A simulation model for evaluating the long-term financial impact of different wine grape production systems

by
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DECLARATION

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ABSTRACT

Agricultural production takes place in an uncertain and complex environment, with production the result of the culmination of a variety of factors within a greater system. Consequently, accounting for the influence of variables in the production system is very difficult, making it a daunting task for decision makers to make good decisions. In the wine grape production context, this problem is accentuated due to the capital intensive and perennial nature of investments, also giving rise to a path dependency. As a result it is essential to make strategically sound decisions in order to ensure the long-term profitability and financial feasibility of wine grape production. Decision making tools, like a model, can be of invaluable support for strategic decision making. A model is used to simplify reality, by imitating and simulating the actual system as closely as possible. A simulation model was therefore developed for this thesis to be able to evaluate the long-term financial impact of different wine grape production systems and to support strategic decision making. This model can be adapted to individual farm specific features, scenarios and preferences, in the evaluation and analysis of different investment and wine grape production system decisions. For this study, the nature of agricultural systems as well as qualities required by a simulation model, were investigated. The former is followed by an investigation of the effect of the grapevine and trellis specific qualities on the possibilities of the production system, as well as the implication of capital budgeting and financing considerations on the performance of the wine grape production system. In view of the above, the model was then applied to simulate and evaluate different wine grape production systems as well as a structural transition and expansion of wine grape production, for a simulated farm in the Breedekloof region, South Africa. The model can be used for decision making and scenario planning purposes by wine grape producers and stakeholders in the wine industry.

OPSOMMING

Landbouproduksie vind plaas in ‘n komplekse omgewing met talle onsekerhede, waar produksie die resultaat is van ‘n aantal faktore binne ‘n groter geheel. Die uitdaging is dus om die spesifieke invloed van veranderlikes binne die produksiestelsel waar te neem sodat besluitnemers ingeligte besluite op grond daarvan kan maak. In die verbouing van langtermyn gewasse, spesifiek die van wyndruif verbouing, word hierdie probleem beklemtoon vanweë die kapitaal intensiewe en meerjarige aard van investerings, wat aanleiding gee tot die afhanklikheid van vorige besluite. Ten einde die langtermyn winsgewendheid en lewensvatbaarheid van wyndruif produksie te verseker, is strategiese en ingeligte besluite deurslaggewend. Hulpmiddels in die besluitnemingsproses, soos modelle, kan onskatbare ondersteuning bied in hierdie konteks. Die doel van ‘n model is om ‘n werklike stelsel te weerspieël, maar terselfdertyd word vereenvoudigende aannames gemaak. Vir die doeleindes van hierdie tesis is ‘n simulasie model ontwikkel om die langtermyn finansiële impak van verskillende wyndruif produksiestelsels te weerspieël en strategiese besluitneming te bevorder. Hierdie model kan aangepas word vir die individuele vereistes, voorkeure en kenmerke van individuele plase, ten einde verskillende investeringsbesluite en wyndruifproduksiestelsels te evalueer. Vir die doeleindes van hierdie studie is die aard van die stelsel waarin landbouproduksie plaasvind, asook eienskappe wat benodig word deur ‘n simulasiemodel, om ‘n goeie weerspieëling van die werklikheid te kan gee ondersoek. Daarna is die invloed van die prieëlstelsel oorweging op die wingerdstok, die uitvoerbaarheid van verskillende bewerkingspraktyke, asook die invloed van kapitaal- en finansiëringsoorwegings op die prestasie van die wyndruifproduksiestelsel ondersoek. In die lig van bogenoemde oorwegings is die model gebruik om verskillende wyndruifproduksiestelsels te simuleer en te evalueer, asook om ‘n strukturele oorgang en uitbreiding vir ‘n plaas in die Breedekloofstreek in Suid-Afrika te ondersoek. Wyndruif produsente en belanghebbendes in die wynbedryf kan hierdie model in scenario beplanning en besluitneming gebruik.

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CHAPTER 1: INTRODUCTION

1.1 Path dependence and the changing production environment

Perennial agriculture, as is the case for wine grape production in South Africa and worldwide is faced with the dilemma of path dependence[1]. Path dependence implies a degree of structural rigidity or resistance with swaying from the initial course. This can be due to a variety of factors such as the natural conditions of production (typography, climate), socio-political considerations (abundance of labour, regulations), technological availability (substitute availability, machinery, more labour efficient technologies) or economic considerations.

Once ventured down an elected course, it is costly and takes time to change paths. Due to additional costs that need to be incurred initially to "switch over" and the implementation lags inherent in perennial crop investments as changes have to be implemented over time. To exacerbate the matter, scale economies usually exist on the initial path (due to the general wide adoption), deterring any deviations from the traditional path. Principals therefore rightly feel complacent in the 'tried and trusted' production systems and any deviation thus have an inherent uncertainty, risk and the usual implementation cost which need to be recovered later.

Complacency nevertheless, quickly diminishes when livelihoods are threatened by a change in the economical, socio-political, natural or technological characteristics of the farm business environment. While adverse conditions are needed to spur average managers into action, successful managers constantly reconsider alternatives and see the opportunity inherent in change. When abrupt changes take place is when greater demands are placed on effective and efficient decision making. As a result pro-active decision making is paramount in mitigating negative consequences or in the exploitation of opportunities, and as such decision making supporting tools becomes invaluable in internalising available data to enable informed decision making. Change is inevitable and can be formidable, yet it does not need to imply demise. The resilience of farming systems to adapt over centuries in the face of change is indicative that practices can adjust to meet the challenges of the present.

Consequently any adjustments to production practices should be well motivated, duly investigated and it should be determined if proposed changes are financially feasible and executable. For this endeavour a bio-economic, whole farm multi-period budgeting simulation model has been developed for this thesis to serve as a tool by which to measure and evaluate the financial performance of alternative production systems, subject to specified conditions.

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[1] Also known as inertia or structural rigidity

1.2 Problem statement

1.2.1 General problem statement

Decision-makers within the South African wine industry are not always sure what the likely effect of changes in the agricultural environment, as well as to the wine grape production system will be on the survivability and prosperity of the farm business. As a result making good strategic decisions in the view of the long-term and capital intensive nature of wine grape production systems, in a dynamic and changing agricultural environment is becoming increasingly difficult.

1.2.2 Specific statement

Decision-makers within the South African wine industry lack a tool with which to analyse the long-term financial impact of alternate wine grape production systems. Consequently the lack of analysis leads to a lack of understanding of the full implication of the adoption of different wine grape production systems, on the path dependence of cultivation practices and margins in the long-term given the dynamic agricultural environment. The culminated effect is that the making of strategic decisions is becoming increasingly difficult.

1.3 Subproblems and hypotheses

In the endeavour of finding possible answers to the problem statement, the effect of the central decision which greatly pre-determine the viable and feasible wine grape production systems, the influence of the trellis system, will be delineated in subproblems and hypothesis:

1.3.1 Subproblems

1. Identify and evaluate the possible influence(s) of different trellising systems on grape quality and production.
2. Identify and evaluate the possible influence of different trellising systems on cultivation, management and resource requirements.
3. Identify and evaluate the possible influence of different trellising systems on input/resource substitutability.
4. Identify and evaluate the possible influence of climatic considerations on the choice of a trellising system.
5. The development and construction of a simulation model by which to evaluate the financial performance of different trellising and wine production systems.
6. Apply and implement the simulation model to specific production systems and scenarios in an appropriate wine region.

1.3.2 Hypothesis

1. Different trellising systems (under sufficient management practices) each influence the density of the canopy, microclimate, grape quality, sunlight penetration, fertility and thus grape production in a particular way.
2. Different trellising systems influence the required cultivation and management practices, and resources required (such as capital, water, fertilizer).
3. The chosen trellising system predetermine the extent of substitution possible (between labour and capital – mechanisation).
4. The climate of the production area greatly determines the wine goal and viable systems.
5. Different trellising and wine production systems have alternate implications for long-term profitability.

1.4 Objectives of the study

1.4.1 General objectives

The general objective of the study is to develop a multi-period farm-level budgeting model which can be extensively designated to be specific of an individual wine grape farm. The farm-level model must be able to simulate and evaluate the effect of different wine grape production systems on the financial viability of the farm. Similarly the model must be able to simulate the expansion of the area under wine grape production, in order to illustrate possible economies of size that may arise, as well as the transition of one wine grape production system to another. Through incorporating the above the model is likely to be able to be used for farm specific wine grape production system evaluations, as well as analysis of the best strategy for the individual farm going forward given farm specific features and constraints. The quantification made possible by the former, are likely to lead to better decision making.

1.4.2 Specific objectives

The specific objective of this study is to apply the simulation model to a specific farming situation. Through the use of a farm-level simulation model developed for the purposes of this thesis, the effect of different wine grape production systems and cultivation practices, will be illustrated as quantified on the financial viability of a simulated farm. The model will be applied for a specific region and farming conditions. The effect of different wine grape production systems and cultivation practices is illustrated, in the view of three different scenarios and discussed in detail in Chapter 5 of this thesis. The first scenario comprise the illustration of financial effect of seven different wine grape production systems for an area of 50 hectares cultivated under wine grapes for the simulated farm. Scenario two illustrates the same seven wine grape production systems but expanded for an area of 80 hectares under wine grape cultivation. The third and final strategy illustrates the financial effect of the expansion of wine grape cultivation from 50 to 80 hectares, accompanied with gradual transition towards a more mechanised wine grape production system over a 20 year projection period.

1.5 Rationale for the study

Principals (decision makers) in agriculture (wine grape producers) are faced daily with increasing complexity, change and uncertainty in their agricultural decision making environment. Contributing to this uncertainty is a combination of climatic, technological, market, socio-economic and political factors. Making good strategic business decisions have hence become increasingly difficult.

The combination of the above give rise to new opportunities in agriculture, but also risk due to the variable environment principals find themselves in. Principals are therefore faced with varying consequences to actions. Relative to other forms of agriculture, perennial crop production can arguably be associated with greater risk and consequences and hence a comprehensive account is needed.

This is due to the greater ratio of fixed capital outlays required for production that is needed by perennial crops than other types of agriculture. In addition investment horizons are longer over which the investments need to be recovered, which accentuates the importance of careful planning. Wine grape production is an example of such an environment, involving substantial initial costs that once incurred, need to be recovered over time.

In this thesis an attempt will be made to internalise some of the many variables, which have an impact on the profitability and financial feasibility of wine grape production through the use of a whole farm multi-period budgeting simulation model. Through the simulation model it would be possible to evaluate at farm-level the financial impact of different wine-grape production systems, for specific production areas over an extended 20 year period.

Principals would thus be assisted in evaluating different production systems, identifying inefficiencies, as well as be aided in future production, planning and capital investment decisions. In addition this study and simulation model could aid as a management tool and give an indication as to the drivers of the long-term financial viability of wine grape production. Different stakeholders of the South African wine industry could then possibly benefit from the application of the simulation model to their specific circumstances and goals.

Should the results of the simulation model be verified to be close enough to reality, it could be used to determine which economies of size[2] are needed before certain structural adjustments could be made on farm level. The simulation model can also be valuable in indicating how existing farm businesses can adapt to obtain greater efficiency in production.

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[2] Economies of size is the preferred term for what is commonly called economies of scale, which is the result of cost savings due to specific cost of fixed nature being carried by a bigger size of operations. The latter then for example leads to a lower cost per hectare

1.6 Research method

In this study use is made of a computer based simulation model which is formulated in Microsoft Excel. The simulation model is constructed to allow for a comprehensive evaluation of the long-term financial impact of different wine grape production systems of a designated farm. The simulation model is primarily designed for research purposes of this study, but also to be able to be applied in practice. In view of the latter the model is designed to be flexible enough to allow maximum user designated input, farm specific features and preferences. In the specification of the model used for the evaluations done in Chapter 5, the fixed and movable asset inventory of an actual farm, as well as actual current prices received for produce by producers from a producer cellar in the region is used. The evaluations are done in nominal terms by adjusting current in- and output prices with indexes over the projection period.

In order to establish representative tendencies between different cultivars, production regions, and trellises a large secondary dataset was used. The large secondary dataset was used due to the absence of specific verified data as required by the model, with the potential to include this data should it become available in the future. The STATISTICA software is used to process the secondary dataset, as well as for the reporting of results from the dataset. In addition the dataset is used to establish a cultivar and trellis specific yield over the lifetime of the vineyard for the evaluation region which is incorporated into the simulation model.

The former is done in order to create a more articulate picture of the cultivar- and trellis specific productivity of the grapevine over its life-time for the purposes of evaluations. Evaluations are done in order to establish the long-term profitability of different wine grape production systems. Financial outputs used in the analysis include: margin above specified costs, margin above specified and allocated costs, net farm and enterprise cash flow, net farm income as well as the calculation of internal rate of return (IRR) and net present value (NPV) performance measures.

The systems approach is the basis for the development of the simulation model used in this study as agricultural production is not a function that occurs in isolation. Rather agricultural production is a function of the culmination of a combination of variables, in what can be regarded a greater whole or system. As such the farm business can be seen as a system and through the use of a model the system can be imitated and alternative wine grape production systems be simulated. In order to enable the evaluation of alternative wine grape production systems, the underlying features, response and possible manipulations of the grapevine to a change in production systems as well as investment implications will be discussed. In conclusion alternate wine grape production systems as specified for a specific region and farm description for different scenarios are then simulated and analysed in the penultimate chapter of this study.

1.7 Outline of the study

This thesis consists of six chapters. The first chapter introduces the production environment, problem statement as well as objectives of the study. Chapter 2 aims to give an overview of systems theory, rationale for simulation modelling and systems analysis. The purposeful discussion of systems theory is done in order to set the framework, on which wine grape production system evaluation should be done. Similarly the study of simulations modelling and systems analysis is done to establish a suitable approach by which to evaluate alternate wine grape production systems.

The third chapter is concerned with physical features of the grapevine, how it is influenced by different trellis systems, as well as the implication of alternate financial aspects of the wine grape production system and farm business. The motivation for studying the physical features and trellis specific considerations is to attempt to understand and correctly model the biological aspects of different wine grape production systems into the model. Similarly the motivation for studying the financial aspects of the trellis and wine grape production system decision is to correctly account for the implication of the investment and financing decision on that of the performance of the wine grape production system and farm business.

Chapter 4 develops the structure and explains the working of the simulation model used for evaluating and analysing different wine grape production systems in this thesis. In Chapter 5 the composition of the simulated farm is developed, different wine grape production systems simulated and evaluated and the results reported. A summary, concluding remarks as well as suggestions for further research are provided in Chapter 6.

CHAPTER 2: OVERVIEW OF SYSTEMS AND RATIONALE FOR SIMULATION MODELLING AND SYSTEMS ANALYSIS

2.1 Introduction

Agrarian advancement is entrenched in the development of civilization as early as with the first humans walking the planet. What started out as a basic task of foraging for food, soon had to adapt through centuries, to not only become more sustainable but also more productive. Agriculture as it is known today has become an innovative science, requiring the integration of: science, technology and biology to supply ever increasing demands. At the core of the demands is the demand for food and fibre, which needs to be supplied by modern day agriculture.

With failure not being an option, boundaries are being pushed to unprecedented levels, necessitating the integration of a variety of forces. Advances into “boundaries” have led to great innovations, but have also added greater complexity and risk. Risk brought by greater planting densities, pathogen pressure and weaker resilience of natural eco-systems. While numerous actions have become easier to complete, accounting for the variables involved in production has become far more complex. Contributing to the greater complexity is the fact that there are many more production factors and substitution now possible in production.

In order to fully comprehend the complexity, a study of systems theory and characteristics of agricultural systems are therefore warranted. Similarly complexity warrants the use of more advanced approaches in accounting for the production processes. As highlighted by the title, this thesis involves a simulation model by which the long-term financial impact of different wine grape production systems will be simulated and evaluated. For this endeavour it is important to note that wine grape production is a perennial investment and as such, the choice of a trellising system has a shaping influence upon production system possibilities.

The literature review in this thesis is spread over two chapters, the first one, Chapter 2 initiates with describing agricultural production in a systems context, as being part of a greater system. After this simulation modelling is then put forth as a methodology by which to analyse outcomes of complex systems. In the ensuing Chapter 3 the focus is then moved to physical and financial factors which largely define system outcomes.

Without further elaboration on the structure of the literature review, this thesis will follow the structure as put out above and turn to the study of systems theory and agricultural systems.

2.2 Systems theory and agricultural systems

Present day agriculture has become an innovative science, requiring the integration of economics, technology and biology to remain competitive in a changing decision making environment. As economic and environmental conditions change over time, successful managers constantly rethink their decisions (Shadbolt & Martin, 2005:62).

As a result, decision-makers are constantly tasked with selecting the best choice from known options (Shadbolt & Martin, 2005:62). Decisions are therefore subject to uncertainty, as decisions need to be made with imperfect information, regarding the present and future (Shadbolt & Martin, 2005:62). Accordingly managers need the savvy and tools to cope with the situation and for the farm to remain resilient in the face of uncertainty, production processes must be attuned to adapt to change (Shadbolt & Martin, 2005:62).

The technological revolution has led to such a transformation in the agricultural setting by introducing new production possibilities, by supplementing existing production inputs and making greater substitution possible in production (Csáki, 1985:13). As a result it becomes more complex to account for the different variables in production and their sophisticated interrelationships (Csáki, 1985:13).

Production is therefore the function of the interaction between a variety of components in a specified setting (Shadbolt & Martin, 2005:63). Specifically this function can be considered to be the product of the culmination of a combination of variables,[3] which are interrelated to one another to form a greater "whole" (Bertalanffy, 1971:30).

This "whole" can consequently be studied by means of two approaches; either by studying it as an interrelated entirety, or by studying its parts in isolation (Bertalanffy, 1971: 30). The earlier approach, dubbed "the general systems theory" was first conceived, by the biologist Ludwig von Bertalanffy (Csáki, 1985:13). Bertalanffy (1971:36) described a system as a body of elements in interrelated, connectedness with one another. The latter study in isolation is called the reductionist or traditional approach, due to its extensive usage at a time and is based on analytical procedures (Shadbolt & Martin, 2005:63).

The application of analytical procedures requires the object in question to be broken into different components (Strauss, 2005:7). By studying each component in isolation it is then argued that a better understanding of the 'whole' or original object would be attained. The successful application of analytical procedures however rest on two assumptions: firstly, there should be extremely weak or no interaction between the different variables that comprise the object and secondly relationships between variables that comprise the object should be linear (Strauss, 2005:8).

In practice however, very few systems exist in which these two assumptions hold (Strauss, 2005:8). Subsequently we can argue that the analytical methods' assumption of linear

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[3] **V**ariables of which some are controllable and others uncontrollable

relationships to be generally unrealistic and that it fails to account for interaction: which is a result of studying components in isolation (Bertalanffy, 1971:36; Csáki, 1985:13; Strauss, 2005:8).

On this point of critique Bertalanffy (1971:36) noted that in order to not refrain from reality, no part of a greater system should be considered in isolation. Agriculture consequently is part of a greater system, characterised by increasing complexity, non-linear interrelationships and a dynamic interaction between the external and internal environment. The failure of analytical procedures to suffice in the above, therefore serves as motivation to dismiss the approach as suitable for agriculture (Csáki, 1985:14; Jones & Luyten, 1997:19; Strauss, 2005:8).

To put forth a laudable account therefore requires *metanoia*, "a complete change of mind" towards the handling of agricultural phenomena. Alternative methods and approaches need to be considered which can describe and evaluate agricultural systems and their functioning in order to facilitate better decision making (Strauss, 2005:6).

The systems approach or "general systems theory" proves to be a methodological basis well-suited to the challenge. The advantage of the systems approach is that it deliberately considers the interaction between component parts, recognizes that as new variables are added to the system it can create a new dynamic, a dynamic which in turn is likely to affect overall system performance (Shadbolt & Martin, 2005:63). Within this context endeavours to simulate the mechanism of the system or optimisation thereof are just two of the possible ends (Csáki, 1985:24), of which the value of optimisation are disputable given the uncertain nature of agriculture and the fact that the transpired result, could differ from the envisaged optimum as when the decision was made (Csáki, 1985:24).

The systems approach therefore is sophisticated enough to describe and analyse whole-farm systems to be useful for agricultural production management and can be utilised as an instrument to achieve higher efficiency (Csáki, 1985:24; Shadbolt & Martin, 2005:63). Now that the systems approach has been established as a suitable approach for agricultural phenomena, the theory and analysis of systems shall be considered.

2.2.1 The description and definition of a system

A system can be considered to incorporate a grouping of elements, such that the elements within the demarcated group are strongly interrelated to one another and very poorly or not at all to all elements outside the group (Shadbolt & Martin, 2005:63). The collective result of the interrelationships within the demarcated group is to produce a behaviour, which is characteristic of the system, even if a stimulus is only applied to a part of the system (Shadbolt & Martin, 2005:63).

A system can be defined as an integrated, organised 'whole' that keeps its character under a variety of conditions and whose components behave in a manner that the observer has decided to view as coordinated; to "accomplish one or more goals" (Shadbolt & Martin, 2005:63).

Nine key features of systems become apparent from the above definitions as listed by Shadbolt and Martin (Shadbolt & Martin, 2005:63,64):

- Systems have **boundaries**, which are demarcated by the reasons for defining the system. The delineation of the boundary identifies the system and where it is situated is critical for suitable analysis.
- A system is part of a **hierarchy**; systems have subsystems and are themselves part of a bigger system, as will be elaborated on in the following section.
- The **environment** of the system is that which is external or outside the system's boundaries.
- A system has a **particular purpose,** related to its boundary and definition.
- A system has a **transformation** process where some type of **input** is transformed into some type of **output.**
- A system is in unison and responds to stimuli as a **whole,** the principle of **holism.**
- A system is compiled out of **components**, which are **interrelated** to one another.
- A system has a **communication** and **control** component, which involves the transfer of information, energy, or materials and the feedback/feed forward mechanisms necessary for achieving the systems purpose.
- Lastly a system has **emergent properties,** which only becomes apparent when considering the system as a whole. The phrase "the whole is more than the sum of its parts", is true for systems, implying a holistic approach.

2.2.2 The nature and classification of agricultural systems

2.2.2.1 The nature of the agricultural system

Agricultural systems can be regarded as representing a particular type of economic system, operating in a natural environment. Upon consideration agricultural systems can be reflected on, within the greater scheme of systems in two ways*:* *bottom-up* or *top-down* (Jones & Luyten, 1997:20). Considered bottom-up the agricultural system forms the basis of a superior system such as the food production system or national economy (Csáki, 1985:16). By the same token when considered top-down, the agricultural system can be viewed to be a system compiled out of smaller subsystems (Csáki, 1985:16).

Csáki (1985:16) regards the agricultural system as: "an organizational group of concrete persons, material and technical means, plant and animal organisms segregated within the division of labour for the task of producing agricultural products". The agricultural system therefore consists of subsystems with the fundamental purpose being: the production of agricultural products (Csáki, 1985:16). When delineating systems, care should be taken not to confuse it with the biological or ecological systems.

The biological system's modus operandi is the growth and proliferation but not the satisfaction of human demands for agricultural commodities (Csáki, 1985:16). The biological system therefore becomes integrated into the agricultural system by means of purposeful human intervention (Csáki, 1985:16). Human intervention involves manipulating vital plant, animal and natural processes through the presence of technology to satisfy human purposes (Csáki, 1985:16). The ecological system in part, forms a basis for the biological system and is a subsystem encompassing the dynamic interaction between living organisms and their natural environment, for a particular geographical location (Csáki, 1985:17).

The agricultural system therefore has all the traits which are typically regarded to be characteristic of the biological and ecological systems (Csáki, 1985:17). Consequently this type of economic system exemplifies the "organic unity" of the natural/biological process with that of management (Csáki, 1985:17). The use of biological processes here implies the "real processes" of the economic system, which is the "material, physical production process"; whereas the management of the economic system is an intellectual one, one which without, there will be no "real process" (Csáki, 1985:17).

Agricultural systems can therefore be regarded as a biological-economic system which can be further classified according to their inner arrangement.

2.2.2.2 The classification of the agricultural system

As is inherent of farming operations, agricultural systems are of the most dissimilar and complex groups of systems (Csáki, 1985:18). Analogous to the differences in physical farm characteristics, there exist different methods for the classification of agricultural systems. This classification fulcrums on the interpretation of the term: agricultural system (Csáki, 1985:18).

The Encyclopaedia of Environmental Ethics and Philosophy regards an agricultural system as consisting of "a cultivated environment and group of socially and economically related production units, or farms with a common feature of continuous renewal of their constituent elements" (Haynes, 2009:28). An agricultural system can also be defined as "encompassing the, purposeful intervention by humans into biological processes with the intent of producing food and fibre for human consumption" (Kornegay, 2010:18). Jones (1997:30) defines the term agricultural system as being the production of food and fibre, under the auspices of technology and capital for human consumption. The term agricultural system can thus be seen to imply multiple meanings, making it worthwhile to elaborate on the exact definition or meaning. In view of the former the view of Csáki (1985:18) will first be considered, followed by that of Johnson and Rausser (1977:161).

Csáki (1985:18) argues that agricultural systems should be distinguished upon on the basis of their "inner arrangement or complexity". Upon the basis of the above criteria, it is then possible to divide agricultural systems into four major types of agricultural systems (Csáki, 1985:18):

- Production systems
- Enterprise systems
- Regional or national systems
- International and global systems

2.2.2.2.1 Production systems

The agricultural production system is the most primitive and least complex of the four mentioned systems. Csáki (1985:18) describes the agricultural production system as "the production of concrete agricultural product under specific physical and natural conditions. As such the agricultural production systems include the "plant and animal vital processes, the men who control production, their labour and the technology of production applied by them (Csáki, 1985:19). Consequently the production system is undeniably the closest related to the biological system.

The terminology "agricultural production system" can be used to convey a variety of meanings. It may be used to refer to specific farm, enterprise and even the producing activities undertaken by a specific agricultural enterprise (Csáki, 1985:19). Subsequently agricultural production systems are purposefully classified.

Production systems are classified firstly upon the basis of the nature of the respective production activity (for example wine grape production); according to the natural conditions of production (e.g. temperate or tropical zone); or by the nature of the technology applied for example irrigated or dry-land farming (Csáki, 1985:19).

2.2.2.2.2 Enterprise systems

The second major group of agricultural systems are called enterprise systems. Enterprise systems are fundamentally a production system with a management component, made to be an enterprise by means of autonomy in legal and economic affairs. Management here primarily refers to the mental effort involved in decision-making, planning, organization and control of the farming enterprise and to a lesser extent the actual physical exertion in the production process (Department of Agriculture, 2005:16).

The enterprise system represents a multifaceted economic system, which includes different production, management, legal, technological, social and political systems (Strauss, 2005:10). These systems are primarily concerned, but not solely bound to the physical production of agricultural products within a specific economic and legal context. The system therefore also encompasses products and services related to agriculture and can include a variety of activities, as long as it does not abolish the agricultural nature of the system. An example of auxiliary activities frequently found on farms can include guesthouses or conference venues.

2.2.2.2.3 Regional or national systems

Regional systems are the systems in-between the enterprise and national systems (Strauss, 2005:10). Regional systems may account for a specific region, provincial area or state within a country. The national system is the collective of all the regional systems within the borders of a country (Strauss, 2005:10).

These systems are also referred to as agricultural macro systems and are representative of larger geographical units than enterprise systems. National systems are where the macro-problems of agriculture appear in their full complexity and can aid as a tool, when making decisions for policy formulation (Csáki, 1985:20).

2.2.2.2.4 International and global systems

International systems are compiled from the national systems of specific countries, within a specific geographical area or trade block of the word. The basis of selection or inclusion may include analogous commercial or agrarian policy or trade agreements, while the global agricultural system is compiled out of all the different international systems of the world.

In view of Csáki's delineation it should thus be apparent that simpler systems are elements of more sophisticated ones. According to Johnson and Rausser, the classification of systems can also be done on the basis of the type of relations, components, and purposes of the system (Johnson & Rausser, 1977:161; Strauss, 2005:11). Accordingly systems can also be classified as follows:

2.2.2.2.5 Open and closed systems

Systems that are influenced by changes in the environment of the system are called open systems (Johnson & Rausser, 1977:165). A farming enterprise is an example of such a system. In closed systems, on the contrary, changes in a system's environment do not influence the interrelationships between variables (Johnson & Rausser, 1977:165).

2.2.2.2.6 Static and dynamic systems

Systems which are not subject to a time component influencing variables or the interrelationships are known as static systems. Examples of static systems are rarely observed in practice, however many neo-classical economic theories, which form the basis of modern economic theory, are founded on assumptions of static systems (Johnson & Rausser, 1977:164).

Dynamic systems are inter temporal systems with variables and interrelationships within the system subject to a time component (Johnson & Rausser, 1977:164). The renowned Latin phrase *ceteris paribus* as used in economics and other fields of science, can therefore not be assumed in dynamic systems as there are "feedback" effects. These feedback effects imply an information flow, between bordering periods, ultimately characterizing the systems as sequential (Johnson & Rausser, 1977:164).

2.2.2.2.7 Stochastic and deterministic systems

A stochastic system consists of a majority of random elements within the system and therefore the majority of the associated relationships between the variables are also random. In turn, deterministic systems are characterised by definite relationships between variables (often mathematical functions) and therefore definite outcomes (Johnson & Rausser, 1977:164).

Systems theory, the nature and classification of agricultural systems has been discussed; proceeding farming systems, a special type of enterprise system will be explored.

2.2.3 The farming system

2.2.3.1 The definition of farming systems

For the purpose of this thesis farming systems will be defined as: the arrangement of production means, land, labour, capital, crops and livestock with the primary purpose of producing plant and or animal products for human consumption (Csáki, 1985:16; Woodward, Romera, Beskow & Lovat, 2008:236).

From a sustainability perspective farming systems can be regarded as the production of products and generation of a profit in such a way that it, not only ensures business viability at the present, but conducts it in such a way without compromising the sustainability of resources or the ability of future generations to meet their own needs (Shadbolt & Martin, 2005:63,69).

Farming systems are fundamentally businesses, producing and trading in a complex environment that requires intense skill and management of a variety of variables (Woodward *et al.,* 2008:236). A key feature of farming systems' environment is that many of the important outcomes are influenced by external factors (Woodward *et al.,* 2008:236).

2.2.3.2 The delineation of farming systems

From the onset farming systems can be delineated according to features universal in all farming systems. The "elements of a farming system include inputs and outputs, a boundary, an external environment and a process for transforming inputs into outputs" (Shadbolt & Martin, 2005:67).

Production is an output from the farming system and is a consequence of combining various inputs with the states of nature. A distinctive trait that distinguishes farm systems from most other systems is the dynamic inter-dependency on the external environment. Subsequently external factors acting upon the farm system should be considered.

2.2.3.3 The external factors acting upon and features of a farm system

External factors acting upon a farm are greatly predetermined or influenced by the geographical locality, natural resource endowments and features of the past and future farm environment (Woodward *et al.,* 2008:236). These external factors include a whole range of physical, biological, economic and social processes, operating within the farm and its environment which are not under direct (immediate) managerial control and influence farming system outcomes (Menz & Knipscheer, 1981:95; Woodward *et al.*, 2008:237).

The former underline a fundamental feature of farming systems, namely that farming is inherently uncertain and risky (Moss, 2010:vii; Schultz, 1939:576; Woodward *et al.*, 2008:245). Schultz (1939:578) emphasised the importance of accounting for uncertainty, when arguing that farming is even more about the management of uncertainty than that of complexity.

Farming system outcomes can therefore be regarded as the culmination of controllable and uncontrollable factors (Woodward *et al.,* 2008:236). Principals (decision makers) can thus at best, manage the controllable variables, with the final outcome dictated to a degree by the uncontrollable variables. The significance of accounting for uncertainty and risk and the accompanying effect on farming systems' outcomes should thus be apparent. Therefore the discussion will consider the uncertainty and risk inherent in agriculture in Section 2.3.3.

The discussion has motivated the need for a systems approach and described theory, features, the nature, classification and delineation of agricultural and farming systems. Perplexing traits inherent to agriculture have been exposed and features required by an account to surmount the preceding recommended.

In an attempt to account for the complexity and uncertainty inherent in agriculture, simulation modelling, which came to the fore out of the system approach, will be applied. The theory behind simulation modelling, uncertainty and risk, as well as some of the characteristics of the more notable models developed for the use of analysing of agricultural systems will be discussed in the next section.

2.3 Simulation modelling and systems analysis

2.3.1 An overview for simulation modelling

Modelling has been a prominent constituent of systems analysis, which is the purposeful study of systems, since the initial development of the system concept (Johnson & Rausser, 1977: 161). By definition a model is an attempt to form an abstraction from reality, capturing the core processes and in turn simplifying reality (Lien, 2003:412; Shadbolt & Martin, 2005:73). Models therefore portray reality in a simplified, manageable form for a particular purpose (Shadbolt & Martin, 2005:74).

Simulation models aid the analysis and evaluation of complex systems (Johnson & Rausser, 1977:162). To be able to construct and develop a theoretically sound simulation model requires not only understanding of the nature of the system, but also the purpose and objective of the analysis. Thus the preceding two sections elaborated on the nature of agricultural systems and physical characteristics to consider of wine grape production systems.

Similarly the purpose of this thesis is to evaluate the financial performance of different trellising and wine grape production systems. In carrying out of this objective a simulation model has been developed. Hence the following section will start by laying the theoretical foundation for simulation modelling, elaborating on the integration of uncertainty into the model and describe features of robust farm simulation models. The former will be rounded off by a synopsis of other agricultural simulation models in dissolution of the section.

2.3.2 The theoretical foundation for simulation modelling

2.3.2.1 Positive and normative philosophical approaches

In order to successfully analyse a particular system, familiarisation of the underlying metaphysical thoughts are important. These thoughts can be divided into two principal view points, namely that of a normative and that of a positive approach.

According to Richardson (2005: 2) the normative approach is concerned with: “what ought to be”, with the accompanying optimisation of the system to meet a particular objective. The normative approach is central to analytical mathematical models with the application in agriculture, usually to calculate an optimum usually by linear programming at a specific point in time (Csáki, 1985:22; Richardson, 2005: 22).

The positive approach in contrast, can be described to be concerned with what is “likely to be” (Richardson, 2005:2). As regularly applied in farm-level simulation this approach generally involves the use of historical data to establish statistical relationships (Strauss, 2005:17). Statistical relationships as well as accounting identities are then used to simulate likely future outcomes, based on historically recorded interrelationships as well as assumptions about these interrelationships in the future (Strauss, 2005:18). The inclusion of assumptions, in contrast with strict analytical methods, thus makes it possible to adjust the system to a future point in time (and one with different conditions) to reflect reality as realistically as possible.

Selection and application of a specific philosophical approach requires comprehension of the nature of the system and problems in order to create the right type of model to be used in systems analysis and associated deductions. Therefore the following subsection will describe hard systems which are concomitant to a normative approach and soft systems which are concomitant to a positive approach.

2.3.2.2 Hard- and soft systems

The hard systems approach is most suitable for problems where a quantifiable, well-structured, well-defined and agreed on objective exists. Hard systems approaches typically start with the development of a model or system and make extensive use of the developer’s expert knowledge (Shadbolt & Martin, 2005:66). The approach is typically used to find an optimal solution as with systems engineering (Shadbolt & Martin, 2005:65).

Agricultural problems are however not as clear cut, with complexity arising from multiple-stakeholder views, multiple criteria and the dynamic nature of farming system problems, deeming the hard systems approach inappropriate for finding an optimal solution for a farm system (Woodward *et al.*, 2008:235). Contrary to the hard systems approach, the soft systems approach is not focused at finding an optimal solution but rather improving outcomes (Shadbolt & Martin, 2005:66).

The soft systems analysis is specifically suited to problems with dynamic circumstances, interrelated problems and problems about which people have alternative views (Shadbolt & Martin, 2005:66). Modelling or system development is typically secondary in the soft approach and requires active participation by stakeholders and the expert to facilitate the process (Shadbolt & Martin, 2005:66).

The watershed between the approaches is accentuated when applying them to agricultural problems. The soft approach allows greater flexibility in expressing problems and the actual process itself is invaluable in gaining a better understanding of the problem, to the extent that it can be more valuable than the actual solution itself (Shadbolt & Martin, 2005:66).

The current section should highlight the importance of taking the nature of the system, the objectives and the purpose of the analysis into account, when developing a model by which to analyse an agricultural system. The subsequent section elaborates on the purpose and use of simulation models.

2.3.2.3 The purpose and use of simulation models

Once decided on a particular development approach, the model which is a simplification of reality is developed. The model should represent aspects relevant to the model-use and the level of detail be such, so over complication and limited usefulness of the model is avoided (Dent, Blackie & Harrison, 1979:2). This "formed abstraction" is created for a particular purpose, based on specific assumptions and requires the gathering of specific data. Examples of a particular purpose could entail the analysing of the financial viability of a current situation, the evaluation of different investments or the development of a decision support model as to guide future managerial decisions.

Data alone by definition is however troublesome for decision making, as it does not concern the future, but rather the present and the past (Shadbolt & Martin, 2005:73). However decisions made today can only render an impact on the future. This is the focal point where well-constructed simulation models fill a void and their value and utility are emphasised. Upon introduction of data into the simulation model, the model performs the function of transforming the data. This data is then used and manipulated in the model, to render specific information and/or achieve specific objectives of the analysis (Shadbolt & Martin, 2005:73). The transformation process in the model thus transforms the data into meaningful information which in turn aids decision making.

This information, which is based on the past, helps decision-makers to render a better understanding of the future (Shadbolt & Martin, 2005:75). However, before making inferences about the real world, it is vital to ensure all assumptions are clearly articulated and make economic and rational sense (Shadbolt & Martin, 2005:73). Modelling therefore aids in arriving at a greater understanding of the subject in question and may be done for several purposes as noted by Shadbolt and Martin (2005:73). These purposes include:

- To communicate meaning and complexity
- To search for new insights on systems behaviour
- To convey mathematical relationships between components
- To evaluate alternative strategies

In soft systems methodology (SSM) models are utilised to debate and learn about alternatives in order to find improvement. SSM have been particularly useful in describing and analysing existing farm businesses and to plan for changes to it (Shadbolt & Martin, 2005:73). The nature of agriculture however sets a particular challenge when attempting to build a simulation model with which to simulate the actual "real world" process. This is due to the physical production process being greatly dependent on the state of the external environment. This state of the external environment in turn is not under managerial influence and hence cannot be represented by a deterministic equivalent. Hence, this state can be considered to be uncertain and stochastic.

2.3.3 Integrating uncertainty and risk into the simulation model

2.3.3.1 Decisions, uncertainty and risk

Principals are required to make decisions daily, upon the representation and interpretation of the data on their current situation. Decisions that have associated consequences which materialise in the future, about which the manager has no absolute certainty, are required to be made in the present (Dent *et al.,* 1979:77). Principals are therefore universally plagued with bounded rationality[4], confronted with uncertainty and bound to experience risk as a result of decisions (Hardaker, Huirne, Anderson & Lien*,* 2004:4).

According to Hardaker *et al.* (2004:5), uncertainty can be defined as imperfect knowledge about the future. The delineation of risk takes the delineation of uncertainty further, due to an existence of a prevailing preference between uncertain outcomes (Hardaker *et al.*, 2004:5). Formally, risk can be described as "uncertain consequences", over which a preference between outcomes and an aversion to particular outcomes exist, "particularly exposure to unfavourable ones" (Hardaker *et al.*, 2004:5).

Principals want their decisions to be good ones; hence a decision which could end up being detrimental to future prospects is undesirable and risky. While managers can endeavour to account for simple decisions, accounting for external variables which influence system outcome is not as easy. Therefore, the difficulty faced by managers to make an intuitive overview of all possible outcomes, can be alleviated by utilising a stochastic simulation model (Hardaker *et al.*, 2004:158).

A stochastic simulation model can be used to make a systematic assessment of what might happen and account for non-linearity, uncertainty and interdependency not possible with a straightforward deterministic model (Hardaker *et al.*, 2004:158). In addition to stochastic simulation often being the only way to account for complexity, it can greatly aid decision makers in exercising well informed choices (Hardaker *et al.*, 2004:159). In the following sections different approaches to account for stochastic dependency will be considered.

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[4] Bounded rationality is a term used to describe intellectual short comings, as a species humans are not all knowing about the future and not God. Our understanding of the world and future are thus limited.

2.3.3.2 Production in the face of adversity

As has been elaborated on earlier, agriculture is inherently dependent and/or influenced by the external environment. The external environment in turn is dynamic and changing which greatly determines actual physical farm outcomes. Intrinsically the outcomes of production can thus be considered uncertain and risky, due to the partial dependence on uncontrollable factors which shall be called stochastic elements (Hardaker *et al.*, 2004:5).

Principals take cognisance of uncertain outcomes by adjusting their own on-farm processes (Hardaker *et al.,* 2004:4). However despite advancements made in the agricultural field, the one thing that remains certain until today is: uncertainty and risk will always be present in agricultural production (Dent *et al.,* 1979: 77; Hardaker *et al.*, 2004: 1).

Despite the salient risky and uncertain nature of agriculture which is tantamount with a dynamic and changing environment, agriculture should not be dreaded but rather be seen as an opportunity. There is a phrase "it is often said that, in business, profit is the reward for bearing risk: no risk means no gain" (Hardaker *et al.,* 2004:4). "The task is rather to manage risk effectively, within the capacity of the individual, business or group to withstand adverse outcomes" (Hardaker *et al.,* 2004:4).

By accounting for the so called stochastic dependency it is then possible to not only better account for the physical "real world" system, but also better guide managerial decisions (Lien, 2003:403). One such approach to attempt to better account for the reality and facilitate decision making is through stochastic simulation (Lien, 2003:411). Stochastic simulation typically involves the combination of a deterministic and stochastic component with the intent to reflect important parts of uncertainty of the "real world" system (Lien, 2003:403).

Different approaches exist to account for stochastic dependency of which a few will subsequently be considered.

2.3.3.3 Approaches to account for stochastic dependency

When attempting to simulate the "real-world" it is usually incorrect to assume that all sources of uncertainty are independent of one another (Hardaker *et al.*, 2004:168). In practice accounting for dependency is often critical to avoid misleading results (Hardaker *et al.*, 2004:168). Accordingly four alternative approaches by which to account for stochastic dependency can be listed (Richardson, Klose & Gray, 2000:300); (Hardaker *et al.*, 2004:169):

- The hierarchy of variables approach
- The use of historical data and a lookup table (can be combined with subjective judgements)
- The specification of a correlation matrix
- The use of copulas (which are an extension on the use of correlations)

The following section will briefly deliberate on each of the four approaches.

2.3.3.3.1 The hierarchy of variables approach

Under this approach two distinctive options can be followed: one by using a regression approach or one by using a 'synthetic engineering' approach (Hardaker *et al.,* 2004:83).

2.3.3.3.1.1 The regression approach

An advantage presented by the hierarchy of variables approach is that, there is no necessity to identify the direct relationship between stochastically dependent variables (Hardaker *et al.*, 2004:169). Instead it is only necessary to identify one or more indicator/surrogate variable/s which are representative of the main underlying causes of the stochastic dependency (Hardaker *et al.*, 2004:169).

Variables of immediate interest can then be related to indicator variables to model the dependency (Hardaker *et al.*, 2004:169). If this deems troublesome an alternative is to relate the prices of variables to index with error terms for unexpected variability (Hardaker *et al.,* 2004:84). Moreover these qualities make the hierarchy of variables approach useful when there is sparse or insufficient historical data available (Hardaker *et al.,* 2004:83).

2.3.3.3.1.2 The synthetic engineering approach

The synthetic engineering approach involves the construction of a simulation model concerned with the representation of the underlying processes that determine the uncertainty in the various relevant variables, as well as the "stochastisicity" in those processes (Hardaker *et al.,* 2004:86). Stochastic simulation models built according to this approach in agriculture are usually concerned with representing agro-biological processes in order to generate production estimates (Hardaker *et al.,* 2004:86).

Unfortunately a common limitation of the synthetic engineering approach is a failure to account for the variability of the uncontrolled factors that negatively impact production (Hardaker *et al.,* 2004:86). Consequently accounts by stochastic simulation models tend to overestimate actual productivity, as well as usually being unsuccessful in representing the actual dispersion in outcomes experienced on farms (Hardaker *et al.,* 2004:86). Therefore when using a synthetic engineering approach it is important to validate such models to see if they are realistic, before attempting to use them to aid with decision analysis (Hardaker *et al.,* 2004:86).

2.3.3.3.2 The use of historical data and a lookup table

The historical data and lookup table method is conditional on two aspects: the availability of historical data over a number of years and that data should be able to be assumed representative of the future (Hardaker *et al.*, 2004:169). When both these conditions are met a state of nature matrix can be specified to represent different states/scenarios, which in union with associated probabilities can be used in the analyses (Hardaker *et al.*, 2004:169).

Failure of the historical data to be able to be assumed representative of the future is however not terminal. Instead it is then possible to incorporate subjective judgements through tweaking the standard deviations and marginal means and using the state of nature matrix purely to reflect the stochastic dependency (Hardaker *et al.*, 2004:169).

When the former phenomenon occur, the historical data set are used to infer the stochastic dependence and a synthesized data series is created (Hardaker *et al.*, 2004:81). The former is done by making use of subjective distributions, obtaining estimates of the mean and standard deviation of each activity, correcting observations for inflation and trend and assigning different probabilities to past years, if a basis for it exists (Hardaker *et al.*, 2004:81).

Ensuing the means and standard deviations of the activity of interest are calculated, using the inflation- and trend-corrected data set as well as the assessed probabilities. The synthetic data set is created thereafter with the original mean and standard deviation, but with the pattern of joint stochasticity represented through the assessed probabilities and subjective judgements (Hardaker *et al.*, 2004:83).

2.3.3.3.3 The specification of a correlation matrix

Central to the use of the specification of the correlation matrix method are a few considerations. From the outset it is important to recognise correlation, as the most important statistical measure of stochastic dependency between variables (Hardaker *et al.*, 2004:170). Correlation matrices represent this characteristic and rely solely on first order co-moments, namely covariance to depict stochastic association between variables (Hardaker *et al.*, 2004:170).

Given the intricate nature of agriculture, representing stochastic dependency between variables is likely to be arduous and not possible by correlation alone (Hardaker *et al.*, 2004:171). Last mentioned characteristic incites criticism as to the applicability to agriculture, as higher order co-movements illustrate additional aspects of stochastic dependency and therefore should also be used (Hardaker *et al.*, 2004:171).

However, a simulation model aims to simplify reality and due to the difficulty of measuring and accounting for higher co-movements, stochastic dependency is restricted to first order correlation in stochastic simulation work (Smit & Lombard, 1996:132); (Hardaker *et al.*, 2004:170); (Woodward *et al.*, 2008:194). In special circumstances it is however possible to make use of the multi-variate normal, transformed variables to fully account for stochastic dependency by correlation alone (Hardaker *et al.*, 2004:170).

2.3.3.3.3.1 Linear and rank order correlation

Linear correlation is the most common type of correlation and comprises the measurement of the linear association between two stochastic variables (Hardaker *et al.*, 2004:171). Despite the extensive occurrence of linear correlation it is mathematically “impossible” to use linear correlation as is, to create random deviates that can be used in stochastic simulation (Hardaker *et al.*, 2004:171).

One approach by which to curb the situation is by using rank order correlation. Rank order correlation involves the specification of the "relationship between two marginal (input) distributions in terms of the rank (position) of the values of each variable in their respective distributions" (Hardaker *et al.*, 2004:171). Rank order correlation has the advantage that the correlation for any two variables can be specified, regardless of the type of their marginal distribution (Hardaker *et al.*, 2004:171). The disadvantage however is that some information on the stochastic association is lost in the process (Hardaker *et al.*, 2004:171). Representation of stochastic association is the same between rank and linear correlation; with values ranging between -1 which depicts perfectly negative- and +1 which depicts perfectly positive correlation (Hardaker *et al.*, 2004:172).

This section illustrated the shortcomings of the correlation matrix and rank correlation method. Subsequently copulas, a more extensive approach to account for stochastic dependency will be considered.

2.3.3.3.4 The use of copulas

Due to correlation sufficing as a limited measure of stochastic dependency, copulas developed as an alternative method to capture co-dependency (Hardaker *et al.*, 2004:172). Fundamentally as suggested by the name, copulas unite two or more marginal distributions (Hardaker *et al.*, 2004:172). Formally expressed, a copula can be regarded as a "multi-variate emperical (MVE) distribution function defined on a unit-cube with uniformly distributed marginals" (Hardaker *et al.*, 2004:172).

The use of copulas makes it possible to take into account the full stochastic dependency (or at least theoretically) between any forms of marginal distributions (Hardaker *et al.*, 2004:172). Intrinsically copulas do not differ in as much the degree of association implied, but rather "which parts of the distributions the association is the strongest" (Hardaker *et al.*, 2004:172).

The methodology to use copulas is twofold: first it involves parameter estimation for a MVE probability distribution and thereafter simulation of the MVE probability distribution (Richardson *et al.,* 2000:307). The steps involved in parameter estimation will be briefly outlined in the ensuing paragraph and that of simulation with the MVE probability distribution thereafter.

The initial step in estimating parameters for a MVE distribution is to separate random and non-random components for each of the stochastic variables (Richardson *et al.,* 2000:301). This is facilitated through calculating the residual of each stochastic variable, through removing the deterministic component. Subsequent steps followed to complete the parameter estimation include: converting residuals to relative deviates; sorting deviates and creating pseudo minimum and maximums; assigning probabilities to sorted deviates; calculating the intra-temporal correlation matrix and lastly the calculation of inter-temporal correlation coefficients (Richardson *et al.,* 2000:306).[5]

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[5] For a comprehensive reflection on the use of copulas refer to Richardson *et al.,* 2000.

Similarly the steps followed for the simulation involve: generating independent standard normal deviates (ISND); calculating correlated (intra-temporally) standard normal deviates (CSNDs); capturing the inter-temporal correlation of the random variables, through calculating adjusted correlated standard normal deviates (ACSNDs); transforming ACSNDs to correlated uniform deviates (CUD); simulating correlated fractional deviates (CFD) through interpolation of CUD and applying CFDs to their respective projected means and make any adjustments for heteroscedasticity (Richardson *et al.,* 2000:308).

2.3.4 Features of robust farm simulation models

As a result of the preceding, any attempt to account for farming systems outcomes needs to account for the interaction between a body of controllable elements, deemed the deterministic component and a body of uncontrollable elements, called the stochastic component (Woodward *et al.,* 2008:245). Any attempt to simulate a farm-level model without acknowledging a stochastic component (and hence risk) would therefore assume a false certainty about the future (Schultz, 1939:576; Woodward *et al.,* 2008:245).

Attempts to develop models for agricultural systems were motivated from a twofold need. Firstly, to be able to account for the uncertainty and secondly to be able to account for the complexity inherent in agriculture (Csáki, 1985:14; Shadbolt & Martin, 2005:73; Strauss, 2005:8). Two methods to account for the above interaction are through mechanistic research models or virtual world simulators. The core difference between the methods stems from a difference in the emphasis of each method. Mechanistic research models are fixated on mimicking the actual system process as with optimisation techniques, whereas virtual world simulators do not (Woodward *et al.,* 2008:242).

Woodword *et al.* (2008:235), in turn found that using simulation models to discover optimal farming systems are usually inappropriate. Their critique stems out of the complexity from multiple stake-holder views, multiple-criteria and the dynamic nature of farming systems problems. Whilst Shadbolt and Martin's critique stems from the fact that agricultural problems are not well enough defined, have multiple stake-holder views or are not quantifiable, which precludes the endeavour of finding an optimum meaningful (Shadbolt & Martin, 2005:65).

Non-optimising simulation modelling (virtual world simulators) in contrast does not aim to exactly mimic a system, but rather system function and performance (Woodward *et al.*, 2008:242). By doing so it simplifies reality, without becoming unrealistic and with no inherent objective it forms an ideal platform for testing what-if scenarios (Smit & Lombard, 1996:132; Woodward *et al.*, 2008: 243). Virtual world simulators therefore by design, have the advantage that they are constructed more cost efficiently, and can be used to simulate alternative management strategies (Woodward *et al.,* 2008:242).

In closing, a simulation model eases the process of accounting for the system and its outcomes with its interrelated variables and inter-temporal effects. Variables in the simulated system which are directly under a manager's influence can be described by mathematical functions and are called deterministic variables. Similarly variables external to the controlled part of the system, which influences system outcome, can be accounted for by accounting for the stochastic dependency. In the following subsection a synopsis of other agricultural simulation models will be given.

2.3.5 A synopsis of other agricultural simulation models

2.3.5.1 Agricultural risk management simulator microcomputer program

Purpose

In 1988 the Agricultural Risk Management Simulator Microcomputer Program (ARMS) was developed by King, Black, Benson & Pavkov (1988:165). ARMS was created for the purpose of being a tool for users to evaluate different strategies for managing yield and price risk in crop farming operations.

Construction

ARMS requires throughout that data and options be entered or selected by the user, by means of menus. ARMS was compiled out of three distinctive parts, firstly the Farm and Enterprise Information Section, secondly the Yield and Price Probability section and thirdly the Strategy Evaluation section (King *et al.,* 1988:166).

In the "farm and enterprise information section", the general structure of the farm operation being analysed is defined by the user and specific enterprises and costs identified. Section two the "yield and price probability section", requires users to enter data to describe the joint probability distribution of yields and price. Users have an additional option to have crop yield and crop price set as non-random or random respectively (King *et al.*, 1988:166).

The third and final "strategy evaluation section" requires the user to select values for parameters that define three management strategies. These are "crop mix", "multiple peril crop insurance coverage" and "forward contracting" decisions (King *et al.*, 1988:166).

Operation

The ARMS program executes the above by means of its probability sub model[6], generating sample states of nature and using the latter's outcome in a deterministic simulation sub model, to budget the performance of any scenario (management strategy) through probabilistic budgeting (King *et al.*, 1988:165). Proceeding the deterministic sub model then calculates the annual before-tax net cash flow for farm operations for the given scenario (King *et al.*, 1988:166). The user is then able to alter the detail of each parameter to arrive at multiple or the desired strategy.

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[6] Central to the probability sub model is the multivariate process generator developed by King in 1979 (King *et al.*, 1988:165). The generator generates sample vectors from multivariate distributions defined by a cumulative distribution function (CDF) for each marginal distribution and a correlation matrix.

2.3.5.2 Farm level income and policy simulator

Purpose

FLIPSIM (Farm level income and policy simulator) was developed with the intent to analyse the likely effect that alternative farm policies and income tax treatments could have on representative farms. This is done by simulating the annual economic activities of a representative farm under price and yield risk over a multiple-year planning horizon ranging between 1 to 10 years (Richardson and Nixon, 1986).

Construction

FLIPSIM V, an improvement on the original FLIPSIM developed by Richard and Nixon in 1981, is in essence a stochastic whole-farm budgeting model. The model has numerous capabilities and a representative farm can be constructed to allow growth options and deterministic or stochastic values for prices and yields (Richardson & Nixon, 1986:7). Similar options exist for depreciation rules and the model allows a variety of options on its input interfaces.

Operation

The model, as the name suggests, has been extensively applied for policy and income tax regulation evaluation. In addition the model has been used for financial viability evaluations by incorporating price and yield risk, different marketing strategies as well as farm management and planning applications (Richardson & Nixon 1986:10).

2.3.5.3 Simulator of land transactions

Purpose

SIMULAND (Simulator of land transactions) was developed as a decision making aid to support the decision process in farmland acquisitions. The prominence of the acquisition decision is depicted by the vast percentage of the entire farm investment that is enclosed in farmland (Lombard, 1993:1). This serves as rationale for meticulous consideration and use of SIMULAND which supports decision making and aims to curb irrational decision maker behaviour. SIMULAND explicitly considers the stochastic nature of agricultural production in the land valuation process. This is done by allowing specifically for a stochastic tendency in agricultural commodity prices and production (Lombard, 1993:4). In addition SIMULAND allows the incorporation of farm-level data of the decision maker, to make circumstances as specific as possible (Lombard, 1993:iii).

Construction

SIMULAND consists of a stochastic capital budgeting model, constructed to have a finite, changeable planning horizon (Lombard, 1993:5) . The model allows for prices and/or production to be either deterministic or stochastic (Lombard, 1993:iii). Additionally the model explicitly allows for the expectations of the user making the model more sensitive to subjective developments in land prices (Lombard, 1993:291). Other features include a delineation between the agricultural, investment and personal value for prospective purchasers (Lombard, 1993:291).

Operation

The stochastic capital budgeting model was used to evaluate the investment value of farmland, according to a variety of different performance parameters and other factors (Lombard, 1993:5). These include the net return to farmland, tax, inflation, financing, time value of money and incorporates the expectations of sellers (Lombard, 1993:5).

2.3.5.4 Gudbrand Lien

Purpose

Gudbrand Lien developed his stochastic budgeting model to assist whole-farm decision making for Norwegian dairy farmers. The model is used to evaluate the financial feasibility of alternate investment and management strategies over a six year planning horizon, whilst taking business and financial risk into account (Lien, 2003:399).

Lien (2003:402) clearly articulates the current financial structure of and business environment in which the mostly owner-operated Norwegian farming businesses operate. Specific challenges, price volatility and uncertainty about future administered prices, quotas and subsidies are given as justification for the development of Lien's stochastic budgeting model.

Construction

In contrast with traditional whole-farm budgeting which is done on fixed-point estimate and are criticized with not turning out as assumed, Lien assumes an alternative approach of stochastic budgeting (Lien, 2003:403). The model applied is constructed in Excel from a deterministic whole-farm budgeting model reporting output in the form of annual financial results derived from linking all farm production, consumption and financial activities (Lien, 2003:403).

Variables assumed to be most risky in terms of influencing the financial outcomes, were made stochastic in the model by specifying probability distributions (Lien, 2003:403). Specified distributions were based jointly on a combination of historical data and subjective judgements allowing for expectations about the future to be factored in (Lien, 2003:404).

Operation

The model uses Palisade's @Risk software to analyse the financial feasibility and riskiness of five alternative investment and production strategies (Lien, 2003:407). Equity is used as the terminal performance measure and to avoid co-incidental bankruptcy mid-year, come solvency end year an extra high interest rate on loans is used (Lien, 2003:404). The former is done due to the fact that negative equity would imply technical bankruptcy and yield misleading results.

2.3.5.5 Grove Taljaard and Cloete

Purpose

The objective of the stochastic budgeting model by Grové, Taljaard and Cloete (2007:514) was to evaluate three possible alternative strategies for a beef-cattle farm to convert to game ranching. The rationale for the development of the model is that an increasing amount of domestic livestock farmers are doing circumspection with regards to the relative profitability and financial feasibility of their enterprises, relative to other options such as game ranching (Grové *et al.*, 2007:514).

Construction
Species-specific enterprise budgets are constructed to calculate the gross margins of enterprises and combined into the whole farm budget (Grové *et al.*, 2007:517). Subsequent net cash flow (NCF) is calculated and discounted to reflect the time value of money and simulated for each scenario (Grové *et al.*, 2007:517).

The model explicitly factors in price as the main source of risk and risk simulation was done according to the procedure described by Richardson *et al.* (2000) (Grové *et al.*, 2007:520). Capital is treated as a limiting constraint and the capital structure is allowed to vary to include external sources of financing. The model uses constant prices and profitability and financial feasibility of each scenario is calculated (Grové *et al.*, Taljaard & Cloete, 2007:518).

Operation
The profitability and financial feasibility of all three conversion strategies are evaluated through the stochastic budgeting model with and without the inclusion of foreign capital (Grové *et al.*, 2007:522). Profitability and risk is accounted and acknowledged for through standard net present value analysis in the simulation (Grové *et al.*, 2007:522). In addition, annual cash flow is analysed to calculate which conversion strategies would be viable. This is also done because a strategy can be profitable, but cash flow could be insufficient to cover obligations during the projected period resulting in bankruptcy (Grové *et al.*, 2007:529).

2.3.5.6 FinSim

Purpose
FinSim was originally developed as a deterministic farm-level model, able to simulate the effect of changes in policy and markets on the financial viability of farming with grain and livestock (Strauss, 2005:3). The former was then later linked to a partial equilibrium model to aid in agricultural policy decision making and concurrently adopted through the Bureau For Agricultural Policy (BFAP) (Strauss, Meyer & Kirsten, 2008:347). Through the link between the farm and sector level it gives decision-makers the ability to simulate the effect of change at both the sector and farm level (Strauss *et al.,* 2008:347).

Construction
The original FinSim model was modified to accommodate stochastic farm level analyses for cash crops and livestock. Lombard adjusted the farm level model in 2004 and 2008 to allow for the simulation of perennial crops, namely wine grapes and deciduous fruit, respectively (Jansen van Vuuren, 2013:33). Jansen van Vuuren constructed a model similar to the approach by Lombard, which linked with the sector level BFAP model to support decision making when evaluating alternative scenarios facing table grape producers (Jansen van Vuuren, 2013:iv).

The BFAP-model or models as known today, consists of dual components, that of a sector and that of a farm-level models linked to another by means of indices (Jansen van Vuuren, 2013:33). In the greater system of BFAP models, sector level models are used to generate five to ten year projections of prices and yields for a specific industry, which is linked to its stochastic farm-level models (Jansen van Vuuren, 2013:33).

Operation

The BFAP models allow for the quantitative analysis and accompanied scenario analysis of a variety of agricultural enterprises and industries (Jansen van Vuuren, 2013:33). The possible effect of any changes to exchange rates, policy and even the climate can be simulated in monetary terms (Jansen van Vuuren, 2013:33). The models' value is therefore accentuated at farm, sector and policy execution level.

As characteristics of agricultural systems have been discussed and simulation modelling has been illustrated to be an appropriate method for system analysis, the following section will consider physical and financial aspects which influence system outcomes.

CHAPTER 3: PHYSICAL AND FINANCIAL ASPECTS WHICH DEFINE WINE GRAPE PRODUCTION SYSTEM OUTCOMES

3.1 Introduction

As delineated in Chapter 2, wine grape production takes place within a greater system in a complex and uncertain environment dictated by controllable and uncontrollable factors. The ensuing chapter will elaborate on physical-biological and financial aspects which influence wine grape production and farm business outcomes.

Chapter 3 commences with an extensive embellishment of the importance of viticultural aspects within the physical biological production process. Correspondingly the viticultural and wine grape production system decision has implications for the financial and capital structure of the farm business, and as such Chapter 3 ends with a consideration of the implication of financing and capital decisions.

3.2 Viticultural characteristics which influence wine grape production

3.2.1 The prominence of the production, training- and trellis system decision

As represented in the systems theory section, wine grape production can be viewed as taking place within a greater environment and farm system. Within the farm system context the dynamic interdependency on the external environment, has been illustrated. The ensuing section will consider external factors which have an explicit influence on the grapevine and in turn wine grape production.

The focus is further extended in this section to training- and trellising systems. This is due to the: (i) influence of different training systems on the physical-biological grapevine processes (ii) predetermining influence of trellises on viable cultivation and management practices (iii) implication thereof for production costs and (iv) the significant capital investment (perennial) incurred on trellising systems. It can thus be accentuated that the proper planning of long-term practices and the training- and trellis system decision, is imperative for producing quality wine, at optimum yields with maximum income (Volschenk & Hunter, 2001:34).

In practice numerous trellising systems and variations thereof have been devised and applied in viticulture (Cerruti, 1974:254; Zeeman, 1981:185). The development of trellises arose out of a realisation that "grapevines cannot be satisfactorily grown without some sort of support" (Reynolds & Vanden Heuvel, 2009:254; Cerruti, 1974:253). A statement that with no doubt may have been seen as contentious in the 1970's has gained a foothold worldwide; with 80 percent of grapevines currently estimated to be trellised globally and higher percentages in new wine producing countries (Strever, 2014). This phenomenon is observed, particularly in non-irrigated areas, as spiralling production costs and diminishing margins contribute to a decreasing percentage of non-trellised grapevines (Strever, 2014; Cerruti, 1974:254).

The greater incidence of trellising can be attributed to the fact that trellising grapevines has advantages with regards to: cultivation, management, sustained production and performance of grapevines (Reynolds & Van den Heuvel, 2009:251; Cerruti, 1974:254; Zeeman, 1981:188). However, the decision to trellis a vineyard should be based primarily on economic considerations; which requires the selection of a trellis system well suited to the presiding conditions, as well as preferences of the decision maker (Reynolds & Vanden Heuvel, 2009:251; Cerruti, 1974:254; Zeeman, 1981:185).

Consequently six different training- and trellising systems and the associated influence it can have on: (i) grape quality and yield, (ii) production costs through cultivation, management and resource requirements, (iii) input and resource substitutability and (iv) topographical factors that influence the choice of trellis will be considered.

In addition there will be elaborated on the: (i) difference between training- and trellising systems, (ii) trellis system and suitability of different size trellises, (iii) motivation for trellis innovation and long-term influence of the trellis decision and (iv) the six different trellis types will be delineated according to their foliage division into vertically divided, horizontally divided and sprawling type systems.

3.2.2 The difference between training- and trellising systems

When studying literature on viticulture, the terminology of "training system" and "trellising system", are frequently used interchangeably. Since wine production varies across countries, languages and continents, some interpretational differences can occur. Therefore to avoid ambiguous denotations, training- and trellising systems as implied in this thesis, will be briefly described.

A trellis or trellising system can be regarded as the structural design of poles and wires that supports the creeping nature of the grapevine. The combination and configuration of poles and wires not only influences the establishment cost of the trellis system, but either facilitates or hinders the implementation of the training system. The training system in turn refers to the method of cultivation or management practices within a specific trellis system (Reynolds & Vanden Heuvel, 2009:253). Intrinsically it is then possible to apply alternate training systems on a particular trellis system, granting that the trellis could be more suited to one training system than another. Similarly grapevine cultivation always involves a training system, but grapevines can be cultivated without a trellis system. Hence the trellis system decision is underlying to the training system.

3.2.3 Types of training and trellising systems used in the South African wine industry

3.2.3.1 The trellis system and suitability of different size trellises

The practice of trellising grapevines involves the spatial distribution of the exposed organs of one or more grapevine/s in order to maximize the utilisation of natural resources and facilitate cultivation and management practices (Strever, 2005:1). This is achieved by supporting the creeping nature of the grapevine with a configuration of poles and wires (Zeeman, 1981:185).

The greater the vigour of the grapevine the bigger a trellising system needs to be to accommodate the growth (Zeeman, 1981: 188; Volschenk & Hunter, 2001: 31). Larger trellises require a greater capital investment in poles and wires and have been proven to be economically viable when appropriately selected for the envisaged vigour of the grapevine (Zeeman, 1981:188). This is due to substantially greater yields that are obtained, which offset the higher capital spending within a few years (Zeeman, 1981:192). Proper trellis system selection is paramount, as an incorrect trellising decision has unfavourable consequences.

While too small a trellis does not preclude the possibility for production, it does require annual canopy management practices to be exhaustively applied in season (Hunter & Volschenk, 2001:27; Strever, 2005:4). This is done in an attempt to curb excessive vigour and create "conditions conducive to continued fertility, yield and grape quality" (Hunter & Volschenk, 2001:27). Too small trellises would thus require annual adjustments, with accompanied higher production costs and offer no long-term solution (Hunter & Volschenk, 2001:27; Volschenk & Hunter, 2001:31). Failure to facilitate required annual adjustments and timeous execution thereof, can in turn preclude production, through inducing gradual infertility (Strever, 2014). Correspondingly over capitalisation in too large a trellis is also unfavourable, due to an opportunity cost of forgone income (Hunter & Volschenk, 2001:27).

3.2.3.2 The motivation for trellises innovation and long-term influence of the trellis decision

In the South African wine grape production arena the current call is for trellising systems which can deliver both quality grapes and high yields, amidst the high cost-pressured environment (Heyns, 2014). In the light of intensified cost pressure on the producer the drive is to increase margins, while also restraining production cost increases (Heyns, 2014). Consequently trellis systems which better accommodate grapevine vigour, induce more balanced growth, aid in increasing yield and restraining production costs are recommended (Bosman, 2014). In addition, substitution of inputs can become vital in curbing future inflation in production costs.

The former consideration spurs a natural inclination towards innovation in vertical trellising systems, as greater input substitution is possible than in horizontal counterparts. This can be attributed to the fact that vertical type systems do not preclude the possibility of substitution of labour for a variety of mechanised actions (Burger, 2013; Bosman, 2014). Labour in turn is a large contributor to the total cost of wine grape production, and mechanisation of cultivation actions an area where great innovation is expected. The significance of the trellis decision can thus be stressed as paramount and implies a particular path dependency. This is due to the fact that the trellis decision has long-term implications for viable training system options, future income, expenses and the greater wine grape production system.

Given the numerous amount of conceived and applied training and trellising systems, this thesis will incorporate examples of three "categories" of training and trellising systems as applied in wine grape production in South Africa, namely; the conventional Perold or vertical shoot positioning (VSP) systems, divided canopy systems such as the Smart-Dyson, Ballerina, Lyre and Gable, as well as sprawling systems such as the "High-Wire or mechanical pruning type systems". The listed systems will be briefly deliberated on before a comprehensive treatment of the possible influence of training and trellising systems on: grape quality and yield of production, production costs through; cultivation, management and resource requirements as well as establishment costs and capital expenditure. The subsection closes with the possible role of macroclimatic considerations on the choice of trellis.

3.2.3.3 Vertical shoot positioning trellis systems

According to Zeeman (1981:189) vertical shoot positioning (VSP) type trellising systems are the most commonly applied trellising system currently in South Africa. VSP type trellising systems include variations from the one-wire system, hedge type trellises to the greater Perold systems first introduced by Perold in South Africa (Zeeman, 1981:189; Strever, 2005:35). The differences between these systems range from differences in; erection costs, vigour accommodation, annual yield, the measure of protection against wind and sunburn and production costs (Zeeman, 1981:186). The production costs are greatly influenced by different labour requirements and labour substitution possibilities inherent in these systems. Examples of adaptions to VSP systems include moveable canopy wires and the differing potential for mechanical pruning (Strever, 2005:31). An example of a type of VSP system: the 4-strand Perold is illustrated in Figure 3.1 (Vinpro & SAWIS, 2014:3).

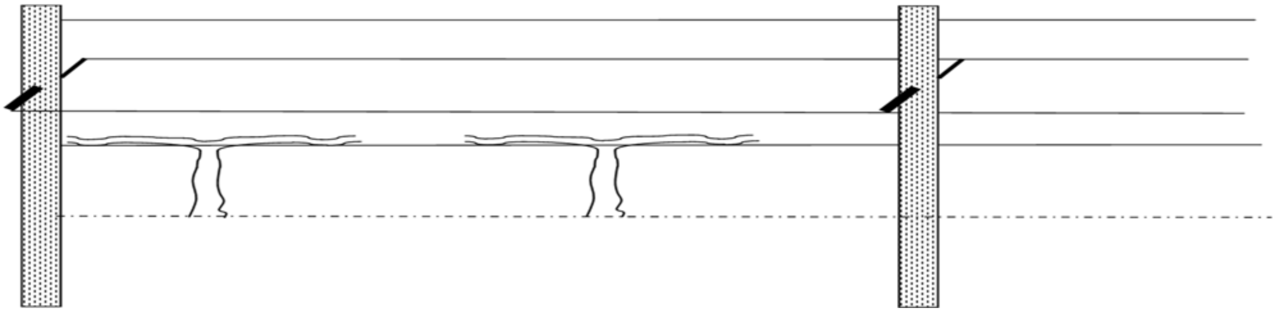

Figure 3.1: The four strand Perold trellis system

The Perold trellis has been the most extensively applied trellis in the past in the South African wine industry (Zeeman, 1981:189). The system can be combined with moveable canopy wires and decreases the labour requirements needed for tucking in shoots in the summer (Strever, 2005:30). The Perold system accommodates moderate growth and labour is required for summer canopy and foliage management to prevent over dense canopies in vigorous conditions. Mechanisation of tipping and "pre-pruning" by barrel pruner is possible.

3.2.3.4 Divided foliage systems

Divided foliage systems were developed out of a need for a greater effective leaf area than that which could be attained by regular VSP systems (Smart & Robinson, 1991:43). The idea is to divide and arrange the foliage, to create a greater effective leaf area for greater photosynthetic capacity, a bigger yield and better micro-climate and grape quality.

Within this category four divided foliage systems as applied in the South African Wine Industry will be considered: two which are vertically and two which are horizontally divided. Horizontally divided foliage systems include the Lyre and Gable, while the Smart-Dyson and the Ballerina system are examples of vertically divided foliage systems (Reynolds & Vanden Heuvel, 2009:253). In a strict classification the Smart-Dyson and Ballerina systems can be considered as training systems.

3.2.3.4.1 Vertically divided systems

3.2.3.4.1.1 The Smart-Dyson system

The Smart-Dyson bilateral cordon system with both upward- and downward facing bearers was co-developed by Richard Smart, an Australian viticultural consultant and John Dyson, an American wine producer (Reynolds & Vanden Heuvel, 2009:253; Bosman, 2011:101). The top half of the system resembles that of a normal VSP system with normal upward trained shoots. Additionally a moveable wire is attached approximately 20cm under the cordon wire, with hooks 40cm under the cordon for vertical downward positioning of shoots (Bosman, 2011:102). To enable the downward positioning of shoots additional bearer positions are developed and as a result the effective bearer shoots and effective leaf area are nearly doubled (Bosman, 2011:101).

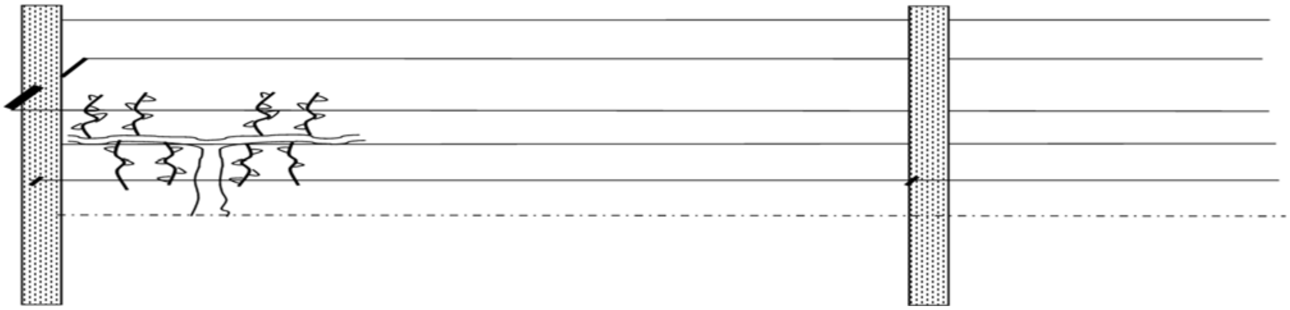

Figure 3.2: Smart-Dyson on a four strand Perold trellis system

A prerequisite for successful implementation of the Smart-Dyson system requires moderate to vigorous growing conditions, with the greater leaf area obtained demanding a 20-40% greater application of fertilizer and water compared to VSP during the first five years (Bosman, 2011:102). Trials thereafter, suggest the additional application relative to a VSP system can be reduced to 15% (Bosman, 2014). On average, yield increases of up to 40% are obtained with the Smart-Dyson system relative to VSP (Bosman, 2011). Better results are obtained specifically on red cultivars, with smaller berries, greater colour and softer tannins (Bosman, 2014).

Common best practice for Smart-Dyson shoot positioning and foliage management involves that: all the foliage on the one side of the vine are positioned upwards and likewise most of the other side downwards (Bosman, 2011:103). The idea is that foliage is divided to ensure a greater effective leaf area (Bosman, 2011:101). Shoots are positioned when they are long enough (50 –

60 cm) to be handled and tucked in. All the shoots on the one side of the grapevine (where no shoots will be faced downwards) are tucked in followed by partial tucking in on the other (Bosman, 2011:103).

The shoots on the partial tucking in side are then lightly brushed and the bottom moveable wire is lifted up and rested upon the protuberant shoots (Bosman, 2011:103). This action slowly accustoms shoots to the downward strain and forces shoots to start facing downwards after which the wire is hooked in after approximately two weeks (Bosman, 2011:103). The positive phototropic nature of the grapevine curbs excessive downward growth.

The Smart-Dyson system places a greater demand upon timeous execution of actions and managerial ability. The latter is especially important when it comes to the foliage division stage listed above (Heyns, 2014). The higher yield potential possible with Smart-Dyson trellis systems requires a greater capital investment in the trellis, more irrigation and nutrients than the normal VSP system (Bosman, 2011:104). Additionally, the system has a greater pruning skill and labour requirement than normal VSP systems and is recommended for cultivars which deliver highly priced wines (Heyns, 2014).

3.2.3.4.1.2 The Ballerina system

The ballerina system can be considered as a further expansion of the Smart-Dyson system with a few modifications (Reynolds & Van den Heuvel, 2009: 254). Both systems involve the vertical division of foliage into different canopies: the Smart-Dyson system strictly vertically into two canopies and the Ballerina system into three sparse canopies by facing shoots downwards on not one, but either side of the grapevine (Mellet, 2010).

Collective to both systems are the facilitation of a better vine balance by establishing a bigger effective leaf area (Bosman, 2014). Nonetheless management of the Ballerina system is easier and labour requirements lower than that of the Smart-Dyson system (Bosman, 2014). Mechanisation of activities, although more difficult than for VSP or Smart-Dyson systems, are possible (Bosman, 2014).

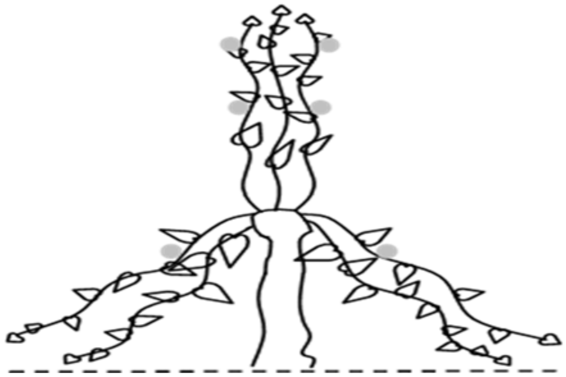

Figure 3.3: The Ballerina system

Very vigorous localities and growing conditions are a prerequisite for the Ballerina system, which exposes an even greater leaf area than the Smart-Dyson system. The greater leaf area obtained similarly demands a 50- 60% higher application of water and fertilizer and yield increases of 40-100% are obtained relative to that of VSP systems for certain cultivars (Mellet, 2010; Bosman, 2014). The system is particularly well suited to high yielding cultivars. In contrast with the Smart-Dyson system the Ballerina does not involve placement of downward facing spurs (Reynolds & Van den Heuvel, 2009: 254).

Instead moveable foliage wires are used to divide canopies upwards and downwards as soon as shoots are long enough. The former is important not only for shoots to be manageable but also for the shoot weight, which helps position lower shoots downwards (Mellet, 2010). Shoot positioning is usually completed in two stages, with shoots divided initially in middle November to obtain the benefits of sunlight exposure and final positioning is usually completed in December (Mellet, 2010). Vigour control of the upright canopy can be done, but tipping of the lateral canopies should be avoided to prevent shoots lifting up (Mellet, 2010).

In order to accommodate the larger yields obtained with the Ballerina system, trellises need to be stronger and larger than normal VSP by means of longer and thicker poles, wires and deeper and more sturdy anchors (Mellet, 2010). Additionally vigorous cultivar and rootstock selection is vital, rows should be at least 2.7 metres wide and weed control needs to be timeously done before shoots are positioned downwards (Mellet, 2010). As with all systems balanced application of fertilizer and water are required to comply with the grapevine's needs.

3.2.3.4.2 Horizontally divided systems

3.2.3.4.2.1 The Lyre or U system

The Lyre trellis system distinctly differs from the other systems discussed in this category. This is attributed due to the dual trellis configuration and the grapevine placement in between the middle of the trellis system as illustrated in Figure 3.4. The Lyre was developed by Charbonneau to improve the micro-climate and in particular the light environment of the canopy (Volschenk & Hunter, 2001:31). Similar goals in low-light intensity localities motivated the development of the Scott-Henry trellis.

The Lyre system separates the foliage into two outward slanting vertical hedges, which allows greater sunlight penetration and sunlight exposure of vines in the interior. Intrinsically two thinner canopies are attained, more favourable microclimate, exposure and less disease pressure than would be the case with a single hedge. Correspondingly lyre trellised grapevines tend to have a greater balance between vegetative and reproductive growth than normal VSP trellised grapevines (Kliewer & Dokoozlian, 2005:178).

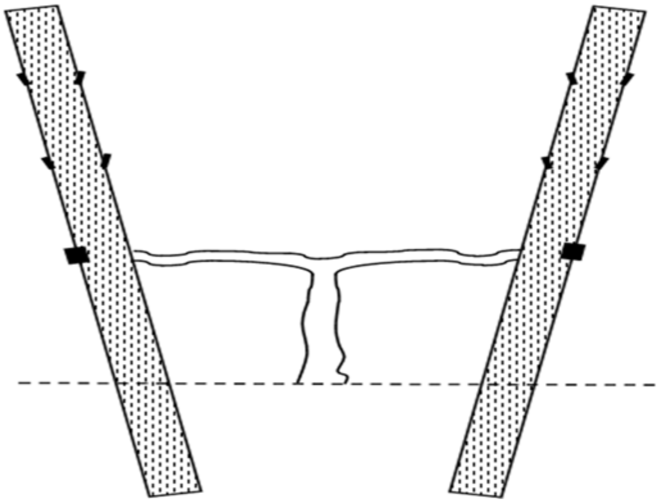

Figure 3.4: The Lyre trellis system

This is due to the facilitation of a greater canopy to root volume ratio (Volschenk & Hunter, 2001:31). Typically the cordon space obtained by normal VSP systems is doubled and greater yields of greater quality are obtained, due to the elimination of canopy densification and overshadowing (Volschenk & Hunter, 2001:33). The system is to be avoided in highly vigorous conditions in the absence of a suitable devigoration method, as lateral growth and consequent shading to the middle are difficult to contain (Smart & Robinson, 1991: 56).

Disadvantages of the Lyre system typically involves greater establishment costs, labour intensive cultivation practices and the need for specialized machinery if mechanisation, especially of harvesting, is required (Smart & Robinson, 1991:56; Dokoozlian, 2006:18). The Lyre trellis system requires timeous execution of actions, failure to do so and densification of the centre, results in poor outcomes (Smart & Robinson, 1991: 56).

3.2.3.4.2.2 The Gable system

Whereas the Lyre system could be strictly considered a hybrid between vertically and horizontally divided systems, the gable system is indisputably a horizontally divided system (Strever, 2014). The Gable system is also commonly referred to as the double slanting trellis and is constructed through linking adjacent rows to each other by joining two slanting poles in the form of an apex, approximately 2.1 metres above the middle of the alley (Zeeman, 1981:194). The large horizontal construction as a result extends over the whole width of the alley, exposing a substantial leaf area and is generally found to induce higher yields than vertical systems (Swanepoel & Archer, 1990: 61).

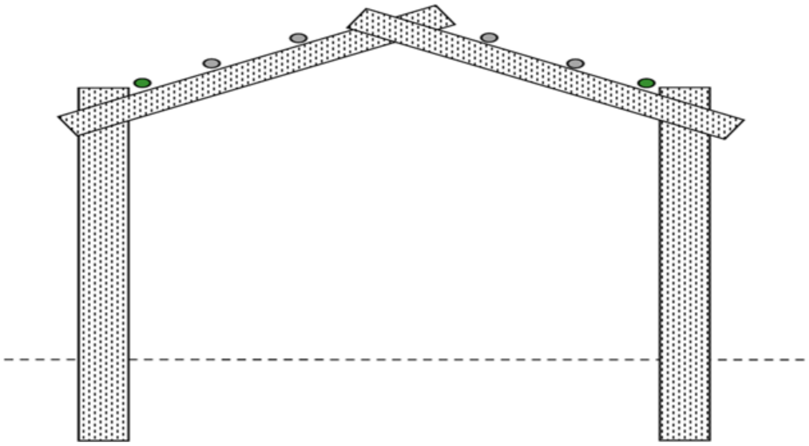

Figure 3.5: The Gable trellis system

Although more commonly associated with table grapes, the Gable system is regularly used in certain localities for wine grape production (Strever, 2014). A advantage to the gable system is that a considerable greater cordon length and more balanced bud load is obtained per grapevine (Strever, 2014). Additionally grapes are all carried at a similar height, apical dominance is mitigated and easy movement between rows is facilitated (Zeeman, 1981:194). Another advantage of larger horizontal systems is that they tend to induce higher budding percentages and fruitfulness primarily due to: more efficient accommodation of vegetative growth as well as an improved light environment within the canopy (Swanepoel & Archer, 1990:65).

A great disadvantage of the Gable system is that shoots regularly tumble towards the inside of the canopy, creating a dense and suffocating environment with accompanied loss of bud fertility in the lower parts of the grapevine (Zeeman, 1981:194). Although the Gable system allows greater mechanical movement than some of the non-illustrated horizontal systems, this system currently has the least potential to be mechanised of all the divided systems illustrated in this section.

In addition the Gable system is very labour and capital intensive (Strever, 2014; Van Niekerk & Van Zyl, 2014). When considering new establishments on this type of trellis system, care should be taken to calculate if the increased capital costs as well as current and future costs of cultivation, will be offset by the greater yield and income to be obtained.

This subsection has deliberated and illustrated particular systems which have different configurations and advantages due to their particular method of canopy division (Smart & Robinson, 1991: 40). Since yield is correlated to the exposed leaf area, yield can be increased as discussed in this subsection by enlarging canopy foliage either by widening the trellis (as with the Gable or Lyre) or by increasing the height of the canopy (i.e. Smart-Dyson and Ballerina) (Swanepoel & Archer, 1990:65). Additionally decreased canopy density contributes to improved quality due to better leaf and berry exposure as well as lower incidence of diseases such as Botrytis and powdery mildew (Smart & Robinson, 1991: 40).

3.2.3.5 Sprawling foliage systems

Sprawling foliage systems, as will be delineated in what follows, was developed out of an attempt to maintain fertility, improve yield and reduce production costs (Smart & Robinson, 1991: 61; Burger, 2013). In South Africa the initial large application of this trellising system type can be considered to have been applied in the lower Orange River production area (Burger, 2013). In this area periodical labour shortages occur due to the cultivation of other higher value crops such as raisins and table grapes, with the accompanied effect that all available labour is assigned to higher value activities (Burger, 2013).

Innovation then led to the large scale adoption of what is propagated as the High-Wire or Two Strand Hedge system. Under the High-Wire system the cordon is established at least 1.4 meters above the soil surface, to allow shoots with their phototropic nature to sprawl over and establish a reasonable leaf area for photosynthesis (Burger, 2013). By design the sprawling nature of the canopy allows for better aeration and exposure to sunlight, with subsequent higher bud fertility and lower disease incidence which contributes to higher yields and better quality grapes (Archer & Van Schalkwyk, 2007:111).

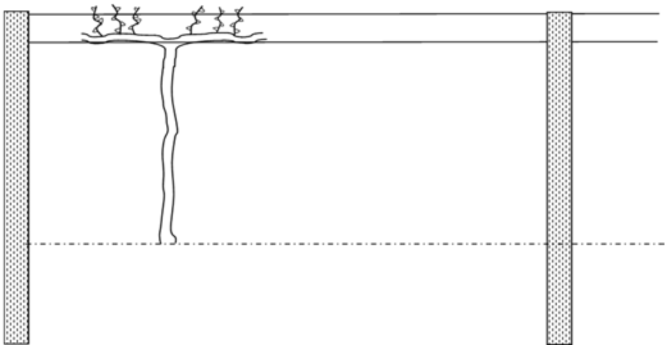

Figure 3.6: The High-Wire System

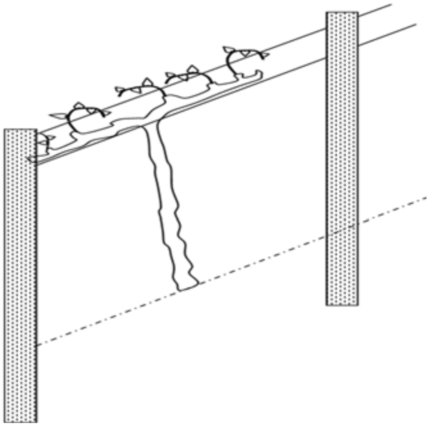

Figure 3.7: Sprawling over wire

The system is ideal for scenarios facing labour constraints, does not require shoot positioning or suckering and allows for mechanical pruning and harvesting. Intrinsically the system requires less managerial input and allows for labour substitution. Vast savings on labour inputs and production costs relative to conventional VSP systems are therefore possible (Intrieri & Poni, 1995:119).

The High-Wire system is particularly suited to irrigated production areas conducive to vigorous growth, high yielding cultivars and cultivars that respond well to mechanical pruning (Christensen, 1997:4). Cultivars sensitive to wind damage should be avoided on the High-Wire system in very windy localities, due to the absence of additional foliage wires as in the preceding systems.

As the different types of trellises considered in this thesis have been delineated, the associated influence the choice of trellis can exert will be considered in the remainder of this section. This influence materialises through an embedded income, production cost and capital decision. Additionally macroclimatic factors have to be considered in trellis and training system selection. The following section will focus on the income generating component, by considering the possible influence a trellis system can have on: grape quality and yield of production.

3.2.4 The effect of trellis systems on grape quality and yield

Upon further investigation into the possible effect of the choice of trellising system on grape quality and production, it is important to note that: (i) the soil potential, (ii) irrigation, (iii) fertilisation, (iv) training, (v) pruning, (vi) geographical locality and (vi) plant spacing of particular rootstock-scion combinations, all exert an influence on grape quality and production (Hunter & Volschenk, 2001:27).

When considering trellis systems, care should thus be taken not to regard it as the sole contributor to grape quality and grapevine yield. Rather the chosen trellis creates the environment in which the above factors combine with nature to either be or not be conducive to acceptable grape composition and high yields, or not. This environment is directly conditional on whether the trellis sufficiently accommodates the envisaged vigour of the grapevine (Strever, 2005:2,4).

This conditional effect of a trellis on the income stream is dual; through an influence on the quality and quantity (yield) of the physical produce (Mota, Amorim & Favero, 2011:969; Smart, Dick, Gravet & Fisher, 1990:5). In addition, considering that the grapevine is a perennial plant, the quantity influence materialises over the lifetime of the grapevine through continued or diminishing fertility and yield (Smart *et al.*, 1990:5). This is also expressed over time by the vine balance, which is the balance between the vegetative and reproductive growth (Reynolds & Vanden Heuvel, 2009:259; Smart *et al.*, 1990:5).

Correspondingly quality-specific attributes of grape composition important for the making of wine are: the titratable acidity, soluble sugars, pH, anthocyanin’s and phenolic compounds (Mota *et al.*, 2011:969). These attributes are directly influenced by the amount of light in- and arrangement of leaves around the cluster zone (Smart *et al.*, 1990:4). The grapevine can thus be considered as a biological factory, one which when correctly managed has the potential to deliver grapes of both great quality and quantity (Strever, 2005:8).

The ensuing sub section will therefore consider specific aspects pertaining to grape quality and yield, which are influenced by the choice and size of the trellis system. These aspects include the: canopy (density), (effective) leaf area, sunlight penetration, fertility and micro-climate, which all influence the grape quality and production of the grapevine (Christensen, 1997:2; Mota *et al.,* 2011:969; Smart *et al.*, 1990:3,4).

3.2.4.1 The canopy

The canopy can be defined by the organs attached to the cordon of the grapevine, specifically the leaf and shoot system (Smart *et al.*, 1990:5). The canopy is typically described by the leaf area and the spatial dimensions it occupies, within the borders of the particular trellis system (Smart 1990:3). Similarly alternate trellis systems influence the percentage of leaves inside the canopy. The particular trellis system in turn influences the spatial arrangement of the canopy, which in turn affects the canopy density (Reynolds & Vanden Heuvel, 2009:254).

Canopy density is one of the most interrelated aspects and can be considered as one of the most important factors that affects grape and wine quality in general grapevine cultivation (Strever, 2005:11). This is due to the determining influence the foliage of the canopy has on the accompanying sunlight penetration, shading, fertility, density and micro-climate within the canopy (Reynolds & Vanden Heuvel, 2009:254; Smart *et al.*, 1990:4). The importance and influence of the canopy on aforementioned aspects for grape quality and yield will be discussed in following subsections.

The importance of canopy density is so pronounced that vineyards are labelled according to their density (Smart *et al.*, 1990:4). This labelling is a result of canopies naturally being a great barometer of the vine balance of a vineyard (Smart *et al.*, 1990:4). In the following subsection principles will be elaborated upon, which contribute to a desirable canopy. It is however important to not only take note of the contributory effects, but rather the negative side-effects sustained by an undesirable canopy (Reynolds & Vanden Heuvel, 2009:255; Strever, 2005:11).

Negative consequences sustained by a too dense canopy include high occurrences of diseases and gradual infertility and by a too open canopy; direct sunlight on bunches with accompanied scorching and organic acid degradation (Mota *et al.*, 2011:970; Reynolds & Vanden Heuvel, 2009:255; Strever, 2005:11). The significance of canopy management should be apparent as the cornerstone on which prosperous grape production ensues. Therefore canopy management shall be defined and principles briefly outlined as put in 1990 by Smart *et al.* (1990:4).

3.2.4.2 Canopy management and principles

Canopy management can be defined as the arrangement of the shoots, leaves and fruit of the grapevine through the application of a variety of techniques to achieve a particular goal/s (Smart *et al.*, 1990:4). These goals can include: improved yield, wine quality, facilitation of cultivation and mechanised actions, ease of application of chemicals and decreased disease pressure (Smart *et al.*, 1990:4; Smart & Robinson, 1991:40).

In order to pursue and attain these goals the following principles of canopy management were described by Smart *et al.* (1990), as desirable for good grape yield and wine quality:

- The development of a large exposed canopy surface area as early as possible in spring, to increase sunlight interception.
- The avoidance of excessive shading of adjacent canopies on the base of another, with a canopy height to row width ratio that should not exceed 1:1.
- Avoid excessive shading in the canopy, especially the fruit renewal zone and endeavour to have the canopy as uniform as possible.
- Maintain an appropriate source-sink balance in the photosynthate partitioning between shoots and fruit, to curb excessive vegetative or reproductive growth.
- Standardise the spatial arrangement of individual organs in definite zones, as to facilitate cultivation and mechanisation.

As principles of canopy management have been described, the other interrelated aspects will be considered under their own subsection. The exposed and effective leaf area will be considered in the following subsection.

3.2.4.3 Exposed and effective leaf area

In order for the biological factory to function correctly, chemical reactions in the plant should run effectively. Optimal photosynthetic assimilation is thus paramount and depends on both sunlight interception and carbon assimilation (Mota *et al.*, 2011:967). Since most sunlight interception is derived from leaf photosynthesis, it is of vital importance for the sugar loading of berries (Kliewer & Dokoozlian, 2005:171; Mota *et al.*, 2011:969).

The general premise is then that trellis systems should facilitate the establishment of the maximum amount of exposed leaf area (Reynolds & VandenHeuvel, 2009:264). This leaf area should be well-balanced with a satisfactory crop load, as to enable the grapevine to ripen the fruit to a given sugar level as required for the wine goal (Kliewer & Dokoozlian, 2005:170; Volschenk & Hunter, 2001:33). Too small a crop load can be detrimental to wine quality, as it can lead to the development of superfluous leaf area and shading within the canopy (Smart *et al.*, 1990:5; Volschenk & Hunter, 2001:33). Moreover unduly crop load reduction in season can disrupt the source-sink balance, reduce photosynthetic activity in the leaves and hinder ripening (Strever, 2014).

The distinction should be made that more leaves don’t imply a greater effective leaf area (Smart *et al.*, 1990:5). Diffuse radiation occurs between different leaf layers and although photosynthesis does take place within the canopy, inefficient leaves should be limited (Reynolds & Vanden Heuvel, 2009:253,255). Excessively shaded leaves contribute marginally to canopy photosynthesis, turn yellow, abscise and can even become parasitic (Reynolds & Vanden Heuvel, 2009:255; Smart *et al.*, 1990:5). The choice of trellising system then has a dominant impact on the exposed leaf area, canopy density and efficiency of leaves (Mota *et al.*, 2011:969; Strever, 2005:8).

The correct cultivar and trellis system combination can thus contribute to a greater exposed and effective leaf area (Smart *et al.*, 1990:5; Strever, 2005:8). When combined with the correct crop load the trellis can then indisputably contribute to the optimisation of yield and quality (Reynolds & Vanden Heuvel, 2009:264). To reinforce this statement the dividing and better exposing of canopies has been found to significantly increase yield in cold and warm climates (Reynolds, Wardle & Naylor*,* 1996:75; Volschenk & Hunter, 2001:32). By selecting the correct trellis system and facilitating a greater exposed and better effective leaf area; it is therefore possible to produce higher yields, without reducing wine quality (Kliewer & Dokoozlian, 2005:175; Reynolds & Vanden Heuvel, 2009:264; Smart *et al.*, 1990:16). Contradictory to common opinion higher yields then don't need to imply reduced wine quality (Smart *et al.*, 1990:16).

The arrangement of the foliage and the leaf area not only has important implications for grape quality and yield as delineated above. In addition the effect also materialise through sunlight penetration into the interior of the canopy. Subsequently the implication of sunlight to the interior of the canopy will be considered.

3.2.4.4 Sunlight penetration and microclimate

As outlined in the canopy management subsection, a basic principle of grape production is the transmission of sufficient sunlight into the interior of the canopy (Volschenk & Hunter, 2001:31). In order to allow the transmission of light the canopy requires canopy gaps, the extent of which not only allows light penetration into, but also airflow through the canopy (Hunter & Volschenk, 2001:31; Reynolds & Vanden Heuvel, 2009:256). In turn canopy gaps, attributed largely to the specific trellis, influence the specific microclimate and shading in the fruit-zone (Mota *et al.*, 2011:967).

The microclimate of the fruit-zone directly influences the rate of ripening and grape quality or composition (Intrieri & Poni, 1995:117; Strever, 2005:8). Although not restricted to these only, microclimatic parameters that have a significant influence on grape quality, are canopy temperature and solar radiation of clusters (Marais, Hunter & Haasbroek, 1999:29). These parameters influence the ripening of the berry by directly influencing the aroma components present in berries (Marais *et al.*, 1999:29). Cooler climates generally benefit from slightly more cluster exposure to sunlight and warmer climates a bit less; with at least some exposure essential for grape quality (Marais *et al.,* 1999:29; Mota *et al.,* 2011:970; Reynolds & Vanden Heuvel, 2009:254).

In the same way good aeration and microclimate contributes to a lower incidence of fungal diseases and indirectly to healthier and better quality grapes (Hunter & Volschenk, 2001:27; Reynolds & Vanden Heuvel, 2009:256). Granting aeration is not the only contributory effect to disease incidence, open canopies and canopies with better airflow, tend to have reduced leaf wetness and disease incidence (Reynolds & Vanden Heuvel, 2009:256). Lower light intensity inside the canopy, ceteris paribus has also been found to contribute to greater powdery mildew infection in certain conditions (Reynolds & Vanden Heuvel, 2009:256).

To denote the importance of microclimate, canopies with well-exposed clusters and leaves generally contribute to wine that scores highest at wine tasting panels (Kliewer & Dokoozlian, 2005:170). As particular quality contributory considerations have been considered, quantity specific considerations will be considered in the sunlight and shading subsection.

3.2.4.5 Sunlight penetration and fertility

An additional consequence of sunlight transmission into the canopy is that of fertility and yield (Kliewer & Dokoozlian, 2005:170; Reynolds & Vanden Heuvel, 2009:254). In view of the relationship between fertility and yield, care should be taken not to confuse it, with greater inherent production yielded by bigger trellis systems (Reynolds & Vanden Heuvel, 2009:254). The preceding can be ascribed to more bearer positions, shoots, leaves and nodes which by nature have a greater capacity for bearing fruit (Reynolds & Vanden Heuvel, 2009:254).

Fertility, also known as fruitfulness, refers to the fruiting capacity or productivity of the actual nodes for the initiation of fruit primordia (Kliewer & Dokoozlian, 2005:170). Alternatively put, it can be perceived as to refer to the fruiting (reproductive) capacity per meter cordon of grapevine (Strever, 2014). The aforementioned is directly related to the amount of sunlight that reaches the cordon and basal buds of the spurs of the grapevine (Reynolds & Vanden Heuvel, 2009:254).

Sufficient sunlight exposure in early summer, late October and November of the previous season, is paramount for the stimulation of basal buds to differentiate to form flower and in turn fruit primordia (Reynolds & Vanden Heuvel, 2009:254; Strever, 2014). In addition, sunlight exposure contributes to greater yield by means of higher budding percentages (Swanepoel & Archer, 1990:65). Sunlight exposure is therefore indirectly causal to the quality and quantity of clusters formed.

On the contrary shading of basal buds stimulates the initiation of tendril primordia and contributes to lower budding percentages (Strever, 2014; Swanepoel & Archer, 1990:65). Shading therefore contributes to a more vegetative vine balance, lower fertility and yield (Kliewer & Dokoozlian, 2005:170; Christensen, 1997:2). Persisted exposure to low light intensity causes the reduction of yield of the subsequent harvest, as well as a diminishing productivity or yield of the grapevine over its lifetime (Kliewer & Dokoozlian, 2005:170).

The chosen trellising system therefore can be regarded to have a multi-dimensional influence on grape quality and production outcomes (Reynolds & Vanden Heuvel, 2009:251). Accordingly the preceding principles are important not only for the production of healthy, quality grapes, but also for the continued fertility and yield (Volschenk & Hunter, 2001:31; Christensen, 1997:2). The evaluation of the above then suggests that the selection of the appropriate trellising system can lead to greater grape yields without a decrease in grape quality (Reynolds & Vanden Heuvel, 2009:260).

In the endeavour of evaluating the long-term financial impact of different wine grape production systems, the income contributing component and impact the trellis decision has, were discussed. Subsequently, the possible influence of trellising systems on cultivation, management and resource requirements, which comprise production costs, will be considered.

3.2.5 The effect of trellis systems on profitability

The evaluation of the profitability of any investment decision or enterprise consists of three components, namely: an income, cost of production and capital investment component (Pindyck & Rubinfield, 2005:283). The purpose of an investment is generally regarded generic to the purpose of the firm, namely to maximize profitability for its stakeholders (Brigham & Daves, 2007:7; Pindyck & Rubinfield, 2005:264). Correspondingly it is common that the agricultural firm is managed by the owner and as a result, profitability is likely to dominate nearly all decisions (Pindyck & Rubinfield, 2005:264).

Profit is however a loosely defined concept and will be replaced by the more specific margins concept in later discussions. The profit and margins concepts can be considered synonyms, as both by definition indicate a difference; however, in the agricultural setting the margins concept can be applied more specifically. Hence any combination that gives rise to increased net income or decreased capital expenditure, *ceteris paribus* would lead to greater profitability (Brigham & Daves, 2007:371). Similarly the initial capital required for the establishment of perennial crops needs to be recovered over an extended period of time, whilst the establishment cost of cash crops can be recovered in the same season. Therefore provided within the context of the time value of money the timing of cash flows matter, as also does the riskiness of investments (Brigham & Daves, 2007:7). Hence the decision maker's risk preference or aversion to risky investments, risky crops or enterprises would also influence the combination of crops that are cultivated (Moss, 2010:9).

As discussed in Section 3.1.4 the trellis system decision influences the income stream through an influence on the quality and quantity of grapes obtained, with the other income stream determining component, being the price received for produce in the market. Agricultural production is characterised by taking place within a perfect competitive market (Pindyck & Rubinfield, 2005:262). This type of marketing arrangement is characterised by numerous producers producing a relatively homogenous product, where no producer has sufficient bargaining power to influence the price (Pindyck & Rubinfield, 2005:262). The average producer is thus a price taker and has limited marketing arrangements or leverage on the market price paid for inputs, or received for produce.

Endeavours of the producer to then unilaterally raise the price of his/her produce above the price the market dictates; leads to a loss of most or all of its business (Pindyck & Rubinfield, 2005:263). On the income stream side, decision makers can therefore only truly influence the quality and quantity of their produce. The former section concentrated on how the trellising decision and consequent effect on the grapevine can influence the quality and quantity of wine grapes and in turn the income from wine grape production. Subsequently grapevine and wine grape production specific qualities and their effect on the expense stream will be considered.

Grapevines are a perennial crop with a productive lifespan for grape production in South-African conditions generally regarded as 20 years (Van Wyk & Van Niekerk, 2013). In addition the decision to produce wine grapes involves a trellis and wine grape production system decision; with a profound influence on establishment and capital expenditure as well as and future costs of production (Bernizzoni & Gatti, 2009:347; Van Niekerk & Burger, 1981:477). The decision to produce wine grapes is therefore a long-term one; involving very high establishment costs, that once incurred need to be recovered over the lifetime of the vineyard (Van Niekerk & Burger, 1981:477).

Wine grape production is consequently inelastic and cannot be swiftly adjusted as with cash crops upon changing circumstances (Van Niekerk & Burger, 1981:477). Thorough planning should therefore be done and appropriate consideration given to available investment and trellising system options (Bernizzoni & Gatti, 2009:347; Van Niekerk & Burger, 1981:479). In contrast to the income stream, decision makers can exercise a greater influence upon the expense stream of wine grape production. The expense stream consists of annual cost of production as well as an initial establishment cost as well as capital expenditure component. Decision makers are able to influence the composition and size of these components. Accordingly the general effect of the trellis system on the cost of production, establishment and capital expenditure will be considered.

3.2.5.1 Cost of production

During the production process inputs, termed factors of production are transformed into outputs (Pindyck & Rubinfield, 2005:188). The level of technology employed in production accompanied with the cost of these inputs determines the farm business' cost of production (Pindyck & Rubinfield, 2005:213). Accordingly managers must decide how to produce by selecting between a combination of technologies, trellis and wine grape production systems (Pindyck & Rubinfield, 2005:213). The selected combination of inputs gives rise to a certain level of output, and accompanied production cost (Pindyck & Rubinfield, 2005:213).

As consequence inflation in the contributory components of cost of production, be that of locally or internationally sourced inputs, then places increased cost pressure on wine grape producers (Archer & Schalkwyk, 2007:107; Weilbach, 2013:12). The phenomenon is reminiscent of the increasing importance of the effective management of cost increases, to shelter shrinking profit margins and ensure the financial sustainability of wine grape production (Archer & Schalkwyk, 2007:107).

Albeit wine grape producers are price-takers for inputs as discussed, decision makers can generally choose the composition of their cash expenditure, the desired level of output, inputs and govern their individual production cost (Carol, 2007:10; Pindyck & Rubinfield, 2005:216). The latter is due to greater levels of output generally requiring more inputs and a measure of substitution being possible between different inputs in wine grape production (Carol, 2007:10; Intrieri & Poni, 1995:116; Pindyck & Rubinfield, 2005:216).

The viable production practices and extent to which inputs can be substituted are in turn influenced by the trellis system in question. The trellis system predetermines the level of technology that can be employed in the wine grape production system and the composition of cost of production. Thus to enable informed decision making, components that contribute to production cost as well as cost drivers (factors that influence these contributors) will be considered.

3.2.5.2 Establishment costs

The specific trellis decision, namely to trellis, the type of trellis or not to trellis has an extensive influence on the establishment cost of the vineyard (Van Wyk & Van Niekerk, 2013:6). The former can be attributed due to different requirements with regards to poles, wires and irrigational infrastructure (Reynolds *et al.*, 1996:75; Van Niekerk & Burger, 1981:479). In addition specific trellis systems require alternate amounts of within and between-row spacing, ultimately placing different demands on grapevine density and plant material cost (Bernizzoni & Gatti, 2009:340; Bosman, 2011:103). An indirect influence of the chosen trellis is upon the capital expenditure or requirement of the production system.

3.2.5.3 Capital expenditure

The former are attributed to the fact that the adoption of intensified production practices are characterized by a greater expenditure on technology and machinery (Van Wyk & Van Niekerk, 2013:8; Van Niekerk & Burger, 1981:478). This observation is exemplified in the capital structure of extensive non-trellised dry land vineyard production systems and enterprises (Van Wyk & Van Niekerk, 2013:6). This phenomenon is partly due to the greater facilitation of trellises for mechanised cultivation actions (Strever, 2005:2).

Accordingly intensive wine grape production systems are frequently characterised by substantial investments required in machinery (Intrieri & Poni, 1995:119). This includes mechanical harvesters, tippers and pruners, which are used to facilitate summer or winter actions, with the extent of mechanisation greatly determined by the specific trellis system (Burger, 2013; Smart et *al.*, 1990:5). Investments in machinery are generally motivated due to cost savings and unreliable- or limited labour availability during critical periods (Burger, 2013; Intrieri & Poni, 1995:119).

In addition adoption of capital intensive machinery and equipment is however subject to economies of size (Van Niekerk & Burger, 1981:478). Therefore it is crucial to not only consider the establishment cost of a specific trellis, but also the envisaged wine grape production system and scale or size of operations which have a profound influence on the total capital requirement and future costs of production (Bernizzoni & Gatti, 2009:137).

3.2.5.4 The drivers of cost of production

Due to the diverse nature of production inputs, it is natural to expect dissimilar rates of inflation over time in the cost of alternate components (Pindyck & Rubinfield, 2005:253). In order to then form a sound expectation it is necessary to better understand the drivers behind the cost of inputs. As stated by accounting standards a cost driver can be defined as a factor that is directly causal to the change of the cost of the activity or component. These drivers include prevailing exchange rates, core technology, world oil-, energy- and food prices to name a few.

Certain input combinations exhibit advantages with regard to economies of size, which in turn influence the relative cost of inputs to one another (Pindyck & Rubinfield, 2005:290). In addition it is important to note that the inflation in and relative cost of inputs is not only influenced by pure market forces (Pindyck & Rubinfield, 2005:588). Instead of a laissez-faire policy that allows supply and demand to dictate price, governments commonly intervene (Pindyck & Rubinfield, 2005:590). These interventions include regulatory levies and taxes that incentivises the use of some inputs to the cost of others (Pindyck & Rubinfield, 2005:329).

The result of the combination of the above implies that cost of production is dynamic over time. Consequently the relative cost and contribution of inputs to production cost change over time (Pindyck & Rubinfield, 2005:213). Therefore it is important to not only consider current costs of inputs when deciding on a specific trellis and wine grape production system, but also expected trends in future input costs (Pindyck & Rubinfield, 2005:213). For example, the direct and indirect cost of labour input is likely to escalate in the future, relative to other inputs, machinery and new technological inventions (Manning, 2014:2). This is due to the likelihood of above inflation adjustments to minimum wages, which are popular with voters and high on the agenda of a variety of countries (Manning, 2014:1; Weilbach, 2013:1). Increasing labour legislation and the issue of land restitution and expropriation has also been a source of great business uncertainty in recent years in South-African agriculture (Du Preez, 2014; Republic of South Africa: Act 15 of 2014). Agricultural producers should therefore take cognisance of both economic and political considerations when making investment, trellis and wine grape production system decisions.

3.2.6 The effect of trellis systems on required cultivation, management and resource requirements

As stated in the former section, the particular combination of inputs used by means of the chosen trellis and wine grape production system influences the production cost. The inputs required for production with a particular trellis and production system, stem from a variety of required cultivation techniques, resources and managerial savvy (Bosman, 2014).

Different trellis systems hold alternate potential for mechanisation as some trellis systems preclude mechanical cultivation of actions. Similarly alternate trellis systems have different requirements with regards to row spacing, plant density and other resources required. Therefore the chosen trellis pre-determines or influences which actions are physically feasible or economically viable (Bosman, 2014). The intent of the following is to elaborate on the influence the chosen trellis has on cultivation, resource and management requirements.

3.2.6.1 Cultivation

The chosen trellis system influences the density and arrangement of the canopy (Volschenk & Hunter, 2001:33). The density and arrangement in turn influences the amount and the range of cultivation techniques, that can and need to be applied to facilitate canopy management (Smart *et al.*, 1990:4). These techniques include winter and summer actions, of which some inputs can be substituted and actions be executed for example by either manual labour or mechanisation (Intrieri & Poni, 1995:117; Smart *et al.*, 1990:4).

With regards to cultivation techniques, different trellises place different demands on the quantity and variety of cultivation techniques that need to be applied (Bosman, 2014). VSP, Smart-Dyson and Ballerina systems for instance can require more shoot positioning, leaf removal and shoot vigour control than sprawling or High-Wire systems. While Smart-Dyson and Ballerina systems under proper management, require less summer actions than VSP systems (Bosman, 2014). However, winter cultivation techniques are slightly more intricate relative to normal VSP systems (Bosman, 2014).

Correspondingly the chosen trellis can facilitate or hinder mechanization of vineyard actions (Reynolds & Vanden Heuvel, 2009:251). Alternate systems occupy different spatial distributions and as a result, it is important for adjacent rows to be wide enough apart to facilitate the movement of machinery (Reynolds & Van den Heuvel, 2009; Bosman, 2014). With regards to mechanisation of cultivation actions some systems, such as the High-Wire and more open sprawling systems are more predisposed to the mechanisation of cultivation techniques (Bosman, 2014).

3.2.6.2 Resource requirements

When deciding upon a specific trellis system, it is important that the decision maker also consider the influence of the decision upon specific resource requirements. A decision maker should therefore take into account: the resource requirements, cultivation techniques, level of management and specific scarcity or constraints faced for a given scenario (Bosman, 2014). Different trellises and accompanying production systems place different demands on resources such as: soil potential, required plant material, fertilisation, water, labour, management, disease control and capital (Bosman, 2014).

Scarcity of labour or seasonal shortages should favour or bias decision makers to consider trellises which are more predisposed to mechanisation (Burger, 2013). Correspondingly limited managerial resources (capacity) and labour skill could also encourage the adoption of trellis systems which require less cultivation and management actions, particularly in the summer months (Bosman, 2014). In the above instances VSP type trellis systems should typically be avoided due to their labour and skill intensive cultivation practices and necessity for timeous managerial execution (Bosman, 2014). Smart-Dyson and Ballerina systems however, have a lower summer labour requirement than VSP, but greater management and winter pruning skill is required (Bosman, 2014; Heyns, 2014).

By the same token capital and water scarcity, low fertilisation potential and poor soil potential should discourage production on bigger trellising systems (Strever, 2005:2). Trellises with a bigger exposed and effective leaf area relative to VSP, such as Ballerina, Smart-Dyson and High-Wire systems typically have greater water and fertilizer requirements (Bosman, 2014). Bigger trellises also require a greater investment in poles and wires; while lower soil potential induces less vigour in grapevines, leaving the capacity of large trellises unutilised (Hunter & Volschenk, 2001:27).

Likewise limitations on the amount of resources or chemicals used for marketing arrangements; such as organic wine production, could favour the use of more open trellis systems. More open trellises such as High-Wire systems are better aerated, less prone to disease pressure and require less disease control (Bosman, 2014). Similarly Smart-Dyson and Ballerina systems tend to shade the basal parts of the grapevine and ground, with less need for herbicide applications (Bosman, 2014).

3.2.6.3 Management

The chosen trellis therefore places different requirements on: the skill level of labourers and amount of management savvy needed; the amount of summer actions desired; the amount of labour hours needed as well as extent of substitution possible (Bosman, 2014). The carrying out of these cultivation techniques are usually time bound to critical periods (Bosman, 2014). Failure to timeously complete actions are therefore typically also detrimental to yield and quality. A trellis system which sufficiently accommodates the vigour of the grapevine induces a better vine balance; consequently less corrective cultivation actions are needed (Bosman, 2011:104).

In addition it is important to ensure that the correct cultivation action is carried out in the correct manner to ensure economic efficiency (Van Niekerk & Burger, 1981:478). Failure to facilitate the correct and efficient application of actions, leads to unnecessary higher production costs and consequently decreased profitability of wine grape production (Bosman, 2014; Van Niekerk & Burger, 1981:478). In conclusion the choice of a trellising- and training system can be agreed to have a definite impact on the net income and consequent profitability of wine grape production. This can be attributed to the fact that the chosen trellis system not only exerts an influence on income derived from grape production, but also the cost of producing grapes. The latter is due to the influence the trellising- and training system exert on production cost by means of viable cultivation techniques, as well as management and resource requirements.

Additionally different trellising systems are more or less predisposed to substitution between alternate factors of production and require different quantities of inputs. The relative cost of different inputs has also been illustrated to inflate at varying rates, ultimately implying a changing relative cost of inputs over time. A decision maker should thus not only base the choice of trellising system on current but also expected future conditions, while taking own specific strengths and weaknesses into account. In order to then be able to fully evaluate the implication of different trellis systems and the consequent implication for the profitability of wine grape production systems; the effect of different trellises on capital expenditure and establishment costs will subsequently be considered.

3.2.7 The effect of macroclimatic considerations on the choice of a trellis system

The grapevine is not only flexible in the way it is cultivated, but also to different geographical localities and soil types (Saayman, 1981:48). While it is not suggested that grape production possibilities are unbounded to virtually anywhere; there are certain prevailing factors to consider, as well as manipulations that can be done to make grapevine proliferation more favourable (Saayman, 1981:48). Mediterranean climates as generally experienced in old world, wine grape growing countries, expediting conditions most favourable for grapevine growth and ripening of wine grapes (Saayman, 1981:48; Smart *et al.*, 1990:1).

However the use of particular cultivation practices, terrains, slopes, soil types, technology, plant material/cultivars and trellis systems within a specific setting can augment and even permit production in alternate climates (Mota *et al.*, 2011:967; Saayman, 1981:48; Smart *et al.*, 1990:1). As such the underlying soil and climate are the principal environmental factors to which the grapevine is subjected (Bernizzoni & Gatti, 2009:347; Hunter & Bonnardot, 2011:137). While the exact physiological interaction between the soil, climate and grapevine are beyond the scope of this thesis; macroclimatic factors and their consequent effect on trellis system choice will be considered (Saayman, 1981:49).

Climatic suitability of specific regions is widely recognized as the most important contributor, to the physiological processes of the grapevine and in turn wine quality (Hunter & Bonnardot, 2011:138; Saayman, 1981:49). The most important macroclimatic components in turn, in order of importance can be delineated as: temperature, relative humidity, wind and light intensity for South African conditions (Hunter & Bonnardot, 2011:139).

3.2.7.1 Temperature

Temperature has a significant impact on wine grape production (Saayman, 1981:49). Not only due to the perquisite for attaining sufficient degree days for grape ripening, but also due to the effect of extreme temperatures on the grapevine (Hunter & Bonnardot, 2011:139; Saayman, 1981:49). Of the two temperature extremes low temperatures are generally regarded more detrimental in South African conditions (Hunter & Bonnardot, 2011:139).

This can be attributed to the fact that the effect of high temperatures can be mitigated, by water (irrigation when available) (Hunter & Bonnardot, 2011:139). In addition by trellising grapevines higher and further away from the ground, heat radiation especially to the cluster zone can be decreased (Burger 2013; Strever, 2005:7).

Correspondingly the choice of trellis system can also mitigate the effect of extreme low temperatures, due to cold air accumulation in low-lying areas (Burger, 2013). This is facilitated by using trellis systems that are suspended high above the ground and can prove valuable in mitigating tissue damage early in spring and in autumn (Burger, 2013; Saayman, 1981:49). The height of the trellis system can therefore manipulate the ambient climate of the cluster zone, effectively shifting the vineyard from one climate to another (Strever, 2005:7).

3.2.7.2 Relative humidity

The effect of the trellising decision upon the relative humidity consideration is interrelated with canopy density and consequential to long-term decisions (Hunter & Bonnardot, 2011:137); (Saayman, 1981:50). Localities more prone to incidences of summer rainfall, high humidity and accompanied high rates of disease infection, should carefully consider trellis system and cultivar combinations (Strever, 2005:13). Care should be taken to avoid very vigorous grapevines with tightly clustered berries and bunches on too small trellises; which further improve conditions conducive to disease proliferation (Strever, 2005:13).

3.2.7.3 Wind

Even though wind can seldom be regarded as a limiting climatic factor for grape production, wind occasionally does contribute to considerable physical damage of the grapevine (Saayman, 1981:50). The former consideration is especially significant when considering trellises with minimal foliage wires, in localities prone to strong summer winds (Dokoozlian, 2006:17). In vineyards across the Western Cape, the notorious “black southeaster” regularly inflicts damage, especially to the shoots and bunches of wind sensitive cultivars (Saayman, 1981:50). Trellises which provide greater support and allow tucking in of shoots could be considered for wind buffeted localities (Strever, 2005:8).

In addition constant and high-velocity winds in summer months, in combination with the effect on transpiration and humidity, lead to less vigorous growth of grapevines (Dokoozlian, 2006:17; Saayman, 1981:50). By the same token cold southwester winds during flowering, can give rise to diminished fruit set, and lower yields (Saayman, 1981:50). In this regard trellising grapevines on trellis systems less prone to wind interception and in between tree hedges can be beneficial (Strever, 2005:8).

3.2.7.4 Light intensity

Wine grape production areas in South Africa are generally situated between 34°40’ and 27°30’ latitude with insufficient light intensity generally not being a problem under sufficient canopy management (Hunter & Bonnardot, 2011:139); (Saayman, 1981:50); (Strever, 2005:33). Rather trellis systems affect the density and interception of the canopy; with thin canopies improving light intensity within the canopy and photosynthetic capacity (Swanepoel & Archer, 1990:59).

The chosen trellis, together with cultivation actions, influences the light quality, intermittent and ambient light within the canopy (Swanepoel & Archer, 1990:65). Given the high maximum light intensities reached on cloudless summer days in very warm localities, well shaded and diffuse exposed leaves can contribute greatly to photosynthesis (Strever, 2005:16) On the contrary insufficient light intensity due to the chosen trellis and climatic conditions prevailing at certain localities, can inhibit colour formation in certain red varieties (Saayman, 1981:50).

Trellis, viticultural and physical wine grape production system considerations have been illustrated to be vast. Similarly financial and capital structure decisions, play an equally important role in the long-term profitability and feasibility of the farm business. As such the latter will be elaborated upon in the following section.

3.3 Capital budgeting, capital structure and finance in agriculture

In this section specific key concepts of modern finance theory and how they relate to agricultural finance will be illustrated. Concepts that are addressed include the firm value maximization principle, the weighted average cost of capital, risk and effects of financial leverage as well as a capital budgeting and structure considerations.

The combination of the above on the wine grape production system is then reviewed in the view of investment analysis. The importance of investment analysis in evaluating farm businesses is depicted with regards to the economic profitability and financial feasibility of an investment. Hereafter the motivation for and theory behind specific performance measures as used in the simulation model (refer to Chapter 4) to measure the economic profitability and financial feasibility are discussed. The above are all addressed in the view of establishing the basis on which economic profitability and financial feasibility analysis is done in Chapter 5.

3.3.1 A contextual review of the role of capital budgeting in the farm business

Agricultural finance focuses on the procurement and use of financial capital by the agricultural sector (Barry & Robison, 2001:515). Financial capital includes three major types of capital: equity, leased- and debt capital (Barry & Robison, 2001:515). Each of these sources may include numerous forms, which can be divided into short- and long-maturity instruments (Myers, 1977: 147).

Issuance of equity capital shares are however precluded to most farm businesses, due to the relatively small-scale, non-corporate structure of most farm businesses (Zhao, Barry & Katchova, 2008:806; Barry & Robison, 2001:516;). This is due to most of these businesses not being listed on capital markets and hence risk pricing of equity capital not being possible (Barry & Robison, 2001:516). Internally raised equity and debt therefore serve as the major sources of financing, with ownership and management consequently generally being concentrated in the hands of individuals whom may have family ties (Zhao *et al*., 2008:806).

Agriculture is characterised by being highly capital intensive, with major investments required in farm real estate, buildings and machinery which are usually highly specialized and have a low asset liquidity (Barry & Robison, 2001:516). This in turn creates the need for longer-term financing, specialized lending-institutions and careful matching of repayment obligations with projected cash flows (Barry & Robison, 2001:517). The sector is also characterised by relatively low current rates of return, geographically dispersed production areas, and volatility in production due to external and climatic factors with capital gains comprising a major part of total economic returns (Barry & Stanton, 2003:2; Barry, Bierlen & Sotomayor, 2000:920). This therefore accentuates the importance of careful capital budgeting, financing decisions as well as meticulous analysis of investments made in the farm business.

3.3.2 Capital budgeting

The value of a farm business can be expressed as the present value of its expected future free cash flows, discounted at its weighted average cost of capital (Brigham & Daves, 2007:509). For the sake of simplicity, a farm business will be assumed to have no non-operating assets and a constant growth rate and can then be expressed as:

$$V = IV_0 + \sum_{t=1}^{\infty} \frac{FCF_t}{(1 + WACC)^t}$$

Where *V* is the value of the farm business, *IV_0* is the value of the initial investment at time zero, *FCF* is free cash flows including the termination value at the end of the period and WACC the weighted average cost of capital. The WACC depends on the percentages of debt and equity in the total capital structure, the cost of debt and the cost of equity as well as the corporate tax rate (Modigliani & Miller, 1963:440) and can be expressed as:

$$WACC = w_d(1 - T)r_d + (w_e \, r_e)$$

Where w_d is the percentage of debt, w_e the percentage of equity, r_d the cost of debt, r_e the cost of equity and *T* the corporate tax rate. As the above equations illustrate the only way by which any decision can change a farm business's value, is by either affecting FCFs or the cost of capital (Brigham & Daves, 2007:511). Given that capital can be acquired from different sources, the question arises if debt capital should be used in the capital structure and if so, in what proportion (Myers, 1984:589).

The capital structure question has vexed at least three different type of economists to ponder over the matter (Modigliani & Miller, 1958:261). These include the corporation finance specialist, the managerial economist and the economic theorist. Corporation finance specialists are concerned with techniques of financing firms (representing farm businesses hereafter) to ensure their growth and survival. Managerial economists are concerned with capital budgeting and economic theorists with explaining investment behaviour, at micro and macro level (Modigliani & Miller, 1958:261).

In the following sections ways in which a higher proportion of debt can affect the WACC, FCF, agency costs and ultimately the value of the firm will be discussed. The term profit as used in the following text can be related to agricultural specific concepts, margins and net farm income. Similarly net operating profit after tax can be related to net cash flow after tax as used in Chapter 4 and 5.

3.3.2.1 Effect of debt on WACC and the value of the firm

An increase in the proportion of debt increases the cost of stock (equity) r_e, reduces taxes paid by a firm through lowering taxable income, and increases the pre-tax cost of debt due to a proportionate increase in the cost of debt (Baker & Wurgler, 2002:26; Brigham & Daves, 2007:511; Myers, 1977:149).

The former is due to the residual claim of stockholders becoming less certain, as the fixed claims of debt holders increase. Debt reduces taxable income due to the interest expenses being deductible from pre-tax income and the cost of debt increases, due to lenders insisting on a higher promised return as compensation for exposure to higher risk (Baker & Wurgler, 2002:26; Brigham & Daves, 2007:511; Myers, 1977:149).

The above changes will be referred to as “side-effects” and it is evident that an increase in debt can have a positive or negative “side-effect” on components (Modigliani & Miller, 1963:440). The coefficient size of components and their side-effects are again subject to factors which the firm cannot directly control. These include the market risk premium, the level of interest rates (repo) and tax rates (Brigham & Daves, 2007:335). The net effect of a change in the capital structure and its consequent effect on the WACC are thus not as easy to determine. A change in the capital structure can thus increase, decrease or balance out exactly and leave the WACC unchanged (Brigham & Daves, 2007:511).

3.3.2.2 Effect of debt on FCF and the value of the firm

As the debt capital in the capital structure of a firm increases, so does the probability of financial distress. Financial distress can be related to what is commonly known as bankruptcy costs (Myers, 1977:148). Bankruptcy cost/risk is not only the costs that would be due if liquidation or reorganisation actually occurs, but also includes the indirect costs which befall the firm (Brigham & Daves, 2007:511).

Bankruptcy risk reduces FCF in three ways: by loss of sales, lower productivity of personnel and tighter credit standards from suppliers (Myers, 1977:148). As the risk of bankruptcy increases some customers may choose to buy from competing firms, leading to lower sales. This in turn reduces FCF, through a decrease in operating profits and net operating profit after tax (NOPAT) (Myers, 1977:148).

Financial distress affects the productivity of employees, because they spend more time worrying about their next employment than their current work (Myers, 1977:148). As previously mentioned this in turn again reduces NOPAT and FCF. Lastly, as the risk of bankruptcy increases suppliers will tighten their credit standards. Tighter credit standards reduce accounts payable, causes net operating working capital to increase and thus reduces FCF. Therefore the risk of bankruptcy can reduce FCF and the value of the firm (Myers, 1977:149).

In the agricultural setting there has however also been evidence that heightened bankruptcy risk can lead to higher FCF (Nasr, Barry & Ellinger, 1998:42). This is due to leverage-induced external financing obligations stimulating increased efforts by agents which tend to be individual/part owners to satisfy the obligation (Nasr *et al.*, 1998:42). Results suggest that a greater reliance by farmers on current debt to finance operations, can induce farmers to work harder (Nasr *et al.*, 1998:42; Barry & Robison, 2001:524).

3.3.2.3 Effect of debt on agency costs and the value of the firm

Higher proportions of debt in the capital may affect the behaviour of managers in two opposing ways. In favourable periods managers/owners may use funds on perquisites and non-necessary expenditures (Brigham & Daves, 2007:512). The good news however is that a higher proportion of debt and thus threat of bankruptcy, decreases incidences of such wasteful spending (Brigham & Daves, 2007:512).

Higher leverage however has negative consequence as well, as managers may become gun-shy and forgo positive net present value projects (NPV). This is due to managers seeing projects which otherwise would have been pursued as too risky, given their firm's leverage (Welch, 2002:24). This problem is commonly known as the underinvestment problem and increases in debt can thus reduce one aspect of agency cost, but also increase another (Brigham & Daves, 2007:512; Welch, 2002:25). Therefore the amount of debt capital affects agency costs and ultimately the value of the firm.

3.3.3 Delineation of risk and financial leverage

When viewing risk from an investor's point of view in modern finance, there can be distinguished between market- and stand-alone risk (Collins & Barry, 2012:153). Market risk is measured by a firm's beta coefficient, as in the Capital Asset Pricing Model (CAPM) and stand-alone risk includes both market risk and an element that can be eliminated by means of diversification (Brigham & Daves, 2007:50). The risk that is faced after diversification is the risk that the asset/stock contributes to a well-diversified (risk-efficient) portfolio, also known as relevant risk (Collins & Barry, 2012:153).

Although the particulars of the CAPM won't be discussed, as risk pricing of equity capital is not possible for most farm businesses, notice must be taken of diversification and its effectiveness in managing risk (Barry & Robison, 2001:518; Brigham & Daves, 2007:72). The latter leads to the consideration of two dimensions of risk in particular, that of business- and financial risk (Barry & Robison, 2001:518). Business risk is the riskiness of a firm if it uses no debt and financial risk the additional risk borne by the equity holders as result of using debt capital (Brigham & Daves, 2007:513).

Conceptually a firm can be viewed as having a certain amount of risk inherent in its operations, which is its business risk. However, if a firm decides to use debt capital it effectively separates the investors into two classes and concentrates all the risk on the one class, the equity holders

(Barry & Robison, 2001:518; Brigham & Daves, 2007:512). The latter is due to debt capital holders having a prior claim to equity holder(s), in the case of bankruptcy occurring (Brigham & Daves, 2007:510).

The rationale behind the use of financial leverage (debt capital) exists in the fact that it is possible to earn profits through leveraging (Barry & Stanton, 2003:9). The net effect of a decision to use financial leverage however, depends on the firm's expected internal rate of return on capital (IRR) and the rate of interest on debt capital (i_d) (Barry & Stanton, 2003:9). If the IRR > i_d it is then possible to obtain advantages through financial leverage and the profits from leveraging can be expressed as:

$$p = \frac{I}{C}(IRR - i_d)$$

Where *p* is the expected rate of profit on an entrepreneur's capital, *I* is the total capital investment in the firm, C the entrepreneurs capital, *IRR* the expected internal rate of return on the firm's capital and (i_d) the rate of interest charged on debt capital (Barry & Stanton, 2003:9).

A decision to use debt financing can thus lead to a greater expected rate of return on equity (ROE) for an investment (Barry & Stanton, 2003:10). However, it also typically leads to greater risk borne by the equity holder(s), so managers also have to consider the risk-efficiency of the decision (Brigham & Daves, 2007:518; Zhao *et al*., 2008:808). The amount of debt capital in the firm's capital structure will ultimately be influenced by risk attitude and capital rationing of the equity holder(s) (Barry *et al*., 2000:920; Barry & Stanton, 2003:7).

Risk aversion and capital rationing is closely related seeing as both have an influence on the availability of capital, with the dissimilarity arising with the first being the reaction of the business manager and the latter the reaction of an outsider (Barry & Stanton, 2003:7). The availability of capital on its part affects the efficiency of resource allocation, by affecting the combination of factors used, as well as the scale of operations (Barry & Stanton, 2003:8). It should therefore be evident that the capital structure of a firm is of crucial importance. Consequently capital structure theory will be discussed in the following section.

3.3.4 Capital structure theory

In the preceding section capital structure choices where shown to affect both a firms ROE and its risk. Consequently it could be expected that capital structures of different firms within an industry would be similar (Brigham & Daves, 2007:519). In practice there are however considerable variation in capital structures (Brigham & Daves, 2007:520). In an attempt to clarify these differences, academics and practitioners developed different theories, which have been subject to empirical tests. While elaboration of all of the theories is outside the scope of this thesis, an abridgment is due on two theories namely, those put forth by Modigliani and Miller and the trade-off theory of leverage.

3.3.4.1 Modigliani- and Miller's capital structure theory

Modern Capital Structure Theory originated in 1958, when Modigliani and Miller (hereafter MM) published the article *"The Cost of Capital, Corporation Finance and the Theory of Investment"* (Modigliani & Miller, 1958:261). Though the assumptions in the paper were evidently unrealistic, by indicating conditions under which capital structure is irrelevant, MM provided clues under which capital structure would be relevant (Brigham & Daves, 2007:521). Consequently all major capital structure research has focused on relaxing the original MM assumptions.

As such in 1963 MM published a follow-up paper *"Corporate Income Taxes and the Cost of Capital: A Correction"* (Modigliani & Miller, 1963:433). MM admitted that the tax advantages of debt financing is greater, than originally suggested in their initial paper and they relaxed the assumption of no corporate taxes (Modigliani & Miller, 1963:434). The deviation originated from the fact that the tax code allows firms to deduct interest payments as an expense, but not dividends (Brigham & Daves, 2007:520). The differential treatment encourages corporations to use debt in their capital structure. This implies that interest payments reduce the taxes paid by a firm and due to less taxes being paid to the government, more cash flow is available to investors (Brigham & Daves, 2007:520).

Thus the tax deductibility of interest payments shields the firm's pre-tax income and a different view of looking at a firm's capital structure can then be introduced (Modigliani & Miller, 1963:439). MM then introduced the idea that the value of a levered firm, is the value of an otherwise identical unlevered firm plus the value of any "side effects" (Modigliani & Miller, 1963:439). The latter expressed as an equation:

$$V_L = V_U + \text{Value of side effects} = V_U + \text{Present Value of tax shield}$$

Simplified to:

$$V_L = V_U + TD$$

Where V_L is the value of a levered firm, V_U the value of an unlevered firm and the present value of the tax shield being equal to the corporate tax rate (T), multiplied by the amount of debt (D). MM then illustrated that the cost or equity, r_e, increases as debt is added, but not as fast as it would in the absence of taxes (Modigliani & Miller, 1963:441). The follow-up paper retained an assumption of no bankruptcy costs and therefore WACC falls as more debt is added, with strict adherence of the theory leading to the result that a firm would be purely financed with debt capital (Brigham & Daves, 2007:521). The latter could thus be considered unrealistic and accordingly the trade-off theory of leverage, relaxed the assumption of no bankruptcy costs (Kraus & Litzenberger, 1973:918).

Apart from other indirect costs mentioned in Section 3.2.2.2 bankruptcy often forces a firm to liquidate or sell assets for less than they would be worth if the firm were to continue operating (Myers, 1984:581). Firms holding specialized capital assets such as farm businesses also incur greater costs if bankruptcy does occur due to the illiquid nature of their assets, due to the difficulty of dissembling certain types of equipment and the absence of active second-hand markets (Myers, 1984:581). Other indirect financial distress costs include that of sub-optimal investment opportunities as well as high administrative and legal fees (Kraus & Litzenberger, 1973:914; Myers, 1977:149). Hence farm businesses which are exposed to seasonal production patterns, volatile earnings and have specialized assets in place should rely less heavily on debt (Barry & Robison, 2001:518; Zhao *et al*., 2008:806).

3.3.4.2 The trade-off theory of leverage

The trade-off theory of leverage can then be described as a process by which firms (farm businesses) trade off the benefits from debt financing, against the higher interest rates and bankruptcy costs (Brigham & Daves, 2007:523). In essence the trade-off theory delineates that the value of a levered firm is equal to the value of an unlevered firm plus any side-effects. These side-effects include the tax-shield and the expected costs due to financial distress (Brigham & Daves, 2007:523). The trade-off theory can be summarized graphically by Figure 3.8 which illustrates the effect of leverage on the value of the firm (Brigham & Daves, 2007:524).

Figure 3.8 illustrates that by adding debt into the capital structure it is possible to increase the value up to a point, which is known as the optimal capital structure (Myers, 1984:577). The optimal capital structure is illustrated by D2 on the graph and at this point the marginal tax shelter benefits are exactly equal to the marginal bankruptcy related costs (Myers, 1984:577). Any point before D2 would imply increasing leverage will increase value and increase in leverage beyond the point would lower the value of the firm (Myers, 1984:577). The point illustrated by D1 is the threshold debt level where bankruptcy costs become material and the horizontal line the value of the firm if it used no leverage (Myers, 1984:577).

Myers however pointed out that if there were no adjustments costs and the trade-off theory was correct then all firms could be expected to operate at the optimal debt to value ratio (Myers, 1984:577). Instead, however, adjustments costs can be substantial and therefore firms generally adjust towards the optimal ratio with lags (Myers, 1984:577). The figure clearly illustrates that firms can gain value by using some leverage, even those prone to higher bankruptcy related costs (Myers, 1984:578).

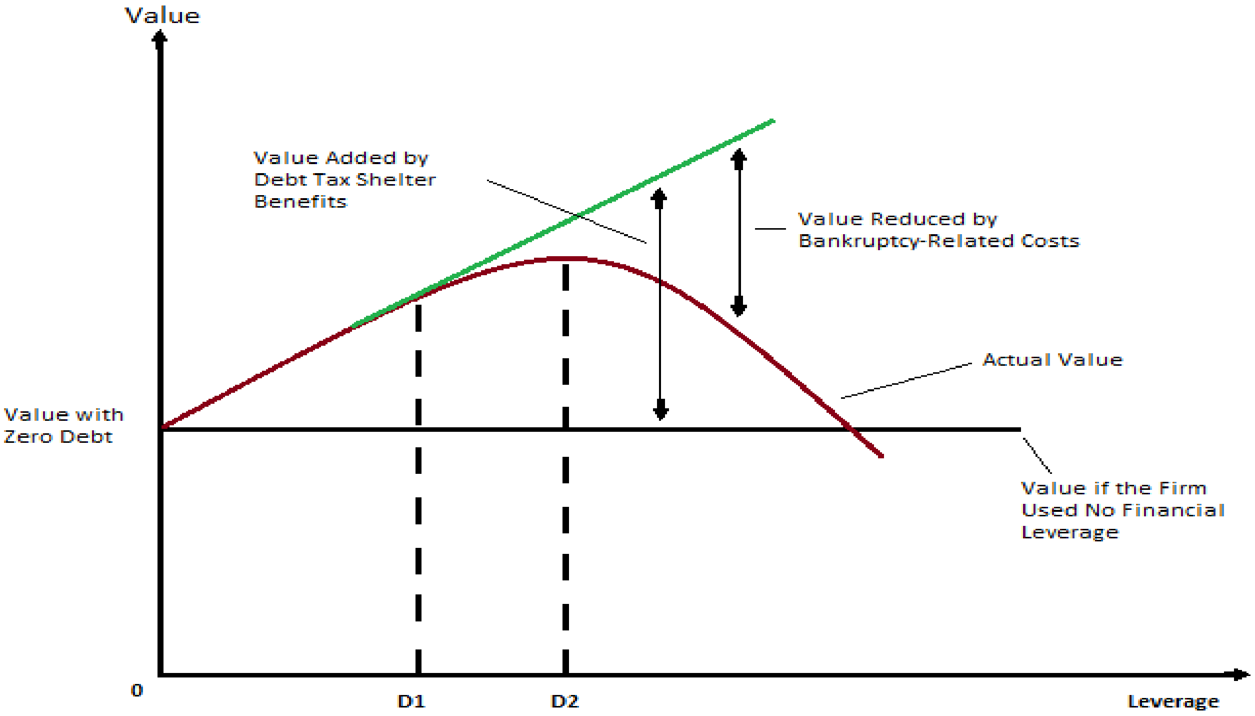

Figure 3.8: The effect of financial leverage on the value of the firm

3.3.5 Investment analysis and performance measurement

Capital investment decisions are among the most critical and strategically important decisions that can be made in the farm business (Boehlje & Eidman, 1984:314). The latter is due to capital investments typically requiring the commitment of large amounts of funds in the present, of which the income streams accrue in the future (Boehlje & Eidman, 1984:315). In addition capital investments made into the farm business can typically be considered sunken costs, which upon investment infer a particular path dependency (refer to Section 1.1 and 3.3).

Therefore it is important to thoroughly evaluate all investments in the farm business as the direction, as well as operation of the farm business, will be affected for a number of years (Boehlje & Eidman, 1984:315). In the wine grape production system context this decision starts with the trellis decision and the path dependency is typically reinforced by other capital intensive investments such as machinery.

In order to decide between different capital investments it is then important to evaluate the economic profitability and financial feasibility of investments. Analysing the economic profitability of an investment, involves establishing the required capital outlay as well as likely earnings that will result and then comparing this outlay to the benefit stream (Boehlje & Eidman, 1984:316). Similarly financial feasibility calculations involve the comparisons of cash inflows generated by investments, with the principal and interest payments that are due on them (Boehlje & Eidman, 1984:316).

Economic profitability analyses are typically done to determine if an investment will contribute to the long-run profits of the farm business. And while an investment project can be evaluated to be economically profitable and in the long-run interest of the farm business, it is not necessarily financially feasible (Boehlje & Eidman, 1984:317). The latter can be due to the investment generating insufficient cash inflows during specific periods, to cover fixed obligations[7] and as such acceptance of the investment would be met with liquidity problems (Boehlje & Eidman, 1984:333). Liquidity problems however do not imply the investment should not be made, it just implies that debt restructuring, stricter cost control or subsidizing by other investments would be needed (Boehlje & Eidman, 1984:333).

Thus the expected profit, capital outlay required and cash flow matters when evaluating any investment, farm business or enterprise. Therefore while the pursuit of increased net income and or decreased capital expenditure, *ceteris paribus* would lead to greater profitability, the latter needs to be pursued with regard to cash flow and time value of money considerations (Brigham & Daves, 2007:371). That is that the timing of cash flows matter, as also do the riskiness of investments (Brigham & Daves, 2007:7).

It is therefore not only the amount of expected cash flows, but also the timing and variability or risk of cash flows that matter (Moss, 2010:9). The latter would then influence rate of investment in, as well as the combination of crops cultivated. In order to analyse and measure the performance of investments, the net farm income (NFI), net present value (NPV) and internal rate of return (IRR) method will be discussed followed by an abridgment of financial feasibility evaluations.

3.3.5.1 The net farm income method

As elaborated, investment analysis should be based on multiple criteria and even though ensuring a healthy cash flow is vital to ensuring the survivability of the farm business, it is not enough to ensure the prosperity (Warren, 1998:183). A farm business also needs to be profitable enough to sufficiently compensate for implicit and opportunity costs related to capital intensive investments in different farm enterprises. Implicit costs are items like depreciation on capital items, the remuneration that own capital could have earned, as well as remuneration to own management.

In the view of the above a performance measure is needed which can be used to evaluate different farm investments, production systems, enterprises and farm businesses. Net farm income is such a general farm profitability measure, as it allows for the universal comparison between different farm investments and systems regardless of the remuneration to management, land and capital.

Net farm income is widely accepted as a method to measure (expected) profitability in comparing alternate cropping and production systems (Lien, Hardaker & Flaten, 2007:542). As regularly applied, economic studies use net farm income to compare alternate cropping systems by comparing average net farm income (NFI) between systems. Regular critics cite the method as

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[7] Such as principal and interest payments

being insufficient, as it does not explicitly allow for the introduction of any riskiness of net income between alternate cropping systems (Lien *et al.,* 2007:542). However for individual farm-level evaluations the latter risk can be considered to be originating mainly from the reigning climatological conditions during critical periods in the production season. In addition due to the evaluations in this study being primarily done between the same crop types on alternate systems, in a small geographical area the effect can be considered systematic. Hence the criticism weighed against the benefits of the NFI measure, were regarded as insufficient to refute NFI altogether (refer to Section 4.2).

Production cost can be described as the sum of the cost of the factors of production expended to produce a given commodity or crop. According to Vinpro, a South African wine industry organisation, cost of production can be divided into two components: cash expenditure and provision for replacement (Van Wyk & Van Niekerk, 2013:7). Cash expenditure can then be further delineated into direct cost, labour, mechanisation, fixed improvements and general expenditure (Van Wyk & Van Niekerk, 2013:10). Provision for replacement in turn does not imply an annual cash outflow, but rather it follows the accounting principle of depreciation; to enable replacement of decrepit assets and the continuity of wine grape production. The combination of the above does not only point at the high establishment costs, but also the cost intensive nature of wine grape production (Van Niekerk & Burger, 1981:477).

Direct costs encompass costs directly related to the proliferation of wine grapes and include the costs with regards to seed (usually cover crop such as oats), fertilizer, organic material, fungicide, pesticide, herbicide and repair and binding materials (Van Wyk & Van Niekerk, 2013:12). Labour in turn involves costs directly concerned with cultivation, facilitation and management of actions concerned with the grapevine and include supervision, permanent and seasonal labour (Van Wyk & Van Niekerk, 2013:12). The mechanisation sub-division encompasses costs directly related with the use of machinery such as fuel, repairs and maintenance, licences and insurance as well as machinery hired to facilitate production (Van Wyk & Van Niekerk, 2013:12).

Fixed improvements encompass costs directly related to the repair and maintenance, as well as insurance of permanent infrastructure used in the production of wine grapes (Van Wyk & Van Niekerk, 2013:12). These costs encompass fixed buildings or infrastructure such as main pipelines, dams and means of production with an expected lifetime of 20 or more years. General expenditure comprises expenses that can be considered overheads, which are not generally allotted to specific enterprises or vineyard blocks and include: electricity, water costs, administration expenses as well as, land, property and municipal taxes (Van Wyk & Van Niekerk, 2013:12).

Formally net farm income is calculated by subtracting total farm costs from gross farm income. (Department of Agriculture, 2005:12). Similarly gross farm income is equal to the gross value of production minus internal transfers, plus sundry incomes. Correspondingly total farm costs are equal to the sum of all variable and fixed costs minus total factor costs (Department of

Agriculture, 2005:7). Total factor costs are interest, rent and share crop paid, as well as hired management and imputed costs (Department of Agriculture, 2005:7). NFI is thus the remuneration to own and foreign factors which are calculated for every year of the projection period and NFI per R100 can be expressed as:

$$\text{NFI per R100 capital investment} = \frac{Net\ farm\ income}{Average\ capital\ investment} \text{ x } \frac{100}{1}$$

Similarly average capital investment is calculated through summing the opening capital and closing capital and dividing by two. Formally expressed as:

$$\text{Average capital investment} = \frac{Opening\ Capital + Closing\ Capital}{2}$$

However, despite the advantages of the NFI method, which enables the measurement and comparison between alternate cropping and production systems, it has a major limitation for use as sole performance measure for long-term evaluations. This is due to the NFI method not taking the time value of money into account and hence being less accurate for evaluations with longer evaluation horizons. Hence additional measures which explicitly take the time value of money into account will be considered.

3.3.5.2 The discounted cash flow and the net present value method

While rudimentary evaluations of the cash flow involve the calculation of the payback period[8], the latter are inadequate as a measure for evaluating the long term investments (Brigham & Daves, 2007:402). This is due to the disregard to the time value of money principle[9]. As result a superior approach is then to evaluate different production systems with alternate cash flow streams, through discounting the different net cash flow streams to convert them to their net present value (Brigham & Daves, 2007:402).

The net present value (NPV) method is centred on the basis that the value of future benefits and costs decline over time (Brigham & Daves, 2007:403). Hence large negative outflows in the beginning of a fixed valuation period will have a greater negative influence on the net present value than the same outflow later in the valuation period. The net present value therefore captures the importance of scope of a capital investment on the profitability of an investment and is particularly useful in comparing mutually exclusive investments[10] (Brigham & Daves, 2007:401). The latter use of NPV is thus in accord with comparing alternate wine grape production systems, which are typically "path dependent" and hence mutually exclusive.

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[8] The payback period is defined as the expected number of years required to recover the original investment.

[9] The time value of money principle, basically states that an amount of money today is worth more than the same amount tomorrow (after an extended period of time). The latter can be attributed due to inflation (the general rise in prices over time eroding away at purchase power), risk and opportunity cost of capital (Boehlje & Eidman, 1984:319)

[10] Mutually exclusive projects or investments imply that if one investment or project is chosen all others must be rejected.

Net present value can be formally expressed as:

$$NPV = IV_0 + \frac{CF_1}{(1+r)^1} + \frac{CF_2}{(1+r)^2} + \cdots + \frac{CF_n}{(1+r)^n} + \frac{TV_n}{(1+r)^n}$$

Where IV_0 is the initial capital investment value at the beginning of year one at time zero, CF_1 the net cash flow at the end of year one, r the discount rate and TV_n the termination value of the capital investment at the end of the valuation period (Brigham & Daves, 2007:403). IV_0 represents the total initial capital outlay required in fixed and moveable assets for the farm business. Similarly CF_1 to CF_n represents the net cash flow after tax accrued back to the farm business at the end of each year and TV_n value of the simulated sale of the farm business at the end of the evaluation period. The latter is in agreement with theory that a big part of the return on agricultural investment is attributed to the appreciation of farmland (refer to Section 3.2.2).

However as can be seen from the NPV equation the use of the NPV method for performance measurement is heavily dependent on the discount rate that is used. This is due to future flows of income, being adjusted back by the discount rate to their present value (Boehlje & Eidman, 1984:321). As such the chosen discount rate should essentially indicate the “cut-off criterion” or minimum acceptable rate of return for an investment, that is the cost of capital of the farm business (Boehlje & Eidman, 1984:321). In order to establish the latter the weighted average cost of capital (WACC) is used which accurately reflects the long-run direct cost of debt as well as opportunity cost of funds (refer to Section 3.3.2).

An implicit advantage of using the WACC as a discount rate in NPV evaluations is that it essentially reflects the method of financing and tax deductibility of interest (Boehlje & Eidman, 1984:323). Therefore net cash flow after tax and before interest and principal payments should be used to avoid double counting the tax deductibility of interest and benefits of financing arrangements (Boehlje & Eidman, 1984:324). Similarly depreciation enters the NPV calculation indirectly through its influence on the tax liability or savings of an investment (Boehlje & Eidman, 1984:324).

For the NPV calculations inflation however remains a contentious issue with no unanimity between analysts whether computations should be done in nominal or “real” terms (Boehlje & Eidman, 1984:325). Therefore since discount rates as calculated through the WACC method are nominal and reflects current expectations of inflation, the estimation of future cash income and cash expenses should also reflect inflation for inputs and outputs (Boehlje & Eidman, 1984:323). In solidarity with the preceding if NPV evaluations are to be done in “real” terms the discount rate needs to be reduced by the expected rate of inflation (Boehlje & Eidman, 1984:325).

However in the endeavour of doing feasibility analyses, making use of nominal values have a major advantage (Boehlje & Eidman, 1984:326). The latter is due to financial feasibility analyses comparing the annual net cash flow in each year to the required principal and interest payments in nominal terms (Boehlje & Eidman, 1984:326). As result the calculation of cash flows in nominal terms during the economic profitability phase, allows for the same cash flows to be used in the financial feasibility phase (Boehlje & Eidman, 1984:326).

Regardless if evaluation in nominal or "real" terms are chosen the rationale for using NPV as a performance measure of evaluating alternate investment and wine grape production systems is straightforward. A NPV of zero typically implies that an investments cash flow is sufficient to repay the invested capital and to provide the required rate of return on that capital (Brigham & Daves, 2007:404). When then comparing alternate investment and wine production systems, investments that lead to a higher NPV should typically be selected (Brigham & Daves, 2007:404). In the endeavour of measuring alternate investment and wine grape production systems, NPV have been illustrated to be valuable in comparing alternate wine grape production systems. However performance measurement on the basis of NPV alone can be tedious to interpret as it is dependent on the size of the initial investment. In addition, as illustrated the use of NPV evaluations is discount rate specific.

The use of a higher discount rate will typically place greater weight on current cash flows, whilst the use of a lower discount rate would place less value on the time value of cash flows. By then using altering discount rates, a disparity in time preference and NPV are facilitated. To overcome the discount rate problem, the use of NPV can be supplemented by the use of internal rate of return (IRR), which will be considered in the following section.

3.3.5.3 The internal rate of return method

The internal rate of return method is an alternative economic profitability measure and can be defined as the discount rate that forces NPV to be zero, formally expressed as:

$$CF_0 + \frac{CF_1}{(1+IRR)^1} + \frac{CF_2}{(1+IRR)^2} + \cdots + \frac{CF_n}{(1+IRR)^n} + \frac{TV_n}{(1+IRR)^n} = 0$$

$$NPV = \sum_{t=0}^{n} \frac{CF_t}{(1+IRR)^t} = 0$$

The rationale behind the use of IRR is behind the embedded "break-even" characteristic of IRR which makes it valuable in evaluating capital projects (Brigham & Daves, 2007:406). Simply put the IRR on an investment is its expected rate of return. If the IRR exceeds the cost of funds used to finance an investment a surplus would remain which is accrued to the farm business (Brigham & Daves, 2007:406). Depending on the scarcity of capital and availability of other viable non-mutually exclusive projects with a IRR exceeding cost of capital will usually be accepted (Boehlje & Eidman, 1984:331).

As a concluding comment on NPV and IRR it is important to ascertain that investments can be mutually exclusive, which may lead to the acceptance of investments with lower (but still above farm average and cost of capital) IRR's (Brigham & Daves, 2007:409). Similarly care must be taken when calculating IRR's for investment projects with non-normal[11] cash flows, which may lead to the calculation of multiple IRR's (Brigham & Daves, 2007:410). Despite this criticism and NPV valuation being better than IRR in multiple respects, IRR are widely used by corporate executives and widely entrenched in industry (Brigham & Daves, 2007:409)

3.3.5.4 Financial feasibility evaluations

Upon the completion of the evaluation- of and establishment of the economic profitability of an investment project, its financial feasibility should be analysed (Boehlje & Eidman, 1984:332). Financial feasibility analyses are typically done in a farm business context, to establish if an investment project is likely to generate sufficient cash income, to cover the principal and interest payments[12] so that acceptance would not lead to liquidity problems (Boehlje & Eidman, 1984:332).

A financial feasibility analysis involves matching the annual net cash flows after tax, to the annual debt repayment schedule after tax to establish if a cash deficit will occur (Boehlje & Eidman, 1984:332). If a cash surplus results for each year of the evaluation and debt recovery period, the investment project will generate sufficient cash flow to cover debt repayments and consequently be financially feasible (Boehlje & Eidman, 1984:333). The latter would then imply an investment project is evaluated to be economically profitable and financially feasible and as such adoption should usually not be accompanied with a cause of liquidity problems.

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[11] Non-normal cash flows occur when there is more than one change in sign of cash flows. The latter is typical of the variability and risk involved in agriculture.

[12] The latter is if debt capital is used. If all investments in the farm business is financed through equity it is not necessary to perform financial feasibility analyses.

CHAPTER 4: DEVELOPMENT AND DESCRIPTION OF THE SIMULATION MODEL FOR WINE GRAPE PRODUCTION SYSTEM EVALUATION

4.1 Introduction

In Chapter 2 systems theory and simulation modelling is demonstrated to be an appropriate basis for evaluating agricultural systems. In Chapter 3 the wine grape production system was described followed by a detailed discussion of trellis and training systems. The prominence of the viticultural and trellis decision is subsequently depicted to have an implication for the path dependence or structural rigidity of the wine grape production system. Chapter 3 concluded with a commensurate discussion of the importance of the composition and application of capital within the wine grape production system.

In view of the above, a model which suffices as an instrument for evaluating different grape production systems needs to allow for the core biological processes in the system and then convert these processes into a measureable financial outcome. This should be attempted without over-simplifying the complex agricultural environment as commonly found in agricultural-economic analyses.

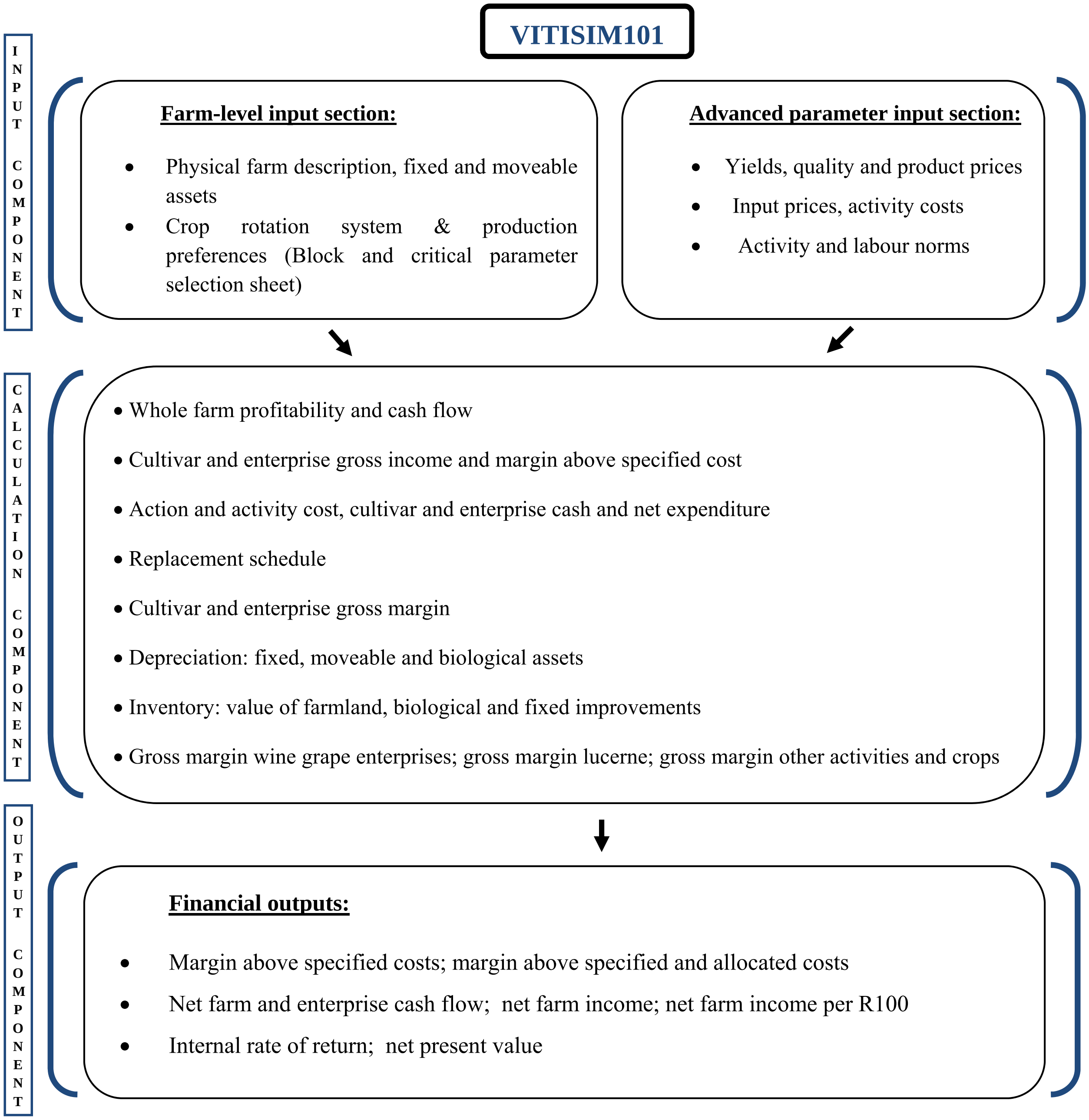
In the endeavour of the above, the model developed for this thesis was developed to be sophisticated enough to allow a great amount of freedom to adapt practices and also to adjust the model to individual farm-specific preferences, conditions and circumstances. Financial results are used as the measurable outcome, with the three key financial performance drivers of the farm business being the cash flow, various margins and the capital structure (refer to Figure 4.1).

The standard developed for evaluating the different paths is a simulation model, capable of simulating the long-term financial impact of different wine grape production systems. Alternative paths are elected by the choice of trellising systems, which largely pre-determine the structural composition of capital and labour as well as other cultivation practices in the wine grape production system.

4.2 The description of VITISIM101

The model, called VITISIM101, meaning Viticultural Simulator 101, was developed as partial fulfilment of the requirements for this thesis. VITISIM101 is a whole farm multi-period budget simulation model which is able to account for various production systems and methods, economies of size and a structural transition from one type of wine grape production system to another. Granting that VITISIM101 is not an optimisation model, VITISIM101 encapsulates the operational effect of what can be considered a strategic decision, to either pursue capital or labour intensive production practices.

The VITISIM101 farm-level model can be graphically illustrated to be consisting of three basic blocks or components, namely an input-, calculation- and output component. The graphical representation can be seen in Figure 4.1



Farm-level input section:

- Physical farm description, fixed and moveable assets
- Crop rotation system & production preferences (Block and critical parameter selection sheet)

Advanced parameter input section:

- Yields, quality and product prices
- Input prices, activity costs
- Activity and labour norms

- Whole farm profitability and cash flow
- Cultivar and enterprise gross income and margin above specified cost
- Action and activity cost, cultivar and enterprise cash and net expenditure
- Replacement schedule
- Cultivar and enterprise gross margin
- Depreciation: fixed, moveable and biological assets
- Inventory: value of farmland, biological and fixed improvements
- Gross margin wine grape enterprises; gross margin lucerne; gross margin other activities and crops

Financial outputs:

- Margin above specified costs; margin above specified and allocated costs
- Net farm and enterprise cash flow; net farm income; net farm income per R100
- Internal rate of return; net present value

Figure 4.1: A graphical representation of the components of the VITISIM101 model

As the structure of the model suggests, outcomes and performance measures are represented in financial terms in order to consider alternative production systems or "paths". However to enable the latter the VITISIM101 simulation model requires the specification of specific measurable farm-level features. It was initially considered to enable stochastic budgeting into the VITISM101 model, as is deemed necessary for robust simulation models (refer to Section 2.3.4). However, upon finalisation of the model outcomes, it became apparent that due to the level of variables already incorporated, incorporation of any further variability would confuse the identification of the relative effect of changing individual variables. In view of the above there was also refrained of an additional functionality of the VITISIM101 model, which permit the specification of alternate lifetimes to individual blocks. The former functionality would be able to be of added value.

In addition, due to VITISIM101 being tailored to be farm-level and farm business specific, the prevalence of undesirable consequences borne by the external environment are likely to be systemic. This can be attributed to the fact that most wine grape producers and the biggest part of the wine harvest are delivered to co-operative or producer wine cellars, characteristically with fixed marketing arrangements. The latter marketing arrangements typically involve bulk wine sale contracts, with a single large buyer monopolistically dominating the South African wine industry. Individual wine grape producers can therefore do little to influence their output price and similarly are too small to have an impact on the price of inputs and be considered price takers. Correspondingly high plant densities and the nature of the grapevine, make systemic spread of and application of disease control necessary regardless of the particular trellis system. Unfavourable natural conditions during critical periods per region in season are then likely to affect all grapevines.

Thus the omitting of stochasticity would not drastically affect the evaluation of alternate wine grape production systems relative to one another. On the contrary it can be argued to aid in the depiction of the effect of specific variables and changes in the wine grape production system, with the culminated effect that better investment and wine grape system analysis can be done. As for the purposes of this thesis, the deterministic use of VITISIM101 as a multi-period budgeting model will be discussed. VITISIM101 was constructed in Microsoft Excel® in such a way so that it can deliver deterministic simulations for use as long-term projections. These projections based on specific assumptions are then used to evaluate the chosen production, management and investment or capital expenditure decisions. Accordingly the model will be described along the following three components.

4.3 The input component

The input component consists of two sub-components, a "farm-level input" and an "advanced parameter input section."

4.3.1 Farm-level input section

The farm-level input section[13] requires the user to complete a description of the farm's natural endowment, such as the physical farmland area, water rights as well as the assignment of an estimated value to each at the start of the evaluation period (refer to Table 4.1).

In addition all fixed and moveable assets, with their construction or purchase date with the current age at purchase, need to be indicated in the inventory. A purchase value as well as a replacement value also needs to be allotted to each item.

Table 4.1: The initial value of farmland and total initial capital investment table

Intial value of farmland	**Initial year value (R/ha)**	**Area (ha)**	**Total Value (R)**
Own land (cultivated)	R 100 000	80	R 8 000 000
Own Land (Idle, arable level)	R 25 000	10	R 250 000
Own land (veld)	R 5 000	300	R 1 500 000
Own land (waste)	R 8 000	11	R 88 000
Own Land (leased)	R 25 000	20	R 500 000
Land Hired	R 25 000	0	R -
Total			**R 10 338 000**
Total initial capital investment summary			**Total Value (R)**
Total farmland value			R 10 338 000
Biological improvements			R 3 012 696
Water rights value			R 8 092 200
Moveable assets			R 3 126 226
Total			**R 24 569 122**

The second sub-component of the "farm-level input section" requires the operator to complete "the block and critical parameter selection sheet". This sheet serves as the base sheet for all subsequent years of the simulation period. All cultivatable land is herein divided into a maximum of 50 block descriptions with accompanied designations required of each block's area, establishment date, crop and or cultivar, land use patterns, crop rotation system, trellis and cultivation practices (refer to Table 4.2). Most cell assignments are selected by means of drop down menus determined in the "advanced parameter input section." In circumstances requiring less than 50 blocks a block area of 0 is designated. Subsequent periods are linked to the "block and critical parameter selection sheet", which is also the profile for the first simulation period via a variety of functions, with any change resulting in an automated change in all subsequent periods.

4.3.2 Advanced parameter input section

Under the "advanced parameter input section" the user can select an assortment of changes to the model. For the purpose of this thesis only the advanced viticultural parameter inputs shall be depicted in this section. This ranges from cultivar, trellis and crop name label inputs to that of crop yields, quality allocation and product prices for specific years in the simulation period.

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[13] For analysis VITISIM101 requires that the total area (hectares) of cultivatable farmland as indicated in Table 4.1 corresponds with the total area cultivated as designated in the block and critical parameter selection sheet illustrated in Table 4.2.

Table 4.2: The block and critical parameter selection sheet

Land Usage:							Crop Rotation Practices													Vineyard cultivation preferences			
Block	Area (ha)	Initial Block Establishment Date	Current Crop	Current Crop Age	Crop (1) (Intitial)	Life* Cycle (1)	Replacement date: Crop 1	Crop (2)	Life* Cycle (2)	Replacement date: Crop (2)	Crop (3)	Life* Cycle (3)	Replacement date: Crop (3)	Crop (4)	Life* Cycle (4)	Replacement date: Crop (4)	Current Trellis System	Initial Trellis System	Follow-up Trellis System	Harvesting	Foliage Management	Pruning	YVD² years
1	2.5	1994/01/01	Chenin Blanc	20	Chenin Blanc	20	2014/01/01	Lucerne	4	2018/01/01	Chardonnay	20	2038/01/01	Chenin Blanc	16	2054/01/01	VSP	VSP	VSP	By Hand	By Hand	By Hand	2
2	2.5	1995/01/01	Colombar	19	Colombar	20	2015/01/01	Lucerne	4	2019/01/01	Colombar	20	2039/01/01	None (Idle)	7	2046/01/01	VSP	VSP	VSP	By Hand	By Hand	By Hand	2
3	2.5	1996/01/01	Sauvignon Blanc	18	Sauvignon Blanc	20	2016/01/01	Lucerne	4	2020/01/01	Shiraz	20	2040/01/01	None (Idle)	7	2047/01/01	VSP	VSP	VSP	By Hand	By Hand	By Hand	2
4	2.5	1997/01/01	Cabernet Sauvignon	17	Cabernet Sauvignon	20	2017/01/01	Lucerne	4	2021/01/01	Colombar	20	2041/01/01	None (Idle)	7	2048/01/01	VSP	VSP	VSP	By Hand	By Hand	By Hand	2
5	2.5	1998/01/01	Chardonnay	16	Chardonnay	20	2018/01/01	Lucerne	4	2022/01/01	Chenin Blanc	20	2042/01/01	None (Idle)	7	2049/01/01	VSP	VSP	VSP	By Hand	By Hand	By Hand	2
6	2.5	1999/01/01	Colombar	15	Colombar	20	2019/01/01	Lucerne	4	2023/01/01	Shiraz	20	2043/01/01	None (Idle)	7	2050/01/01	VSP	VSP	VSP	By Hand	By Hand	By Hand	2
7	2.5	2000/01/01	Shiraz	14	Shiraz	20	2020/01/01	Lucerne	4	2024/01/01	Chardonnay	20	2044/01/01	None (Idle)	7	2051/01/01	VSP	VSP	VSP	By Hand	By Hand	By Hand	2
8	2.5	2001/01/01	Colombar	13	Colombar	20	2021/01/01	Lucerne	4	2025/01/01	Chenin Blanc	20	2045/01/01	None (Idle)	7	2052/01/01	VSP	VSP	VSP	By Hand	By Hand	By Hand	2
9	2.5	2002/01/01	Chenin Blanc	12	Chenin Blanc	20	2022/01/01	Lucerne	4	2026/01/01	Cabernet Sauvignon	20	2046/01/01	None (Idle)	7	2053/01/01	VSP	VSP	VSP	By Hand	By Hand	By Hand	2
10	2.5	2003/01/01	Shiraz	11	Shiraz	20	2023/01/01	Lucerne	4	2027/01/01	Colombar	20	2047/01/01	None (Idle)	7	2054/01/01	VSP	VSP	VSP	By Hand	By Hand	By Hand	2
11	2.5	2004/01/01	Chardonnay	10	Chardonnay	20	2024/01/01	Lucerne	4	2028/01/01	Shiraz	20	2048/01/01	None (Idle)	7	2055/01/01	VSP	VSP	VSP	By Hand	By Hand	By Hand	2
12	2.5	2005/01/01	Chenin Blanc	9	Chenin Blanc	20	2025/01/01	Lucerne	4	2029/01/01	Shiraz	20	2049/01/01	None (Idle)	7	2056/01/01	VSP	VSP	VSP	By Hand	By Hand	By Hand	2
13	2.5	2006/01/01	Cabernet Sauvignon	8	Cabernet Sauvignon	20	2026/01/01	Lucerne	4	2030/01/01	Chenin Blanc	20	2050/01/01	None (Idle)	7	2057/01/01	VSP	VSP	VSP	By Hand	By Hand	By Hand	2
14	2.5	2007/01/01	Colombar	7	Colombar	20	2027/01/01	Lucerne	4	2031/01/01	Shiraz	20	2051/01/01	None (Idle)	7	2058/01/01	VSP	VSP	VSP	By Hand	By Hand	By Hand	2
15	2.5	2008/01/01	Shiraz	6	Shiraz	20	2028/01/01	Lucerne	4	2032/01/01	Colombar	20	2052/01/01	None (Idle)	7	2059/01/01	VSP	VSP	VSP	By Hand	By Hand	By Hand	2
16	2.5	2009/01/01	Shiraz	5	Shiraz	20	2029/01/01	Lucerne	4	2033/01/01	Cabernet Sauvignon	20	2053/01/01	None (Idle)	7	2060/01/01	VSP	VSP	VSP	By Hand	By Hand	By Hand	2
17	2.5	2010/01/01	Chenin Blanc	4	Chenin Blanc	20	2030/01/01	Lucerne	4	2034/01/01	Chenin Blanc	20	2054/01/01	None (Idle)	7	2061/01/01	VSP	VSP	VSP	By Hand	By Hand	By Hand	2
18	2.5	2011/01/01	Shiraz	3	Shiraz	20	2031/01/01	Lucerne	4	2035/01/01	Colombar	20	2055/01/01	None (Idle)	7	2062/01/01	VSP	VSP	VSP	By Hand	By Hand	By Hand	2
19	2.5	2012/01/01	Colombar	2	Colombar	20	2032/01/01	Lucerne	4	2036/01/01	Sauvignon Blanc	20	2056/01/01	None (Idle)	7	2063/01/01	VSP	VSP	VSP	By Hand	By Hand	By Hand	2
20	2.5	2013/01/01	Cabernet Sauvignon	1	Cabernet Sauvignon	20	2033/01/01	Lucerne	4	2037/01/01	Cabernet Sauvignon	20	2057/01/01	None (Idle)	7	2064/01/01	VSP	VSP	VSP	By Hand	By Hand	By Hand	2
21	2.5	2010/01/01	Lucerne	4	Lucerne	4	2014/01/01	Chenin Blanc	20	2034/01/01	None (Idle)	21	2055/01/01	None (Idle)	7	2062/01/01	VSP	VSP	VSP	By Hand	By Hand	By Hand	2
22	2.5	2011/01/01	Lucerne	3	Lucerne	4	2015/01/01	Colombar	20	2035/01/01	None (Idle)	20	2055/01/01	None (Idle)	7	2062/01/01	VSP	VSP	VSP	By Hand	By Hand	By Hand	2
23	2.5	2012/01/01	Lucerne	2	Lucerne	4	2016/01/01	Sauvignon Blanc	20	2036/01/01	None (Idle)	1	2037/01/01	None (Idle)	20	2057/01/01	VSP	VSP	VSP	By Hand	By Hand	By Hand	2
24	2.5	2013/01/01	Lucerne	1	Lucerne	4	2017/01/01	Cabernet Sauvignon	20	2037/01/01	None (Idle)	4	2041/01/01	None (Idle)	20	2061/01/01	VSP	VSP	VSP	By Hand	By Hand	By Hand	2
25	2.5	2012/01/01	Lucerne	2	Lucerne	4	2016/01/01	None (Idle)	1	2017/01/01	Lucerne	4	2021/01/01	None (Idle)	20	2041/01/01	VSP	VSP	VSP	By Hand	By Hand	By Hand	2
26	2.5	2011/01/01	Lucerne	3	Lucerne	4	2015/01/01	None (Idle)	1	2016/01/01	Lucerne	4	2020/01/01	None (Idle)	20	2040/01/01	VSP	VSP	VSP	By Hand	By Hand	By Hand	2
27	2.5	2010/01/01	Lucerne	4	Lucerne	4	2014/01/01	None (Idle)	1	2015/01/01	Lucerne	4	2019/01/01	None (Idle)	20	2039/01/01	VSP	VSP	VSP	By Hand	By Hand	By Hand	2
28	2.5	2013/01/01	Lucerne	1	Lucerne	4	2017/01/01	None (Idle)	1	2018/01/01	Lucerne	4	2022/01/01	None (Idle)	20	2042/01/01	VSP	VSP	VSP	By Hand	By Hand	By Hand	2
29	2.5	2012/01/01	Lucerne	2	Lucerne	4	2016/01/01	None (Idle)	1	2017/01/01	Lucerne	4	2021/01/01	None (Idle)	21	2042/01/01	VSP	VSP	VSP	By Hand	By Hand	By Hand	2
30	2.5	2011/01/01	Lucerne	3	Lucerne	4	2015/01/01	None (Idle)	1	2016/01/01	Lucerne	4	2020/01/01	None (Idle)	20	2040/01/01	VSP	VSP	VSP	By Hand	By Hand	By Hand	2
31	2.5	2010/01/01	Lucerne	4	Lucerne	4	2014/01/01	None (Idle)	1	2015/01/01	Lucerne	4	2019/01/01	None (Idle)	20	2039/01/01	VSP	VSP	VSP	By Hand	By Hand	By Hand	2
32	2.5	2013/01/01	Lucerne	1	Lucerne	4	2017/01/01	None (Idle)	1	2018/01/01	Lucerne	4	2022/01/01	None (Idle)	20	2042/01/01	VSP	VSP	VSP	By Hand	By Hand	By Hand	2
33	2.5	2014/01/01	None (Idle)	0	None (Idle)	7	2021/01/01	Lucerne	4	2025/01/01	None (Idle)	1	2026/01/01	Lucerne	4	2030/01/01	VSP	VSP	VSP	By Hand	By Hand	By Hand	2
34	2.5	2014/01/01	None (Idle)	0	None (Idle)	5	2019/01/01	Lucerne	4	2023/01/01	None (Idle)	1	2024/01/01	Lucerne	4	2028/01/01	VSP	VSP	VSP	By Hand	By Hand	By Hand	2
35	2.5	2013/01/01	None (Idle)	1	None (Idle)	1	2014/01/01	Lucerne	4	2018/01/01	None (Idle)	1	2019/01/01	Lucerne	4	2023/01/01	VSP	VSP	VSP	By Hand	By Hand	By Hand	2
36	2.5	2014/01/01	None (Idle)	0	None (Idle)	6	2020/01/01	Lucerne	4	2024/01/01	None (Idle)	1	2025/01/01	Lucerne	4	2029/01/01	VSP	VSP	VSP	By Hand	By Hand	By Hand	2
37	2.5	2013/01/01	None (Idle)	1	None (Idle)	1	2014/01/01	Lucerne	4	2018/01/01	None (Idle)	2	2020/01/01	Lucerne	4	2024/01/01	VSP	VSP	VSP	By Hand	By Hand	By Hand	2
38	2.5	2014/01/01	None (Idle)	0	None (Idle)	7	2021/01/01	Lucerne	4	2025/01/01	None (Idle)	1	2026/01/01	Lucerne	4	2030/01/01	VSP	VSP	VSP	By Hand	By Hand	By Hand	2
39	2.5	2014/01/01	None (Idle)	0	None (Idle)	8	2022/01/01	Lucerne	4	2026/01/01	None (Idle)	1	2027/01/01	Lucerne	4	2031/01/01	VSP	VSP	VSP	By Hand	By Hand	By Hand	2
40	2.5	2014/01/01	None (Idle)	0	None (Idle)	8	2022/01/01	Lucerne	4	2026/01/01	None (Idle)	1	2027/01/01	Lucerne	4	2031/01/01	VSP	VSP	VSP	By Hand	By Hand	By Hand	2
41	2.5	2014/01/01	None (Idle)	0	None (Idle)	10	2024/01/01	Lucerne	4	2028/01/01	None (Idle)	1	2029/01/01	Lucerne	4	2033/01/01	VSP	VSP	Smart-Dyson	By Hand	By Hand	By Hand	2
42	5	2014/01/01	None (Idle)	0	None (Idle)	14	2028/01/01	Lucerne	4	2032/01/01	None (Idle)	1	2033/01/01	Lucerne	4	2037/01/01	VSP	VSP	Smart-Dyson	By Hand	By Hand	By Hand	2
43	2.5	2014/01/01	None (Idle)	0	None (Idle)	9	2023/01/01	Lucerne	4	2027/01/01	None (Idle)	4	2031/01/01	Lucerne	4	2035/01/01	VSP	VSP	Smart-Dyson	By Hand	By Hand	By Hand	2
44	2.5	2014/01/01	None (Idle)	0	None (Idle)	9	2023/01/01	Lucerne	4	2027/01/01	None (Idle)	3	2030/01/01	Lucerne	4	2034/01/01	VSP	VSP	Smart-Dyson	By Hand	By Hand	By Hand	2
45	2.5	2014/01/01	None (Idle)	0	None (Idle)	11	2025/01/01	Lucerne	4	2029/01/01	None (Idle)	1	2030/01/01	Lucerne	4	2034/01/01	VSP	VSP	Smart-Dyson	By Hand	By Hand	By Hand	2
46	2.5	2013/01/01	None (Idle)	1	None (Idle)	16	2029/01/01	Lucerne	4	2033/01/01	None (Idle)	1	2034/01/01	Lucerne	20	2054/01/01	VSP	VSP	Smart-Dyson	By Hand	By Hand	By Hand	2
47	2.5	2013/01/01	None (Idle)	1	None (Idle)	18	2031/01/01	Lucerne	4	2035/01/01	None (Idle)	20	2055/01/01	None (Idle)	20	2075/01/01	VSP	VSP	Smart-Dyson	By Hand	By Hand	By Hand	2
48	5	2013/01/01	None (Idle)	1	None (Idle)	19	2032/01/01	Lucerne	4	2036/01/01	None (Idle)	20	2056/01/01	None (Idle)	20	2076/01/01	VSP	VSP	Smart-Dyson	By Hand	By Hand	By Hand	2
49	0	2013/01/01	Lucerne	1	Lucerne	5	2018/01/01	Colombar	20	2038/01/01	Lucerne	4	2042/01/01	Colombar	20	2062/01/01	VSP	VSP	Smart-Dyson	By Hand	By Hand	By Hand	2
50	0	2013/01/01	Lucerne	1	Lucerne	5	2018/01/01	Chenin Blanc	20	2038/01/01	Lucerne	4	2042/01/01	Chenin Blanc	20	2062/01/01	VSP	VSP	Smart-Dyson	By Hand	By Hand	By Hand	2

*Life Cycle as measured in years; ²Young Vine Development (YVD)

Table 4.3,“the projected cultivar trellis combination yield per hectare” depicts the yield input sheet. This sheet allows for 60 trellis cultivar combinations with a corresponding age dependent yield for the combination and allows for the increasing and decreasing productivity of the vine over its lifetime. Depending on the block specific designation made in Table 4.2 VITSIM101 then looks-up the applicable cultivar, trellis and age dependent, yield per hectare, tonnage per class and price per ton.

The second viticultural aspect of the “advanced parameter input section” allows for the introduction of trellis and cultivar specific quality parameters (refer to Table 4.4). The model allows the allocation into six different classes and the assignment of a bonus per ton for early produce deliveries, with Class 1 being the highest grading grapes can attain at the cellar, Class 5 the lowest and class LA being a special class for grapes intended for low alcohol wine.

Within the quality input sheet it is also possible to assign different percentages of classes being attained on alternate trellis systems. Hence trellis and cultivar combinations prone to better quality grapes would be assigned higher ratios of Class 1 and fewer of Class 5. The model therefore allows for discrepancies between systems which could be attributed to better aerated canopies and less disease pressure.

The last viticultural component of the “advanced parameter input section” allows for the allocation of cultivar and class specific prices per ton. These prices are specified for all ten cultivars allowed for by the model. After any alterations these three tables of the “advanced parameter input section” needs to be refreshed as they are used as pivots in the calculation block. Due to the sensitive nature of cultivar prices per ton fictional prices and not the actual prices obtained and used for this study will be illustrated in Table 4.5 as an example.

The class specific payment per ton for Chardonnay is illustrated in Table 4.5.

Table 4.3: The projected cultivar trellis combination yield in tonnes per hectare

Cultivar	Trellis	YR1	YR2	YR3	YR4	YR5	YR6	YR7	YR8	YR9	YR10	YR11	YR12	YR13	YR14	YR15	YR16	YR17	YR18	YR19	YR20
Chardonnay	Lyre	0.0	0.0	5.7	13.0	16.0	20.7	21.8	22.8	23.5	21.9	21.3	21.2	21.3	21.1	20.9	20.6	19.8	19.1	19.1	18.4
Chardonnay	Smart-Dyson	0.0	0.0	5.3	12.0	14.8	19.1	20.1	21.0	21.7	20.3	19.7	19.6	19.7	19.4	19.3	19.0	18.3	17.6	17.7	17.0
Chardonnay	VSP	0.0	0.0	4.4	10.0	12.3	15.9	16.8	17.5	18.1	16.9	16.4	16.3	16.4	16.2	16.1	15.8	15.2	14.7	14.7	14.2
Chardonnay	Ballerina	0.0	0.0	5.7	13.0	16.0	20.7	21.8	22.8	23.5	21.9	21.3	21.2	21.3	21.1	20.9	20.6	19.8	19.1	19.1	18.4
Chardonnay	Gable	0.0	0.0	6.6	15.0	18.5	23.8	25.2	26.3	27.1	25.3	24.6	24.5	24.6	24.3	24.2	23.7	22.8	22.0	22.1	21.3
Chardonnay	High-Wire	0.0	0.0	5.9	13.5	16.6	21.5	22.7	23.7	24.4	22.8	22.2	22.0	22.1	21.9	21.7	21.4	20.5	19.8	19.9	19.2
Chenin Blanc	Lyre	0.0	4.1	16.9	31.0	32.5	41.4	35.8	32.2	32.3	36.5	33.8	34.9	28.8	27.8	31.0	29.5	27.1	23.7	24.3	21.8
Chenin Blanc	Smart-Dyson	0.0	3.8	15.6	28.6	30.0	38.2	33.0	29.7	29.8	33.7	31.2	32.2	26.6	25.7	28.6	27.3	25.0	21.9	22.4	20.1
Chenin Blanc	VSP	0.0	3.1	13.0	23.8	25.0	31.9	27.5	24.8	24.9	28.1	26.0	26.8	22.2	21.4	23.9	22.7	20.9	18.2	18.7	16.7
Chenin Blanc	Ballerina	0.0	4.1	16.9	31.0	32.5	41.4	35.8	32.2	32.3	36.5	33.8	34.9	28.8	27.8	31.0	29.5	27.1	23.7	24.3	21.8
Chenin Blanc	Gable	0.0	4.7	19.5	35.8	37.5	47.8	41.3	37.2	37.3	42.2	39.0	40.2	33.3	32.1	35.8	34.1	31.3	27.3	28.1	25.1
Chenin Blanc	High-Wire	0.0	4.2	17.5	32.2	33.8	43.0	37.2	33.5	33.5	37.9	35.1	36.2	30.0	28.9	32.2	30.7	28.2	24.6	25.2	22.6
Colombar	Lyre	0.0	0.0	15.5	27.9	40.2	42.9	46.0	45.1	43.1	41.8	39.9	36.6	36.3	36.0	34.3	34.8	32.7	29.9	28.2	27.1
Colombar	Smart-Dyson	0.0	0.0	14.3	25.7	37.1	39.6	42.4	41.6	39.8	38.6	36.8	33.8	33.5	33.2	31.7	32.1	30.2	27.6	26.0	25.0
Colombar	VSP	0.0	0.0	11.9	21.5	31.0	33.0	35.4	34.7	33.1	32.2	30.7	28.1	27.9	27.7	26.4	26.8	25.2	23.0	21.7	20.8
Colombar	Ballerina	0.0	0.0	15.5	27.9	40.2	42.9	46.0	45.1	43.1	41.8	39.9	36.6	36.3	36.0	34.3	34.8	32.7	29.9	28.2	27.1
Colombar	Gable	0.0	0.0	17.9	32.2	46.4	49.5	53.0	52.0	49.7	48.2	46.0	42.2	41.9	41.5	39.6	40.1	37.7	34.5	32.6	31.2
Colombar	High-Wire	0.0	0.0	16.1	29.0	41.8	44.5	47.7	46.8	44.7	43.4	41.4	38.0	37.7	37.4	35.6	36.1	34.0	31.0	29.3	28.1
Shiraz	Lyre	0.0	0.0	16.1	19.3	20.4	21.9	22.5	23.3	22.1	22.3	23.5	25.2	23.2	21.2	20.7	18.2	17.8	17.3	15.5	14.7
Shiraz	Smart-Dyson	0.0	0.0	14.9	17.8	18.9	20.2	20.8	21.5	20.4	20.6	21.7	23.3	21.4	19.6	19.1	16.8	16.5	16.0	14.3	13.5
Shiraz	VSP	0.0	0.0	12.4	14.9	15.7	16.9	17.3	17.9	17.0	17.2	18.1	19.4	17.9	16.3	15.9	14.0	13.7	13.3	11.9	11.3
Shiraz	Ballerina	0.0	0.0	16.1	19.3	20.4	21.9	22.5	23.3	22.1	22.3	23.5	25.2	23.2	21.2	20.7	18.2	17.8	17.3	15.5	14.7
Shiraz	Gable	0.0	0.0	18.6	22.3	23.6	25.3	26.0	26.9	25.5	25.8	27.1	29.1	26.8	24.5	23.9	21.0	20.6	20.0	17.9	16.9
Shiraz	High-Wire	0.0	0.0	16.8	20.1	21.2	22.8	23.4	24.2	22.9	23.2	24.4	26.2	24.1	22.0	21.5	18.9	18.5	18.0	16.1	15.2
Sauvignon Blanc	Lyre	0.0	0.0	11.7	19.5	22.3	27.8	30.1	28.0	28.6	27.2	26.2	25.9	24.1	23.5	22.9	22.2	22.1	21.4	21.7	20.5
Sauvignon Blanc	Smart-Dyson	0.0	0.0	10.8	18.0	20.6	25.7	27.8	25.8	26.4	25.1	24.2	23.9	22.2	21.7	21.1	20.5	20.4	19.7	20.0	18.9
Sauvignon Blanc	VSP	0.0	0.0	9.0	15.0	17.1	21.4	23.2	21.5	22.0	20.9	20.2	19.9	18.5	18.1	17.6	17.1	17.0	16.5	16.7	15.8
Sauvignon Blanc	Ballerina	0.0	0.0	11.7	19.5	22.3	27.8	30.1	28.0	28.6	27.2	26.2	25.9	24.1	23.5	22.9	22.2	22.1	21.4	21.7	20.5
Sauvignon Blanc	Gable	0.0	0.0	13.5	22.5	25.7	32.1	34.8	32.3	33.0	31.4	30.2	29.8	27.8	27.1	26.4	25.6	25.5	24.7	25.1	23.6
Sauvignon Blanc	High-Wire	0.0	0.0	12.2	20.3	23.1	28.9	31.3	29.1	29.7	28.2	27.2	26.9	25.0	24.4	23.7	23.0	23.0	22.2	22.5	21.3
Cabernet Sauvignon	Lyre	0.0	0.0	7.3	13.7	14.8	15.8	14.9	17.2	17.9	19.5	19.3	18.6	17.8	17.1	16.7	15.8	14.3	13.4	13.1	13.0
Cabernet Sauvignon	Smart-Dyson	0.0	0.0	6.7	12.7	13.6	14.6	13.8	15.9	16.5	18.0	17.8	17.1	16.5	15.8	15.4	14.6	13.2	12.3	12.1	12.0
Cabernet Sauvignon	VSP	0.0	0.0	5.6	10.6	11.4	12.1	11.5	13.3	13.8	15.0	14.9	14.3	13.7	13.2	12.9	12.1	11.0	10.3	10.1	10.0
Cabernet Sauvignon	Ballerina	0.0	0.0	7.3	13.7	14.8	15.8	14.9	17.2	17.9	19.5	19.3	18.6	17.8	17.1	16.7	15.8	14.3	13.4	13.1	13.0
Cabernet Sauvignon	Gable	0.0	0.0	8.4	15.8	17.0	18.2	17.2	19.9	20.7	22.5	22.3	21.4	20.6	19.7	19.3	18.2	16.5	15.4	15.2	15.0
Cabernet Sauvignon	High-Wire	0.0	0.0	7.6	14.3	15.3	16.4	15.5	17.9	18.6	20.3	20.0	19.3	18.5	17.8	17.4	16.4	14.9	13.9	13.6	13.5

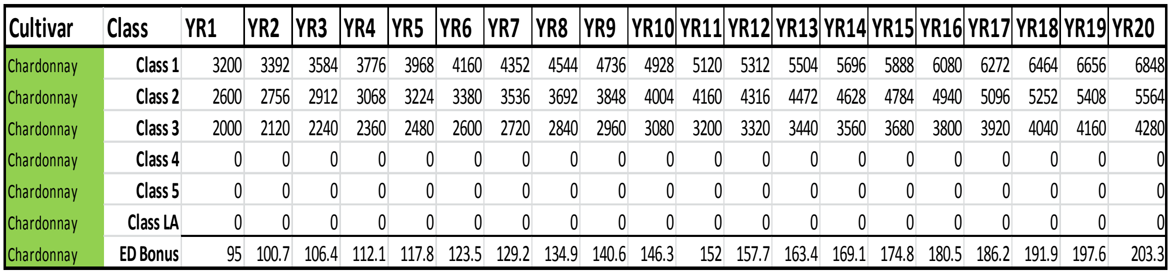
Source: Based on WineMS data

Table 4.4 : A subjective quality matrix for Chenin Blanc

Cultivar	Trellis	Distribution	YR1	YR2	YR3	YR4	YR5	YR6	YR7	YR8	YR9	YR10	YR11	YR12	YR13	YR14	YR15	YR16	YR17	YR18	YR19	YR20
Chenin Blanc	High-Wire	Class 1	0.3526	0.3526	0.3526	0.3526	0.3526	0.3526	0.3526	0.3526	0.3526	0.3526	0.3526	0.3526	0.3526	0.3526	0.3526	0.3526	0.3526	0.3526	0.3526	0.3526
Chenin Blanc	High-Wire	Class 2	0.4118	0.4118	0.4118	0.4118	0.4118	0.4118	0.4118	0.4118	0.4118	0.4118	0.4118	0.4118	0.4118	0.4118	0.4118	0.4118	0.4118	0.4118	0.4118	0.4118
Chenin Blanc	High-Wire	Class 3	0.1863	0.1863	0.1863	0.1863	0.1863	0.1863	0.1863	0.1863	0.1863	0.1863	0.1863	0.1863	0.1863	0.1863	0.1863	0.1863	0.1863	0.1863	0.1863	0.1863
Chenin Blanc	High-Wire	Class 4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Chenin Blanc	High-Wire	Class 5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Chenin Blanc	High-Wire	Class LA	0.0493	0.0493	0.0493	0.0493	0.0493	0.0493	0.0493	0.0493	0.0493	0.0493	0.0493	0.0493	0.0493	0.0493	0.0493	0.0493	0.0493	0.0493	0.0493	0.0493
Chenin Blanc	High-Wire	ED Bonus	0.8800	0.8800	0.8800	0.8800	0.8800	0.8800	0.8800	0.8800	0.8800	0.8800	0.8800	0.8800	0.8800	0.8800	0.8800	0.8800	0.8800	0.8800	0.8800	0.8800
Chenin Blanc	Gable	Class 1	0.4128	0.4128	0.4128	0.4128	0.4128	0.4128	0.4128	0.4128	0.4128	0.4128	0.4128	0.4128	0.4128	0.4128	0.4128	0.4128	0.4128	0.4128	0.4128	0.4128
Chenin Blanc	Gable	Class 2	0.3947	0.3947	0.3947	0.3947	0.3947	0.3947	0.3947	0.3947	0.3947	0.3947	0.3947	0.3947	0.3947	0.3947	0.3947	0.3947	0.3947	0.3947	0.3947	0.3947
Chenin Blanc	Gable	Class 3	0.1400	0.1400	0.1400	0.1400	0.1400	0.1400	0.1400	0.1400	0.1400	0.1400	0.1400	0.1400	0.1400	0.1400	0.1400	0.1400	0.1400	0.1400	0.1400	0.1400
Chenin Blanc	Gable	Class 4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Chenin Blanc	Gable	Class 5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Chenin Blanc	Gable	Class LA	0.5250	0.5250	0.5250	0.5250	0.5250	0.5250	0.5250	0.5250	0.5250	0.5250	0.5250	0.5250	0.5250	0.5250	0.5250	0.5250	0.5250	0.5250	0.5250	0.5250
Chenin Blanc	Gable	ED Bonus	0.8800	0.8800	0.8800	0.8800	0.8800	0.8800	0.8800	0.8800	0.8800	0.8800	0.8800	0.8800	0.8800	0.8800	0.8800	0.8800	0.8800	0.8800	0.8800	0.8800
Chenin Blanc	Ballerina	Class 1	0.3526	0.3526	0.3526	0.3526	0.3526	0.3526	0.3526	0.3526	0.3526	0.3526	0.3526	0.3526	0.3526	0.3526	0.3526	0.3526	0.3526	0.3526	0.3526	0.3526
Chenin Blanc	Ballerina	Class 2	0.4118	0.4118	0.4118	0.4118	0.4118	0.4118	0.4118	0.4118	0.4118	0.4118	0.4118	0.4118	0.4118	0.4118	0.4118	0.4118	0.4118	0.4118	0.4118	0.4118
Chenin Blanc	Ballerina	Class 3	0.1863	0.1863	0.1863	0.1863	0.1863	0.1863	0.1863	0.1863	0.1863	0.1863	0.1863	0.1863	0.1863	0.1863	0.1863	0.1863	0.1863	0.1863	0.1863	0.1863
Chenin Blanc	Ballerina	Class 4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Chenin Blanc	Ballerina	Class 5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Chenin Blanc	Ballerina	Class LA	0.0493	0.0493	0.0493	0.0493	0.0493	0.0493	0.0493	0.0493	0.0493	0.0493	0.0493	0.0493	0.0493	0.0493	0.0493	0.0493	0.0493	0.0493	0.0493	0.0493
Chenin Blanc	Ballerina	ED Bonus	0.8800	0.8800	0.8800	0.8800	0.8800	0.8800	0.8800	0.8800	0.8800	0.8800	0.8800	0.8800	0.8800	0.8800	0.8800	0.8800	0.8800	0.8800	0.8800	0.8800
Chenin Blanc	VSP	Class 1	0.3426	0.3426	0.3426	0.3426	0.3426	0.3426	0.3426	0.3426	0.3426	0.3426	0.3426	0.3426	0.3426	0.3426	0.3426	0.3426	0.3426	0.3426	0.3426	0.3426
Chenin Blanc	VSP	Class 2	0.4108	0.4108	0.4108	0.4108	0.4108	0.4108	0.4108	0.4108	0.4108	0.4108	0.4108	0.4108	0.4108	0.4108	0.4108	0.4108	0.4108	0.4108	0.4108	0.4108
Chenin Blanc	VSP	Class 3	0.1963	0.1963	0.1963	0.1963	0.1963	0.1963	0.1963	0.1963	0.1963	0.1963	0.1963	0.1963	0.1963	0.1963	0.1963	0.1963	0.1963	0.1963	0.1963	0.1963
Chenin Blanc	VSP	Class 4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Chenin Blanc	VSP	Class 5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Chenin Blanc	VSP	Class LA	0.0503	0.0503	0.0503	0.0503	0.0503	0.0503	0.0503	0.0503	0.0503	0.0503	0.0503	0.0503	0.0503	0.0503	0.0503	0.0503	0.0503	0.0503	0.0503	0.0503
Chenin Blanc	VSP	ED Bonus	0.8800	0.8800	0.8800	0.8800	0.8800	0.8800	0.8800	0.8800	0.8800	0.8800	0.8800	0.8800	0.8800	0.8800	0.8800	0.8800	0.8800	0.8800	0.8800	0.8800
Chenin Blanc	Lyre	Class 1	0.3626	0.3626	0.3626	0.3626	0.3626	0.3626	0.3626	0.3626	0.3626	0.3626	0.3626	0.3626	0.3626	0.3626	0.3626	0.3626	0.3626	0.3626	0.3626	0.3626
Chenin Blanc	Lyre	Class 2	0.4018	0.4018	0.4018	0.4018	0.4018	0.4018	0.4018	0.4018	0.4018	0.4018	0.4018	0.4018	0.4018	0.4018	0.4018	0.4018	0.4018	0.4018	0.4018	0.4018
Chenin Blanc	Lyre	Class 3	0.1863	0.1863	0.1863	0.1863	0.1863	0.1863	0.1863	0.1863	0.1863	0.1863	0.1863	0.1863	0.1863	0.1863	0.1863	0.1863	0.1863	0.1863	0.1863	0.1863
Chenin Blanc	Lyre	Class 4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Chenin Blanc	Lyre	Class 5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Chenin Blanc	Lyre	Class LA	0.0493	0.0493	0.0493	0.0493	0.0493	0.0493	0.0493	0.0493	0.0493	0.0493	0.0493	0.0493	0.0493	0.0493	0.0493	0.0493	0.0493	0.0493	0.0493	0.0493
Chenin Blanc	Lyre	ED Bonus	0.8800	0.8800	0.8800	0.8800	0.8800	0.8800	0.8800	0.8800	0.8800	0.8800	0.8800	0.8800	0.8800	0.8800	0.8800	0.8800	0.8800	0.8800	0.8800	0.8800
Chenin Blanc	Smart-Dyson	Class 1	0.3526	0.3526	0.3526	0.3526	0.3526	0.3526	0.3526	0.3526	0.3526	0.3526	0.3526	0.3526	0.3526	0.3526	0.3526	0.3526	0.3526	0.3526	0.3526	0.3526
Chenin Blanc	Smart-Dyson	Class 2	0.4118	0.4118	0.4118	0.4118	0.4118	0.4118	0.4118	0.4118	0.4118	0.4118	0.4118	0.4118	0.4118	0.4118	0.4118	0.4118	0.4118	0.4118	0.4118	0.4118
Chenin Blanc	Smart-Dyson	Class 3	0.1863	0.1863	0.1863	0.1863	0.1863	0.1863	0.1863	0.1863	0.1863	0.1863	0.1863	0.1863	0.1863	0.1863	0.1863	0.1863	0.1863	0.1863	0.1863	0.1863
Chenin Blanc	Smart-Dyson	Class 4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Chenin Blanc	Smart-Dyson	Class 5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Chenin Blanc	Smart-Dyson	Class LA	0.0493	0.0493	0.0493	0.0493	0.0493	0.0493	0.0493	0.0493	0.0493	0.0493	0.0493	0.0493	0.0493	0.0493	0.0493	0.0493	0.0493	0.0493	0.0493	0.0493
Chenin Blanc	Smart-Dyson	ED Bonus	0.8800	0.8800	0.8800	0.8800	0.8800	0.8800	0.8800	0.8800	0.8800	0.8800	0.8800	0.8800	0.8800	0.8800	0.8800	0.8800	0.8800	0.8800	0.8800	0.8800

Source: own data

Table 4.5: Chardonnay class specific cellar payment per tonne in Rand



Cultivar	Class	YR1	YR2	YR3	YR4	YR5	YR6	YR7	YR8	YR9	YR10	YR11	YR12	YR13	YR14	YR15	YR16	YR17	YR18	YR19	YR20
Chardonnay	**Class 1**	3200	3392	3584	3776	3968	4160	4352	4544	4736	4928	5120	5312	5504	5696	5888	6080	6272	6464	6656	6848
Chardonnay	**Class 2**	2600	2756	2912	3068	3224	3380	3536	3692	3848	4004	4160	4316	4472	4628	4784	4940	5096	5252	5408	5564
Chardonnay	**Class 3**	2000	2120	2240	2360	2480	2600	2720	2840	2960	3080	3200	3320	3440	3560	3680	3800	3920	4040	4160	4280
Chardonnay	**Class 4**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chardonnay	**Class 5**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chardonnay	**Class LA**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chardonnay	**ED Bonus**	95	100.7	106.4	112.1	117.8	123.5	129.2	134.9	140.6	146.3	152	157.7	163.4	169.1	174.8	180.5	186.2	191.9	197.6	203.3

4.3.3 Activity and cost norms

Upon completion of the farm input section and advanced parameter input section it is important to update the activity and cost norms section. The calibration of this section is imperative to ensure accurate outcomes, particularly when new trellises or systems are introduced. Under this section it is vital that a skilled model user is involved, with a thorough understanding of the activities to avoid misleading results.

Characteristically labour norms need to be specified for a variety of listed activities as well as the duration time for sixty possible mechanised activities. The duration time of mechanised activities is dependent on the working width of the implement or activity, working speed, as well as a factor for efficiency or down-time. Furthermore, the power demand of each application, being either low, medium or high, needs to be specified as well as the combination of machinery to be used. The latter specification is crucial as it will determine the mechanised activity cost in the calculation block.

4.3.4 Model input limitations

Physical farm description limitations of the VITISIM101 model are that the model allows for the maximum input of 50 different block descriptions. The maximum block allocation can be regarded as more than sufficient as there is no limit to individual block sizes and total blocks seldom exceed 50 for an individual wine grape farm in South Africa.

In the moveable assets inventory section of the farm inventory section the maximum amount of vehicles allocation include three pick-ups, one truck and three motorcycles. Likewise the maximum amount of machinery allocations are 15 tractors, 15 trailers, 10 spray pumps, 10 viticultural specific equipment, 15 other equipment, 20 irrigation equipment, 10 lucerne equipment and one self-propelled and one trailed harvester. Fixed asset limitations include a maximum of 10 building descriptions and a maximum of 10 other fixed improvements.

Maximum cultivation or economic lifetime options for crops was limited to 25 years which could be argued to be the case for specific vineyard blocks, stemming from good mother material, which is situated on high potential soil. Other crop cultivation limitations include options between a maximum of 10 different grapevine cultivars, a maximum of six different trellis system types, three alternative cash crops, lucerne and idle land.

4.4 The calculation component

4.4.1 The working of the calculation component

The cornerstone of the calculation block rests on the calculation of an annual farm profile and replacement cycle for the simulation period of 20 years. From this yearly farm profile VITISIM101 calculates a yearly farm output in terms of the area allocated to each crop, the quality and combination of crops produced. Similarly the quantity and combination of inputs required annually, as specified by the cultivation practices, determined in the "block and critical parameter selection page" are calculated.

The quantities are thereafter multiplied by the specific period's input and output prices to arrive at a gross production value as well as total cash expenditure per crop. For inter-cultivar comparison purposes manual labour directly involved with a particular cultivar, as well as labour related to mechanised activities and mechanical costs are also allocated to individual cultivars to arrive at a margin above specified cost per ha per cultivar per year. The latter enables the ranking of the more and less profitable cultivars for the individual farm enterprises.

VITISIM101's simulation period encompasses 20 years and different individual crop lifetimes between one and 25 years can be specified for each individual block. The model also allows for up to five crop rotations per block, maximum consecutive cultivation before rotation of 25 years and the option to switch between trellis types upon expiration of the crop lifetime. Upon replacement of an existing vineyard it is therefore possible to not only establish another cultivar but also a different trellis system. It is important to note that the sequence is automated and all succeeding years are dependent on designations made in year one.

After calculating individual outcomes for specific crops VITISIM101 collectively pools crops into one of three clusters, namely the collective wine grape enterprise, lucerne enterprise or other crop enterprise for purposes of net farm income calculations. The collective wine grape enterprise comprises all income and costs related to all the individual wine grape cultivars, the lucerne enterprise all costs and income related to lucerne and the other crop enterprises all income and costs allocated to other cash crops and other activities.

4.4.2 The calculation of expenditure parameters in the model

In the VITISIM101 model cash expenditure is treated as all expenditures incurred for the financial year and includes, direct cost[14], labour, mechanisation, fixed improvements and general expenditure items. Depreciation is calculated for moveable assets, fixed improvements and biological assets (refer to Section *4.4.2.4.6)*.[15]

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[14] Direct cost: All fertiliser, chemicals, seed, repair and binding material related to proliferation of crop

[15] Biological assets: treatment hinges on IAS 41.5 under bearer plants, a) that is used in the production or supply of agricultural produce, b) is expected to bear produce for more than one period, and c) has a remote likelihood of being sold as agricultural produce, except for incidental scrap sales. The latter is measured at cost minus depreciation in the absence of an active market *(International GAAP 2013, 2013:95).*

4.4.2.1 The rationale for VITISIM101 expenditure allocations

The deviation from conventional cost allocations of expenditure in the VITISIM101 simulation model is vindicated[16] by the functional capabilities and purpose of the model. These include functionalities by which it is possible to alter the block specific cultivation practices, as well as the total area under cultivation for and between each year of the projection period. Moreover it is possible to manipulate the combination of machinery used for every mechanical action and to compare and analyse the cost of alternate cultivation actions on an operational level for each year of the projection period.

As such VITISIM101 calculates the total annual units used, man and machinery hours relating it to an annual use and cost per hectare per year. As such the annual use of different machinery varies on a yearly basis, having implications for the lifetime of machinery as well as cost per hour. The explanation for the latter is two-fold. Firstly due to costs such as depreciation and interest which are conventionally considered as fixed and calculated over a pre-determined fixed lifetime needing to be recovered over a varying lifetime, depending on the annual use till depletion of the asset. Secondly, in view of the above, interest and insurance costs as well as license fees, which represent fixed annual outflows, are now "serviced" by alternate hours depending on the annual usage and essentially hectares over which the activity is applied per year. Depreciation and repairs and maintenance cost are considered as variable cost and only incurred by the amount of usage.

As a consequence economies of size then develop for the activity as the above "fixed annual outflows" are now "serviced" by a larger (if operations expanded) or smaller denominator. As such the cost per hectare would then vary depending on the total annual cost and hectares cultivated. The latter can typically involve large economies of size for very expensive machinery such as mechanical harvesters. Therefore the rationale for the extensive allocation of conventional fixed costs are founded in the need to compare the "cost of apples with apples" and thus expenditure and implicit cost of different mechanised and labour cultivation activities and hence wine grape production systems to another. Thus conventional cost allocations won't suffice for VITISIM101 and the above forms the basis for the margin above specified cost concept in Section 4.4.1.

4.4.2.2 The outline of the expenditure division of the VITISIM101 model

The expenditure division of the VITISIM101 model is divided into an establishment and production component. The establishment cost component will be discussed before a treatment of the production expenditure component of the VITISIM101 model.

4.4.2.3 The establishment cost component of VITISIM101

Under the establishment component a variety of cost items need to be specified on year one of the simulation period and the establishment preferences selected. The selected establishment preferences are then uniformly applied for all new establishments in all years of the simulation period. These selections involve a physical soil displacement, material related, labour related and trellis configuration related section.

The soil preparation section requires the user to select the machinery and actions to be completed for soil preparation, chemical correction to be made as well as the soil restitution

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[16] Refer to Section 4.5.1 for an additional justification for the deviation due to the inconsistent use in practice of the gross margin concept

or clearing cost upon maturity of a vineyard's lifetime. The material related section requires the user to specify cost items for poles, wires, different irrigation systems and plant material. Similarly the labour related section requires the specification of the trellis specific man hours and cost per man hour of actions to be done by permanent labour, seasonal labour or contractors to erect each type of trellis.

The trellis configuration related section requires the specification of the amount of wires, within row, vine- and within row pole spacing. The required total length of wires and quantity of poles are then calculated. Thereafter VITISIM101 requires the specification of the particular poles, wires, anchors and irrigation system type to be used. The establishment cost section then concludes by relating the physical material, plant material, erection and soil preparation cost to arrive at a trellis specific establishment cost per hectare.

4.4.2.4 The cost of production component of VITISIM101

The cost of production component of VITISIM101 is multi-faceted with the main cash expenditure cost contributing components being labour, mechanisation, "direct cost"[17], general expenditure[18] and fixed improvements. Depreciation (an implicit cost) accrued against the use of capital in the production process is treated separately in Section 4.3.2.4.6.

4.4.2.4.1 Labour cost

In the wine grape production system labour is currently the largest single cost item (Van Niekerk & Van Zyl, 2014:10). While it would not be possible to totally exclude any form of labour from the commercial wine grape production process, it is possible to increase labour productivity and decrease dependency on labour by using more capital. In the wine grape production system the latter can be largely facilitated by substituting manual labour for capital by the use of more machinery, equipment and alternate trellis and irrigation systems. Depending on the scope of the required capital investments the net effect can then be to increase or decrease production cost and profitability, ceteris paribus.

Given the substitutability of labour in the wine grape production system, the declining trend in employment levels in agriculture and in the wine industry as can be observed from and before the late nineties are more than likely to continue (Department of Agriculture, 2010:17). The latter are likely to be facilitated by a substitution of labour for mechanised actions and the adoption of less labour intensive trellis and wine grape production systems.

In view of the above VITISIM101 provides for the possibility of substitution of manual labour for mechanised activities. This is done by the provision of individual block and trellis specific selections between mechanised and non-mechanised cultivation practices. Block and trellis specific labour norms can also be designated, particularly with young vine development and the inception of mechanised actions for mechanically designated blocks,

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[17] Direct cost as used in the thesis entails costs directly involved with the proliferation of the crop, for vineyards it encompasses seed, fertilizer, organic fertilizer, herbicide, pesticide, fungicide and repair and binding material.

[18] General expenditure is categorised in VITISIM101 as electricity cost, water cost, land-property and municipal taxes as well as administration costs. Of those listed above electricity is the biggest cost contributor followed by water cost. VITISIM101 allocates electricity into a fixed electricity component and an irrigation electricity component.

which can be postponed up to a maximum of four years. The latter "per block delay in onset of mechanisation" functionality is particularly useful as the specific soil profile, cultivar and trellis combinations of individual blocks can take different lengths of time to complete vine development.

Vineyard cultivation activities can be divided into the four most costly and intensive activities being harvesting, summer foliage management, young vine development and pruning. As such VITISIM101 requires the cultivation practices selection for each block, namely harvesting either by hand or machine, foliage management either being by hand or tip machine, young vine development being between one and four years and pruning either to be done by hand, pre-pruning and hand or mechanically (refer to Table 4.6). The preferences are all selected through drop down menus. All the cultivation activities involve different skill-levels and measures of labour.

Table 4.6: The four most intensive cultivation activities

Cultivation activity	**Choice**
Harvesting	By hand or machine
Summer foliage management	By hand or tip machine
Young vine development	One, two, three or four years
Pruning	By hand, pre-pruner and hand or mechanical pruner

VITISIM101 allows for the allocation of labour into five different skill-levels and remuneration rates per hour. Labour is allocated in the VITISIM101 model into two components, manual labour and labour involved with mechanisation. Trellis specific manual labour requirements for activities such as harvesting, pruning blunt, pruning blunt and clear, summer foliage management, irrigation and general labour can be designated. The latter general labour designation per trellis and hectare is the designation for general activities as well as unproductive labour hours as are experienced on farm level.

The amount of labour involved with mechanisation in the VITISIM101 model is very specific and dependent on the number of applications, working speed, implement with and efficiency or down-time per hectare. The skill-level and accompanied remuneration rate per hectare needs to be specified for each mechanical activity. Depending on all the preferences listed above VITISIM101 then calculates the total activity and labour time and labour cost of each mechanical activity for each year of the projection period.

4.4.2.4.2 Mechanisation cost

The calculation of mechanisation costs in VITISIM101 follows the methodology of the Department of Agriculture, Forestry and Fisheries as published in "The guide to machinery cost" (GTMC) for the year 2012/13 (Lubbe, Archer & Whitehead, 2013: 3-8). The costs in the guide are based on technical and financial data as provided by manufacturers and suppliers of agricultural machinery. Similarly the life expectancies and annual usage as specified by the cost guide are based on studies done in South Africa, Great Britain and the United States. However, the cost figures calculated in the guide to machinery cost are average figures and for an average farm inventory and thus won't necessarily suffice for the individual farm and VITISIM101 model.

The above and the objective of developing a farm specific simulation model, led to the development of the cost of mechanisation component in the VITISIM101 model. In contrast to the approach by Lubbe *et al* (2013), costs are calculated on the farm specific inventory and self-specified item lifetimes are possible. In addition the VITISIM101 model also calculates the machinery hours per year, which are dependent on the cultivation practices and area cultivated annually. The latter, in combination with the detailed allocation of tractor and implement hours to specific activities, is noteworthy as it enables the calculation of economies of size which are related to the costs of owning and operating machinery.

The expense of owning and operating machinery can be considered to consist of two components, namely fixed costs and variable costs. Annual fixed costs are constant regardless of the measure of usage per year. Variable cost on the contrary is directly related to the degree of utilisation of machinery. Fixed costs typically are insurance, depreciation, licence fees as well as interest. Variable costs of mechanised activities typically include repairs, maintenance and fuel cost. While the division of fixed and variable costs are sometimes a contentious issue with valid arguments for and against each side, depreciation was treated as a variable cost in VITISIM101 and calculated according to the utilisation method for machinery and other moveable assets, with a constant charge for every unit of usage (refer to Section 4.4.2.1 and 4.4.2.4.2).

Similarly while repairs and maintenance costs are bound to vary as a result of different operating conditions, management and maintenance programs, there is consensus that repair costs per unit of usage will increase with age before levelling off as equipment becomes older (Lubbe *et al.,* 2013:2). The method used by the VITISIM101 model entails the estimation of repair costs as a percentage of the purchase price of the machinery, divided by the annual use. In reality machinery is seldom used the same hours per year and VITISIM101 incorporates the latter by calculating higher and lower repair and maintenance expenditures depending on the use per particular year. The method therefore estimates an average repairs and maintenance cost during the machines useful life and despite the disadvantages to the method, it is the most practical (Lubbe *et al.,* 2013:2).

The estimation of fuel cost in the GTMC and VITISIM101 model is an intricate technique based on results of studies done in South Africa and the United States. Despite the arguable merits of the technique and the fact that it does vary for area, machine and operator it is regarded as an acceptable approach (Lubbe *et al.,* 2013:3). The technique involves the calculation of the fuel consumption in litres per kW-hour for tractors, which vary depending on the level of power demand required for the activity. Power demand is divided into three levels, namely low, medium and high and the percentage of kilowatts available at each power level also varies (Lubbe *et al.,* 2013:3).

The calculation of the fuel usage for normal vehicles, motorcycles, pick-ups or LDV's and trucks is based on fuel usages per 100km as obtained from manufacturers and dealership standards. Similarly, fuel usage for self-propelled harvesters per hour was obtained from the Vinpro Cost Guide (Van Niekerk & Van Zyl, 2014:24). The activity and total fuel usage is then multiplied by the applicable diesel or petrol prices as specified in the model to estimate fuel costs.

Fixed costs of insurance and license fees are individually specified in the VITISIM101 model. Similarly a fixed cost for interest is calculated in the VITISIM101 model, which is representative of the opportunity cost of the money which could have been invested elsewhere than in machinery. The interest calculation in VITISIM101 is calculated based on the average investment in each mechanical item[19] allowed for in the model for each year in the simulation period. Average investment is calculated by taking the calculated value of each of these line items in the beginning and end of each period. The model therefore takes the replacement schedule and accumulated depreciation into account.

4.4.2.4.3 Direct proliferation cost

Direct proliferation costs in the VITISIM101 model are those cost items directly related to the proliferation of the crop. Direct proliferation cost items include seed, fertiliser, pesticide, fungicide, herbicide, twine and repair and binding material costs for the crop or collective enterprise. Labour, mechanisation, water and electricity cost which are also directly allocated in the VITISIM101 model are excluded from this description and individually specified in output.

Trellis specific application rates of the above vary and as such application specific costs were calculated in particular due to variations in application and resource requirements between alternate trellises. The latter is essential for an articulate picture of differences obtainable between different trellis and production systems.

4.4.2.4.4 General expenditure

The general expenditure components in the VITISIM101 model constitute electricity, water, administration and land-, property- and municipal taxes. General expenditure items typically consist of fixed and variable cost, which are allocated to each of the collective enterprises in order to enable the relative performance comparison of enterprises (refer to Section 4.4.1).

For the calculation of the electricity cost the VITISIM101 model requires the specification of all fixed infrastructure, not primarily involved with the electricity used for irrigation. These include the number of management houses, labourer houses, workshops and sheds. The estimated kilowatt hours required per month by each type of improvement is then specified after which the total fixed yearly units are calculated. The latter is then multiplied with the price per kilowatt hour to arrive at an estimated fixed electricity cost accrued to fixed infrastructure.

The number of electricity points on the farm are then multiplied by the annual point hire and summed with the estimated fixed electricity cost to arrive at a fixed electricity cost before

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[19] Mechanical item is used to represent the actual line item as specified in the inventory. Asset replacement takes place at year end and hence the old item value at period beginning and new item value at period end is used.

irrigation. The user then simply has to provide the farm's annual electricity account from which the estimated fixed electricity cost is deducted to arrive at an estimated irrigation electricity cost for the year. The latter is then divided by the total annual water requirement in cubic meter, which is estimated from the specific year profile to arrive at an electricity cost per cubic metre. By doing the above it is then possible to account for farm specific differences in gravity as well as frictional induced energy requirements to deliver a cubic meter of water. The alternate electricity cost of the annual irrigation water requirement as implied by the cultivation of different crops and trellis systems is thus allocated.

An annual fixed electricity component is then allocated to each collective enterprise for each year of the simulation period, based on the percentage of the total cubic metres of water for the year that is used for the particular collective enterprise. Similarly a variable electricity amount is allocated to each collective enterprise component by multiplying the total cubic metres used by the enterprise with the electricity cost per cubic metre. Correspondingly the annual water cost per collective enterprise is calculated by dividing the total annual water tax through the total amount of cubic metres applied to arrive at a water cost per cubic metre. The water cost per cubic metre is then multiplied by the amount of cubic metres used per enterprise to arrive at a collective enterprise water cost.

Administration cost per collective enterprise is allocated proportional to the area of the collective enterprise to that of total cultivated hectares. Thus as the contribution of a specific enterprise to the farm business changes during the projection period, so does the allocation of administration cost to the specific collective enterprise. Likewise the amount due to land, property and municipal taxes are calculated based on the total area cultivated under specific crops, for each year of the simulation period. For example higher land, property and municipal taxes are charged against a hectare of grapevines than a hectare of lucerne or cash crops. As such VITISIM101 allows for the taxation of alternate rates per hectare for grapevines, lucerne and cash crops.

4.4.2.4.5 Fixed improvements

The fixed improvement constituent component of the VITISIM101 model includes cash expenditures items such as repair and maintenance as well as insurance costs incurred on fixed improvements. Due to the heterogeneity of risk and insurance premiums as well as the value and age of fixed improvements per farm the model allows for the designation of insurance, repair and maintenance costs.

Fixed improvement costs are allocated to the three collective enterprises according to the relative percentage of the collective enterprise to total cultivated area.

4.4.2.4.6 Depreciation

Depreciation, an implicit cost, is the loss in value of a capital asset caused by age, wear and tear and obsolescence (Standard Bank, 2005:32). While the division of fixed and variable costs are sometimes a contentious issue with valid arguments for and against each side, depreciation was treated as a variable cost (refer to Section 4.4.2.1). In the VITISIM101 model fixed improvements are regarded as any capital improvement made upon the underlying land asset which has an inherent value. Examples of fixed improvements allotted for, include buildings, main irrigation lines, dams and biological improvements. Biological improvements, a sub component of fixed improvements, are considered to be the expenditure incurred upon establishment of perennial crops such as lucerne or grapevines in the VITISIM101 model.

In unanimity with depreciation on moveable assets which are replaced upon lifetime expiration the same applies to fixed improvements in the VITISIM101 model. However depreciation on fixed improvements is calculated according to the straight-line method, with depreciation on biological assets only accrued to the two perennial enterprises, namely the lucerne and collective grapevine enterprise.

4.4.2.4.7 Incorporation of price variability and inflation

As variability in input and output prices are a common feature of modern day economies in which wine grape production ensues, an annual price variability matrix was introduced into the VITISIM101 model. The price variability matrix allows for a disparity in yearly adjustment rates between different categories of in- and output prices as experienced in modern day agriculture. The effect of the latter implies that the prices of inputs change relative to another over time as will be simulated in results in Chapter 5.

Yearly adjustment rates can either be zero, inflationary or deflationary. The South African economy has been characterised by single and even double digit inflation in the past and as such yearly inflationary adjustments between alternate input and output prices were introduced. The VITISIM101 allows for the specification of 30 different price adjustment rates, which could be variable or alternatively long term projections of price movements can be obtained from organisations such as the Bureau for Food and Agricultural Policy (BFAP) or Global Insight.

4.5 The output component

The output component of the VITISIM101 model was designed to satisfy a triad of goals. At the outset the output component of the model had to be constructed in such a manner that it enables the quantification and illustration of the financial effect of individual actions and activities. By undertaking the former it would then be possible to compare the financial implication of alternate cultivation options on an operational level.

Secondly the output component needs to report financial outcomes in such a format that interpretation of activity and whole-farm level are facilitated. In addition the chosen formats should illustrate outcomes for the entire projection period to enable the identification of improvement or decline over time. Thirdly the output format should be of such a nature that it facilitates universal performance measurement and as such needs to be in accordance with accounting standards and uses. Moreover the performance measures chosen to evaluate model outcomes should be goal orientated for the endeavour of the evaluation.

In order to evaluate the long-term financial impact of different wine grape production systems, it is necessary to examine the three indicators of financial health of a business, namely cash flow, yearly margins and capital and thus the financial statements used to measure these indicators. When streamlining farming operations and the making of strategic decisions, farm managers must be able to estimate the likely effect of changes in the farm financial outcome. With the use of long-term projections it is then possible to avoid cash shortfalls, identify inefficiencies and estimate future capital requirements, as well as how they should be financed to ensure the prosperity of the farm business. This can all be done before detrimental effects transpire on the farm business. Performance measures such as margins, measures of profitability as well as financial feasibility of investments, will be considered in the view of outputs of the VITISIM101 model in the following sections.

4.5.1. Margins

Management accounting in agriculture and in effect farm reporting developed divergent to that of mainstream management accounting and reporting due to specific needs of the agricultural sector. Farm businesses are principally businesses characterised by large overheads and shared costs and a perilous endeavour to allocate costs to specific enterprises. The latter dictated a need for fixed-[20] and variable[21] costs to be treated differently and the subsequent development of the gross margin concept per enterprise to show each enterprise's contribution to the profit of the farm business (Warren, 1998:53). Gross margin of an enterprise is defined as the enterprise gross production value minus directly allocatable variable costs (Department of Agriculture, 2005:8). Similarly, gross production value is crop specific (providing for internal transfers), gross income is enterprise specific and gross farm income is used to describe the income accrued for the farm business in totality.

As such the gross margin concept is enterprise specific, referring to all income accruable to a specific profit centre (Warren, 1998:53). The gross margin concept however had short comings for the VITISIM101 model due to the need of VITISIM101 to differentiate between different trellis and wine grape production systems within the same profit centre. As such the "margin above specified cost" concept is used, where specified cost items are deducted from gross income. The difference between the gross margin and margin above specified cost concept arises due to the extensive cultivar and trellis specific allocation of variable as well as fixed cost for the latter.

The motivation for the extensive allocation is founded in the specific goal of being able to identify better and worse cultivars, trellis- and wine grape production systems. Failure to do the latter would leave a distorted picture with the applicable cost not accrued to the specific cost point and the consequential subsidising of less efficient cultivar, trellis and wine grape production systems by more efficient ones. In addition the gross margin concept can be ambiguous, as no standard set and different cost items are frequently subtracted from gross production value (Department of Agriculture, 2005:9).

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[20] Fixed costs are those costs that cannot be directly allocated to an enterprise and which do not vary with changes in enterprise size.

[21] Variable costs are those costs that can be directly allocated and varies directly with small changes in enterprise size.

In view of the preceding the margin above specified cost performance measure is illustrated in Table 4.7. The division is done per cultivar and collectively calculated from selections made on the block and critical parameter selection sheet (refer to Table 4.2). Depending on block specific trellis selections, trellis dependent cost consisting of direct proliferation costs, mechanisation and labour costs are then collectively allocated under the specific trellis heading (refer to Section 4.4.2.4.3). The VITISIM101 model works with the preposition that a specific cultivar and trellis combination are chosen for a specific wine goal. As such trellis specific, direct proliferation, labour and mechanisation costs are the same between cultivars on the same trellis. However, major cultivation practices and cultivar dependent specific cost items[22] are individually listed. The latter allows for the easy comparison of the financial outcome between alternate trellis systems, cultivation practices and in effect wine grape production systems per cultivar.

The VITISIM101 model allows for inter cultivar comparison output as illustrated in Table 4.8. The table illustrates the performance of individual cultivars and eases comparison relative to other cultivars and the (collective) wine grape enterprise average. The inter cultivar comparison output allows for the comparison of the margin above specified cost, margin above specified and unallocated cost, as well as net farm income between cultivars per ha. The use of the results in this format and other results will be discussed in Chapter 5.

4.5.2 Measures of profitability

The benefit of monitoring farming margins and capital used in the business is that it allows for the comparison of the current year's results with that of previous years. This enables the farm manager to view the progress of the farm business in terms of both major expansion and general improvement (or decline) in productivity between years (Warren, 1998:185). Through monitoring margins it is thus possible to derive a clear impression of the efficiency of a specific enterprise or farm business.

As illustrated in Section 3.2 and elaborated upon with specific performance measures in Section 3.2.5, margins, capital and cash flow matter in the analysis of any investment. In the view of the preceding NFI, NPV and IRR were shown to be worthy performance measures of evaluating alternate investment and wine grape production systems. By using NPV analysis with the WACC as a discount rate, it is possible to evaluate the effect of an investment project and use of leveraging on the estimated value of the firm. The IRR method's "break-even" characteristic likewise makes it conceptually easy to identify which investment projects should be accepted or rejected. Similarly NFI and NFI per R100 are valuable in measuring annual performance.

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[22] These specific costs are largely caught in the young vine development cost, grape to cellar transport cost as well as delayed onset of mechanisation items. The latter functionality is due to vigorous cultivars completing vine training on the trellis system earlier as well as yielding more tonnes to be transported to the wine cellar.

Table 4.7: The margin above specified cost for Chenin Blanc, for the first three years of the simulation period

Chenin Blanc	**Yield (t)**		**2014/01/01**	**Yield (t)**		**2015/01/01**	**Yield (t)**		**2016/01/01**
Tonnes per class									
Class 1	184.5	R	415 863	150.6	R	359 820	164.8	R	415 933
Class 2	46.1	R	90 912	37.7	R	78 661	41.2	R	90 928
Class 3	0.0	R	-	0.0	R	-	0.0	R	-
Class 4	0.0	R	-	0.0	R	-	0.0	R	-
Class 5	0.0	R	-	0.0	R	-	0.0	R	-
Class LA	0.0	R	-	0.0	R	-	0.0	R	-
ED Bonus	203.0	R	19 280	165.7	R	16 682	181.2	R	19 284
Total tonnnage	230.6			188.3			206.0		
Gross income Chenin Blanc		**R**	**526 056**		**R**	**455 162**		**R**	**526 145**
Trellis specific expenditure	ha								
High Wire	0.0	R	-	0.0	R	-	0.0	R	-
Gable	0.0	R	-	0.0	R	-	0.0	R	-
Ballerina	0.0	R	-	0.0	R	-	0.0	R	-
VSP	10.0	R	70 232	10.0	R	75 794	10.0	R	81 345
Lyre	0.0	R	-	0.0	R	-	0.0	R	-
Smart-Dyson	0.0	R	-	0.0	R	-	0.0	R	-
Water cost		R	14 194		R	15 046		R	15 897
Electricity cost (irrigation)		R	18 714		R	21 147		R	23 580
Young vine development (YVD) (man hours)	0.0	R	-	750.0	R	9 533	500.0	R	6 355
Harvesting cost by hand (labour) (tonnage dependent)		R	32 288		R	29 254		R	35 176
Harvesting cost (mechanical)		R	-		R	-		R	-
(of which labour component of mechanical harvesting)		*R*	-		*R*	-		*R*	-
Pruning cost (by hand)		R	14 850		R	16 484		R	18 117
Pruning cost (pre-prune machine)		R	-		R	-		R	-
(of which operator labour component)		*R*	-		*R*	-		*R*	-
(of which labour cut clear)		*R*	-		*R*	-		*R*	-
Pruning cost mechanical pruning (machine)		R	-		R	-		R	-
(of which labour component)		*R*	-		*R*	-		*R*	-
Foliage management (by hand)		R	29 233		R	32 449		R	35 664
Foliage management (mechanical)		R	-		R	-		R	-
(of which labour component)		R	-		R	-		R	-
Grapes to cellar transport cost (mech cost)		R	12 930		R	11 164		R	12 846
(of which labour component)		*R*	*2 196*		*R*	*1 939*		*R*	*2 277*
	ha			*ha*			*ha*		
Additional manual labour (delayed onset prepruning)	*0.0*	*R*	-	*0.0*	*R*	-	*0.0*	*R*	-
Additional manual labour (delayed onset mechanical p)	*0.0*	*R*	-	*0.0*	*R*	-	*0.0*	*R*	-
Additional manual labour (delayed onset foliage m mach)	*0.0*	*R*	-	*0.0*	*R*	-	*0.0*	*R*	-
Gross income per ha (Chenin Blanc)		**R**	**52 606**		**R**	**45 516**		**R**	**52 614**
Total of specified costs enterprise		R	194 637		R	212 808		R	231 258
Total ha cultivar			**10.0**			**10.0**			**10.0**
Specified cost per ha		**R**	**19 464**		**R**	**21 281**		**R**	**23 126**
	ha			*ha*			*ha*		
Establishment cost	2.50	R	420 831	0.00	R	-	0.00	R	-
Average establishment cost per ha	R/ha	R	168 332	R/ha	R	-	R/ha	R	-
Margin above specified cost (Chenin Blanc)		**R**	**-89 411**		**R**	**242 354**		**R**	**294 887**
Margin above specified cost per ha (Chenin Blanc)		R	-8 941		R	24 235		R	29 489
Margin above specified cost (renewal excluded) (Chenin Blanc)		R	33 142		R	24 235		R	29 489

The total specified costs are subtracted from the gross income for Chenin Blanc to arrive at a margin above specified cost. Non-allocated cost items subtracted from the collective enterprise include electricity, administration, land-, property- and municipal taxes as well as a general machinery, general vehicles and fixed improvements cost.

Table 4.8: The inter cultivar comparison for alternate cultivars per hectare[23]

Margin above specified cost (R/ha)	2014/01/01	2015/01/01	2016/01/01	2017/01/01	2018/01/01	2019/01/01	2020/01/01	2021/01/01	2022/01/01	2023/01/01	2024/01/01	2025/01/01	2026/01/01	2027/01/01	2028/01/01	2029/01/01	2030/01/01	2031/01/01	2032/01/01	2033/01/01
Chardonnay	33 658	33 386	33 693	35 166	35 104	7 199	7 320	16 398	27 478	33 414	41 394	8 542	11 099	25 263	37 597	43 428	54 275	58 506	61 600	64 461
Chenin Blanc	33 142	24 235	29 489	36 498	38 971	39 767	48 015	44 450	41 412	22 787	28 602	36 817	31 479	30 611	44 331	54 227	50 884	39 333	39 955	47 332
Colombar	27 767	33 598	27 380	31 592	37 707	42 153	35 866	36 868	32 677	38 188	49 296	55 800	63 183	62 756	50 074	48 881	54 455	59 661	65 236	47 125
Shiraz	31 653	36 005	36 505	37 221	37 780	37 970	39 556	30 444	28 386	39 434	28 173	26 397	39 834	40 059	40 294	27 057	13 606	29 912	35 007	38 436
Sauvignon Blanc	31 619	33 658	32 045	-22 647	-22 746	11 148	34 034	43 400	62 221	71 711	66 737	70 874	68 043	66 309	66 921	61 381	60 375	59 310	57 710	58 804
Cabernet Sauvignon	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cultivar 7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cultivar 8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cultivar 9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cultivar 10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Margin above specified cost WGE average	27 459	28 371	29 158	30 071	30 462	30 840	33 491	33 483	33 599	35 399	36 884	36 996	41 364	40 126	41 050	41 022	40 395	43 822	47 059	44 895
Other unallocated costs (R/ha)	9 718	10 224	10 730	11 235	11 740	12 235	12 769	13 269	13 810	14 356	15 211	15 698	16 241	16 747	17 233	17 837	18 466	19 227	19 731	20 238
Depreciation (Fixed improvements)*(R/ha)	1 297	1 297	1 297	1 297	1 385	1 385	1 385	1 385	1 385	1 385	1 385	1 385	1 385	1 385	1 385	1 385	1 385	1 385	1 646	1 646
Margin above specified and allocated cost (R/ha)																				
Chardonnay	23 940	23 668	23 975	25 447	25 386	-2 519	-2 398	6 680	17 760	23 696	31 675	-1 177	1 380	15 545	27 879	33 709	44 556	48 788	51 881	54 743
Chenin Blanc	23 423	14 517	19 770	26 780	29 252	30 048	38 297	34 731	31 693	13 069	18 884	27 098	21 761	20 892	34 613	44 509	41 166	29 615	30 237	37 614
Colombar	18 048	23 880	17 662	21 874	27 989	32 434	26 148	27 150	22 959	28 470	39 578	46 082	53 465	53 038	40 355	39 163	44 737	49 943	55 517	37 407
Shiraz	21 934	26 287	26 787	27 503	28 061	28 252	29 837	20 726	18 667	29 715	18 455	16 679	30 116	30 341	30 576	17 339	3 887	20 194	25 289	28 718
Sauvignon Blanc	21 901	23 940	22 326	-32 366	-32 464	1 430	24 316	33 682	52 503	61 992	57 018	61 156	58 324	56 591	57 202	51 662	50 657	49 591	47 992	49 086
Cabernet Sauvignon	-2 858	-2 377	5 731	11 506	-233	803	7 608	16 652	18 230	20 344	19 085	21 516	22 296	6 670	6 857	15 483	21 994	21 922	23 358	21 297
Cultivar 7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cultivar 8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cultivar 9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cultivar 10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Wine Grape Enterprise avg gross margin	17 741	18 147	18 428	18 836	18 722	18 604	20 722	20 215	19 790	21 043	21 673	21 298	25 123	23 379	23 817	23 185	21 930	24 596	27 327	24 657
NFI per cultivar (R/ha)** (Cultivar specific implicit cost allocated)																				
Chardonnay	18 283	18 011	18 318	19 790	19 641	-12 234	-12 113	-3 035	8 045	13 981	21 960	-16 626	-14 069	96	12 430	18 260	29 107	33 339	36 170	39 032
Chenin Blanc	17 209	6 956	12 209	19 219	21 603	22 399	30 648	27 082	24 044	2 835	8 650	16 865	8 524	7 655	21 376	31 272	27 928	12 748	13 108	20 485
Colombar	11 791	17 622	10 197	14 409	20 436	24 882	16 884	17 886	11 744	17 255	28 363	34 867	42 250	41 823	26 528	25 336	30 909	36 116	41 428	20 238
Shiraz	14 892	19 244	19 744	20 460	20 931	21 121	22 707	11 763	9 704	20 752	7 310	5 534	18 971	19 196	19 431	3 481	-12 781	3 526	5 366	8 795
Sauvignon Blanc	17 270	19 309	17 695	-43 676	-43 863	-9 969	12 917	22 283	41 104	50 593	45 620	49 757	46 925	45 192	45 803	40 263	39 258	38 192	36 331	37 425
Cabernet Sauvignon	-9 839	-9 358	-1 250	4 525	-9 740	-8 704	-1 899	7 145	8 723	10 836	9 577	12 008	12 789	-7 019	-6 832	1 793	8 305	8 233	9 407	7 346
Cultivar 7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cultivar 8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cultivar 9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cultivar 10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
WGE average Net Farm Income (R/ha)	**11 328**	**11 465**	**11 445**	**11 519**	**10 950**	**10 436**	**12 126**	**11 161**	**10 248**	**10 984**	**11 069**	**10 120**	**13 345**	**10 973**	**10 758**	**9 448**	**7 490**	**9 430**	**11 152**	**7 712**

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[23] *Depreciation on non-biological* fixed improvements
**Cultivar specific allocation of implicit (depreciation on biological assets)costs are allocated as different cultivars can be planted on alternate trellises at alternate dates and hence depreciation costs can vary and need to be cultivar, trellis and age specific.

As will be illustrated in the remainder of the Tables 4.9 to 4.13 in Section 4.5.2 and Section 4.5.3 the NPV and IRR were illustrated to be concerned with net cash flow after tax. NFI is useful in the analysis due to the incorporation of the implicit cost of depreciation (refer to Table 4.9). Failure to account for depreciation, the implicit depletion of the value of capital assets, would lead to lower farm costs and misinterpretations of the actual profit of a farm business. In addition NFI per R100 capital investment is chosen in the VITISIM101 model as it also makes it possible to measure the efficiency of an investment given the amount of capital invested.

In view of the above VITISIM101 analyses the wine grape production system and farm business in terms of low-level and high-level descriptions, of the wine grape production and whole farm system. This is done in order to permit the analysis of individual changes to the wine grape production system in terms of cultivar, trellis and cultivation preferences. For this undertaking, farm business outcomes are compared on per ha, collective enterprise and whole farm basis, with all inputs and outputs converted as applicable. The specific farm description, assumptions, output and reporting of results is done in Chapter 5.

By using low-level and high-level descriptions in VITISIM101 analyses it is then possible to identify more and less profitable cultivars, trellis and cultivation practice combinations or wine grape production systems to one another. The effect of envisaged changes in cultivars, trellises and cultivation practices used in the wine grape production system can then be simulated and measured against the IRR performance measure. Adoption of combinations or strategies that lead to a higher IRR would then increase margins and profitability.

In the following VITISIM101 outputs, performance measures are calculated as discussed in Section 3.2.5. The only difference is in the presentation of the output respective to conventional analyses due to the model dividing and allocating virtually all costs per enterprise (cultivar) as well as collective enterprise to allow greater performance measurement within the same profit centre (refer to Section 4.4.1 and 4.5.3). In addition as elaborated in this section VITISIM101 also simulates the whole farm effect of the wine grape production system on annual net farm cash flow. The latter is due to farming businesses regularly failing, not due to profitability or solvency problems but rather liquidity related problems in specific periods (Warren, 1998:175).

Table 4.9: The multiple period budget for the calculation of net farm income

Multiple period budget (R)	2014/01/01	2015/01/01	2016/01/01	2017/01/01	2018/01/01	2019/01/01	2020/01/01	2021/01/01	2022/01/01	2023/01/01	2024/01/01	2025/01/01	2026/01/01	2027/01/01	2028/01/01	2029/01/01	2030/01/01	2031/01/01	2032/01/01	2033/01/01
Whole farm gross income	**3 279 967**	**3 465 765**	**3 643 421**	**3 833 150**	**3 994 111**	**4 152 629**	**4 431 267**	**4 568 306**	**4 715 870**	**4 954 714**	**5 178 726**	**5 329 690**	**5 704 758**	**5 772 347**	**5 953 925**	**6 105 047**	**6 213 225**	**6 535 420**	**6 850 852**	**6 859 377**
Gross income collective wine grape enterprise (WGE)	2 308 155	2 435 644	2 554 991	2 686 411	2 789 064	2 889 273	3 109 602	3 188 332	3 277 587	3 458 123	3 623 826	3 716 481	4 033 240	4 042 520	4 165 790	4 258 603	4 308 472	4 572 359	4 829 482	4 779 699
Gross income lucerne enterprise	971 813	1 030 121	1 088 430	1 146 739	1 205 048	1 263 356	1 321 665	1 379 974	1 438 283	1 496 591	1 554 900	1 613 209	1 671 518	1 729 826	1 788 135	1 846 444	1 904 753	1 963 061	2 021 370	2 079 679
Gross income other crops enterprise	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Production cost (cash expenditure items)	**2 023 424**	**2 179 255**	**2 333 306**	**2 493 955**	**2 651 019**	**2 806 253**	**2 969 095**	**3 120 752**	**3 277 225**	**3 438 233**	**3 616 344**	**3 775 907**	**3 948 137**	**4 093 503**	**4 246 813**	**4 411 202**	**4 578 885**	**4 752 231**	**4 933 284**	**5 074 094**
Direct proliferation cost	318 818	346 659	374 500	402 342	430 183	458 024	485 865	513 707	541 548	569 389	597 230	625 072	652 913	680 754	708 595	736 436	764 278	792 119	819 960	847 801
Labour	638 318	693 678	747 717	805 622	861 993	917 209	977 717	1 029 438	1 079 937	1 135 783	1 198 581	1 256 278	1 325 043	1 371 671	1 424 709	1 479 481	1 530 606	1 593 893	1 659 998	1 696 775
Mechanisation (lisences, insurance and fuel included)	387 029	408 757	430 024	454 025	475 974	497 247	520 838	542 030	569 260	595 679	632 248	655 371	680 092	700 086	721 614	752 486	790 302	821 616	857 821	883 110
Electricty (fixed and irrigation)	250 000	282 500	315 000	347 500	380 000	412 500	445 000	477 500	510 000	542 500	575 000	607 500	640 000	672 500	705 000	737 500	770 000	802 500	835 000	867 500
Water	139 559	147 933	156 306	164 680	173 053	181 427	189 800	198 174	206 548	214 921	223 295	231 668	240 042	248 415	256 789	265 162	273 536	281 909	290 283	298 657
General expenditure																				
Fixed improvements	180 000	183 200	186 400	189 600	192 800	196 000	199 200	202 400	205 600	208 800	212 000	215 200	218 400	221 600	224 800	228 000	231 200	234 400	237 600	240 800
Land- property and muncipal taxes	24 700	26 429	28 158	29 887	31 616	33 345	35 074	36 803	38 532	40 261	41 990	43 719	45 448	47 177	48 906	50 635	52 364	54 093	55 822	57 551
Administration	85 000	90 100	95 200	100 300	105 400	110 500	115 600	120 700	125 800	130 900	136 000	141 100	146 200	151 300	156 400	161 500	166 600	171 700	176 800	181 900
Net capital expenditure	**532 581**	**582 969**	**784 450**	**1 313 856**	**734 136**	**827 958**	**1 035 335**	**1 495 307**	**1 276 992**	**1 581 033**	**1 165 236**	**1 321 296**	**1 131 047**	**1 187 637**	**1 891 551**	**1 942 512**	**1 930 250**	**3 914 594**	**2 270 684**	**1 657 897**
Moveable assets	-	-	154 474	-	-	43 433	204 931	610 004	341 300	600 308	128 765	234 437	-	-	660 290	661 144	591 446	687 723	831 101	176 100
Fixed assets and Improvements	532 581	582 969	629 976	1 313 856	734 136	784 525	830 404	885 303	935 692	980 725	1 036 470	1 086 859	1 131 047	1 187 637	1 231 261	1 281 368	1 338 804	3 226 871	1 439 582	1 481 796
Total farm cash expenditure	**2 556 004**	**2 762 225**	**3 117 756**	**3 807 811**	**3 385 156**	**3 634 211**	**4 004 430**	**4 616 059**	**4 554 217**	**5 019 267**	**4 781 580**	**5 097 203**	**5 079 184**	**5 281 141**	**6 138 363**	**6 353 714**	**6 509 135**	**8 666 825**	**7 203 968**	**6 731 991**
Net farm cash flow after cash expenditure	**723 963**	**703 540**	**525 665**	**25 338**	**608 956**	**518 418**	**426 837**	**-47 753**	**161 653**	**-64 552**	**397 146**	**232 487**	**625 574**	**491 206**	**-184 439**	**-248 667**	**-295 911**	**-2 131 405**	**-353 116**	**127 387**
Depreciation	**594 325**	**612 927**	**630 471**	**663 024**	**697 076**	**725 751**	**757 940**	**790 727**	**833 970**	**875 060**	**926 689**	**964 981**	**1 007 801**	**1 048 682**	**1 087 765**	**1 135 295**	**1 200 066**	**1 248 069**	**1 329 878**	**1 396 511**
on moveable assets	136 344	136 301	132 326	140 569	140 569	139 621	140 649	140 761	149 843	155 313	169 894	169 741	172 752	172 495	169 148	172 994	192 867	194 802	208 489	226 849
on fixed improvements	103 736	103 736	103 736	103 736	110 776	110 776	110 776	110 776	110 776	110 776	110 776	110 776	110 776	110 776	110 776	110 776	110 776	110 776	131 705	131 705
on biologicals	354 245	372 890	394 409	418 719	445 732	475 354	506 515	539 190	573 352	608 971	646 019	684 464	724 273	765 411	807 841	851 526	896 423	942 491	989 685	1 037 957
Total Farm costs	2 617 749	2 792 182	2 963 777	3 156 979	3 348 096	3 532 003	3 727 035	3 911 478	4 111 195	4 313 293	4 543 033	4 740 888	4 955 938	5 142 185	5 334 577	5 546 496	5 778 951	6 000 300	6 263 163	6 470 605
Net farm income	**662 219**	**673 583**	**679 644**	**676 171**	**646 016**	**620 625**	**704 232**	**656 828**	**604 675**	**641 421**	**635 693**	**588 802**	**748 820**	**630 162**	**619 347**	**558 550**	**434 274**	**535 120**	**587 689**	**388 772**

4.5.3 Measures of feasibility/ cash flow analysis

The term 'cash flow analysis' is descriptive of its purpose and meaning, which is the study of the cash in-and-out flow of a business for a specific period (Warren, 1998:9). A healthy cash flow is indispensable to a healthy farm business as it will determine if cash is available to ensure the timeous execution of essential actions. Similarly insufficient cash flow could lead to the loss of a viable business opportunity. As such the demise of farm businesses are frequently preceded by the start of liquidity problems and timeous intervention can often avert insolvency and accompanied business failure (Warren, 1998:175). Cash flow is also the easiest, most sensitive and arguably most important financial indicator to monitor on the farm (Warren, 1998:175).

For this reason care was taken to allow for detailed cash flow budgeting, in the VITISIM101 model. To determine the cash flow of the farm business and eventually internal rate of return (IRR), VITISIM101 made use of partial as well as whole farm cash flow budgeting. Partial cash flow budgets were drawn up for each collective enterprise, after which they were added to form the whole-farm cash flow budget (refer to Table 4.10 to Table 4.12). The use of partial cash flow budgets allowed for the illustration of the contribution of specific enterprises to the whole farm cash flow (refer to Table 4.13).

The cash flow budgets are calculated in VITISIM101 by subtracting the total cash expenditure, from gross income. Gross income is calculated by multiplying the class[24] specific yield per hectare, with the class specific price. Similarly total cash expenditure is constituted out of all cash outflows related to direct cost, labour, mechanisation, fixed improvements and general expenditure to arrive at a total cash expenditure or outflow. The total calculated cash expenditure is then subtracted from the total gross farm income to arrive at a net cash flow before capital expenditure.

The net cash flow before capital expenditure, as calculated from the partial budgets of the three collective enterprises, is then added to arrive at a total net farm cash flow before capital expenditure. Subsequent capital expenditure is subtracted to calculate the net farm cash flow. From the net farm cash flow, tax, external factor costs (excluding interest) and return to own management are subtracted to calculate the annual net farm cash flow. The annual net farm cash flow is used in the IRR and NPV calculation, along with the total initial investment and total final investment value at the end of the projection period. The partial cash flow budgets for the collective wine grape, lucerne and all other crops enterprise are illustrated followed by the illustration of the whole farm cash flow budget and IRR calculation in Table 4.13. The use of outputs, incorporation of data and results follow in Chapter 5.

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[24] In the VITISIM101 model yields are divided into different classes of quality. The latter is done by the designation of specific quality % assumptions. For example 30% of the grapes on a particular Sauvignon Blanc could be assumed to be of class 1, 50% of class 2 and 20% of class 3.

Table 4.10: The partial cash flow budget of the collective wine grape enterprise

Partial cash flow budget (R)	2014/01/01	2015/01/01	2016/01/01	2017/01/01	2018/01/01	2019/01/01	2020/01/01	2021/01/01	2022/01/01	2023/01/01	2024/01/01	2025/01/01	2026/01/01	2027/01/01	2028/01/01	2029/01/01	2030/01/01	2031/01/01	2032/01/01	2033/01/01
Wine grapes gross income	**2 308 155**	**2 435 644**	**2 554 991**	**2 686 411**	**2 789 064**	**2 889 273**	**3 109 602**	**3 188 332**	**3 277 587**	**3 458 123**	**3 623 826**	**3 716 481**	**4 033 240**	**4 042 520**	**4 165 790**	**4 258 603**	**4 308 472**	**4 572 359**	**4 829 482**	**4 779 699**
Chardonnay	258 716	265 184	274 702	290 538	298 054	165 543	170 279	220 358	288 901	329 603	380 662	220 445	238 480	316 348	391 046	431 899	499 331	530 275	554 909	578 364
Chenin Blanc	526 056	455 162	526 145	613 478	657 864	682 909	791 361	768 619	752 906	573 104	650 997	753 032	719 733	722 712	886 205	1 017 491	997 427	893 648	913 194	1 006 044
Colombar	594 704	689 655	634 847	711 140	810 541	893 706	836 978	868 898	836 375	933 855	1 104 731	1 218 675	1 344 106	1 359 339	1 210 108	1 214 257	1 309 229	1 404 648	1 505 020	1 277 238
Shiraz	620 492	698 648	725 152	754 684	781 913	803 998	844 826	751 914	742 159	906 571	783 326	775 594	970 726	993 319	1 015 441	867 830	710 949	942 848	1 035 230	1 098 043
Sauvignon Blanc	124 308	133 769	133 386	-	-	88 610	154 466	183 922	239 449	269 755	260 194	275 596	271 780	271 038	276 559	266 050	267 491	268 505	267 992	274 914
Cabernet Sauvignon	183 879	193 225	260 761	316 570	240 692	254 506	311 692	394 620	417 798	445 236	443 915	473 139	488 416	379 764	386 431	461 075	524 046	532 436	553 136	545 096
Cultivar 7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cultivar 8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cultivar 9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cultivar 10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Direct proliferation expenditure	**196 103**	**213 791**	**231 480**	**249 168**	**266 856**	**284 545**	**302 233**	**319 921**	**337 610**	**355 298**	**372 986**	**390 675**	**408 363**	**426 051**	**443 740**	**461 428**	**479 116**	**496 805**	**514 493**	**532 181**
Labour	**555 494**	**604 917**	**653 020**	**704 988**	**755 423**	**804 702**	**859 274**	**905 058**	**949 621**	**999 530**	**1 056 391**	**1 108 151**	**1 170 980**	**1 211 672**	**1 258 773**	**1 307 609**	**1 352 797**	**1 410 147**	**1 470 316**	**1 501 156**
Mechanisation	**218 918**	**231 352**	**243 312**	**256 742**	**269 397**	**281 360**	**295 541**	**307 417**	**322 198**	**339 322**	**361 787**	**375 637**	**390 927**	**401 617**	**413 851**	**435 403**	**451 958**	**472 928**	**487 624**	**495 741**
Fuel	137 294	148 778	159 897	172 089	183 744	194 849	207 559	218 095	228 597	240 163	252 962	265 332	279 008	289 004	300 299	311 075	321 911	335 265	348 607	356 505
Repairs, parts and maintenance	62 175	62 125	61 981	62 204	62 204	62 079	62 530	62 892	66 178	70 738	79 398	79 857	80 460	80 165	80 104	89 907	94 631	101 215	101 560	100 824
Licenses and insurance	19 449	20 449	21 435	22 449	23 449	24 432	25 451	26 430	27 423	28 421	29 426	30 448	31 459	32 448	33 448	34 421	35 416	36 448	37 456	38 413
Hired machinery	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fixed improvements	**112 500**	**114 500**	**116 500**	**118 500**	**120 500**	**122 500**	**124 500**	**126 500**	**128 500**	**130 500**	**132 500**	**134 500**	**136 500**	**138 500**	**140 500**	**142 500**	**144 500**	**146 500**	**148 500**	**150 500**
Repair and maintenance	87 500	87 500	87 500	87 500	87 500	87 500	87 500	87 500	87 500	87 500	87 500	87 500	87 500	87 500	87 500	87 500	87 500	87 500	87 500	87 500
Insurance	25 000	27 000	29 000	31 000	33 000	35 000	37 000	39 000	41 000	43 000	45 000	47 000	49 000	51 000	53 000	55 000	57 000	59 000	61 000	63 000
General expenditure	**271 228**	**296 601**	**321 975**	**347 348**	**372 721**	**398 094**	**423 467**	**448 840**	**474 213**	**499 586**	**524 959**	**550 332**	**575 705**	**601 078**	**626 451**	**651 824**	**677 197**	**702 570**	**727 943**	**753 316**
Electricity fixed component accrued to PGV	33 563	37 926	42 290	46 653	51 016	55 379	59 742	64 106	68 469	72 832	77 195	81 558	85 922	90 285	94 648	99 011	103 374	107 738	112 101	116 464
Electrcity irrigation component accrued to PGV	93 570	105 734	117 898	130 062	142 226	154 390	166 555	178 719	190 883	203 047	215 211	227 375	239 539	251 703	263 867	276 031	288 195	300 360	312 524	324 688
Water cost PGV	70 970	75 229	79 487	83 745	88 003	92 261	96 520	100 778	105 036	109 294	113 553	117 811	122 069	126 327	130 585	134 844	139 102	143 360	147 618	151 877
Land- property and muncipal taxes	20 000	21 400	22 800	24 200	25 600	27 000	28 400	29 800	31 200	32 600	34 000	35 400	36 800	38 200	39 600	41 000	42 400	43 800	45 200	46 600
Administration	53 125	56 313	59 500	62 688	65 875	69 063	72 250	75 438	78 625	81 813	85 000	88 188	91 375	94 563	97 750	100 938	104 125	107 313	110 500	113 688
Total wine grape cash expenditure	**1 354 244**	**1 461 162**	**1 566 286**	**1 676 745**	**1 784 897**	**1 891 201**	**2 005 014**	**2 107 736**	**2 212 140**	**2 324 235**	**2 448 623**	**2 559 295**	**2 682 475**	**2 778 918**	**2 883 314**	**2 998 764**	**3 105 568**	**3 228 950**	**3 348 876**	**3 432 895**
Cash flow after cash expenditure PGV	**953 911**	**974 481**	**988 705**	**1 009 665**	**1 004 167**	**998 072**	**1 104 589**	**1 080 596**	**1 065 447**	**1 133 888**	**1 175 203**	**1 157 186**	**1 350 766**	**1 263 603**	**1 282 475**	**1 259 839**	**1 202 905**	**1 343 409**	**1 480 606**	**1 346 804**
Net cash flow per hectare (before capital expenditure)	19 078	19 490	19 774	20 193	20 083	19 961	22 092	21 612	21 309	22 678	23 504	23 144	27 015	25 272	25 650	25 197	24 058	26 868	29 612	26 936

Table 4.11: The partial cash flow budget of the lucerne enterprise

Partial cash flow budget (R)	2014/01/01	2015/01/01	2016/01/01	2017/01/01	2018/01/01	2019/01/01	2020/01/01	2021/01/01	2022/01/01	2023/01/01	2024/01/01	2025/01/01	2026/01/01	2027/01/01	2028/01/01	2029/01/01	2030/01/01	2031/01/01	2032/01/01	2033/01/01
Lucerne gross income	**971 813**	**1 030 121**	**1 088 430**	**1 146 739**	**1 205 048**	**1 263 356**	**1 321 665**	**1 379 974**	**1 438 283**	**1 496 591**	**1 554 900**	**1 613 209**	**1 671 518**	**1 729 826**	**1 788 135**	**1 846 444**	**1 904 753**	**1 963 061**	**2 021 370**	**2 079 679**
Class 1	886 613	939 809	993 006	1 046 203	1 099 400	1 152 596	1 205 793	1 258 990	1 312 187	1 365 383	1 418 580	1 471 777	1 524 974	1 578 170	1 631 367	1 684 564	1 737 761	1 790 957	1 844 154	1 897 351
Class 2	85 200	90 312	95 424	100 536	105 648	110 760	115 872	120 984	126 096	131 208	136 320	141 432	146 544	151 656	156 768	161 880	166 992	172 104	177 216	182 328
Class 3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Direct proliferation cost	**122 715**	**132 868**	**143 021**	**153 174**	**163 327**	**173 480**	**183 632**	**193 785**	**203 938**	**214 091**	**224 244**	**234 397**	**244 550**	**254 703**	**264 856**	**275 009**	**285 161**	**295 314**	**305 467**	**315 620**
Labour	**81 703**	**87 539**	**93 375**	**99 211**	**105 047**	**110 884**	**116 720**	**122 556**	**128 392**	**134 229**	**140 065**	**145 901**	**151 737**	**157 573**	**163 410**	**169 246**	**175 082**	**180 918**	**186 754**	**192 591**
Mechanisation	**157 087**	**165 705**	**174 333**	**184 234**	**192 852**	**201 481**	**210 223**	**218 856**	**230 630**	**239 249**	**252 678**	**261 283**	**270 039**	**278 668**	**287 286**	**295 921**	**316 506**	**326 186**	**347 020**	**363 505**
Fuel	93 359	101 294	109 229	117 165	125 100	133 036	140 971	148 907	156 842	164 778	172 713	180 649	188 584	196 520	204 455	212 391	220 326	228 262	236 197	244 132
Repairs, parts and maintenance	51 021	51 021	51 021	52 312	52 312	52 312	52 449	52 449	55 598	55 598	60 414	60 414	60 562	60 562	60 562	60 562	72 524	76 258	85 830	93 664
Licenses and insurance	12 707	13 390	14 082	14 756	15 439	16 133	16 803	17 500	18 190	18 873	19 551	20 220	20 893	21 586	22 269	22 969	23 656	21 667	24 992	25 708
Hired machinery	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fixed improvements	**67 500**	**68 700**	**69 900**	**71 100**	**72 300**	**73 500**	**74 700**	**75 900**	**77 100**	**78 300**	**79 500**	**80 700**	**81 900**	**83 100**	**84 300**	**85 500**	**86 700**	**87 900**	**89 100**	**90 300**
Repair and maintenance	**52 500**	**52 500**	**52 500**	**52 500**	**52 500**	**52 500**	**52 500**	**52 500**	**52 500**	**52 500**	**52 500**	**52 500**	**52 500**	**52 500**	**52 500**	**52 500**	**52 500**	**52 500**	**52 500**	**52 500**
Insurance	**15 000**	**16 200**	**17 400**	**18 600**	**19 800**	**21 000**	**22 200**	**23 400**	**24 600**	**25 800**	**27 000**	**28 200**	**29 400**	**30 600**	**31 800**	**33 000**	**34 200**	**35 400**	**36 600**	**37 800**
General expenditure	**227 831**	**250 146**	**272 462**	**294 777**	**317 093**	**339 408**	**361 724**	**384 039**	**406 355**	**428 670**	**450 986**	**473 301**	**495 617**	**517 932**	**540 248**	**562 564**	**584 879**	**607 195**	**629 510**	**651 826**
Electricity fixed component accrued to lucerne	32 437	36 654	40 870	45 087	49 304	53 521	57 738	61 954	66 171	70 388	74 605	78 822	83 038	87 255	91 472	95 689	99 906	104 122	108 339	112 556
Electrcity irrigation lucerne	90 430	102 186	113 942	125 698	137 454	149 210	160 965	172 721	184 477	196 233	207 989	219 745	231 501	243 257	255 013	266 769	278 525	290 280	302 036	313 792
Water cost lucerne	68 589	72 704	76 819	80 935	85 050	89 165	93 281	97 396	101 511	105 627	109 742	113 857	117 973	122 088	126 203	130 319	134 434	138 549	142 665	146 780
Land- property and muncipal taxes	4 500	4 815	5 130	5 445	5 760	6 075	6 390	6 705	7 020	7 335	7 650	7 965	8 280	8 595	8 910	9 225	9 540	9 855	10 170	10 485
Administration	31 875	33 788	35 700	37 613	39 525	41 438	43 350	45 263	47 175	49 088	51 000	52 913	54 825	56 738	58 650	60 563	62 475	64 388	66 300	68 213
Total lucerne cash expenditure	**656 835**	**704 958**	**753 090**	**802 496**	**850 619**	**898 753**	**946 999**	**995 137**	**1 046 415**	**1 094 539**	**1 147 472**	**1 195 582**	**1 243 843**	**1 291 977**	**1 340 100**	**1 388 239**	**1 448 329**	**1 497 513**	**1 557 851**	**1 613 841**
Cashflow after cash expenditure	**314 977**	**325 163**	**335 340**	**344 243**	**354 429**	**364 604**	**374 666**	**384 837**	**391 867**	**402 052**	**407 428**	**417 627**	**427 675**	**437 850**	**448 035**	**458 204**	**456 424**	**465 548**	**463 519**	**465 838**
Net cashflow per hectare (before capital expenditure)	**10 499**	**10 839**	**11 178**	**11 475**	**11 814**	**12 153**	**12 489**	**12 828**	**13 062**	**13 402**	**13 581**	**13 921**	**14 256**	**14 595**	**14 935**	**15 273**	**15 214**	**15 518**	**15 451**	**15 528**

Table 4.12: The partial cash flow budget of the all other enterprise[25]

Partial cash flow budget (R)	2014/01/01	2015/01/01	2016/01/01	2017/01/01	2018/01/01	2019/01/01	2020/01/01	2021/01/01	2022/01/01	2023/01/01	2024/01/01	2025/01/01	2026/01/01	2027/01/01	2028/01/01	2029/01/01	2030/01/01	2031/01/01	2032/01/01	2033/01/01
All other farm income	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Oats	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Onions (Seed)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Butternut	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
None (Idle)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Direct proliferation cost	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Labour	**1 121**	**1 222**	**1 322**	**1 423**	**1 523**	**1 623**	**1 724**	**1 824**	**1 924**	**2 025**	**2 125**	**2 225**	**2 326**	**2 426**	**2 526**	**2 627**	**2 727**	**2 828**	**2 928**	**3 028**
Mechanisation	**11 024**	**11 699**	**12 379**	**13 049**	**13 724**	**14 406**	**15 075**	**15 757**	**16 433**	**17 108**	**17 784**	**18 451**	**19 126**	**19 801**	**20 476**	**21 162**	**21 837**	**22 502**	**23 177**	**23 864**
Fuel	7 167	7 776	8 385	8 994	9 603	10 212	10 822	11 431	12 040	12 649	13 258	13 867	14 477	15 086	15 695	16 304	16 913	17 522	18 132	18 741
Repairs, parts and maintenance	3 031	3 031	3 031	3 031	3 031	3 031	3 031	3 031	3 031	3 031	3 031	3 031	3 031	3 031	3 031	3 031	3 031	3 031	3 031	3 031
Licenses and insurance	826	892	963	1 024	1 090	1 162	1 222	1 295	1 362	1 428	1 494	1 552	1 618	1 684	1 750	1 826	1 893	1 948	2 014	2 092
Hired machinery	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fixed improvements	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Repair and maintenance	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Insurance	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
General expenditure	**200**	**214**	**228**	**242**	**256**	**270**	**284**	**298**	**312**	**326**	**340**	**354**	**368**	**382**	**396**	**410**	**424**	**438**	**452**	**466**
Electricity fixed component accrued to other	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Electrcity irrigation other	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Water cost other	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Land- property and muncipal taxes	**200**	**214**	**228**	**242**	**256**	**270**	**284**	**298**	**312**	**326**	**340**	**354**	**368**	**382**	**396**	**410**	**424**	**438**	**452**	**466**
Administration	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total farm cash expenditure before renewal	**12 345**	**13 135**	**13 929**	**14 714**	**15 503**	**16 299**	**17 082**	**17 879**	**18 669**	**19 459**	**20 249**	**21 030**	**21 820**	**22 609**	**23 399**	**24 199**	**24 989**	**25 768**	**26 557**	**27 358**
Income after cash expenditure	**-12 345**	**-13 135**	**-13 929**	**-14 714**	**-15 503**	**-16 299**	**-17 082**	**-17 879**	**-18 669**	**-19 459**	**-20 249**	**-21 030**	**-21 820**	**-22 609**	**-23 399**	**-24 199**	**-24 989**	**-25 768**	**-26 557**	**-27 358**
Planting cost (establishment cost)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Net cashflow, planting cost included	-12 345	-13 135	-13 929	-14 714	-15 503	-16 299	-17 082	-17 879	-18 669	-19 459	-20 249	-21 030	-21 820	-22 609	-23 399	-24 199	-24 989	-25 768	-26 557	-27 358

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[25] Diverse land clearing and soil preparation costs typically involved with cash crops, including annual grading of roads were allocated to the other crops component in the VITISIM101 model. As consequence the other crops enterprise can have allocated costs despite no production of other crops for a specific year.

Table 4.13: The whole farm cash flow budget and calculation of IRR and NPV

Multiple period budget (R)	2014/01/01	2015/01/01	2016/01/01	2017/01/01	2018/01/01	2019/01/01	2020/01/01	2021/01/01	2022/01/01	2023/01/01	2024/01/01	2025/01/01	2026/01/01	2027/01/01	2028/01/01	2029/01/01	2030/01/01	2031/01/01	2032/01/01	2033/01/01
Whole farm gross income	**3 279 967**	**3 465 765**	**3 643 421**	**3 833 150**	**3 994 111**	**4 152 629**	**4 431 267**	**4 568 306**	**4 715 870**	**4 954 714**	**5 178 726**	**5 329 690**	**5 704 758**	**5 772 347**	**5 953 925**	**6 105 047**	**6 213 225**	**6 535 420**	**6 850 852**	**6 859 377**
Gross income collective wine grape enterprise (WGE)	2 308 155	2 435 644	2 554 991	2 686 411	2 789 064	2 889 273	3 109 602	3 188 332	3 277 587	3 458 123	3 623 826	3 716 481	4 033 240	4 042 520	4 165 790	4 258 603	4 308 472	4 572 359	4 829 482	4 779 699
Gross income lucerne enterprise	971 813	1 030 121	1 088 430	1 146 739	1 205 048	1 263 356	1 321 665	1 379 974	1 438 283	1 496 591	1 554 900	1 613 209	1 671 518	1 729 826	1 788 135	1 846 444	1 904 753	1 963 061	2 021 370	2 079 679
Gross income other crops enterprise	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Production cost (cash expenditure items)	**2 023 424**	**2 179 255**	**2 333 306**	**2 493 955**	**2 651 019**	**2 806 253**	**2 969 095**	**3 120 752**	**3 277 225**	**3 438 233**	**3 616 344**	**3 775 907**	**3 948 137**	**4 093 503**	**4 246 813**	**4 411 202**	**4 578 885**	**4 752 231**	**4 933 284**	**5 074 094**
Direct proliferation cost	318 818	346 659	374 500	402 342	430 183	458 024	485 865	513 707	541 548	569 389	597 230	625 072	652 913	680 754	708 595	736 436	764 278	792 119	819 960	847 801
Labour	638 318	693 678	747 717	805 622	861 993	917 209	977 717	1 029 438	1 079 937	1 135 783	1 198 581	1 256 278	1 325 043	1 371 671	1 424 709	1 479 481	1 530 606	1 593 893	1 659 998	1 696 775
Mechanisation (lisences, insurance and fuel included)	387 029	408 757	430 024	454 025	475 974	497 247	520 838	542 030	569 260	595 679	632 248	655 371	680 092	700 086	721 614	752 486	790 302	821 616	857 821	883 110
Electricty (fixed and irrigation)	250 000	282 500	315 000	347 500	380 000	412 500	445 000	477 500	510 000	542 500	575 000	607 500	640 000	672 500	705 000	737 500	770 000	802 500	835 000	867 500
Water	139 559	147 933	156 306	164 680	173 053	181 427	189 800	198 174	206 548	214 921	223 295	231 668	240 042	248 415	256 789	265 162	273 536	281 909	290 283	298 657
General expenditure																				
Fixed improvements	180 000	183 200	186 400	189 600	192 800	196 000	199 200	202 400	205 600	208 800	212 000	215 200	218 400	221 600	224 800	228 000	231 200	234 400	237 600	240 800
Land- property and muncipal taxes	24 700	26 429	28 158	29 887	31 616	33 345	35 074	36 803	38 532	40 261	41 990	43 719	45 448	47 177	48 906	50 635	52 364	54 093	55 822	57 551
Administration	85 000	90 100	95 200	100 300	105 400	110 500	115 600	120 700	125 800	130 900	136 000	141 100	146 200	151 300	156 400	161 500	166 600	171 700	176 800	181 900
Net capital expenditure	**532 581**	**582 969**	**784 450**	**1 313 856**	**734 136**	**827 958**	**1 035 335**	**1 495 307**	**1 276 992**	**1 581 033**	**1 165 236**	**1 321 296**	**1 131 047**	**1 187 637**	**1 891 551**	**1 942 512**	**1 930 250**	**3 914 594**	**2 270 684**	**1 657 897**
Moveable assets	-	-	154 474	-	-	43 433	204 931	610 004	341 300	600 308	128 765	234 437	-	-	660 290	661 144	591 446	687 723	831 101	176 100
Fixed assets and Improvements	532 581	582 969	629 976	1 313 856	734 136	784 525	830 404	885 303	935 692	980 725	1 036 470	1 086 859	1 131 047	1 187 637	1 231 261	1 281 368	1 338 804	3 226 871	1 439 582	1 481 796
Total farm cash expenditure	**2 556 004**	**2 762 225**	**3 117 756**	**3 807 811**	**3 385 156**	**3 634 211**	**4 004 430**	**4 616 059**	**4 554 217**	**5 019 267**	**4 781 580**	**5 097 203**	**5 079 184**	**5 281 141**	**6 138 363**	**6 353 714**	**6 509 135**	**8 666 825**	**7 203 968**	**6 731 991**
Net farm cash flow after cash expenditure	**723 963**	**703 540**	**525 665**	**25 338**	**608 956**	**518 418**	**426 837**	**-47 753**	**161 653**	**-64 552**	**397 146**	**232 487**	**625 574**	**491 206**	**-184 439**	**-248 667**	**-295 911**	**-2 131 405**	**-353 116**	**127 387**
Depreciation	**594 325**	**612 927**	**630 471**	**663 024**	**697 076**	**725 751**	**757 940**	**790 727**	**833 970**	**875 060**	**926 689**	**964 981**	**1 007 801**	**1 048 682**	**1 087 765**	**1 135 295**	**1 200 066**	**1 248 069**	**1 329 878**	**1 396 511**
on moveable assets	136 344	136 301	132 326	140 569	140 569	139 621	140 649	140 761	149 843	155 313	169 894	169 741	172 752	172 495	169 148	172 994	192 867	194 802	208 489	226 849
on fixed improvements	103 736	103 736	103 736	103 736	110 776	110 776	110 776	110 776	110 776	110 776	110 776	110 776	110 776	110 776	110 776	110 776	110 776	110 776	131 705	131 705
on biologicals	354 245	372 890	394 409	418 719	445 732	475 354	506 515	539 190	573 352	608 971	646 019	684 464	724 273	765 411	807 841	851 526	896 423	942 491	989 685	1 037 957
Total Farm costs	2 617 749	2 792 182	2 963 777	3 156 979	3 348 096	3 532 003	3 727 035	3 911 478	4 111 195	4 313 293	4 543 033	4 740 888	4 955 938	5 142 185	5 334 577	5 546 496	5 778 951	6 000 300	6 263 163	6 470 605
Net farm income	**662 219**	**673 583**	**679 644**	**676 171**	**646 016**	**620 625**	**704 232**	**656 828**	**604 675**	**641 421**	**635 693**	**588 802**	**748 820**	**630 162**	**619 347**	**558 550**	**434 274**	**535 120**	**587 689**	**388 772**

CHAPTER 5: INCORPORATION OF DATA AND DESCRIPTION OF RESULTS

5.1. Introduction

Within this chapter the influence of alternate wine grape production systems on the long term profitability of a farm business will be evaluated. This is illustrated with the use of the VITISIM101 simulation model. For the endeavour alternate strategies within three scenarios will be simulated. Within the first scenario different strategies in the view of alternate cultivation practices and trellis systems are evaluated, with the cultivar composition and farm size fixed for all strategies. Scenario two illustrates differing economies of size between alternate strategies, by expanding the area under wine grape production as well as machinery capacity if required by the strategy, of the simulated farm from 50 to 80 hectares. Under the third and final scenario a gradual structural transition as well as expansion of the wine grape production system, from an area of 50 to 80 hectares over a 20 year projection period is simulated.

As discussed in the preceding chapters, the purpose of this thesis was to develop a simulation model by which to evaluate alternate wine grape production systems. In Chapter 2 and 3 the theoretical basis for the VITISIM101 model is established, followed by a discussion of the functioning of the VITISIM101 model in Chapter 4. In addition the long-term nature of the evaluation period vindicated the pursuit of the establishment of representative cultivar and trellis specific yield and income data, for each year of the life spectrum of the vine. While failure to establish representative data would not impede the functioning of the VITISIM101 model, it would make it less realistic, with numerous inputs already farm specific.

In view of the above Chapter 5 commences with a discussion on the incorporation of secondary data sources into the VITISIM101 model. Hereafter empirical observations as obtained in the secondary dataset are illustrated, which endorse the theoretical cornerstone of the model, followed by a subsequent discussion of outputs and results from the VITISIM101 model.

5.2 The incorporation of secondary data

The VITISIM101 model was constructed to allow for the input of any yield, quality percentage and price per class, for every year of the projection period. The latter was done to allow for the subjective input of the farmer and allow the tailoring to farm specific circumstances. For the purposes of designating representative yield and income tendencies per cultivar and trellis combination over the economic life of a vineyard, a large dataset was required.

The requirement is motivated out of the limited life-span of primary trials and as such secondary data was chosen. Secondary data from *WineMS*®[26] was used to establish representative yield and income tendencies per cultivar and trellis specific combinations. The latter was done in an attempt to account for the variable yields of the grapevine over its lifetime. The data was specifically insightful[27] to illustrate yield per hectare and income per tonne disparities between cultivars, trellises and production regions (refer to Section 5.3). The data was hereafter imported into the advanced parameter input section in the format of matrixes as displayed in the tables of Section 4.3.2. As the VITISIM101 model is primarily designed to allow maximum farm specific input yield, quality and income parameters can be revised to incorporate farm specific data.

The dataset obtained from *WineMS*® was the dataset for the 2012 wine grape harvest encompassing 885 410 tonnes of the South African wine grape harvest or 62,5% of the estimated 2012 wine grape harvest of 1 414 483 tonnes (Floris, 2014:5; Spies, 2014). Specific wine production areas were hereafter combined in order to create a greater dispersion of data, from which aggregate cultivar and trellis specific information and trends could be established for specific regions over the lifetime of the vineyard. The approach followed is discussed in the subsequent section.

5.2.1 Amalgamating wine production areas to form regions

Alternate production areas were pooled together based on a broad classification of similar cultivation practices and climatological features. The approach proved useful in obtaining a greater dispersion of data over which representative tendencies could be based. The primary 2012 *WineMS*® wine grape production dataset was specified in 44 different production areas or wards (Spies, 2014). As listed in the preceding paragraph these 44 areas were then pooled into 15 production regions. These regions were specified as: Breedekloof, Durbanville, Eastern Cape, Franschhoek, Klein Karoo, Northern Cape, Olifantsrivier, Overberg, Paarl, Robertson, Stellenbosch, Swartland, Western Cape, Worcester and Tulbagh. Due to the small contribution to the overall wine industry the Tulbagh and Eastern Cape regions were removed which left 13 regions. A figure of the broad designation of the wine producing regions as used for the VITISIM101 model can be seen in Figure 5.1.

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[26] Secondary data was obtained from Wine Management Systems, a South African based wine information management system.

[27] In addition the histograms and figures illustrated in Section 5.3 can be considered empirical validation of theory discussed in Section 3.1.

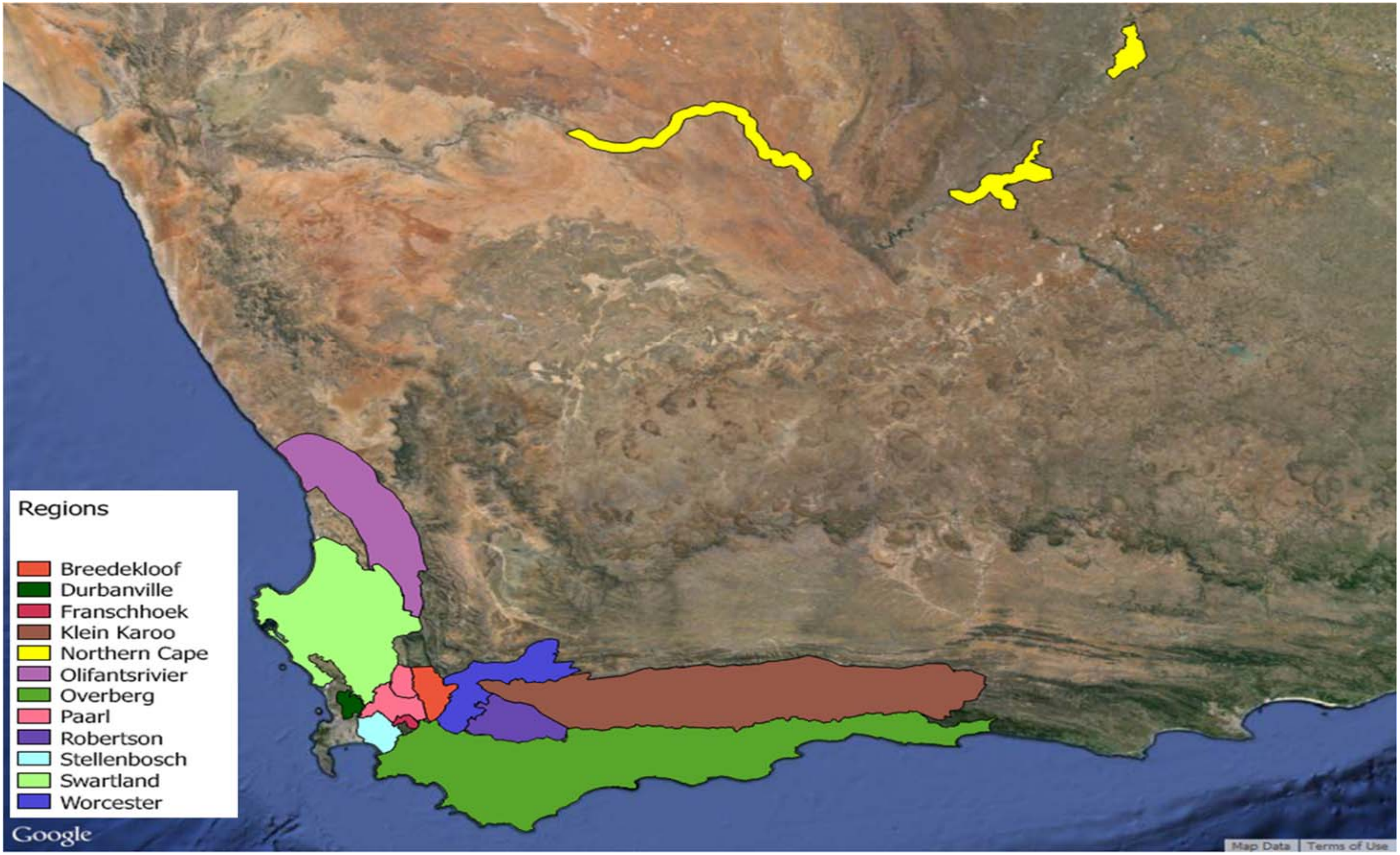

Figure 5.1: A broad designation of production areas into regions as used for the VITISIM101 model
Source: (Strever, 2014)

5.2.2 Combining trellis descriptions to reflect their size

While the original 2012 *WineMS*® wine production dataset with over 18 090 observations was invaluable in compiling a large sample to use in the simulation model, it also posed unique challenges with the description of trellis systems. The latter was exacerbated by the fact that there was little conformity in the nomenclature of trellis system types in the South African wine industry before 2013. The latter motivated the publication of "Trellis System Types: 2014" by the South African Wine Industry Statistics (SAWIS) and VINPRO industry organisations in an attempt to create greater conformity in the future (Vinpro & SAWIS, 2014:3).

The secondary dataset appeared to illustrate this disparity with the designation of trellis systems. To create bigger samples, trellises of similar design and magnitude were combined to reflect the relative size. The original dataset had 41 different trellis types, of which synonymous trellis denotations were re-classified after which 21 systems were pooled to create eight "relative magnitude" systems and nine systems were omitted due to their insignificant number of observations or ambiguous designation.

5.2.3 Dataset screening

The dataset was first cleared or screened for erroneous fields or irrational results and thereafter of all blocks smaller than 0.2 hectares and bigger than 20 hectares. In the same way all blocks or fields were cleared to include only blocks that deliver a minimum of two tonnes per hectare and a maximum of 60 tonnes per hectare. Additional data removals included removing table grape varieties, wine grape varieties with limited plantings as well as lines with empty data fields or irrational values. The screening decreased the total tonnage of the dataset to 724 569 tonnes and 14 931 observations or blocks.

5.3 The illustration of secondary data

From the screened dataset the cultivars best represented in the dataset, across all wards or regions can be viewed in Figure 5.2. The cultivars arranged from most represented to least are: Chenin Blanc, Colombar, Shiraz, Chardonnay, Cabernet Sauvignon, Sauvignon Blanc, Pinotage, Merlot, Muscat Alexandrie (Hanepoot), Ruby Cabernet, Cinsaut and Semillon.

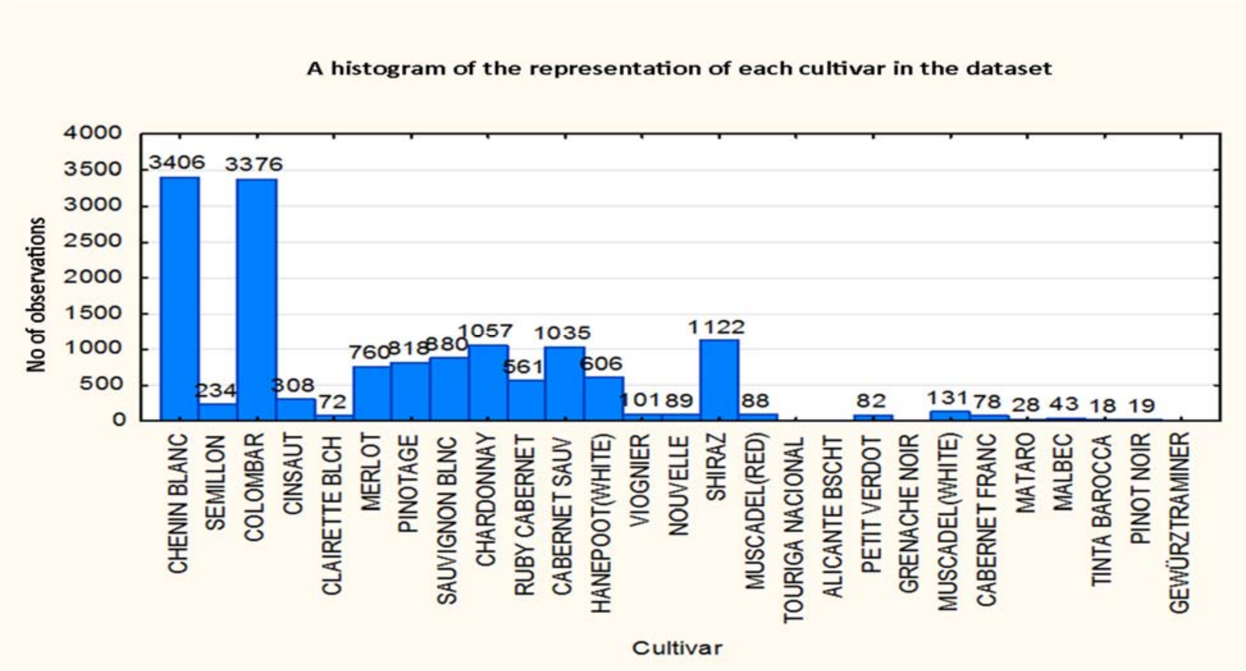

Figure 5.2: A histogram of the representation of each cultivar in the dataset

Similarly the dataset was screened for the representation of the combined wards or regions (refer to Figure 5.3). The amalgamated regions considered for the model arranged from most to least observations are: Breedekloof, Olifantsrivier, Worcester, Robertson, Northern Cape, Paarl and the Klein Karoo. The "Western Cape" amalgamated region was not considered due to the ambiguous denotation and fact that as per wine of origin scheme, it is usually used for grapes originating from more than one production area (refer to Figure 5.1).

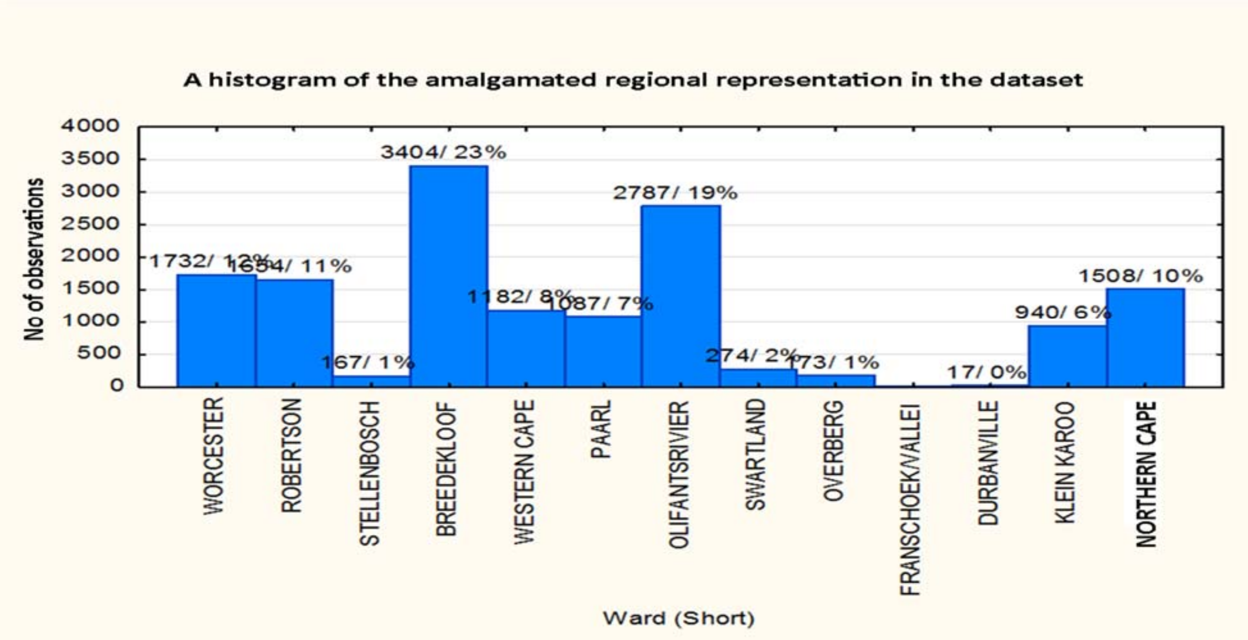

Figure 5.3: A histogram of the amalgamated regional representation in the dataset

The representation of alternate regions in the dataset was consistent with expectations, due to the wide usage of *WineMS*® software at co-operative cellars which are abundant in the irrigated wine grape production areas of South Africa. Additionally yield differences, in the overall data set in tonnes per hectare, are apparent to be dependent on a combination of the specific cultivar, rootstock, trellis size, production region, as well as irrigation system.

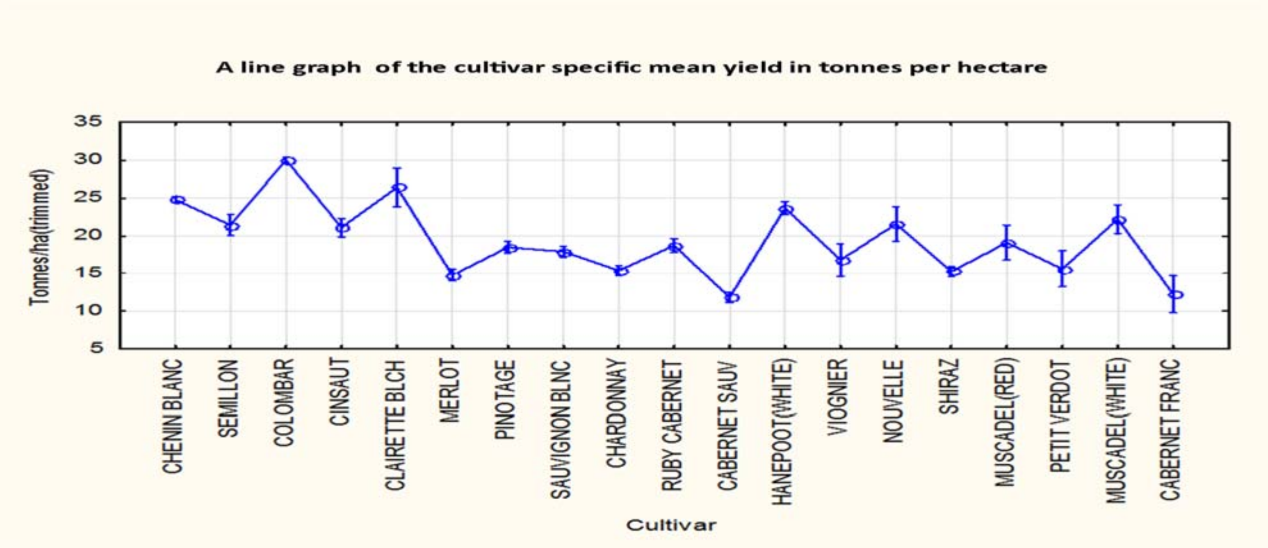

Figure 5.4: A line graph of the cultivar specific mean yield in tonnes per hectare

Similarly rootstock specific differences could be observed from Figure 5.5. The latter illustrates that the selection of rootstocks is important, yet due to alternate representation of different cultivars on particular rootstocks, as well as cultivation on different trellises, inferences should be made with caution.

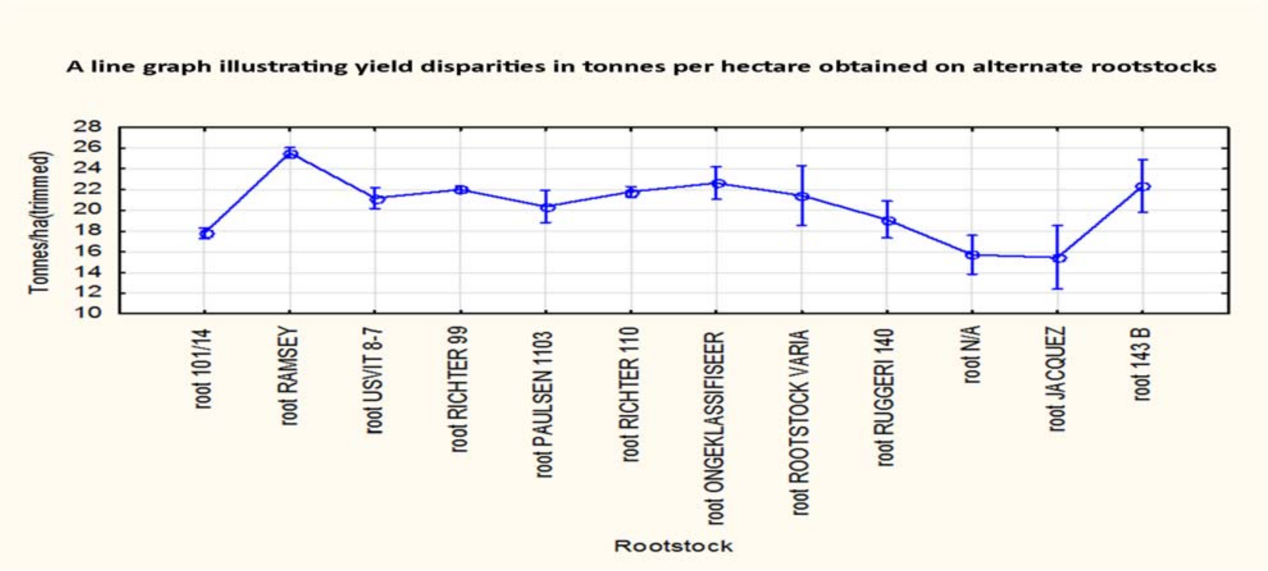

Figure 5.5: A line graph illustrating yield disparities in tonnes per hectare obtained on alternate rootstocks

Equally great care should be taken when making inferences based on the yield per hectare and relative trellis size. Size is used here to refer to the magnitude of the physical framework of the trellis system. The latter is multi-dimensional due to the need to take the region, cultivar, cultivation actions, such as suckering, as well as irrigation influences, amongst others, into account. However as illustrated in Figure 5.6, there is as case to be made for the relationship between trellis system size and yield per hectare. As illustrated in Figure 5.6 the relative magnitude or size of systems, increase from smallest largest from left to right.

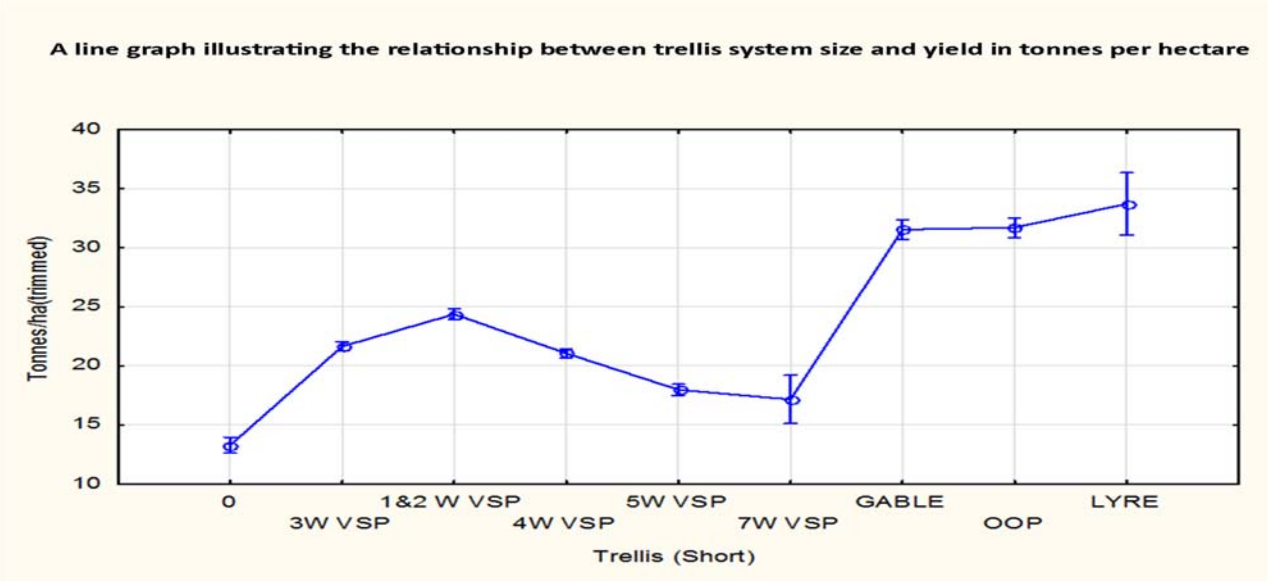

Figure 5.6: A line graph illustrating the relationship between trellis system size and yield in tonnes per hectare

Figure 5.6 illustrates a positive tendency between yield per hectare and relative trellis system size, suggesting a positive relationship between trellis system size and yields obtained per hectare. However, the line graph is beset with a decline between four- and seven wire VSP systems (4W VSP & 7W VSP). Possible clarifications to this phenomenon could be that these systems are being well represented in low yielding areas, where limited irrigation as well as suckering takes place, in the endeavour of producing ultra-premium wines (refer to Figure 5.7). In addition the varietal composition of producing areas and specific cultivars cultivated on these systems, as well as the onset of diminished fertility due to canopy densification, could be possible clarifications (refer to Section 3.2.1 and Figure 5.6).

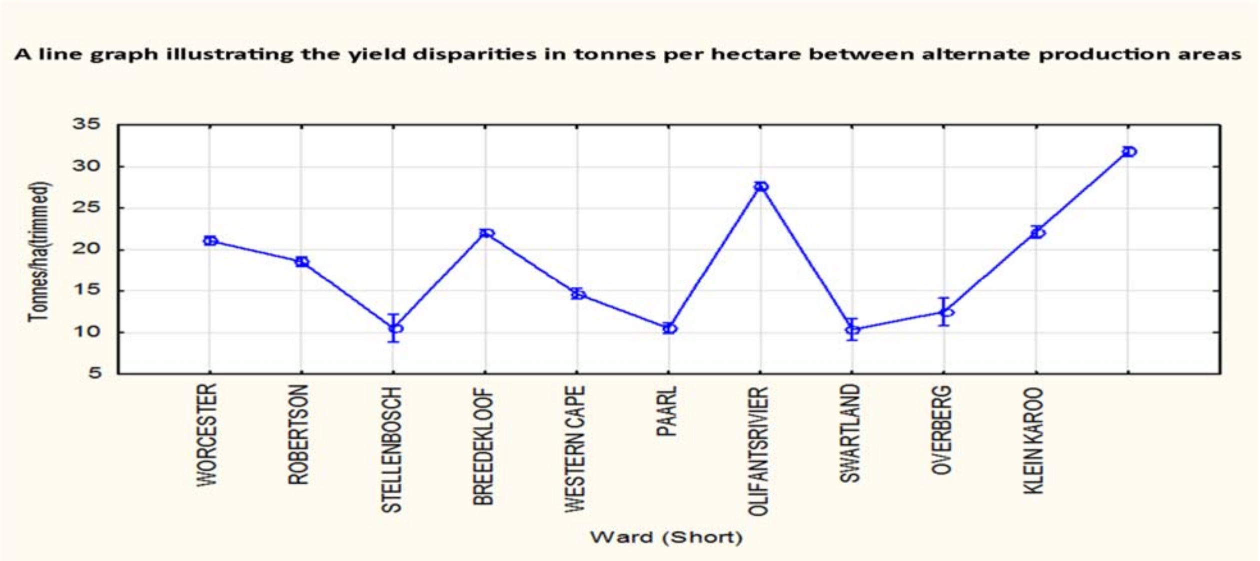

Figure 5.7: A line graph illustrating the yield disparities in tonnes per hectare between alternate production areas

As illustrated in Figure 5.7 yield disparities are common between different production regions. Although multi-dimensional and dependent on a variety of factors, the mean yield per hectare are influenced by the cultivars, trellises, cultivation practices, irrigation and greater environment amongst others. It can thus be safely derived that regional production differences do occur.

As referred to under the clarification for Figure 5.6 the data set illustrated a relationship between yields obtained between irrigated and non-irrigated areas. Similarly caution should be taken to make inferences between the relative efficiency of alternate irrigation systems as illustrated in Figure 5.8. The high disparity between alternate irrigation systems and flood irrigation, can also be attributed to the high prevalence of flood irrigation and high yielding cultivars generally being proliferated in the Northern Cape (refer to Figure 5.4 and 5.7).

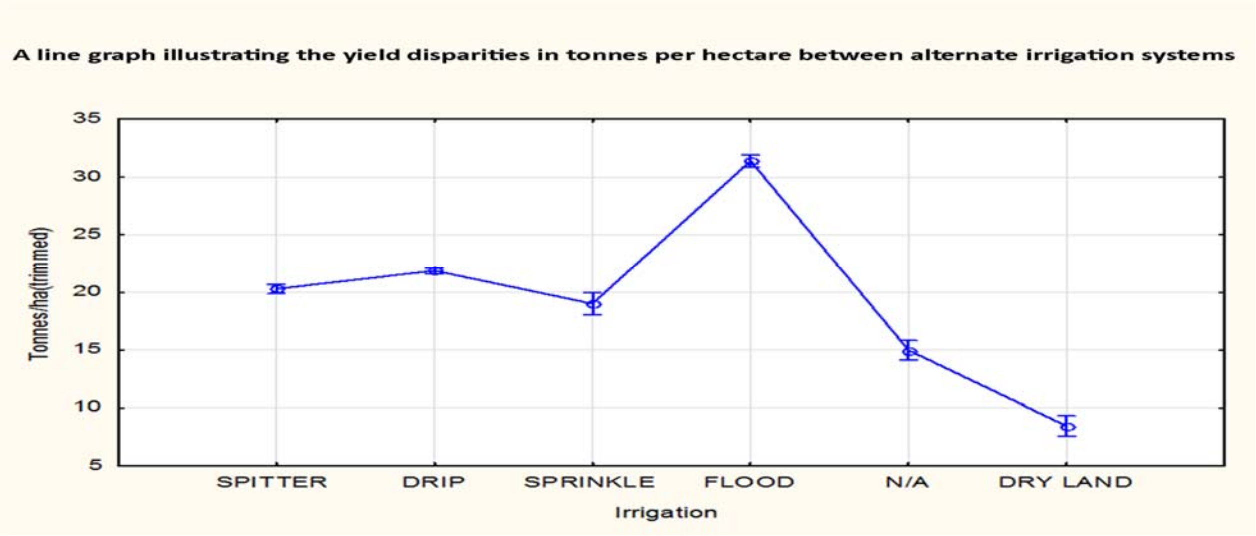

Figure 5.8: A line graph illustrating the yield disparities in tonnes per hectare between alternate irrigation systems

5.4 Other data sources

Data required for input prices and norms in the VITISIM101 model was determined through own calculation and measurement in consultation with industry representatives, or based on industry information booklets. Information on the cost of different irrigation systems and soil preparation costs were obtained from the Vinpro Cost Guide for the 2014/15 season (Van Niekerk & Van Zyl, 2014:25).

Vinpro's trellis specific labour norms with regards to trellis erection, specific cultivation practices, as well as general- and clearing activities were obtained from the cost guide (Van Niekerk & Van Zyl, 2014:22). These norms and prices were used in the initial year of the projection period after which only prices are inflated by a price variability matrix as referred to in Section 5.5.1.

5.5 An introduction to the application of the VITISIM101 model

In order to be able to evaluate alternate wine grape production systems, a simulated farm had to be constructed for the VITISIM101 model. However, given the advanced capabilities and adaptability of the model, which allows alteration of multiple parameters, at activity and operational level, there was decided on three general simulation scenarios and 15 simulations for the purpose of this thesis. These parameters and assumptions can be individually tailored to be specific for circumstances and production preferences of a specific farm.

Before commencement of the evaluation of alternate strategies and wine grape production systems, the cultivar composition and age distribution of grapevines on the simulated farm are presented. The former is illustrated in Table 5.1 with block specific detail, on the relative age composition of cultivars, as well as rotation sequence of all cultivated blocks on the farm. Hereafter, the location of the production region of the simulated farm and region specific climate on cultivar- and trellis specific yields over the life-time of the vine are discussed and illustrated in Figure 5.9. The reconciliation of the illustrated yields, combined with cultivar and trellis specific output prices, plus specified and allocated costs, are then represented in Table 5.2.

The former is done to illustrate the relative contribution of each cultivar to the overall wine grape production system profitability. However, in order to illustrate the relative contribution of alternate cultivars, a temporary concession was made for the age composition of the farm. The latter was done in order to enable a meaningful comparison, as grapevines of similar age need to be compared to one another, therefore strict adherence to Table 5.1 would distort evaluated results. The distortion would be due to the varying productivity of the grapevine over its lifetime and accompanied penalising of cultivars with an older age composition for the evaluation relative to another as evaluations are done with nominal values.

In advance it should be noted for the delineation of the scenarios and strategies, that the initial moveable and fixed asset inventory, although it will not explicitly be elaborated upon as used in the VITISIM101 model, was based on that of an actual farm. The former has the potential to vary greatly between alternate farms, hence results are likely to be farm specific and although could be seen as representative, farm specific differences will exist. As will be described in the scenarios, the simulated farm's moveable asset inventory also includes machinery used for lucerne cultivation and can be considered over capitalised for the 50 hectare wine grape system

Table 5.1: The relative age composition and rotation sequence for the first two rotations of different blocks and cultivars for scenario one and two

Land Usage:							Crop Rotation Practices				
Block	Area (ha)	Initial Block Establishment Date	Current Crop	Current Crop Age	Crop (1) (Intitial)	Life* Cycle (1)	Replacement date: Crop 1	Crop (2)	Life* Cycle (2)	Replacement date: Crop (2)	Crop (3)
1	2.5	1994/01/01	Chenin Blanc	20	Chenin Blanc	20	2014/01/01	Lucerne	4	2018/01/01	Chardonnay
2	2.5	1995/01/01	Colombar	19	Colombar	20	2015/01/01	Lucerne	4	2019/01/01	Colombar
3	2.5	1996/01/01	Sauvignon Blanc	18	Sauvignon Blanc	20	2016/01/01	Lucerne	4	2020/01/01	Shiraz
4	2.5	1997/01/01	Cabernet Sauvignon	17	Cabernet Sauvignon	20	2017/01/01	Lucerne	4	2021/01/01	Colombar
5	2.5	1998/01/01	Chardonnay	16	Chardonnay	20	2018/01/01	Lucerne	4	2022/01/01	Chenin Blanc
6	2.5	1999/01/01	Colombar	15	Colombar	20	2019/01/01	Lucerne	4	2023/01/01	Shiraz
7	2.5	2000/01/01	Shiraz	14	Shiraz	20	2020/01/01	Lucerne	4	2024/01/01	Chardonnay
8	2.5	2001/01/01	Colombar	13	Colombar	20	2021/01/01	Lucerne	4	2025/01/01	Chenin Blanc
9	2.5	2002/01/01	Chenin Blanc	12	Chenin Blanc	20	2022/01/01	Lucerne	4	2026/01/01	Cabernet Sauvignon
10	2.5	2003/01/01	Shiraz	11	Shiraz	20	2023/01/01	Lucerne	4	2027/01/01	Colombar
11	2.5	2004/01/01	Chardonnay	10	Chardonnay	20	2024/01/01	Lucerne	4	2028/01/01	Shiraz
12	2.5	2005/01/01	Chenin Blanc	9	Chenin Blanc	20	2025/01/01	Lucerne	4	2029/01/01	Shiraz
13	2.5	2006/01/01	Cabernet Sauvignon	8	Cabernet Sauvignon	20	2026/01/01	Lucerne	4	2030/01/01	Chenin Blanc
14	2.5	2007/01/01	Colombar	7	Colombar	20	2027/01/01	Lucerne	4	2031/01/01	Shiraz
15	2.5	2008/01/01	Shiraz	6	Shiraz	20	2028/01/01	Lucerne	4	2032/01/01	Colombar
16	2.5	2009/01/01	Shiraz	5	Shiraz	20	2029/01/01	Lucerne	4	2033/01/01	Cabernet Sauvignon
17	2.5	2010/01/01	Chenin Blanc	4	Chenin Blanc	20	2030/01/01	Lucerne	4	2034/01/01	Chenin Blanc
18	2.5	2011/01/01	Shiraz	3	Shiraz	20	2031/01/01	Lucerne	4	2035/01/01	Colombar
19	2.5	2012/01/01	Colombar	2	Colombar	20	2032/01/01	Lucerne	4	2036/01/01	Sauvignon Blanc
20	2.5	2013/01/01	Cabernet Sauvignon	1	Cabernet Sauvignon	20	2033/01/01	Lucerne	4	2037/01/01	Cabernet Sauvignon
21	2.5	2010/01/01	Lucerne	4	Lucerne	4	2014/01/01	Chenin Blanc	20	2034/01/01	None (Idle)
22	2.5	2011/01/01	Lucerne	3	Lucerne	4	2015/01/01	Colombar	20	2035/01/01	None (Idle)
23	2.5	2012/01/01	Lucerne	2	Lucerne	4	2016/01/01	Sauvignon Blanc	20	2036/01/01	None (Idle)
24	2.5	2013/01/01	Lucerne	1	Lucerne	4	2017/01/01	Cabernet Sauvignon	20	2037/01/01	None (Idle)
25	2.5	2012/01/01	Lucerne	2	Lucerne	4	2016/01/01	None (Idle)	1	2017/01/01	Lucerne
26	2.5	2011/01/01	Lucerne	3	Lucerne	4	2015/01/01	None (Idle)	1	2016/01/01	Lucerne
27	2.5	2010/01/01	Lucerne	4	Lucerne	4	2014/01/01	None (Idle)	1	2015/01/01	Lucerne
28	2.5	2013/01/01	Lucerne	1	Lucerne	4	2017/01/01	None (Idle)	1	2018/01/01	Lucerne
29	2.5	2012/01/01	Lucerne	2	Lucerne	4	2016/01/01	None (Idle)	1	2017/01/01	Lucerne
30	2.5	2011/01/01	Lucerne	3	Lucerne	4	2015/01/01	None (Idle)	1	2016/01/01	Lucerne
31	2.5	2010/01/01	Lucerne	4	Lucerne	4	2014/01/01	None (Idle)	1	2015/01/01	Lucerne
32	2.5	2013/01/01	Lucerne	1	Lucerne	4	2017/01/01	None (Idle)	1	2018/01/01	Lucerne
33	2.5	2014/01/01	None (Idle)	0	None (Idle)	7	2021/01/01	Lucerne	4	2025/01/01	None (Idle)
34	2.5	2014/01/01	None (Idle)	0	None (Idle)	5	2019/01/01	Lucerne	4	2023/01/01	None (Idle)
35	2.5	2013/01/01	None (Idle)	1	None (Idle)	1	2014/01/01	Lucerne	4	2018/01/01	None (Idle)
36	2.5	2014/01/01	None (Idle)	0	None (Idle)	6	2020/01/01	Lucerne	4	2024/01/01	None (Idle)
37	2.5	2013/01/01	None (Idle)	1	None (Idle)	1	2014/01/01	Lucerne	4	2018/01/01	None (Idle)
38	2.5	2014/01/01	None (Idle)	0	None (Idle)	7	2021/01/01	Lucerne	4	2025/01/01	None (Idle)
39	2.5	2014/01/01	None (Idle)	0	None (Idle)	8	2022/01/01	Lucerne	4	2026/01/01	None (Idle)
40	2.5	2014/01/01	None (Idle)	0	None (Idle)	8	2022/01/01	Lucerne	4	2026/01/01	None (Idle)

*Life Cycle as measured in years

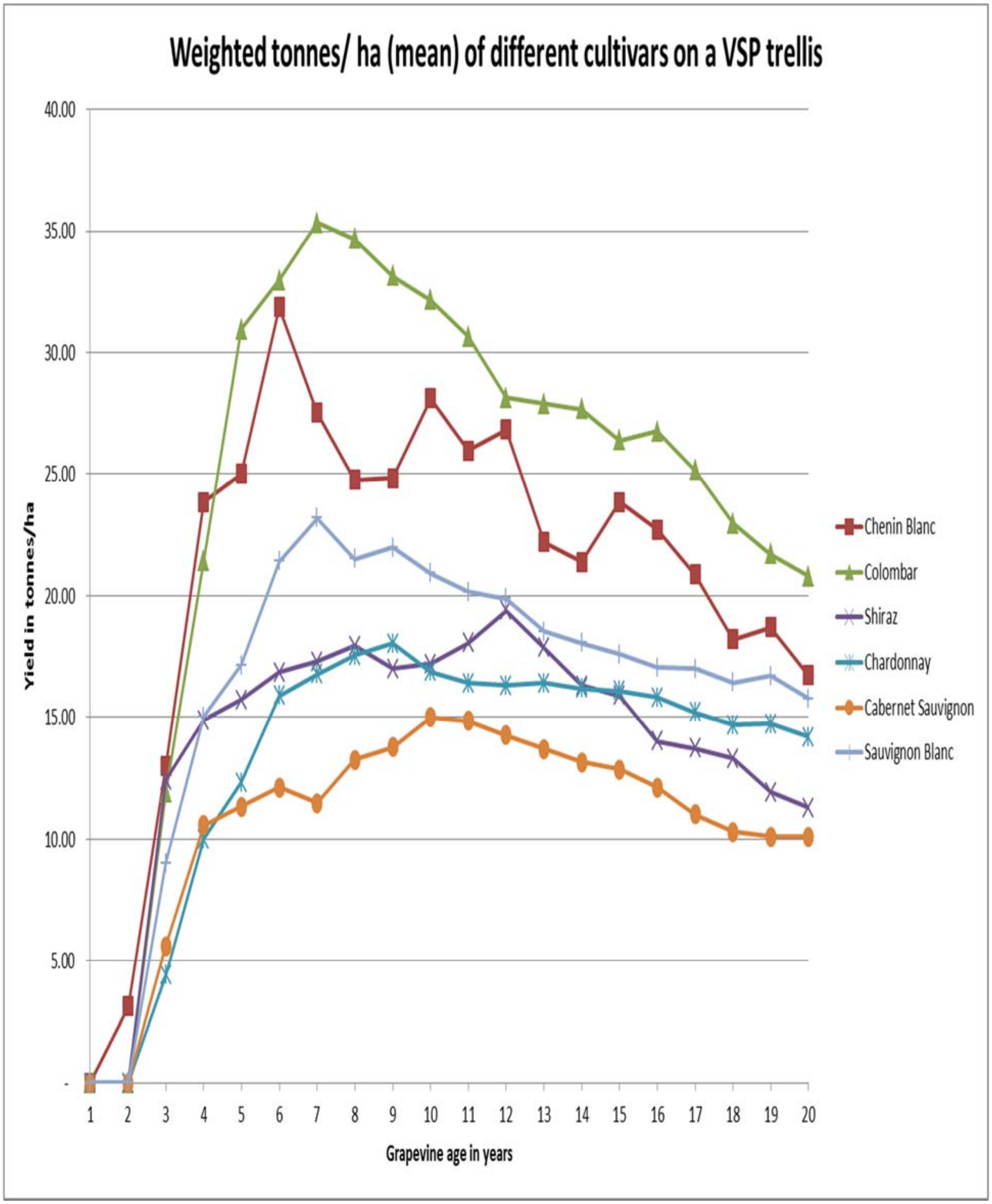

Figure 5.9: An inter-cultivar comparison of the annual yield in tonnes per hectare over the lifetime of the grapevine
Source: Based on WineMS data

Table 5.2: The relative contribution of individual cultivars to the collective wine grape enterprise (WGE)

Margin above specified cost (R/ ha)	2014/01/01	2015/01/01	2016/01/01	2017/01/01	2018/01/01	2019/01/01	2020/01/01	2021/01/01	2022/01/01	2023/01/01	2024/01/01	2025/01/01	2026/01/01	2027/01/01	2028/01/01	2029/01/01	2030/01/01	2031/01/01	2032/01/01	2033/01/01
Chardonnay	-1 719	14 950	22 702	35 328	39 210	43 444	47 148	43 801	43 080	43 824	46 146	46 778	47 859	47 789	45 370	43 578	45 163	43 566	-44 270	-44 385
Chenin Blanc	12 188	35 972	39 785	57 556	50 641	42 633	44 303	55 187	50 516	54 505	41 784	40 538	50 405	47 719	41 660	32 458	35 349	28 628	-44 270	-31 220
Colombar	8 244	27 437	48 512	54 616	61 719	62 466	60 796	60 309	58 064	52 360	53 890	54 983	52 709	55 362	50 908	44 362	41 031	39 084	-44 270	-44 385
Shiraz	21 525	29 627	33 259	37 949	40 263	44 133	41 983	44 174	49 256	56 533	51 879	46 296	45 834	37 444	36 463	34 977	28 334	25 752	-44 270	-44 385
Sauvignon Blanc	10 667	28 470	35 863	50 918	58 413	54 702	58 458	56 343	55 044	55 531	51 889	51 534	51 043	49 817	50 469	48 861	51 732	48 257	-44 270	-44 385
Cabernet Sauvignon	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cultivar 7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cultivar 8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cultivar 9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cultivar 10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Margin above specified cost WGE average	10 412	26 713	35 226	43 932	45 356	46 223	46 613	49 673	49 390	50 471	47 094	45 583	46 947	44 516	40 945	36 362	34 722	31 980	-43 402	-40 836
Other unallocated costs (R/ha)	8 916	10 051	11 444	13 206	15 540	16 152	16 826	17 454	18 061	18 737	18 290	18 119	18 052	18 582	20 568	20 482	20 278	66 113	19 202	19 679
Depreciation (Fixed improvements) (R/ha)	1 297	1 431	1 596	1 804	2 216	2 216	2 216	2 216	2 216	2 216	2 014	1 927	1 846	1 846	2 014	1 927	1 846	1 704	1 881	1 881
Margin above specified and allocated cost (R/ha)																				
Chardonnay	-10 635	6 034	13 786	26 412	30 293	34 528	38 231	34 884	34 164	34 907	37 229	37 862	38 943	38 873	36 454	34 661	36 247	34 650	-53 187	-53 301
Chenin Blanc	3 272	27 055	30 869	48 640	41 725	33 717	35 387	46 271	41 600	45 589	32 868	31 621	41 489	38 802	32 744	23 541	26 433	19 712	-53 187	-40 136
Colombar	-672	18 521	39 595	45 700	52 803	53 549	51 880	51 393	49 147	43 444	44 974	46 067	43 793	46 446	41 992	35 446	32 115	30 167	-53 187	-53 301
Shiraz	12 609	20 710	24 343	29 033	31 346	35 217	33 067	35 257	40 340	47 617	42 962	37 379	36 918	28 527	27 547	26 061	19 418	16 836	-53 187	-53 301
Sauvignon Blanc	1 751	19 554	26 947	42 002	49 497	45 786	49 542	47 427	46 128	46 615	42 973	42 618	42 127	40 901	41 553	39 945	42 815	39 341	-53 187	-53 301
Cabernet Sauvignon	-7 777	6 648	9 502	12 423	10 357	17 533	20 549	26 533	27 064	25 670	24 989	23 759	23 699	21 093	15 814	12 651	12 468	12 922	-47 398	-47 191
Cultivar 7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cultivar 8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cultivar 9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cultivar 10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Wine Grape Enterprise avg gross margin	1 496	16 662	23 782	30 726	29 816	30 072	29 787	32 219	31 329	31 735	28 804	27 464	28 896	25 935	20 377	15 880	14 443	-34 133	-62 605	-60 514
NFI per culitvar (R/ha) (Cultivar specific implicit cost allocated)																				
Chardonnay	-19 128	-2 594	4 993	17 411	20 881	25 116	28 819	25 472	24 751	25 495	28 018	28 739	29 900	29 830	27 243	25 538	27 204	25 749	-165 895	-166 009
Chenin Blanc	-5 222	18 428	22 076	39 639	32 312	24 305	25 975	36 858	32 187	36 177	23 657	22 498	32 446	29 759	23 533	14 418	17 390	10 811	-144 707	-131 657
Colombar	-9 166	9 894	30 803	36 699	43 391	44 137	42 468	41 980	39 735	34 032	35 763	36 944	34 750	37 403	32 781	26 323	23 072	21 266	-165 895	-166 009
Shiraz	4 116	12 083	15 550	20 032	21 934	25 805	23 655	25 845	30 927	38 205	33 751	28 256	27 875	19 484	18 336	16 937	10 375	7 935	-165 895	-166 009
Sauvignon Blanc	-6 743	10 926	18 154	33 001	40 085	36 373	40 129	38 015	36 716	37 203	33 762	33 495	33 084	31 858	32 342	30 821	33 772	30 440	-165 895	-166 009
Cabernet Sauvignon	-16 270	-1 980	710	3 422	944	8 120	11 137	17 121	17 651	16 258	15 778	14 635	14 656	12 050	6 603	3 527	3 425	4 021	-160 107	-159 900
Cultivar 7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cultivar 8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cultivar 9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cultivar 10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
WGE average Net Farm Income (R/ha)	**-6 997**	**8 034**	**14 989**	**21 725**	**20 404**	**20 659**	**20 374**	**22 806**	**21 917**	**22 322**	**19 593**	**18 341**	**19 852**	**16 891**	**11 166**	**6 757**	**5 400**	**-43 035**	**-171 075**	**-168 985**

evaluation, with machinery having surplus capacity with only minor adjustments needed to cultivate 80 hectares. In addition, as will be illustrated in scenario three, the size of the lucerne enterprise is gradually decreased as the collective wine grape enterprise is expanded. Similarly, though not illustrated due to the sensitive nature, cultivar and class specific prices received per tonne by producers from one of the larger producer cellars in the Breedekloof region were used.

The first scenario comprises the development of a simulated farm and evaluation between alternate trellis and cultivation practices with the view of a measure of structural rigidity. As such only specialized cultivation machinery is altered in between the discussed strategies. In scenario two the area under wine grape cultivation of all strategies in scenario one, is expanded to 80 hectares in order to illustrate the economies of size inherent in alternate strategies. Similarly, the third scenario flouts the notion of structural rigidity and simulates the long-term impact of an expansion of wine grape production from 50 to 80 hectares, accompanied with a shift towards more mechanically inclined and hence capital intensive practices. All three mentioned scenarios are simulated with a lucerne enterprise on the farm, forming part of a greater wine grape crop rotation system. Water and not arable land is regarded as a potential limiting factor for the VITISIM101 simulation. The maximum cultivated area at any point in time are limited to 90 hectares, cultivatable land at 100 hectares and the maximum area under lucerne at 30 hectares.

5.5.1 The description of the simulated farm for scenario analysis

The simulated farm and production area, as led by the data availability, was delineated to border and have features of both the Breedekloof and Worcester region (refer to Figure 5.9). Regardless of the particular cultivation preferences, all farmland parcels or block area in scenario one were simulated to be two and a half hectares each, with a total of 20 blocks and area of 50 hectares under grapevines. The varietal composition of varieties were chosen to closely mirror that recorded by SAWIS with red varieties designated as 40% and white varieties as 60 % of the farm area, with the economic lifetime of grapevines set to 20 years and one block or 5 % of the total area of grapevines being replaced annually (Floris, 2014:11).

The result of the former on the age composition of grapevines is that each year the same area and cultivar are replaced that was removed and hence the average age of grapevines stay constant through the projection period at 10 and a half years. However, due to grapevines being replaced annually on a per block basis the average age and yield per cultivar varies during the projection period, depending on the specific cultivar and block being replaced. The above were done in the endeavour of simplicity as individual block sizes, life cycles and replacement dates can be individually specified and be at intermittent intervals.

For the cultivar composition in scenario one and two four blocks or 20% was designated as Chenin Blanc, five blocks or 25 % as Colombar, one block or 5% as Sauvignon Blanc, two blocks or 10% as Chardonnay, three blocks or 15% as Cabernet Sauvignon and five blocks or 25 % as Shiraz. For the expansion of the area under wine grape production in scenario three the varietal composition over the projection period is maintained, although small annual fluctuations occur due to new establishments.

To mitigate the effect of nematodes on new plantings all new establishments are rotated with and planted upon previously lucerne blocks. The relative age composition of cultivars, rotation sequence and date for the first establishment, as well as the first two crop rotations upon a specific block are illustrated in Table 5.1. As can be expected and experienced with the cultivation of perennial crops such as grapevines, yield disparities occur over the life-time of the grapevine. The former is illustrated within and between different cultivars in Figure 5.9.

Figure 5.9 was compiled with trellis and cultivar specific data mainly originating from the Breedekloof region, which was best represented in the *WineMS*® dataset (refer to Figure 5.3). In addition, only a sufficient number of observations could be ascertained for Chenin Blanc, Colombar, Shiraz, Chardonnay, Cabernet Sauvignon and Sauvignon Blanc on a VSP trellis (four and five wire) to make the establishment of a cultivar and age specific yield per hectare meaningful (refer to Figure 5.2).

The high incidences of VSP trellises and in particular with regards to older blocks were in line with expectations, as currently it is still the highest adopted trellis system in the South African wine industry (refer to Section 3.2.3.3). A weighted mean tonnes per hectare per cultivar per year was compiled by taking a weighted average between the mean tonnes per hectare for the specific cultivar on a four wire and five wire trellis. The former was done with consideration of the observed standard deviation. Standard deviation for grapevines' yields increased as vines became older, accompanied with a decrease in the diminishing yield, year on year observably between 15 and 20 years.

The observation could be due to underperforming vines being removed before a 20 year lifecycle is reached and hence yields tended to be artificially higher than, if all vines were kept in production for the latter part of the lifecycle. To mitigate the former outliers, a third of the standard deviation of observations with a standard deviation of greater than 10 (for observations between 15 and 20 years of age) were subtracted from the mean tonnes per hectare and substituted into the weighted mean tonnes per hectare calculation. Additional modifications of the data included the inclusion of data from the Worcester region for specific cultivars to enlarge the sample and occasionally from the Robertson region where observations for a particular age were sparse. The latter was only done if observations for Breedekloof were absent, Breedekloof observations were irregular and the inclusion into the weighted average tonne per hectare (mean) could be regarded as plausible.

In Figure 5.9 cultivar specific yield per year and differences between annual yields are illustrated. Out of the former the designated white cultivars appeared to reach peak production by approximately seven years and red cultivars by 10 to 12 years with Colombar yielding the highest and Cabernet Sauvignon the lowest yields. As discussed in Section 4.5.1 gross income per cultivar is a function of its class specific yield and price received per tonne. Therefore disparities in the profitability between alternate cultivars exist, when cultivated on similar trellis systems and cultivation practices.

For illustrational purposes, although it could be regarded impractical, all 50 hectares or 20 blocks were simulated to be established three years before the start of the simulation period, to be harvested mechanically, tipped by machine and pruned manually. In designating the former, the age composition of different cultivars could be aligned and the disparity in the relative profitability of individual cultivars be illustrated (refer to Table 5.2). The particular establishment date was selected as all varieties in the dataset as illustrated, were found to be in production by three years of age (refer to Figure 5.9). Initially low or negative margins are obtained in part due to small initial yields, followed by a period of increasing and decreasing profitability, as directed by the productivity of the grapevine over its lifetime.

The former is followed by negative margins upon removal and re-establishment of grapevines. Due to the VITISIM101 calculating outcomes in nominal values as illustrated in Table 5.2, it is worthy to note that a larger absolute margin in the future needs to be viewed in the context of the time value of money. Despite the fact that nominal values do make it slightly more difficult to identify an improvement or decline per cultivar over time, it is invaluable to illustrate the time value of money and is used for profitability and performance measure calculations. The latter was discussed in Chapter 3.2 and will be used in the accompanied evaluations.

The VITISIM101 model applies actions trellis specifically as there is assumed that a specific trellis and cultivar combination is selected for a specific wine goal. Although smaller cultivar, trellis and wine grape production system changes are possible at operational level and lead to different costs of production, the disparity in the profitability of alternate cultivars can be greatly attributed to alternate prices received per tonne as well as the yield or productivity of the grapevine over its lifetime as illustrated in Figure 5.9. Taken on face value, strict interpretation of Table 5.2 would lead to the notion that only specific cultivars such as Colombar and Chenin Blanc should be cultivated.

However, despite these evident disparities between the profitability of different cultivars, cultivar selection is not only made on economic considerations but also on practical and logistical considerations and their impact on the greater wine grape production system. The latter implies that a combination of cultivars with alternate harvesting dates need to be cultivated, in order to facilitate and accommodate the harvest at harvesting and cellar level. Similarly the age dispersion and replacement of grapevine blocks are staggered for practical (such as rearing) and financial feasibility concerns. In view of the above and the fact that gross production value is a function of yield and the price received per tonne, different yields obtained on alternate trellises are likely to have a definite impact on the margins obtained on different trellises. In addition, different trellis system configurations facilitate or inhibit the execution of different manual and or mechanical cultivation practices. The latter has an implication for the substitutability of cultivation practices, as well as current and future cost of cultivation, due to alternate inflation rates being likely for different inputs.

Upon further examination the simulated effect of different trellises and cultivation preferences on the margins or profitability of the wine grape production system will be evaluated. In view of the above and large effect of the relative age and cultivar composition on wine grape production system outcomes, the relative age distribution and relative cultivar composition will be assumed fixed, as in Table 5.1 for all scenarios up and until expansion in scenario three.

The evaluation of all strategies in the scenarios simulated by the VITISIM101 model that follow, were done in nominal terms. The VITISIM101 model allows for the specification of 30 different indexes or inflation rates for various input as well as output prices. Of the former yearly adjustment in some of the main drivers was designated as: low-skilled labour 11%, skilled-labour 8%, own management 7%, fuel 9%, electricity 13%, water-tax 6%, capital expenditure-items between 4% and 8%, chemical items between 8% and 11% and product prices received 6%.

5.5.2 Scenario one: the evaluation between alternate trellis and cultivation preferences

For the first scenario, alternate wine grape production systems or strategies for a simulated farm with an area of 50 hectares of grapevines and 30 hectares of lucerne under cultivation is evaluated. Alternate production systems are differentiated on the basis of different trellis systems as well as cultivation preferences. The age distributions of grapevines, relative combination of cultivars as well as block replacement schedule are typically retained. The former is done to permit a measure of conformity between alternate wine grape production systems, so as to allow meaningful comparison upon system evaluation. In view of the above all evaluations in the first scenario are done with an identical investment in fixed and moveable assets, except for differences due to the varying capital investment in alternate trellises and additional machinery. The inclusion or omitting of specialised cultivation machinery as dictated by cultivation preferences, are typically specified and all other moveable assets retained.

As the disparity in the relative profitability of alternate cultivars in the wine grape production system has been illustrated in Table 5.2, there will be turned from this abstraction to the goal of evaluating the effect of alternate trellises and cultivation preferences on whole farm level. As elaborated upon in the discussion of the data used to illustrate Figure 5.9, insufficient observations were available in the dataset to create a cultivar and trellis specific yield over the life-time of the vineyard for the following: Smart-Dyson, High-Wire, Gable, Lyre and Ballerina trellises in the Breedekloof region. A possible clarification for the latter could be due to specific trellis and training system adoption in new establishments being implemented for a shorter span of time. Similarly as elaborated in Section 3.1.2 it is possible to modify and adapt a particular training system within the framework of an existing trellis system. The cumulative effect could lead to under reporting of alternate trellises at cellar level in *WineMS*® data if records are not frequently updated or provided.

However, since the objective of the thesis and the VITISIM101 model is to establish a method by which wine grape production system evaluation can be done, trellis specific assumptions could be made. The illustration of the trellis specific effect on the yield per cultivar over its lifetime was assumed to mirror that of VSP systems. Smart-Dyson trellises were assumed to deliver 20%, Ballerina 30%, High-Wire 30%, Lyre 30% and Gable trellises 50% higher yields than obtained for the same cultivar by VSP systems. Due to the variety of different denotations used in the dataset to represent a particular grade or quality of grapes known as a “class”, there was refrained from the endeavour of establishing a quality composition of the cultivar specific harvest, as allowed for by the VITISIM101 model in the subjective quality matrix illustrated in Table 4.4.

Additional concerns which reinforced the refrainment decision are the subjectivity involved in the determination of wine quality and cellar specific marketing arrangements which would skew data and inferences. However, to illustrate the quality matrix white varieties were assumed to retain the same quality composition, whilst a 5% higher class 1 or highest quality grading was assumed to be attained for red varieties on Smart-Dyson, Lyre and Gable trellises. The latter could be motivated by better colour expression attained on these trellises. In addition, due to the margin above specified cost functionality and extensive trellis and cultivar specific designation possibilities, as illustrated in Table 4.7, the effect of alternate trellis systems and cultivation preferences can be evaluated. The former implies that it is not only possible to evaluate the effect of alternate trellises and cultivation practices on the relative profitability of the overall wine grape production system, but also on that of the individual cultivar. However for the purpose of this thesis wine grape production system evaluation was prepared on whole farm level, to account for the effect cultivar and wine grape production system preferences on the farm as a whole. As such the evaluation of cultivar specific wine grape production system evaluation and alteration were typically treated secondary, with the evaluation of the profitability of the overall wine grape production system and farm business being the primary goal.

In pursuit of the evaluation of the effect of alternate trellises and cultivation practices seven strategies were developed. Each strategy requires the selection of a specific trellis and a combination of the four most costly and intensive production preferences (refer to Table 4.6). These include the method of harvesting, of summer foliage management, of pruning and amount of years required for the cultivar and trellis specific young vine development. In order to represent different wine grape production systems defined by alternate trellis and cultivation practice preferences, for the simulated farm, each wine grape production system or strategy was allocated a number.

Strategy one (S1) is an approach by which VSP trellises, harvesting, foliage management and pruning by hand are applied. Strategy two (S2) involves VSP trellises, mechanical harvesting, mechanical foliage management and pre-pruning with an accompanied hand blunt pruning action. Strategy three (S3) involves High-Wire trellises, mechanical harvesting, mechanical foliage management as well as mechanical pruning. Strategy four (S4) involves the Ballerina trellis, mechanical harvesting, foliage management and pruning by hand. Strategy five (S5) involves Smart-Dyson trellises, mechanical harvesting, foliage management and pruning by hand. Strategy six (S6) involves Gable trellises and accompanied harvesting, foliage management and pruning by hand. Strategy seven (S7) involves Lyre trellises, harvesting by hand, mechanical foliage management and pruning by hand. Table 5.3 illustrates the relative performance of each strategy as measured by IRR and NPV performance measures, as well as the investment required in each strategy.

Table 5.3: The relative performance matrix of seven different strategies for 50 ha of grapevine cultivation

	S1	S2	S3	S4	S5	S6	S7
IRR (%)	2.08	2.77	5.47	4.58	3.52	5.30	3.93
NPV (R)	197 313	3 777 747	17 432 616	12 824 887	7 476 992	16 829 354	9 584 999
IMA (R)	3 126 226	3 808 206	3 795 406	3 388 726	3 388 726	3 124 889	3 126 226
IFA (R)	21 442 896	21 442 896	21 139 208	21 295 673	21 316 898	22 058 704	21 794 863
TI (R)	24 569 122	25 251 102	24 934 614	24 684 399	24 705 624	25 183 593	24 921 090

IRR – internal rate of return
NPV – net present value (discounted at 2%)
IMA – investment in moveable assets
IFA – investment in fixed assets
TI – total investment

As discussed in Chapter 3.2, margins, the invested capital and the timing of cash flows matter in the analysis of an investment or wine grape production system. While a detailed description of the financial result of each scenario is bound to be cumbersome, an abstraction of the changes made for each scenario on the margins, cash flow and capital investment will be given in Section 5.5.4.

5.5.3 Scenario two: the evaluation of expansion on economies of size

In order to evaluate the different economies of size inherent in different wine grape production systems, all strategies followed in scenario one were simulated by increasing the size of all blocks. Profound changes made included expanding the simulated collective wine grape enterprise by 60% to 80 hectares and the accompanied decreasing of the lucerne enterprise to 10 hectares.

As specified in Section 5.5 the initial moveable asset inventory of the simulated farm can be considered over capitalised. Hence, only minor changes to the moveable asset inventory were needed to accommodate an expansion in the collective wine grape enterprise namely, substitution of the existing two row high wind velocity sprayer with a three row high wind velocity sprayer for all strategies, except for strategy six. For strategy six, an additional sprayer was designated due to the design of gable trellises precluding multiple row sprayers. For strategy three, two simulations was done to firstly illustrate the effect of the cultivation with a second hand trailed harvester in scenario three (S3) and then the same simulation, but inclusion of a second hand self-propelled harvester indicated as S3(B) in Table 5.4.

The accompanied results are illustrated in Table 5.4. Table 5.5 illustrates the change in IRR or inherent economies of size differences between each strategy in scenario one and two (50 hectares vs. 80 hectares).

Table 5.4: The relative performance matrix of eight different strategies for 80 ha of grapevine Cultivation

	S1	S2	S3	S4	S5	S6	S7	S3 (B)
IRR (%)	2.90	3.94	7.79	6.47	4.96	7.20	5.37	7.44
NPV (R)	4 860 790	11 091 913	33 208 457	25 476 644	16 786 776	30 618 741	19 356 410	30 862 911
IMA (R)	3 144 975	3 826 955	3 782 565	3 407 475	3 407 475	3 142 157	3 144 975	5 281 655
IFA (R)	24 055 444	24 055 444	23 480 534	23 819 888	23 853 847	25 040 738	24 618 592	23 480 534
TI (R)	27 200 419	27 882 399	27 263 099	27 227 363	27 261 322	28 182 895	27 763 567	28 762 189

IRR – internal rate of return
NPV – net present value (discounted at 2%)
IMA – investment in moveable assets
IFA – investment in fixed assets
TI – total investment

Table 5.5 The difference arising in IRR and NPV for each strategy between scenario one and two

	S1	S2	S3	S4	S5	S6	S7	S3 (B)
IRR (DIFF) (%)	0.82	1.16	2.33	1.89	1.45	1.90	1.45	1.98
NPV (DIFF) (R)	4 663 477	7 314 166	15 775 841	12 651 757	9 309 784	13 789 387	9 771 411	13 430 295
DTCI vs S1S2 (R)	1 949 317	2 631 297	2 011 997	1 976 261	2 010 220	2 931 792	2 512 465	3 511 087

IRR (DIFF) – the difference in the IRR for the specified strategy between scenario one and two
NPV (DIFF) - the difference in the NPV for the specified strategy between scenario one and two
DTCI vs S1S2 – is the difference in the total initial capital investment relative to scenario one strategy two.

DTCI vs S1S2 is a strategy by which an area of 50 hectares is cultivated by VSP, mechanical harvesting, foliage management and barrel and blunt pruning are used under the collective wine grape enterprise. Scenario one strategy two was specifically chosen due it being a widely adopted strategy currently in the Breedekloof area. As such grapevines of most producers are typically trellised on VSP trellis systems, harvested mechanically, and mechanically assisted foliage management or pruning applied.

Through comparing different strategies between scenario one and two as illustrated by Table 5.3 and Table 5.4, it is evident that economies of size for all strategies for the simulated farm exist. However, as illustrated by Table 5.5 alternate strategies have a different inherent economies of size as measured by IRR(DIFF). Similarly DTCI vs S1S2 illustrates the additional capital requirement that would be needed to expand the collective wine grape enterprise or switch over to a different wine grape production system, before commencement of the simulation. The former would also assume that moveable assets, if dictated by the strategy, would be sold at a price exactly equal to their current value. From Tables 5.3 to 5.5 it can then be ascertained that differences in the long term profitability of alternate wine grape production systems, as well as the initial capital required, exist.

5.5.4 Differences in results between scenario one and two

From the simulations with assumptions as delineated in this study a wine grape production system in strategy one, by which all grapevines are trellised by VSP, manually harvested, foliage management as well as pruning are done manually, was illustrated to require the smallest capital investment, as well as lead to the lowest IRR of 2.08% in the 50 hectare and 2.90% in the 80 hectare scenario. In addition, the strategy was also shown to have the lowest improvement in IRR or inherent economies of size for an expansion in operations from 50 hectare to 80 hectares and required the smallest investment in moveable assets as is similar for a strategy trellised under Gable vines.

The second strategy that made use of mechanical harvesting, mechanical foliage management and barrel pruning of VSP vines led to a higher IRR of 2.77% for the 50 hectare scenario and required the biggest total investment as well as moveable asset investment of all strategies in scenario one. In the second scenario of 80 hectares the IRR of the strategy increased to 3.94% and required the third largest total investment and illustrated the second smallest inherent economies of size.

Strategy three involved the designation of all grapevines on High-Wire trellises, accompanied with mechanical harvesting (trailed harvester), mechanical foliage management as well as mechanical pruning of grapevines. Pursuit of this strategy led to the highest IRR of 5.47%, required the third largest total investment, smallest investment in fixed assets and of the largest investments in moveable assets of all strategies in scenario one. Pursuit of strategy three in scenario two, led to an IRR of 7.79% and illustrated the largest improvement in IRR or inherent economies of size for an expansion of operations from 50 to 80 hectares.

In the fourth strategy all trellis systems are selected as Ballerina trellises, harvesting as done mechanically and foliage management, as well as pruning by hand. Pursuit of strategy four led to the third highest IRR of 4.58% for scenario one and 6.47% for scenario two. Strategy four illustrated the third largest improvement in IRR for an expansion to 80 hectares. In addition strategy three, four and five required similar total investments for scenario two with disparities arising out of the required investment in fixed and moveable assets between strategies. For the fifth strategy all grapevines were designated to be cultivated on Smart-Dyson trellises, to be harvested mechanically and for foliage management and pruning to be done by hand. Pursuit of strategy five resulted in the fifth highest IRR of 3.52% in scenario one and 4.96% in scenario two. Strategy five was illustrated to have the fourth largest inherent economies of size.

Strategy six was designated as Gable trellises with harvesting, foliage management and pruning to be done by hand. Pursuit of strategy six led to the second highest IRR of 5.30% and required the second largest total investment for scenario one. Similarly the pursuit of strategy six in scenario two led to the second highest IRR of 7.20% and required the largest total investment of the seven standard strategies. In the seventh strategy, all grapevines were designated to be trellised on Lyre trellises and harvesting, foliage management and pruning to be done by hand.

Pursuit of this strategy led to an IRR of 3.93% in scenario one and 5.37% in scenario two, with the third largest total investment required in both strategies.

5.5.5 Scenario three: the evaluation of the expansion in and structural transition of the wine grape production system

In the ensuing section an expansion of the collective wine grape enterprise from an area of 50 to an area of 80 hectares, as well as a change in the wine grape production system used over a 20 year period, is simulated. In adherence to structural rigidity and financial feasibility considerations, the collective wine grape enterprise is slowly expanded bearing the particular cultivar composition implications in mind. The latter involves gradually switching over from a wine grape production system making sole use of VSP trellising systems for all cultivars, mechanical harvesting, mechanical foliage management and pruning by hand to a wine grape production system with High-Wire and Smart-Dyson trellising systems.

Upon replacement of existing and establishment of new blocks all white varieties are established on a High-Wire trellis, designated to be harvested mechanically, foliage management to be done mechanically and to be mechanically pruned. Correspondingly, replacement and new establishment of all red varieties are designated on Smart-Dyson trellises, to be harvested mechanically and foliage management and pruning to be done by hand. The former is put forth as a possible strategy for producers striving to ensure long-term sustainability and growth of the farm business given the current wine grape production environment.

The goal for the producer who is a price taker, is therefore assumed to increase the profitability of the wine grape production system by increasing margins through a combination of increasing yield, increasing margins through limiting costly inputs and pursuing strategies with economies of size and by managing the additional capital investments which are regarded as scarce and limited. As is illustrated in the preceding Table 5.4 and Table 5.5 strategy three, the pursuit of a High-Wire orientated trellis system is one of the most profitable and not the most capital intensive strategy. Similar for the purposes of the model red varieties are simulated on a Smart-Dyson trellis system.

The evaluation and result of the pursuit of the above simulated strategy led to an IRR of 4.95%, a NPV of R17 185 382 (discounted at 2%), required an initial investment of R21 694 643 in fixed assets and an investment of R3 814 154 in moveable assets. The transition of the simulated farm is illustrated in Table 5.6.

Table 5.6: An illustration of the transition of a farm from 50 ha to 80 ha of grapevines over a 20 year period

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
PGV (ha)	50	53	55	58	58	60	60	63	65	68	73	75	75	75	75	78	80	80	80	80
Lucerne (ha)	30	30	30	30	30	28	25	25	23	20	20	18	15	13	13	10	10	10	10	10
PGV (t)	891	885	885	936	1033	1113	1121	1140	1213	1285	1396	1509	1659	1764	1797	1840	1826	1881	1951	1918
LUCERNE (t)	510	515	555	550	510	485	475	450	383	358	375	323	255	228	228	195	158	178	180	195
PGV (t/ha)	18	17	16	16	18	19	19	18	19	19	19	20	22	24	24	24	23	24	24	24
Lucerne (t/ha)	17	17	19	18	17	18	19	18	17	18	19	18	17	18	18	20	16	18	18	20

PGV – Perennial grapevines used to designate collectively refer to all grapevines

5.6 Results obtained from the VITISIM101 model

In the above sections of Chapter 5 the long term financial impact and outcomes of the wine grape production system were illustrated to be dependent on the complex interaction of a variety of factors. Alternate wine grape production strategies and scenarios were simulated in order to illustrate the long-term financial impact of different wine grape production systems. The designated cultivar and age composition, chosen trellis system, size of operations, cultivation preferences as well as production area were illustrated and evaluated to have an influence on long-term profitability and financial feasibility of the wine grape production system.

Differences in the margins of alternate cultivars and between yields of different white and red varieties were also illustrated. Inherent in different wine grape production systems and cultivation preferences are also alternate economies of size and initial capital investment requirements needed in fixed and moveable assets. In addition the long-term financial effect of the expansion of the cultivated area under wine grape production, as well as effect of a structural transition of a farm business towards more mechanically intensive wine grape production system was illustrated.

In view of the above, the VITISIM101 model was illustrated to be complex enough to account for a complex wine grape production system, wine grape production system evaluation and analysis. Given the particular capital investment in the farm business, prices received for produce, cultivar and trellis specific yield as well as assumptions about alternate future inflation rates, better and worse trellis and wine grape production systems were illustrated. The substitution of major cultivation actions on VSP trellises for that of mechanised ones on other trellises, were generally more affordable in the presence of sufficient economies of size. However current prices received for grapes and yields obtained were regarded insufficient to warrant the purchase of new cultivation specific equipment such as mechanical harvesters. The summary and conclusions will be provided in Chapter 6.

CHAPTER 6: SUMMARY OF FINDINGS, CONCLUSION AND RECOMMENDATIONS

Within recent years the South African economy and agricultural sector have been plagued by major shocks originating from international markets and social-political conditions locally. As a result sudden and volatile price shocks followed on markets for inputs used in wine grape production, triggering uncertainty in the likely course of future adjustments. Hence the making of good strategic decisions has become increasingly difficult, increasing the risk already borne by decision makers due to the complex, dynamic and open system in which wine grape production takes place. The former is exacerbated due to the capital intensive and path dependent nature implied by investments in the wine grape production system.

The general objective of this thesis was to identify and construct a farm-level simulation model that can analyse the long-term financial impact of different wine grape production systems, for a representative or user designated farm. The specific application of the simulation model involved simulating seven different wine grape production systems for a farm business cultivating an area of 50 as well as 80 hectares under wine grapes, followed by a simulation of the expansion of the area under cultivation from 50 to 80 hectares within a 20 year period for a farm in the Breedekloof region, South Africa.

The first part of this thesis outlined basic principles behind the study and nature of agricultural systems, as well as inherent qualities required by a simulation model to form a reasonable representation. This was followed by an elaboration on the implication of the trellis specific decision on the biological functioning, possible cultivation practices and cost of cultivating and establishing grapevines. The former was followed by capital budgeting and financing considerations in conclusion of the literature review, before a discussion on the functioning and structure of the simulation model developed in this study.

The penultimate chapter and last part of the study starts with a discussion on the incorporation and application of secondary data sources into the model, as well as illustration of empirical observations as obtained in the secondary dataset. Thereafter the simulated farm to be used for wine grape production system evaluation and analysis was compiled. The simulation and evaluation of different wine grape production systems included the designation of different trellis systems, as well as cultivation practices for a 20 year projection period, which were regarded as the economic life-time of the grapevine. As depicted in the results in Chapter 5, different wine grape production systems were illustrated to require a dissimilar investment in fixed and moveable assets. Similarly different yields obtained on specific cultivars and trellises were illustrated to compensate, in varying degrees for the cost of production, as well as initial capital investment required. With the result that the long-term financial impact and profitability varies between different wine grape production systems.

In view of the above and as indicated through the results from the model, disparities in the long-term profitability between different wine grape production systems can be attributed to the size of the income generated (output yielded and output prices received), cost of production, cost of investment and the timing of each aforementioned flow. While the size, as well as the composition of the cost of production per hectare, do vary between different wine grape production systems, results from the model suggest that cost considerations are subordinate in the determination of the long-term financial impact and profitability of wine grape production systems.

Instead main drivers of the long-term profitability of wine grape production systems, as simulated through the model, is rather to be the output prices and yields received, as well as the total investment required for production to take place. By stipulating the former it should not be inferred that management of production cost is unimportant, but rather that increases in yield and or lower capital investment in alternate wine grape production systems, can more than offset any differences in production cost, in the determination of the long-term profitability of different wine grape production systems.

As such the results of this study indicated that, the adoption of wine grape production systems which bring about greater yields are one of the most sensitive and main contributors to long-term profitability of the farm business. Similarly, the size of the required capital investment in the wine grape production system, as well as time that elapses before full production is attained, had a large impact. The former disparity was especially apparent between white and red varieties, where red varieties took three to five years longer to reach peak production. In the interpretation of the results it should also be noted that the relative costs of different inputs used in the production process, change relative to one another over time due to different inflationary trends in inputs.

Through the evaluation of the different wine grape production systems, a strategy by which grapevines are cultivated on High-Wire trellises and harvesting, foliage management as well as pruning were done mechanically, was found to lead to the highest IRR in all scenarios. The performance of the strategy can be attributed to the wine grape production system being geared towards higher yields, lower cost of production as well as having the greatest inherent economies of size of the evaluated wine grape production systems.

For all the strategies strict use was made of pre-owned mechanical harvesters and trailed harvesters were found to lead to better outcomes for both 50 and 80 hectare scenarios. As such the greater harvesting rate and efficiency of self-propelled harvesters was found to not justify the larger required investment in these harvesters. While greater economies of size and being in a taxable position could make the investment in new and self-propelled harvesters more viable, decision-makers should carefully consider whether they would not do better by investing the same amount of capital elsewhere.

Correspondingly strategy six, whereby grapevines are trellised on a Gable system and harvesting, foliage management as well as pruning are done by hand, was found to lead to the second best outcome in the long-term evaluation. The outcome is based on the assumption that no additional fixed infrastructure would be needed to be built for labour, that required labour would be sourced locally, that no labour shortages would exist and no additional management would be needed. The higher yields obtained compensated for the higher cost of production as well as higher total investment required.

As for the other strategies, manually cultivated and harvested VSP wine grape production systems led to the least favourable outcomes and whilst the Smart-Dyson wine grape production system was simulated to lead to better outcomes than VSP trellises, other alternative wine grape production systems did better. The last mentioned could be attributed to the fact that producer cellars do not sufficiently compensate for the higher quality grapes that could be obtained on these systems, given the higher costs of cultivating grapevines on these systems. Similarly, cultivation of red varieties was found to be less viable given the lower yields and delayed production of red varieties relative to white varieties.

Through the expansion and wine grape production system transition functionality of the simulation model, the model was illustrated to be valuable as a tool for strategic long-term planning. The former is due to the current wine grape production system as well as envisaged changes being able to be simulated and adjusted to determine the long-term financial effect and adjustment to farm specific goals. The development of the VITISIM101 simulation model as used in this study therefore contributes to the research done in the field of farm-level modelling in South Africa. The VITISIM101 model was illustrated to have the ability to simulate different wine grape production systems and be able to allow for the meticulous designation of a variety of parameters to allow the specification and tailoring to farm specific features and management plans. However the study was found to have several issues.

As discussed in Chapter 4 a decision was made to limit this study and simulation model to deterministic simulations and evaluations which are not entirely realistic. This is due to the open, highly dynamic as well as extreme environment in which agricultural production takes place, bound to inhibit some uncertainty and risk. Similarly the model allowed for depreciation and accompanied tax advantages that can be obtained from the use of capital in the wine grape production system. However the VITISIM101 model provided for depreciation according to the utilisation and straight-line method as with the "use" of these capital assets. The former then imply that depreciation was written off over a longer period than implied by the tax-code. As a result, due to the time value of money, the use of capital in the wine grape production system would therefore be less costly and could lead to greater margins than illustrated.

Additional limitations of the model included not being able to establish cultivar and trellis specific quality percentages or class specific yield in the dataset. Further research in establishing trellis and cultivar specific quality outcomes, as influenced by the use of a specific trellis, will be a great addition to the information needed in the model, as income is a multiple of the class specific yield and price per tonne. However, with the perception of wine quality already being subjective, combined with different wine styles, the former could be a daunting task. Similarly the better collection of data and establishing of a cultivar and trellis specific yield for the life-time of grapevines, in particular the alternative trellis systems, as the adoption of these systems and specific cultivars become more widely-spread would be a great addition to the information needed for the model. In addition a more detailed study of the labour norms for different wine grape cultivation actions, as obtained from industry organisations would be valuable.

In conclusion it can be deliberated that investments in the wine grape production system are not always done purely on economic considerations. In particular wine grape producers produce a combination of cultivars despite disparities in the margins on different cultivars, due to producer cellar arrangements or limitations, managerial considerations and the maximum harvesting capacity or the need to stretch their harvesting season, amongst others. Similarly wine grape production takes place in a complex environment with production outcomes dependent on a variety of factors, a number which were not determined as part of this study. Insinuating that the VITISIM101 model would exactly mirror the wine grape production system outcomes would be over ambitious.

However, proclaiming that definite differences in the long-term margins or profitability of wine grape production systems occur, can be stipulated with surety. In addition it can be ascertained that the average wine grape producer, producing for co-operative cellars is under immense financial pressure. Given the marginal prices obtained for produce and individual producers having a negligible, if any, influence on their product price, producers will be forced to be production driven, as well to expand operations to capture economies of size in their operations in an endeavour to farm wine grapes sustainably. The accompanying pursuit of this strategy would likely dampen future increases in product prices due to a greater supply of grapes and supply of wine to the market. Economies of size in turn is likely to be largely precluded to smaller producers, implying that wine grape producers would become less as smaller producers exit the industry and their farm businesses are amalgamated into larger ones.

Due to the climate in which wine grape production ensue also being generally suited to fruit production, wine grape producers could also diversify into an export fruit enterprise, such as citrus, stone fruit or table grapes. The inherent advantage of the latter enterprise can be ascertained as to have substantial greater margins being obtained with the same natural capital, the perishable nature of produce preventing the forming of a surplus, the geographical origin of produce facilitating the delivery of produce in a niche time period to world markets and producers directly benefiting from an exchange rate differential.

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