

Interviewee: Could add the considerations manpower/hectare additional considerations

f)

Interviewer: Please comment on the applicability and usability of this DSS, from your professional viewpoint, to evaluate possible land use alternatives.

Interviewee: Applicable, specifically to assess the development of a complete new area i.e. Piketberg from wheat to table grapes

Further comments

Please provide any further comment should you deem it necessary

Thank you very much for your time and effort in the validation of this research study. It is greatly appreciated.

INTERVIEW QUESTIONNAIRE 4

Interviewer: Jeanne-Mari de Villiers

Interviewee: Interviewee 4

Date: 19 November 2017

Interviewee background contextualisation

a)

Interviewer: What is your occupation and the industry thereof?

Interviewee*: Blueberry industry*

b)

Interviewer: What is your current role in the organisation?

Interviewee*: Manager and analyst of blueberries on a blueberry farm in the Stellenbosch region.*

c)

Interviewer: Previous exposure to the farming industry? Please elaborate.

Interviewee*: I have a BSc Agriculture degree. Began working at my current place of employment after I've completed my studies.*

d)

Interviewer: Previous exposure to the field of decision support systems? Please elaborate.

Interviewee*: None*

Methodology related questions

a)

Interviewer: To what extent do you agree or disagree with the stepwise process that was followed to apply the decision support system for the identification of land use alternatives in a specified region, as visually depicted in Figure 37?

i)

Interviewer: If you do not agree with the process what improvements do you propose?

Interviewee*: NA*

ii)

Interviewer: Considering the stepwise process that was followed to apply the developed DSS, what is your opinion of the potential of the DSS as guidance to establish land use alternatives for the Stellenbosch region?

Interviewee*: There are many variables that needs to be taken into consideration when choosing an agriculture activity. The methodology seems logical and applicable.*

b)

Interviewer: To what degree do you agree with the process followed in identifying the various considerations?

***Interviewee**: Agree with the method that was followed. I think it's good to start with research as a basis and to then get inputs from experts in the agriculture field to establish the considerations.*

DSS related questions

a)

Interviewer: Do you believe that the considerations (refer to Figure 42) identified in the DSS comprise a comprehensive set for the assessment of alternative land use options?

Interviewee: *I think it's a good set of considerations that comprise of various aspects. I think the most important generic considerations are listed. I believe that an in depth analysis of a specific alternative might bring about more considerations that are specific to that farming activity.*

i)

Interviewer: Are there any additional considerations that you feel must be included in the model?

Interviewee: *Not as a generic criteria no*

b)

Interviewer: Please comment on the following structural aspects of the DSS?

i)

Interviewer: How would you rate the easiness of understanding the DSS?

Interviewee: *Easy*

ii)

Interviewer: How would you rate the easiness of use of the model?

Interviewee: *Easy and straightforward*

c)

Interviewer: In your opinion, what are strong points of the proposed DSS to assess possible land use alternatives?

Interviewee: *As mentioned, I think the DSS takes the critical generic considerations into account. Also easy to use and understand which are important factors.*

d)

Interviewer: In your opinion, what are weak points of the proposed DSS to assess possible land use alternatives?

Interviewee: *None that I can think of atm.*

e)

Interviewer: In your opinion, how can the DSS be improved?

Interviewee: *NA*

f)

Interviewer: Please comment on the applicability and usability of this DSS, from your professional viewpoint, to evaluate possible land use alternatives.

Interviewee: *Useful and applicable. It can help a farmer or manager to review different considerations when they are investigating the possibility of a new farming activity.*

Further comments

Please provide any further comment should you deem it necessary

Thank you very much for your time and effort in the validation of this research study. It is greatly appreciated.

APPENDIX G: MODEL VBA CODE

```
Private Sub DetermineViableOptions_Click()

'Empty any current data on sheet
Worksheets("User_Interface").Range(Cells(3, "L"), Cells(50, "T")) = ""

'##################################
' CREATE ARRAY FOR USER INPUT
'##################################

Dim userInput(18) As Double

For i = 1 To 18
   userInput(i) = Worksheets("User_Interface").Cells(3, "C").offset(i, 0).Value
Next i

'##################################
' CREATE MATRIX TO HOLD CRITERIA
'##################################

Dim criteria(9, 22) As Double 'additional row to hold "viable"/"not viable" data
Dim criteriaAdditional(9, 3) As Double 'additional row to hold "viable"/"not viable" data

For i = 1 To 9
   For j = 1 To 22
      criteria(i, j) = Worksheets("Data_Sheet").Cells(4, "B").offset(j, i).Value
   Next j
   criteria(i, 22) = 1 'initialise to viable
Next i

For i = 1 To 9
   For j = 1 To 2
      criteriaAdditional(i, j) = Worksheets("Data_Sheet").Cells(47, "B").offset(j, i).Value
   Next j
   criteriaAdditional(i, 3) = 1 'initialise to viable
Next i

'####################################################
' CHECK CRITICAL CRITERIA FOR ALL LAND-USE OPTIONS
'####################################################

' Check budget, water, land, manpower requirements for all options
For i = 1 To 8
   'budget must be > total capital investment + total input cost per year
   If userInput(1) < (criteria(i, 1) + criteria(i, 3)) * criteria(i, 8) Then
```

```
        criteria(i, 22) = 2 'not viable

    ElseIf userInput(4) < (criteria(i, 6) * criteria(i, 8)) / 1000 Then 'water requirement checked for
remaining viable options
        criteria(i, 22) = 2 'not viable

    ElseIf userInput(6) < criteria(i, 8) Then 'land requirement checked for remaining viable options
        criteria(i, 22) = 2 'not viable


    End If
Next i

' Check average temperature requirements for citrus
For i = 2 To 4
    If criteria(i, 22) = 1 Then 'only check if still a viable option
        If criteria(i, 4) > userInput(2) Then
            criteria(i, 22) = 2 'not viable
        End If
    End If
Next i

' Check rainfall season and cellar requirement for Cabernet Sauvengnon
If criteria(1, 22) = 1 Then 'only check if still a viable option
    If userInput(9) <> criteria(1, 11) Then
        criteria(1, 22) = 2 'not viable

    ElseIf userInput(12) <> criteria(1, 15) Then
        criteria(1, 22) = 2 'not viable
    End If
End If


' Check availability of packing store for citrus and decideous fruit
For i = 2 To 6
    If criteria(i, 22) = 1 Then 'only check if still a viable option
        If userInput(11) <> criteria(i, 14) Then
            criteria(i, 22) = 2 'not viable
        End If
    End If
Next i


'########################################################
' CHECK FAVOURABLE CONDITIONS FOR ALL LAND-USE OPTIONS
'########################################################
Dim unfav(9) As Integer 'counter for unfavourable conditions
```

```
Dim unfavConditions(9, 10) As String 'will hold the unfavourable conditions for each option

' Check human, equipment and stability for all options
For i = 1 To 8

   For j = 1 To 10
      unfavConditions(i, j) = "" 'initiate as blank strings
   Next j

   unfav(i) = 0 'initiate counter
   If criteria(i, 22) = 1 Then 'only check if still a viable options

     If userInput(7) < criteria(i, 9) * criteria(i, 8) Then 'manpower requirement checked for remaining
viable options
       unfav(i) = unfav(i) + 1
      unfavConditions(i, unfav(i)) = Worksheets("User_Interface").Cells(10, "B").Value
     End If



      If userInput(5) < criteria(i, 7) Then 'Human requirement
         unfav(i) = unfav(i) + 1
         unfavConditions(i, unfav(i)) = Worksheets("User_Interface").Cells(8, "B").Value
      End If

      If userInput(8) < criteria(i, 10) Then 'equipment requirement
         unfav(i) = unfav(i) + 1
         unfavConditions(i, unfav(i)) = Worksheets("User_Interface").Cells(11, "B").Value
      End If

      If userInput(10) = 1 And criteria(i, 12) > 4 Then 'production stability requirement given &
option in lower half of stability ranking
         unfav(i) = unfav(i) + 1
         unfavConditions(i, unfav(i)) = Worksheets("User_Interface").Cells(13, "B").Value
      End If

      If userInput(17) = 1 And criteriaAdditional(i, 1) > 4 Then 'sales stability requirement given &
option in lower half of stability ranking
         unfav(i) = unfav(i) + 1
         unfavConditions(i, unfav(i)) = Worksheets("User_Interface").Cells(20, "B").Value
      End If

      If userInput(18) = 1 And criteriaAdditional(i, 2) > 3 Then 'price stability requirement given &
option in lower two-thirds of stability ranking
         unfav(i) = unfav(i) + 1
         unfavConditions(i, unfav(i)) = Worksheets("User_Interface").Cells(21, "B").Value
```

```
      ElseIf userInput(18) = 2 And criteriaAdditional(i, 2) > 5 Then 'price stability requirement given
& option in lower third of stability ranking
         unfav(i) = unfav(i) + 1
         unfavConditions(i, unfav(i)) = Worksheets("User_Interface").Cells(21, "B").Value
      End If
   End If
Next i

' Check soil ph range for all options
For i = 1 To 8
   If criteria(i, 22) = 1 Then 'only check if still a viable option
      If userInput(13) < criteria(i, 16) Or userInput(14) > criteria(i, 17) Then 'soil ph range required
         unfav(i) = unfav(i) + 1
         unfavConditions(i, unfav(i)) = Worksheets("User_Interface").Cells(18, "B").Value
      End If
   End If
Next i

' Check chilling units requirement for deciduous fruit
For i = 5 To 6
   If criteria(i, 22) = 1 Then 'only check if still a viable option
      If userInput(3) < criteria(i, 5) Then
         unfav(i) = unfav(i) + 1
         unfavConditions(i, unfav(i)) = Worksheets("User_Interface").Cells(6, "B").Value
      End If
   End If
Next i

' check rainfall season for citrus, decideous fruit and vegetables
For i = 2 To 8
   If criteria(i, 22) = 1 Then 'only check if still a viable option
      If criteria(i, 11) = 1 And userInput(9) <> 1 Then 'if specific season is required but not realised
         unfav(i) = unfav(i) + 1
         unfavConditions(i, unfav(i)) = Worksheets("User_Interface").Cells(12, "B").Value
      End If
   End If
Next i

' check rainfall requirement for Cabernet Sauvegnon, citrus, vegetables
For i = 1 To 4
   If criteria(i, 22) = 1 Then 'only check if still a viable option
      If userInput(14) < criteria(i, 18) Or userInput(14) > criteria(i, 19) Then
         unfav(i) = unfav(i) + 1
         unfavConditions(i, unfav(i)) = Worksheets("User_Interface").Cells(17, "B").Value
      End If
   End If
Next i
```

```
For i = 7 To 8
   If criteria(i, 22) = 1 Then 'only check if still a viable option
      If userInput(14) < criteria(i, 18) Or userInput(14) > criteria(i, 19) Then
         unfav(i) = unfav(i) + 1
         unfavConditions(i, unfav(i)) = Worksheets("User_Interface").Cells(17, "B").Value
      End If
   End If
Next i

' check temperature requirement for citrus, vegetables
For i = 2 To 4
   If criteria(i, 22) = 1 Then 'only check if still a viable option
      If userInput(15) < criteria(i, 20) Then 'lower limit breached
         unfav(i) = unfav(i) + 1
         unfavConditions(i, unfav(i)) = Worksheets("User_Interface").Cells(18, "B").Value
      End If

      If userInput(16) > criteria(i, 21) Then 'upper limit breached
         unfav(i) = unfav(i) + 1
         unfavConditions(i, unfav(i)) = Worksheets("User_Interface").Cells(19, "B").Value
      End If
   End If
Next i

For i = 7 To 8
   If criteria(i, 22) = 1 Then 'only check if still a viable option
      If userInput(15) < criteria(i, 20) Then 'lower limit breached
         unfav(i) = unfav(i) + 1
         unfavConditions(i, unfav(i)) = Worksheets("User_Interface").Cells(18, "B").Value
      End If

      If userInput(16) > criteria(i, 21) Then 'upper limit breached
         unfav(i) = unfav(i) + 1
         unfavConditions(i, unfav(i)) = Worksheets("User_Interface").Cells(19, "B").Value
      End If
   End If
Next i


'############################################################
' PROVIDE VIABLE OPTIONS TO USER WITH EXTRA INFO
'############################################################
Dim viable As Integer 'stores the number of viable options
Dim offset As Integer

viable = 9 'initiate
```

```
offset = 1

For i = 1 To 8
    If criteria(i, 22) = 2 Then
        viable = viable - 1
    End If
Next i

For i = 1 To 8
    If criteriaAdditional(i, 3) = 2 Then
        viable = viable - 1
    End If
Next i

'fill user options interface
Dim maxUnfav As Integer

maxUnfav = 0 'initiate

For i = 1 To 8
    If unfav(i) > maxUnfav Then
        maxUnfav = unfav(i)
    End If
Next i

For i = 1 To 8
    If criteria(i, 22) = 1 Then
        Worksheets("User_Interface").Cells(3, "K").offset(0, offset) =
Worksheets("Data_Sheet").Cells(3, "B").offset(0, i).Value
        Worksheets("User_Interface").Cells(4, "K").offset(0, offset) =
Worksheets("Data_Sheet").Cells(28, "B").offset(0, i).Value * criteria(i, 8)
        Worksheets("User_Interface").Cells(5, "K").offset(0, offset) = (criteria(i, 1) * criteria(i, 8)) +
Sqr(criteria(i, 8) * 10000) * criteria(i, 2) * 4
        Worksheets("User_Interface").Cells(6, "K").offset(0, offset) = criteria(i, 3) * criteria(i, 8)
        Worksheets("User_Interface").Cells(7, "K").offset(0, offset) = (criteria(i, 1) + criteria(i, 3)) *
criteria(i, 8) + Sqr(criteria(i, 8) * 10000) * criteria(i, 2) * 4
        Worksheets("User_Interface").Cells(8, "K").offset(0, offset) = userInput(1) -
Worksheets("User_Interface").Cells(7, "K").offset(0, offset).Value
        Worksheets("User_Interface").Cells(9, "K").offset(0, offset) = criteria(i, 8)
        Worksheets("User_Interface").Cells(10, "K").offset(0, offset) = userInput(6) - criteria(i, 8)
        Worksheets("User_Interface").Cells(11, "K").offset(0, offset) =
Worksheets("Data_Sheet").Cells(29, "B").offset(0, i).Value
        Worksheets("User_Interface").Cells(12, "K").offset(0, offset) =
Worksheets("Data_Sheet").Cells(30, "B").offset(0, i).Value
        Worksheets("User_Interface").Cells(13, "K").offset(0, offset) =
Worksheets("Data_Sheet").Cells(31, "B").offset(0, i).Value
        For j = 1 To 4
```

```
            Worksheets("User_Interface").Cells(13 + j, "K").offset(0, offset) =
Worksheets("Data_Sheet").Cells(31 + j, "B").offset(0, i).Value
        Next j

        For j = 1 To 4
            Worksheets("User_Interface").Cells(17 + j, "K").offset(0, offset) =
Worksheets("Data_Sheet").Cells(35 + j, "B").offset(0, i).Value
        Next j

        For j = 1 To 5
            Worksheets("User_Interface").Cells(22 + j, "K").offset(0, offset) =
Worksheets("Data_Sheet").Cells(39 + j, "B").offset(0, i).Value
        Next j

        For j = 1 To maxUnfav
            Worksheets("User_Interface").Cells(28 + j, "K").offset(0, offset) = unfavConditions(i, j)
        Next j

          Worksheets("User_Interface").Cells(36, "K").offset(0, offset) =
Worksheets("Data_Sheet").Cells(45, "B").offset(0, i).Value

        offset = offset + 1
    End If
Next i



End Sub

Private Sub ResetOptions_Click()

'Empty any current data on sheet
Worksheets("User_Interface").Range(Cells(3, "L"), Cells(38, "T")) = ""

End Sub
```

APPENDIX H: EXTENSION OF DSS

The formulas of the DSS extension can be seen in Figure 64 and Figure 65. Formulas that are too long are added below the two figures.

Considerations	VIABLE LAND USE ALTERNATIVES
Land-use alternative	=IF(User_Interface!L3="","",CELL("contents",User_Interface!L3))
Hectares Assigned	20
Hectares Remaining	=IF(B3="","",User_Interface!$C$9-Extended_Model!B3)
Annual Gross Income	=IF(B3="","",User_Interface!L4/User_Interface!L9*Extended_Model!B3)
Capital Investment in first year	=IF(B3="","",User_Interface!L5/User_Interface!L9*Extended_Model!B3)
Input Cost per year	=IF(B3="","",User_Interface!L6/User_Interface!L9*Extended_Model!B3)
Total Cost in first year	=IF(B3="","",SUM(B6:B7))
Remaining budget	=IF(B8="","",User_Interface!$C$4-B8)
Manpower required	=IF(B2=Data_Sheet!$C$3,Data_Sheet!$C$13*B3,IF(B2=Data_Sheet!$D$3,Data_
Manpower remaining	=IF(B2<>"",IF(User_Interface!$C$10-Extended_Model!B10>0,User_Interface!$
Water required (ML/year)	=IF(B2=Data_Sheet!$C$3,Data_Sheet!$C$10*B3/1000,IF(B2=Data_Sheet!$D$3,
Water remaining (ML/year)	=IF(B2<>"",IF(User_Interface!$C$7-Extended_Model!B12>0,User_Interface!$C

Figure 64: Formulas of considerations according to assigned hectares

- Where the formula for Manpower required is:

  =IF(B2=Data_Sheet!$C$3,Data_Sheet!$C$13*B3,IF(B2=Data_Sheet!$D$3,Data_Sheet!$D$13*B3,IF(B2=Data_Sheet!$E$3,Data_Sheet!$E$13*B3,IF(B2=Data_Sheet!$F$3,Data_Sheet!$F$13*B3,IF(B2=Data_Sheet!$G$3,Data_Sheet!$G$13*B3,IF(B2=Data_Sheet!$H$3,Data_Sheet!$H$13*B3,IF(B2=Data_Sheet!$I$3,Data_Sheet!$I$13*B3,IF(B2=Data_Sheet!$J$3,Data_Sheet!$J$13*B3,""))))))))

- Manpower remaining is:
  =IF(B2<>"",IF(User_Interface!$C$10-Extended_Model!B10>0,User_Interface!$C$10-Extended_Model!B10,"Manpower inadequate"),"")

- Water required (ML/year) is :
  =IF(B2=Data_Sheet!$C$3,Data_Sheet!$C$10*B3/1000,IF(B2=Data_Sheet!$D$3,Data_Sheet!$D$10*B3/1000,IF(B2=Data_Sheet!$E$3,Data_Sheet!$E$10*B3/1000,IF(B2=Data_Sheet!$F$3,Data_Sheet!$F$10*B3/1000,IF(B2=Data_Sheet!$G$3,Data_Sheet!$G$10*B3/1000,IF(B2=Data_Sheet!$H$3,Data_Sheet!$H$10*B3/1000,IF(B2=Data_Sheet!$I$3,Data_Sheet!$I$10*B3/1000,IF(B2=Data_Sheet!$J$3,Data_Sheet!$J$10*B3/1000,""))))))))

- Water remaining (ML/year) is:
  =IF(B2<>"",IF(User_Interface!$C$7-Extended_Model!B12>0,User_Interface!$C$7-Extended_Model!B12,"Water insufficient"),"")

	TOTALS
Hectares Assigned	=SUM(B3:O3)
Hectares Remaining	=IF(User_Interface!$C$9-Extended_Model!B16<0,CONC
Annual Gross Income	=SUM(B5:L5)
Capital Investment in first year	=SUM(B6:L6)
Input Cost per year	=SUM(B7:L7)
Total Cost in first year	=SUM(B8:L8)
Remaining budget	=IF(User_Interface!$C$4-SUM(Extended_Model!B21)<0
Manpower required	=CEILING(SUM(B10:L10),1)
Manpower remaining	=IF(User_Interface!$C$10-Extended_Model!B23<0,CON
Water required (ML/year)	=SUM(B12:L12)
Water remaining (ML/year)	=IF(User_Interface!$C$7-Extended_Model!B25<0,CON

Figure 65: Formulas of the Totals

- Where the formula for Hectares remaining is: =IF(User_Interface!$C$9-Extended_Model!B16<0,CONCATENATE("Insufficient hectares. Additional ", Extended_Model!B16-User_Interface!$C$9, " hectares required"),User_Interface!$C$9-Extended_Model!B16)

- Remaining budget is: =IF(User_Interface!$C$4-SUM(Extended_Model!B21)<0,CONCATENATE("Insufficient funds. Additional R ", SUM(Extended_Model!B21)-User_Interface!$C$4, "

- Manpower remaining: =IF(User_Interface!$C$10-Extended_Model!B23<0,CONCATENATE("Insufficient manpower: ",CEILING.MATH(Extended_Model!B23-User_Interface!$C$10),"

- Water remaining (ML/year): =IF(User_Interface!$C$7-Extended_Model!B25<0,CONCATENATE("Insufficient water. Additional ", Extended_Model!B25-User_Interface!$C$7, " ML/year

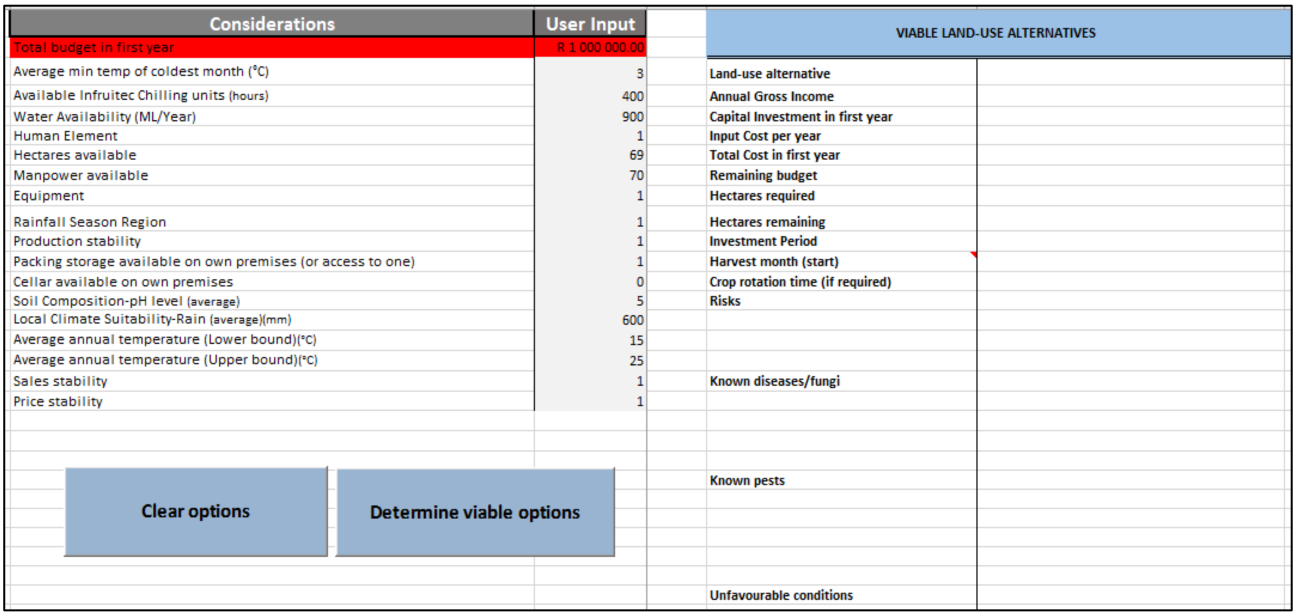
APPENDIX I: INTERNAL VALIDATION SCENARIOS

The importance of performing an internal validation to test the logic of the DSS was highlighted in Section 8.1. Different scenarios, where input values were manipulated to generate various results, were done. Some of the scenarios that the researcher conducted are described in this section. Other scenarios that are not included in this section were conducted following the same logic and reasoning as the ones that are described.The different scenarios are explained with accompanying figures for ease of understanding.

SCENARIO 1

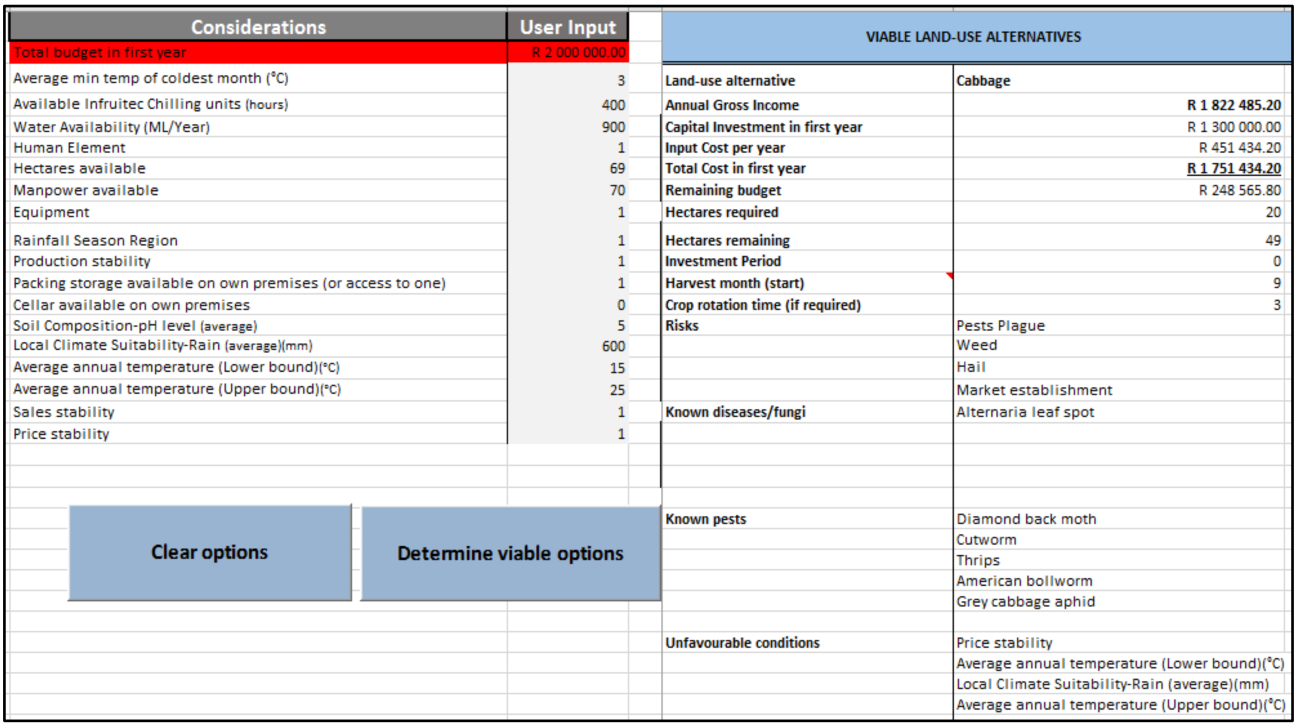
The first scenario evaluate the user input ‘Total budget in first year’, which is a combination of the critical considerations ‘total capital investment’ and ‘input cost per year’. The input value chosen for ‘total budget in first year’ was therefore manipulated. Provided that the researcher knew which of the possible land use alternatives are the cheapest, limiting input values were chosen to 1) generate no viable land use alternatives and 2) to generate only one viable land use alternative. If the DSS works as it should, an input value of R1 million for the consideration ‘Total budget in first year’ shouldn’t provide any viable alternatives whereas using an input value for the same consideration of R2 million should provide one viable land use alternative. The one alternative that should be generated when using an input value of R2 million is cabbage, provided that the rest of the input values fulfil the required critical input consideration values for cabbage. Seeing as the aim of this scenario was to evaluate the user input value ‘Total budget in first year’, the rest of the input values that were chosen for this scenario were of such a nature that they fulfil the required critical considerations.

The output from the DSS when firstly using an input value of a R1 million and secondly a value of R2 million for the consideration ‘Total budget in first year’ are illustrated in Figure 66 and Figure 67 respectively. As can be seen from Figure 66, no viable alternatives were generated when a user input value of R1 million for the consideration ‘Total budget in first year’ was used, but that the DSS generate one viable alternative when a user input value of R2 million for this consideration was used (Figure 67). Both of these outputs were expected for the chosen user inputs, thus validating the functionality and correctness of the DSS and considerations for this input.



Considerations	User Input	VIABLE LAND-USE ALTERNATIVES	
Total budget in first year	R 1 000 000.00		
Average min temp of coldest month (°C)	3	Land-use alternative	
Available Infruitec Chilling units (hours)	400	Annual Gross Income	
Water Availability (ML/Year)	900	Capital Investment in first year	
Human Element	1	Input Cost per year	
Hectares available	69	Total Cost in first year	
Manpower available	70	Remaining budget	
Equipment	1	Hectares required	
Rainfall Season Region	1	Hectares remaining	
Production stability	1	Investment Period	
Packing storage available on own premises (or access to one)	1	Harvest month (start)	
Cellar available on own premises	0	Crop rotation time (if required)	
Soil Composition-pH level (average)	5	Risks	
Local Climate Suitability-Rain (average)(mm)	600		
Average annual temperature (Lower bound)(°C)	15		
Average annual temperature (Upper bound)(°C)	25		
Sales stability	1	Known diseases/fungi	
Price stability	1		
Clear options	Determine viable options	Known pests	
		Unfavourable conditions	

Figure 66: User input value and corresponding DSS output using a value of R1 mil



Considerations	User Input	VIABLE LAND-USE ALTERNATIVES	
Total budget in first year	R 2 000 000.00		
Average min temp of coldest month (°C)	3	Land-use alternative	Cabbage
Available Infruitec Chilling units (hours)	400	Annual Gross Income	R 1 822 485.20
Water Availability (ML/Year)	900	Capital Investment in first year	R 1 300 000.00
Human Element	1	Input Cost per year	R 451 434.20
Hectares available	69	Total Cost in first year	R 1 751 434.20
Manpower available	70	Remaining budget	R 248 565.80
Equipment	1	Hectares required	20
Rainfall Season Region	1	Hectares remaining	49
Production stability	1	Investment Period	0
Packing storage available on own premises (or access to one)	1	Harvest month (start)	9
Cellar available on own premises	0	Crop rotation time (if required)	3
Soil Composition-pH level (average)	5	Risks	Pests Plague
Local Climate Suitability-Rain (average)(mm)	600		Weed
Average annual temperature (Lower bound)(°C)	15		Hail
Average annual temperature (Upper bound)(°C)	25		Market establishment
Sales stability	1	Known diseases/fungi	Alternaria leaf spot
Price stability	1		
Clear options	Determine viable options	Known pests	Diamond back moth
			Cutworm
			Thrips
			American bollworm
			Grey cabbage aphid
		Unfavourable conditions	Price stability
			Average annual temperature (Lower bound)(°C)
			Local Climate Suitability-Rain (average)(mm)
			Average annual temperature (Upper bound)(°C)

Figure 67: User input value and corresponding DSS output using a value of R2 mil

SCENARIO 2

To further test the coding logic of the DSS the input values, as illustrated in Figure 68, were used. Provided these input values, it is expected that mandarins, cabbage, and carrots will be viable land use alternatives. It is expected that the viable options cling peaches, lemons and navel oranges will be excluded because of the input consideration ‘Water Availability’, wine cultivar will be excluded due to a lack of available area, and plums due to a lack of funds. The land use alteranatives lemons and navel oranges are also expected to exceed the consideration 'Total budget in first year'.

The corresponding output values of the provided input values of Figure 68 can be seen in Figure 69. The DSS generated the expected viable alternatives, namely mandarins, cabbage, and carrots, thus further validating the correctness and logic of the DSS.

Considerations	User Input
Total budget in first year	R 9 000 000.00
Average min temp of coldest month (°C)	3
Available Infruitec Chilling units (hours)	600
Water Availability (ML/Year)	150
Human Element	1
Hectares available	50
Manpower available	170
Equipment	1
Rainfall Season Region	1
Production stability	1
Packing storage available on own premises (or access to one)	1
Cellar available on own premises	1
Soil Composition-pH level (average)	5
Local Climate Suitability-Rain (average)(mm)	600
Average annual temperature (Lower bound)(°C)	15
Average annual temperature (Upper bound)(°C)	25
Sales stability	1
Price stability	1

Clear options | Determine viable options

Figure 68: Input values used for scenario 2

VIABLE LAND-USE ALTERNATIVES			
Land-use alternative	**Mandarins**	**Cabbage**	**Carrots**
Annual Gross Income (Based on hectars req	**R 4 024 725.00**	**R 1 822 485.20**	**R 6 755 294.40**
Capital Investment in first year (Based on he	R 2 799 750.00	R 1 300 000.00	R 3 600 000.00
Input Cost per year (Based on hectars requir	R 2 923 680.00	R 451 434.20	R 1 126 370.40
Total Cost in first year (Based on hectars req	**R 5 723 430.00**	**R 1 751 434.20**	**R 4 726 370.40**
Remaining budget	R 3 276 570.00	R 7 248 565.80	R 4 273 629.60
Hectares required	15	20	48
Hectares remaining	35	30	2
Investment Period	2	0	0
Harvest month (start)	4	9	0
Crop rotation time (if required)		3	3
Risks	Markets regulation changes	Pests Plague	Flood
	Change of overseas protocalls and regulations	Weed	Weed
	New diseases, specifically Asian Greening	Hail	Pest/Disease
	Labour related risks	Market establishment	
Known diseases/fungi	Alternaria brown spot	Alternaria leaf spot	Bacterial blight
	Fusarium (secondary fungus)		White mould
	Phytophthora parasitica		
Known pests	Red scale	Diamond back moth	Nematodes
	South African citrus thrips	Cutworm	Cutworms
	Mediterranean fruit flies	Thrips	Aphids
	Budworm	American bollworm	
	Woolly whitefly	Grey cabbage aphid	
Unfavourable conditions	Human Element	Price stability	Human Element
	Equipment	Average annual temperature (Lower bound)(°C)	Equipment
	Production stability	Local Climate Suitability-Rain (average)(mm)	Average annual temperature (Lower bound)(°C)
	Sales stability	Average annual temperature (Upper bound)(°C)	Local Climate Suitability-Rain (average)(mm)
	Price stability		Average annual temperature (Upper bound)(°C)
	Average annual temperature (Lower bound)(°C)		
Harvest length (months)	2.5	1	1

Figure 69: Viable alternatives generated for the input values of Figure 68

SCENARIO 3

The highlighted considerations illustrated in Figure 70 are the considerations that differ from the previous scenario. This scenario was conducted to evaluate the functionality and logic of the DSS regarding the favourable condition considerations. It is expected that changing the ‘Human elemen’ consideration from low skill staff to medium skill staff will result in the elimination of ‘Human element’ as an unfavourable consideration for mandarins and carrots. The unfavourable conditions ‘Production per hectare’ and ‘Sales stability’ for the alternative mandarins are expected to be eliminated when assigning a key of 2 to each of the considerations.

Considerations	User Input
Total budget in first year	9000000
Average min temp of coldest month (°C)	3
Available Infruitec Chilling units (hours)	600
Water Availability (ML/Year)	150
Human Element	2
Hectares available	50
Manpower available	170
Equipment	1
Rainfall Season Region	1
Production stability	2
Packing storage available on own premises (or access to one)	1
Cellar available on own premises	1
Soil Composition-pH level (average)	5
Local Climate Suitability-Rain (average)(mm)	600
Average annual temperature (Lower bound)(°C)	15
Average annual temperature (Upper bound)(°C)	25
Sales stability	2
Price stability	1

Clear options | Determine viable options

Figure 70: Input values for scenario 3

The corresponding outputs generated for the input values of Figure 70 are shown in Figure 71. Figure 71 shows that the expected changes were obtained, thus further validating the functionality and the logic of the developed DSS.

VIABLE LAND-USE ALTERNATIVES			
Land-use alternative	**Mandarins**	**Cabbage**	**Carrots**
Annual Gross Income (Based on hectars req	**R 4 024 725.00**	**R 1 822 485.20**	**R 6 755 294.40**
Capital Investment in first year (Based on he	R 2 799 750.00	R 1 300 000.00	R 3 600 000.00
Input Cost per year (Based on hectars requir	R 2 923 680.00	R 451 434.20	R 1 126 370.40
Total Cost in first year (Based on hectars rec	**R 5 723 430.00**	**R 1 751 434.20**	**R 4 726 370.40**
Remaining budget	R 3 276 570.00	R 7 248 565.80	R 4 273 629.60
Hectares required	15	20	48
Hectares remaining	35	30	2
Investment Period	2	0	0
Harvest month (start)	4	9	0
Crop rotation time (if required)		3	3
Risks	Markets regulation changes	Pests Plague	Flood
	Change of overseas protocalls and regulations	Weed	Weed
	New diseases, specifically Asian Greening	Hail	Pest/Disease
	Labour related risks	Market establishment	
Known diseases/fungi	Alternaria brown spot	Alternaria leaf spot	Bacterial blight
	Fusarium (secondary fungus)		White mould
	Phytophthora parasitica		
Known pests	Red scale	Diamond back moth	Nematodes
	South African citrus thrips	Cutworm	Cutworms
	Mediterranean fruit flies	Thrips	Aphids
	Budworm	American bollworm	
	Woolly whitefly	Grey cabbage aphid	
Unfavourable conditions	Equipment	Price stability	Equipment
	Sales stability	Average annual temperature (Lower bound)(°C)	Average annual temperature (Lower bound)(°C)
	Price stability	Local Climate Suitability-Rain (average)(mm)	Local Climate Suitability-Rain (average)(mm)
	Average annual temperature (Lower bound)(°C)	Average annual temperature (Upper bound)(°C)	Average annual temperature (Upper bound)(°C)
Harvest length (months)	2.5	1	1

Figure 71: Viable alternatives generated for the input values of Figure 70