ASSESSING RISK IN THE PAARL/BERG RIVER REGION BY MEANS OF VARIOUS PORTFOLIO DIVERSIFICATION MODELS

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Declaration

I, the undersigned, hereby declare that the work contained in this thesis is my own original work and that I have not previously in its entirety or in part submitted at any university for a degree.

Signature: Date:

Summary

The need to take account of risk in agriculture must be part of every decision taken in agriculture. Yet risk is nothing to be too afraid of. Risk is a choice rather than a fate. The actions we dare to take, which depend on how free we are to make choices, are what the theory of risk is all about. The task is rather to manage risk effectively, within the capacity of the farmer, business or group in order to withstand adverse outcomes. Some methods of managing risks are feasible for all types of farms. Others are only feasible for certain sizes and types of farms. Therefore, farmers in general need a systematic technique that will enable them to choose an efficient investment strategy from among all feasible strategies. Specifically, given *n* risky assets (such as the different enterprises in the Paarl/Berg River region), it is essential to seek a diversification strategy which yields a portfolio lying on the efficient frontier.

The research question was whether different diversification models (Markowitz diversification model, Single Index Model and the Capital Asset Pricing Model) that are normally applied in capital markets for the construction of optimal diversified portfolios consisting out of different shares, are also applicable on risky portfolios in agriculture comprising different enterprises in the Paarl/Berg River region.

The efficient frontier can be seen as the graphical representation of a set of portfolios that maximize expected return for each level of portfolio risk. The Microsoft Excel portfolio optimiser (SOLVER) programme was used to illustrate the investment proportions, expected returns, and standard deviations of the portfolios of the efficient frontier.

The Single Index Model (SIM) can be used as an alternative to Markowitz diversification model. It drastically reduces the number of parameters needed to be estimated and yields the efficient set relatively easily without the technical difficulties characterising the full-rank solution. However, if the SIM assumptions are in contradiction to the actual data, the simplification of the calculations is achieved at the cost of getting imprecise results. The simplicity of SIM calculations was attained at a cost of constructing a sub-optimal portfolio, which does not lie on the corresponding efficient frontier.

The Capital Asset Pricing Model (CAPM) reveals that there is a great deal of systematic risk in relation to the portfolio enclosed in this study. By using the CAPM it is possible to determine which part of the risk the producer can control (non-systematic risk) and which part the producer has no control over (systematic risk). The proportions of systematic risk that can be diversified away are small, relative to the total risk of the Farm Sector Portfolio.

The success of these models depends on the efficiency of the market, as well as a large, up-to-date and reliable data source. Many younger cultivars could not be included in this study, due to the limited availability of data. In the next few years as data become available, it will be possible to construct efficient frontiers out of a wider range of enterprises. Different enterprises and cultivars will increase the number of alternative uses for natural resources in the Paarl/Berg River region through diversification. This will result in more choices for the farmer, and more flexibility in the decision-making process. Without reliable data, the result will be "garbage in, garbage out."

Opsomming

In elke besluit wat geneem word in landbou moet risiko as 'n faktor in ag geneem word. Tog is risiko nie iets om te vrees nie. Dit is eerder keuse as noodlot. Die stappe wat ons waag om te neem, wat afhang van hoe vry ons is om keuses te maak, is waaroor die teorie van risiko gaan. Die doel van die tesis is om risiko effektief te bestuur binne die vermoëns van die boer om sodoende negatiewe resultate die hoof te bied Sommige metodes van risikobestuur is lewensvatbaar vir alle soorte plase. Ander is slegs lewensvatbaar vir sekere groottes en tipes plase. Daarom benodig boere in die algemeen 'n tegniek wat dit vir hulle moontlik maak om 'n effektiewe beleggingstrategie te kies uit die verskillende uitvoerbare strategiee. Gegewe *n* as riskante aktiwiteite (soos die verskillende gewasse in die Paarl/Bergrivierstreek) is dit noodsaaklik om `n diversifiseringstrategie te vind wat 'n portefeulje sal lewer wat raak aan die effektiewe grens.

Die navorsingsvraag was of verskillende diversifiseringsmodelle (Markowitz diversifiseringsmodel (MVC), "Single Index Model" (SIM) en die "Capital Asset Pricing Model" (CAPM)) wat gewoonlik toegepas word in kapitaalmarkte vir die samestelling van optimale gediversifiseerde portefeuljes bestaande uit verskillende aandele, ook van toepassing sal wees op riskante portefeuljes in die landbou in die Paarl/Bergrivierstreek, wat verskillende gewasse insluit.

Die effektiewe grens kan gesien word as die grafiese voorstelling van `n stel portefeuljes wat die verwagte winste vir elke vlak van portefeuljerisiko vermeerder. Die Microsoft Excel portefeulje optimeringsprogram (SOLVER) word gebruik om die

beleggingsverhoudings, verwagte winste en standaardafwykings van die portefeuljes aan die effektiewe grens te illustreer.

Die "Single Index Model" (SIM) kan gebruik word as 'n alternatief vir die Markowitz diversifikasiemodel. Dit verminder drasties die getal parameters en lewer maklik die effektiewe reeks, sonder die tegniese probleme wat ondervind word met die oplossing by die Markowitz model. Nietemin, indien die SIM die werklike data weerspreek sal die vereenvoudiging van die berekenings bereik word ten koste van onakurate resultate. Die eenvoud van die SIM is verkry ten koste van die samestelling van 'n suboptimale portfeulje, wat nie aan die ooreenstemmende effektiewe grens lê nie.

Die "Capital Asset Pricing Model" (CAPM) wys dat daar baie sistematiese risiko gekoppel is aan die portfeulje ingesluit in hierdie studie. Deur gebruik temaak van die CAPM is dit moontlik om vas te stel watter deel van die risiko (nie-sistematies) die produsent kan beheer en watter deel die produsent nie kan beheer nie (sistematiese risiko). Die verhouding van sistematiese risiko wat weggediversifiseer kan word is klein in verhouding tot die algehele risiko van die boerderysektor portefeulje.

Die sukses hang af van die doeltreffendheid van die mark, sowel as 'n groot tot-op-datum en betroubare bron van data. Baie van die jonger aangeplante kultivars kan nie ingesluit word in hierdie studie nie as gevolg van beperkte data. In die volgende paar jaar, soos data beskikbaar word, sal dit moontlik wees om effektiewe grense van 'n wye reeks gewasse saam te stel. Verskillende gewasse en kultivars sal die hoeveelheid alternatiewe gebruike van natuurlike hulpbronne in die Paarl/Bergrivierstreek vermeerder deur diversifikasie. Dit sal lei tot meer keuses vir die boer en meer buigsaamheid in die besluitnemingsproses. Sonder betroubare data kan betroubate resultate nie verkry word nie.

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CHAPTER 1

INTRODUCTION

"All we know for sure, is that tomorrow will not be the same as today."[1]

1.1 Setting

Agriculture is an industry that is confronted by various forms of risk. However, risk is not a phenomenon that is unique to the agricultural sector of the economy. The agricultural sector is faced with a combination of risk variables that are very seldom found in the same blend in any other sector. In the Paarl/Berg River region fluctuating real interest rates, the exchange rate of the Rand and unstable prices caused by the unpredictable climate are the most important factors that contribute to risk that can influence management decisions.

The rapid process of deregulation and liberalisation in the past decade has exposed the limited capacity of many farmers to adjust to policy and market changes. Greater exposure to international competition has increased their uncertainties in decision-

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[1] *Van Zyl et al. (1999).*

making and affected their competitiveness negatively. Decisions in agriculture are frequently based on incomplete knowledge of the exact outcome of a particular decision. When decisions have to be made, farmers usually find their knowledge of external or exogenous factors to be incomplete. Decisions based on incomplete information of this nature will most probably result in risky outcomes. Therefore, effective risk management tools are critical for effective risk management strategies.

It is generally accepted in the financial world that risk in investments can be reduced through diversification. However, even with a large number of risky enterprises in a portfolio, there is no way of avoiding all risk. The risk that remains even after diversification is called systematic risk or non-diversifiable risk. The risk that can be eliminated by diversification, on the other hand, is called non-systematic risk, or diversifiable risk (see Section 3.1.5).

The diversification strategies that are most commonly practised in the financial markets are naïve and efficient diversification. Naïve diversification is where a portfolio is constructed with equal proportions invested in each asset, and not divided proportionally between assets. This results in portfolios where risk is not minimised for the level of return, i.e. inefficient portfolios. Naïve diversification will result in inefficient diversification and only focuses on the return of the cultivar, and not the risk-reducing properties on a quantitative basis. In practice this means that the farmer will experience a net margin that fluctuates considerably over time. Efficient diversification, on the other hand, comprises the construction of an efficient frontier where a minimum level of risk exists for each level of return. From the efficient frontier a portfolio is selected, based on the investor's preference to risk. For the purpose of this study it is assumed that the investors are risk averse. Such an investor prefers more wealth to less wealth and prefers less risk to more risk. These investors will maximise the expected utility from their risk class, or conversely, the minimum risk at any particular level of expected return.

1.2 Statement of problem and research question

The need to take account of risk in agriculture must be part of every decision made in agriculture. The actions we dare to take, which depend on how free we are to make choices, are what the theory of risk is all about. The task is rather to manage risk effectively, within the capacity of the farmer, in order to withstand adverse outcomes.

Several methods exist for incorporating risk behaviour in farm and sector planning models. These models all have advantages and disadvantages. No one model or approach to risk analysis is best at farm level. The appropriate model depends on the specific problem, objectives of research, data availability, and cost and computational considerations. Some methods of managing risks are feasible for all types of farms. Others are only feasible for certain sizes and types of farms.

A number of different models exist in the literature for the construction of the optimum portfolios in capital markets, of which the Markowitz model, the Single Index Model (which is very similar to the Markowitz model) and the Capital Asset Pricing Model (CAPM) are most commonly used.

Therefore, farmers in general, need a technique that will enable them to choose an efficient investment strategy from among all feasible strategies. Specifically, given n risky assets (such as the different enterprises in the Paarl/Berg River region), it is essential to seek a diversification strategy, which yields a portfolio lying on the efficient frontier.

The research question will be whether different diversification techniques (models) that are normally applied in capital markets for the construction of optimal diversified portfolios consisting out of different shares are also applicable on risky portfolios in agriculture comprised out of different enterprises in the Paarl/Berg River region.

1.3 Underlying hypothesis and objectives

The hypothesis underlying this study is that most farmers can manage their risk by thorough diversification, that is, by using different enterprises to reduce the overall risk on the farm.

The aim of this study is to indicate how the risk of an individual farmer in the Paarl/Berg River region can be lowered. To accomplish this aim, a portfolio of different agricultural enterprises can be developed according to the various individual preferences of particular farmers by looking at the different risk-return relationships of enterprises in the Paarl/Berg River region.

The objectives of this study are therefore:

1) To investigate the existence of risk and the role it plays in agriculture by conducting a review of the relevant literature. For the purpose of this study diversification is used as part of risk management by constructing a portfolio out of more than one enterprise in order to reduce the total risk on a producer's farm in the Paarl/Berg River region. It is therefore suggested that farmers[2] should consider both risk and return characteristics of the various enterprises, as well as the correlation of the enterprise's return with other cultivars, before a new enterprise or cultivar is introduced to a farmer's portfolio. This should be done in combination with conventional methods as currently practised, which will ensure efficient portfolios with the highest return for each level of risk. Typical agricultural risk programming and optimising models that can be used to help farmers in planning and decision making in a risky environment are also discussed.

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[2] *It is important to note that throughout this study theories in the capital market are applied in the agricultural sector. Different authors use different terminology in their work. For the purpose of this study, "investor" was substituted by "farmer or producer" and "shares, assets, securities or stocks" by "enterprise" or "activity".*

2) Modern Portfolio Theory (MPT) explores how risk averse investors construct portfolios in order to optimise market risk against expected returns. To investigate how the mean variance portfolio (MVC) can be used to evaluate enterprises on the basis of their expected return and variance, a efficient frontier of optimal portfolios can be constructed. Portfolios lying along the efficient frontier dominate all other portfolios and together comprise the efficient set of portfolios, because for these portfolios it is not possible either to obtain a greater expected return without incurring greater risk or to obtain smaller risk without decreasing expected return. Farmers should be able to choose among all possible investments on the basis of their risk (portfolio variance) and return (portfolio return).

3) An alternative to MVC is the Single Index Model (SIM). The estimation of essential parameters by means of the full-covariance models can become extremely time consuming because of the infinite number of possibilities that must be considered. A comparison between the SIM and MVC on the same data and region will be investigated.

4) The last objective of this study will be to determine the extent of systematic and non-systematic risk within the Paarl/Berg River region and to generate Beta coefficients for all those activities included in the market portfolio in order to report on the relationship between farm enterprise returns and systematic risk. In doing so the feasibility of using the CAPM as a tactical farm management tool is evaluated by the construction of an optimal portfolio consisting of risk-free and risk-efficient assets[3] for a typical farm in the Paarl/Berg River region.

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[3] *In this study agricultural enterprises can be seen as risky assets. Farm rental land will be used as a risk-free asset.*

1.4 Methodology

1.4.1 Delimiting of study area

Compared to international standards, South Africa has a poor natural resource base. Rainfall is unreliable and the country as a whole is subject to severe and recurrent droughts. Furthermore, only a small proportion of the land is suitable for cultivation of agricultural enterprises.

Because of variations in soil types, different climatic conditions and farming enterprises, the Western Cape cannot be seen as homogeneous. As a result it is divided into different farming sub regions (see *Appendix 1.1*). The Paarl/Berg River region is characterized by unpredictable fluctuations in the temporal and spatial quantity of rainfall. It is therefore impossible to do an intensive study covering the whole region. A study of a specific homogeneous sub region instead was necessary. The Paarl/Berg River region (sub farming region) was chosen for this study and falls within the Wellington agricultural extension region, stretching on both sides of the Bergriver from the N1 in the South up to Wellington in the North. It also includes a small part of the Suider-Agter-Paarl area and the Perdeberg region and consists of a total area of 17 800 hectare (see *Appendix 1.1*).

1.4.2 Data

Historical data used in this study were obtained from wine grape, table grape, soft citrus, plum, olive and sweet melon producers in the Paarl/Berg River region. Data can be gathered in various forms, i.e. individual data, aggregate data and pooled data. Each form has its advantages and disadvantages and can be analysed for a specific purpose. The ideal will be to use the data of an individual farmer as far back as possible, but because of several factors (see Chapter 5) pooled data were used for the purpose of this study.

The data were collected by means of questionnaires (see *Appendix 2.1, 2.2* and *2.3*) that were sent to 21 farmers with sufficient data in close vicinity in the Paarl/Berg River region in order to be able to pool the data of the different enterprises. The interviews were conducted on the basis of a schedule of structured and semi-structured questions where each farmer was interviewed personally on his farm in order to complete the questionnaire together with the interviewer. The questionnaires were constructed in a uniform sequence in order to compare the different industries with each other. The questions themselves focused on a number of aspects, including the income or the sales of the enterprise and in the second part, the different costs (see Section 5.3 for further detail). Margins above specified cost of the different enterprises were used in this study. The margin above specified cost is defined by subtracting costs from the gross value of the production of an enterprise. The specific variable costs that are included (see *Appendix 2.2* and *2.3*) depend on the purpose of the calculations and the practical feasibility of the allocation. All comparisons between enterprises were based on this margin above specified cost.

1.5 Sequence of chapters

Since risk plays such an important role in this study, risk theory is outlined in Chapter 2. The existence of risk and the role it plays in agriculture is discussed. Different ways to manage risk in agriculture are discussed. Diversification by means of enterprises and cultivars can be used as a tool to manage risk in the Paarl/Berg River region. The last section a briefly reviews risk programming and optimising models that can be used alternatively to assist the farmer in planning and decision-making in a risky environment.

In Chapter 3 the theoretical aspects of Modern Portfolio Theory and Markowitz-diversification are discussed. The construction of an optimal efficient portfolio in order to optimise market risk against expected returns is analysed. Out of a universe of risky assets, an efficient frontier of optimal portfolios can be constructed. Portfolios lying along the efficient frontier dominate all other portfolios and together comprise the efficient set of portfolios. An alternative to MVC is the Single Index Model (SIM). The estimation of the essential parameters through the full-covariance models becomes extremely time-consuming because of the infinite number of possibilities that must be considered. The SIM is discussed as a model that simplifies the amount and the type of data in the portfolio structure.

In Chapter 4 the theoretical aspects of the CAPM are discussed. The model is described as it is used in the financial environment, then compared and implemented in the agricultural sector. The assumptions of the model are listed in order to implement the model in real world circumstances. In addition, Beta coefficients are described as a tool to determine systematic risk. The CAPM is also evaluated in terms of other models. Limitations of the CAPM are also considered.

In Chapter 5 the different agricultural enterprises that are included in the study are summarised. The enterprise data, the type of data and the technique that were used to collect the data in the Paarl/Berg River region are discussed and compared.

Chapter 6 outlines the results of the study. In order to obtain an efficient portfolio, the results are provided by means of mathematical calculations in the form of graphs and diagrams. The chapter consists of three sections. In Section 6.2 the Markowitz portfolio selection model is described by using a Microsoft Excel computer programme to construct the efficient frontier. Section 6.3 makes use of the Single Index Model to construct the optimal efficient frontier. The SIM reduces dramatically the amount of work required to trace the efficient frontier. The answers elicited by the different techniques are compared in order to see how much there is in common between the portfolios. Section 6.4 focuses on the amount of systematic and non-systematic risk in agriculture. Beta coefficients and the theory of the Capital Asset Pricing Model are used to examine systematic risks in the Paarl/Berg River region. Options to reduce systematic risk within agriculture will be discussed.

Chapter 7 contains a short summary and recommendations for future research.

CHAPTER 2

REVIEW OF RISKY DECISION MAKING THEORY

2.1 Introduction

The development of agriculture in early times was partly a response to the riskiness of relying on hunting and gathering of food. Since then, farmers and others have tried to find ways to make farming less risky by achieving better control over production processes.

In this chapter risk and risk in agriculture will be discussed. Risk is an essential part of the farmers' decision making process. There exist various ways to manage risk in agriculture. For the purpose of this study various diversification models in agriculture will be discussed in order to manage farmers risk according to their risk preferences. Risk management help the farmer to choose between alternative options to reduce, shift or manage the risk that threatens the economic success of an industry.

2.2 Risk

The concept of risk has permeated the agriculture and financial community to such an extent that no one needs to be convinced of the necessity of including risk in investment analysis. Knight (in Barry, 1984) argued that there are three categories of knowledge in decision situations: Perfect knowledge, risk and uncertainty. Perfect knowledge exists when the decision outcomes are known with certainty. Decision-making is simple if perfect knowledge is available, but this is a rare occurrence.

In modern decision theory uncertainty is a state of mind in which the individual perceives alternative outcomes to a particular action. Risk on the other hand, has to do with the degree of uncertainty in a given situation. According to Roumasset (1979) there appear to be no consensus, however, regarding how risk should be measured. The distinction between risk and uncertainty has focused primary on the objective versus subjective probabilities. Subjective and objective probabilities are distinguished by assumptions about prior information. Anderson *et al.* (in Barry, 1984) argues that all probabilities are subjective because the decision-maker must subjectively assess whether any objective data are appropriate for the decision situation. All probabilities in decision-making are to some extent subjective; thus the distinction between risk and uncertainty is unimportant.

The consequences of events or decisions are often not known with certainty until long after they have occurred. It is therefore difficult to predict outcomes with any measure of certainty. Risk is that uncertainty that affects the welfare of individuals, and is often associated with adversity and loss. Risky decisions occur when at least some of the consequences are not known (Barry, 1984). Typically, this uncertainty arises because of the interval between the decision point and the final outcome. When aggregate crop output or export demand changes sharply as with the deregulation of the an enterprise, for example, farm prices can fluctuate substantially and farmers may realise returns that differ largely from their expectations.

Because the consequences of every decision occur in the future, those consequences are uncertain. These uncertainties are defined in various ways in the literature. According to Hardaker *et al.* (1997) uncertainty is imperfect knowledge that leads to uncertain consequences, and particularly to exposure to unfavourable consequences where the probabilities of the possible outcomes are not known. Risk on the other hand can be defined as imperfect knowledge where the probabilities of the possible outcomes are known.

Risk is not a phenomenon that is unique to the agricultural sector of the economy. However, the agricultural sector is faced with a combination of risk variables that are very seldom found in the same blend in any other sector. Barry *et al*. (2000) argued that business risk for farmers include: production and yield risk; market and price risk; losses from severe casualties and disasters; social and legal risk from changes in tax laws, government programs, trade agreements; human risk on performance of labour and management; and risk of technological change. It is true that some of these risks are insurable, even though at a high cost, but it is equally true that other risk variables are not insurable. The effect of some risk variables is instantly recognisable (flood and fire damage), while the effect of others is only visible over the short to medium term (drought). It is even true that the effect of some other risk variables will only be visible over the medium to long term (changes in consumer preferences and technology). Dealing with all these types of risks systematically, whether for farmers, researchers or policy makers, is difficult (Huirne and Hardaker, 2000). Yet risk is nothing to be too afraid of. It is often said that in business, profit is the reward for risk bearing. No risk means no economic gain. The task is rather to manage risk effectively, within the capacity of the individual, business or group to withstand averse outcomes. The word "risk" derives from the early Italian *risicare,* which means, "to dare". In this sense, risk is a choice rather than a fate. The action we dare to take, which depends on how free we are to make choices, are what the theory of risk is al about.

2.3 Risk management

Bernstein (1998) defined risk management as the ability to predict what may happen in the future and to choose among alternatives to reduce risk. Many of the most sophisticated ideas about risk, managing risk and making decisions have developed from the analysis of the most childish of games. One does not have to be a gambler or an investor to recognise what gambling and investing reveal about risk. Risk exposition therefore makes on-farm risk management a task of major concern for farm managers. However, risk management may be severely hampered by liquidity constraints. Due to high risk, only small amounts of credit may be available for farms at initial stages, in which case farm managers have to make the best of their existing technology and farm equipment (Martin and Ditges, 2000).

There are two main reasons why risk analysis matters in agriculture. First, most people are risk averse. A person who is risk averse will be willing to forgo some expected return for a reduction in risk. Risk management involves the selection of methods for countering business and financial risks in order to meet a decision-makers risk-averting goal. Evidence of farmers' risk aversion is to be found in studies on elicted attitudes towards risk (Lombard and Kassier, 1990; Botes *et al.,* 1994) and in many of their actions, the commonest of which is their willingness to buy certain kinds of insurance for their enterprises. However, risk is generally associated with a reduction in expected returns. Thus it is important to account for the risk-return trade-off in designing risk management strategies.

Second is the issue of downside risk[1], which refers to those situations in which significant deviations from the 'norm' lead to worse outcomes rather than to better ones. The yield of a crop, which depends on a large number of variables such as rainfall and temperature, provides an obvious example. Large deviations of these variables in either direction from their expected values tend to have averse effects.

Risk in agriculture is of some importance to society as a whole. Risk aversion can be thought of as a sort of friction preventing the sufficient allocation of farm resources. For example risk averse farmers may be slow in adopting untried improved technologies. Such risk-induced friction means that the aggregate farm output is less than it would be if there has been less risk. Attitudes towards risk vary depending on the individual's objectives and financial resources (Boehlje and Eidman, 1984).

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[1] *See Pike and Dobbins (1986) for the One-in-Six rule.*

Risk management is not a set of procedures that are followed, once and for all, to 'protect' the organisation against risk, since that is impossible in a turbulent world. It is rather a continuous, adaptive process that needs to be integrated into all relevant aspects of the decision making procedures of the organisation. It is a way for an organisation to balance the chances of serious losses against the opportunities for profit making. Risk management for risk averse entrepreneurs involve choosing among alternatives to reduce the effect of various types of risk. For any organisation, whether a large corporation or a family farm, risk management is, or should be, an integral part of good management.

As postulated above, risk is an important factor that must be dealt with in agriculture. Risk exposition makes risk management a task of major concern for farm managers.

2.4 Actions to reduce risk in agriculture

In general, an action is considered risk reducing if, when repeated numerous times, it lowers the variability of income at a given expected value compared to alternative actions. If an action both reduces income variability and increases expected income, it is unclear whether such a decision is made to increase profit and to reduce risk.

Several methods exist of how to deal with risk in agriculture (Barry *et al.*, 2000 and Hardaker *et al.*, 1997) designed strategies for how to cope with risk in the risk management process. Some risk responses focus on reducing risks within the business. Effective diversification over several types of assets and business enterprises is an example. A brief literature review by Barry (1984) highlights some of the extensive literature on risk analysis and also illustrates some of the analytical responses to the changes in agriculture's risk environment. The farmers' actions to manage risk are categorised in terms of the production, marketing and financial organisational areas of the farm business (Barry *et al.,* 2000). Some methods of managing risks are feasible for all types of farms. Other is only feasible for certain sizes and types of farms. The methods can be categorised in terms of production, marketing, and financial organisations of farm businesses. In production risk responses include enterprise diversification, informal insurance, organisation flexibility, multiple production practices, and avoidance of high-risk enterprises.

Production responses: Enterprise selection greatly affects the variability of cash flows. The variability of yields and farm incomes differs substantially among regions and enterprises. In order to reduce this income variability, the risk averse farmer will select a more stable region or enterprise. Another strategy involved in enterprise selection is diversification.

Market responses: Farmers may reduce price variability by selecting enterprises with low expected price variability. Marketing alternatives allow farmers to price their commodity prior to delivery (Gronum and Van Schalkwyk, 2000). Forward and future contracts are other means of reducing price variability and determines a selling price for a specified future delivery. Forward contracting prior to harvest also introduces some flexibility in marketing and raises concerns about yield risk in meeting the contract commitment. Hedging involves taking a position in the future markets opposite to an exposure in the cash market. Hedging through forward contracts for commodities or farm inputs focus on transferring risk outside the business. Hedging reduces exposure to the price risk by shifting that risk to others with opposite risk profiles, or to investors who are willing to accept the risk in exchange for profit opportunity. Basis risk is the major distinction between risk and forward contracting. The basis is the difference between the future price and the local market price. According to Barry (1984) hedging[2] is used less by farmers than forward contracting because the availability of limited suitable contracts, the discrete size of the contracts, brokerage fees and potentially margin calls.

Marketing decisions also involve learning because new information becomes available during the marketing period. Farmers need to develop skills in marketing and processing of market information to effectively use these strategies.

For non-storable commodities, production may be timed to sell output periodically during the year. Spreading sales over time as is common in livestock production, results in price averaging over the marketing period and reduces the variability of expected returns (Barry, 1984). Spreading sales is essentially diversification over time rather than over enterprises. Investments in on-farm storage for grain, provides

[2] *For more information about hedging and future contracts see www.safex.co.za.*

flexibility for farmers to sell storable commodities throughout the year. Spreading sales can insure that an individual roughly achieves the average price received by all farmers in that year. A disadvantage of spreading sales, however, is the lost possibility for achieving above average prices.

Financial responses: Financial response to risk becomes increasingly important because of the volatility of commodity prices. This volatility increases the price need for marketing responses to risk.

An important financial measure of the firm's ability to survive shortfalls in net income is its liquidity position. Barry (1984) argued that a financial response to risk is maintaining liquidity. Liquid assets are categorised by the time required to liquidate an asset and the discount in sale proceeds resulting from a forced sale. An example of a liquid asset can be a savings account; because it is easy to convert the cash and their liquidation cost are low. On the other hand, to liquidate something like a track of land on short notice generally involves a substantial discount in sales values. Painter (1999) argued that investors who choose to hold a low risk portfolio would not include farmland in their portfolio. The financial gains from farmland are the results of its negatively correlated returns with other equity markets. Farmland investment has associated problems including illiquidity, poor marketability and asset lumpiness. Therefore, land is considered as an illiquid asset.

Another source of liquidity is the farmers credit reserve. A credit reserve is a farm unused borrowing capacity that it can provide additional loans to cope with cash flow problems (Barry and Baker, 1971).

Leasing of land is another way to maintain liquidity in the farm business. Leasing avoids debt commitments, adds to liquidity and can provide flexibility in operations. Land is commonly leased on a cash or share basis and allows farmers to invest more in intermediate assets instead of less liquid farm real estate. Land rent will be discussed in Chapter 4 and 6 as it serves as the risk-free part of a farmer's portfolio.

Another way of managing risk is to spread risk over different economic structures. Barry and Fraser (1976) focused in their study on the feasibility and structural implications of relevant risk responses available to producing firms that differ in size and type. Emphasis is given to the value of managerial information in formulating uncertain expectations and for the producer's financial and marketing choices for managing these risks. This does not mean that more than one farm with different industries is needed but that the decision maker can generate income outside the farm in non-agriculture industries or investments.

Agricultural producers face a variety of types of risks and have much risk reducing actions available. Widespread risk management strategies that integrate several of these actions are necessary in dealing with this multiple sources of risk. Financial responses are also used to build the farm capacity to bear risks in production and marketing and to cope with financial risks as well. A comprehensive strategy integrating production, marketing and financial responses should reduce risk more than the individual responses to risk.

In the next section, diversification will be discussed in more detail. In a region where diversification options are limited, it is important to find the best diversification option or portfolio that will optimise a farmer's return. According to Barry *et al.* (2000) the portfolio model can be used to explain why risk will decline from combining two seemingly comparable investments.

2.5 Diversification

"My ventures are not in one bottom trusted,
Nor to one place; nor is my whole estate
Upon the fortune of this present year;
Therefore, my merchandise makes me not sad."
(Antonio, Shakespears' Merchant of Venice[3])

Diversification reduces risk (Lattmann, 1996). The notion of diversification is very old. The idea is to reduce the risk of the overall return by selecting a mixture of activities that have net returns with low or negative correlations (Binding *et al.*, 1977). It may be possible to reduce the total variability of returns by combining several assets,

[3] *As shown in Bernstein (1998:93).*

enterprises, or income-generating activities without unduly sacrificing expected returns. By reducing both predictable and unpredictable fluctuations, diversification smoothes the flow of income (Valdivia *et al.,* 1996). Valdivia notes that combining enterprises and activities that generate returns during different times of the year can smooth predictable seasonal fluctuations in income. The question arise that why does risk decline from combining two seemingly comparable investments? The answer is based on a relationship between two investments. Barry *et al.* (2000) developed this relationship by using a portfolio model.

The word portfolio refers to a mix, or combination of assets, enterprises, or investments (Barry *et al.,* 2000). The word has a Latin root, from *portare,* to carry, and *foglio,* leaf or sheet. Portfolio has thus come to mean a collection of paper assets (Bernstein, 1998). It is most commonly used to describe holdings of financial assets such as stocks and bonds. However, it can also be applied to holdings of tangible assets like grain inventories, growing crops, livestock, and land. Hence, the portfolio of a wine grape – sweet melon producer is considered to hold two investments, wine grapes and sweet melons. These two investments could further broaden the decisions the decisions an investor can make to construct a portfolio. The portfolio model indicates how different combinations of investments may reduce an investor's risk more than having only a single investment. Holding combinations of investments is called diversification. The number of the investments held and, the co-variation among the expected returns of the individual investments determine the potential for the different combinations to reduce risk. Barry *et al.* (2000) explains how the gains in risk reduction from diversification increase as the correlation among investment declines and the number of investments in a portfolio increases. A positive co-variation means that high profits in one investment are associated with high profits in another investment. Negative co-variation means that high profits in one investment are associated with low profits in another investment. Zero co-variation means that there is no statistical association between the variations of profits of these investments.

A diversified portfolio of economic activities with variances that are not perfectly correlated can reduce unpredictable fluctuations that create an unexpected loss in income. Diversification may in fact make variability greater if similar seasonal and market forces affect the various activities (Makeham and Malcom, 1993).

Diversification to reduce risk, like all other strategies, comes with a cost. The cost is the income sacrificed over a period of years by organising the farm to reduce the variability between years. Diversification to reduce risk means that the income will probably not be too low in bad years, but will also not be as high in good years (Binding *et al.*, 1993). Diversification to lessen variability is more effective as means of combating yield variability (Binding *et al.*, 1993).

If producers have only one enterprise in a risky portfolio, the sources affecting the risk can be classified into two broad groups of uncertainty as explained above. According to Bodie *et al.* (1995) diversifying into more than one enterprise continues to minimise exposure to risk, with a result that portfolio volatility should continue to fall. However, even with a large number of risky enterprises in a portfolio, there is no way of avoiding all risk. The risk that remains even after diversification is called systematic risk or non-diversifiable risk. The risk that can be eliminated by diversification, on the other hand, is called non-systematic risk, or diversifiable risk. While portfolio risk does decrease with diversification on the average, the power of diversification to reduce risk is limited by common sources of risk (see Chapter 4).

Enterprise diversification in farm business should be carefully considered, although most farm experience limited range of available enterprises without sacrificing too much expected return. Moreover, most enterprises grown in a given area tend to be positively correlated. This correlation occurs because, in the same location most enterprises experience similar weather patterns, use similar resources, and experience similar market factors. Therefore, diversification as a risk reducing-strategy becomes more effective as the co-variation among investments is lower and preferable negative.

A problem with enterprise diversification is the loss in efficiencies in, and returns from specialised production. Resources, climatic conditions, and market outlets often limit opportunities for enterprise diversification. Relatively high, positive correlations among enterprise returns in local areas may also diminish the gains in risk efficiency from diversification. Other forms of diversification described in the literature are discussed below.

The dominance principle: According to the dominance principle, the investment with the least risk of all the investments with any given expected rate of return is the most desirable, or among all the assets in a given risk-class, the one with the highest expected rate of return is the most desirable (Francis, 1976).

Naïve (simple) diversification: Naïve diversification concentrates on owning many assets – in other words "not putting all your eggs in one basket". In contrast to naïve diversification, Markowitz-diversification is an analytical method of diversification (Alexander and Francis, 1986). Each asset has the same chance to be included in the portfolio. A portfolio is thus constructed with equal proportions invested in each asset, and not divided between assets, as in Markowitz-diversification. Naïve diversification reduces risk by allowing the independent random errors (non-systematic risk) from the individual shares to average out to zero, leaving only the systematic risk component. However it ignores the covariance between shares, and therefore is not expected to completely minimise risk (Alexander and Francis, 1986).

Diversifying across industries: By selecting shares from different and unrelated industries, better diversification can be achieved. This type of diversification is, however, not much better than naïve diversification. Studies have shown that the rate of return of shares in many industries is highly correlated with one another. Systematic variability of return cannot be naively diversified away merely by selecting shares from different industries (Francis, 1976).

International diversification: This allows for the inclusion of foreign shares. If markets are segmented, the potential gains might be greater than national diversification. The major implication in the consideration of foreign shares is the presence of exchange rate risk.

Geographic dispersion is another form of diversification. This strategy involves spreading production out over a wide geographic space to minimise losses associated with the highly localised, severe storms and other hazardous events. Gains from the reduced risk must be compared with the increased cost of operating geographically dispersed tracts of land (Barry, 1984). By diversifying location and seasonality of production, farmers may stabilise annual income, expand credit, and increase their rate of firm growth.

The different strategies that exist to reduce risk by diversification do not eliminate all risk, but it balances risk and yield according to the farmers' potential to accommodate a broad range of results. Several farm- and sector planning models exist for incorporating risk behaviour in management. These models all have advantages and disadvantages. No one model or approach to risk analysis is best at farm level. The appropriate model depends on the specific problem, objectives of research, data availability, and cost and computational considerations. A brief summary of risk programming and optimising models will be discussed in the next section that can also be used to help the farmer in planning and the decisions that he has to make in a risky environment.

2.6 Different models in agriculture for planning and decision making

Hardaker *et al.* (1997) described farms along with other agricultural businesses in a systems context. All the parts in the business are working together. Decisions making in one part of the business will have an effect on other parts of the business. However, farms and other businesses are constrained systems, in the sense that what can be done is limited by the available amounts of resources such as land, labour and capital in its various forms and by the restrictions imposed from outside the farm. Therefore, in modelling a decision affecting the operation of such a business, it may be wise to cast the analysis in a whole-farm, rather than in a partial, context.

In agricultural economics and farm management portfolio research has traditionally emphasised the use of quadratic programming techniques (Freud 1956; Scott and Baker, 1972). Linear approximations such as Minimisation of Total Absolute Deviations (MOTAD) (Brink and McCarl, 1978) or the linear programming-risk simulator (LP-RS) (Hazell, 1971) had also been used in this kind of research. These techniques provide a decision framework for delineating the expected return variance (E-V) of efficient farm plans.

2.6.1 Computerised planning in farm systems

Valid experiments on the farm systems are expensive, difficult and it takes time. On the contrary, modelling by means of computers is easy, not so expensive and much faster after an adequate model is developed for a farming system (Pandey, 1990).

According to Pandey, (1990) models can be used to understand the real aspects of a farming system because a model can be seen as a tool to simplify the reality. The purpose of any model is to aggregate all the individual components of information to get an integrated outlook of the entity as a whole. This can be achieved by means of optimising and non-optimising models.

2.6.2 Non–Optimising models

The most common computerised planning methods for farm planning are normal spreadsheets like Lotus, Quattro Pro and Excel. Beside normal spreadsheet programmes, simulation models can be used to investigate the behaviour of farming systems over a period of time.

Evans (2000) defined simulation as the quantitative method that described a real process or situation. This is possible by constructing a model that copy the functioning of the process over a specific period in time in order to investigate the behaviour of a system over time. Simulation is normally a set of mathematical equations, trying to simulate the correlation between the variables within a system, in order to forecast changes within the system. The advantage of simulation is that non-linear relationships can easily be handled. The relationship that input coefficients have on each other can easily be simulated as in Linear Programming (LP) techniques. The main use of simulation is to find out the consequences of different proposals over time. A way of handling risk in simulation models is by combining distributions using random numbers by what is known as the Monte Carlo technique. The term Monte Carlo was introduced during the World War II as a code name for simulation of problems associated with development of the atomic bomb. Monte Carlo techniques are entirely random. That is that any given sample may fall anywhere within the given range of input distribution (Hardaker *et al.*, 1997). The disadvantage of simulation is that there is no guarantee that the best optimum will be found like with LP.

2.6.3 Mathematical Programming

Mathematical programming (MP) models are very well adapted for whole-farm systems and are relatively simple to construct and solve.

The impact of uncertainty[4] on planning any farm is likely to be complex and pervasive. It is not possible to account for all sources and impacts of uncertainty and some simplifications will be necessary. Hardaker *et al.* (1997) outlined these uncertainties in decision trees that provide good means for capturing the principal kinds of decision that can be made and their consequences. In developing MP models of risky farming systems it is necessary to distinguish between embedded and non-embedded risk (Hardaker *et al.,* 1997).

In reality, most real systems have embedded risk. MP models for non-embedded risks will be called risk-programming models and those for embedded risk will be called stochastic programming models.

2.6.3.1 Linear Programming

Linear programming (LP) is the most widely applied MP method used for farm planning (Hardaker *et al.,* 1997). LP is widely recognised as a method for determining a profit maximising combination of farm enterprises that is feasible with respect to linear fixed farm constraints (Hazell, 1971 and Karloff, 1991). Bernstein (1998) defined LP as a mathematical model for minimising costs while holding outputs constant, or maximising outputs while holding costs constant.

The importance of linear programming derives in part from its many applications and in part from the existence of good *general-purpose* techniques for finding optimal solutions

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[4] *According to Hazell (1971), uncertainty is used to denote situations in which knowledge of the future events is limited to estimates of both possible outcomes and relative frequencies.*

In order to understand the nature of linear programming it is necessary to explore what is meant by a mathematical model. Daellenbach and Bell (1970) described a model as a representation of all or part of the properties of some subject of reality, such as an object, an event, or a system. Note that any model, and in particular a mathematic model, is but a partial representation of reality. Thus, a linear program is a mathematical model that expresses the physical behaviouristic, or economic relationship between the various elements of a decision problem in a standardised mathematical form; and linear programming is a standardised method of determining the optimal decision, action, or policy for the problem investigated.

According to Dalton (1982) linear programming is well understood and it has been applied in many different ways to a large number of problems. Howcroft and Ortmann (1990) used linear programming in the development of a regional programming model for simulating the South African wheat industry. The results showed that the model successfully simulates production in the main wheat growing regions of South Africa. Hazell and Scandizzo (1974) presented a method for solving agriculture sector models under risk to obtain perfectly competitive levels of output and prices in all product markets when producers behave according to an E-V decision criterion. Similar findings exist under Chen and Baker (1974).

Variants of the technique enable the method to cope with time, risk, indivisible or lumpy resources and interrelationships between activities and constraints. The common feature of all the applications of LP is that they involve the allocation of scarce resources to activities. Planning agriculture on a regional level is conceptually no different from planning an enterprise mix on a farm.

The development of linear programming was a great advance in planning methodology. Its widespread application was based on the importance of the allocation problem combined with low cost of constructing and solving linear models. The model does depend on assumptions such as linearity, independence and divisibility of activities (Hazell, 1971). The technical relationship is usually taken to be both deterministic and static while the solution is implicitly a stationary one. Management may not take the absolute values of the results for all these reasons literally but they do help to clarify the important determinants of success. However, the conventional deterministic model ignores uncertainty, and may lead to a farm plan that is unacceptable. Uncertainties may arise in the linear programming model in forecasted costs, yields, and prices for individual activities; in activity requirements for fixed resources; and in the total fixed constraint levels. These uncertainties may be summarised as uncertainties in gross margins (gross returns net of variable costs) (Hazell, 1971). In the context of whole farm planning under risk, LP may be used to maximise expected profit subject to the farm resource constraints and other restrictions.

In many situations it is necessary for management to investigate the behaviour of systems over time and to evaluate risk. A common variant of LP is the technique of Dynamic Linear Programming.

2.6.3.2 Dynamic Linear Programming

According to Barnard and Nix (1979) Dynamic Linear Programming (DLP) use exactly the same methodology in calculating as used in LP technique with the only exception that more than one time period is used in the model. This specific period can be of any length and do not have to be the same over the whole planning period. Burt (1982) see dynamic programming is one of the most versatile methods of linear programming for long-term planning and its applicability comes best to word in whole farm planning. Nowers (1990) used DLP for an economic evaluation of restructuring possibilities in the Swartland.

In the literature DLP is also referred to as multi period planning, dynamic optimisation, and multi stage planning. The difference between static and dynamic DLP is that all the coefficients in static linear programming refer to a single period, while the latter refers the resource restrictions, activities and output-input coefficients all to a specific period within the planning horizon.

Anderson (1972) defined two types of DLP techniques:

a) Recursive LP where a LP problem is determined for one single period. The outcome is then used, in terms of the availability of resources to calculate the next period. The same process will then repeat it to determine the following periods.

b) Multi period linear programming (MPL) is where more than one production period is been muddled and determined at the same time.

The disadvantage of the first method is that decision is taken independently from the following periods. In the latter method (MLP) all the consequences of an activity over the whole planning period are taken into consideration before the activity is chosen.

A detailed discussion of Dynamic Linear Programming can be found in Louw (1996). Lombard and Smit (1996) used a dynamic linear programming-planning model for mixed livestock-pasture-grain farms.

2.6.3.3 Dynamic Programming

Kennedy (1981) has done a thorough literature study on dynamic programming (DP) as an optimal solution in agriculture planning. He pointed out that dynamic programming is not a programming algorithm for solving a specific type of problem, but rather an approach to solving a multi stage decision problem by converting it to a problem requiring the solution of sequential single-period problems. DP is a technique ideally suited for the use in finding the optimal sequencing of injection of inputs and harvesting of outputs in many types of agriculture production.

2.6.3.4 Quadratic Risk Programming

Quadratic Risk Programming (QRP) can be used to generate a set of farm plans lying on the *E, V* efficient frontier (Freund 1956). The expected income-variance *(E-V)* criterion of quadratic programming assumes that a farmer holds preferences among alternative farm plans solely on the basis of their expected income *(E)* and associated variance *(V)*. Quadratic programming further assumes that the iso-utility curves are convex, or that the farmer is a risk averter. That is, the farmer will choose a higher variance only if the expected income were also greater along every iso-utility curve. The purpose of quadratic programming is to develop a set of feasible farm plans where the variance *(V)* is a minimum for associated expected income level (*E*). Such plans are called efficient *E-V* pairs and define an efficient boundary over the set of all feasible farm plans (segment *OQ* in Figure 2.1).

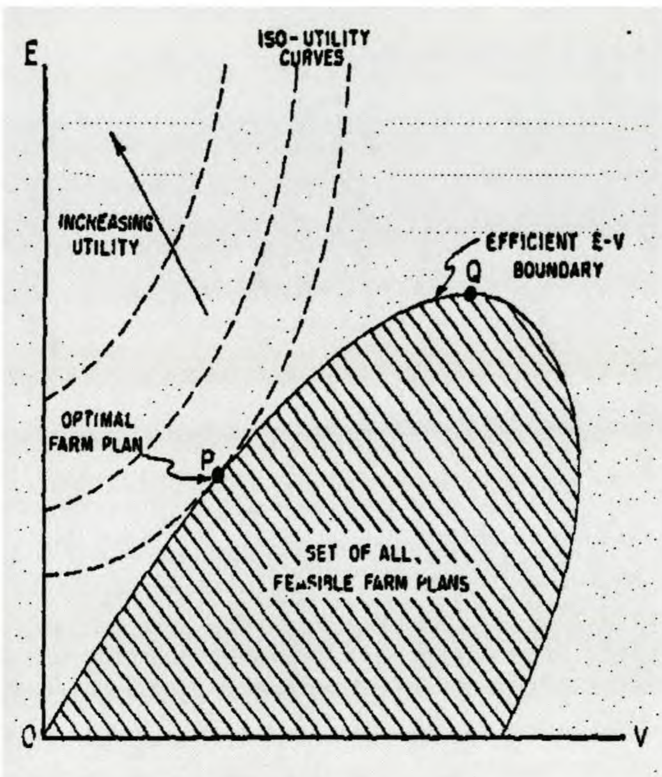

Figure 2.1: The optimal (*E*- *V*) farm plan
Source: Hazell, 1971:54

Given a set of efficient farm plans the acceptability of any particular one to an individual farmer will depend on his preferences among various expected income and associated variance levels as described by the *E-V*- utility function. When this function can be measured, a unique farm plan can be identified, which offers the farmers highest utility. This is the efficient farm plan *P* in Figure 2.1.

This technique also tries to take account of risk, resulting from conditions of uncertainty. However, only variations in gross margin, due to fluctuations in yield and price, are considered and are assumed to follow a normal distribution. Data requirements are still very demanding because, not only is it necessary to estimate the variance of each activity's gross margin, it is also essential to estimate the covariance in gross margin for each pair of activities (Sprecher, 1978).

Quadratic utility function is characterised by increasing absolute risk aversion and has been rejected as invalid by many theorists. Yet there is little evidence that to suggest that farm income is normally distributed, so Freud's *E-V* model may be of limited use. On the other hand the computational advantages of the *E-V* model must compensate against these difficulties (Hazell, 1982).

An alternative for quadratic programming, when computer programming codes were less available and less reliable, attempts to find *LP* approximations to the QRP formulation were made. MOTAD[5] programming, developed by Hazell (1971) is the most widely used of these attempts.

2.6.3.5 MOTAD programming

In MOTAD programming the variance constraint of QRP is replaced with a constraint on the mean absolute deviation of net income. The advantage of this model is that it can be solved on conventional linear programming codes and provide a set of farm plans that are efficient for expected income and mean absolute income deviation.

The MOTAD formulation generates the expected income and mean (*E-M)* efficient frontier that approximates the (*E-V)* frontier but, as the latter is generally not stochastically efficient, the (*E-M)* frontier is slightly less likely to contain the utility-maximising solution for the farmer. Hazell (1971) concluded that it seems reasonable that the MOTAD model may have potential as an alternative computational procedure to quadratic programming in deriving efficient *E-V* farm plans, particularly when an adequate quadratic programming code is not available. MOTAD can, however, not rigorously be justified as a substitute for quadratic programming in deriving efficient (*E-V)* frontiers.

The advantages of linear risk programming models over non-linear ones were important in the past when reliable non-linear computer codes were less widely available. The ease of the LP formulation explains the wide popularity of MOTAD, despite its

[5] *Since the model is minimising mean absolute income deviation it will be referred to hereafter as MOTAD.*

theoretical limitations (Hardaker *et al*., 1997). While still retaining the advantages of LP, attempts were made to overcome these limitations.

Target MOTAD programming, as developed by Tauer (1983) is one such modification. Target MOTAD as a model is proposed for computing stochastically efficient mixtures of risky alternatives. The Target MOTAD model realise a set of farm plans for the decision-maker to choose a plan with the highest utility. That will be the plan that fit the best with the decision-makers personal risk preferences and circumstances (McFarquar, 1961). Target MOTAD is related to MOTAD in that it entails a constraint on income deviations, but this time it is from a target level of income.

Stochastic dominance according to functions is a powerful analytical instrument (King and Robison, 1981). The main advantage is that is that the solutions of the target MOTAD are second-degree stochastic dominant (SSD) (Mcamley and Kliebenstein, 1987; Tauer, 1983; Mcamley and Kliebenstein, 1986). Hadar and Russel (1969) introduced SSD analysis, enabling preference ordering of uncertain prospects under the assumption that the utility function is risk-averse (concave), and so efficient for risk-avers decision makers. Tauer (1983) speculated that all efficient SSD solutions could be obtained by computing the solutions associated with the possible target return levels.

The disadvantage of Target MOTAD is that there is usually no good reason to set any particular value of the target income, *t*. That means that the model usually is solved maximising E for a relatively large number of combinations of *t* and *d*, making the results infinite.

The *Mean–Gini programming*, is another linear risk programming method constructed by Okenev and Dillon (1988) that also has the advantage of generating efficient solution sets that are always stochastically efficient.

2.6.3.6 Utility-efficient programming

In an uncertain environment, theory suggests that a decision-maker will choose among alternatives with outcomes expressed by probability distributions so as to maximise expected utility (Arrow and Dillon in Barry and Fraser, 1976). The utility-maximising choice rests on the decision maker's strength of belief, on the relevant characteristics (mean, variance, *etc.*) of the expected probability distributions, and the farmer's personal valuation of the potential outcomes.

According to Barry and Fraser (1976) farmers behave in a risk-averse way because of the riskiness of agriculture. That risk-averse behaviour results when the decision-maker reveal diminishing marginal utility for increases in expected wealth. This feature of economic theory implies that the disutility of losses outweighs the utility of gains and losses are of equal magnitude and likelihood. Hence a risk-averter will value a risky alternative at less than its expected monetary value. It effect the difference between the expected monetary value and risk averter's value is a risk premium or cost of risk bearing required to convert the risky expectation into one that is certain. The greater the aversion is to risk, the higher is the risk premium. Moreover, the levels of risk aversion, and therefore the size of risk premium, are assumed responsive to changing wealth, experience, age and other relevant factors.

Neglect of risk-averse behaviour in agriculture models can lead to important overstatements of the output levels of risky enterprises, to overly specialised cropping patterns, and to bias estimates of the supply elasticties of individual commodities.

According to Hardaker *et al.* (1988) there has been no completely satisfactory method of finding the utility-maximisation farm plan from among a set of possible risky farm plans. The reason is that the utility function of the farmer must be known in order to determine the optimal farm plan. However, to find this utility function from farmers are difficult and the difficulties are intensified when general recommendations are being formulated for many farmers.

2.6.3.7 Stochastic programming

Stochastic efficient analysis is used as a method to identify a set of efficient plans from which a farmer can choose. The efficient set should contain all farm plans that farmers could prefer if they have utility functions belonging to some specified class and there should be no farm plan outside the identified set that would give such a farmer a higher expected utility. While methods of stochastic efficiency analysis have been developed, their effective use in whole farm planning has been limited Hardaker *et al.* (1988).

2.7 Conclusion

In this chapter risk and risk in agriculture have been discussed. The need to take account of risk in agriculture must be part of every decision take in agriculture. Yet risk is nothing to be too afraid of. Risk is a choice rather than a fate. The action we dare to take, which depends on how free we are to make choices, are what the theory of risk is al about. The task is rather to manage risk effectively within the capacity of the farmer, business or group to withstand adverse outcomes. There exist different ways how to manage risk in agriculture. Effective diversification over several types of assets and business enterprises is an example. Some methods of managing risks are feasible for all types of farms. Other is only feasible for certain sizes and types of farms. The methods can be categorised in terms of production, marketing, and financial organisations of farm businesses.

Several methods exist for incorporating risk behaviour in farm and sector planning models. These models all have advantages and disadvantages. No one model or approach to risk analysis is best at farm level. The appropriate model depends on the specific problem, objectives of research, data availability, and cost and computational considerations.

CHAPTER 3

PORTFOLIO CONSTRUCTION AND MANAGEMENT

3.1 Introduction

A logical starting point in portfolio management is the analysis of an investor's financial circumstances, goals, needs, and aversion to risk. The reason for such an analysis is that investors differ in financial requirements and preferences. As a consequence to this, portfolio shares needs to be constructed to produce a probable performance that satisfies the requirements or preferences of each investor. Underlying the portfolio approach to decision-making is the argument that in combining a number of shares in a portfolio, some degree of income stabilisation can be achieved, without weakening the expected profit. Diversification cannot, however, completely eliminate risk, and the investor should accept a certain amount of income fluctuation. As discussed in Chapter 2, the diversification strategies that are most commonly practised in the financial markets are naïve and efficient diversification. Naïve diversification is where a portfolio is constructed with equal proportions invested in each asset, and not divided proportionally between assets. This results into portfolios where risk is not minimised for the level of return, i.e. inefficient portfolios. Efficient diversification, on the other hand, comprises the construction of an efficient frontier where a minimum level of risk exists for each level of return. From the efficient frontier a portfolio is selected, based on the investors preference to risk.

Different methods exist in literature to determine the efficient frontier of a portfolio. In this chapter the Modern Portfolio Theory (MPT) explores how risk averse investors construct portfolios in order to optimise market risk against expected returns. The mean variance portfolio (MVC) has been developed by Markowitz to evaluate investments on the basis of their expected return and variance. Investors choose among all possible investments on the basis of their risk (portfolio variance) and return (portfolio return). Out of a universe of risky assets, an efficient frontier of optimal portfolios can be constructed.

An alternative to MVC is the Single Index Model (SIM) that was developed since the estimation of the essential parameters through the full-covariance models becomes extremely time consuming because of the infinite number of possibilities that must be considered. A comparison between the SIM and MVC models will be discussed in Chapter 6.

3.2 Modern Portfolio Theory

When considering investing into asset markets, an investor has to make three decisions:

1) the amount that wants to be invested into the asset market,
2) determine the assets that wants to be invested in,
3) determine the amount that wants to be invested into each selected asset.

Tobin (1966) described a method how to make these decisions and find an optimal portfolio. Such a portfolio

> " is more than a long list of good stocks and bonds. It is a balanced whole, providing the investor with protections and opportunities with respect to a wide range of contingencies. The investor should build toward an integrated portfolio, which best suites his needs."
> (Markowitz, 1959:3).

The objective of portfolio management is therefore to invest in several shares in order to provide the maximum yield and minimise risk that will meet the particular investors' investment goals. Portfolio managers need to maximise return in a specific risk class or preferred risk habit of the investor. For this reason the associated theory is called portfolio selection theory or short portfolio theory.

The process of selecting a portfolio may be divided into two stages. The first stage starts with observation and experience and ends with beliefs about future performances of available securities. The second stage starts with the relevant beliefs of future performances and ends with the choice of portfolio. The portfolio selection theory has been developed by Markowitz (1959) and Tobin (1958, 1966). Although the concepts employed in their theory have much been criticized for capturing the reality only poorly, it had been the starting point for many asset-pricing models and up to date there has been no widely accepted alternative developed.

3.3 Utility analysis

Since John von Neumann and Oscar Morgenstein introduced the subjective expected utility (SEU) hypothesis in 1944, it has become the most popular criterion for modelling decisions under risk[1]. The value and therewith the returns of assets depends on their future cash flows. These future cash flows cannot be predicted with certainty by investors, they are random variables, hence returns are also random variables. Investment decisions therewith have to be made under risk. The objective of most investors is to maximise the utility of wealth. Francis (1976) defines utility as a way of describing the differences in individual preferences. Thus, if an investor is faced with a decision, the expected utility with every investment should be calculated. The alternative with the highest expected utility is the preferred option. In view of obvious uncertainties, where the rate of return is random variables, the investor must act in such a way as to maximise expected utility.

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[1] *For more information on the SEU hypothesis, see Hardaker (1997:86).*

Expected utility of a portfolio is a numerical value assigned to the probability distribution associated with a particular portfolio's rate of return. Utilities are then assigned to each possible rate of return. The numerical value is calculated by taking the weighted average of the utilities of the various possible returns. The weights are the probabilities of occurrence associated with each of these possible returns (Francis and Alexander, 1976).

$$E_u(X) = \Sigma p_i U_i \qquad (3.1)$$

where

E_u = expected utility
p_i = probability of i^{th} outcome
U_i = utility of i^{th} outcome

Where the probability function is a discrete distribution and the notation is defined above. The expected utility model clearly delineates between a decision makers perceptions of the amount of uncertainty involved in their attitude towards additional income. The amount of uncertainty is reflected by the decision maker's expectations. The amount of uncertainty and other characteristics associated with the action choices are valued by the decision makers according to their unique attitudes.

According to Harrington (1983) and Hardaker *et al.* (1997) there exist three forms of utility functions (see Figure 3.1). Firstly, a diminishing marginal utility for wealth, which means that each increment of wealth is enjoyed less than the last, because each increment is less important in satisfying the basic needs and desires of the individual. Such an investor prefers more wealth to less wealth and prefers less risk to more risk. These investors will maximise the expected utility from their risk class, or conversely, the minimum risk at any particular level of expected return.

The second utility function describes a risk neutral investor who would find each increment of wealth equally attractive. Each increment would have the same utility.

The third utility function is that of an investor with a preference for risk. This person would have an increasingly positive marginal utility of wealth. The description the investor would have in mind would be risk seeking (risk taker).

From many empirical investigations it is known that individuals are risk averse, where the degree of risk aversion differs widely between individuals (Elton and Gruber, 1995). The degree of risk aversion will vary from individual to individual, simply because some are willing to accept more risk than others (Sprecher, 1987).

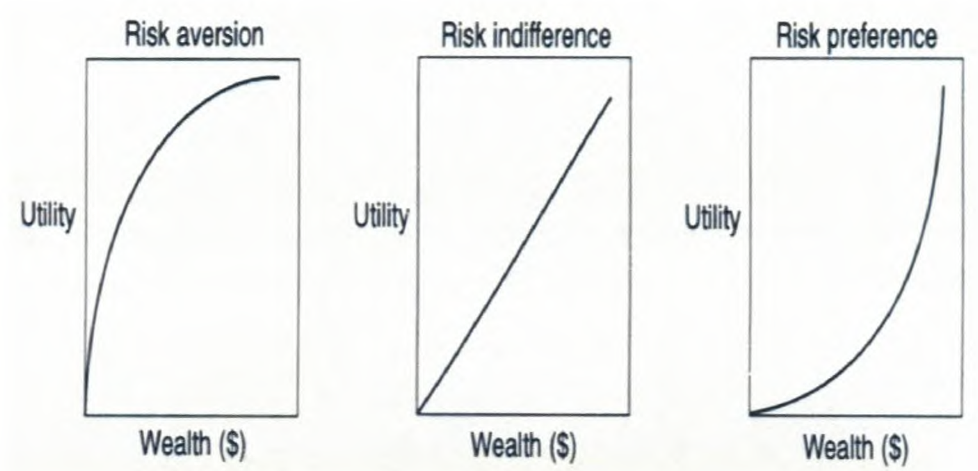

Figure 3.1: Risk attitudes and the shape of the utility function
Source: Hardaker *et al.*,1997:97

3.4 The Mean-Variance (E-V) criterion

As far back as the eighteen century, decisions under conditions of uncertainty could not be made solely on the basis of expected (mean) returns (Levy and Sarnat, 1984). The mean-variance (E-V) criterion is the most popular criterion in finance. The reason is that it is easy to apply and has some accurate properties in terms of moments of a distribution.

The basis of the moment method is usually, but not always, a Taylor series expansion of the utility function. The value of a function *U(x)* can be approximated in the region of a given value of *x*, such as the mean, E[x] = E, by the expansion:

$$U(x) = U(E) + U^{(1)}(E)\,(x-E) + U^{(2)}(E)\,(x-E)^2/2! + U^{(3)}(E)\,(x-E)^3/3! + \ldots \qquad (3.2)$$

Where $U^{(k)}(.)$ is the k-th derivative of the function U(.) and n! is factorial n, i.e., n(n-1) (n-2) ...(1). Taking expectations and simplifying gives:

$$U(x) = U(E) + U^{(2)}(E)\,M_2[x]/2! + U^{(3)}(E)\,M_3[x]/3! + \ldots \qquad (3.3)$$

Where $M_k[x]$ is the k-th moment of the distribution of x about the mean. Provide $U^{(k)}(.)/k!$ becomes small more quickly than $M_k[x]$ gets big, a series with only the first two or three terms may be adequate approximation. In the case where the distribution of x is normal, $M_3[x] = 0$. Moreover, because the normal distribution is completely specified by the mean and the variance, decision analysis using only two moments can be exact.

The mean-variance (E-V) criterion is also used in the basic works on portfolio selection by Markowitz (1959), Tobin (1958, 1966). Consequently, theories based on their work, like the Capital Asset Pricing Model (CAPM), also apply the mean-variance criterion, which by this measure became the most widely used criterion in finance (see Chapter 4). E-V has the advantage that only two moments of the distribution of outcomes, mean and variance have to be determined, whereas other criteria make use of the whole distribution (Levy *et al.*, 1972). The outcome is characterized by its expected value, the mean, and its risk, measured by the variance of outcomes.

In applying the portfolio theory to determine the optimal portfolio several problems are faced:

1) determination of the risk aversion of the investor,
2) determination of the expected returns, variances and covariances of the assets,
3) computation of the efficient frontier and the optimal portfolio.

One of the main critics of the mean-variance criterion starts with the assumption that risk can be measured by the variance. Many empirical investigations have shown that the variance is not an appropriate measure of risk. Many other risk measures have been proposed in literature. These measures have the disadvantage of being less easily computable and difficult to implement as a criterion. In more recent models higher moments, such as skewness and kurtosis are also incorporated to cover the distribution in more detail. The transformation into a quantitative measure is an unsolved, but for the determination of the optimal portfolio, critical problem.

When having solved the above-mentioned problems, the portfolio theory does allow to answer the questions raised at the beginning of this section:

1) the proportion to be invested into risky assets is determined by the optimal portfolio,
2) the assets to invest in are those included in the optimal risky portfolio,
3) the proportion to invest in each selected asset are given by the weights of the optimal risky portfolio.

A shortcoming of the portfolio theory is that it is a static model. It determines the optimal portfolio at a given date. If the time horizon is longer than one period, the prices of assets change over time, and therewith the weights of the assets in the initial portfolio change. Even if the expected returns, variances and covariances do not change, this requires to rebalance the portfolio in every period. As assets with a high-realized return enlarge their weight, they have partially to be sold to buy assets that have a low return (sell the winners, buy the losers). In a dynamic model other strategies have been shown to achieve a higher expected utility for investors, but due to the static nature of the model such strategies cannot be included in this framework.

3.5 Portfolio construction

3.5.1 Portfolio risk

Modern Portfolio Theory provides a broad context for understanding the interactions of risk and reward. It has profoundly shaped how institutional portfolios are managed, and motivated the use of passive investment management techniques. In finance, a portfolio consists of several assets, each with an average return, that is, a variance over time in a return (Sharpe, 1970, Brealy and Myers, 1996). The difference between a traditional portfolio choice problem in agriculture and the portfolio choice problem in the capital markets is that capital market investors focus on the contribution that individual securities make to the variance of portfolio returns. In individual assets, risk equals the standard deviation, whereas in a portfolio it is the combined product of the correlation between assets and the standard deviation. The number and the proportions that each asset constitutes therein can alter the risk in a portfolio. In agriculture the traditional portfolio choice problem is based on the total variance of the farm plan relative to the expected returns. The contribution that each farm activity makes to the variance of the portfolio has largely been ignored (Turvey *et al.,* 1987). The higher the risk of each asset (crop), the higher is the risk of the portfolio. However, the risk of the portfolio is also affected by the covariance between the assets. Negative or even low positive correlations between assets reduce the risk of the portfolio (Bearly and Myers, 1996). Thus, the overall risk of the portfolio is the result of the risks of the assets and the correlations between the assets. The organisation can likewise be seen as a portfolio in that it contain several assets with certain returns, risk, and correlations that interact to produce overall organisational return and risk. To understand the construction of a portfolio, it is necessary to define the important elements that are used to mould a portfolio.

The total risk or standard deviation (σ) of a portfolio can be decomposed into two parts, systematic risk and non-systematic risk. One is the risk of being in the market, which Sharpe (1964) called systematic risk. This risk, later (see Chapter 4) referred to as "Beta", cannot be diversified away. Barry *et al.* (2000) defined this systematic risk for farmers as: production and yield risk; market and price risk; losses from severe casualties and disasters; social and legal risk from changes in tax laws, government programs, trade agreements; human risk on performance of labour and management; and risk of technological change. Systematic variability of returns is found in nearly all securities in varying degrees because most securities move together in a systematic manner.

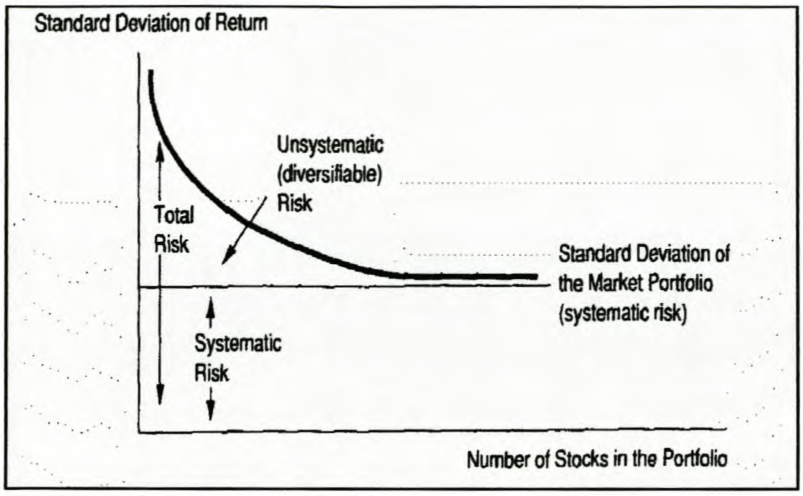

Figure 3.2: The total make up of risk
Source: Ross *et al.*, 1993:381

Non-systematic risk is that portion of total risk that is unique to a firm or industry. Changes such as labour strikes, management errors and shifts in consumer taste cause non-systematic variability of returns in an industry. Non-systematic variations are independent of factors affecting other industries in general (see Chapter 4 for a detailed discussion on systematic and non-systematic risk). Harrington (1983) defined risk as the volatility of security's returns relative to the volatility of the market portfolio's returns. All the other variability can be diversified away by proper portfolio formation (Brealey and Myers, 2000).

One way of measuring the total risk in a portfolio, is to measure the standard deviation of the portfolio return (σ_p), the correlation of the returns of individual assets (r_{ij}), the covariance (σ_{ij}) between shares i and j, the proportion (x) of the portfolio invested in each share and the number (n) of different shares in the portfolio (Hayes and Baumann, 1976). An understanding of the following equation is essential to understand portfolio analysis, and more particularly diversification.

$$\sigma_p = \left[\sum_{i=1} X_i^2 \sigma_i^2 + \sum_{i=1}^{N} \sum_{\substack{i=1 \\ j \neq i}}^{N} X_i X_j \sigma_i \sigma_j \rho_{ij} \right]^{\frac{1}{2}} \quad (\text{if } N = 2) \qquad (3.4)$$

where:

σ = The standard deviation of the portfolio

X_i^2 = proportion of the portfolio invested in a given share i

σ_i^2 = variance of the expected yield of share i

$X_i X_j$ = proportion of the portfolio invested in a given share such as i and j

σ_i, σ_j = standard deviation of the expected yields of shares i and j

N = number of shares in a portfolio

ρ_{ij} = correlation coefficient consisting of assets i and j

The standard deviation (σ) as described for individual shares, cannot by itself serve as the risk index, unless each investor holds only one share in a portfolio. In individual assets, risk equals the standard deviation, whereas in a portfolio it is the combined product of the correlation between assets and the standard deviation. The standard deviation (variance) as an indicator of risk can be misleading. The larger the variance of earning, the larger is the chance that the actual return will deviate significantly from the average or expected return. In some cases the expected profit of the proposal under consideration may be so large that the proposal should be considered relatively safe, even if it has a large variance.

The number and the proportions that each asset constitutes therein can alter the risk in a portfolio. Investors do diversify to some extent, which implies that the true measure of risk lies somewhere between σ and Beta (β), non-diversifiable risk, but properly closer to σ, since investors portfolios are closer to a non-diversified portfolio than to a fully diversified one (Levy and Sarnat, 1982). In agriculture the traditional portfolio choice problem is based on the total variance of the farm plan relative to the expected returns (Turvey *et al.,* 1987).

The *covariance* is the measure in which two stocks "co-varies" and is an indicator of the direction of the dependence between two variables. It is, however, dependent on the unit of measurement, and changes with any change in the unit of measurement (Levy and Sarnat, 1982). If two assets move together their covariance is positive. If two variables are independent, their covariance is zero. If two variables move inversely, their covariance is negative. A share may thus have a very high variance, and may still be considered safe in portfolio context as long as it has negative covariances with other shares included in the portfolio (Levy and Sarnat, 1984).

In Figure 3.3 the returns of two shares show a negative correlation, (*AC*) and (*AD*). The returns move inversely and are plotted against each other over a certain time period. Because each share's return are counterbalanced by the other share's return, the portfolio overall variance (*AB*) is lower than the variance of either share's returns. An investor can thus reduce risk by putting together assets whose returns do not follow similar patterns (Harrington, 1983). Negative or even low positive correlations between assets reduce the risk of the portfolio (Brealey and Myers, 2000). Thus, the overall risk of the portfolio is the result of the assets and the correlation between the assets.

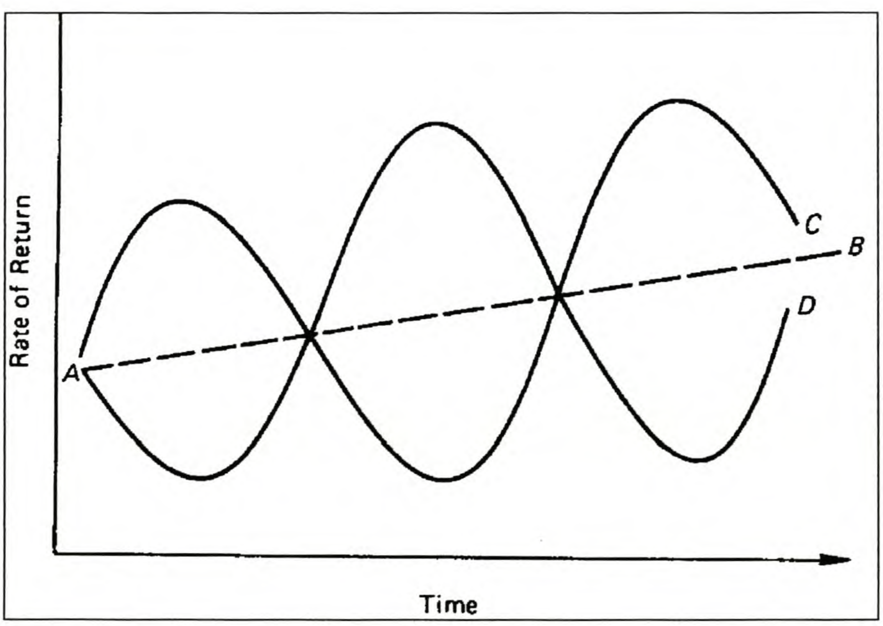

Figure 3.3: Shares with negative correlated returns
Source: Harrington, 1983:8

Mathematically the covariance is defined by Francis (1976) as:

$$\sigma_{ij} = (\sigma_i)(\sigma_j)(r_{ij}) \qquad (3.5)$$

where:

σ_{ij} = covariance of returns between assets i and j

r_{ij} = correlation coefficient between the returns of asset i and j

σ_i, σ_j = standard deviation of assets i and j, respectively.

One way to determine the degree to which the variation in returns of two shares depends on one another, is to measure the *correlation coefficient* (r) of the variance of two returns.

The covariance can be expressed as the product of correlation coefficients r_{ij} and two standard deviations:

Covariance between stocks i and j = $\sigma_{ij} = rij\ \sigma i\ \sigma j$ (3.6)

For most part stocks tend to move together. If the correlation coefficient r_{ij} is positive, the covariance σ_{ij} will also be positive. If the prospects of the stocks where unrelated, both the correlation coefficient and the covariance would be zero and if the stocks tended to move in opposite directions, the correlation coefficient and the covariation would be negative (Brealey and Myers, 2000).

Mathematically the correlation coefficient is defined by Francis and Archer (1971), as:

$$r_{ij} = \frac{\sigma_{ij}}{\sigma_i \sigma_j} \qquad (3.7)$$

where

r_{ij} = correlation coefficient of the variation in return of shares i and j

σ_{ij} = covariance of return between shares i and j

σ_i, σ_j = standard deviations of returns of shares i and j

The coefficient of variation has been advocated as a measurement of risk, because of these shortcomings.

Mathematically it can be defined as:

$$C = \frac{\sigma_i}{E_i} \tag{3.8}$$

where:

C = coefficient of variation of share i

σ_i = standard deviation of share i

E_i = expected return of share i

However, considerable caution must be exercised when using either of these measures to determine risk. Under some circumstances these measures might not provide a clear answer.

An organisation can likewise be seen as a portfolio in that it contains several assets with returns, risks and correlations that interact to produce overall return and risk. If the probability distribution of portfolio returns is normal, then by knowing the means and variances, it is sufficient to make comparisons between competing investments.

Most investors are only able to give a qualitative measure of risk aversion, if at all. However, Hardaker et al. (1997:233-250) described ways to determine risk aversity of investors. The transformation into a quantitative measure is an unsolved, but for the determination of the optimal portfolio, a critical problem. Expected returns, variances and covariance's can be obtained from estimates based on past data. But there is no guarantee that these results are reasonable for the future. To determine the efficient frontier and the optimal portfolio, non-trivial numerical optimisation routines have to be applied.[2] Advances in computer facilities and the availability of these routines do not impose a threat anymore as it has done in former years.

[2] *For a detailed description of the mathematical concepts to solve these problems see Markowitz (1959).*

3.6 Portfolio models

3.6.1 The Markowitz Diversification Model

A model which shows how to make the most of the power of diversification, was developed in the 1950s by Professor Harry Markowitz of the City University of New York, who developed the ingenious approach to investment that has become known as modern portfolio theory (MPT). The systems that he developed examine the performance of a portfolio of assets based on the combination of the risk and return of its components. Markowitz's hypothesis and subsequent work were so revolutionary that he became a joint Nobel Laureate for economics in 1990 (Lattmann, 1996).

Markowitz defined the risk to owning securities as variance, a familiar statistical concept, and rigorously developed the principles governing how portfolio variance or risk is affected by removing individual securities from a portfolio, which is simply a combination of securities (Bodie *et al.,* 1995).

As indicated in Section 3.5.1, the difference between a traditional portfolio choice problem in agriculture and the portfolio choice problem in the capital markets is that capital market investors focus on the contribution that individual securities make to the variance of portfolio returns. In individual assets, risk equals the standard deviation, whereas in a portfolio it is the combined product of the correlation between assets and the standard deviation. In agriculture the traditional portfolio choice problem is based on the total variance of the farm plan relative to the expected returns. The contribution that each farm activity makes to the variance of the portfolio has largely been ignored (Turvey *et al.,* 1987). The Markowitz approach to portfolio construction does not select common shares on the basis of the need for income or appreciation, but rather in terms of risk and return (Sprecher, 1978). Markowitz showed that to avoid diversification was enormously risky and could only be justified economically if financial markets were efficient.

Modern Portfolio Theory (MPT) explores how risk averse investors construct portfolios in order to optimise market risk against expected returns. The mean variance portfolio (MVC) has been developed by Markowitz to evaluate investments on the basis of their expected return and variance. Hardaker *et al.* (1997) defined the mean-variance or efficiency rule as follows:

If the expected value of choice A is greater than or equal to the expected value of choice B, with al least one strict inequality, then A is preferred to B by all decision makers whose preferences meet certain conditions. Investors choose among all possible investments on the basis of their risk (portfolio variance) and return (portfolio return). In theory, all conceivable risky assets and combinations of risky assets could be plot in a diagram in the return-standard deviation space. The word "theory" is used, not because there is a problem in calculating the risk and return on a stock or portfolio, but because there are an infinite number of possibilities that must be considered. To be able to plot all these combinations in a risk return space, Elton and Gruber (1995) argued that some of these infinite combinations must be eliminated to construct the diagram.

Therefore, if an investor prefer more return to less and would prefer less risk to more, with portfolios that offer:

1) a bigger return for the same risk, or
2) a lower risk for the same return

all the portfolios that an investor would consider to hold will be identified. All other portfolios could then be ignored.

3.6.2 Size of portfolio

To derive the statistical estimates of risk, return and the covariance Bodie *et al.* (1995) described the full-covariance model, the market model and multiple index models. However, for the purpose of this study, only the model of Sharpe will be discussed as the portfolio represents the entire investment fund.

The number of shares to be included in the portfolio depends on how efficient the market is, and how many suitable attractive shares are available. Non-systematic risk could be diversified away in an efficient portfolio by employing efficient diversification. Owning a portfolio with the characteristics of what is called the market portfolio could do this.

Elton and Gruber (1995) calculated a cut off rate to determine which stocks are included in the optimal portfolio. The desirability of any stock is directly related to its excess return to Beta ratio. Excess return is the difference between the expected return on the stock and the riskless rate of interest. The numerator of this ranking device is the extra return over riskless asset from holding a security. The dominator is the non-diversifiable risk that investors are subject to by holding a risky security rather than the riskless asset.

The index to rank stocks is:

$$\frac{\overline{R}_i - R_F}{\beta_i} \tag{3.9}$$

If a stock with a particular ratio ($\overline{R}_i$ - R_F)/β_I is included in an optimal portfolio, all stocks with a higher ratio will also be included and stocks with a lower ratio will be excluded.[3]

The objective of portfolio analysis is to define the efficient set of portfolios – that is constructing the efficient frontier. According to Francis (1976) the individual assets in a portfolio consist of weights or participation levels of the assets in the portfolio. The weights of the assets are the variables which portfolio analysis adjusts in order to obtain the optimum portfolio. The weights allocated to each asset are dependent on the return and standard deviation of that asset, as well as the correlation and the covariance of that asset in the portfolio. By varying these weights, the portfolios' expected return and risk are varied, which give rise to the efficient frontier.

[3] *See Collins and Barry (1986:158) for quasi-optimal plans as a solution for negative Betas in a portfolio.*

Individuals are risk averse when they would prefer the portfolio of shares with the highest expected returns for a given level of risk. On the other hand, individuals would prefer portfolios with the lowest risk for a given expected return. Portfolios that meet this criterion are described as efficient portfolios – located on the efficient frontier.

Levy and Sarnat (1982) showed the impact of the number of shares on risk reduction in Figure 3.4. The transformation curve *(I)* of portfolio comprised different proportions of shares *(A)* and (B*)*. Curves *(II)* and *(III)* are the relevant transformation curves for portfolios, which include shares *(B)* and *(C)*, and *(A)* and *(C)* respectively. Curve *(IV)* represents the transformation curves for portfolios, which include all three shares. Curve *(IV)* lies to the left of the other three curves and illustrates that the highest expected return for a given standard deviation can be attained by combining all three shares in different proportions, to the contrast of curves *(I)* and *(III)*.

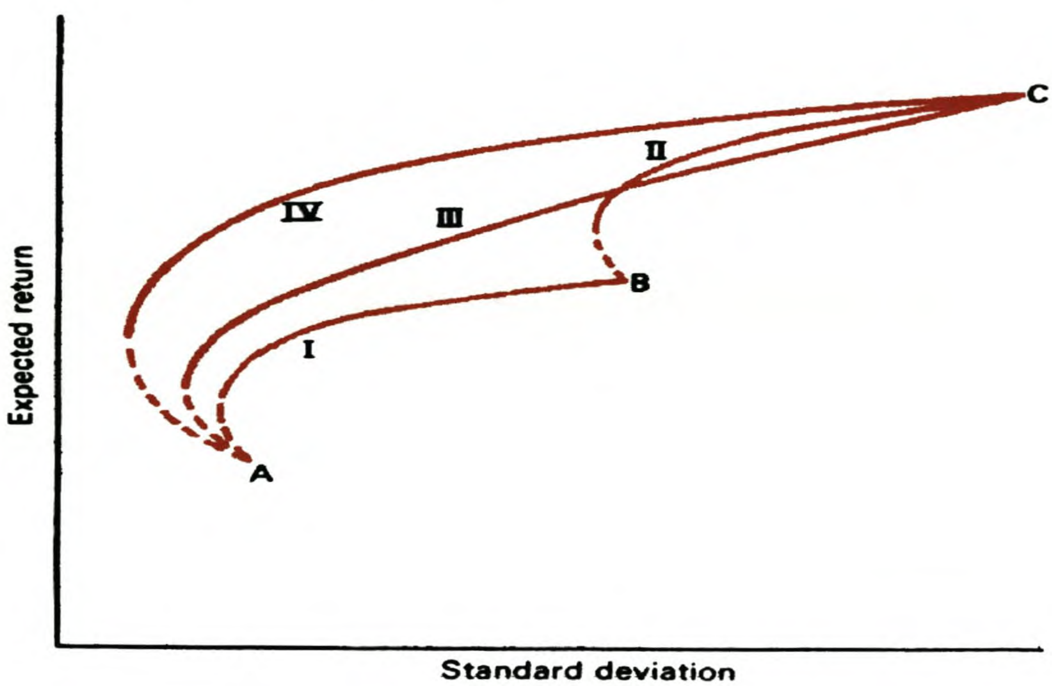

Figure 3.4: Relationship between number of shares and standard deviation of return
Source: Levy and Sarnat, 1982:293

Figure 3.5 illustrates a transformation curve (ACB) that represents pairs of expected return and variance, which result from combining two shares in all possible proportions. This curve has a minimum variance at point (C). All the portfolios (points) on curve (ACB) correspond to the different proportions (weights) in which the amount invested is divided between the shares. Only the solid part of the curve represents efficient portfolios of shares (A) and (B). The dashed segment (AC) is irrelevant, since these portfolios are by definition inefficient because alternatives exist which offer higher expected return for the same level of risk.

The investor's final choice out of the efficient set depends on his/her "taste"(utility). In accordance with the expected utility maxim (Corner and Mayes, 1983; Bodie *et al.,* 1995) the investor will choose that portfolio which permits him/her to reach the highest indifference curve - with highest utility. The optimal portfolio will be at point (D), which lies on indifference curve I_2.

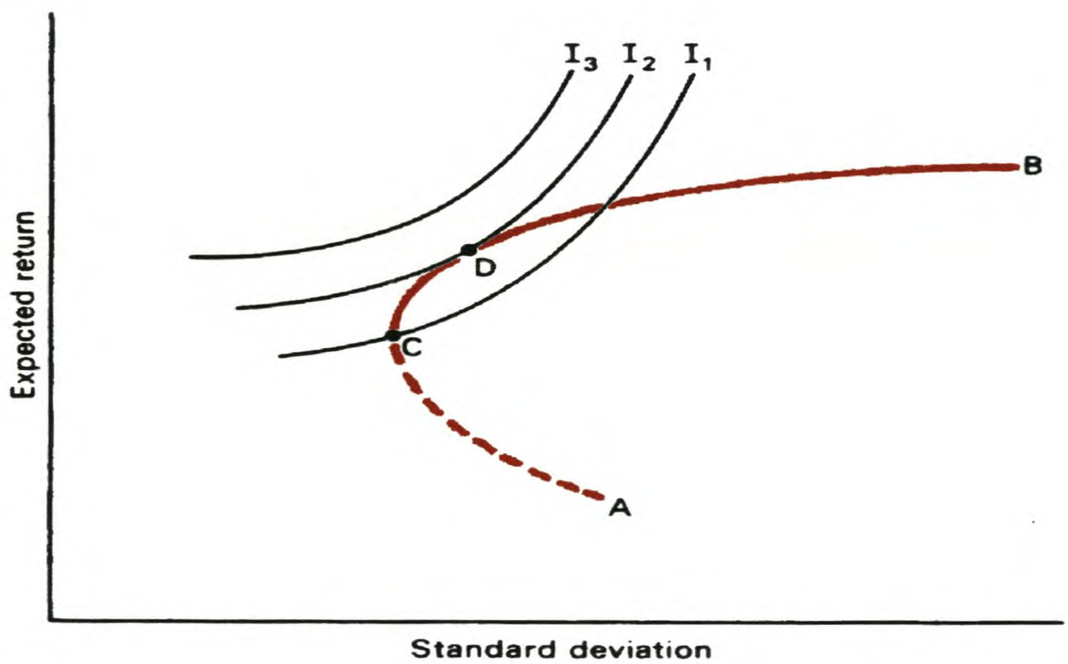

Figure 3.5: Relationship between proportions invested in shares and standard deviation
Source: Levy and Sarnat, 1982:289

According to Alexander and Francis (1986) the expected return of a portfolio is fixed with certain proportions (weights) of shares included in the portfolio. The risk of the portfolio can still be altered with the inclusion of shares that vary in their correlations to one another. Diversification reduces variance, except in an extreme case when the returns are perfectly correlated (R= + 1). The highest benefit of diversification would be obtained if the yields of shares were negatively correlated, or if there was a small degree of correlation among shares in the portfolio. Diversification with the above concepts yields the efficient frontier. Consequently the two characteristics risk and return can be plotted graphically for a group of investments (Corner *et al.,* 1983). The portfolios are made up of all the possible combinations of the individual investment alternatives. Thus, all possible choices are represented on the graph in Figure 3.6.

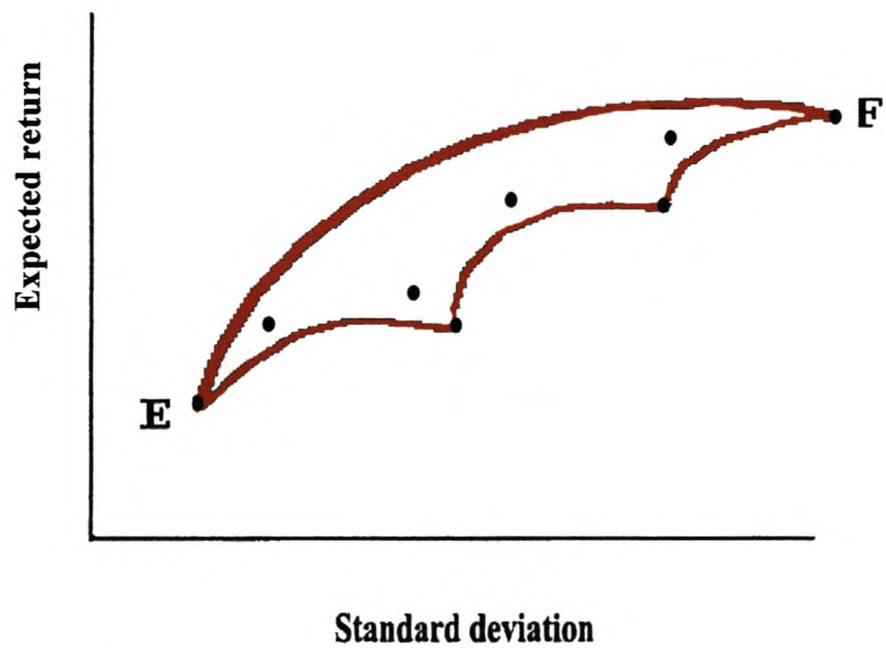

Figure 3.6: Efficiente frontier
Source: Francis, 1976:448

The efficient frontier is illustrated in Figure 3.6. Out of a universe of risky assets, an efficient frontier [4] of optimal portfolios can be constructed to be represented by the quarter-moon-shaped design (Harrington, 1983). Portfolios lying along the upper boundary (EF) dominate all other portfolios and together comprise the efficient set of portfolios, because for these portfolios it is not possible to either obtain a greater expected return without incurring greater risk or obtain smaller risk without decreasing expected return.

Jensen (1969) said, "In a world dominated by risk averse investors, a risky portfolio must be expected to yield higher returns than a less risky portfolio, or it would not be held". Individual assets that lie along the bottom of line (EF) contain both systematic and non-systematic risk

Elton and Gruber (1995) pointed out that to define the efficient frontier the expected return and standard deviation of return on a portfolio must be determined. The expected return on a portfolio is constructed as:

$$\overline{R}_P = \sum_{i=1}^{N} X_i R_i \tag{3.10}$$

where

$\overline{R}_P$ = Expected return on a portfolio

X_i = The proportion of i invested in the portfolio

R_i = Return on asset i

while the standard deviation of return on any portfolio can be written as

$$\sigma_p = \sqrt{\sum_{i=1}^{n} x_i^2 \sigma_i^2 + \sum_{i=1}^{n} \sum_{j=1}^{n} x_i x_j \sigma_{ij}} \tag{3.11}$$

[4] *See Elton and Gruber (1995) for different techniques in calculating the efficient frontier.*

where:

σ_p = The standard deviation of the portfolio

$x_i^2 x_j^2$ = proportion of the portfolio invested in a given asset such as i and j

σ_i^2 =variance of the rate of return for asset i

σ_{ij} = the co-variance of the return between assets i and j, where $\sigma_{ij}= r_{ij}\sigma_i\sigma j$

n = number of asset in a portfolio

These equations define the data necessary to perform portfolio analysis. From equation (3.10) estimates of each security is needed for inclusion in the portfolio. In equation (3.11) estimates of the variances of each security are needed, plus estimates of the correlation between each possible pair of securities for the stocks under consideration. The need for estimates differs both in magnitude. Elton and Gruber (1995) argued that the number of correlation coefficients needed is staggering, and that it seems unlikely that it will be able to directly estimate correlation structures. Their ability to do so is severely limited by the nature of organization structure and the huge number of correlation coefficients that must be estimated. In Section 3.9 the Single Index Model will be discussed as an alternative for the construction of the efficient frontier. In general the efficient frontier will differ among individuals because of differences in expectations (Elton and Gruber, 1995, Harrington, 1983).

3.7 Portfolio adjustment under risk

As indicated earlier the shortcoming of a portfolio is it's static behaviour. Portfolios need to be revised on a continuous basis, even if an investor experiences no change in preference. The reason is that it determines the optimal portfolio at a given date. Cash dividends and interest income increase cash holdings; some assets actual weight decline from their optimal values because of capital losses; some assets experience capital gains which inflates their weights in the portfolio above their optimal values; the risk class of some assets may change and some expected returns may change. The length of the investment horizon of most portfolios is probably less than a year. At the end of this period it is likely that the portfolio will be revised, meaning that certain shares will be sold and others will be bought (Alexander and Francis, 1986).

As described in Section 3.3.1, the mean variance approach is applicable if a decision maker's utility function reflects preferences only towards mean and variance of expected returns or if he regards uncertain outcomes as normally distributed.

For an agricultural firm, the choices in production, marketing and finance generates a portfolio comprised of physical and financial assets. An efficient set of portfolio results from business plans providing minimum variance of expected returns for various levels of returns. An optimal choice among the efficient portfolios provides maximum expected utility. Portfolio adjustments refers to changes in an optimal portfolio that result from changing risk aversion and/or shifts in the efficient set caused by changing expectations on levels of risk, rates of return, or wealth (Robinson and Barry, 1975).

Barry and Fraser (1976) argued that the level of risk aversion is assumed responsive to changing wealth, experience, age and other relevant factors and that the level of absolute risk aversion generally decreases as wealth increases, although the wealth responses of relative risk aversion have been less clear.

The expectations of increasing price variability of agricultural products imply a shifting set of efficient portfolios for the producer that yield lower levels of expected return for the same level of risk carried prior to the increase. Hence, a reversed optimal portfolio for a producer with constant absolute risk aversion will yield lower expected returns, risk and growth. Even more averse effects will occur for producers characterized by aversion to risk that increases as expected wealth declines.

Several factors make it difficult for producers to directly bear these risks of portfolio adjustments. Low price and income elasticity's for many commodities make subject to weather and other uncontrollable events provide an inherent setting for relatively wide price fluctuations.

According to Barry and Fraser (1976) the response to these risks may include the opportunity for transferring risk to other economic units more willing and/or better able to bear the risks through their wealth, their ability to pool risk over numerous and diverse activities, or their ability to spread risks over numerous claimants.

3.8 Performance evaluation

In assessing the performance of a portfolio, it is necessary to consider both risk and return of a portfolio. There exist various definitions for the rate of return in capital markets. For investment decisions the investor is primarily concerned with the rate at which wealth or value increases. The market rate of return is appropriate for this measurement and can be calculated as follows:

$$r_i = \frac{[(P_i - P_o) + D_i]}{P_o} \tag{3.12}$$

where

r_i = return on share i

P_o = price at the beginning of some period

P_i = price at the end of some period

D_i = dividends of some period

(Francis and Archer, 1971).

The historic performance of a portfolio can be measured by the average return over the period under evaluation. Two techniques are used for calculating average returns. Simple (arithmetic) averages, and compound (geometric) averages.

$$\text{Arithmetic mean} = \frac{1}{n}\sum_{t}^{n} r_t \tag{3.13}$$

$$\text{Geometric mean} = \sqrt[n]{(1+r_1)(1+r_2)\ldots(1+r_n)-1} \tag{3.14}$$

where

r_t = return

n = the period involved

r_n= returns in period n

If investors evaluate investments as if the proceeds are to be reinvested, then the geometric return is the appropriate method. However, if returns were viewed as a single holding period's return, then arithmetic averages would be the ideal choice.

Copeland *et al*. (1996) used a geometric mean of rates of return because arithmetic averages are biased by the measurement period. Three issues should be resolved: Should a more recent, but shorter, time frame be used? Should the geometric or the arithmetic average be chosen? Should the forecasted risk premium be based on historical estimates or analysts' forecasts?

An arithmetic average estimates the rates of return by taking a simple average of the single period rates of return. On the other hand, the geometric average represents a better estimate of investors' expected returns over longer periods of time. By calculating the market risk premium, the premium can vary significantly depending on the time frame chosen and the type of average[5]. The difference between the arithmetic and the geometric averages is that arithmetic averages infers expected returns by assuming independence, and the latter treats the observed historical path as single best estimate of the future. It is important to note that the arithmetic return is always higher than the geometric return and become greater as a function of the variance of return. Arithmetic averages depend on the interval chosen. An average of monthly returns will be higher than an average of annual returns. Though, the geometric average, being a single estimate for the entire time interval, is invariant to the choice of interval. When moving from a single asset in isolation to evaluating a portfolio, some factors change.

[5] *See Copeland et al. (1994).*

By ranking only portfolios average returns ignores the skill with which they minimise risk, and is therefore an oversimplified performance measure. With this ranking, an efficient low-risk portfolio may appear doing poorly. The real need is for an index of portfolio performance, which is determined by both the return and the risk of a portfolio (Francis, 1976).

The three most commonly described models that consider both risk and return are Sharpe's reward-to-variability ratio, Treynor's reward-to-variability ratio, and Jensen's differential return measure. The appropriate performance measure depends on the role of the portfolio to be evaluated. The Sharpe measure is most appropriate when the portfolio represents the entire investment fund. The Treynor measure or Jenson measure is appropriate when the portfolio is to be mixed with several other assets, allowing for diversification of non-systematic risk outside of the portfolio. For the purpose of this study, only the model of Sharpe will be discussed the portfolio only represents investments within the agricultural sector and diversification in the real-estate or capital markets are not applicable in this study.

$$S_p = \frac{\bar{r}_p - \bar{R}_f}{\sigma_p} = \frac{reward}{totalrisk} = \frac{riskpremium}{\sigma} \qquad (3.15)$$

where

S_p = ratio of reward per unit of variability (Sharpe index)

$\bar{r}_p$ = net average return of portfolio

$\bar{R}_p$ = estimate of risk-free return

σ_P = standard deviation of portfolio return

(Alexander and Francis, 1986).

The fact that portfolios have different average returns or risk does not disqualify a direct comparison of the index of portfolio performance. Portfolio revision should be done not only because of a change in the weights of assets (due to a change in risk and return), but also because of change in investors' needs, goals and risk preferences.

Therefore, in order to construct the optimal portfolio, the mathematical properties of the mean-variance efficient frontier were established by deriving a method of solving the optimum portfolio at each riskless interest rate. In the next section the Single Index Model, an alternative model for constructing the optimal portfolio is discussed.

3.9 The Single Index Model

The Single Index Model (SIM) was developed because the estimation of the essential parameters through the full-covariance models becomes extremely time consuming in tracing the efficient frontier as the number of shares is increased (Levy and Sarnat, 1983). In order for investors to choose the optimal portfolio the SIM is one of the oldest and most widely used models to simplify the amount and the type of data in the portfolio structure (Bodie *et al.*, 1995). The single index portfolio model (Sharpe, 1963) is a simplified version of the Markowitz model of portfolio choice. The SIM provides a measure of risk for an individual activity of a multi-product firm that directly accounts for the variance and the covariances and closely approximates a full variance-covariance matrix. When this model is used in portfolio analyses to derive risk efficient sets of decision choices, the single index model offers a computationally efficient way to use quadratic programming that accounts for a full constraint set and for the covariance relationships among the decision choices. This model requires much less computer capacity than the traditional risk programming approaches and is a feasible model for personal computers.

The basic idea underlying this model is that stock prices normally go up and down together with some common factor. These factors can be political, economical or even international. Thus the rate on return on stock *i* is related to some common index I by a linear equation of the form:

$$R_{it} = \alpha_i + \beta_i I_i + u_{it} \qquad (3.16)$$

where

R_{it} = the rate on return on stock *i* in period *t*

α_i = the component of the return of stock *i* which is independent of the index *I*

I_t = the value of the index for period *t*

β_i = a measure of the average change in R_i as a result of a given change in the index *I*

u_{it} = a deviation of the actual observed return from the straight line $\alpha_i + B_i I_t$ (it is the error term with variance σ_{ui}^2)

The parameters α_i and β_i are constant. while u_{it} and I_t are random variables.

According to Levy and Sarnat (1984) the SIM can be derived from a diversity of indexes and that there exist no consistent theoretical set of assumptions from which the SIM is derived. The index *I* generally used for this model is the rate of return on the R_m. According to Sharpe (Barry and Collins, 1986) the R_m variable should be "…any factor thought to be the most important single influence on returns…" In finance, many of the available market indices and gross national product (GNP) have been used as proxies for R_m. For agriculture activities, assume that a region of homogeneous land has *N* crop production activities with expected returns r_i *(i =1, ..., N)* to risk, management and capital. Further assume that the variable R_m is a generalized *measure* of the regions' income. The annual value of R_m will depend upon the regions growing conditions (weather, disease, etc.) and prices for the resources and products. A crop with a β_1 = 1 on average would experience the same systematic volatility as the average of all crops – it will follow the market. For the purpose of this study the R_m consist of different agricultural enterprises in the Paarl/Berg River region (see Chapter 6). Ignoring the time subscript *t* when no confusion can arise and using the return on the market portfolio R_m as the index *I*, the rates of return can be written as:

$$R_i = \alpha_i + \beta_i R_m + u_i \text{ for stock/enterprise i} \qquad (3.17)$$

$$R_i = \alpha_i + \beta_j R_m + u_j \text{ for stock/enterprise j} \qquad (3.18)$$

The major assumption of Sharpe's single-index model is that all the co-variation of security returns can be explained by a single factor. This factor is called the index, hence the name "single-index".

The crucial assumption of the SIM is that for every pair of enterprises (*i .j*) the error terms are uncorrelated, i.e. $Cov\ (u_i, u_j) = 0$. This assumption dramatically reduces the number of parameters that have to be estimated for the portfolio construction problem. To summarize the basic assumptions of the model:

1) The generating process of returns is described by equation (3.15),
2) The error term is on the average zero for every stock *i,* i.e., $Eu=0$,
3) The error term is uncorrelated with the market portfolio,
4) The most crucial assumption of the model is that the error terms of enterprises *i* and *j* are uncorrelated. (Levy and Sarnat, 1984).

Therefore the only reason that stocks systematically vary together is because of a common co-movement with the market.[6]

In the study by Greyling and Laubcher (1990) the SIM was used to quantify the systematic and non-systematic risk of maize production in the Free State. In the study by Barry and Collins (1986) the single index model was used to determine the concepts of systematic and non-systematic risk as a risk measure in farm planning models.

Other approaches that describe and explain the correlation structure of security returns exists and are widely used in finance. What is surprising is the ability of simple models like the single index model to outperform more complex models in simple tests. Although

[6] *For a detailed description of the derivation of the Single-index model see Elton and Gruber (1995:132).*

complex models better describe the historical correlation, they often contain more noise than information with respect to prediction. The use of these simple models, as pointed out, is to cut down on the number of inputs and simplify the nature of the inputs needed to perform portfolio analysis and increase the accuracy with which correlations and covariance can be forecast. Another advantage is that they allow the development for a system to computing the composition of optimal portfolios. Estimating of the SIM parameters in practice will be discussed and compared with the Markowitz portfolio selection model in Chapter 6.

3.10 Conclusion

When an investor considering investing into asset markets, three decisions must be made:

1) The amount that wants to be invested into the asset market,
2) Determine the assets that wants to invested in,
3) Determine the amount that wants to be invested into each selected asset.

The utility analysis is used to make decisions under risk. There exist three forms of utility functions namely risk avers, risk seeking and risk neutral. For this study it is assumed that all the investors are risk averse. Such an investor prefers more wealth to less wealth and prefers less risk to more risk.

The (E-V) criterion is used in practice for basing decisions on the expected utility concept and to determine the optimal portfolio. A portfolio needs to be constructed towards a specific target group that will serve their goals, needs and attitudes towards risk. One way of measuring the total risk in a portfolio is to measure the standard deviation of the portfolio return (σ_p), the correlation of the returns of individual shares (r_{ij}), the covariance (σ_{ij}) between shares i and j, the proportion (x) of the portfolio invested in each share and the number (n) of different shares in the portfolio.

Different methods exist in literature to determine the efficient frontier of a portfolio. Modern Portfolio Theory (MPT) explores how risk averse investors construct portfolios in order to optimise market risk against expected returns. The mean variance portfolio (MVC) had been developed by Markowitz to evaluate investments on the basis of their expected return and variance. Investors choose among all possible investments on the basis of their risk (portfolio variance) and return (portfolio return). Out of a universe of risky assets, an efficient frontier of optimal portfolios can be constructed. Portfolios lying along the efficient frontier dominate all other portfolios and together comprise the efficient set of portfolios, because for these portfolios it is not possible to either obtain a greater expected return without incurring greater risk or obtain smaller risk without decreasing expected return.

An alternative to Markowitz MVC is the Single Index Model that was developed because the estimation of the essential parameters through the full-covariance models becomes extremely time consuming because there are an infinite number of possibilities that must be considered.

The number of shares to be included in the portfolio depends on how efficient the market is, and how many suitable attractive shares are available. A cut-off rate can be calculated to determine which stocks should be included in the optimal portfolio. Each asset consists of a weight. The weights allocated to each asset are dependent on the return and standard deviation of that asset, as well as the correlation and the covariance of that asset in the portfolio. By varying these weights, the portfolios' expected return and risk are varied, which give rise to the efficient frontier.

In the next chapter all the micro foundations of portfolio analysis have been aggregated to a market level in the equilibrium capital asset pricing model (CAPM). This model will allow an investor to determine the relevant measure of risk for any asset and the relationship between expected return and risk for any asset when markets are in equilibrium. The total risk or standard deviation of a portfolio will be decomposed into two parts, namely systematic risk and non-systematic risk.

CHAPTER 4

THE CAPITAL ASSET PRICING MODEL AS AN ALTERNATIVE DECISION FRAMEWORK IN FARM MANAGEMENT

" If you look into the seeds of time, and say which seeds will grow and which will not, speak then to me..."Shakespeare – Mac Beth

4.1 Introduction

In essence, this chapter spells out a normative theory of investment behaviour for a variety of assumptions regarding investors' utility functions (tastes and preferences) and sets out the optimal patterns of investment choice. Following the portfolio theory, the capital market theory extends portfolio theory and develops a model for pricing all risky assets.

Chapter 4 begins with the background of the capital market theory that includes the underlying assumptions of the theory and a discussion of the factors that led to its development following by the Markowitz portfolio. Principal among these factors was the analysis of the effect of assuming the existence of a risk-free asset. This is the subject of the next section.

The existence of a risk-free rate has significant implications for the potential return and risk and alternative risk-return combinations. A central portfolio of risky assets on the efficient frontier is constructed which is called the market portfolio.

A stock's contribution to the risk of a fully diversified portfolio depends on its sensitivity to market changes. The systematic risk of an asset is that part of an asset's price change that has some degree of sensitivity or responsiveness to broad market forces. This sensitivity is generally known as Beta *(β)*. The limitations of the Capital Asset Pricing Model (CAPM) are discussed followed by the test of the CAPM. A brief discussion of an alternative asset valuation model has been proposed, entitled the arbitrage-pricing model (APT). Discussions of this model will follow at the end of this chapter.

4.2 Background of the capital asset pricing model

The mechanical complexity of the Markowitz model kept practitioners and academics from adopting the concept for practical uses. Nevertheless the logic of the model spurred the creativity of a number of people. Simplified versions for this model were developed by Sharpe (1963), Linter (1965) and Mossin (1966). The most practical version is the CAPM. The CAPM was first published by William F. Sharpe in the Journal of Finance in 1964 and took the world of finance by storm. It was a logical extension of the Modern Portfolio Theory (MPT), both intuitively and mathematically (Harrington, 1983). Developed to evaluate the entire market, the CAPM gave a precise prediction of the relationship between the risk and equilibrium expected returns on risky assets (Bodie *et al.,* 1995, Reilly and Brown, 1994 and Harrington, 1983). The CAPM gives the same risk ranking as the Markowitz method where both methods are concerned with risk and return only and the CAPM uses weighted averages as the benchmark for calculating correlation. There is a close relationship between the single-index model (market model) of Sharpe (1963), and the CAPM. According to Barry (2001), the CAPM and the Single Index Model (SIM) are identical in their empirical forms:

However, "...the CAPM need risk premiums to compensate for an asset's systematic risk-the risk it adds to a well diversified market portfolio. The SIM is not a market equilibrium model-it basically gives an estimate of the systematic risk an asset adds to any "portfolio" represented by the independent variable. It was developed to shortcut the need to estimate a full variance-covariance matrix"(Barry, 2001).

Nevertheless, it is important to note that the market portfolio in the CAPM is not the same as a "market index." In fact, if a market index such as the America's S&P 500 is used in the SIM, it is quite unlikely that it will coincide with the tangency portfolio identified by the CAPM. This will become readily apparent when the single-index model is used to analyse real-world data. Second, even though the functional form for the expected return is similar, the single-index model leads to a simplification of the portfolio choice model because of the additional assumption that the characteristic components of return are independent across stocks.

Farm management applications of the CAPM have been limited. Johnson (1976) posits a model of the Sharpe-Lintner type based on the separation theorem by Tobin (1958). A model analogous to Johnson's has been discussed by Barry and Collins (1986) as well as by Turvey and Driver (1987). Returns to agriculture investment measured in terms of agricultural assets and associated risk have been compared to returns and risk of non-agricultural investments by Barry (1980). Irwin *et al.* (1988) extended Barry's study by incorporating an inflation factor in the asset-pricing model and found that agriculture returns are sensitive to the inflation factor. In the paper by Gu (1996) the CAPM analyses the relationship between returns and risk of agriculture assets. The study also compares these relationships with those of non-agricultural assets and investments outside the agricultural sector. Arthur *et al.* (1988) studied the relationship between risks and returns for agricultural assets using both CAPM and arbitrage pricing model (APM).

Therefore, the CAPM can be used in various ways. An analyst might want to know whether the expected return forecasted on a stock is more or less than its "fair" return given the risk it must undergo. The model can be used to make an educated guess as to the expected return on assets that have not yet been traded in the marketplace. According to Copeland *et al.* (1996) the essence of the CAPM postulates that the opportunity cost of equity is equal to the return on risk-free securities, plus the company's systematic risk (Beta), multiplied by the market price of risk (market risk premium).

The simplicity of the CAPM rests on some rigorous assumptions. These assumptions have repeatedly been challenged.

4.3 Assumptions of capital market theory

When dealing with any theory in science (economy or finance) it is necessary to articulate a set of assumptions that specify how the world is expected to act. This, allow the theoretician to concentrate on developing a theory that explains how some facets of the world will respond to changes in the environment.

A number of simplified assumptions lead to the basic version of the CAPM. The fundamental idea is that individuals are as alike as possible, with exceptions of wealth and risk aversion. The real world is sufficiently complex that to understand it and construct models of how it works, one must assume away the complexities (institutional frictions) that are thought to have only a small effect on its behaviour. The CAPM will thus be approached in a simplified world. Thinking about an admittedly unrealistic world allows a relatively easy leap to a solution. With this accomplished, complexity might be added to the environment one step at a time, and see how the theory must be amended. The list of assumptions that describes the necessary conformity of investors follows (Bodie *et al.*, 1995, Elton and Gruber, 1995, Levy and Sarnat, 1982 and Lumby, 1994):

1) Individuals cannot affect prices by their individual trades. This means that there are many individuals, each with an endowment that is small compared with the total endowment of all individuals,
2) All investors plan for one identical holding period (time horizon),
3) There are no transaction costs. There is no cost of buying and selling any assets. To include transaction cost in a model adds a great deal of complexity. Whether it is worthwhile to introducing this complexity depends on the importance of transaction costs to individuals,

4) Assets are infinitely divisible. This means that investors could take any position in an investment, regardless of the size of their wealth,
5) Individuals are expected to make decisions solely in terms of expected values and standard deviations of the returns on their portfolios,
6) Unlimited short sales are allowed. The individual investor can sell short any amount of any shares,
7) Unlimited lending and borrowing at the risk-less rate. The individual can lend or borrow any amount of funds desired at a rate of interest equal to the rate for risk-less securities,
8) Absence of income tax. This means, for example, that the individual is indifferent to the form (dividends or capital gains) in which the return on the investment is received,
9) All individuals are assumed to have identical expectations with respect to the necessary inputs to the portfolio decision. Hence, they all end with identical estimates of the probability distribution of future cash flows from investing in the available securities. This means that given a set of security prices and risk-free interest rate, all investors use the same *expected returns* (r_i), *standard deviations* (σ), *and correlations* (r_{ij}) to generate the efficient frontier and the unique optimal risky portfolio. This assumption is often called *homogeneous expectations,*
10) All assets are marketable. All assets including human capital can be sold and bought on the market.

The above-mentioned assumptions are needed to create the simple CAPM. Because these assumptions are critical to understand the CAPM, there are some statements that describe the model and its meaning (Harrington, 1983):

1) Risk is the variance of expected portfolio returns,
2) Risk can be broken into two components: diversifiable (non-systematic) risk and non-diversifiable (systematic) risk,
3) Proper diversification can reduce non-systematic risk,
4) Beta is the relevant measure of risk for investors with diversified portfolios,

5) Risk and return are linearly related by Beta - that is, risk and return are in equilibrium,
6) Return on the portfolio is the is total return,
7) An investor holds portions of portfolios: the risk-free asset and the market portfolio,
8) The return that an investor actually receives is derived from only two sources: risk-proportional market return plus non-systematic random return. No other factor is consistent in its effect on security returns.

Models are meant to abstract from reality and to ignore irrelevant or trivial factors (Harrington, 1983). To various degrees, all the CAPM assumptions are violated in the real world. Some of the above mentioned assumptions may be considered unrealistic and one may wonder how a useful theory these assumptions can derive. Relaxing many of these assumptions would have only minor impacts on the model and would not change its main implications or conclusions. Another important fact is that a theory should never be judged on the basis of its assumptions, but rather on how well it explains and helps us predict behaviour in the real world.

If this theory and the model it implies help us to explain the rate of return on a wide variety of risky assets, it is very useful, even if some of its assumptions are unrealistic.

The final test of the model is not how reasonable the assumptions behind it appear, but how well the model describes reality.

4.4 Development of the capital asset pricing model

4.4.1 Risk-free asset

According to Reilly and Brown (1997), the concept of the risk-free asset (R_f) is the major factor that allowed the portfolio theory to develop in the capital market theory. In areas where a risk-free method of land control exists, such as leasing with a fixed cash rent per hectare, an alternative method of risk response is available that allows farmers to adjust their risk position through changes in the level of leasing, given an optimal enterprise mix, rather than through changes in the enterprise mix.[1] This method is based on the separation theorem and illustrated by Johnson (1967) in a farm diversification situation. In this model the risk-free asset is cash rental land in combination with efficient farm sector portfolios. The hectares of land available for rent (supply) and the number of tenants wanting to rent for cash (demand) can affect the amount of rent that can be paid or charged. High rents increase the tenant's risk, and a variable or flexible cash rent based on yields and prices can help distribute risk (http://muextension.missouri.edu). The result is a portfolio combination that dominates all other portfolios in a feasible set. Combining the risk-free activity with risk-efficient combinations of risky assets enlarges the risk-efficient set and makes it more efficient.

The risk-free asset has zero variance and zero covariance, that means that correlation with all other risky assets are zero and would provide a risk-free rate of return (R_f). This assumption allows deriving a general theory of capital asset pricing under conditions of uncertainty from the Markowitz portfolio model (Sharpe, 1964).

According to Copeland *et al.* (1996) the risk-free rate is the return on a share or a portfolio of shares that has no default risk whatsoever, and is totally uncorrelated with returns on anything else in the economy. Theoretically, the best estimate of the risk-free rate would be the return on a zero-Beta portfolio. However, due to the cost of constructing zero-Beta portfolios, they are not available for use in estimating the risk-free rate. Copeland *et al.* (1996) used three alternatives of government securities: (1) the rate for Treasury bills, (2) the rate for ten-year Treasury bonds, and (3) the rate for thirty-year Treasury bonds. In their studies they recommended the ten-year Treasury bond.

As noted, the assumption of the risk-free asset is critical to asset pricing theory. Reilly and Brown (1997) defined a risky asset as one which future returns are uncertain. The variance and the standard deviation of return measured the uncertainty of risky an asset. However, because the expected return of a risk-free asset is entirely certain, the standard deviation of

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[1] *Other risk responses are available, too, as described in Section 2.4 of Chapter 2.*

its return is zero *(σ_{RF} = 0)*. The rate of return earned on such an asset should be the risk-free rate of return (R_f).

The covariance of a risk-free asset with any risk-free asset or portfolio of assets will always equal zero, because the returns of a risk-free asset are certain (σ_{RF} = 0), which means $R_i = E(R_i)$ during all periods. Thus, $R_i - E(R_i)$ will also equal zero, and the product of this expression with any other expression will equal zero. Similarly, the correlation between any risky assets *i*, and risk-free asset, R_f, would be zero as well.

Figure 4.1 shows a graph depicting portfolio possibilities when a risk-free asset is combined with alternative risky portfolios on the Markowitz efficient frontier.

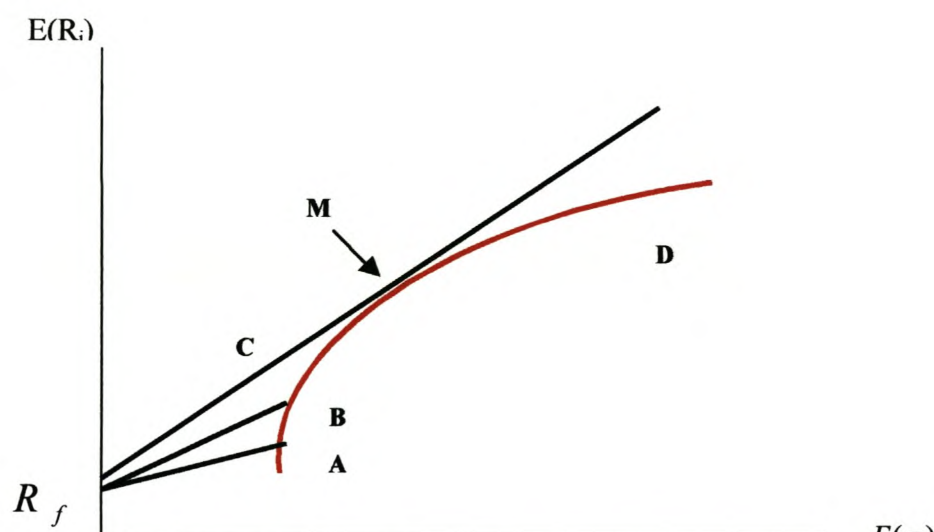

Figure 4.1: Portfolio possibilities combining the risk-free asset and risky portfolios on the efficient frontier
Source: Reilly and Brown, 1997:282

An investor can attain any point along the straight line R_f-A by investing some portion of the portfolio in a risk-free asset R_f, and the remainder (1-R_f) in the risky asset portfolio at point A on the efficient frontier. The set of portfolio possibilities dominates all the risky asset portfolios on the efficient frontier below point A, because some portfolio along Line R_f-A has equal variance with a higher rate of return than the portfolio on the original efficient frontier. Likewise, an investor can attain any point along the line R_f-B by investing in some combinations of the risk-free asset and the risky asset portfolio at point B. An investor can draw further lines from the R_f to the efficient frontier until the point is reached where the line is tangent to the frontier, point M in Figure 4.1. The set of portfolio possibilities along Line R_f-M dominates all portfolios below point M. That means that an investor could attain a risk and return combination between the R_f (C) and point M by investing one-half of his portfolios in the risk-free asset (lending money at the R_f) and the other half in the risky portfolio at M.

An investor may even want to attain a higher expected return than available at point M in exchange for accepting higher risk. One alternative would be to invest in one of the risky asset portfolio on the efficient frontier beyond point M such as the portfolio at point D. A second alternative is to add leverage to the portfolio by borrowing money at a risk-free rate and investing the proceeds in the risky asset portfolio at Point M (Reilly and Brown, 1997).

The effect of leverage on the investors return and risk of his portfolio will be that the return and the standard deviation (risk) of the expected portfolio will increase in a linear fashion along the line R_f-M. This extension dominates everything below the line on the original efficient frontier. Thus a new efficient frontier is constructed - the straight line from R_f tangent to point M. This line is referred to as the capital market line (CML) in Figure 4.2.

Individuals however, require compensation for the risk that cannot be diversified away. The CAPM models the systematic risk in a particular asset and can avoid much of the risk they incur through diversification. Therefore, only unavoidable risk should or will be compensated. Since this uncertainty can be reduced through appropriate diversification, Sharpe figured that a portfolio's expected return hinges solely on its Beta, and that is, its relationship to the overall market. The CAPM helps measure portfolio risk and the return an investor can expect for taking that risk.

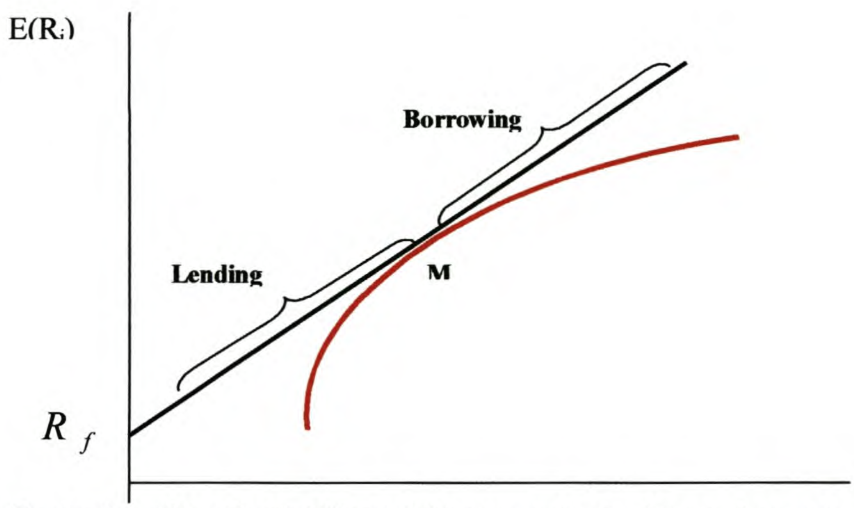

Figure 4.2: Derivation of the Capital Market Line assuming lending or borrowing at the risk-free rate
Source: Reilly and Brown, 1997:283

4.4.2 Beta, a measure of the sensitivity of an assets systematic risk

Specific risk is the risk that is unique to an individual asset. It represents the component of an asset's volatility, which is uncorrelated with general market movements. Specific risk is unexpected, unpredictable and unrewarded. Nevertheless, even after an individual diversifies his/her portfolio, some risk will remain. Because some risk is associated with the market as a whole, this risk cannot be neutralised through diversification. A stock's contribution to the risk of a fully diversified portfolio depends on its sensitivity to market changes. The systematic risk of an asset is that part of an asset's price change that has some degree of sensitivity or responsiveness to broad market forces. The degree of sensitivity tends to persist over time. This sensitivity is generally known as Beta *(β)* (Brealey and Myers, 2000). Factors that affect the price of all marketable shares (who moves together) are changes in the economical, political and social environment.

To get a deeper insight into risk, consider the estimation of the *Beta* coefficient from an ordinary least squares regression (Jagannathan and McGrattan, 1995):

$$R_{it} - R_{ft} = \alpha_i + \beta(R_{mt} - R_{ft}) + \varepsilon_{it} \tag{4.1}$$

where:

$\beta(R_{mt} - R_{ft})$ = Non-diversifiable or Systematic risk

ε_{it} = Diversifiable or Non-systematic risk.

In this regression, the *Beta* is the ratio of the covariance to the variance of the market return. The *Alpha* is the intercept in the regression. This is not the CAPM equation. This is a regression that allows us to estimate the stock's *Beta* coefficient.

The asset's characteristic line is the line of the best fit for the scatter plot that represents simultaneous excess returns on the asset and on the market.

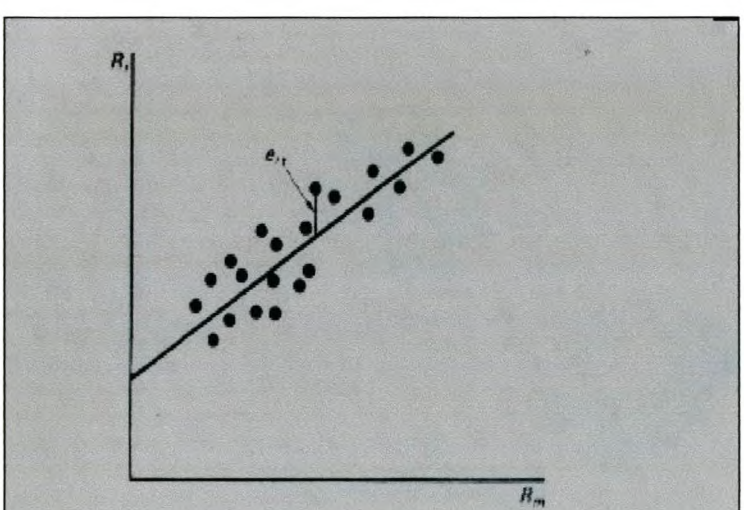

Figure 4.3: Characteristic line that represents simultaneous excess returns on the asset and on the market
Source: Jagannathan and McGrattan, 1995:187

The non-systematic part is also called the residual variance (e_i) round the regression line in statistical terms, or non-systematic risk in capital market theory. Non-systematic risk is unique to an enterprise or industry, and is caused by changes such as labour, strikes, management errors and shift in consumer taste. Non-systematic risk is independent of factors affecting other industries and varies widely from industry to industry. Since non-systematic risk is caused by factors that affect one industry, it must be forecasted separately for each industry (Francis, 1976).

The movements of an individual stock relative to the movements of the overall market portfolio can be calculated using daily, weekly or monthly historical data taken over a year or more. It is important to consider the following aspects when calculating Beta. The length of the intervals affects the estimation of Beta within the chosen period. Harrington (1983) showed that once Beta is calculated, it is assumed to be a predictor of future market behaviour. If the stock market goes up (or down) by a particular percentage, the theory is that there is a tendency for the stock itself to go up (or down) by the same percentage multiplied by Beta. Note that, by definition, the Beta of the market portfolio equals 1 and the Beta of the risk-free asset equals 0. This is why stocks with a Beta greater than 1 are considered riskier, however if the market fluctuates, the high-Beta stocks fluctuate even more. If the Beta is negative, the tendency of the stock is to move in the opposite direction to that of the market. Therefore, with a Beta of zero, the return should be zero. A Beta above zero should bring a positive return to a long position, while a Beta below zero should bring a negative return.

Much research has been conducted to determine the usefulness of Beta as a measure of risk, and it was found that a positive relationship appears to exist between historically observable Betas and portfolio realised returns, and that the relationship is linear (Hayes and Baumann, 1976). The goodness of fit, that is how much of the activity of the dependant variable was explained by the independent variable, is measured by the coefficient of determination (R^2), the standard error estimate (S), and the standard error of coefficient (of Beta coefficient). The quality of the regression results is determined by means of a variety of simple tests. The standard error of the estimated Beta or alpha gives some idea of how much in error the estimate may be. The degree of confidence one has in alpha, the Beta and the entire regression can be determined by the t and F tests, while the Durbin-Watson test can indicate whether important factors have been omitted (Harrington, 1983).

Beta is defined as the covariance of the returns of the stock and the market divided by the variance of the returns of the market.

$$\beta_i = \frac{\sigma_{im}}{\sigma_m^2} \tag{4.2}$$

where:

1) σ_{im} = the covariance between the returns on asset i and the market portfolio and

2) σ_m^2 = the variance of the market portfolio.

An asset's systematic risk, therefore, depends upon its covariance with the market portfolio. The market portfolio is the most diversified portfolio possible as it consists of every asset in the economy held according to its market portfolio weight (Burton, 1998). In a study by Barry and Collins (1986) that is analogue to the study by Johnson (1967) Beta were estimated and the systematic and non-systematic risk for a portfolio of crops were measured.

The main problem with estimating the share's Beta value in order to make decisions is to estimate what the company's Beta value in the future will be. With this done, it is possible to estimate what the expected returns of a company will be. However, the approach in portfolio theory used for estimating Beta looks at the past, or historical, relationship between the shares and the stock market and not the future relationship.

Therefore, whether this method to estimating Beta is a satisfactory approach depends upon a single issue: how stable is Beta over time? Generally, according to various literatures, Beta values are fairly stable and do not change substantially over relatively short periods of time. According to Lumby (1994) there is some tendency over time for shares with high and low Betas to move towards a Beta of one.

4.4.3 The Market Portfolio (M)

If an investor's indifference curve is tangent to point M in Figure 4.2, this individual will invest all his/her resources in risky securities. On the other hand, the indifference curves of most investors presumably will not be tangent to point M. The investor might either invest part of his portfolio in the risk-free rate and the rest in a risky asset portfolio M, or the investor can borrow at the risk-free rate and invest these funds in the risky asset portfolio. As showed in Figure 4.2, portfolio M lies at the point of tangency, therefore, it has the highest portfolio possibility line, and every investor will want to invest in Portfolio M and borrow or lend to be somewhere on the CML. This portfolio must, therefore, include all risky assets. The portfolio that includes all risky assets is referred to as the market portfolio (M) (Elton and Gruber, 1995, Reilly and Brown, 1997). All individuals hold the (M) as their optimal risky portfolio, differing only in the amount invested in it as compared to the investment in the risk-free asset. Because the market portfolio contains all risky assets, it is a completely diversified portfolio, which means that all the risk unique to individual assets in the portfolio is diversified away.

A diagrammatic comparison (see Figure 4.4) is made between modern portfolio theory (MPT) and the CAPM. Markowitz efficient frontier is the curved line AO. The risk-free asset (R_f) creates a new and more efficient frontier, R_fZ (the CML) in the CAPM. The portfolio or asset lying on this straight line provides more return for the same risk, or they offer less risk for the same level of return as the efficient frontier. All investors will end up with portfolios somewhere along the capital market line and all efficient portfolios would lie along the capital market line. The Capital Market Line (CML) described all possible mean variance efficient portfolios that were a combination of a risk-free asset and the tangency portfolio of risky assets, *(M)*. The capital market line changes the risk-return trade-off available to investors. Risk averse investors choose a portfolio shown at point *B* in Figure 4.4. With no change in risk, this investor could improve return by *X*. To obtain this improved return, the risk-avers investor would have to purchase portions of the market portfolio (*M*) and of the risk-free security (R_f) in a combination that suited the investors' tolerance for risk. The more aggressive risk taker would borrow money to buy as much of *M* as possible. The debt-supported or leverage portfolio would lie on the portion of the line labelled *MZ*.

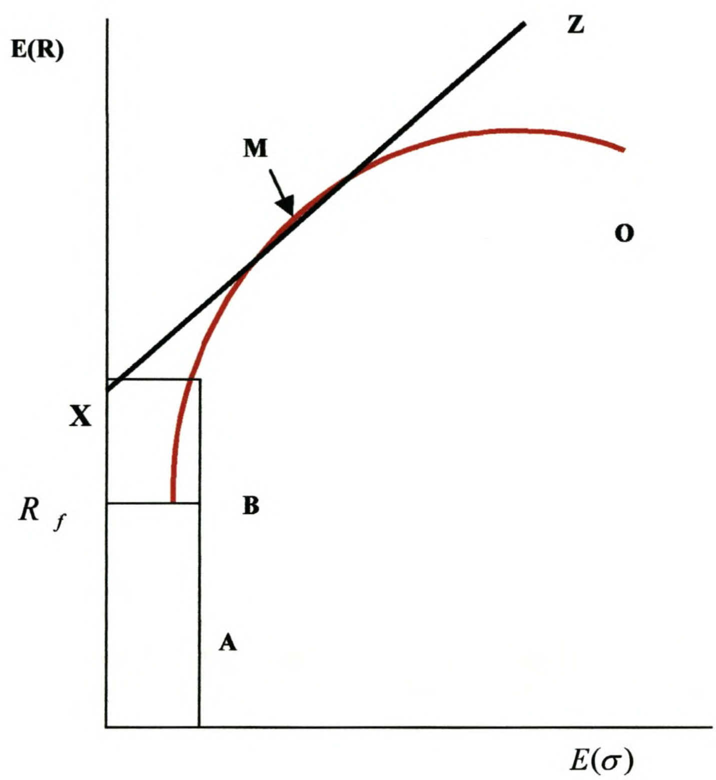

Figure 4.4: The Capital Market Line with point M as the market portfolio
Source: Harrington, 1983:13

4.4.4 The Separation Theorem

When an investor faces risky assets and borrowing or lending at a risk-less interest rate, the investment process can be dichotomies as follows:

1) Choosing the proportions of the risky securities to be included in the investor's tastes,

2) Choosing the optimal proportions of risk-less bonds and of the risky portfolio in accordance with the investor's tastes.

The first stage corresponds to finding the risky portfolio that lie on the highest transformation line; the second stage corresponds to finding the tangency point between the transformation line and the investor's indifference curve.

The separation of the investment decision into two stages is called the "*separation theorem*", which implies that all investors independently of their preferences hold the same risky portfolio. They differ only with respect to the mix of this portfolio with the risk-less assets (Bodie *et al*., 1995). Tobin (1958) called this deviation of the investment decision from the financing decision the separation theorem. He argued that to be somewhere on the CML efficient frontier, an investor initially decide to invest in the market portfolio M.

This is called the investment decision. Since the investments are based on the investors risk preferences, the investor makes a separate financing decision either to borrow or to lend to attain the preferred point on the CML. According to Ross (1976) separation occurs in a portfolio problem of allocating wealth across many risky assets when the problem can be simplified to that of choosing amongst combinations of a few funds formed from these assets.

The first separation results in portfolio theory were due to Markowitz (1959) and Tobin (1958). Earlier work by Knight (1964) and Hicks (1939) had made it clear that relevant parameters in asset choice problems were those of return and risk and had long played an important role in neoclassical literature.

4.4.5 Systematic and non-systematic risk

Until now, it is clear that the only relevant portfolio is the M portfolio. Reilly and Brown (1997) showed that the only relevant risk measure for risky assets is their covariance with the M portfolio, which is referred to as their systematic risk. Thus, because all individual assets are part of the M portfolio, the rates of return can be described in relation to the returns for the M portfolio by using the following linear model (Irwin *et al.*, 1988, Barry, 1980, Reilly and Brown, 1997, Turvey and Driver, 1987):

$$R_{it} = a_i + \beta_i R_{Mt} + \varepsilon \quad (4.3)$$

where:

R_{it} = return for asset i during period t
a_i = constant term for asset i
β_i = slope coefficient for asset i
R_M = return for the M portfolio during period t
ε = random error term

The variance of returns for a risky asset could be described as:

$$Var(R_{it}) = Var(a_i + b_iRM_t + \varepsilon) \quad (4.4)$$

$$= Var(a_i) + Var(b_iRM_t) + Var(\varepsilon)$$

$$= 0 + Var(b_iRM_t) + Var(\varepsilon)$$

where:

$Var(b_iRM_t)$ = the variance of return for an asset related to variance of the market return or the systematic risk.

Var(ε) = the residual variance of return for the individual asset that is not related to the market portfolio (non-systematic risk).

Therefore:

Var(R_{it}) = Systematic Variance + Non-systematic Variance

Now recall that:

$$B_i = \frac{Cov(R_i, R_m)}{\sigma^2 m}$$

and by definition:

$$\frac{[Cov(R_i, R_m)]^2}{\sigma^2 m \sigma_i^2} = \rho_i^2{}_m \qquad (4.5)$$

Where ρ_{im} denotes the coefficient of correlation between R_i and R_m (Levy and Sarnat, 1984). When $\rho^2{}_{im}$=1 (i.e., security or portfolio *i* perfectly correlated with the market *m*), the non-systematic risk σ_e^2 is zero and there remains only systematic or non-diversifiable portion of the variance. Levy and Sarnat (1984) defines such a security (portfolio) as being "efficiently diversified" since further diversification will not reduce its risk.[2] The variance about the regression line, σ_e^2, or the non-systematic component can be eliminated by diversified portfolio. The ratio σ_e^2/σ_i^2, (which is bounded between 0 and 1) also serves as an indicator of the desirability of diversification. If this ratio is zero for a given portfolio all the diversifiable risks has already been eliminated, so that further diversification cannot

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[2] *When* $\rho^2{}_{im}$ *=1 the portfolio variance can be greater or smaller than the market portfolios variance. An aggressive security may have a Beta coefficient greater than 1, while* $\rho^2{}_{im}$ *=1, such a portfolio will be more volatile than the market portfolio.*

reduce risk. On the other hand if the ratio is positive for a given portfolio, further diversification is desirable to eliminate the remaining non-systematic risk. The closer the ratio is to unity, the greater the potential gains from diversification.

4.4.6 The Security Market Line

The security market line (SML) represents the relationship between risk and the expected or required rate of return on an asset. The SML is a linear relationship between the expected return and the systematic risk for portfolios and individual shares. In contrast, the CML is a linear relationship between expected return and total risk on which only portfolios lie (Francis and Archer, 1971).

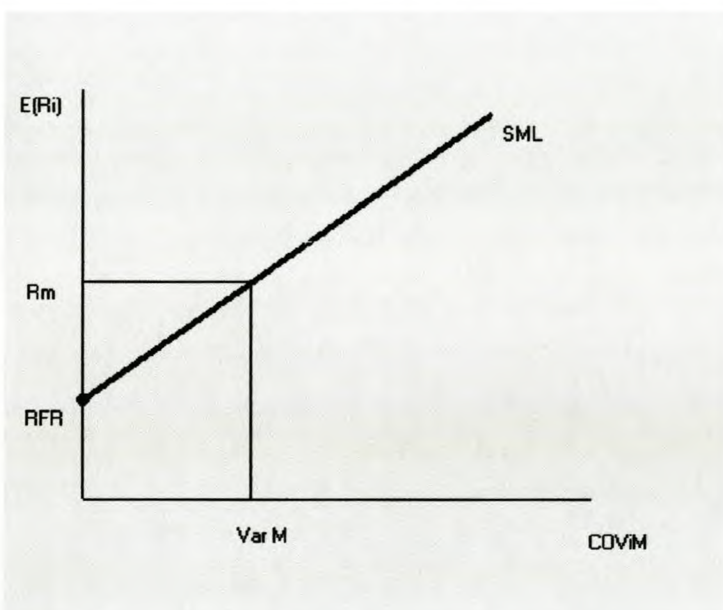

Figure 4.5: The Security Market Line as the relationship between the expected rate of return and the systematic risk measure

Source: Reilly and Brown, 1997:288

Figure 4.5, represents the relationship between risk and the expected or the required rate of return on an asset, with the systematic covariance variable (Cov_{iM}) as the risk measure. The equation for the risk returns line in Figure 4.5 is:

$$E\,(Ri) = R_f + \frac{R_M - R_f}{\sigma_M^2}(Cov_{i,M}) \tag{4.6}$$

$$= R_f + \frac{Cov_{i,M}}{\sigma_M^2}(R_M - R_f) \tag{4.7}$$

The solid line is called the security market line (SML). Because the forecasted return for every asset depends upon its systematic risk, the line represents the trade-off between systematic risk and return for every asset. Risk that is labelled Beta, can replace variance as the measure of portfolio risk because we are assuming that the investor will hold only a fully diversified portfolio. In a fully diversified portfolio only systematic risk remains, and therefore Beta is a reasonable alternative for total risk (variance).

By defining $Cov_{i,M} / \sigma_M^2$ as (β_i), this equation can be stated as:

$$E\,(R_i) = R_f + \beta_i\,(R_M - R_f\,) \tag{4.8}$$

As discussed in Chapter 2, β_i can be viewed as the standardized measure of systematic risk. Given this standardized measure, the SML graph can be expressed as shown in Figure 4.6. This is the same graph as in Figure 4.5 only the risk measure that is different. The graph in Figure 4.6 replaces the covariance of an asset's returns with the market portfolio as the risk measure with the standardized measure of systematic risk (Beta), which is the covariance of an asset with the market portfolio divided by the variance of the market portfolio.

According to Grinold and Kahn (2000) the CAPM is about expectations. If the expected returns of any collection of stocks and portfolios are plotted against the Betas of those stocks and portfolios, the outcome would be that they all lie on a straight line, with an intercept equal to the risk-free rate (R_f), and a slope equal to the expected excess return on the market.

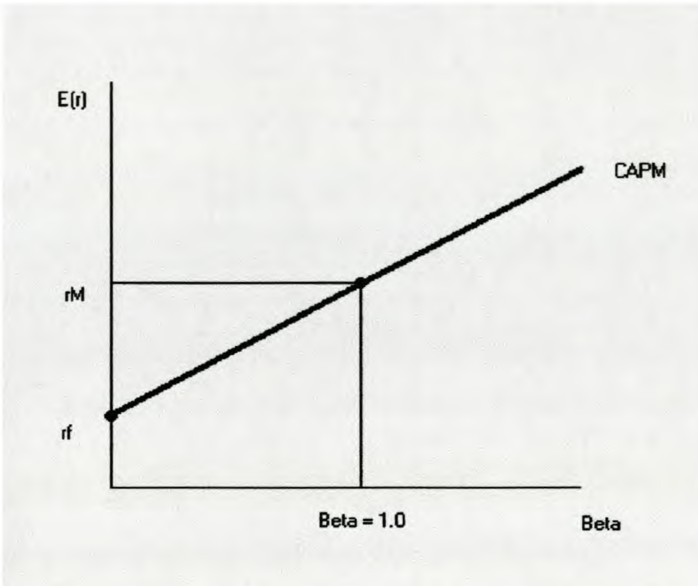

Figure 4.6. The CAPM relationship
Source: Lumby, 1994:286

To conclude this section, given the CML and the dominance of the market portfolio, the relevant risk measure for an individual risky asset is its covariance with the market portfolio (systematic risk). Beta, the measure of systematic risk and SML that relates the expected or the required rate of return for an asset to its Beta, is derived when the covariance is standardized by the covariance of the market portfolio. Because all individual securities and portfolios should plot on this SML, an investor can determine the required return on a security based on its Beta.

Undervalued and overvalued securities can be identified by assuming that the market is not always efficient. An investor can do this by comparing the estimate risk of return to be earned on an investment to its expected rate of return. Undervalued prices occurred when prices are lower than when they would be in equilibrium. These shares have unusual high returns for the amount of non-systematic risk they bear. Overvalued shares occurred when assets do not offer sufficient return to induce rational investors to accept the amount of systematic risk it involves (Francis, 1976).

Although the CAPM might not fully withstand empirical tests, it is widely used because of the insight it offers and because its accuracy suffices for many important applications (Sharpe and Cooper, 1972).

4.5 Multi-Risk formulations

The goal of most economic models is to simplify reality so that a greater understanding can be gained of how the world works. The CAPM is an example of such a simplification. A very complicated process (how prices are set in equilibrium) is reduced to a single firm-specific parameter - the Beta. The Beta is multiplied by the risk premium for Beta (the expected excess return on the market portfolio) to obtain the expected excess return on the security (Brealy and Myers, 2000). As for all models, with enough data it is possible to "statistically" reject the model. However, this does not mean that the model is not useful. On the contrary, a rejection of the model leads to the refinement and expansion of the generality of the model. One of the most obvious sources of generalization is to add additional risk factors. Ross (1976), Merton (1973) and Campbell (2000) have generalized asset-pricing theory to multiple sources of risk in important papers.

The perception of these models is that assets have exposures to various types of risk: inflation risk, business-cycle risk, interests rate risk, exchange rate risk, and default risk. It is difficult to capture all of these risk measures with the Beta of the CAPM. The multi-risk models have multiple Betas. Instead of running a regression of the asset return at time t on the market return at time t, a regression of the asset return at time t on various "factors" at time t, like the change in the interest rate are ruined. The Betas from this increased regression are sometimes called factor loadings, risk sensitivities or risk exposures. The basic idea of the CAPM is maintained. The higher the exposure the greater the expected return on the asset.

Multifactor asset pricing formulations that tried to explain average returns with average risk loadings are discussed in Roll and Ross (1980). However, these studies assume that risk is constant, risk premiums are constant and expected returns are constant. Another popular formulation is the 3-factor model of Fama and French (1993). While substantial advances have been made in asset pricing theory, there is still much work to be done.

In addition, standard asset pricing models need to be modified to apply according to international settings. For example, Bekaert and Harvey (1995)[3] detailed the impact of capital market integration on asset pricing. Two markets are integrated when the same risk project commands the same expected returns in both markets. Regulations that prevent foreigners from transacting in the domestic market or that prevent domestic investors from diversifying their portfolios internationally, lead to market segmentation.

4.6 Limitations of the CAPM

Regarding to literature, the CAPM's simplifying assumptions do not conform to reality. Various literatures argued that most investors are not fully diversified, as CAPM assume. Roll and Ross (1994) went further, claiming that a fully diversified portfolio is not possible to construct. According to Roll (1977) two problems arise in applying the CAPM to real world investments. One problem concerns the definition of the market portfolio and the second of the "efficient portfolio". Roll pointed out that the CAPM could never be definitely tested because, as a practical matter, it is impossible to define the "market portfolio" with any degree of precision.

Roll (1977) argued that no one truly "efficient" portfolio exists that would be appropriate for all investors. Research is costly, not all investors have access to the same information,

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[3] *As shown in Fama and French (1993).*

nor do they have the same opinions and beliefs. As long as investors have different expectations about the future risks and returns of various investments, they will not agree on the same "efficient" portfolio but rather choose securities that have the best prospect according to their own judgments.

The assumptions underlying the CAPM are very restrictive. Some restrictions such as the absence of transaction cost and taxes, unlimited borrowing and lending at the risk-free rate and short sales have been lifted by more recent contributions without changing the results significantly. A restriction that is not mentioned frequently in literature is that the assets have to be linear dependent. The linearity, also used in portfolio theory is implied by the use of the covariance, which is only able to capture linear dependencies correctly. This linearity of return rules out the inclusion of derivatives that mostly have strong non-linearities in their pay-offs and have become an important tool for investment in recent years. By excluding such assets, the need to include all assets is violated (Roll, 1977).

Besides the theoretical critiques, empirical investigations showed a mixed support for the CAPM. There exist a large number of empirical investigations of the CAPM using different econometric specifications (Cambell *et al.*, 1997, Dumaz and Allas, 1996). Early investigations by Fama and MacBeth (1973) mainly supported the CAPM, but more recent results by Fama and French (1992) and Fama and French (1993), show that the CAPM is not able to explained the observed returns.

Another critical point in the CAPM is that unconditional beliefs (means, variances and covariances) are used and that the investors are not able to condition their beliefs on information that they receive. A direct implication of this is the assumption that the beliefs are constant over time. Many empirical investigations gives strong support that believes is varying over time.

Another assumption remains critical for the CAPM is that all assumptions are marketable. Some investment restrictions due to legislation in foreign countries are taken into account by the International CAPM (Elton and Gruber, 1995) but assets such as human capital are not marketable. Therefore the market portfolio cannot be determined correctly. Roll

(1977) argued that the determinants of a correct market are important to achieve correct results, and only small deviations from the true market portfolio can bias the result significantly.

Finally the CAPM explains the expected returns only by a single variable, the risk of an asset relative to the market. It is reasonable to assume that other factors may as well influence the expected returns.

4.7 Test of the CAPM

To understand and model any process, elements in the real world are simplified or assumed away. While a model based on simplified assumptions can always be called into question because of these assumptions, the relevant test of how much damage has been done by the simplification is to examine the relationship between the predictions of the model and observed real-world events.

In various studies a relevant test is how well the CAPM describes the behaviour of the actual capital markets and how well the model fits history. In reweaving the different tests, the purpose is to determine whether the CAPM fits the real world, and if not, to determine the source and the size of the discrepancies between the model and the real world. A lot of research has been done to test the CAPM. In this section, only a small sample of the flood of work that have been done and published by researchers will be examined.

Other studies would choose to report different research. This section will consist of the results of major works that provide new insights. The approach in this section is to review the hypotheses that should be tested, to review some of the early work on testing the CAPM, and then to discuss briefly few of the problems inherent in any test of the CAPM.

According to Elton and Gruber (1995) certain hypotheses can be formulated that should hold whether one believes in the CAPM or not. The first is that higher risk (Beta) should be associated with a higher level of return. The second is that return is linearly related to Beta, that is, for every unit increase in Beta, there is the same increase in return. The third is there should be no added return for bearing non-market risk. In addition, if some form of the model holds, then investing should constitute a fair game with respect to it.

Sharpe and Cooper (1972) examined the results of a simple test of the CAPM to see if over long periods of time, higher returns has been associated with higher risk (as measured by Beta). They analysed whether following alternative strategies, with respect to risk over long periods of time, would produce returns consistent with modern capital theory. Sharp and Cooper's work presented rather clear and easily interpreted evidence that there was a positive relationship between risk and Beta and that the relationship was both strong and linear.

Most of the early tests of the CAPM involved the use of time series (using returns for a number of stocks over several time periods) regression to estimate Beta and the use of a cross-sectional (looking at a number of stock returns over one time period) regression to test the hypotheses we derived from the CAPM.

The early empirical studies by Douglas and Lintner (Douglas, 1969) made this statement more concrete. The results that they found seem to violate the CAPM by showing discrepancies between what was expected on the basis of the model and the actual relationship that were apparent in the capital markets. These early results caused some concern and many analysts suggested that the tests were faulty and were thus not given accurate results. According to Harrington (1983) the results could have been caused by either of two things. The CAPM could have been wrong or the test procedures could have been faulty. Retests by other researchers produced the same results that Douglas had obtained in his tests. The conclusion was that a faulty model could lead the findings of Douglas.

Miller and Scholes (1972) reformulated the test procedures to deal with other problems. They provided the statistical problems inherent in all empirical tests of the CAPM. They also conducted a series of simulations designed to measure the extent to which certain previous studies have produced results that were biased by these statistical problems. They started with a discussion of possible biases due to misspecification of the basic estimation equations. Miller and Scholes reported that they did not find good reason to reject Lintner's results. Lintner's results could be accurate reflections of the world.

Black *et al*. (1972) did another study that is now more famous than Lintner's. Lintner had used what is called the cross-sectional method. Black *et al.* (1972) were the first to conduct an in-depth time series test of the CAPM. They used returns for a number of stocks over several time periods. To make their test, Black *et al*. (1972) assumed that what had happened in the past were a good substitute for investor expectations. Using historical data, they generated estimates using the market model (Equation 3.6).

Black *et al*. (1972) formed portfolios instead of single stocks in an effort the cancel out one source of error. The reason was that Betas of one single firm are quite unstable. The results that Black *et al*. (1972) found were just what some of the theoretical adoptions suggested (Harrington 1983). The results were similar to those of Lintner.

Fama and McBeth (1973) calculated the actual risk premium and their study were performed over various periods of time. They too used a technique that settled down the Beta instability from individual security errors. They formed portfolios of securities to estimate Beta from time series regression, using the same procedure as Black *et al*. (1972). Fama concluded that the model described the data only in one period of all the periods that they tested.

In addition to testing the CAPM, Black *et al*. (1972) tried to provide a better explanation of the underlying security-pricing system. Elton and Gruber (1995) referred to this model as the zero-Beta portfolio. They suggested the adoption of the simple CAPM as:

$$R_{jt} = (1-\beta_j)\, R_{zt} + \beta_j\, R_{mt} + \varepsilon_j \qquad (4.9)$$

Substantial evidence exists that something is wrong with the simple form of the CAPM. No one piece of the research is sufficiently strong to allow *rejecting* the model outright.

Roll (1977) has argued that the CAPM are not agreeable to testing or, at least, that the tests performed so far provide little evidence in support of, or against the CAPM. Roll pointed out that the CAPM is an expectational model and requires using the full set of assets available to the investor as an index. The logical conclusion to Roll's work is that equilibrium theory is not testable unless the exact composition of the true market portfolio is known and used in the tests.

Therefore, the tests have not been tests of expectations, but of what really occurred. Thus, true satisfactory conclusions from any tests of the CAPM cannot be drawn up. All tests have been joint tests of the model and of the data on which it has been tested. Perhaps Roll's feelings about the state of testing of the capital asset pricing theory can best be summarized by a quote from his work: "Unfortunately, it (capital asset pricing theory) has never been subjected to an unambiguous empirical test. There is considerable doubt, moreover, at least by me, that it ever will."

While the empirical work is not fully satisfactory tests of the CAPM, it produces results that cannot be ignored. New ways of thinking about the world (new models or theories) displace old ones when the old models become either intolerably inconsistent with data, or when the new model is more consistent with available data. As a result of these critiques the CAPM has been modified and today a wide variety of extensions exist. The other point, which should not be lost sight of, is that although there may be a number of other factors, which go to determining the returns, it still appears that relative systematic risk (Beta) is by far the most important of these factors (Lumby, 1994).

The CAPM is not a perfect model and certainly not the last word on asset pricing. Alternatives that use a different approach to asset pricing are not frequently found and had, with the exception of the arbitrage pricing theory, no great impact as well as in application as in academic literature. In the next section, the Arbitrage Pricing Theory (APT) will be discussed as an alternative to the CAPM framework.

4.8 The arbitrage pricing model

As noted in the previous section, there are major obstacles in testing any of the equilibrium theories. Beside the problem of identifying the market portfolio and the critiques concerning the mean-variance criterion, a critical point in the concept of the CAPM is the aggregation of all risks into a single risk factor, the market risk. This aggregation is useful for optimal or at least well-diversified portfolios, but for the explanation of returns of individual assets this aggregation may be problematic. It is well observable that assets are not only driven by general factors like the market movement, but that industry or country specific influences also have a large impact on returns. Given these obstacles, the academic community has considered an alternative asset pricing theory that is reasonably intuitive and requires only limited assumptions. This arbitrage pricing theory (APT), developed by Ross in the early 1970s and initially published in 1976 has three major assumptions:

1) Capital markets are perfectly competitive,

2) Investors always prefer more wealth to less wealth with certainty,

3) The stochastic process generating asset returns can be represented as a (K) factor (multi factor model).

The APT is based on the concept of arbitrage, which is the exploitation of the relative mis-pricing among two or more securities to earn risk-free economic profits. An arbitrage portfolio is defined as a portfolio with no risk, no net investment, but a positive certain return (Schneller, 1990). A risk-less arbitrage opportunity arises when an investor can construct a zero-investment portfolio that will yield a sure profit. Studies by Roll and Ross (1980) have provided results that support the APT because the model was able to explain different rates of return, in some cases with results that were superior to those of the CAPM. Empirical evidence by Chen (1983) confirms that the APT explains expected returns better than the CAPM. In contrast, results of a study by Reinganum (1981) did not support the model because it did not explain small firm results. At present, the theory is still new and will be subject to continued testing. The important points to remember are functions as the CAPM. It gives us a benchmark for fair rates of return that can be used for capital budgeting, security evaluation, or investment performance evaluation. Moreover, the APT highlights the crucial distinction between non-diversifiable risk (systematic or factor risk) that require a reward in the form of a risk premium and diversifiable risk that does not. An important remark is that neither of these two theories dominates the other. The APT is more general in that it gets us to the expected-return Beta relationship without requiring many of the unrealistic assumptions of the CAPM (Bodie *et al.,* 1995).

At a first glance we could interpret the APT as a generalization of the CAPM to a multi-Beta model. The structure of the model does not differ much from the structure of the CAPM, but it has clearly to be pointed out that the models differ substantially in their assumptions. The CAPM is concerned to find an equilibrium of the market by holding optimal portfolios as implied by portfolio theory, whereas the APT finds this equilibrium by ruling out arbitrage possibilities. The APT allows including other sources of risk than only the market risk, e.g. industry specific factors. Furthermore a market portfolio has not to be determined, consequently. Also other measures of risk than variances and covariances could be used in determining the Betas that are not predetermined by this theory. As noted in Fama and French (1992, 1993) evidence exist that other variables are able to explain the observed returns better than the market risk. The APT could be a framework to find a justification of their results on a sound theoretical basis.

The first problem to solve in applying the APT is to identify the risk factors. Risk factors can either be constructed by finding a portfolio of assets that has a high correlation regarding a certain risk, this portfolio is called a factor portfolio, or by using other variables, such as macroeconomic data, e.g. gross domestic product (GDP). The advantage of the former approach is that expected returns for the risk factor can easily be determined from the market and the risk can also be estimated from market data. The identification of these parameters for macroeconomic data imposes much more difficulties. This is the reason why in most cases factor portfolios are used for the statistical methods of forming factor portfolios and estimating the relevant parameters (Campbell *et al.,* 1997). To identify the systematic risk and hence, the characteristics of the factor portfolios, theoretical considerations or statistical methods can be used to identify these risks. Widely used statistical methods are factor analysis and principal components method (Cambell *et al.*, 1997). There exist a large number of surveys investigating the explanation of asset returns using APT (Fama and French, 1996). The factors mostly identified in these studies are related to dividends or earnings, book-market relations, the size of a company and the variance of asset returns. As a market portfolio is not needed for the APT the variance represents an appropriate risk measure instead of the covariance in the CAPM. The investigations cited gave evidence that the APT can explain the observed returns quite good for long and medium time horizons. For time horizons below one year they are not able to explain the data adequately. Compared to the present value model, the time horizon can be reduced significantly from four to about one year, but as in the CAPM there remain many effects that cannot be explained sufficiently.

The assumption of a linear relation between the assets in the CAPM by the co-variances is replaced by the assumption of a linear relationship with risk factors. Like in the CAPM this assumption limits the theory, as non-linear assets, like derivatives, cannot be modelled adequately. The advantage of the APT in this case is that it is not necessary to form a market portfolio and to include these assets; it enables to exclude human capital or real estate. It enables also to restrict the analysis to a certain group of assets, provided that the number of assets is sufficiently large. The more assets are included the more precise the findings should be, with restricting to only a few.

To find out if the APT is stronger than the CAPM, Burton (1998) argued that APT assumes that relatively few factors generate correlation, and said the expected return on a security or an asset class ought to be a function of its exposure to those relatively few factors. The APT is stronger in that it makes some very strong assumptions about the return-generating process, and it's weaker because it doesn't tell you very much about the expected return on those factors.

The CAPM and its extended versions offer some notion of how people determine prices in the market. The CAPM tells you more. The CAPM does not require that there be three factors or five factors. There could be a million. Whatever number of factors there may be, the expected return of a security will be related to its exposure to those factors.

The APT remains the newest and most promising explanation of relative returns. The theory promises to supply us with a more complete description of returns than the CAPM. Until now the basic theoretical ideas of Markowitz portfolio theory, and equilibrium models in finance were discussed and will serve as a primary basis for the discussion of this study.

4.9 Conclusion

The essence of the CAPM postulates that the opportunity cost of equity is equal to the return on risk-free securities, plus the company's systematic risk, multiplied by the market price of risk. The assumptions of the capital market theory expand on those of the Markowitz portfolio model and include considerations of risk-free rate of return. Some of the above mentioned assumptions may be considered unrealistic and one may wonder how a useful theory these assumptions can derive. Relaxing many of these assumptions would have only minor impacts on the model and would not change its main implications or conclusions. Another important fact is that a theory should never be judged on the basis of its assumptions, but rather on how well it explains and helps us predict behaviour in the real world.

The correlation and covariance of any asset with a risk-free asset is zero, so that any combination of an asset or portfolio with a risk-free asset generates a linear return and risk function. The existence of a risk-free rate has significant implications for the potential return and risk and alternative risk-return combinations. Combining the risk-free activity with risk-efficient combinations of risky assets enlarges the risk-efficient set and makes it more efficient. A central portfolio of risky assets on the efficient frontier is constructed which is called the market portfolio. All individuals hold the market portfolio (*M*) as their optimal risky portfolio, differing only in the amount invested in it as compared to the investment in the risk-free asset.

The Single Index Model (SIM) represents the relationship between risk and the expected or required rate of return on an asset. The line represents the trade-off between systematic risk and return for every asset

A lot of research has been done to test the CAPM. No one piece of the research is sufficiently strong to allow rejecting the model outright. True satisfactory conclusions from any tests of the CAPM cannot be drawn up. All tests have been joint tests of the model and of the data on which it has been tested. While the empirical work is not fully satisfactory test of the CAPM, it produces results that cannot be ignored.

The CAPM is not a perfect model and certainly not the last word on asset pricing. Alternatives that use a different approach to asset pricing are not frequently found and had, with the exception of the arbitrage pricing theory, no great impact as well as in application as in academic literature.

In Chapter 6 the results of the applications of the CAPM in the Paarl/Berg River region will be discussed.

CHAPTER 5

DESCRIPTION OF AGRICULTURAL ENTERPRISES IN THE PAARL/BERG RIVER REGION

5.1 Introduction

This chapter gives a summarized background of the study area (Paarl/Berg River region). The climatic conditions will be outlined that have a large influence on the nature of enterprises. The various enterprises that were included in the study will be discussed in context to the South African market. Enterprise data collected in the study area in the form of income and cost calculations (margin above specified cost) over time will be examined. These data will be implemented numerically and graphically in Chapter 6 by means of the various diversification models discussed in the previous chapters.

5.2 Climatic conditions in the Paarl/Berg River region

Climatic conditions in the Paarl/Berg River region play a big role in the type of enterprise/cultivar that is produced in the region. Within the region itself, the climate and the soil fluctuate to a vast extent. Crops are therefore produced to suit these different conditions, leading to unsystematic risk. In this study the systematic risk of the crops as well as the different cultivars will be taken into account in order to develop a portfolio and effectively manage risk in line with the producers' risk tolerance.

The Paarl/Berg River region falls within the Wellington agricultural extension region and stretches on both sides of the Berg River from the N1 in the South up to Wellington in the North and consists of a total surface of 17 800 hectare (see *Appendix 1.1*). A small part of the Suider-Agter-Paarl region was included in the study area seeing that sweet melons are produced on the border of the Paarl/Berg River region and the Suider-Agter-Paarl region.

With the exception of the mountain areas, the rainfall in the Paarl/Berg River region is mild to low (see *Appendix 1.4*). The summers are very dry and the evaporation is high. The average summer temperatures are very high and heat waves occur regularly. Cultivation of crops on dry land is excluded except for wine grapes and olives. The moderate wind temperature excludes the production of deciduous fruit with a high cold resistance. In the summer the evaporation rate can reach extremely high values that will put crops under severe stress if the moisture status of the soil is low. In the winter a situation can occur where crops can be drenched because of the weak drainage of the soil. The reason for this is that most of the rainfall occurs between May and August. High summer temperatures above 34 degrees can be found for a couple of days in January and February (see *Appendix 1.2 and 1.3*). These high temperatures are unfavourable for the production of premium wine cultivars. Heat waves cause sunscald on some table grape cultivars.

Gale force northern and southern winds can cause extreme damage to fruit and grapes. According to the Elsenburg Landbou-ontwikkelingsinstituut (1990), a wide range of soil types exists in the region. The better soil is mostly close to the mountainside and in the flood plain next to the Berg River and its smaller tributaries.

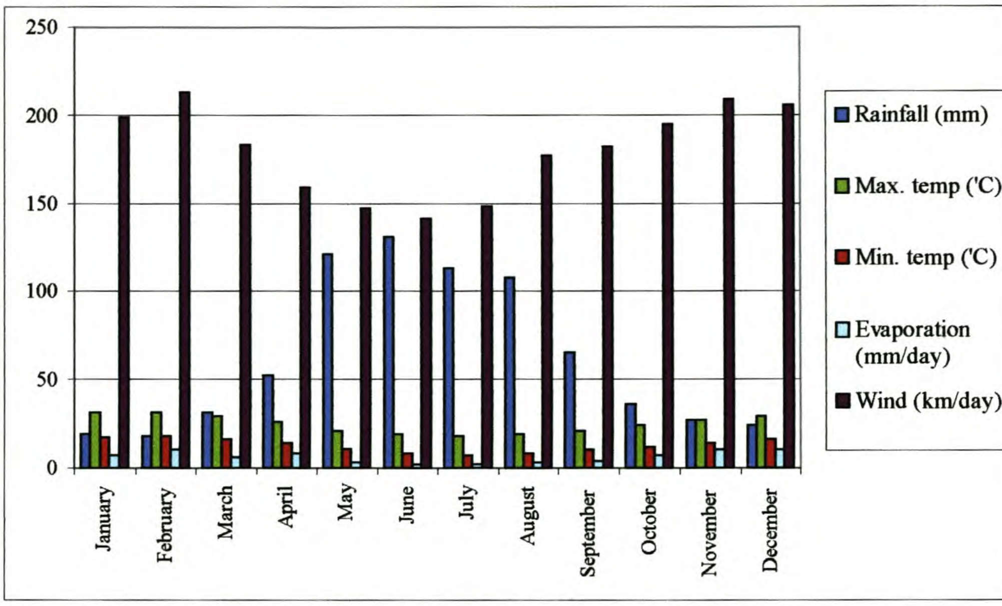

Figure 5.1: Climatic conditions in the Paarl/Berg River region
Source: Elsenburg Landbou-ontwikkelingsinstituut, 1990

The Berg River is the main source of irrigation water to the riparian farms (see *Appendix 1*). Both the quality and the availability of water are favourable in this region. Compensation water provides the Berg River with sufficient water throughout the warm summer season.

5.3 Collection of data and the type of data used

Historical data used in this study were obtained from wine grape[1], table grape, soft citrus, plums, olives and sweet melon producers in the Paarl/Berg River region. Data can be gathered in various forms, i.e. individual data, aggregate data and pooled data. Each form has its advantages and disadvantages and can be analysed for a specific purpose.

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[1] *Wine grape data were collected from farmers in the Paarl/Berg River region who sell their grapes to wine cooperatives. Farmers who have their own cellars on their farms were not included in the study as the prices for the different wine grape cultivars are not the same and thus not comparable.*

The ideal for this study would be to use data of an individual farmer over a period of time. However, no data from the period before the deregulation of the South African agricultural sector could be used because of structural differences in the data. The major advantage in using individual data on a single farm is that it allows for a detailed understanding of a particular situation to be obtained so that certain interrelationships and causalities, the why and how, can be better understood in the context of the individual farm. This is, however at the expense of the comparability, statistically analysis and generalisability of the data.

Many studies have used aggregate data to estimate variations in the gross income over time for different enterprises. Plaxico and Tweeten (1963) concluded that any computation of combined variance of aggregate data might result in a serious distortion of the true situation and lead to faulty conclusions. They found that yield variability based on average yields was consistently lower than individual farm variability. Often it is assumed that the population is normally distributed with respect to the variable in question. Plaxico and Tweeten (1963) considered this to be a somewhat brave assumption. Besides, large variation exists within agriculture. Elliott (1928) came to the conclusion that a mean farm constructed out of aggregated data is obviously not representative, nor does it accurately describe the whole distribution. In spite of the latter source dating back to 1928, it is referred to several times in consequence of the pioneer work done by the author. Both Elliott (1928) and Meiring (1994) pointed out that an actual farm of the same area and set-up as the mean farm seldom exists.

However, pooled variability tends to be more representative than the variability of individual farms (Greyling and Laubscher, 1990). It was also found that the relationships observed using average data were outside the range of levels experienced by individual farms and that pooled yield data give correlation coefficients that are "average" for those experienced on the individual farms. In the light of these findings Howcroft and Ortmann (1990) decided to use pooled data in their study, where they developed a regional mathematical programming model with the objective of simulating the wheat industry. It appears that pooled data give more representative variances within and correlation coefficients between enterprises than aggregated data in risk analysis.

Six different enterprises that are produced in the Paarl/Berg River region were used in this study. Optimally one would like to perform analyses for every individual, but this is not practically possible. Farm situations are so diverse in nature that only one mean analysis is mostly inapplicable for the majority of farmers within a specific group. Therefore, in this study the producers were chosen at random but in close proximity to each other in the Paarl/Berg River region in order to pool the data of the specific enterprises. Since time series data are used in this study, a situation could occur on a specific farm where both old and newly planted cultivars of an enterprise are produced. Time series data longer than two years were very difficult to obtain. Most farmers did not keep records of time series data and it was difficult to obtain sufficient data of different enterprises. Pooled data were obtained by selecting farmers in close proximity with sufficient data for the purpose of this study. Data of individual farmers in a specific pool over the same time period were merged to calculate average returns and costs.

Seeing that sufficient data could be a problem, some assumptions were made as a basis for conducting this study:

1) a cultivar's mean and standard deviation characterised a cultivar if they were based on at least three years of production data
2) production costs (per hectare) do not differ significantly between farmers who cultivate the same cultivars

Questionnaires (see *Appendix 2.1, 2.2* and *2.3*) were sent to 21 farmers with sufficient data in the Paarl/Berg River region in order to be able to pool the data of the different enterprises. The farmers were asked to gather all the data necessary to complete the questionnaires. The interviews were conducted on the basis of a schedule of structured and semi-structured questions where each farmer was interviewed personally on his farm in order to complete the questionnaire together with the interviewer. The questionnaires were constructed in a uniform sequence in order to compare the different industries with each other. The questions themselves focused on a number of aspects, including the income of the enterprise as well as the different costs (production, establishment, labour and housing costs). Regular labour was the only fixed cost item included in the questionnaire because of the lack of sufficient farm records. The questionnaires (see *Appendix 2.2* and *2.3*) were specifically constructed to simplify the gathering of data but still represent the key variables necessary for the purpose of the study. Non-directly allocatable cost was excluded in the questionnaires because of the lack of sufficient farm records.

In the study done by Collins and Barry (1986), net returns to land, risk and management were estimated. In order to calculate the net return of an enterprise, the overhead costs must be deducted from the gross margin. A disadvantage in using net revenues is the availability of sufficient data. Margins above specified cost of the different enterprises were used in this study. The margin above specified cost is defined by subtracting costs from the gross value of production of an enterprise. The specific variable costs that are included (see *Appendix 2.2* and *2.3*) depend on the purpose of the calculations and the practical feasibility of the allocation. All comparisons between enterprises were based on this margin above specified cost.

One might question the use of gross revenues rather than net revenues to measure risk. According to Turvey and Driver (1987) the farmer prior to production knows the factor prices and factor quantities. For example, the price of seed and fertilizer and the amount of each to be applied has been consciously predetermined. Because input usage is related to conscious choice rather to random choice, no statistical distribution is readily verifiable. Collins and Barry (1986) found in their study that the proportion of systematic risk is lower than the non-systematic risk when the net revenues are used to calculate betas. The reasons for these differences arise from various sources. Collins and Barry (1986) used deflated values where in this study nominal values were used seeing that systematic risk captures inflationary effects common to all farm activities. Therefore, the measure used in this study captures inflationary effects common to all farm activities.

The data collected were further subjected to statistical tests. Box plots are an excellent tool for conveying location and variation information in data sets, particularly for detecting and illustrating location and variation changes between different groups of data (Chambers, 1983). A box plot provides an excellent visual summary of many important aspects of a distribution. The box stretches from the lower hinge (defined as the 25th percentile) to the upper hinge (the 75th percentile) and therefore contains the middle half of the scores in the distribution. The median is shown as a small box in the centre of the box. Therefore ¼ of the distribution is between this line and the top of the box and ¼ of the distribution is between this line and the bottom of the box. This box plot, comparing six enterprises for margin (rand per hectare) output, shows that enterprises have a significant effect on the margin with respect to both location and variation. Sweet melons have the highest margin response (about R43 000 per hectare). Table grapes have the least variable margin response with all of its readings being in one margin unit. Olives have the lowest margin response with R9 407 per hectare.

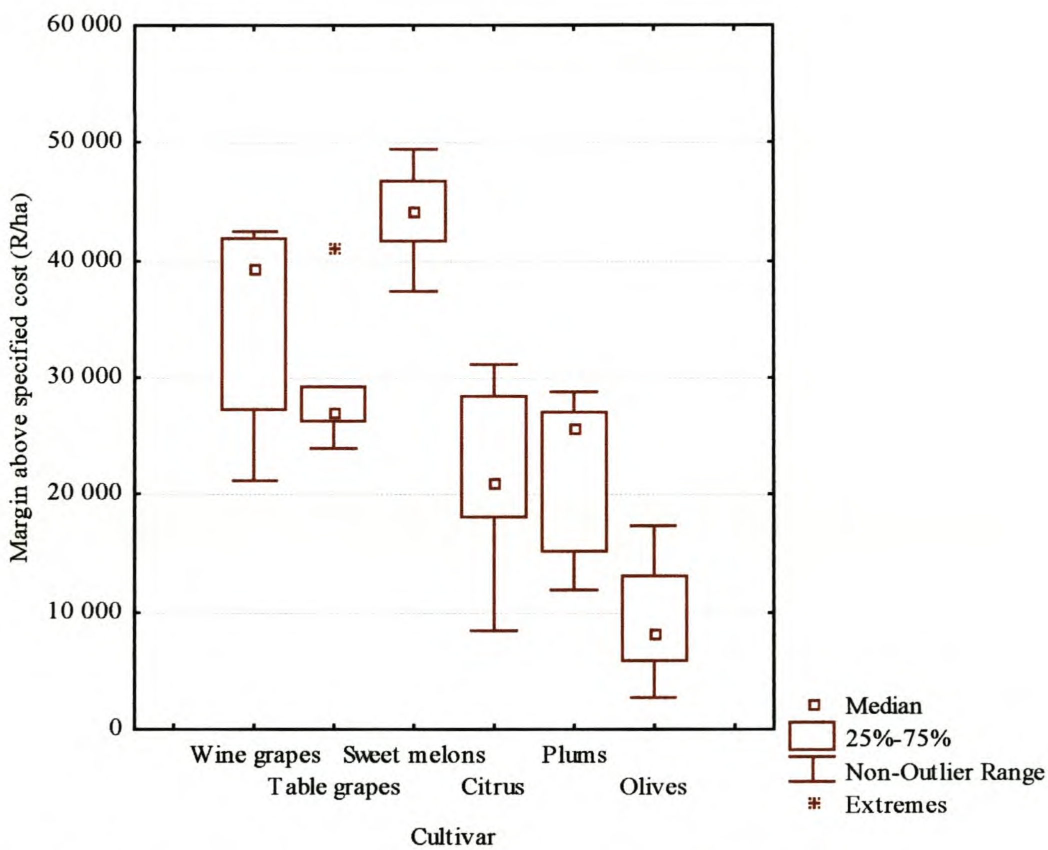

Figure 5.2: Box plots of the six enterprises in the Paar/Berg River region over the years 1997-2002

The data from wine grapes are higher than, for instance, sweet melons, which are more spread out, and have a negative skew. That the skew is negative can be determined by the fact that the upper whisker is shorter than the lower whisker.

There are two bordering values at a box plot for every enterprise. For instance, the largest value below the upper inner fence of wine grapes is R41 823 per hectare and the smallest value above the lower inner fence is R21 298 per hectare. For the data plotted in Figure 5.2, the minimum value is above the lower inner fence and is therefore the lower bordering value. The maximum value is the inner fences so it is not the upper bordering value. As shown in Figure 5.2, a line is drawn from the upper hinge to the upper bordering value and from the lower hinge to the lower bordering value. That is to determine the skewness of the data as indicated above for wine grapes.

Every score between the inner and outer fences is indicated by an "**o**", whereas score beyond the outer fences is indicated by a "*". Table grapes show a score (R41 111 per hectare) beyond the outer fence of R40 000 per hectare. In Figure 5.3 the different cultivars of wine grapes and table grapes together with the enterprises sweet melons, citrus, plums and olives are outlined in various box plots. The box plot provides an excellent visual summary of many important aspects of the distribution of data in the Paarl/Berg River region. As shown in Figure 5.3, Red globe shows a score (R42 391 per hectare) between the inner and the outer fence and indicated by "**o**".

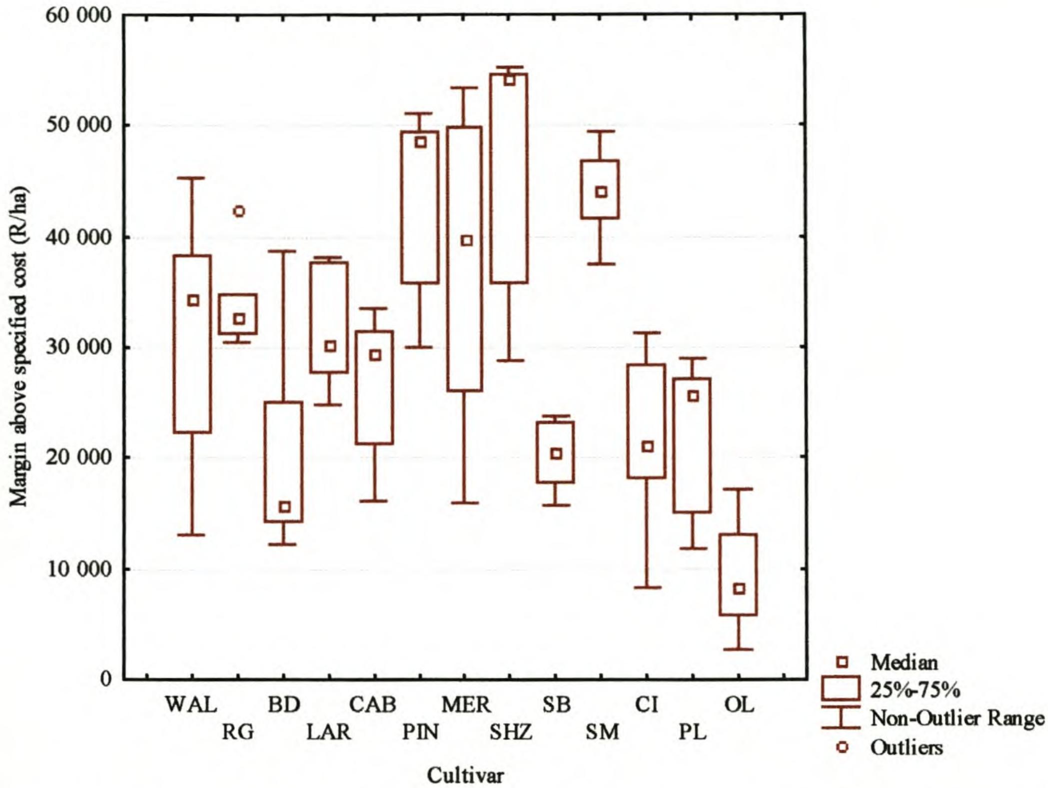

Figure 5.3: Box plots of the margin above specified cost for the different cultivars in the Paarl/Berg River region

5.4 Diversification in the Paarl/Berg River region

The removal of the sanctions after the first democratic elections in 1994 opened a new world market for South African agriculture, but the country's integration into the world economy necessitated the removal of reduction or artificial protective measures such as import tariffs and export incentives which they had previously enjoyed. Although new marketing opportunities developed for them in the markets abroad, international companies also increasingly entered the domestic market. Increased competition meant that local companies had to improve their competitiveness through acceptance of the 'best international practices' and by means of large-scale improvements in productivity and efficiency.

As recently as a decade ago, South African agriculture was characterized by subsidies and other concessions, which supported producers not only in difficult times but also in good times. A few years ago the last agricultural control boards were abolished and the agricultural sector were deregulated, resulting in an extremely dynamic environment. The globalisation of the world agro-food economy, coupled with an unprecedented deregulation of agriculture by the end of the 1990's, is a generally recognized fact. Both at the level of consumption and the level of production and distribution, the food economy has been restructured in radically new ways.

By international standards, South Africa has a poor natural resource base. Rainfall is unreliable and the country as a whole is subject to severe and recurrent droughts. Furthermore, only a small proportion of the land is suitable for cropping in the Western Cape.

Wine grapes and table grapes are the most important cultivated crops grown in this region. Smaller areas of plums, soft citrus and olives can also be found. Sweet melons and strawberries are planted in addition to wine and table grapes and serve as an excellent crop to diversify the different long-term enterprises during the stages that optimal production patterns are not reachable (Elsenburg Landbou-ontwikkelingsinstituut, 1990).[2]

In Figure 5.4 the different enterprises distributions in gross income (R per hectare) within the Paarl/Berg River region are given.

[2] *For futher information about different cultivars see "Suid Afrikaanse wynbedryf-statistiek nr 24, 2000".*

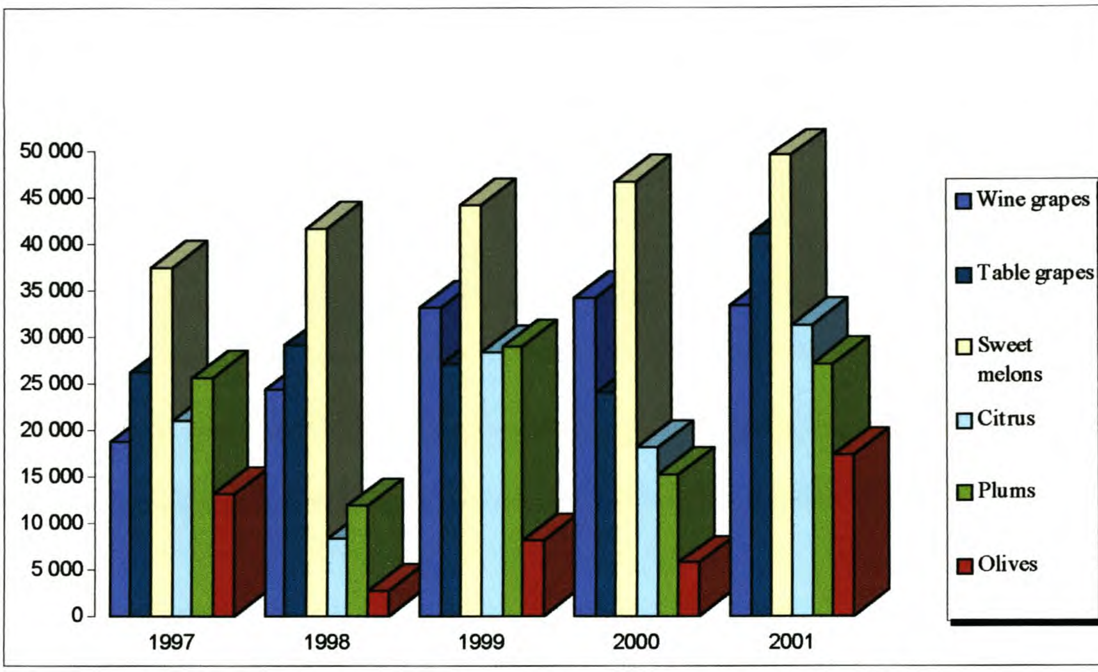

Figure 5.4: Enterprise distributions in gross income (R per hectare) within the Paarl/Berg River region

Diversification can also occur within an enterprise. With the fast growing technology, research and the opening of world markets, new cultivars are introduced to the market daily. The result is that cultivars can be marketed more widely and bring more variety in to the market.

Consumers are offered an expanding choice of varieties with new characteristics. One of the most fundamental requirements for profitability and survival over the long-term is to provide for the demand of consumer preferences. In recent years the Western Cape was known as an area where the production of seedless grapes was not executed in a very successful way. The deregulation of the markets changed this scenario drastically.

The swift changes in a producer's capital inputs will guarantee a better demand for his products, a longer production season and a better utilisation of the infrastructure with the same work force during the peak periods of the season. All these changes will directly and indirectly lower the effective management of risk.

A wide range of factors that is out of the control of farmers influences the production system(s) of an individual in a specific enterprise. With the deregulation of the agricultural sector, coupled with political, economical and natural uncertainties farmers are faced with an increasing risk. Diversified farming systems in the Paarl/Berg River area are important, because it is too expensive to leave scarce resources fallow for long periods. Economic realities like the diminution of profit margins require that all resources must be used as effectively as possible.

It is clear that risk is reduced through diversification and for the same amount of risk, diversification can increase returns. In order to utilise the new market opportunities, farmers will have to adopt a new approach not only to agricultural systems, but also the farming systems that they use.

However, managers who make use of the different diversification techniques must be well informed and familiar with the new and different strategies and diversified systems. New enterprises and techniques include new skills and management.

5.5 Deciduous fruit

5.5.1 Production areas

The main deciduous fruit producing areas of South Africa are the Western, Southern and Eastern Cape. In these areas warm, dry summers and cold winters prevail. The area producing deciduous fruit for fresh consumption during the 2000 season was estimated at 60 000 hectares and the area producing deciduous fruit for canning and dried fruit purposes was estimated at 15 000 hectares (Deciduous Fruit Grower, October 2001).

5.5.2 Production

Although some producers produce fruit for both canning and the fresh market (locally and internationally), it is estimated that there are about 2 500 producers of fruit for fresh consumption and about 1 000 producers for canned and dried fruit in the country. The production of deciduous fruit for 1999/2000 is estimated to be 1 461 054 tons, which is 76 802 tons or 5,5 percent more than in 1998/99. During the 1999/2000 seasons, plums and apricots reflected a decrease in production of 15 and 12 percent respectively. The production of deciduous fruit showed an annual average growth of 4.6 percent during the period 1995/96 to 1999/2000.

According to Saunders (1995) South African producers pay more for the development of a hectare of fruit trees than their counterparts in Chile and Argentina. While the cost of land, water, equipment and packing facilities is similar between the countries, South African producers have to provide for using permanent farm workers, and their orchards establishment costs are higher. These latter costs are probably the result of poorer soils and the availability of water in South Africa. In addition, producers in the South American countries do not compensate for the fact that they do not have to provide worker housing by paying higher wages.

5.5.3 Marketing

The Deciduous Fruit Board (DFB) was formed on 6 October 1939. The Board was formed under the auspices of the 1937 Marketing Act and was given statutory powers to arrange all export of deciduous fruit. The Marketing Act was based on the argument of inelastic demand for farm products, the averse climate in South Africa, the lack of information and the risk inherent to a free market system. These were all factors that justified state intervention in the agricultural sector. Changes and adjustments to the Marketing Act were made regularly, but perhaps the most significant was the formation of Unifruco in 1987, and the board's decision to appoint this organisation as its sole agent to export on its behalf (Deciduous Fruit Grower, October 2000). All decisions pertaining to export marketing were centralised in Unifruco and it controlled the entire associated infrastructure. In 1992 the Kassier Report (1992) on South African Marketing Schemes appeared, calling for the deregulation of the Control Boards. Both the local and export marketing of deciduous fruit are now free from government intervention. The exporting of fruit is subject to compliance with certain quality requirements and obtaining a PPECB (Perishable Products Export Control Board) certificate.

When the industry was deregulated in the early 1990's, the single marketing channel for export was abolished. At present there are about 50 exporters selling South African fruit abroad. As a result, South African products are now competing against each other on the international market and this had an adverse effect on prices.

During the 1999/2000 marketing season, approximately 357 319 tons of deciduous fruit were sold locally on the 16 major fresh produce markets, other markets and direct to retailers, which was 23 390 tons more than during the 1998/99 season. Preliminary indications are that 635 816 tons of deciduous fruit were exported in 1999/2000. This figure is 23 percent higher than the figure for 1998/99. During 1999/2000, deciduous fruit contributed approximately 25 percent to the gross value of horticultural production. The exporting of deciduous fruit is also a very important earner of foreign exchange for South Africa. During the 1999/2000 seasons, about 44 percent of deciduous fruit produced was exported and approximately 86 percent of gross value from deciduous fruit was earned in foreign exchange through exports.

In the Paarl/Berg River region, table grapes are the main enterprise in the deciduous fruit industry. La Rochelle, Bien Donne, Red Globe, and Waltham Cross are some of the cultivars that are produced in the Paarl/Berg River region. There is a wide range of cultivars in the table grape industry within the Paarl/Berg River region but because of lack of sufficient data and record keeping of producers over a specific time period only the above-mentioned cultivars were included in this study.

Four price categories exist, two for the export market (class 1 and 1½) and two for local markets. The highest price is paid for class 1 grapes, which are of superior quality. In addition to quality, prices are also determined by supply and demand, which vary on a weekly basis. The average price (see Table 5.1) paid per cultivar (class 1) in the Paarl/Berg River region was used in the calculation of the margins. These prices differ from other production areas, mainly because of difference in time of harvesting.

Table 5.1: Selling price ranges of table grapes cultivars in the Paarl/Berg River region (R per ton)

Cultivars	1997	1998	1999	2000	2001
Bien Donne	18 282	1 631	15 037	17 648	29 526
La Rochelle	39 377	35 130	32 387	38 011	63 596
Red Globe	7 031	6 273	5 783	6 78	11 356
Waltham Cross	23 907	21 329	19 663	23 078	38 611

The percentage cost structure per cultivar is outlined in Table 5.2. Labour- and packaging costs comprise the highest percentage of the costs.

Table 5.2: Structure of direct allocatable costs (percentage) in the table grape industry in the Paarl/Berg River region

Input	1997 (%)	1998 (%)	1999 (%)	2000 (%)	2001 (%)
Labour	37	46	45	44	42
Fertiliser	2	2	2	2	1
Pesticides	0	1	1	0	1
Weed killers	1	2	1	2	1
Fungicides	1	7	7	2	4
Packaging cost	47	34	34	40	41
Depreciation	10	7	7	8	8
Marketing cost	1	1	1	2	2
Total	**100**	**10**	**100**	**100**	**100**

The rate of replacement of table grapes with newly adopted and market related cultivars has a big influence on the yield and the profitability of the industry. The importance of good prices and high yields for profitability must be stressed because of the high cost structure that can affect the margins in the table grape industry. Competition with the Chilean grapes in the overseas market and the peak supply of Waltham Cross that decreases prices later in the season focuses more attention on early cultivars.

Margins that are used in this study are calculated as margin above specified cost, which is obtained if costs are deducted from the income.

Table 5.3: Margin above specified cost of different table grape cultivars (R per hectare)

Cultivars	1997	1998	1999	2000	2001
Bien Donne	12 144	7 381	6 002	8 864	2 086
La Rochelle	26 156	15 899	12 927	19 091	44 943
Red Globe	4 670	2 839	2 308	3 409	8 025
Waltham Cross	15 880	9 653	7 849	11 591	27 287

Table 5.4: Establishment costs in Paarl/Berg River region (R per hectare)*

Establishment costs	1996	1997	1998	1999	2000
Soil preparation	4 461	4 957	5 508	6 120	6 800
Plant material	7 873	8 748	9 720	10 800	12 000
Trellised material	6 114	6 794	7 549	8 388	9 320
Irrigation	5 248	5 832	6 480	7 200	8 000
Plastic	393	437	486	540	600
Other cost items	3 280	3 645	4 050	4 500	5 000
Total	27 372	30 413	33 793	37 548	41 720

*** The land value is not included in the total establishment cost.**

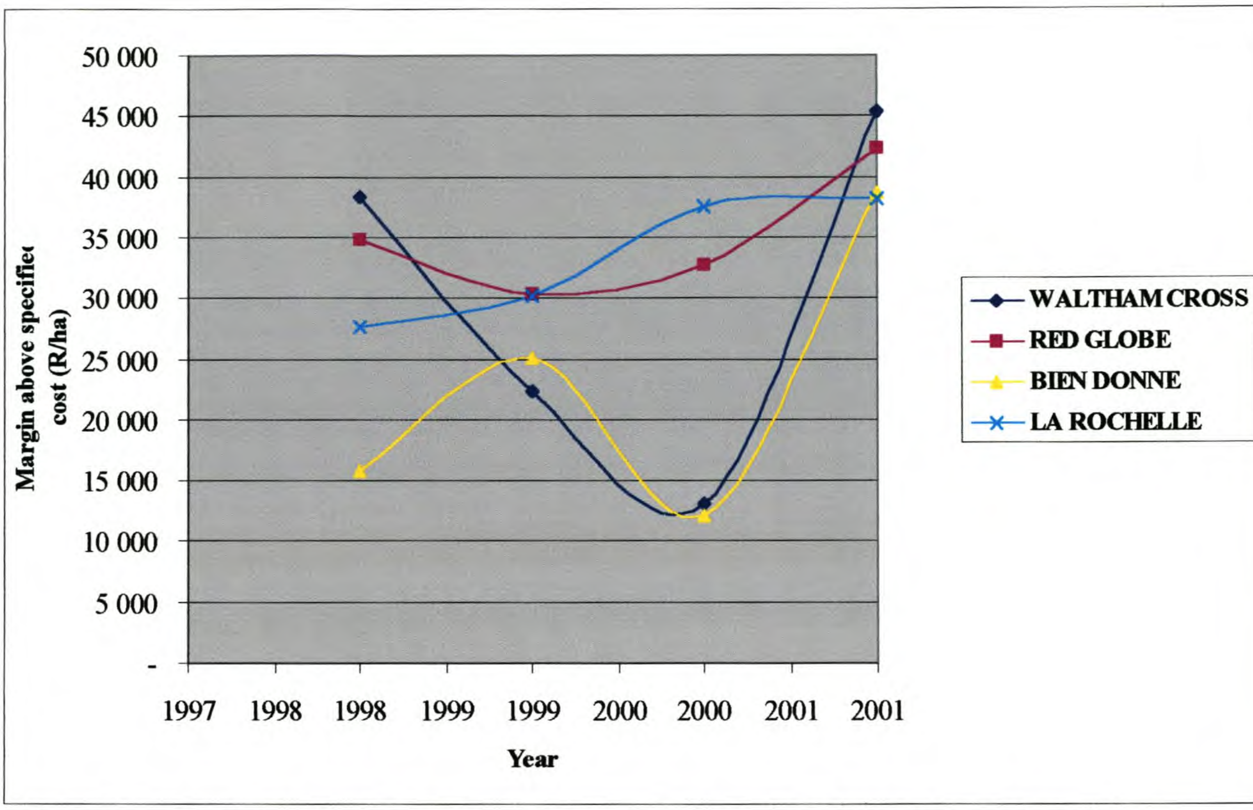

Figure 5.5: Comparing the different margin above specified cost of table grape cultivars in the Paarl/Berg River region

5.6 Viticulture

5.6.1 Production area

The wine region of the Western Cape is situated at the confluence of the Atlantic and Indian oceans, where temperatures are moderated by the cold Benguela current that flows up the West Coast of Africa. Its Mediterranean climate and its mountain slopes and valleys form an ideal habitat for growing vines. The climate in the Paarl region is typically Mediterranean, with long warm summers. Annual rainfall is about 650mm, just enough not to make irrigation crucial. Soils are mainly of three types: Table Mountain sandstone near the Berg river, granite in the vicinity of the town itself, and weathered shale to the north east. Favourable climate and soil conditions have led to the establishment of a strong wine-growing sector in the Western Cape, which is home to most of South Africa's wineries and account for 91 percent of production. Viticulture contributes to about 30 percent of the region's total horticulture income (SAWIS, November 2001).

5.6.2 Restructuring of the South African wine industry

Deregulation and access to export markets have created a profoundly new environment for the growers and cellars. In response to the havoc caused by periodic booms and busts, the industry created an intricate system of regulation, which was to last nearly eight decades. The lynchpin of the system was the Cooperative Winegrowers Association of South Africa or KWV (established as the 'Ko-operatieve Wijnbouwers Vereniging van Zuid-Afrika' in 1918). It not only set planting quotas for each and every grower, but was also charged with absorbing surplus production against a guaranteed minimum price per ton of grapes delivered. Until 1993, the KWV was also the sole exporter of South African wine. Starting with the effective abolition of the quota system in the late 1980s, the system has been deconstructed to the point where it is essentially market-driven. With the termination of trade sanctions against South African products and the opening of external markets in 1993, the need for a minimum price effectively fell away. Since then the centre of gravity in the industry has effectively shifted away from the KWV to the cooperative and estate cellars. In this brave new world, the latter have to forge their own strategies from planting programmes, to marketing and sales negotiations with buyers. Ineffective diversification can occur because of wrong allocation of cultivars farmland. The reason for this could be that the allocation of cultivars and hectares was based on the traditional criteria consisting of yield and consumers' choices and where the risk of each cultivar was not taken into consideration.

With the possibility of exports being foreclosed both legally and politically, the domestic market used to be heavily tilted in favour of a handful of big, local merchants, leaving especially cooperative cellars in a weak bargaining position. This situation has changed completely over the last five years. Going through a strenuous learning process, cellars have forged divergent strategies to realize the best possible price for their product in both local and overseas markets. While some stick to the 'staple' cultivars to be converted into lower-priced wines, brandy and grape juice concentrate, others have adopted a clear 'quality' strategy, involving a determined shift in planting programmes towards noble cultivars. This shift is not easy to bring about as new vineyards take three to four years to

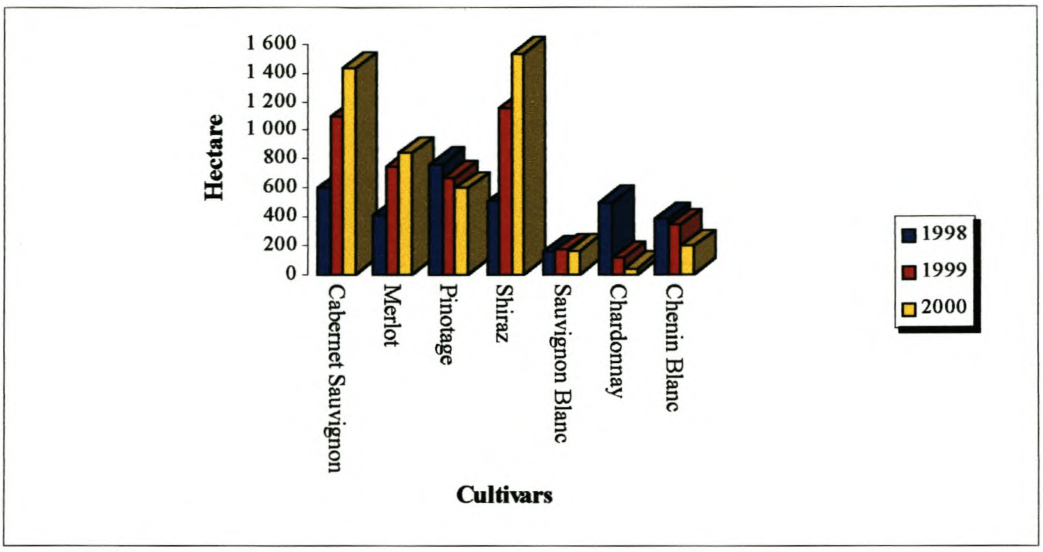

Figure 5.6: Area under wine grapes in hectare in South Africa
Source: SAWIS, 2001

From Figure 5.6 it is clear that Shiraz and Cabernet Sauvignon made up the largest area per hectare. The variety distribution of the different cultivars for 2001 is depicted in the following graphical presentation.

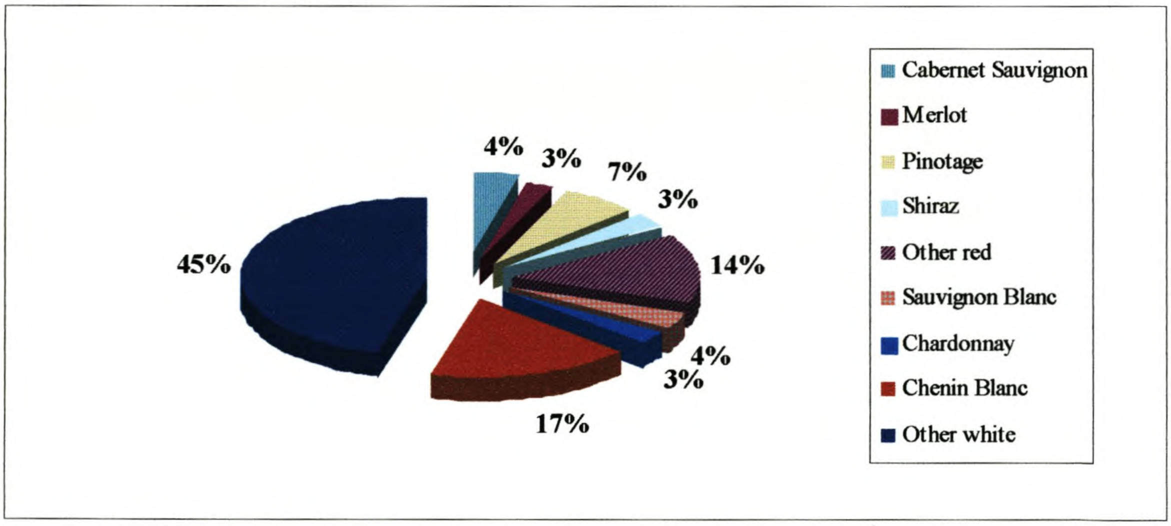

Figure 5.7: Cultivar distribution in 2001
Source: SAWIS, 2001

come into production and involve heavy capital expenditures in both new plantings[3] and in cellar equipment.

Adopting the new market ethos, cellar management is also reluctant to be too prescriptive as far as the 'right' cultivars are concerned. Instead they put their faith in price signals to nudge farmers away from the conventional cultivars towards those that fetch the most money in the market. As indicated above, the allocation of cultivars was based on traditional criteria of only yield and consumer preferences where the risk factor of each cultivar was not taken into consideration.

At present, 104 179 hectares are under vines in South Africa. Although ranking 19th in the world in terms of area under vines, South Africa is the sixth-largest wine producer, producing 3.3 percent of the world's wine.

The wine industry is labour intensive and provides a living to approximately 345 000 farm workers, including dependants, and 3 300 wine cellar personnel. Primary wine producers in South Africa are estimated at 4 515. Wine is mainly produced in the Western Cape and along the Orange River in the Northern Cape.

5.6.3. Production

The total area under wine grapes expanded by 1 387 hectare (1.3 percent) during 2000 to a total of 105 566 hectare. The cultivation of grapes in 2000 was 16 percent white and 84 percent red.

[3] *The establishment costs for wine grapes is the same as for table grapes in Table 5.4.*

Since South Africa's readmission to the world markets in 1994, there has been a greater focus on quality, accompanied by extensive replanting to cater for demand. Both internationally and domestically, supplies of white wine currently far exceed demand, while there is an increased shortage of red wine. In South Africa's case, too, excess white grape stock has been the result of the decline in the brandy market and cutbacks in the quantities of grapes used for distilling.

The growth in production coincided with a shift from white to red wine cultivars. In Figure 5.8 it is clear that the shift from white to red wine started between 1997 and 1998.

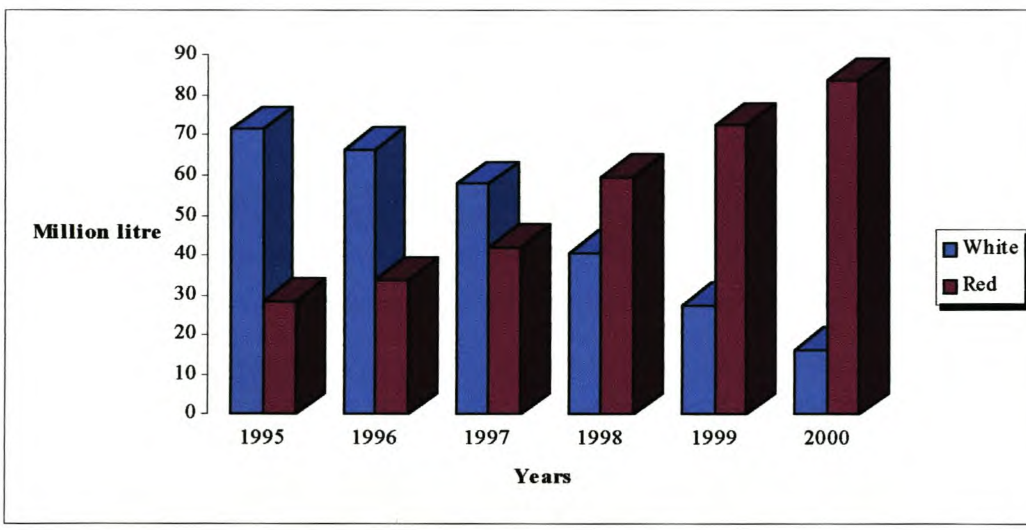

Figure 5.8: Shift from white wine to red wine production in South Africa
Source: SAWIS, 2001

The selling price ranges are calculated as the price of each cultivar times the yield per ton in each year. Non-producing grapes are also included into the calculations and are calculated as a percentage the total producing grapes.

Table 5.5: Selling price ranges of different wine grape cultivars in the Paarl/Berg River region (R per ton)

Cultivars	1997	1998	1999	2000	2001
Cabernet Sauvignon	15 120	22 888	28 800	42 400	41 296
Pinotage	23 760	36 720	43 200	60 000	58 500
Merlot	20 520	22 680	33 480	58 800	63 156
Shiraz	20 520	35 640	43 200	63 600	65 040
Sauvignon Blanc	17 901	22 500	25 200	32 000	30 450

The cost structure of the wine grape industry in the Paarl/Berg River region is summarized in Table 5.6. The wine industry is very labour intensive with an average of 38 percent of the total labour. Depreciation is also high, because of the considerable capital investment per hectare.

Table 5.6: Directly allocatable cost structure (percentage) of the red wine industry

Input	1997 (%)	1998 (%)	1999 (%)	2000 (%)	2001 (%)
Labour	39	38	38	38	38
Fertiliser	6	6	6	6	7
Pesticides	7	7	7	7	7
Fungicides	8	8	8	9	9
Depreciation	41	41	41	41	40
Total	**100**	**100**	**100**	**100**	**100**

Production of red wine varieties, namely Cabernet Sauvignon, Pinotage, Merlot and Shiraz, dramatically increased during the past four years. Although the grape production increased by 12.8 percent during 1999, the producers' income increased by only 1.6 percent, mainly due to a decrease of 4.8 percent in prices. Exports as a percentage of the good wine crop increased from 12 percent in 1994 to 21.7 percent in 1999.

In Table 5.7 the various cultivars that were included in the study margins per hectare are outlined over the years 1997 to 2001.

Table 5.7: Margin above specified cost of the different cultivars in the wine grape industry between 1997-2001 in the Paarl/Berg River region (R per hectare)

Cultivars	1997	1998	1999	2000	2001
Cabernet Sauvignon	16 101	21 333	29 427	33 497	31 431
Pinotage	29 933	35 733	49 427	51 097	48 635
Merlot	15 893	26 013	39 827	49 897	53 291
Shiraz	28 853	35 733	54 227	54 697	55 175
Sauvignon Blanc	15 713	17 733	23 727	23 097	20 585

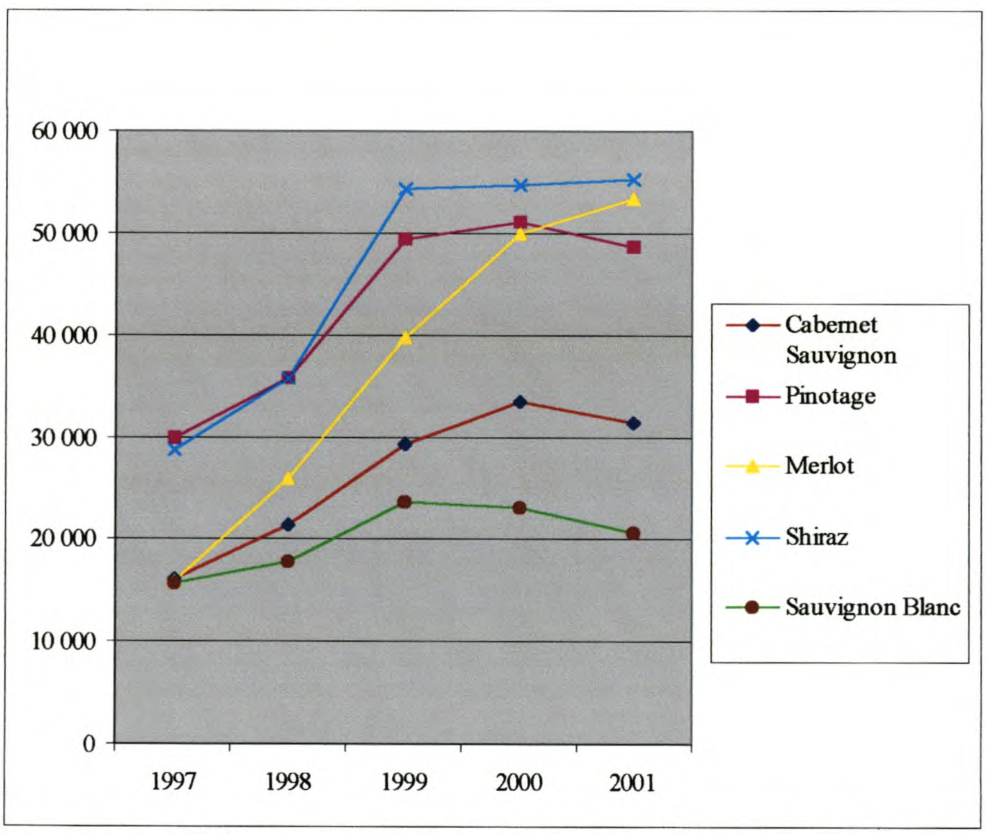

Figure 5.9: Comparison between the margin above specified cost of different wine grape cultivars in the Paarl/Berg River region (R per hectare)

5.7 Other enterprises

5.7.1 Citrus industry

5.7.1.1 Areas of production

Production of citrus in South Africa is widespread throughout South Africa. Citrus is grown where subtropical conditions; warm to hot summers; and mild winters; prevail. There is a large variation in input costs, varieties, production techniques, climate, age and distribution of the trees across the production areas in South Africa. The South African Citrus industry currently supplies more than 50 million cartons to more than 60 different countries across the globe.

5.7.1.2. Production

On average, citrus fruit production increased by 7 percent per annum between 1995/96 and 1999/2000. According to statistics from the FAO (Food and Agriculture Organization of the United Nations), South Africa accounts for about 1.5 percent of the world production of citrus fruit and 13.5 percent of production in Africa.

Table 5.8: Citrus production for the past five productions seasons (1 February–31 January) (R per hectare)

	1995/96	1996/97	1997/98	1998/99	1999/2000
Citrus	72 531	85 268	85 132	79 663	118 920

Source: National Department of Agriculture, 2002

5.7.1.3 Marketing

The citrus industry is export orientated. Exports increased from 1995/96 to 1999/2000 by 23 percent and the earnings seems to raise its export earnings even higher in the next year or two. During 1999/2000, about 63.4 percent of the crop was exported, 0.3 percent less than the volume exported during 1998/99. Total exports of citrus fruit decreased owing to excessive rain during the 1999/2000 seasons hampering the spraying of orchards. This adversely affected fruit quality. A certificate from the PPECB (Perishable Products Export Control Board) is needed and phytosanitary requirements and quality standards must be adhered to for the export of citrus fruit.

During 1999/2000, about 12 percent of citrus production was sold on the fresh produce markets in South Africa, 11 percent was sold directly to retailers and 26.7 percent was taken in for processing. There was a noticeable decrease in the prices of citrus fruit sold on the 16 fresh produce markets during 1999/2000 compared to 1998/99.

5.7.2 Sweet melon industry

5.7.2.1 Area of production

Melons have been grown in South Africa for many years but until fairly recently, melon production was mostly confined to the Western Cape.

The choice of cultivars was limited, keeping the melon industry static. The poor disease-resistance (particularly to leaf diseases) of these cultivars meant that melons could only be grown in areas with very dry and hot summers. The introduction of new disease resistant varieties stimulated melon production in many more areas in South Africa. Not only did new cultivars differ from the old in terms of disease resistance, they also introduced a greater choice into the market. Consumers were offered an extended choice of melon varieties with new flavours and colours. Sweet melons serve as excellent alternative in the Paarl/Berg River region to plant in-between long-term crops such as wine grapes and table grapes.

The cultivars used in this study are Rock and Gallia. Opportunities for sweet melon growers are increasing as the world demand is rapidly growing. South American countries immediately reacted to market signals but the production and export of melons in South Africa has subsided over the last fifteen years. Only a decade ago South America's melon production was twice the size it is today. The production of 800 000 to 900 000 cartons has declined to 300 000 cartons at present.

A prerequisite for the successful export of melons is that the fruit must be at the right stage of ripeness when picked, of accessible size, have a healthy appearance and be free from lesions. One of the biggest problems in melon production is getting the produce to on the markets in the Northern Hemisphere in a good condition. Airfreight is decreasing and exporters will focus more on sea freight transportation. The cost of see freight is much cheaper than airfreight (average R1.50/kg against R7.50/kg to R12.50/kg). Therefore, to increase export volumes, methods together with export companies must be found preserve the quality of the produce.

Table 5.9: Percentage cost structure of the sweet melon industry in the Paarl/Berg River region

Input	1998 (%)	1999 (%)	2000 (%)	2001 (%)
Fertilizer	21	22	22	22
Pesticides	9	10	10	10
Fungicides	0	0	0	0
Weed Killers	6	6	6	6
Packaging	17	17	18	18
Labour	14	14	14	15
Depreciation	33	31	30	29

Table 5.10: Gross income over the years 1998 to 2001(R per hectare)

Enterprise	1998	1999	2000	2001
Sweet melon	54 652	58 140	61 852	65 800

Table 5.11: Margin above specified cost of the sweet melon industry in the Paarl/Berg River region (R per hectare)

Enterprise	1998	1999	2000	2001
Sweet melon	42 624	45 183	47 721	50 488

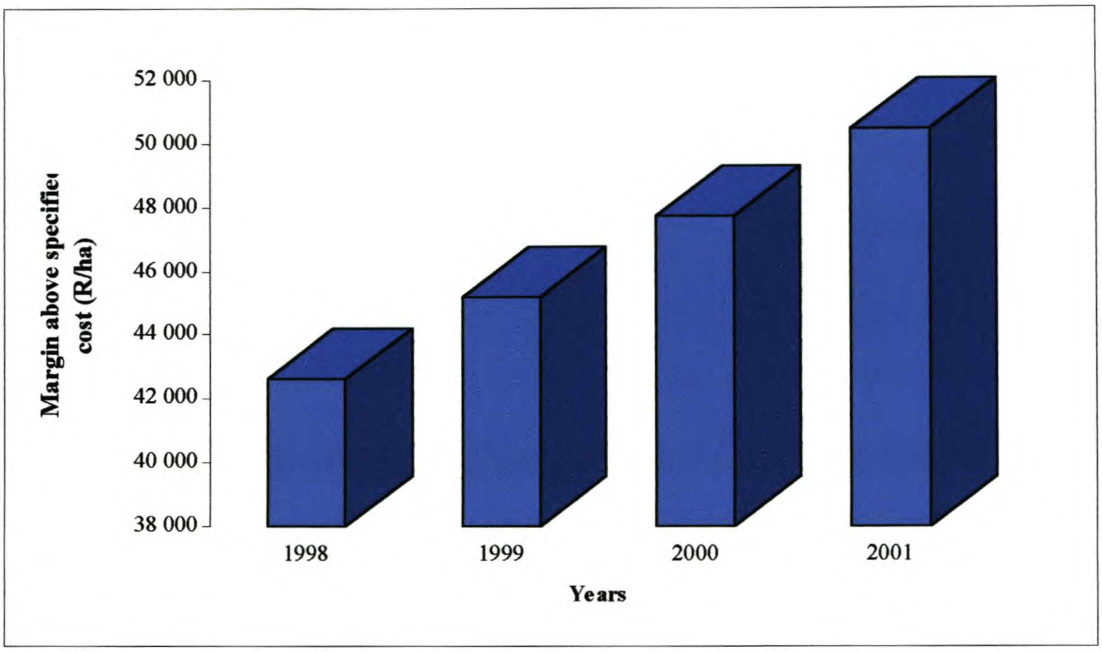

Figure 5.10: Gross income of the sweet melon industry in the Paarl/Berg River region in (R per hectare)

5.7.3 Olive industry

5.7.3.1 Area of production

The rapidly increasing local demand for olive oil and table olives has prompted many grape producers to investigate the option of cultivating olives as a secondary, complementary activity. Table olives and olive oil are, like wine, associated with an element of mystique. The natural synergy between wine and olives is obvious; there is also a lot of sense in the practical implications of a combined venture – for example the Cape's eminently suitable Mediterranean climate as well as the possibility of using seasonal labour to harvest the olives in the "quiet" winter months, from March to July.

However, to an industry in which periodic surplus situations have long been a cause of great concern, the most significant factor is the excellent marketing prospects for olives.

Plantings in South Africa have increased dramatically over the past decade and approximately 10 000 hectares are now planted to olives, with the Western Cape accounting for approximately 90 percent of production. The task of comparing products out of the agricultural sector is not trivial. If it is to be done correctly, then it is important to establish what makes product profitable.

5.7.3.2 Marketing

In the case of olives, the profit margins lie in the added value that is in the processed product or, what the consumer will absorb. According to a producer in the Paarl/Berg River region, a packet (200g) of olives retails at R4.00 in a supermarket. The farm sells fresh olives at R1.00/100g or R10/kg. Transport and packaging costs account for a further R1.10. Marketing varies, depending on the distribution network and can account for much as 25 percent of the retail cost. Therefore, the answers do not lie in the absolute figures in the cost of production, but in what the market can absorb. It is important to bear in mind that olive trees have the tendency to produce every second year with full production in the third year. Not an all or nothing, but in general a production of a ratio of 3:1. This factor must be taken into account in the construction of a farm portfolio.

Local olives have a competitive edge over other enterprises. The cost of hand picking olives is prohibitive in European countries. Where this is the case the table olives are then used for oil production. As far as table olives are concerned, South Africa has a competitive export edge. Compared to global plantings, our industry is diminutive, but what the industry lacks in size, it makes up for in quality. The skill of our dexterous farm workers and South Africa's reputation as a supplier of high quality fruit make the exports of the table olives very feasible comparing in the light of the fact that most olives are mechanically harvested overseas. Subsidies on olive oil in European countries enable overseas suppliers to undercut the prices of the local product, flooding the market and forcing local suppliers to reduce profit margins. Oil olives fetch R2.50/kg unprocessed, i.e. 20 percent of table olives.

Important factors when comparing the various products from the agricultural sector are perishability and theft. An olive cannot be eaten off the tree, and once it has been processed, it has a shelf life of a year or more. In other words, it is not seasonal as are the other enterprises in the portfolio. It is clear, then, that table olives for the export market are a good option to consider.

5.8 Conclusion

It is clear that farming in the Paarl/Berg River region entails a high risk because of the extreme climatic conditions that occur through the year.

With the deregulation of the agricultural sector through the removal of the agriculture control boards and subsidies, the sector has changed into an extremely dynamic environment. Both at the level of consumption and the level of production and distribution, the food economy has been restructured in radically new ways. The removal of sanctions opened a new world market for South African agriculture, but the country's integration into the world economy necessitated the removal or reduction of artificial protective measures such as import tariffs and export incentives which they had previously enjoyed. Although new marketing opportunities developed for them in the markets aboard, international companies also increasingly entered the domestic market. Increased competition meant that local companies had to improve their competitiveness through acceptance of the 'best international practices' and by means of large-scale improvements in productivity and efficiency.

The main enterprises that are cultivated in the Paarl/Berg River region are wine grapes, table grapes, citrus, plums, sweet melons and olives. Wine grapes and table grapes are the most important crops in the study area. Smaller areas under production of plums and soft citrus can also be found. Sweet melons and strawberries are planted in addition to wine and table grapes and serve as an excellent crop to diversify the different cultivations.

The margin above specified cost of the different enterprises can be summarized over the years 1997-2001.

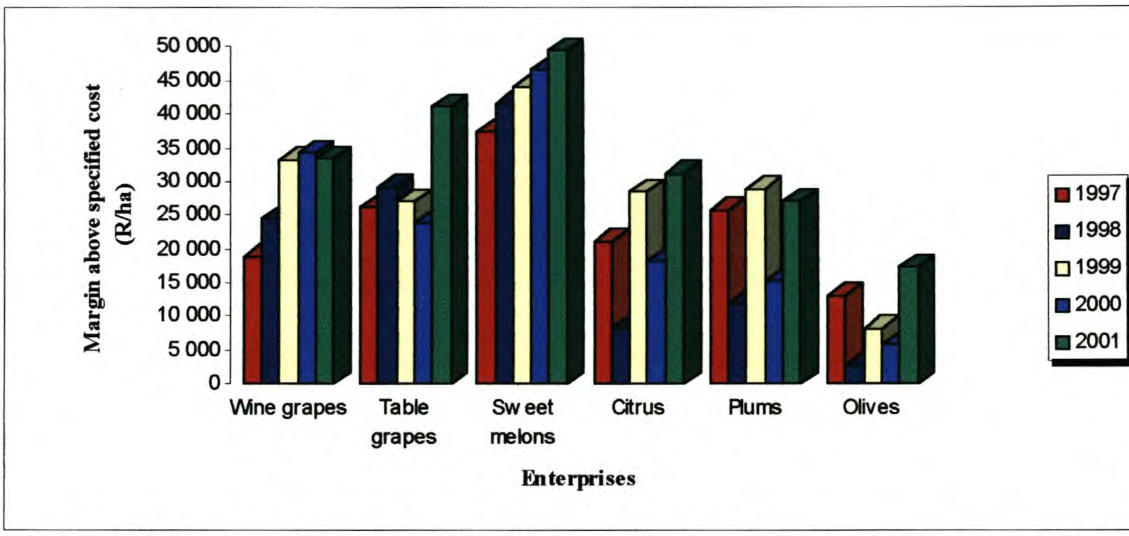

Figure 5.11: Margin above specified cost distribution in the Paarl/Berg River region over the years 1997-2001 (R per hectare)

Favourable climate and soil conditions have led to the establishment of a strong wine-growing sector in the Western Cape, which is home to most of South Africa's wineries and accounts for 91 percent of production. Viticulture contributes to about 30 percent of the region's total horticultural income. As indicated in Section 5.4.1, the allocation of cultivars in the past was based on traditional criteria of only yield and consumer preferences where the risk factor of each cultivar was not taken into consideration. In the next chapter risk will play an important role in selecting cultivars for the producers farm portfolio.

Sweet melons serve as an excellent alternative in the Paarl/Berg River region to plant in-between long-term crops such as wine grapes and table grapes. Income from sweet melons tends to increase systematically with the exchange rate of the Rand against the American dollar ($) over the years. As seen in Figure 5.10, sweet melons tend to have the highest margins of the enterprises.

In the case of olives, the profit margins lie in the added value; therefore the answers do not lie in the absolute figures in the cost of production, but in what the market can absorb. It is important to bear in mind that olive trees have the tendency to produce every second year with an optimal production in the third year. This factor must be taken into account in the construction of a farm portfolio.

Profitability in the agricultural sector is slowly starting to improve. The sharp decline in the value of the Rand improved various producer prices in the export industry over the last quarter of 2001. Along with all the changes through deregulation, risk has increased for producers. Risk averse producers can manage their risk - climatically as well as market risk by diversifying their portfolio on a farm and in the region to spread the risk over different enterprises and cultivars. Ineffective diversification occurs because of wrong allocation of cultivars and farmland. The reason for this could be that the allocation of cultivars and hectares was based on the traditional criteria consisting of yield and consumers' choices where the risk of each cultivar was not taken into consideration. In the next chapter, risk will play an important role in the planning of the farm portfolio.

CHAPTER 6

APPLICATIONS OF VARIOUS MODELS FOR ENTERPRISE DIVERSIFICATION IN THE PAARL/BERG RIVER REGION

6.1 Introduction

The purpose of this chapter is to introduce numerically and graphically the concepts that have been explained in the previous chapters. The is chapter is divided into three sections: In Section 6.2 the Markowitz portfolio selection model is applied to the data by using a Microsoft Excel computer program to construct the efficient frontier. Efficient diversification facilitates efficient portfolios (lying on the efficient frontier), where the highest return is obtained for each level of risk. The results of diversification were compared on a risk-return basis, as suggested by Markowitz.

In Section 6.3 the Single Index Model (SIM) is applied to construct the optimal efficient frontier. The SIM reduces dramatically the amount of work in tracing the efficient frontier. The answers of the different techniques are compared in order to see how much there is in common between the optimum portfolios.

There is a price to pay for the computational simplicity of the SIM: the quick calculations produce a portfolio that is not necessarily Mean variance (MV) efficient and the farmer is confronted with into a sub optimal strategy.

Section 6.4 focuses on the amount of systematic and non-systematic risk in agriculture. Beta coefficients and the theory of the Capital Asset Pricing Model are used to examine systematic risks in agriculture. Options to reduce systematic risk within agriculture will be discussed.

6.2 Markowitz portfolio construction

In this section the Markowitz portfolio construction problem as discussed in Chapter 3 and Chapter 4, can be generalized into the case of many risky enterprises and one risk-free investment (farm rental land). According to Bodie *et al.* (1999), this problem can be divided into three parts. The first step is to identify the risk-return combinations available from the set of risky enterprises. Next, by finding the portfolio weights that result in the steepest Capital Allocation Line (CAL) must identify the optimal portfolio of risky enterprises. Finally, a complete portfolio can be constructed by mixing the risk-free asset with the optimal risky portfolio.

6.2.1 Risk and return of enterprises in the Paarl/Berg River region

The Farm Sector Portfolio[1] (market portfolio) developed in this study is comprised of six enterprises in the Paarl/Berg River region, wine grapes, table grapes, citrus, plum, olive and sweet melon. Wine grapes can further be divided in to five cultivars and table grapes into four cultivars. Historical time series data of the margin above specified cost of the different enterprises were used. Therefore, the relationship between assets returns and risk has to be estimated by using *ex post* data. That is, farm plans are chosen on the basis of each activity's contribution to the mean and the variance of the Farm Sector Portfolio.

Enterprises were ranked according to Sharpe's model (Alexander and Francis, 1986), which also incorporate risk (S_p = reward/total risk) in the performance evaluation. Reward is

[1] *Portfolio consisting out of diversified agricultural activities in the Paarl/Berg River region.*

taken as the margin above specified cost of the different enterprises in the Farm Sector Portfolio and total risk as the portfolio standard deviation (see *Appendix* 3).

The consideration of both risk and return are illustrated with the evaluation of investment performance in Table 6.1 where data of the six main enterprises in the Paarl/Berg River region are summarized. The enterprises are rated from one to six according to the Sp reward to risk levels.

Table 6.1: Return parameters for enterprises in the Paarl/Berg River region for the period 1997-2001 (R per hectare)

Enterprises	Portfolio Mean	Portfolio Standard Deviation	Sp (Reward/ risk)	Ratings
Sweet melons	43 863	4 629	9.5	1
Table grapes	29 478	6 770	4.4	2
Wine grapes	34 443	9 568	3.6	3
Plums	21 743	7 686	2.8	4
Citrus	21 447	9 038	2.4	5
Olives	9 407	5 802	1.6	6

Sp = reward to risk rating of the six enterprises included in this study

In Table 6.2 specific cultivars for table and wine grapes are included for the Paarl/Berg River region. The risk-return evaluation of investment performance is demonstrated where Shiraz would be preferred on a return basis over all the other activities, but not on a reward/risk basis. It is clear that only the S_p levels give a true indication of enterprise performance. An S_p ratio of 9.5 (sweet melon) for example means that the owner of the portfolio was rewarded 9.5 percentage points of return for each percentage point of standard deviation. This measure should therefore be used when new enterprises are considered for cultivation on a specific farm.

In an efficient capital market, where risk is also considered in the investment process, there normally exists a strong relationship between these two parameters, for the higher the risk, the higher the return. According to the efficient market hypothesis, Merlot with the highest risk should have had the highest return. This divergence can be explained by the inefficiency of the market or a lack of data.

Table 6.2: Return parameters of enterprises and cultivars in the Paarl/Berg River region for the period 1997-2001 (R per hectare)

Enterprises	Symbol	Mean return	Standard deviation	Sp (Reward/Risk)	Ratings
Sweet melons	SM	43 863	4 629	9.5	1
Red Globe	RG	34 319	4 809	7.1	2
Sauvignon Blanc	SB	20 171	3 435	5.9	3
La Rochelle	LAR	31 704	5 914	5.4	4
Pinotage	PIN	42 965	9 515	4.5	5
Shiraz	SHZ	45 737	12 516	3.7	6
Cabernet Sauvignon	CAB	26 358	7 358	3.6	7
Plums	PL	21 743	7 686	2.8	8
Waltham Cross	WAL	30 697	12 896	2.4	9
Citrus	CI	21 447	9 038	2.0	10
Merlot	MER	36 984	15 858	2.3	11
Bien Donne	BD	21 191	10 942	1.9	12
Olives	OL	9 407	5 802	1.6	13

In real life farmers (and other investors) are constantly faced with more than two risky assets/enterprises to choose from. Suppose that there are n risky enterprises and one riskless asset. The general Lagrange functions as described in Levy and Sarnat (1984) can be used to solve the equations. The system of n equations in n unknowns is in principle solvable, but in practice its solution is not a simple task when n is large. Several computer programmes can be used to solve such linear systems of simultaneous equations easily and quickly in order to generate the efficient frontier, provided of course n is not too large. In this study Microsoft Excel were used to demonstrate the construction of the efficient frontier. According to Bodie *et al.* (1999) Excel is far from the best program for this purpose and is limited in the number of assets it can handle, but by using the Excel portfolio optimiser (SOLVER) it can illustrate concretely the nature of the calculations used in more sophisticated "black box" programs[2].

The risky assets in this study are 13 common enterprises in the Paarl/Berg River region. A historical record of the annual rates of return on these enterprises for the five years 1997-2001 was used to estimate the relevant parameters - the mean return (μ_i) and the standard deviation (σ_i) of each enterprise and the covariances (σ_{ij}) for all pairs of different enterprises (i, j = 1,2, ..., 13). Summarized from *Appendix 3,* the estimated mean return and the standard deviations of returns are given in Table 6.2, which also list the enterprise by name.

The working formula for computing the portfolio standard deviation is the following:

$$\text{Minimize portfolio variance} = \sigma_p^2 = \sum_{i=1}^{n} x_i^2 \sigma_i^2 + 2\sum_{i=1}^{n}\sum_{j=1}^{n} x_i x_j \sigma_{ij}$$

Subject to the constraints:

1) $$\mu_p = \sum_{i=1}^{n} x_i \mu_i$$

2) $$\sum_{i=1}^{n} x_i = 1$$

3) $$x_i \geq 0$$

The non-negativity constraint is an inequality constraint and it is therefore impossible to construct a Lagrange function therefore, mathematical programming techniques must be applied (Levy and Sarnat, 1984). The function to be minimised (portfolio variance) is

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[2] *Various quadratic programming computer programs are available, such as MPOS or IMSL. A program based on the reduced gradient algorithm, PHIMAQ, developed by Electricite de France can also be used. The SOLVER program was chosen because of the availability of the program and the consumer friendly way of using the program.*

quadratic and constraints 1 and 2 are linear, therefore quadratic programming can be used to find the efficient investment strategy. The technique involves complex mathematics.[3] In this study Microsoft Excel optimisation program (SOLVER) was used to demonstrate the construction of the efficient frontier.

The correlation matrix for the 13 enterprises is shown in *Appendix 4*. Each element in the correlation matrix represents the correlation coefficient ρ_{ij} between the corresponding pair of activities of enterprises *i* and *j*. The correlation matrix is also symmetric, and its diagonal elements are all equal to 1.00 (the correlation of any enterprise to itself is always 1.00). Mostly low and even negative correlations were observed for the return on the various enterprises. According to Levy and Sarnat (1984) this would be the ideal condition to obtain the highest benefit from diversification. The most ideal combination in a portfolio, if only correlations are considered, would be Waltham Cross and Sauvignon Blanc, where $r = -0.62$. This moderate negative correlation implies the situation where Waltham Cross return increases while at the same time Sauvignon Blanc return decreases.

The weights that will be attached to the different enterprises in the construction of the efficient portfolio would be positively influenced by these low and negative correlations, apart from the risk and return characteristics of each enterprise.

The covariance matrix (see *Appendix 5*) were calculated using the relationship Cov $(r_i, r_j) = \rho_{ij}\sigma_i\sigma_j$. as described in Chapter 3 (see Equation 3.3.) The minimum-variance portfolio can be calculated for a targeted expected return. These risk-return opportunities are summarized by the minimum-variance frontier (efficient frontier) of risky assets. The frontier is a graph of the lowest possible portfolio variance that can be attained for a given portfolio expected return, meaning that a higher return could not be attained for that specific risk level. The plot of these return-standard deviation pairs is presented in Figure 6.1.

According to Levy and Sarnat (1984) there exist two main types of efficient frontiers that are considered in portfolio analysis in capital markets: one is the efficient frontiers of

[3] *More information can be found in any textbook of non-linear programming, like Huirne et al. (1997).*

portfolios in which both long and short positions are allowed (the proportions x_i may be both positive and negative), while the other consists of efficient portfolios without short positions (derived subject to nonnegativity constraints $x_i \geq 0$ for all $_i$). In the capital markets, positive proportions represent stocks held "long", i.e. that is stocks purchased and included into the portfolio. Negative proportions represent stocks held "short", these are stocks actually owned by somebody else that are borrowed and sold, using the proceeds of such short sales to augment the holding of other stocks. The shorted stocks have to be returned to its pre-owner at a pre-agreed date or on demand. For agricultural products, short sales (negative investments) are not feasible. The efficient frontier represented in Figure 6.1 is similar to the frontiers in the capital markets, being convex towards the return axis (Francis, 1976). When short sales (negative investments) are prohibited, single enterprises may lie on the frontier. For example, the enterprise with the highest expected return must lie on the frontier, as that enterprise represents the only way to obtain that return.

Table 6.3 gives the investment proportions represented in percentage hectare been allocated to the different enterprises and presents a number of points on the frontier. The proportions (weights) are thus the participation levels of the individual enterprise in the portfolio (Francis, 1976). These weights are affected by the standard deviation of the each enterprise, as well as the correlation of that enterprise to other enterprises in the portfolio. The first row in Table 6.3 gives the required mean and show the resultant standard deviation of efficient portfolios. Note that the efficient frontier cannot obtain a mean return less than R9 407 per hectare (which is the mean for olives, the enterprise with the lowest mean return) or more than R45 737 per hectare (corresponding to Shiraz, the enterprise with the highest mean return).

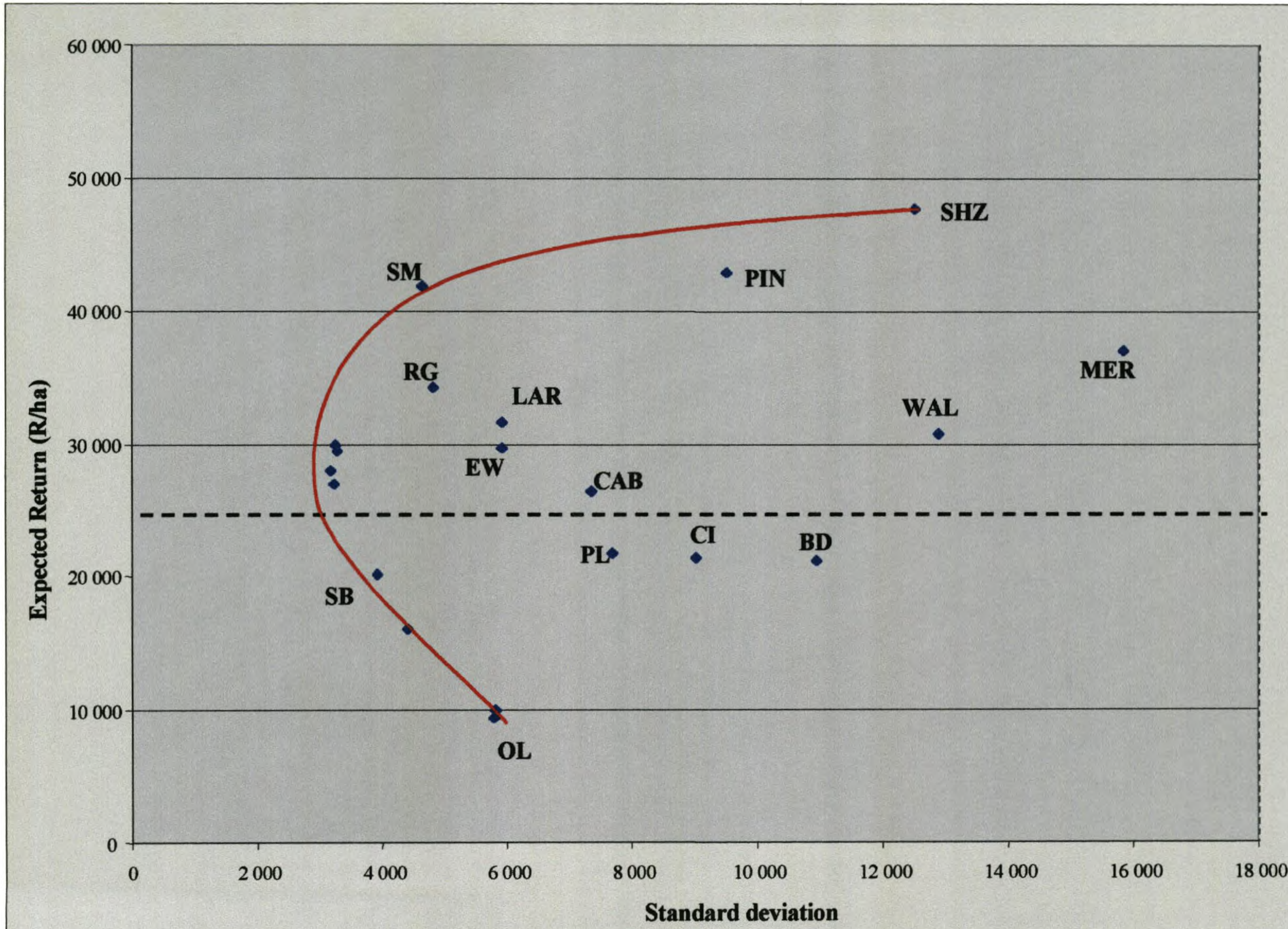

Figure 6.1: Efficient frontier with expected return-standard deviation pairs

The last 11 columns show the portfolio weights of the 13 enterprises in the optimal portfolios. It can be seen that the weights are never negative, because of the non-negativity constraint. The efficient portfolios include a relative small number of enterprises in positive proportions and the remaining activities are omitted (their proportions are $x_i = 0$).

It is important to notice that despite the fact that Shiraz offers the highest mean return, the weights of sweet melon, Red Globe and Cabernet Sauvignon is generally higher in the portfolio. According to Levy and Sarnat (1984) this can be due to the lower correlations of sweet melon, Red Globe and Cabernet Sauvignon with other enterprises, and it illustrates the importance of diversification when forming efficient portfolios. Notice that all the individual enterprises lie to the right, inside the frontier (see Figure 6.1). The reason for this is that risky portfolios constituted of a single asset are inefficient. All the portfolios that lie on the minimum-variance frontier form the global minimum-variance portfolio and upwards provide the best risk-return combinations, and are therefore candidates for the optimal portfolio.

The part of the frontier that lies above the global minimum-variance portfolio (the scattered line in Figure 6.1) is called the efficient frontier. For any portfolio on the lower portion of the minimum-variance frontier, there is a portfolio with the same standard deviation and a greater expected return positioned directly above it. Hence, the bottom part of the minimum-variance frontier is inefficient. The enterprises that lie underneath the global minimum-variance line are plum, olive, citrus, Sauvignon Blanc, and Bien Donne. These enterprises will not be included into the portfolio. Only eight of the thirteen enterprises are included in the optimal portfolios and lie above the global minimum-variance line, whilst five of the enterprises lie below the global minimum-variance line and will be considered as inefficient.

Table 6.3: The number of points on the efficient frontier along with the weights of each enterprise

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Mean	9 407	10 000	12 000	16 000	27 000	28 000	29 000	29 500	30 000	45 000	45 736
Standard deviation	5 801	5 815	5 916	4 415	3 238	3 188	5 916	3 280	3 268	9 283	12 515
Waltham Cross	0.00	0.00	0.00	0.02	0.05	0.06	0.06	0.04	0.06	0.00	0.00
Red Globe	0.00	0.00	0.00	0.02	0.08	0.07	0.16	0.07	0.07	0.00	0.00
Bien Donne	0.00	0.00	0.00	0.00	0.00	0.09	0.00	0.00	0.00	0.00	0.00
La Rochelle	0.00	0.00	0.00	0.02	0.03	0.08	0.04	0.03	0.03	0.00	0.00
Cabernet Sauvignon	0.00	0.00	0.00	0.02	0.00	0.08	0.00	0.00	0.00	0.00	0.00
Pinotage	0.00	0.00	0.00	0.03	0.00	0.06	0.05	0.00	0.00	0.00	0.00
Merlot	0.00	0.00	0.00	0.03	0.00	0.07	0.00	0.00	0.00	0.00	0.00
Shiraz	0.00	0.00	0.00	0.03	0.00	0.06	0.00	0.00	0.00	0.61	1.00
Sauvignon Blanc	0.00	0.00	0.11	0.00	0.35	0.09	0.05	0.31	0.30	0.00	0.00
Sweet melons	0.00	0.00	0.00	0.03	0.27	0.06	0.31	0.37	0.38	0.39	0.00
Citrus	0.00	0.00	0.03	0.01	0.00	0.09	0.00	0.00	0.00	0.00	0.00
Plums	0.00	0.05	0.08	0.06	0.07	0.09	0.06	0.06	0.05	0.00	0.00
Olives	1.00	0.95	0.77	0.73	0.16	0.10	0.27	0.12	0.11	0.00	0.00
	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

The occurrence of inefficient portfolios can be ascribing that no sufficient diversification models are used in the different enterprises in the Paarl/Berg River region. Most farmers use naïve diversification and are not always aware of other methods to select new enterprises and cultivars. These suggestions only highlights on the return of the cultivar, and not the risk reducing properties on a quantitative basis. Another reason might be that farmers are not always aware of the risk characteristics of each enterprise, nor the historic return statistics. This might be due to the fact that data on the prices (Py_i) are not readily available throughout the different enterprises. Bear in mind that the various models used in this study focus on risk-averse farmers (see Chapter 3). It is possible that not all the farmers' preferences to risk are risk-averse but risk seeking.

The relative position (distance) of these enterprises to the efficient frontier is an indication of the risk-return performance. This also correlates with their S_p ranking as indicated in Table 6.2. Sweet melons' and Shiraz dominates all enterprises in the risk-return space.

The second part of the optimisation plan involves the risk-free asset. As described in Chapter 4 (see Figure 4.1 and 4.2), CAL with the highest reward-to-variability ratio (the steepest slope) is shown in Figure 6.2.

The CAL that is supported by the optimal portfolio, P, is tangent to the efficient frontier. This CAL dominates all alternative feasible lines. Portfolio P is thus the optimal risky portfolio. Sweet melon is represented by Point P. This extension dominates everything below the line on the original efficient frontier. Thus a new efficient frontier is constructed, that is, the straight line from R_f tangent to Point P. Portfolio P is the optimal risky portfolio and all clients will choose this portfolio regardless of their degree of risk aversion.

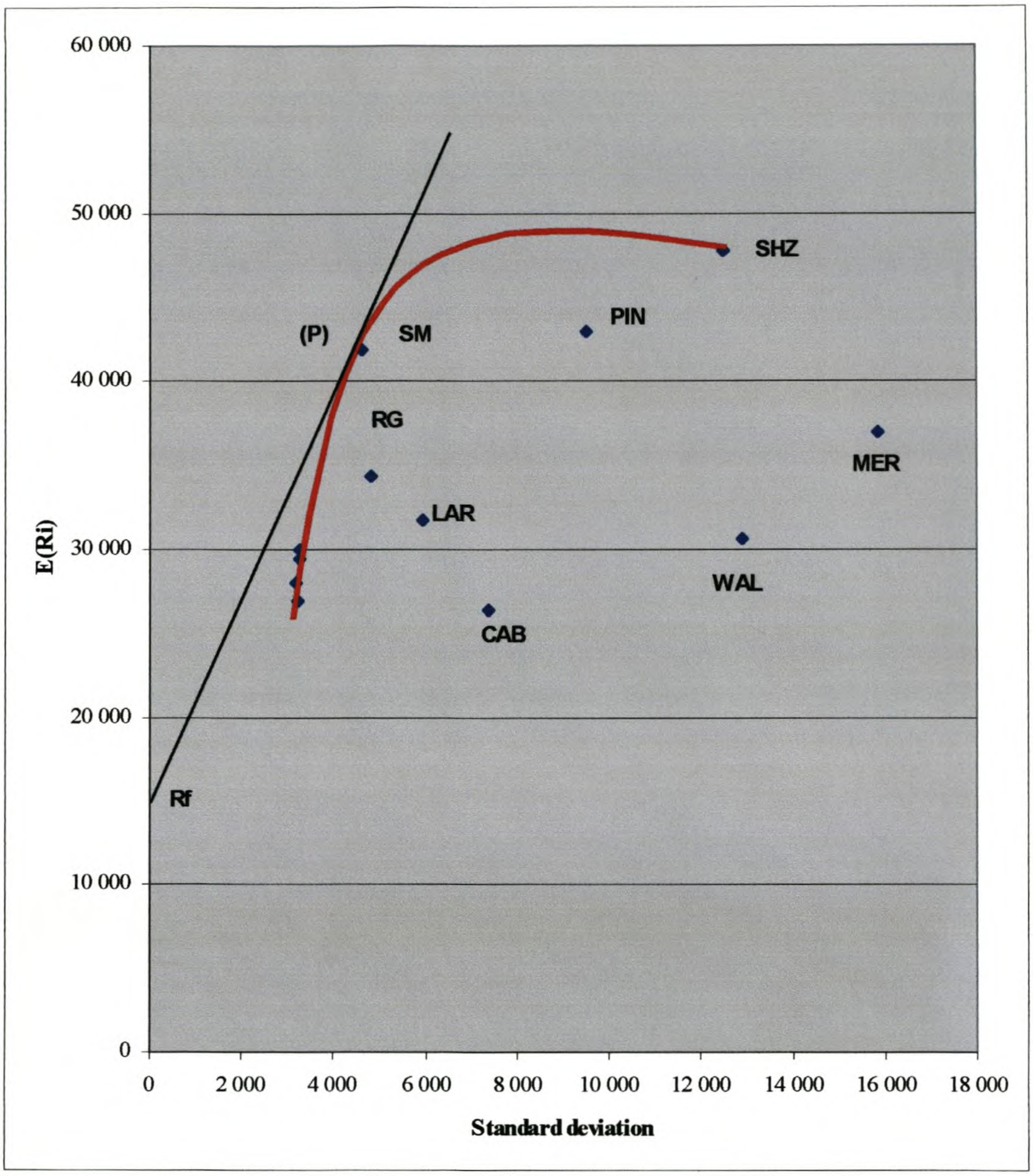

Figure 6.2: The efficient frontier of risky assets with the optimal capital allocation line (CAL)

The only difference between farmers' choice is that more risk-avers farmers will invest more in the risk-free enterprise and less in the optimal risky portfolio than in the case of a less risk adverse farmer. However, both will use portfolio P (sweet melon) as their optimal risky investment vehicle.

The CAL constructed out of the risk-free asset (R_f) will be discussed in detail in Section 6.3. of the Farm Sector Capital Asset Pricing Model to distinguish between systematic and non-systematic risk.

6.3 Estimating parameters with the Single Index Model in the Paarl/Berg River region

In this section an alternative model for constructing the optimal portfolio is applied. The purpose of this section is to introduce numerically and graphically the concepts that have been explained in the previous chapters. The Single Index Model (SIM) reduces dramatically the amount of work in tracing the efficient frontier (Levy and Sarnat, 1984). Obviously, there is a price to pay for adopting this "simple" model as it involves assumptions that do not necessarily hold to actual behaviour. Yet the SIM may actually hold *ex-ante*, although due to sampling errors they appear to brake down with actual *ex-post* data.

Data from the Farm Sector Portfolio[4] (see *Appendix 3*) in the Paarl/Berg River region for the years 1997-2001 and with the aid of the time series regression in Equation 6.1, the parameters α_i, bi and $\sigma^2_{u\,i}$. in Equation 6.1 were estimated:

$$R_{it} = a_i + b_i R_{mt} + e_{it} \qquad (6.1)$$

where

R_{it} = the return on security *i* in period *t*

R_{mt} = the return on the market portfolio in period *t*

a_i = the vertical intercept of the regression line

[4] *The Farm Sector Portfolio is similar to the market portfolio (M) as discussed in Chapter 4. The Farm Sector portfolio is constructed out of diversified farm activities whereas the market portfolio in capital markets, is constructed out of a large amount of diversified shares like the Standard and Poor 500 index or the Fisher index as explained in Levy and Sarnat (1983).*

b_i = the slope of the regression line

e_i = the residual, or the deviation about the regression line (the analog of the error term u_i in equation 3.15).

Thus comparing the regression equation (6.1) with equation (3.15), it can be seen that a_i is the estimate of α_i, *bi* is the estimate *of* β_i, and the residual variance $\sigma^2{}_{ei}$ is the estimate of $\sigma^2_{u\,i}$. Moreover R_m calculated from historical data is the estimates of the mean return and the variance of returns on the Farm Sector Portfolio.

Therefore, it is possible to calculate α_i, β_i and $\sigma^2_{u\,i}$. The term $\Sigma e_i e_j$ is measured as an estimate of the covariance of the error terms, which is assumed to be zero by assumption 4 in Chapter 3 (see Section 3.9). *Appendix 6* sets out the return on the Farm Sector Portfolio and on the different enterprises in the Farm Sector Portfolio over the five years 1997-2001.

The standard expressions for the slope b_i of the regression line of stock *i* and of the vertical intercept a_i are the following (Levy and Sarnat, 1983):

Slope: $b_i = \sum_{t=1}^{n} R_{it} R_{mt} - n\overline{R}_i \overline{R}_m / \sum_{t=1}^{n} R_{mt}^2 - n\overline{R}_m^2$

Intercept: $a_i = \overline{R}_i - b_i \overline{R}_m$

By using the formulas above and the estimates in *Appendix* 6 the slope and the vertical intercept of the enterprises in the Farm Sector Portfolio are determined in Table 6.4.

Table 6.4 The slope (a_i) and the intercept (b_i) of different enterprises

Enterprises	b_i	a_i
Waltham Cross	0.25	23 267
Red Globe	0.53	18 523
Bien Donne	1.57	-25 363
La Rochelle	0.82	7 386
Cabernet Sauvignon	0.99	-3 186
Pinotage	1.28	4 847
Merlot	2.36	-33 243
Shiraz	1.81	-7 965
Sauvignon Blanc	0.37	9 286
Sweet melons	0.70	22 927
Citrus	1.18	-13 712
Plums	0.61	3 716
Olives	0.53	-6 483

The observed rate of return of the various enterprises was plotted on different scatter grams as shown in *Appendix 7* along with their corresponding estimated regression lines[5] for the period 1997 to 2001. To make any valid assumptions about the this relationship (an activities return with the market return), there must be a high degree of confidence, which is dependant in part on the goodness of fit of the regression line. The goodness of fit is measured by the coefficient of determination (R^2) as indicated in *Appendix 7*.

The observed return as shown in *Appendix 8* is a point on the estimated regression line corresponding to a given value of R_m. The observations are scattered around the regression lines and for each point the deviations e_{it}, that is the difference between the observed rate of

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[5] *A computer program (Microsoft Excel) was used to run linear regression estimating the parameters a_i and b_i and to plot the various enterprises on various scatter grams.*

return R_{it} and the regression estimate $\hat{R}_{it}$[6]. The average of these deviation terms is indeed zero as assumed in Chapter 3 (see Section 3.9) and is shown in *Appendix 8*. The crucial assumption of the SIM is that for every pair of enterprises (*i, .j*) the error terms is uncorrelated, i.e. $Cov\ (u_i, u_j)\ =0$ (Levy and Sarnat, 1984). In the case of the Farm Sector Portfolio the covariance of the error terms between the different enterprises is not zero. According to Levy and Sarnat (1984) it may be that in the population $Cov\ (u_i, u_j)\ =0$ as required, the error covariance does not vanish in the sample only due to sampling errors. In this set of circumstances the SIM can be safely used even though in the sample $Cov\ (e_i, e_j)$ $=0$ for some or all pairs of enterprises.

6.3.1 Employing the SIM to construct the Optimum Portfolio

As denoted in Section 6.1, there exist two main types of efficient frontiers that are considered in portfolio analysis: one is the efficient frontier of portfolios in which both long and short sales are allowed (the proportion x_i may be both positive and negative), while the other consists of efficient frontier without any short positions (derived subject to non-negativity constraints $x_i \geq 0$ for all *i*).

In order to calculate the optimum portfolio with *n* risky assets it is obtained from a system of *n* equations in *n* unknowns. Although the system is solvable, hand calculations become very cumbersome even for a relatively small *n* and a computer must be used. One of the advantages of the SIM is that the constructions of the optimal portfolio require only simple calculations.

The left hand side of *Appendix 9* lists ex-post estimates of parameters on 13 enterprises based on historical data for the 5-year period from 1997-2001. The Beta of each enterprise (column 2) was determined by regressing the enterprise returns on the Farm Sector Portfolio (see *Appendix 3*), while σ_{ei}^2 (column 3) is the residual variance of the observations about the estimated regression line. The second part of the table in *Appendix*

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[6] *Estimated values are indicated as* $\hat{R}_t$.

6 is a SIM worksheet developing the various quantities needed to calculate the optimum proportions by the SIM.

The reward-to-volatility ratio (column 4) given by

$$(R/V)_i = (\mu_i - r)/\beta_i$$

was calculated for r = 15 000 (this figure represent farm rental land and is used as the risk-free rate). The remaining columns list the ratio β_i / σ_{ei}^2 (Column 5)

which together with $(R/V)_i$ enters the optimal investment proportions where:

$$y_i = \frac{\beta_i}{\sigma_{ei}^2}[(R/V)_i - C^*]$$

as well as the factors $\beta_i^2 / \sigma_{ei}^2$ as indicated in column 6, which is needed to calculate the sums that enter the definition of C^* where:

$$C^* = \sigma_{ei}^2 \sum_{j=1}^{n} \frac{\mu_j - r}{\sigma_{ej}^2} \beta_j / \left(1 + \sigma_m^2 \sum_{j=1}^{n} \frac{\beta_j^2}{\sigma_{ej}^2} \right)$$

Summing columns 6 and 7 in *Appendix 9*, C* was calculated as:

$$C^* = \frac{\sigma_m^2 \times \sum (column\ 7)}{1 + \sigma_m^2 \times \sum (column\ 6)}$$

When short sales are not allowed, the same basic set of *n* equations with *n* unknowns must be solved but under the additional constraint that the investment proportions are non-negative. With short sales are not allowed a new quantity C_i must be introduced:

$$C_i = \frac{\sigma_m^2 \sum_{j=1}^{i} (\mu_j - r) \beta_j / \sigma_{ej}^2}{1 + \sigma_m^2 \sum_{j=1}^{i} (\beta_j^2 / \sigma_{ej}^2)}$$

All stocks with $(R/V)_i < C^*$ appear in the given portfolio with zero proportions. All stocks with $(R/V)_i > C^*$ appear in the given portfolio with positive proportions. The results from the estimates in *Appendix* 10 indicate that the optimal portfolio for r = 15 000 consists of six activities that are positive and seven activities that are negative.

In order to satisfy the constraint ($\sum_1^n = 1$) $z_i = 1$, the optimum investment is calculated in the ith risky asset z_i by the following standardization:

$$z_i = \frac{y_i}{\sum_{i=1}^{n} y_1}$$

So that they add up to 1 as required:

$$\sum_1^n z_i = \sum_1^n \frac{y_i}{\sum_1^n y_i} = 1$$

According to Levy and Sarnat (1984) this procedure is valid as long as the Betas of all risky enterprises are non-negative. Since it is exceedingly rare to find a risky asset with a negative Beta, this procedure almost always holds.

The optimal investment proportions z_i, as shown in Table 6.5 were calculated by standardizing the corresponding y_i as shown above.

$$z_i = y_i \; y_i \Big/ \sum_{i=1}^{13} y_i = y_i / 0.00335$$

The corresponding optimal proportions are given in Table 6.5.

Table 6.5: Optimal investment proportions (z_i) of the different activities in the Farm Sector Portfolio

	Single Index Model (SIM)	
Enterprises	**Investment proportions (z_i)**	**(%)**
Waltham Cross	0.026369435	2.6
Sweet melons	0.373878529	37.4
Red Globe	0.364259084	36.4
Pinotage	0.148434295	14.8
La Rochelle	0.078467666	7.8
Shiraz	0.008590991	0.9
Sauvignon Blanc	0	0
Cabernet Sauvignon	0	0
Plums	0	0
Merlot	0	0
Citrus	0	0
Bien Donne	0	0
Olives	0	0
Total	**1**	**100**
Portfolio Mean	**0.08**	**8**
Portfolio Standard deviation	**0.14**	**14**

6.3.2 The SIM Optimum Portfolio versus the Exact Optimum Portfolio

By employing the SIM the optimal investment proportions were obtained. The simplicity of the calculations is attained, however, only if the assumptions for the SIM are assumed to hold. Thus, in effect it can be assumed that ($\sigma_{ij} = \beta_i \beta_j \sigma_m^2$) or equivalent that $Cov(e_i, e_j) = 0$, which does not necessarily hold in reality. Therefore, the proportions obtained by using the SIM technique are only approximations to the true optimal proportions, and the quality of the approximation depends on how closely the SIM assumption approximate to real enterprise price behaviour.

To establish the price to be paid in terms of lost opportunity for the simplicity of the SIM technique, the optimal investments was calculated in *Appendix* 10 for the Farm Sector Portfolio of 13 enterprises, assuming that the SIM holds and then by the technique explained above in Section 6.2. Appendix 9 and *10* list the SIM parameters of the 13 enterprises estimated on the basis of historical data. It also developed the worksheet for the calculations of C^* and where short sales (negative values) were not allowed C_i and y_i. In these calculations r = 15 000 as the risk-free rate. Table 6.5 lists the optimal investment proportions for the 13 enterprises obtained by the SIM technique and the corresponding proportions of the optimal portfolio obtained by the exact method in Section 6.2.

According to Levy and Sarnat (1984) there is very little in common between the two portfolios. The portfolio obtained through the SIM technique for the same riskless interest rate r =15 000 lies inside the MV efficient frontier and is not efficient. There is thus a price to pay for the computational simplicity of the SIM: the quick calculations produce a portfolio that is not necessarily MV efficient and the farmer is forced into a sub-optimal strategy.

The SIM optimal portfolio consisted of six enterprises held long (positive) and seven enterprises held short (negative), while the exact optimal portfolio consisted of eight enterprises that is efficient and lied above the global minimum-variance line and five of the enterprises that were inefficient and not included into the optimal portfolio. Moreover not all the enterprises shorted in the SIM portfolio were shorted in the exact portfolio. When the SIM technique was used, Merlot and Cabernet Sauvignon were not included into the optimal portfolio, but were included into the portfolio when the SOLVER program was used. The SIM provided a convenient shortcut for the constructing of an optimal portfolio.

Recall from Figure 6.2, that the CAL that is supported by the optimal portfolio, P, is tangent to the efficient frontier. Portfolio P (sweet melon) was thus the optimal risky portfolio. This extension dominated everything below the line on the original efficient frontier. Thus a new efficient frontier is constructed, that is, the straight line from R_f (15 000) tangent to Point P with a mean return of 41.8 percent and a standard deviation of 4.6 percent. Compared to the SIM with a standard deviation of 13.7 percent and a mean return of 7.7 percent (Table 6.5).

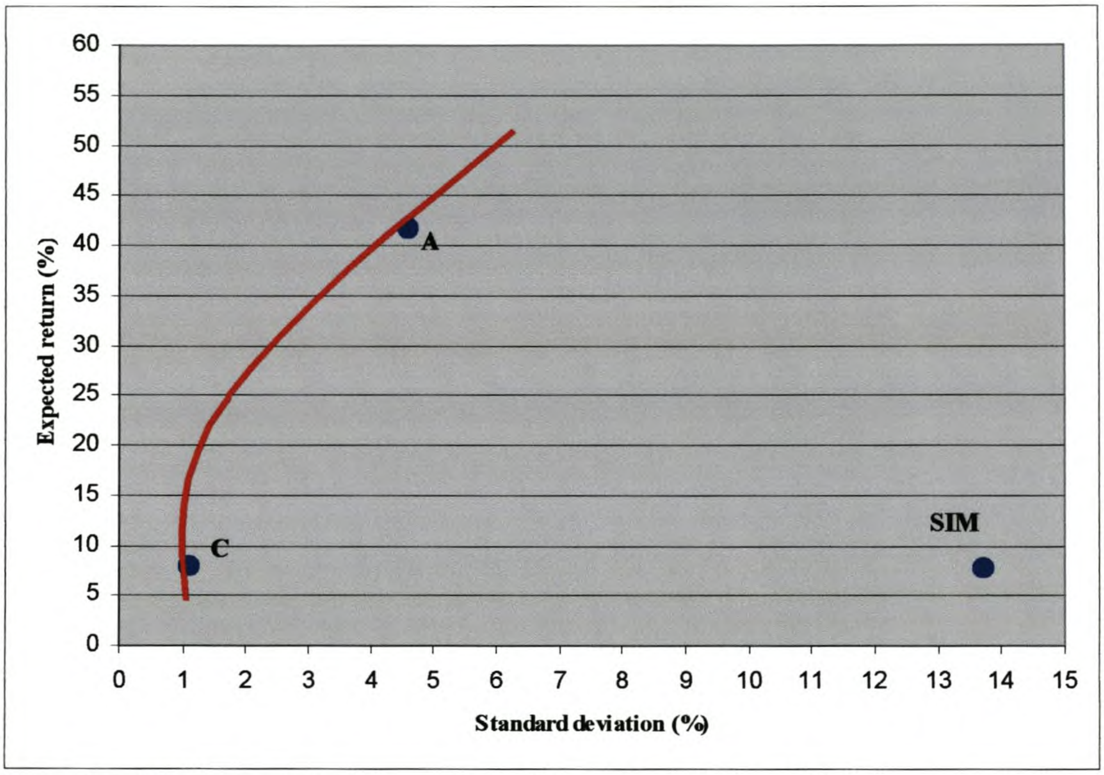

Figure 6.3: Differences in the composition of the two optimal portfolios

The two portfolios are represented by points SIM and A in Figure 6.3. There are significant differences in the composition of the two portfolios. SIM is the portfolio obtained by the SIM technique for the same risk-less rate of R15 000. It lies inside the efficient frontier and is not at all efficient. Portfolio C on the efficient frontier has the same mean return as the SIM portfolio and yet its standard deviation is significantly smaller. Therefore, the simplicity of SIM calculations is attained at a cost of constructing a sub-optimal portfolio, which does not lie on the corresponding efficient frontier.

6.4 Capital Asset Pricing Model

The Capital Asset Pricing Model (CAPM) is an extension of the Markowitz portfolio approach to capital market investment and can be used to examine the systematic risk in agriculture. A difference between the traditional portfolio choice problem in agriculture and the portfolio choice problem in capital markets is that capital markets focus on the contribution that individual securities make to the variance of the portfolio returns. In agriculture, the traditional portfolio choice problem is based on the total variance of the farm plan relative to the expected returns.

In this study the CAPM is constructed in terms of the expected gross revenues of a Farm Sector Portfolio. The CAPM is based on expected returns. However, only *ex post* returns are observed. Therefore, the equilibrium relationship between asset returns and risk has to be estimated by using *ex post* data. That is, farm plans are chosen on the basis of each activity's contribution to the mean and the variance of the Farm Sector Portfolio (see Section 5.3 for detailed discussion). Because it is diversified, the Farm Sector Portfolio reflects only the risk that is common to all activities. The risk is inherent and cannot be diversified away. As described in Chapter 4 (see Section 4.4.3), there exist two types of risk for individual activities that can be included in the Farm Sector Portfolio. The first is the non-diversifiable because it is correlated with the Farm Sector Portfolio (systematic risk). The second component is not correlated with variations in the Farm Sector Portfolio (non-systematic risk). Further diversification can potentially eliminate this risk.

6.4.1 Developing of the CAPM

As discussed in Chapter 4, a number of simplifying assumptions lead to the basic version of the CAPM and requires that all markets be in equilibrium. However, in the study reported here, by including farmland cash rents as a risk-free asset and by examining a portfolio choice problem based on the separation theorem, an equilibrium condition within the farm sector is implied by construction. Therefore it is expected that the empirical results and relationship are consistent with the Capital Asset Pricing theory. For this reason the CAPM or the Farm Sector Capital Asset Pricing Model as labelled by Turvey and Driver (1987), is used in this section. It should also be noted that the Farm Sector Portfolio is just one of many portfolios held in combinations to obtain the equilibrium market portfolio of the Capital Asset Pricing Model (Turvey and Driver, 1987). The expected returns of a diversified portfolio of agriculture activities (i.e., a Farm Sector Portfolio) should reflect only the non-diversifiable risk inherent in the industry. Accordingly, Beta coefficients are derived for various agricultural activities (enterprises) in the Paarl/Berg River region according to Equation 4.1. From this the expected or the theoretical returns associated with an individual activity, which is based on *i*'s contribution to the systematic risk of the Farm Sector Portfolio can be generated according to Equation 4.6. Activity Beta coefficients and expected gross revenues per hectare are shown in Table 6.6.

Table 6.6 Risk return measures of the Farm Sector Portfolio model in the Paarl/Berg River region (R per hectare)

	Beta	Ri	r_{im}	$E[R_i]$	$E[R_i]-R_i$	Total risk	Non-Systematic risk	Systematic risk
Waltham Cross	0.25	30 697	0.12	18 682	-12 014	12 896	11 348	1 547
Red Globe	0.53	34 318	0.66	22 828	-11 490	4 808	1 634	3 173
Bien Donne	1.57	21 191	0.86	38 071	16 880	10 941	1 531	9 410
La Rochelle	0.82	31 704	0.83	27 051	-4 652	5 914	1 005	4 908
Cabernet Sauvignon	0.99	26 357	0.81	29 641	3 283	7 358	1 398	5 960
Pinotage	1.28	42 964	0.81	33 890	-9 074	9 515	1 807	7 707
Merlot	2.36	36 984	0.89	49 803	12 819	15 858	1 744	14 113
Shiraz	1.81	45 736	0.86	41 613	-4 122	12 515	1 752	10 763
Sauvignon Blanc	0.37	20 170	0.64	20 394	223	3 435	1 236	2 198
Sweet melons	0.70	43 863	0.91	25 375	-18 487	4 628	416	4 211
Citrus	1.18	21 446	0.78	32 424	10 977	9 038	1 988	7 049
Plums	0.61	21 742	0.47	23 933	2 190	7 686	4 073	3 612
Olives	0.53	9 407	0.55	22 875	1 3468	5 801	2 610	3 191
Portfolio	1.00	29 737	1.00	29 737	0	3 030	0	3 030

The estimated Beta coefficients ranged from a low 0.25 percent for Waltham Cross to a high of 2.36 percent for Merlot. As a general observation the wine grape cultivars Merlot and Shiraz contributed the most to the systematic risk of Farm Sector Portfolio, followed by table grape cultivar (Bien Donne) and citrus. Plums and olives are relative low with sweet melons only 0.70 times as risky as the Farm Sector Portfolio with a $\beta = 1$.

The relationship between an activities total risk, σ_i, the total risk of the Farm Sector Portfolio, σ_m, and the correlation coefficient, r_{im} in generating Beta coefficients is shown in Table 6.6. Beta coefficients are estimated from Equation 4.2. The Beta coefficients reflect the systematic risk of an equally weighted Farm Sector Portfolio. If a value-weighted index of the Farm Sector Portfolio were used or if the gross revenues were deflated, the Betas would be different.

The standard deviation of an enterprise was given in the total risk column in Table 6.6. This were broken down further into their systematic $r_{im}\sigma_I$ and non-systematic $(1-r_{im})\sigma_I$ components. Most of the activities in the Farm Sector Portfolio are highly correlated with the returns in the portfolio. Waltham Cross correlation coefficient is very low at 0.12. The rest of the enterprises mean r_{im} value is 0.76. Some 8 of the 13 enterprises have r_{im} values greater than 0.70. Therefore, most of the enterprises show a high degree of systematic risk relative to non-systematic risk.

For instance, the standard deviation of returns for Merlot is R15 858 per hectare. With a r_{im} value of 0.89 the diversifiable portion of the risk is only R1 744 per hectare, whereas the non-diversifiable portion is R14 113 per hectare. This implies that because Merlot is so highly correlated with the Farm Sector Portfolio, diversification strategies may not be very effective. On the other hand, the standard deviation of plums is R21 742 with a r_{im} of 0.47 that is lower than the mean r_{im} value of 0.76. The diversifiable portion of the risk is R4 073 per hectare, whereas the non-diversifiable portion is R3 612 per hectare. This indicated that because plums are not so highly correlated with the Farm Sector Portfolio, diversification strategies might be effective.

The return on a risk-free asset is reflected by the cash rental value of land (Johnson, 1967). According to Hofmeyer (2002) the cash rental value of farmland (with established water facilities) varies between R15 000 and R20 000 per hectare depending where it is situated and because of variation in the quality of land over the area. The hectares of land available for rent (supply) and the number of tenants wanting to lease for cash (demand) can affect the amount of rent that can be paid or charged. High rents increase the tenant's risk, and a variable or flexible cash rent based on yields and prices can help distribute risk. The choice of cash rental value of land is arbitrary.

The risk-free asset, R_f used in this study is the rental value of land in the Paarl/Berg River region. It was assumed that farmers could rent out land for a certain payment of R15 000 per hectare. If each enterprise is evaluated with a "true" cash rental rate, the error structure will differ with the errors not summing up to zero. The return on the Farm Sector Portfolio, R_m is the mean gross revenue per hectare on the Farm Sector Portfolio over the five-year time horizon (R29 737 per hectare). Thus the risk premium R_m - R_f, on the Farm Sector Portfolio is R14 737 per hectare (R29 737-R15 000).

The value used for R_f per hectare is higher for melon, plum, olive and soft citrus but lower for table grapes and wine grapes. Similar for land that lay furrow comparing to land that is cultivated. The particular vicinity in the Paarl/Berg River region also plays a big role in the allocation of the rental value of farmland, because of variation in quality of land over the area. As described in Chapter 5, the Paarl/Berg River region is not a homogeneous region and differs significantly within a small area.

The SML equation which generated the expected enterprise returns to systematic risk, $E(R_i)$ according to Equation 4.8 (see Section 4.4.6), is:

$$E\,(R_i) = R_f + \beta_i\,(R_M - R_f)$$

The efficiency of the predicting power of the SML is examined by subtracting from $E(R_i)$ the mean revenue, R_i. From the error column in Table 6.4 there were seven of the 13 enterprises in the Farm Sector Portfolio with $E(R_i) > R_i$ whereas six had $E(R_i) < R_i$. This implies that just more than half of the enterprises are being under compensated relative to the amount of systematic risk in the system. Some of the enterprises have negative errors. According to Turvey and Driver (1987) it implies that average returns for these activities are overcompensated for the amount of systematic risk accepted. In the capital market model this represents an arbitrage opportunity. The reality of the Farm Sector Portfolio prohibits farmers from taking advantage of such arbitrage opportunities on a large scale. For example, set-up costs, soil types, climate and expertise can all be limiting factors in switching from one industry to another. Within the CAPM framework, this is analogous to violating the assumption of no transaction cost (see Section 4.3). The security market line for Farm Sector Portfolios are shown in Figure 6.4:

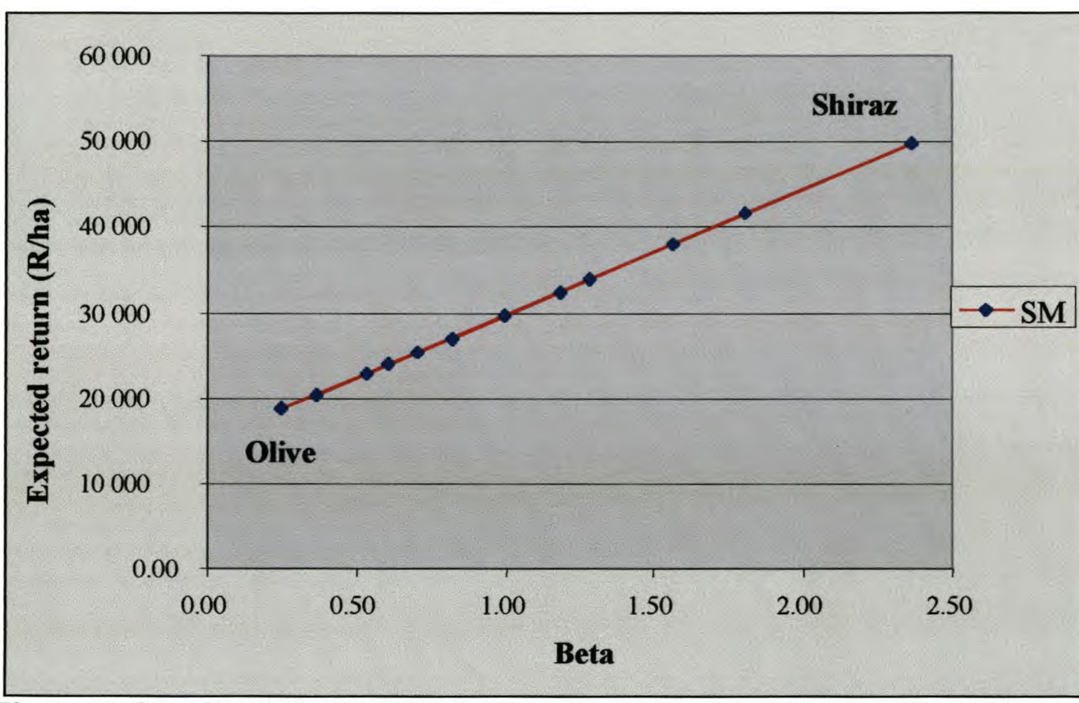

Figure 6.4: Security Market Line for the Farm Sector Portfolio in the Paarl/Berg River region

The CAPM states that under market equilibrium, all assets would be priced in accordance with their market risk (Gu, 1996). Those assets with smaller market risks should have lower expected returns and those with larger market risks should yield higher expected returns. Therefore the relationship between expected returns and risk are defined to be linear. Figure 6.4 illustrates the relationship between expected return and Beta. As Beta increases so does expected revenue. Wine grape activities such as Merlot with $\beta = 2.36$ and Shiraz with $\beta = 1.81$, have higher values of $E(R_i)$ than plums with a $\beta = 0.60$ and olives with $\beta = 0.53$. The associated revenue for Merlot which is 2.36 times more risky as the Farm Sector Portfolio with a $\beta = 1$, would expect a gross return of R49 803 per hectare, whereas plums which is only 0.60 times as risky as the Farm Sector Portfolio, expects a return of R23 933 per hectare.

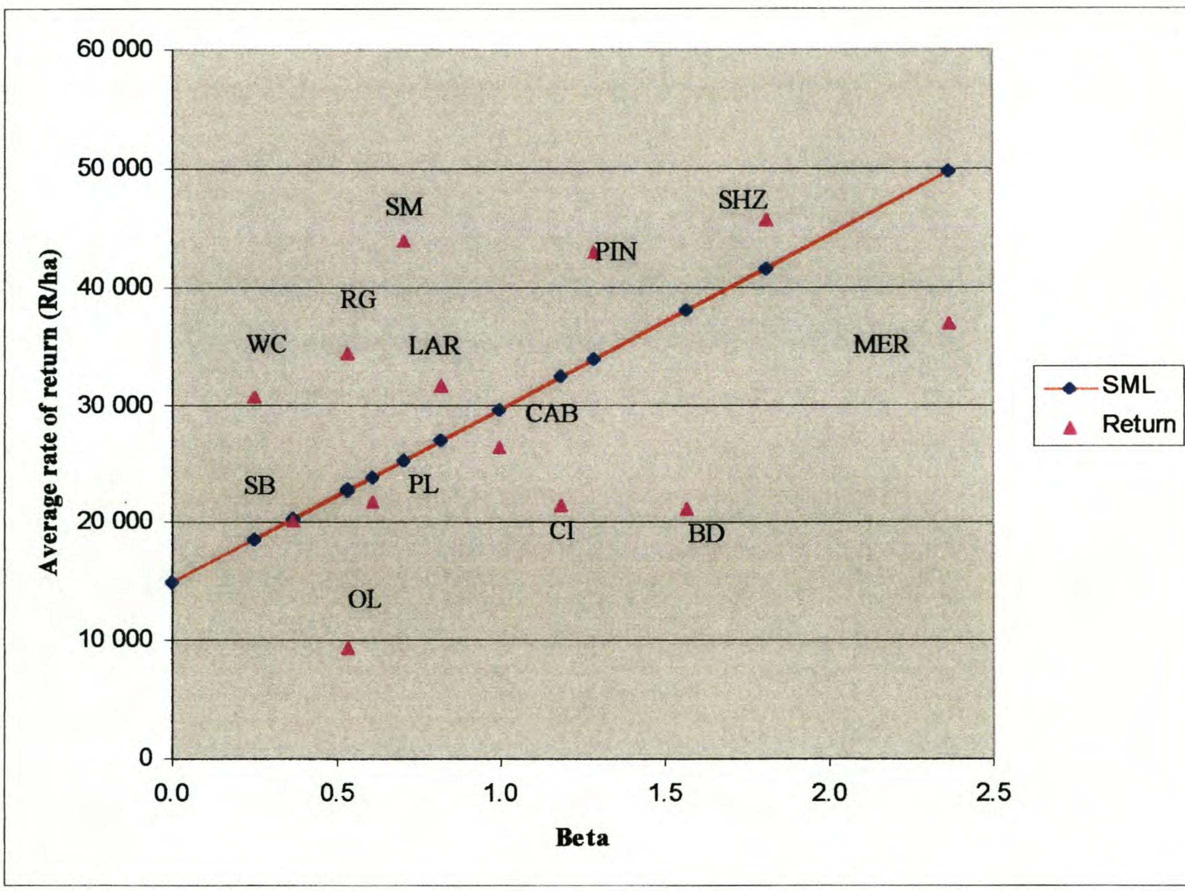

Figure 6.5: Returns and market risk of various enterprises in the Paarl/Berg River region

By using the estimated market risks (β) of individual assets in the CAPM against their average rates of returns, the relations between returns and market risk are plotted in Figure 6.5. The estimated SML is also shown in the diagram. As indicated in Figure 6.4 those assets with smaller market risks should have lower expected returns and those with larger market risks should yield higher expected returns. From Figure 6.5 the following conclusions can be drawn. Olives, citrus and plums exhibit relatively low market risk compared to the red wine cultivars. According to Gu (1996) agriculture enterprises are regarded as illiquid and less traded than assets in the capital markets and investment in these assets are also poorly diversified, thus the variation in returns of these assets are greatly affected by the unique supply and demand conditions of agricultural market rather than the market in general. Olives, citrus, plums, Bien Donne and two red wine cultivars, Cabernet Sauvignon and Merlot have plotted below the SML during the period of the study. The implication of this is that these assets have earned much lower market returns than other assets with similar market risks. The reason for this can be that farmer's produce on unprofitable land, and resources are still allocated to insufficient farming. This situation stresses out the importance of sufficient information where farmers should have consider both risk and return characteristics of the various enterprises before a new enterprise or cultivar are introduced to a farmer portfolio.

To recall from Chapter 4, the CML is a linear relationship between expected return and total risk on which only portfolios lie (Francis and Archer, 1971). Undervalued and overvalued shares can be identified by assuming that the market is not always efficient. An investor can do this by comparing the estimated risk of return to be earned on an investment to its expected rate of return. Undervalued prices occurred when prices are lower than when they would be in equilibrium. These shares have unusual high returns for the amount of unsystematic risk they bear. Overvalued shares occurred when assets do not offer sufficient return to induce rational investors to accept the amount of systematic risk it involves (Francis, 1976).

The graph represented by the line R_f -f in Figure 6.5 plots the expected revenues if al of σ_I is systematic and is used to illustrate the relationship between systematic risk and non-systematic risk. This is similar to the capital market line (CML) in the CAPM framework (see Section 4.1.1).

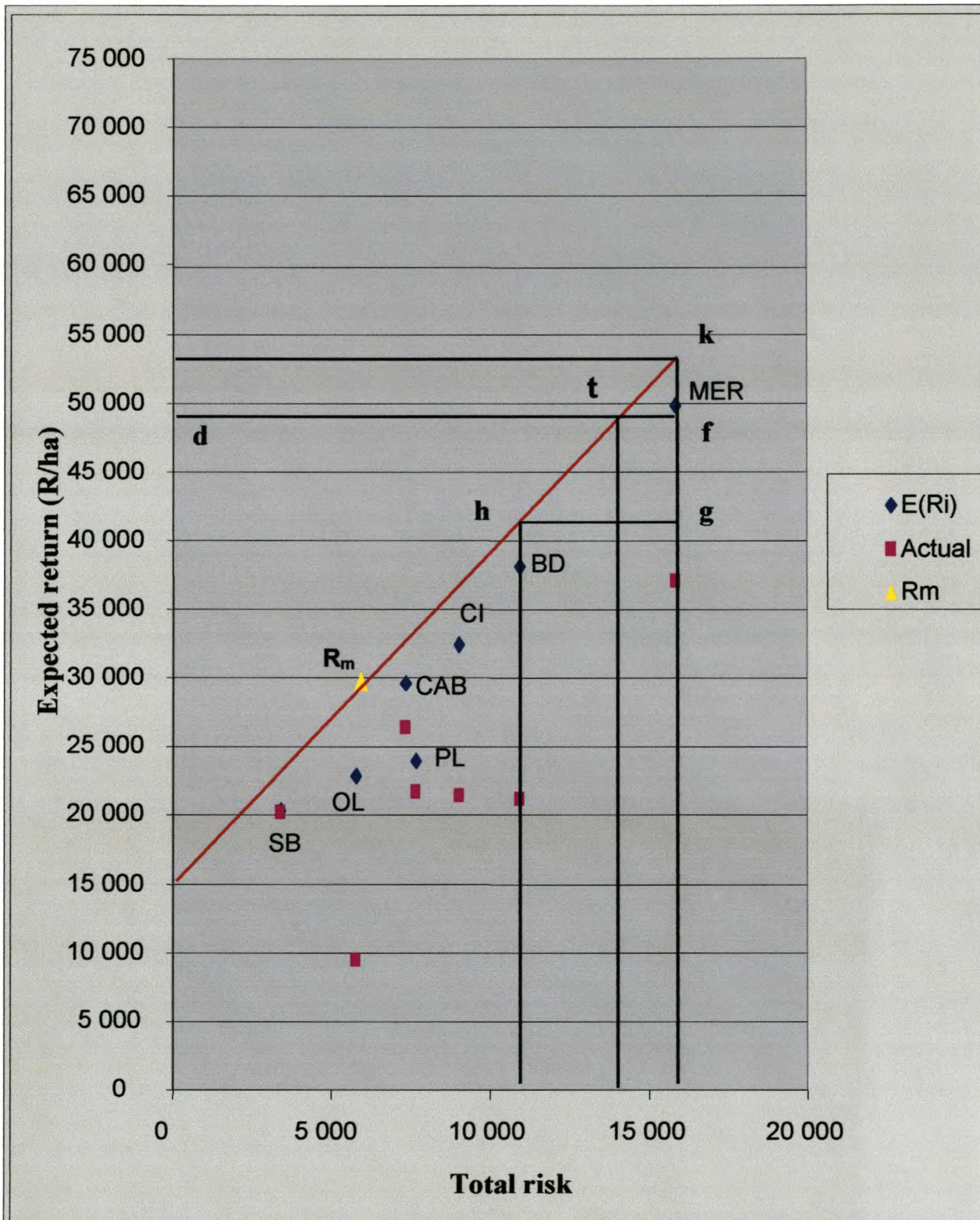

Figure 6.6: The Capital Market Line for the different enterprises in the Paarl/Berg River region

All points along the CML reflect the most efficient portfolios because all of the risk is systematic. This implies that the entire opportunity set is dominated by the CML. The activities represented along the line reflect possible opportunities for a typical diversified farmer in the Paarl/Berg River region. For instance, the Merlot activity (as shown in Table 6.6.), under this condition, with a total risk of R15 858 per hectare, all of which is assumed to be systematic, would expect to receive R53 661 per hectare (Point *d*). However, only R14 113 of this risk is actually systematic while R1 744 per hectare is non systematic. Point *t* represents an expected return of R49 803 per hectare for accepting R14 113 per hectare worth of systematic risk.

Therefore, the horizontal distance between point *d* and *t* is the systematic risk component. The distance *tf* is the diversifiable portion of total risk. Point *g* is the observed return for the Merlot activity where R_i = R36 984. However, the expected revenue compensation at Point *g* reflects a level of systematic risk of only R10 000 per hectare (Point h), which is lower than the calculated value of R14 113 per hectare at Point t. According to Turvey and Driver (1987) this further illustrates that farmers are not being fully compensated for the amount of systematic risk held in their portfolios.

By using the CAPM it is possible to determine the part of risk the producer can control (non-systematic risk) and which part the producer has no control over (systematic risk). According to the CAPM risk adverse producers must organise their production to exclude systematic risk in their portfolios. The large degree of systematic risk within agriculture reflects the volatility of the export and the domestic markets. The result of this study indicates that opportunities for diversification within agriculture are limited.

According to the study by Barry (1980) and Moss *et al.* (1986), the opportunities for farmers to reduce the amount of systematic risk in their portfolio are much higher through the combination of farm portfolios with off-farm portfolios. The advantage of off-farm investments is that these portfolios have low correlations with the Farm Sector Portfolios. Furthermore, the liquidity of capital markets allows for greater flexibility in transferring capital between and among portfolios, an advantage, farmers would not have if all their capital were invested into the farm.

6.5 Conclusions

It was showed in Section 6.2 that it is possible to quantify and classify each enterprise on a risk return basis. Apart from the fact that more calculated decisions can be made regarding an enterprise performance (risk and return), the standard deviation, as determined for each enterprise can also be used in highlight possible problem areas in farming practices.

The efficient frontier represented throughout the study is similar to the frontiers in the capital markets, being convex towards the return axis as indicated by (Francis, 1976). With short sales (negative investments) prohibited, single enterprises may lie on the frontier. The efficient frontier cannot obtain a mean return less than R9 407 per hectare (which is the mean in Olives, the enterprise with the lowest mean return) or more than R45 737 per hectare (corresponding to Shiraz, the enterprise with the highest mean return). The efficient portfolios include a relative small numbers of enterprises in positive proportions and the remaining stocks are omitted (their proportions are $x_i = 0$).

Efficient diversification, based on the Markowitz portfolio concepts, can be successfully applied to the Paarl/Berg River region. It is therefore suggested that farmers should consider both risk and return characteristics of the various enterprises, as well as the correlation of the enterprise return with other cultivars, before a new enterprise or cultivar an introduced to a farmer portfolio. This should be done in combination with conventional methods as currently practised, which will ensure efficient portfolios with the highest return for each level of risk

The SIM was discussed in Section 6.3. It was found that there were significant differences in the composition of the two portfolios. The portfolio obtained through the SIM technique for the same risk-free rate of R15 000 per hectare lied inside the efficient frontier and is not at all efficient. A portfolio on the efficient frontier could be found that has the same mean return as the SIM portfolio and yet its standard deviation was significantly smaller. Therefore, the simplicity of SIM calculations is attained at a cost of constructing a sub-optimal portfolio, which does not lie on the corresponding efficient frontier.

The CAPM as discussed in Section 6.4 revealed that there was a great deal of systematic risk in relation to the portfolio enclosed in this study. Farmers are not being compensated in terms of gross returns for almost half of the 13 enterprises in relation to the portfolios systematic risk.

Since Beta coefficients are a relative measure of the riskiness of a farm enterprise with respect to the riskiness of a diversified portfolio, enterprise Beta coefficients provides important *ex ante* risk information. Farmers can first evaluate a list of Beta coefficients, standard deviations and revenues such as those presented in Table 6.4. Once a decision has been made with respect to which enterprises are to be included into the farm portfolio, the individual weights (hectare proportions), as seen in Section 6.2 and 6.3, can be attached. The systematic risk a farmer wants to hold in his portfolio will be based on the weighting of the portfolio. Therefore, the selection will be based on the farmers' attitude towards risk as well as on the feasibility of the portfolio, given available resources. The proportions of systematic risk that can be diversified away are small, relative to the total risk of the Farm Sector Portfolio. On the basis of the portfolio enclosed in this study, it is also concluded that systematic risk are very high within agriculture. Portfolios consisting of non-farm activities in combination with farm enterprises could reduce the amount of systematic risk because of the low correlation and the greater flexibility in transferring capital between and among portfolios.

The success of these models, however, depends on the efficiency of the market, as well as a large and up-to-date, reliable data source. Many relatively new cultivars could not be included into this study, due to the limited availability of data. In the next few years as data become available it will be possible to construct efficient frontiers from a wider range of enterprises. Without reliable data, the result will be "garbage in, garbage out."

CHAPTER 7

Conclusions and Recommendations

7.1 Conclusions

The need to take account of risk in agriculture must be part of every decision made in agriculture. Yet risk is nothing to be too afraid of. Risk is a choice rather than a fate. The action we dare to take, which depends on how free we are to make choices, is what the theory of risk is all about. The task is rather to manage risk effectively, within the capacity of the farmer, business or group, in order to withstand adverse outcomes.

In agricultural economics and farm management, portfolio research has traditionally emphasised the use of typical agricultural risk programming and optimising models. Linear approximations such as Minimisation of Total Absolute Deviations (MOTAD) or the linear programming-risk simulator (LP-RS) have also been used in this kind of research (see Section 2.6 for more detail). These techniques provide a decision framework for delineating the expected return variance (E-V) of efficient farm plans. Some methods of managing risks are feasible for all types of farms. Others are only feasible for certain sizes and types of farms. An alternative decision framework was used by means of the portfolio diversification models. Conceptually, such an examination was made by utilizing the fundamental constructs of the Markowitz mean variance (MVC) model, the Single Index Model (SIM) (which is very similar to the Markowitz model) and the Capital Asset Pricing

Model (CAPM). Therefore, farmers in general, need a technique that will enable them to choose an efficient investment strategy from among all feasible strategies.

It was shown in Section 6.2 that it is possible to quantify and classify each enterprise on a risk-return basis. Investors should choose among all possible investments on the basis of their risk (portfolio variance) and return (portfolio return) out of a universe of risky assets, in order to construct an efficient frontier of optimal portfolios. The expected return of a portfolio is the weighted average of the expected returns of the different enterprises, with the investment proportions as the weights.

The variance of the portfolio is the weighted sum of the elements of the covariance matrix (see Appendix 5) with the product of the investment proportions as weights. Therefore, the variance of each enterprise is weighted by the square of its investment proportion. Each covariance of any pair of assets appears twice in the covariance matrix. As long as the enterprises are not perfectly positively correlated, the portfolio standard deviation will be less than the weighted average of the component standard deviation. The correlation matrix for the 13 enterprises was calculated in Appendix 4. Each element in the correlation matrix represents the correlation coefficient ρ_{ij} between the corresponding pair of activities of enterprises i and j. The correlation matrix is also symmetrical, and its diagonal elements are all equal to 1.00 (the correlation of any enterprise to itself is always 1.00). Mostly low and even negative correlations were observed for the return on the various enterprises. Thus portfolio diversification is of value as long as enterprises are less than positively correlated. The greater an enterprise covariance with the other enterprise in the portfolio, the more it contribute to the portfolio variance. An enterprise that is perfectly negatively correlated with a portfolio can serve as an ideal hedge. The most ideal combination in a portfolio, if only correlations are considered, would be Waltham Cross and Sauvignon Blanc, where $r = -0.62$. This moderate negative correlation implies a situation where Waltham Cross´s return would increase while at the same time Sauvignon Blanc's return would decrease. The ideal hedge enterprise can thus reduce the portfolio variance to zero.

Given n risky assets (such as the different enterprises in the Paarl/Berg River region), it is essential to seek a diversification strategy, which yields a portfolio lying on the efficient frontier. The system of n equations in n unknowns is in principle solvable, but in practice its solution is not a simple task when n is large. Several computer programmes can be used to solve such linear systems of simultaneous equations easily and quickly in order to generate the efficient frontier, provided, of course, that n is not too large. In this study Microsoft Excel was used to illustrate the construction of investment proportions, expected returns, and standard deviations of the portfolios of the efficient frontier.

The investment proportions represented in percentage hectare have been allocated to the different enterprises and present a number of points on the frontier as shown in Table 6.3. These weights are affected by the standard deviation of each enterprise, as well as the correlation of that enterprise to other enterprises in the portfolio. The efficient frontier cannot obtain a mean return less than R9 407 per hectare (which is the mean for olives, the enterprise with the lowest mean return) or more than R45 737 per hectare (corresponding to Shiraz, the enterprise with the highest mean return) because for agricultural products, short sales (negative investments) are not feasible.

It is important to notice that despite the fact that Shiraz offers the highest mean return, the weights of sweet melons, Red Globe and Cabernet Sauvignon are generally higher in the portfolio because of the lower correlations of sweet melons, Red Globe and Cabernet Sauvignon with other enterprises, and it illustrates the importance of diversification when forming efficient portfolios. All the individual enterprises lie to the right, inside the frontier (see Figure 6.1). The reason for this is that risky portfolios constituted of a single asset are inefficient. All the portfolios that lie on the minimum-variance frontier form the global minimum-variance portfolio and upwards provide the best risk-return combinations, and are therefore candidates for the optimal portfolio.

The part of the frontier that lies above the global minimum-variance portfolio (the scattered line in Figure 6.1) is called the efficient frontier. For any portfolio on the lower portion of the minimum-variance frontier, there is a portfolio with the same standard deviation and a greater expected return positioned directly above it. Hence, the bottom part of the minimum-variance frontier is inefficient. The enterprises that lie underneath the global minimum-variance line are plums, olives, citrus, Sauvignon Blanc, and Bien Donne. These enterprises will not be included in the portfolio. Only eight of the thirteen enterprises are included in the optimal portfolios and lie above the global minimum-variance line, whilst five of the enterprises lie below the global minimum-variance line and will be considered as inefficient. The relative position (distance) of these enterprises to the efficient frontier is an indication of the risk-return performance. This also correlates with their S_p ranking as indicated in Table 6.2. Sweet melons and Shiraz dominate all enterprises in the risk-return space.

The CAL that is supported by the optimal portfolio, P, is tangent to the efficient frontier. This CAL dominates all alternative feasible lines. Portfolio P is thus the optimal risky portfolio. Sweet melon is represented by Point P (see Figure 6.2) and lies on the efficient frontier. This extension dominates everything below the line on the original efficient frontier. Thus a new efficient frontier is constructed, that is, the straight line from R_f (R = 15 000) tangent to Point P. Portfolio P is the optimal risky portfolio and all clients will choose this portfolio regardless of their degree of risk aversion.

When the input lists are identical and a risk-free asset is available as in this case with farm rental land, all farmers will choose the same portfolio on the efficient frontier of risky assets, and that is the portfolio tangent to the CAL. All the farmers with an identical input list will hold an identical risky portfolio, differing only in how much each allocates to this optimal portfolio and to the risk-free asset. The only difference between farmers' choice is that a more risk-averse farmer will invest more in the risk-free enterprise and less in the optimal risky portfolio than in the case of a less risk-averse farmer.

Only eight of the 13 enterprises were included in the optimal portfolio, whilst five of the enterprises lie below the global minimum-variance line and will be considered as inefficient. The occurrence of inefficient portfolios can be ascribed to the fact that not all farmers are risk averse in the Paarl/Berg River region. From the efficient frontier a portfolio can be selected, based on the investor's preference to risk. For the purpose of this study it was assumed in Chapter 1 that the investors are risk averse and that the portfolio diversification models assumptions are based on risk averse investors. Such an investor prefers more wealth to less wealth and prefers less risk to more risk. These investors will maximise the expected utility from their risk class, or conversely, the minimum risk at any particular level of expected return.

It can thus be assumed that no sufficient diversification models are used in the different industries within the Paarl/Berg River region and that most farmers use naïve diversification. These suggestions focus only on the return of the cultivar, and not the risk-reducing properties on a quantitative basis. Another reason might be that farmers are not aware of the risk characteristics of each enterprise, nor the historic return statistics. Nevertheless, efficient diversification, based on the Markowitz portfolio concepts, could be successfully applied to the Paarl/Berg River region. It is therefore suggested that farmers should considerer both risk and return characteristics of the various enterprises, as well as the correlation of the enterprises' returns with other cultivars, before a new enterprise or cultivar is introduced to a farmer's portfolio. This should be done in combination with conventional methods as currently practised, which will ensure efficient portfolios with the highest return for each level of risk.

The SIM was discussed in Section 6.3. The SIM can be used alternatively to the Markowitz diversification model. It drastically reduces the number of parameters needing to be estimated and yields the efficient set relatively easily without the technically difficulties characterising the full-rank solution. By employing the SIM, optimal investment proportions were obtained. The simplicity of the calculations is attained, however, only if the assumptions for the SIM are assumed to hold. Thus, in effect it can be assumed that ($\sigma_{ij} = \beta_i \beta_j \sigma_m^2$) or, equivalent, that $Cov(e_{i,} e_j) = 0$, which does not necessarily hold in reality. In the case of the Farm Sector Portfolio the SIM's most crucial assumption of uncorrelated error terms does not hold whereas the covariance of the error terms between the different enterprises is not zero. The reason for this is that in the population $Cov(u_i, u_j) = 0$ as required, the error covariance does not vanish in the sample only because of sampling errors. Therefore, the proportions obtained by using the SIM technique are only approximations to the true optimal proportions, and the quality of the approximation depends on how closely the SIM assumption approximates to real enterprise price behaviour. In this set of circumstances the SIM can be safely used even though in the sample $Cov\ (e_i, e_j) = 0$ for some or all pairs of enterprises.

Table 6.5 lists the optimal investment proportions for the 13 enterprises obtained by the SIM technique and the corresponding proportions of the optimal portfolio obtained by the exact method in Section 6.2. There is very little in common between the SIM and the MVC model as discussed in Section 6.2. The portfolio obtained through the SIM technique for the same riskless interest rate, r =15 000, lies inside the MV efficient frontier and is not efficient. There is thus a price to pay for the computational simplicity of the Single Index Model: the quick calculations produce a portfolio that is not necessarily MV efficient and the farmer is forced into a sub optimal strategy.

The SIM optimal portfolio consists of six enterprises held long (positive) and seven enterprises held short (negative), while the Markowitz optimal portfolio consists of eight enterprises that are efficient and lied above the global minimum-variance line and five of the enterprises that were inefficient and not included in the optimal portfolio. Moreover not all the enterprises shorted in the SIM portfolio were shorted in the exact portfolio. When the SIM technique was used, Merlot and Cabernet Sauvignon were not included into the optimal portfolio, but were included in the portfolio when the SOLVER program was used. The SIM provided a convenient shortcut for the constructing of an optimal portfolio. Therefore, the simplicity of SIM calculations is attained at a cost of constructing a sub-optimal portfolio, which does not lie on the corresponding efficient frontier.

Beta coefficients were generated in Section 6.4 for all those activities included in the Farm Sector Portfolio in order to report on the relationship between farm enterprise returns and systematic risk. In doing so the feasibility of using the CAPM as a strategic farm management tool was evaluated by the construction of an optimal portfolio consisting of risk-free and risk efficient enterprises for a typical farm in the Paarl/Berg River region.

Since Beta coefficients are a relative measure of the riskiness of a farm enterprise with respect to the riskiness of a diversified portfolio, enterprise Beta coefficients provides important *ex ante* risk information. Farmers can first evaluate a list of Beta coefficients, standard deviations and revenues such as those presented in Table 6.6. The estimated Beta coefficients ranged from a low 0.25 percent for Waltham Cross to a high of 2.36 percent for Merlot. As a general observation the wine grape cultivars Merlot and Shiraz contributed the most to the systematic risk of the Farm Sector Portfolio, followed by table grape cultivar (Bien Donne) and citrus. Plums and olives are relative low, with sweet melons only 0.70 times as risky as the Farm Sector Portfolio with a $\beta = 1$.

Once a decision has been made with respect to which enterprises are to be included in the farm portfolio, the individual weights (hectare proportions), as determined in Section 6.2 and 6.3, can be attached. As seen in Section 6.2 of the Markowitz mean-variance technique, portfolio P is the optimal risky portfolio and all clients will choose this portfolio regardless of their degree of risk aversion. The only difference between farmers' choices is that more risk-averse farmers will invest more in the risk-free enterprise and less in the optimal risky portfolio than with a less risk averse farmer. However, both will use portfolio P (sweet melons) as their optimal risky investment vehicle.

Therefore, the selection will be based on the farmers' attitude towards risk as well as on the feasibility of the portfolio, given available resources. The proportions of non-systematic risk that can be diversified away are small (see Figure 6.5), relative to the total risk of the Farm Sector Portfolio. By using the CAPM it is possible to determine the part of the risk the producer can control (non-systematic risk) and which part the producer has no control over (systematic risk). According to the CAPM, risk-averse producers must organise their production to minimise systematic risk in their portfolios. The large degree of systematic risk within agriculture reflects the volatility of the export and the domestic markets. The result of this study indicates that opportunities for diversification within agriculture are limited.

On the basis of the portfolio enclosed in this study, it is also concluded that systematic risk is high within agriculture. The CAPM reveals that there is a great deal of systematic risk in relation to the Farm Sector Portfolio in this study. Farmers for almost half of the 13 enterprises are not compensated, in terms of expected return, for systematic risk. Olives, citrus and plums exhibit relatively low market risk compared to the red wine cultivars. Agriculture enterprises are regarded as illiquid and less traded than assets in the capital markets and investment in these assets are also poorly diversified, thus the variation in returns of these assets are greatly affected by the unique supply and demand conditions of agricultural market rather than the market in general. Olives, citrus, plums, Bien Donne and two red wine cultivars, Cabernet Sauvignon and Merlot have plotted below the SML during the period of the study. The implication of this is that these assets have earned much lower market returns than other assets with similar market risks. The reason for this can be that farmer's produce on unprofitable land, and resources are still allocated to insufficient farming. This situation stresses out the importance of sufficient information where farmers should have consider both risk and return characteristics of the various enterprises before a new enterprise or cultivar are introduced to a farmer portfolio.

Portfolios that are comprised out of non-farm activities in combination with farm enterprises could reduce the amount of systematic risk because of the low correlation and the greater flexibility in transferring capital between and among portfolios.

7.2 Recommendations

It is seldom possible in a thesis to answer all possible questions without transgressing the boundaries of the research. This was no exception. Following from the insights gained during this research, a number of topics worthy of further research can be identified.

To reduce inefficient portfolios, sufficient diversification models can be used in the different enterprises within the Paarl/Berg River region. It must be acknowledged that not all producers would take advantage of the opportunities described above. It is, therefore, necessary to contemplate solutions for those farmers that choose to remain the users of naïve diversification. As the only route to survival for farmers is through staying ahead on the treadmill, the development and availability of new technology is important.

To overcome this problem of scarce and insufficient data, some recommendations can be made:

1) Study groups of farmers must be formed within the Paarl/Berg River region where individual farmers can be evaluated and compared with other farmers in the study group, based on each farmer's preference for risk. Records of different enterprises

and of cultivars must be gathered in order to build up a data bank of historical data over time. These measures could assist (risk-averse) farmers in their decision-making process not only between the different industries, but also between the various cultivars within industries.

2) The technique used to gather data is very important. The outcome of the models is entirely based on the input data gathered in a specific region. Without reliable data, the result will be garbage in, garbage out. New technologies like geographical information systems (GIS) can improve the process of gathering sufficient data.

It is posited out that portfolio holdings of non-farm assets that are uncorrelated with the farm sector portfolio could reduce the amount of systematic risk in farm portfolios. Further research in this and extension applications of these models are strongly recommended.

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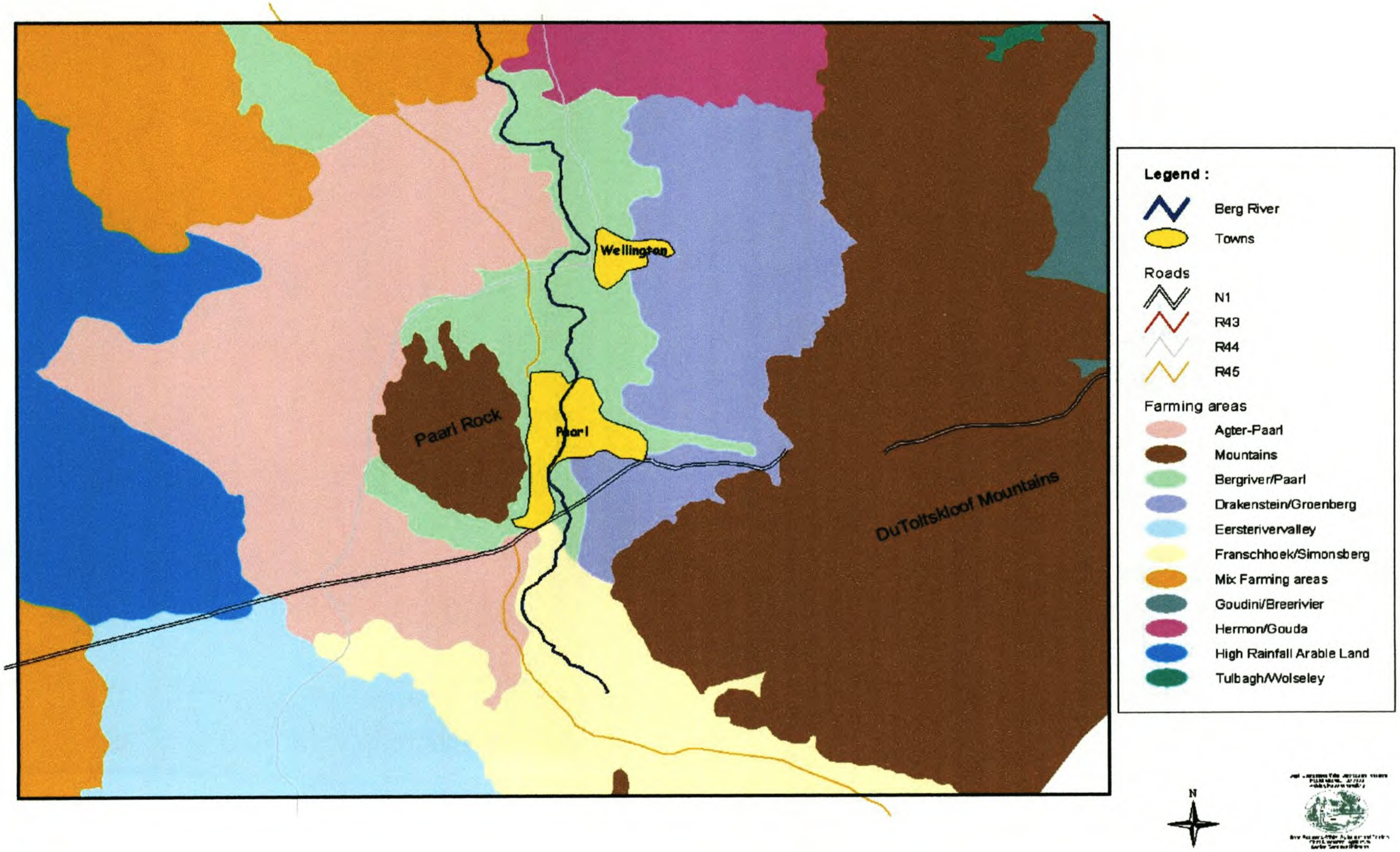
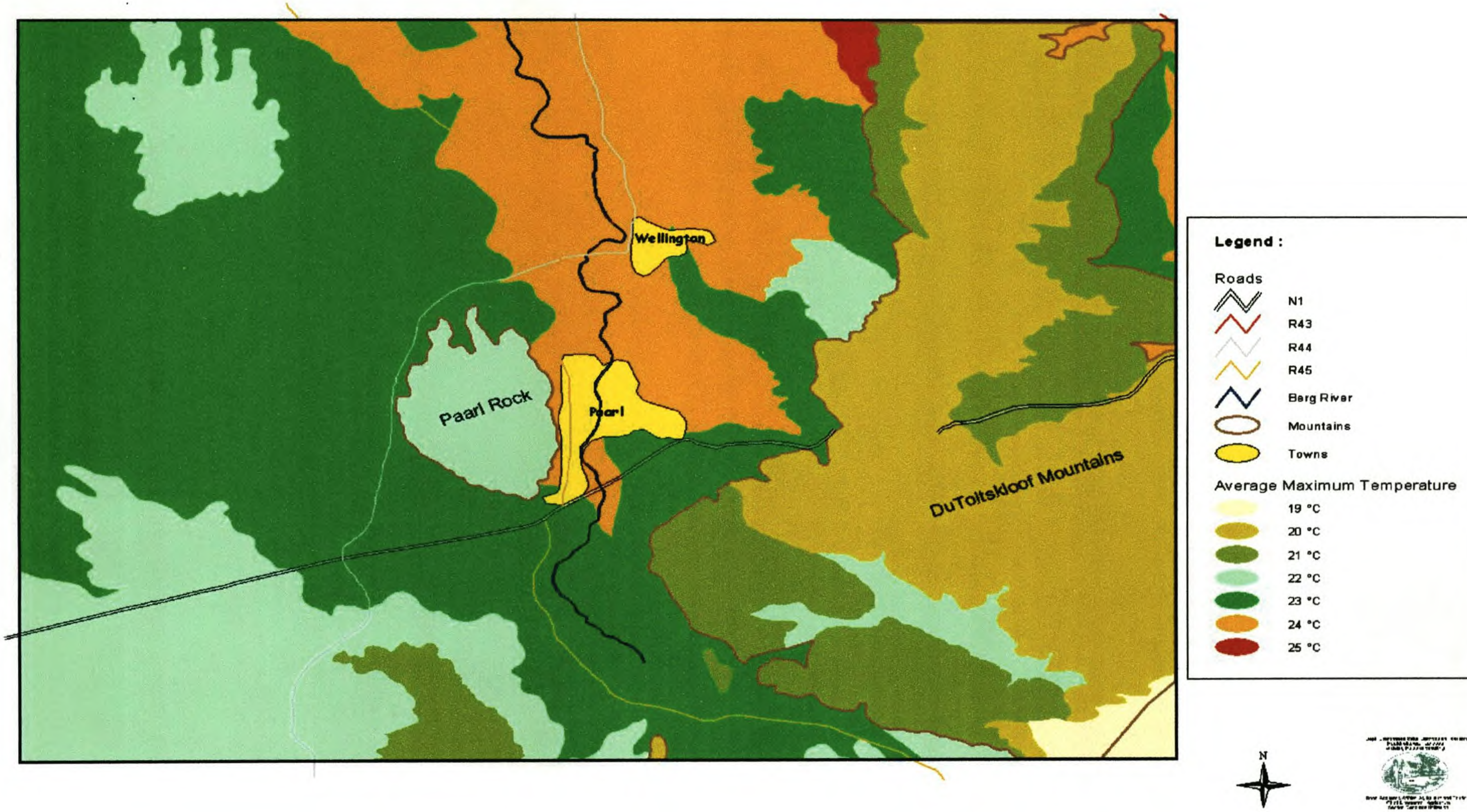
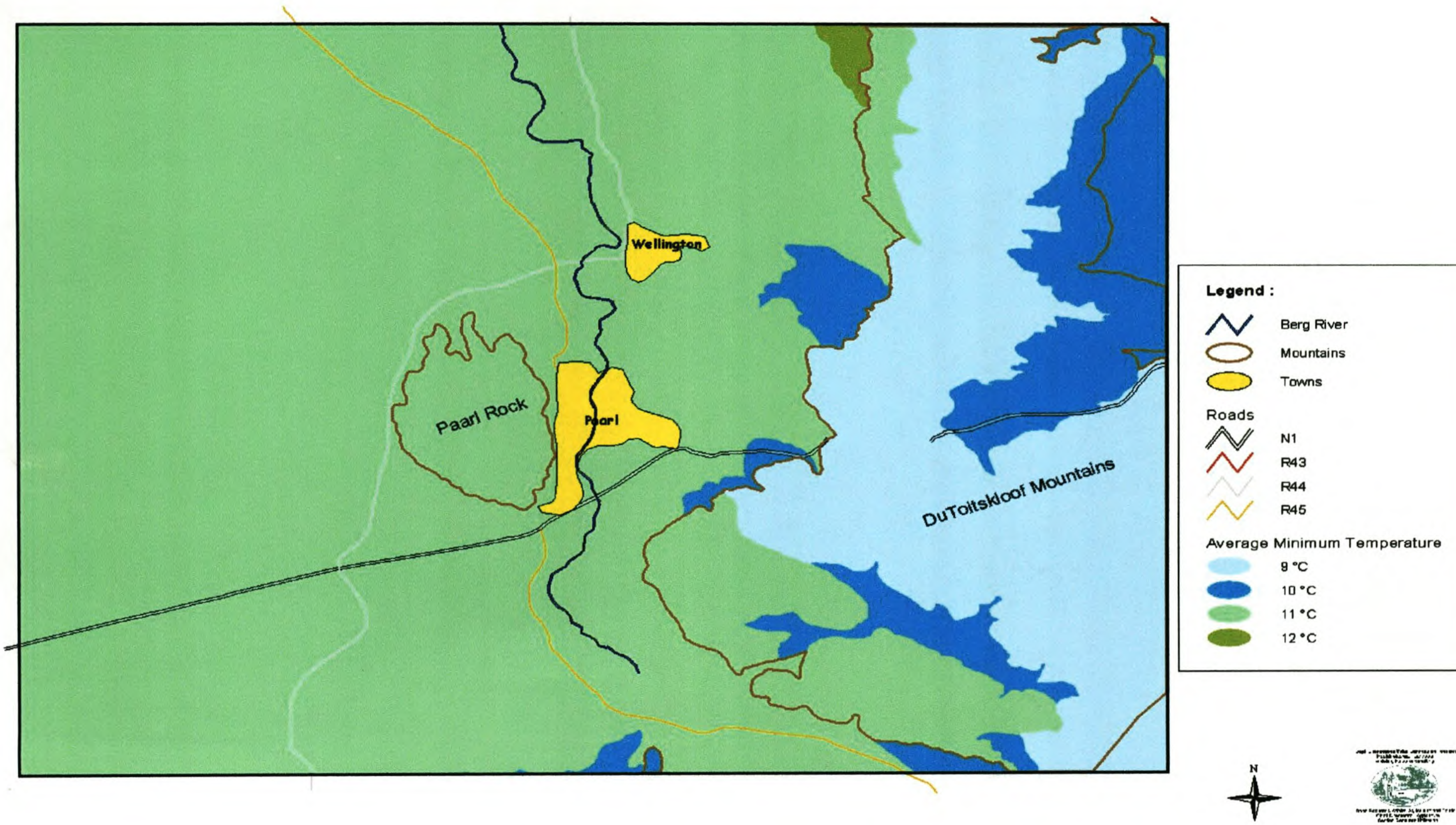
APPENDIX 1.1
FARMING AREAS IN THE PAARL/BERG RIVER REGION



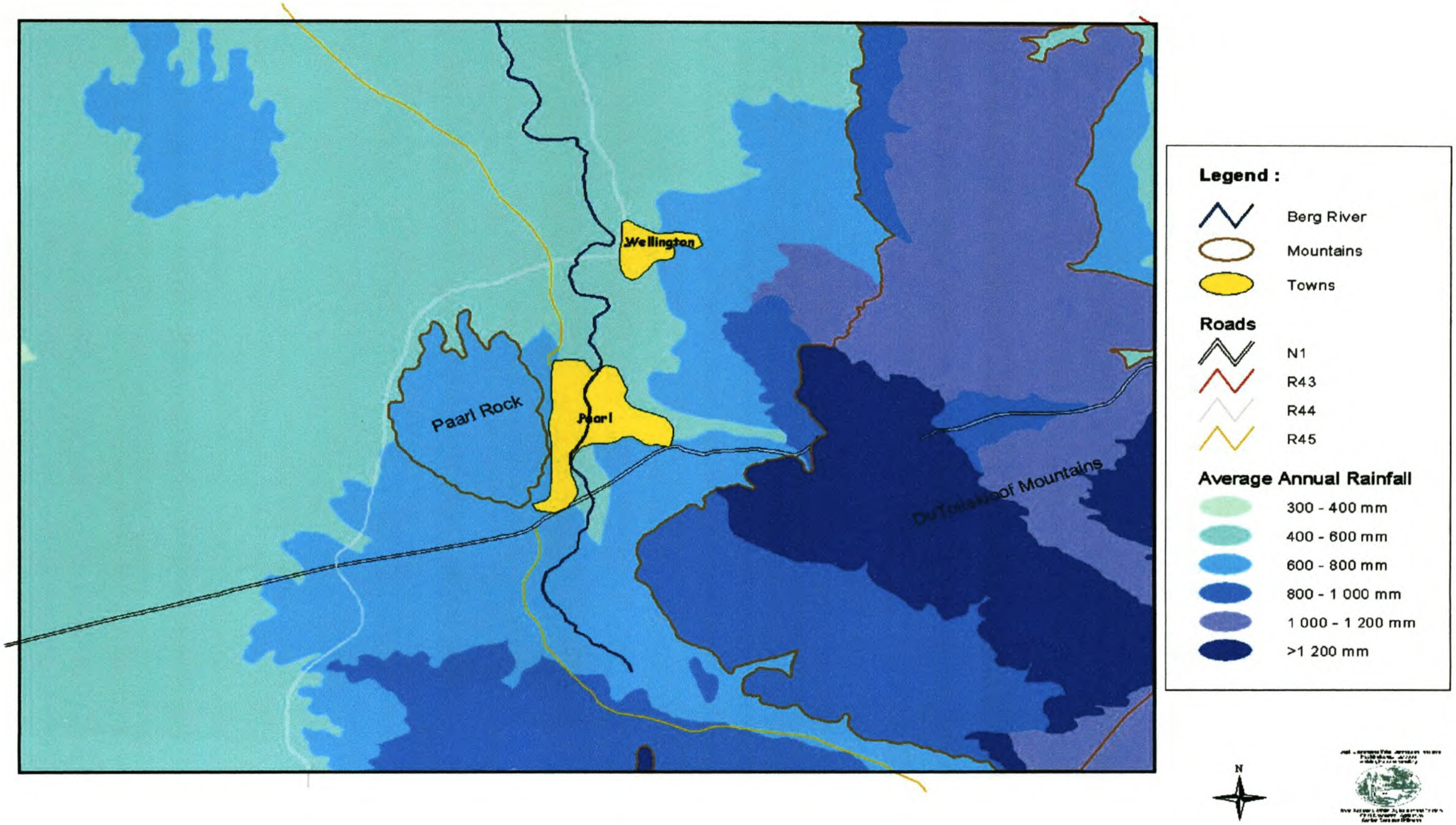
APPENDIX 1.2
AVERAGE MAXIMUM TEMPERATURE IN THE PAARL/BERG RIVER REGION



APPENDIX 1.3
AVERAGE MINIMUM TEMPERATURE IN THE PAARL/BERG RIVER REGION



APPENDIX 1.4
AVERAGE ANNUAL RAINFALL IN THE PAARL/BERG RIVER REGION



APPENDIX 2.1
COVERLETTER FOR QUESTIONNAIRE

UNIVERSITEIT VAN STELLENBOSCH
UNIVERSITY OF STELLENBOSCH

10 November 2002

Dear Mr. ....

Risk is an important part in agriculture and must be managed sufficiently at all costs. I am a student at the University of Stellenbosch from the Department of Agriculture Economics. My study consists of risk management procedures in the Paarl/Berg River region by investigating different diversification methods.

Thank you very much that you are willing to make your data available for this study and you can be ensured that the data would be handeld very confidentially!

Attached is a confidential income- and cost questionnaire for the (spesific industry). The questionnaire is constructed uniformly for the different enterprises. It is very important in this study that the cost of the different enterprises must be specified in order to calculate a comparable margin over a certain time period. To make the study sufficient it is necessary to gain data for at least five years to evaluate the variance within the cost and income structure.

Thank you that you are willing to assist me in my study. If anything is unclear, please feel free to contact me immediately.

Yours sincerely

Gerrit Maritz
(082 418 3399)
E-mail: 12670049@narga.sun.ac.za

APPENDIX 2.2
QUESTIONNAIRES USED TO GATHER DATA

CONFIDENTIAL		
INCOME AND COST OVER TIME		
PRODUCTION YEAR		
PRODUCT		
CULTIVAR		
AGE COMPOSITION		Ha
3 YEARS AND YOUNGER		Ha
4 – 15 YEARS		Ha
16 – 25 YEARS		Ha
OVER 25 YEARS		Ha
LIVESPAN OF ORCHARD/VINES		Years

INCOME	UNIT	PRICE/UNIT	QUANTITY	R/HA
• EXPORT				
• DOMESTIC MARKET				
• CANNED				
• PRIVATE USE				
• LABOUR USES				

APPENDIX 2.2 (continued)
QUESTIONNAIRES USED TO GATHER DATA

ALLOCATABLE COST (NON BEARING)				
	UNIT	PRICE/UNIT	QUANTITY	R/Ha
LABOUR				
CONTRACT LABOUR				
FERTILIZER				
ORGANIC				
CHEMICAL				
LIME				
PESTICIDES				
HERBICIDES				
FUNGICIDES				
INSURANCE				
OTHER				

APPENDIX 2.2 (continued)
QUESTIONNAIRES USED TO GATHER DATA

ALLOCATABLE COST (BEARING)				
	UNIT	PRICE/UNIT	QUANTITY	R/Ha
LABOUR				
CONTRACT LABOUR				
FERTILIZER				
ORGANIC				
CHEMICAL				
LIME				
PESTICIDES				
HERBICIDES				
FUNGICIDES				
MARKETING COST				
COMMISSION				
INSURANCE				
OTHER				

APPENDIX 2.2 (continue)
QUESTIONNAIRES USED TO GATHER DATA

FIXED COST				
	UNIT	PRICE/UNIT	QUANTITY	R/Ha
REGULAR LABOUR				
ESTABLISHMENT COST				
SOIL PRPARATION				
PLANT MATERIAL				
TRELLISING				
FERTILIZER				
OTHER				

APPENDIX 2.3

QUESTIONNAIRES USED TO GATHER DATA FOR SWEET MELONS

CONFIDENTIAL	
INCOME AND COST OVER TIME	
PRODUCTION YEAR	
PRODUCT	
CULTIVAR	

INCOME	UNIT	PRICE/UNIT	QUANTITY	R/HA
• EXPORT				
• DOMESTIC MARKET				
• CANNED				
• PRIVATE USE				
• LABOUR USES				

ALLOCATABLE COST				
	UNIT	PRICE/UNIT	QUANTITY	R/Ha
LABOUR				
CONTRACT LABOUR				
FERTILIZER				

APPENDIX 2.3 (continue)
QUESTIONNAIRES USED TO GATHER DATA FOR SWEET MELONS

ORGANIC				
CHEMICAL				
LIME				
PESTICIDES				
HERBICIDES				
FUNGICIDES				
MARKETING COST				
COMMISSION				
INSURANCE				
OTHER				

FIXED COST				
	UNIT	PRICE/UNIT	QUANTITY	R/Ha
REGULAR LABOUR				

APPENDIX 2.3 (continue)

QUESTIONNAIRES USED TO GATHER DATA FOR SWEET MELONS

ESTABLISHMENT COST				
SOIL PREPARATION				
PLANT MATERIAL				
FERTILIZER				
OTHER				

APPENDIX 3
FARM SECTOR PORTFOLIO OF THE PAARL/BERG RIVER REGION

	1997	1998	1999	2000	2001	Mean	Stan.dev.
Waltham Cross	34 453	38 281	22 432	13 025	45 292	**30 697**	**12 896**
Red Globe	31 289	34 766	30 374	32 772	42 391	**34 318**	**4 808**
Ben Donne	14 224	15 804	25 128	12 161	38 635	**21 191**	**10 941**
La Rochelle	24 930	27 700	30 187	37 574	38 126	**31 704**	**5 914**
Cabernet Sauvignon	16 101	21 332	29 427	33 496	31 431	**26 357**	**7 358**
Pinotage	29 932	35 732	49 427	51 096	48 635	**42 964**	**9 515**
Merlot	15 892	26 012	39 827	49 896	53 291	**36 984**	**15 858**
Shiraz	28 852	35 732	54 227	54 696	55 175	**45 736**	**12 515**
Sauvignon Blanc	15 712	17 732	23 727	23 096	20 585	**20 170**	**3 435**
Sweet melons	37 436	41 595	44 151	46 685	49 448	**43 863**	**4 628**
Citrus	21 058	83 62	28 410	18 155	31 248	**21 446**	**9 038**
Plums	25 683	11 835	28 901	15 202	27 092	**21 742**	**7 686**
Olives	13 084	27 32	8 196	57 55	17 267	**9 407**	**5 801**
Mean	**23 742**	**24 432**	**31 878**	**30 278**	**38 355**	29 737	5 983
Standard deviation	**8 289**	**12 511**	**12 299**	**16 848**	**12 196**	10 919	3 030

APPENDIX 4
CORRELATION MATRIX OF 13 ENTERPRISES IN THE PAARL/BERG RIVER REGION

	Waltham Cross	*Red Globe*	*Bien Donne*	*La Rochelle*	*Cabernet Sauvignon*	*Pinotage*	*Merlot*	*Shiraz*	*Sauvignon Blanc*	*Sweet melons*	*Citrus*	*Plums*	*Olives*
Waltham Cross	1	0.68	0.56	-0.17	-0.41	-0.44	-0.22	-0.36	-0.62	-0.05	0.09	0.19	0.51
Red Globe	0.68	1	0.75	0.59	0.33	0.24	0.52	0.31	-0.04	0.65	0.3	0.06	0.54
Bien Donne	0.56	0.75	1	0.47	0.42	0.43	0.55	0.53	0.26	0.64	0.76	0.61	0.69
La Rochelle	-0.17	0.59	0.47	1	0.92	0.85	0.97	0.86	0.67	0.96	0.41	-0.01	0.24
Cabernet Sauvignon	-0.41	0.33	0.42	0.92	1	0.99	0.98	0.98	0.91	0.93	0.44	0.05	0.03
Pinotage	-0.44	0.24	0.43	0.85	0.99	1	0.94	0.99	0.95	0.89	0.50	0.15	0.03
Merlot	-0.22	0.52	0.55	0.97	0.98	0.94	1	0.96	0.81	0.98	0.50	0.10	0.20
Shiraz	-0.36	0.31	0.53	0.86	0.98	0.99	0.96	1	0.93	0.91	0.57	0.22	0.12
Sauvignon Blanc	**-0.62**	-0.04	0.26	0.67	0.91	0.95	0.81	0.93	1	0.72	0.43	0.14	-0.15
Sweet melons	-0.05	0.65	0.64	0.96	0.93	0.89	0.98	0.91	0.72	1	0.48	0.07	0.23
Citrus	0.09	0.30	0.76	0.41	0.44	0.50	0.50	0.57	0.43	0.48	1	0.91	0.79
Plums	0.19	0.06	0.61	-0.01	0.05	0.15	0.10	0.22	0.14	0.07	0.91	1	0.77
Olives	0.51	0.54	0.69	0.24	0.03	0.03	0.20	0.12	-0.15	0.23	0.79	0.77	1

APPENDIX 5

COVARIANCES OF THE 13 ENTERPRISES IN THE PAARL/BERG RIVER REGION

	WAL	RG	BD	LAR	CAB	PIN	MER
WAL	166 309 948.93	42 443 497.89	78 655 353.58	(13 316 076.77)	(38 526 441.86)	(54 536 373.01)	(44 024 305.40)
RG	42 443 497.89	23 124 264.19	39 489 782.10	16 869 861.87	11 656 807.76	10 987 236.20	39 859 719.08
BD	78 655 353.58	39 489 782.10	119 725 250.80	30 453 509.82	33 661 960.15	45 170 384.25	96 276 770.53
LAR	(13316 076.77)	16 869 861.87	30 453 509.82	34 980 255.77	39 855 704.73	47 894 167.09	90 751 755.66
CAB	(38 526 441.86)	11 656 807.76	33 661960.15	39 855 704.73	54 140 819.30	69 163 771.93	113 771 257.67
PIN	(54 536 373.01)	10 987 236.20	45 170 384.25	47 894 167.09	69 163 771.93	90 544 429.98	142 512 090.76
MER	(44 024 305.40)	39 859 719.08	96 276 770.53	90 751 755.66	113 771 257.67	142 512 090.76	251 486 874.74
SHZ	(57 508 273.27)	18 879 022.20	72 172 206.11	63 687 566.92	90 335 844.85	118 407 225.30	189 901 718.08
SB	(27 570 807.70)	(698 801.91)	9 750 510.97	13 599 490.79	22 969 657.98	31 213 437.23	4 385 5154.01
SM	(3 018 345.01)	14 510 609.05	32 518 130.39	26 154 012.40	31 670 140.32	39 159 863.38	72 194 099.08
CI	10 746 614.04	13 018 822.80	75 327 102.64	22 019 603.91	29 333 663.30	43 374 959.81	72 218 709.12
PL	18 540 015.91	2 173 577.02	51 617 459.21	(482 725.14)	2 946 048.66	10 924 589.78	12 176 003.45
OL	60 248 845.82	17 190 095.59	68 710 285.26	2 979 522.10	(4 607 746.50)	(2 887 751.05)	10 042 493.61

WAL = WALTHAM CROSS, RG = RED GLOBE, BD = BIEN DONNE, LAR = LA ROCHELLE, CAB = CABERNET SAUVIGNON, PIN = PINOTAGE

MER = MERLOT, SHZ = SHIRAZ, SB = SAUVIGNON BLANC, SM = SWEET MELONS, CI = CITRUS, PL = PLUMS, OL = OLIVES

APPENDIX 5 (continue)

COVARIANCES OF THE 13 ENTERPRISES IN THE PAARL/BERG RIVER REGION

	SHZ	SB	SM	CI	PL	OL
WAL	(57 508 273.27)	(27 570 807.70)	(3 018 345.01)	10 746 614.04	18 540 015.91	60 248 845.82
RG	18 879 022.20	(698 801.91)	14 510 609.05	13 018 822.80	2 173 577.02	17 190 095.59
BD	72 172 206.11	9 750 510.97	32 518 130.39	75 327 102.64	51 617 459.21	68 710 285.26
LAR	63 687 566.92	13 599 490.79	26 154 012.40	22 019 603.91	(482 725.14)	2 979 522.10
CAB	90 335 844.85	22 969 657.98	31 670 140.32	29 333 663.30	2 946 048.66	(4 607 746.50)
PIN	118 407 225.30	31 213 437.23	39 159 863.38	43 374 959.81	10 924 589.78	(2 887 751.05)
MER	189 901 718.08	43 855 154.01	72 194 099.08	72 218 709.12	12 176 003.45	10 042 493.61
SHZ	156 649 540.61	39 995 092.55	52 912 132.72	64 898 702.95	21 309 789.85	6 712 644.70
SB	39 995 092.55	11 799 624.48	11 444 079.66	13 206 558.88	3 781 032.51	(4 906 578.91)
SM	52 912 132.72	11 444 079.66	21 423 442.80	19 906 295.53	2 653 573.75	4 189 429.02
CI	64 898 702.95	13 206 558.88	19 906 295.53	81 687 373.42	62 977 883.76	66 866 379.89
PL	21 309 789.85	3 781 032.51	2 653 573.75	62 977 883.76	59 082 141.26	61 177 852.61
OL	6 712 644.70	(4 906 578.91)	4 189 429.02	66 866 379.89	61 177 852.61	80 503 825.30

WAL = WALTHAM CROSS, RG = RED GLOBE, BD = BIEN DONNE, LAR = LA ROCHELLE, CAB = CABERNET SAUVIGNON, PIN = PINOTAGE

MER = MERLOT, SHZ = SHIRAZ, SB = SAUVIGNON BLANC, SM = SWEET MELONS, CI = CITRUS, PL = PLUMS, OL = OLIVES

APPENDIX 6
RETURN ON THE MARKET PORTFOLIO

R_i	Waltham Cross	Red Globe	Bien Donne	La Rochelle
1997	34 453	31 289	14 224	24 930
1998	38 281	34 766	15 804	27 700
1999	22 432	30 374	25 128	30 187
2000	13 025	32 772	12 161	37 574
2001	45 292	42 391	38 635	38 126
Mean	**30 697**	**34 318**	**21 191**	**31 704**

R^2	Waltham Cross	Red Globe	Bien Donne	La Rochelle
1997	1 187 021 949	979 044 352	202 332 609	621 540 753
1998	1 465 459 197	1 208 696 732	249 793 344	767 334 263
1999	503 225 656	922 617 890	631 441 715	911 267 308
2000	169 669 276	1 074 014 706	147 907 515	1 411 855 724
2001	2 051 433 276	1 797 061 145	1 492 733 041	1 453 654 605
Sum	**5 376 809 355**	**5 981 434 826**	**2 724 208 226**	**5 165 652 654**

$(R_m \times R_i)$	Waltham Cross	Red Globe	Bien Donne	La Rochelle
1997	818 004 573	742 895 179	337 721 957	591 917 475
1998	935 308 478	849 428 209	386 152 132	676 799 924
1999	715 117 422	968 293 256	801 055 499	962 318 570
2000	394 393 825	992 278 581	368 233 778	1 137 689 271
2001	1 737 221 557	1 625 952 818	1 481 895 519	1 462 369 519
Sum	**4 600 045 857**	**5 178 848 045**	**3 375 058 887**	**4 831 094 759**

R_i	Cabernet Sauvignon	Pinotage	Merlot	Shiraz
1997	16 101	29 932	15 892	28 852
1998	21 332	35 732	26 012	35 732
1999	29 427	49 427	39 827	54 227
2000	33 496	51 096	49 896	54 696
2001	31 431	48 635	53 291	55 175
Mean	**26 357**	**42 964**	**36 984**	**45 736**

R^2	Cabernet Sauvignon	Pinotage	Merlot	Shiraz
1997	259 257 194	895 964 470	252 576 820	832 476 312
1998	455 086 348	1 276 829 634	676 663 316	1 276 829 634
1999	865 961 747	2 443 050 868	1 586 208 090	2 940 592 257
2000	1 122 015 512	2 610 852 312	2 489 660 712	2 991 707 112
2001	987 907 761	2 365 363 225	2 839 930 681	3 044 280 625
Sum	**3 690 228 564**	**9 592 060 509**	**7 845 039 620**	**11 085 885 940**

$(R_m \times R_i)$	Cabernet Sauvignon	Pinotage	Merlot	Shiraz
1997	382 288 968	710 676 166	377 331 535	685 034 271
1998	521 212 604	873 040 684	635 556 730	873 040 684.
1999	938 091 769	1 575 658 971	1 269 626 714	1 728 675 099
2000	1 014 210 106	1 547 104 524	1 510 770 813	1 656 105 654
2001	1 205 548 565	1 865 414 860	2 043 997 601	2 116 259 174
Sum	**4 061 352 014**	**6 571 895 205**	**5 837 283 394**	**7 059 114 883**

APPENDIX 6 (continue)
RETURN ON THE MARKET PORTFOLIO

R_i	Sauvignon Blanc	Sweet melons	Citrus	Plums
1997	15 712	37 436	21 058	25 683
1998	17 732	41 595	83 62	11 835
1999	23 727	44 151	28 410	28 901
2000	23 096	46 685	18 155	15 202
2001	20 585	49 448	31 248	27 092
Mean	**20 170**	**43 863**	**21 446**	**21 742**

R^2	Sauvignon Blanc	Sweet melons	Citrus	Plums
1997	246 887 860	1 401 462 731	443 449 943	659 651 186
1998	314 450 527	1 730 200 902	69 925 719	140 075 547
1999	562 981 348	1 949 325 371	807 128 100	835 288 887
2000	533 448 312	2 179 549 916	329 604 025	231 102 020
2001	423 742 225	2 445 154 152	976 453 753	733 976 464
Sum	**2 081 510 274**	**9 705 693 073**	**2 626 561 541**	**2 600 094 106**

$(R_m \times R_i)$	Sauvignon Blanc	Sweet melons	Citrus	Plums
1997	373 057 886	888 826 785	499 975 426	609 794 539
1998	433 255 584	1 016 286 772	204 308 520	289 167 293
1999	756 385 117	1 407 466 735	905 664 209	921 328 113
2000	699 317 949	1 413 552 402	549 698 758	460 288 764
2001	789 545 901	1 896 616 978	1 198 539 499	1 039 124 486
Sum	**3 051 562 439**	**6 622 749 671**	**3 358 186 414**	**3 319 703 197**

R_i	Olives	Mean
1997	13 084	23 742
1998	2 732	24 432
1999	8 196	31 878
2000	5 755	30 278
2001	17 267	38 355
Mean	**9 407**	**29 737**

R^2	Olives	Mean
1997	171 199 200	563 706 073
1998	7 465 618	596 947 326
1999	67 190 563	1 016 229 840
2000	33 128 466	916 762 850
2001	298 156 195	1 471 136 679
Sum	**577 140 043**	**4 564 782 770**

$(R_m \times R_i)$	Olives
1997	310 654 195
1998	66 757 627
1999	261 306 439
2000	174 272 622
2001	66 229 035
Sum	**1 475 281 240**

APPENDIX 7

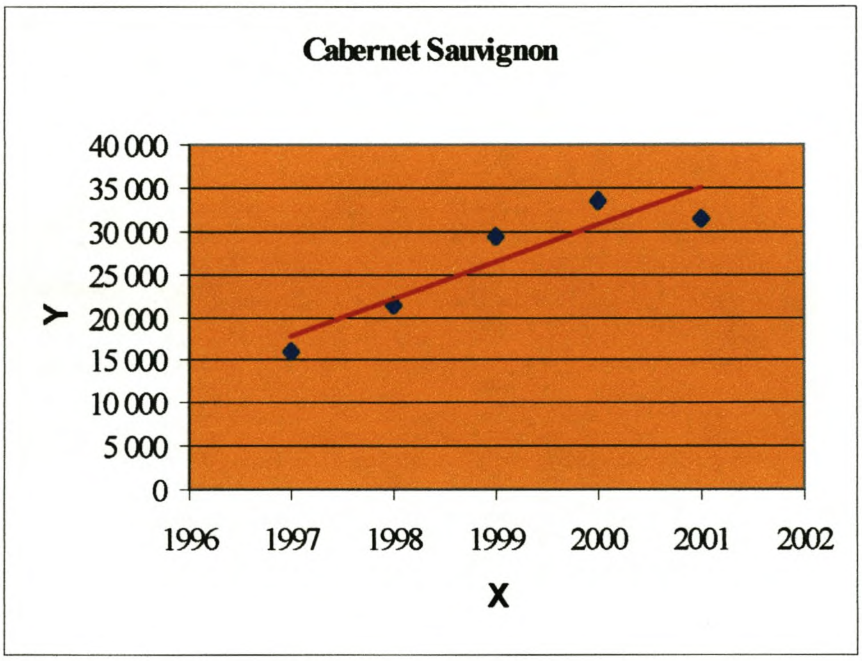
LINEAR REGRESSION CALCULATIONS OF THE 13 ENTERPRISES IN THE PAARL/BERG RIVER REGION

Cabernet Sauvignon

1997	16 101.47
1998	21 332.75
1999	29 427.23
2000	33 496.50
2001	31 431.00

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.92
R Square	0.85
Adjusted R Square	0.80
Standard Error	3 325.85
Observations	5



APPENDIX 7 (continue)

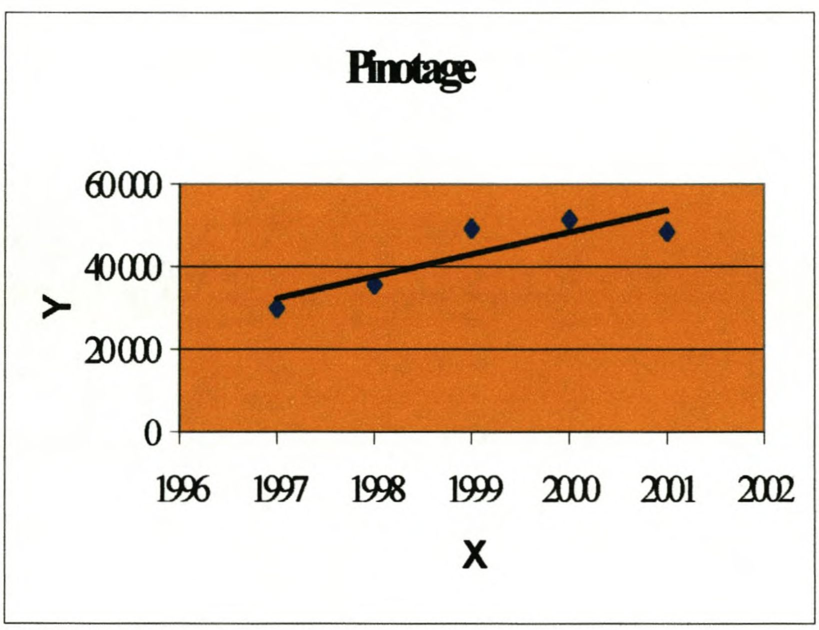
LINEAR REGRESSION CALCULATIONS OF THE 13 ENTERPRISES IN THE PAARL/BERG RIVER REGION

Pinotage

1997	29 932.67
1998	35 732.75
1999	49 427.23
2000	51 096.50
2001	48 635.00

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.88
R Square	0.77
Adjusted R Square	0.69
Standard Error	5 282.90
Observations	5



APPENDIX 7 (continue)

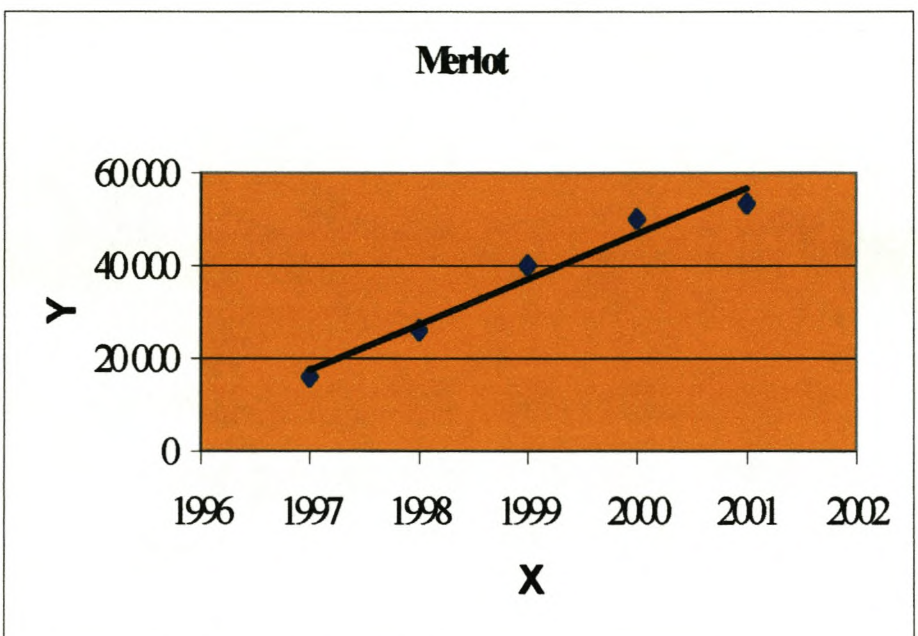
LINEAR REGRESSION CALCULATIONS OF THE 13 ENTERPRISES IN THE PAARL/BERG RIVER REGION

Merlot

1997	15 892.67
1998	26 012.75
1999	39 827.23
2000	49 896.50
2001	53 291.00

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.98
R Square	0.97
Adjusted R Square	0.96
Standard Error	3274.40
Observations	5



APPENDIX 7 (continue)

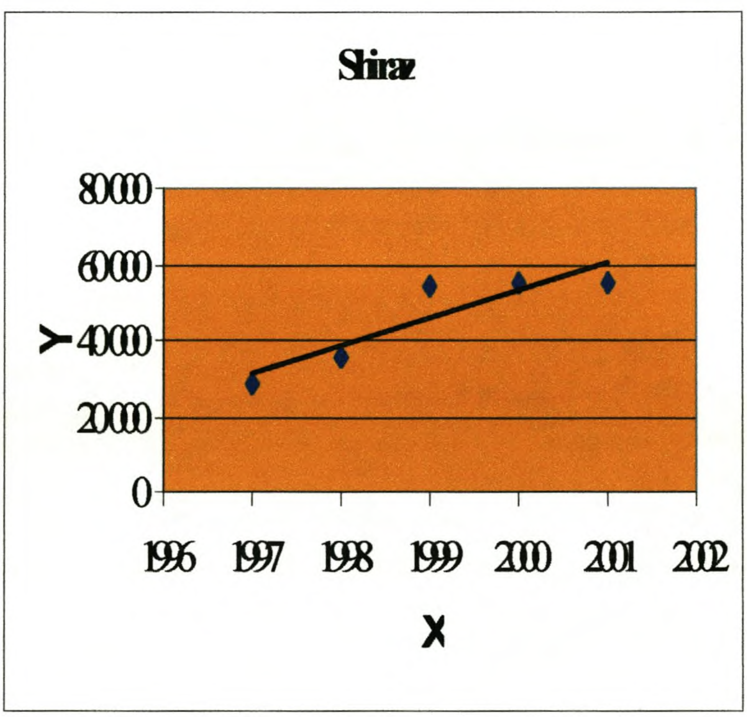
LINEAR REGRESSION CALCULATIONS OF THE 13 ENTERPRISES IN THE PAARL/BERG RIVER REGION

Shiraz

1997	28 852.67
1998	35 732.75
1999	54 227.23
2000	54 696.50
2001	55 175.00

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.90
R Square	0.82
Adjusted R Square	0.76
Standard Error	6159.59
Observations	5



APPENDIX 7 (continue)

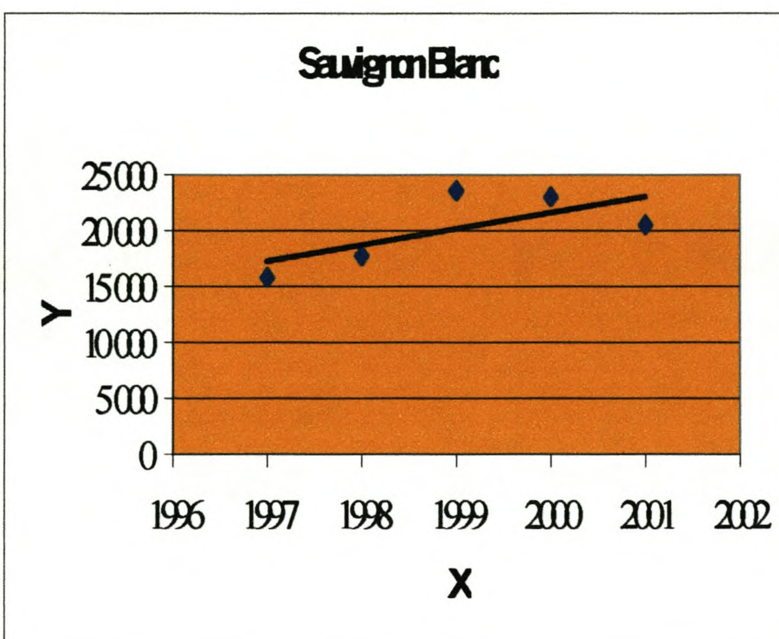
LINEAR REGRESSION CALCULATIONS OF THE 13 ENTERPRISES IN THE PAARL/BERG RIVER REGION

Sauvignon Blanc

1997	15 712.67
1998	17 732.75
1999	23 727.23
2000	23 096.50
2001	20 585.00

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.70
R Square	0.48
Adjusted R Square	0.31
Standard Error	2850.27
Observations	5



APPENDIX 7 (continue)

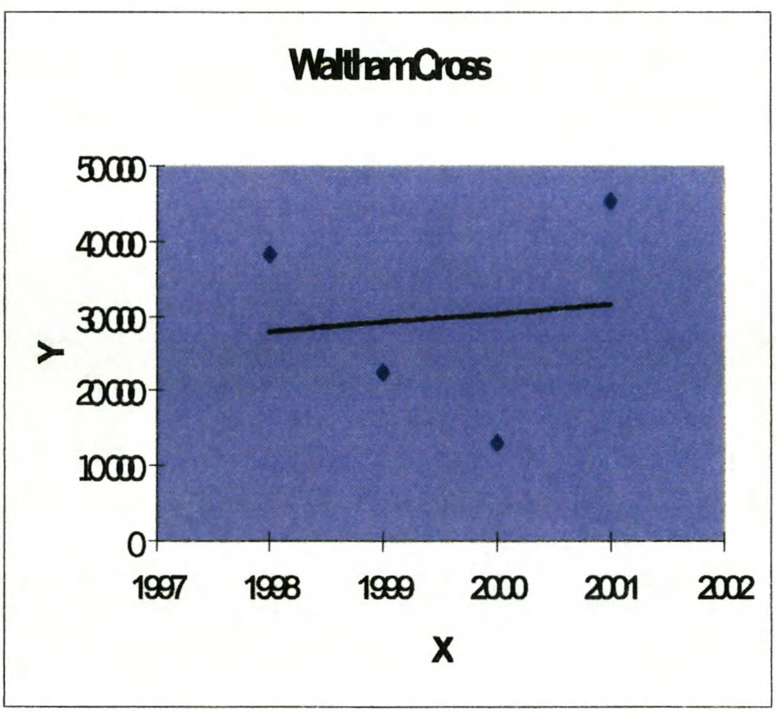
LINEAR REGRESSION CALCULATIONS OF THE 13 ENTERPRISES IN THE PAARL/BERG RIVER REGION

Waltham Cross

1998	38 281.32
1999	22 432.69
2000	13 025.72
2001	45 292.75

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.10
R Square	0.01
Adjusted R Square	-0.48
Standard Error	17 900.35
Observations	4



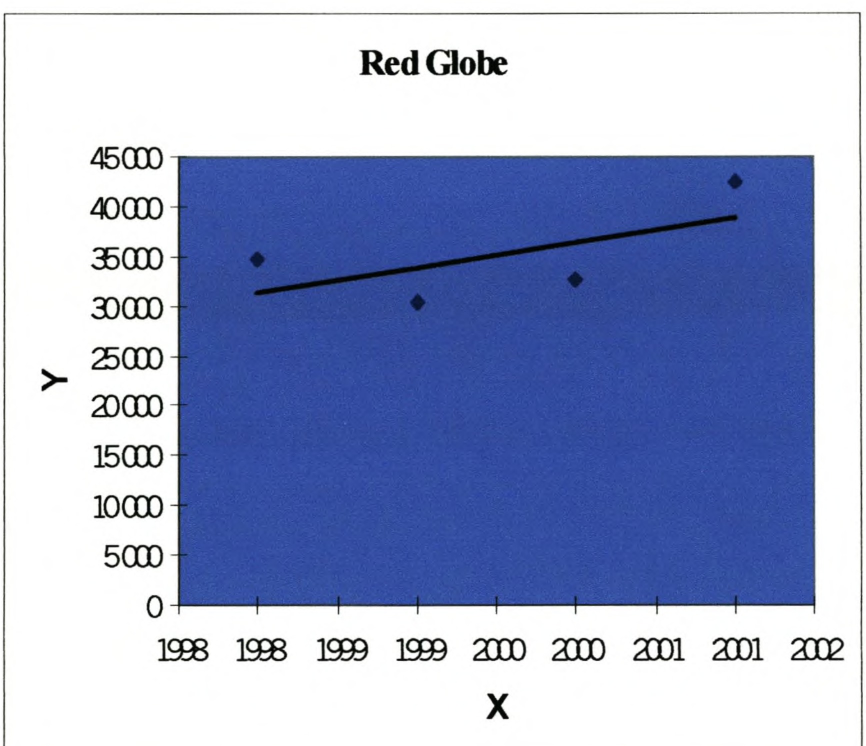
LINEAR REGRESSION CALCULATIONS OF THE 13 ENTERPRISES IN THE PAARL/BERG RIVER REGION

Red Globe

1998	34 766.32
1999	30 374.63
2000	32 772.16
2001	42 391.76

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.62
R Square	0.39
Adjusted R Square	0.09
Standard Error	4 954.20
Observations	4



APPENDIX 7 (continue)

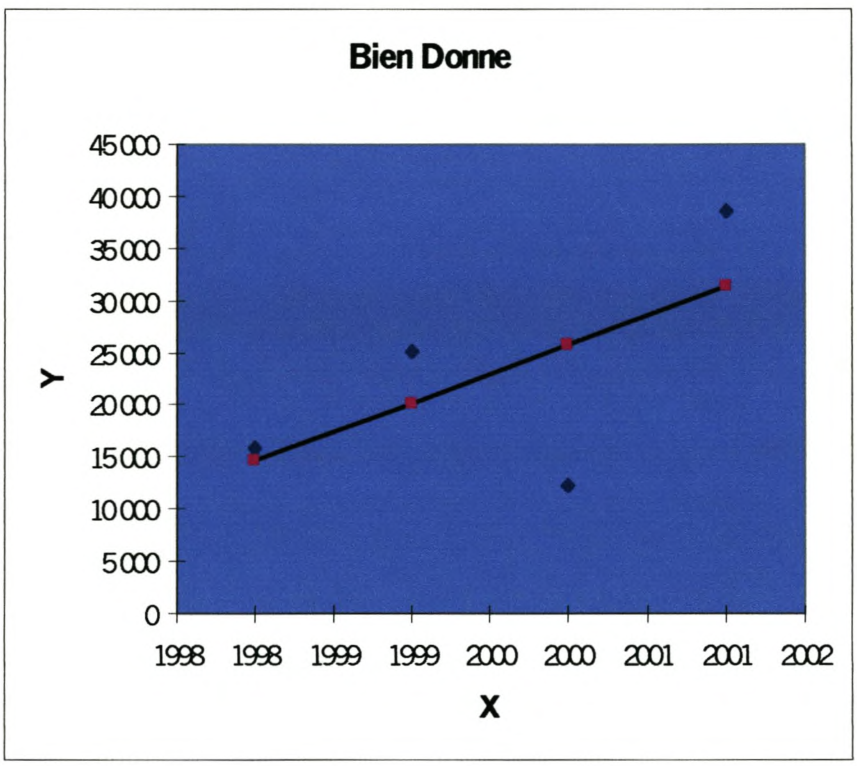
LINEAR REGRESSION CALCULATIONS OF THE 13 ENTERPRISES IN THE PAARL/BERG RIVER REGION

Bien Donne

1998	15804.85
1999	25128.50
2000	12161.72
2001	38635.90

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.60
R Square	0.36
Adjusted R Square	0.05
Standard Error	11 490.72
Observations	4



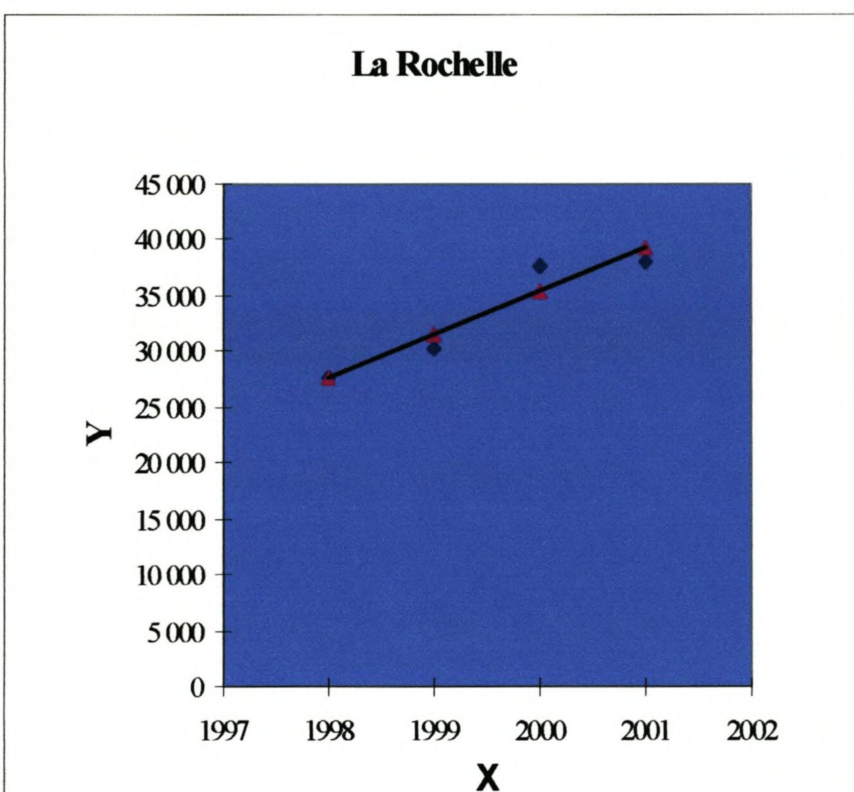
LINEAR REGRESSION CALCULATIONS OF THE 13 ENTERPRISES IN THE PAARL/BERG RIVER REGION

La Rochelle

1998	27700.80
1999	30187.20
2000	37574.67
2001	38126.82

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.95
R Square	0.90
Adjusted R Square	0.85
Standard Error	1 977.68
Observations	4



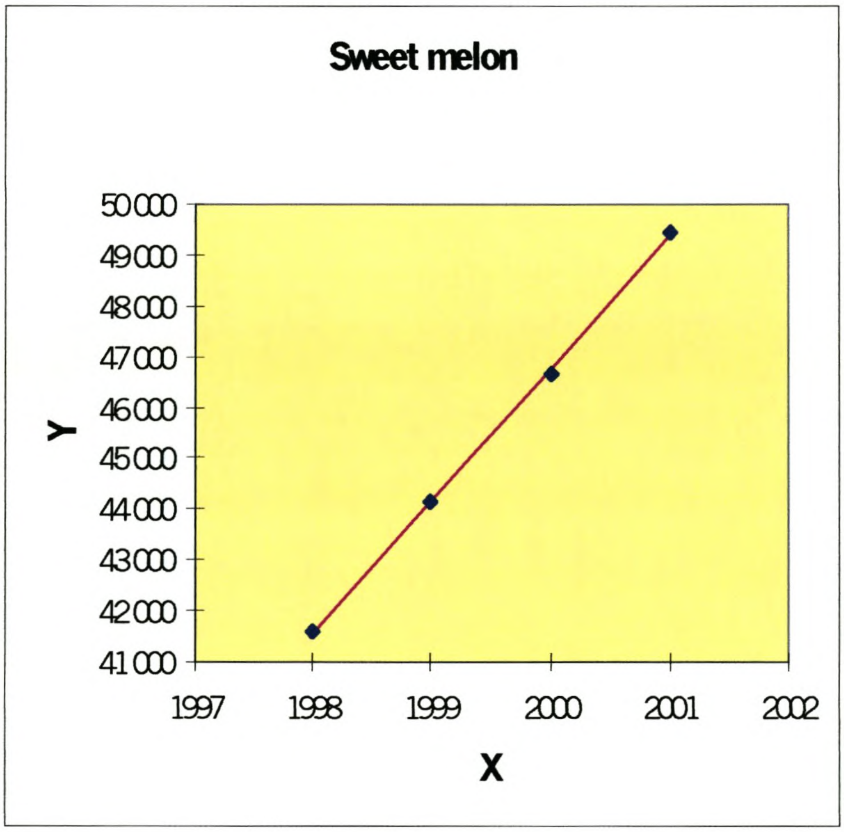
LINEAR REGRESSION CALCULATIONS OF THE 13 ENTERPRISES IN THE PAARL/BERG RIVER REGION

Sweet melon

1998	41,595.68
1999	44,151.17
2000	46,685.65
2001	49,448.50

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.99
R Square	0.99
Adjusted R Square	0.99
Standard Error	83.24
Observations	4



APPENDIX 7 (continued)

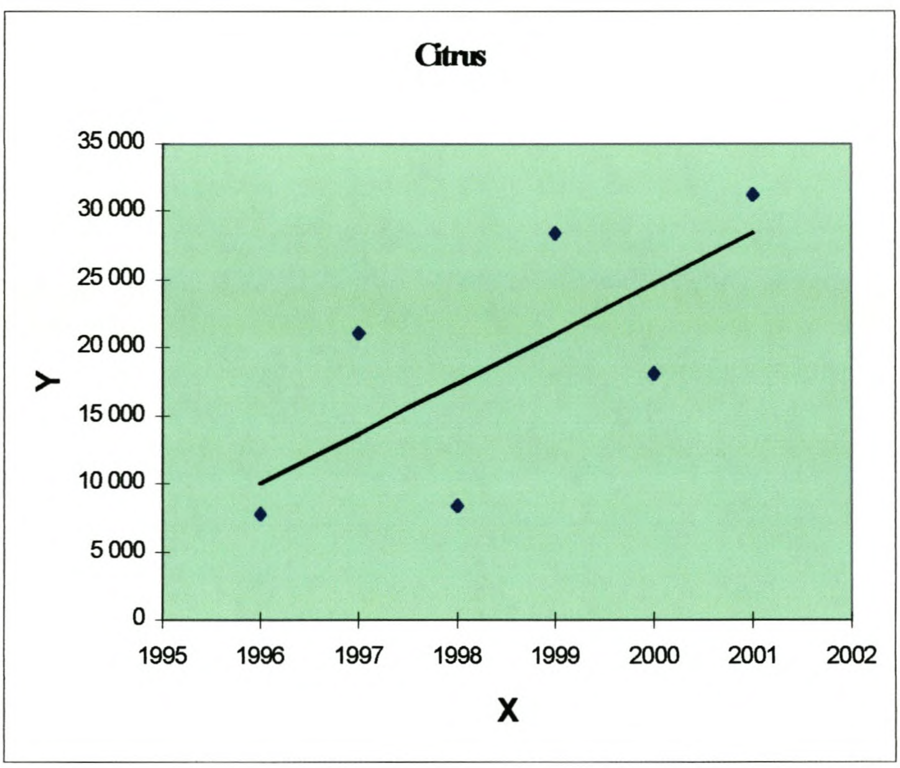
LINEAR REGRESSION CALCULATIONS OF THE 13 ENTERPRISES IN THE PAARL/BERG RIVER REGION

Citrus

1996	7,789.93
1997	21,058.25
1998	8,362.16
1999	28,410.00
2000	18,155.00
2001	31,248.26

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.70
R Square	0.49
Adjusted R Square	0.36
Standard Error	7839.12
Observations	6



APPENDIX 7 (continue)

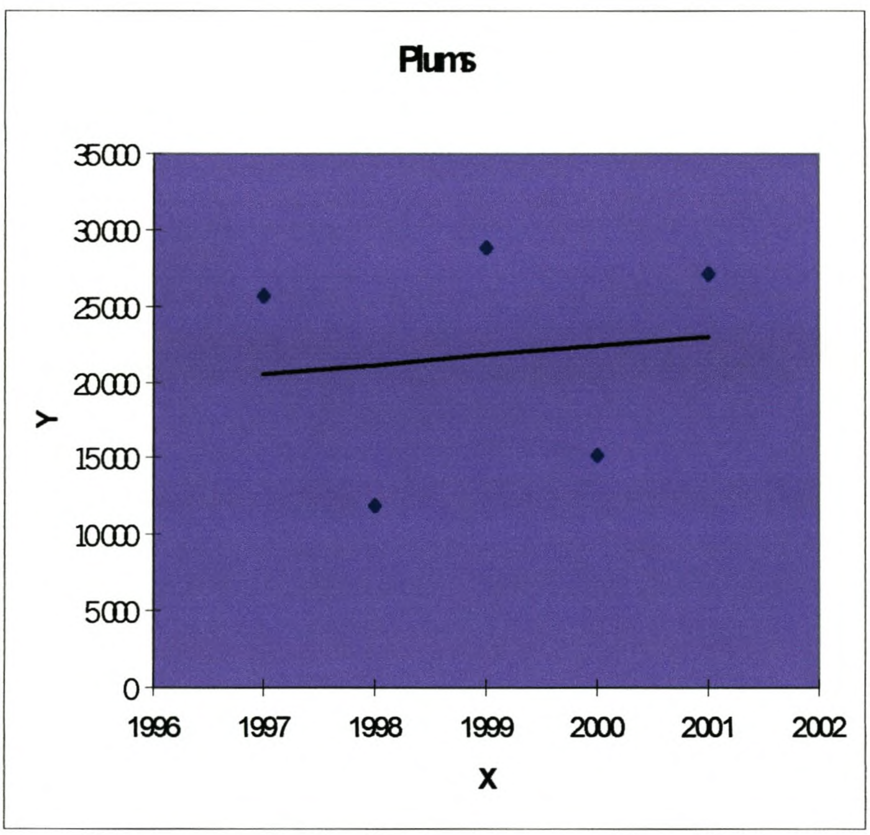
LINEAR REGRESSION CALCULATIONS OF THE 13 ENTERPRISES IN THE PAARL/BERG RIVER REGION

Plums

1997	25,683.68
1998	11,835.35
1999	28,901.36
2000	15,202.04
2001	27,092.00

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.12
R Square	0.01
Adjusted R Square	-0.31
Standard Error	8803.50
Observations	5



APPENDIX 7 (continued)

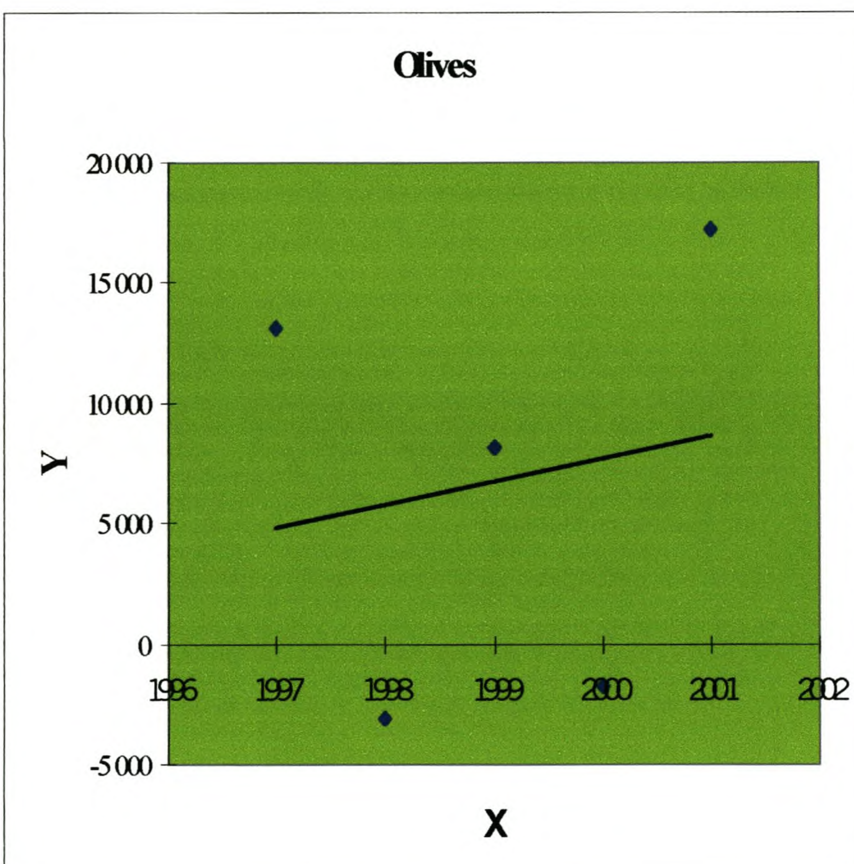
LINEAR REGRESSION CALCULATIONS OF THE 13 ENTERPRISES IN THE PAARL/BERG RIVER REGION

Olives

1997	13,084.31
1998	2,732.33
1999	8,196.99
2000	5,755.73
2001	17,267.20

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.17
R Square	0.02
Adjusted R Square	-0.29
Standard Error	10207.8
Observations	5



APPENDIX 8

THIS TABLE LISTS THE RETURN ESTIMATES, THE ACTUAL OBSERVATIONS FROM APPENDIX 4 AND THE CORRESPONDING DEVIATIONS

Waltham Cross	**Observed**	**Estimated**	**e_i**	**e^2**
1997	34 453	29 199	5 253	27 603 494
1998	38 281	29 371	8 909	79 381 539
1999	22 432	31 232	-8 799	77 429 041
2000	13 025	30 832	-17 806	317 072 083
2001	45 292	32 850	12 442	154 812 340
Sum	**153 485**	**153 485**	**0.00**	**656 298 500**
Red Globe				
1997	31 289	31 134	155	24 043
1998	34 766	31 501	3 265	10 661 391
1999	30 374	35 456	-5 081	25 821 723
2000	32 772	34 606	-1 833	3 363 408
2001	42 391	38 896	3 495	12 216 639
Sum	**171 594**	**171 594**	**-0**	**52 087 205**
Bien Donne				
1997	14 224	11 805	2 418	5 848 840
1998	15 804	12 886	2 918	8 518 766
1999	25 128	24 542	585	342 993
2000	12 161	22 037	-9 875	97 532 625
2001	38 635	34 682	3 953	15 626 794
Sum	**105 955**	**105 955**	**0**	**127 870 019**
La Rochelle				
1997	24 930	26 801	-1 871	3 501 203
1998	27 700	27 366	334	112 016
1999	30 187	33 454	-3 267	10 677 105
2000	37 574	32 146	5 428	29 468 212
2001	38 126	38 751	-624	389 898
Sum	**158 520**	**158 520**	**-0**	**44 148 436**
Cabernet Sauvignon				
1997	16 101	20 401	-4 300	18 493 750
1998	21 332	21 087	245	60 186
1999	29 427	28 484	942	888 066
2000	33 496	26 894	6 601	43 579 878
2001	31 431	34 919	-3 488	12 171 523
Sum	**131 788**	**131 788**	**0**	**75 193 405**
Pinotage				
1997	29 932	35 280	-5 347	28 599 526
1998	35 732	36 164	-432	186 822
1999	49 427	45 709	3 718	13 823 893
2000	51 096	43 657	7 438	55 332 274
2001	48 635	54 011	-5 376	28 907 118
Sum	**214 824**	**214 824**	**0**	**126 849 635**
Merlot				
1997	15 892	22 826	-6 933	48 078 403
1998	26 012	24 456	1 556	2 423 310
1999	39 827	42 040	-2 212	4 897 213
2000	49 896	38 261	11 635	135 384 912
2001	53 291	57 336	-4 045	16 365 074
Sum	**184 920**	**184 920**	**-0**	**207 148 914**

APPENDIX 8 (continued)

THIS TABLE LISTS THE RETURN ESTIMATES, THE ACTUAL OBSERVATIONS FROM APPENDIX 4 AND THE CORRESPONDING DEVIATIONS

Shiraz	**Observed**	**Estimated**	e_i	e^2
1997	28 852	34 910	-6 058	36 701 367
1998	35 732	36 156	-424	179 903
1999	54 227	49 603	4 624	21 381 728
2000	54 696	46 713	7 983	63 731 403
2001	55 175	61 299	-6 124	37 514 606
Sum	**228 684**	**228 684**	**0**	**159 509 008**
Sauvignon Blanc				
1997	15 712	17 976	-2 263	5 125 054
1998	17 732	18 229	-496	246 348
1999	23 727	20 954	2 772	7 688 041
2000	23 096	20 368	2 727	7 440 621
2001	20 585	23 325	-2 740	7 509 179
Sum	**100 854**	**100 854**	**-0**	**28 009 246**
Sweet melons				
1997	37 436	39 642	-2 206	4 869 779
1998	41 595	40 128	1 467	2 152 162
1999	44 151	45 370	-1 219	1 487 352
2000	46 685	44 244	2 441	5 961 142
2001	49 448	49 930	-482	232 557
Sum	**219 317**	**219 317**	**-0**	**14 702 994**
Citrus				
1997	21 058	14 358	6 699	44 881 183
1998	8 362	15 174	-6 812	46 410 949
1999	28 410	23 978	4 431	19 642 125
2000	18 155	22 086	-3 931	15 453 050
2001	31 248	31 635	-387	150 304
Sum	**107 233**	**107 233**	**0**	**126537 612**
Plums				
1997	25 683	18 108	7 574	57 377 449
1998	11 835	18 527	-6 691	44 780 283
1999	28 901	23 040	5 860	34 347 141
2000	15 202	22 070	-6 868	47 177 987
2001	27 092	26 967	125	15 624
Sum	**108 714**	**108 714**	**-0**	**183 698 486**
Olives				
1997	13 084	6 203	6 880	47 341 947
1998	2 732	6 572	-3 840	14 746 852
1999	8 196	10 551	-2 354	5 543 346
2000	5 755	9 696	-3 940	15 527 773
2001	17 267	14 012	3 254	10 592 261
Sum	**47 036**	**47 036**	**0**	**93 752 180**

APPENDIX 9

LISTS OF THE SIM PARAMETERS OF THE 13 ENTERPRISES ESTIMATED ON HISTORICAL DATA AND DEVELOPMENT OF THE WORKSHEET FOR THE CALCULATION OF C* AND y_I

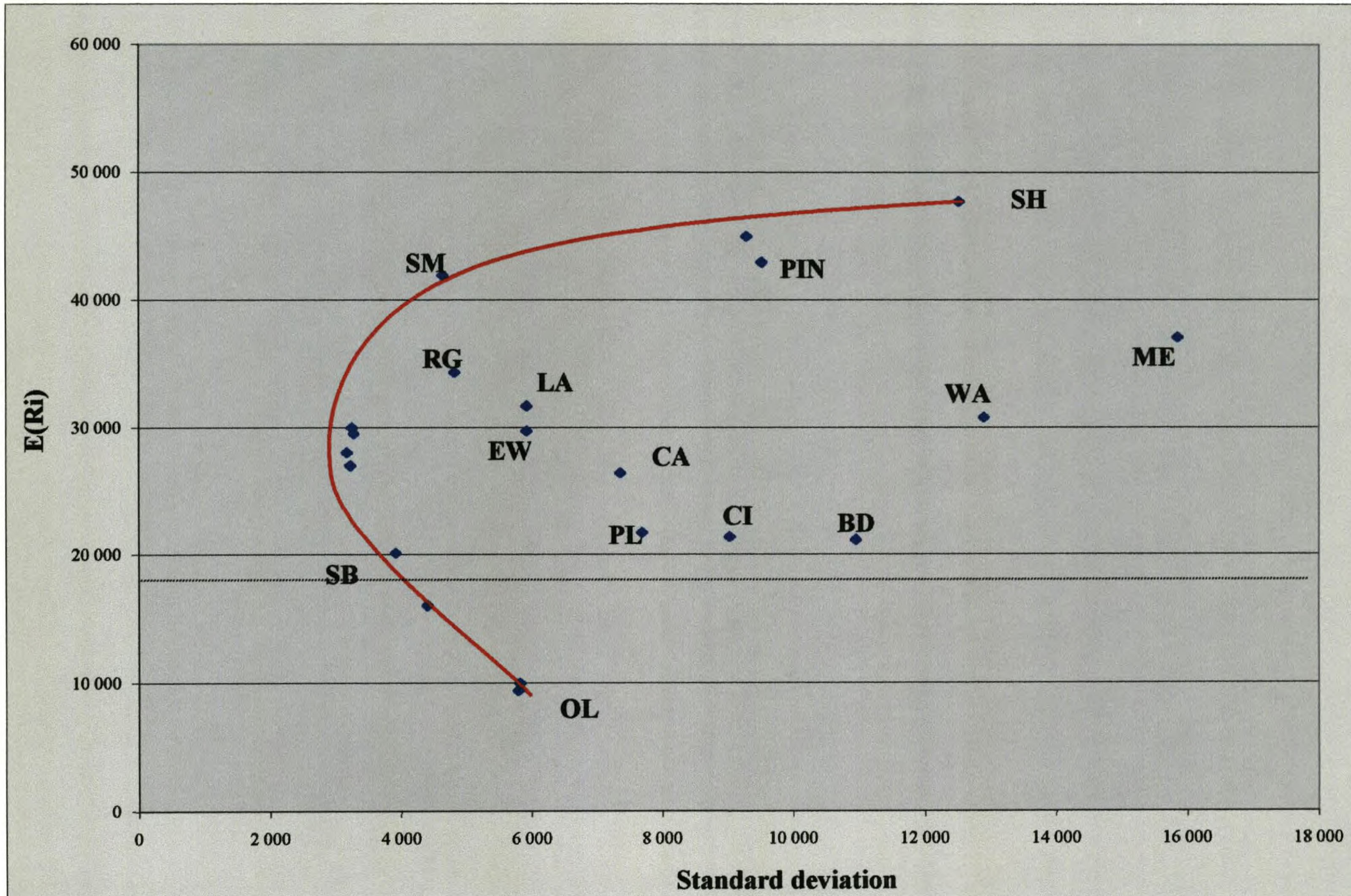
Rf=15 000	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
i	**i**	β_i	σ_{ei}^2	$(R/V)_i$	$_i\beta_i / \sigma_{ei}^2$	$\beta_i^2 / \sigma_{ei}^2$	$\frac{(\mu_i - r)\beta_{ii}}{\sigma_{ei}^2}$	**(R/V)i-C***	**Yi**
Waltham Cross	30 697.13	0.25	131 259 700.06	62 824.95	1.9035E-09	4.75603E-10	0.000030	46 373.70	8.82731E-05
Red Globe	34 318.91	0.53	10 417 441.11	36 370.65	5.0988E-08	2.70833E-08	0.000985	19 919.39	0.001015656
Bien Donne	21 191.07	1.57	25 574 004.00	3 954.62	6.1216E-08	9.58346E-08	0.000379	-12 496.64	-0.000764989
La Rochelle	31 704.04	0.82	8 829 687.25	20 427.40	9.2611E-08	7.57307E-08	0.001547	3 976.14	0.000368235
Cabernet Sauvignon	26 357.79	0.99	15 038 681.17	11 432.14	6.6063E-08	6.56331E-08	0.000750	-5 019.12	-0.000331577
Pinotage	42 964.83	1.28	25 369 927.08	21 816.62	5.0525E-08	6.47635E-08	0.001413	5 365.36	0.000271084
Merlot	36 984.03	2.36	41 429 782.91	9 308.95	5.7002E-08	1.34617E-07	0.001253	-7 142.31	-0.000407129
Shiraz	45 736.83	1.81	31 901 801.76	17 020.46	5.6607E-08	1.02226E-07	0.001740	569.20	3.22209E-05
Sauvignon Blanc	20 170.83	0.37	5 601 849.32	14 126.78	6.5341E-08	2.39168E-08	0.000338	-2 324.48	-0.000151883
Sweet melons	43 863.42	0.70	2 940 598.96	40 997.65	2.3942E-07	1.68555E-07	0.006910	24 546.39	0.005876797
Citrus	21 446.73	1.18	25 307 522.48	5 452.64	4.6718E-08	5.52352E-08	0.000301	-10 998.62	-0.000513832
Plums	21 742.89	0.61	36 739 697.27	11 123.49	1.6499E-08	1.00017E-08	0.000111	-5 327.77	-8.79053E-05
Olives	9 407.31	0.53	18 750 436.18	-10 465.73	2.8500E-08	1.52297E-08	-0.000159	-26 916.99	-0.000767125
				244 390.62		**8.39302E-07**	**0.015598**	227 939.37	0.004627826

APPENDIX 10

SIM PARAMETERS OF 13 ENTERPRISES ESTIMATED ON HISTORICAL DATA AND DEVELOPMENT OF THE WORKSHEET FOR THE ESTIMATION OF C_I AND y_I WHEN SHORT SALES ARE NOT ALLOWED

R_f = 15 000	(1)	(2)	(3)	(4)	(5)	(6)
	$(R/V)_i$	$\sum_{j=1}^{i} \beta_j^2 / \sigma_{ej}^2$	$\sum_{j=1}^{i} (\mu_j - r) \frac{\beta_j}{\sigma_{ej}^2}$	C_i	(R/V)-C*	Y_i
Waltham Cross	62 824.95	4.75603E-10	2.98798E-05	273.28	46 373.70	0.00009
Sweet melons	40 997.65	1.69031E-07	0.006940243	24 909.72	24 546.39	0.00125
Red Globe	36 370.65	1.96114E-07	0.007925282	7 245.88	19 919.39	0.00122
Pinotage	21 816.62	2.60878E-07	0.009338202	8 137.79	5 365.36	0.00050
La Rochelle	20 427.40	3.36608E-07	0.010885183	8 380.55	3 976.14	0.00026
Shiraz	17 020.46	4.38834E-07	0.012625112	8 242.71	569.20	0.00003
Sauvignon Blanc	14 126.78	4.62751E-07	0.012962979	2 544.60	0.00	0.00000
Cabernet Sauvignon	11 432.14	5.28384E-07	0.013713306	4 300.01	0.00	0.00000
Plums	11 123.49	5.38386E-07	0.013824560	935.98	0.00	0.00000
Merlot	9 308.95	6.73003E-07	0.015077704	5 146.84	0.00	0.00000
Citrus	5 452.64	7.28238E-07	0.015378882	1 835.37	0.00	0.00000
Bien Donne	3 954.62	8.24073E-07	0.015757872	1 851.48	0.00	0.00000
Olives	-10 465.73	8.39302E-07	0.015598482	0.00	0.00	0.00000
						0.00335

APPENDIX 11
EFFICIENT FRONTIER FOR DIFFERENT ENTERPISES IN THE PAARL/BERG RIVER REGION



APPENDIX 12

THE NUMBER OF POINTS ON THE EFFICIENT FRONTIER ALONG WITH THE WEIGHTS OF EACH ENTERPRISE

	1	2	3	4	5	6	7	8	90	10	11
Mean	9 407.31	10 000.00	12 000.00	16 000.00	27 000.00	28 000.00	29 000.00	29 500.00	30 000.00	45 000.00	45 736.83
Stan. Dev.	5 801.99	5 815.00	5 916.00	4 415.00	3 238.00	3 188.00	5 916.00	3 280.00	3 268.00	9 283.00	12 515.97
Waltham	0.00	0.00	0.00	0.02	0.05	0.06	0.06	0.04	0.06	0.00	0.00
Red Globe	0.00	0.00	0.00	0.02	0.08	0.07	0.16	0.07	0.07	0.00	0.00
Bien Donne	0.00	0.00	0.00	0.00	0.00	0.09	0.00	0.00	0.00	0.00	0.00
La Rochelle	0.00	0.00	0.00	0.02	0.03	0.08	0.04	0.03	0.03	0.00	0.00
Cabernet Sauvignon	0.00	0.00	0.00	0.02	0.00	0.08	0.00	0.00	0.00	0.00	0.00
Pinotage	0.00	0.00	0.00	0.03	0.00	0.06	0.05	0.00	0.00	0.00	0.00
Merlot	0.00	0.00	0.00	0.03	0.00	0.07	0.00	0.00	0.00	0.00	0.00
Shiraz	0.00	0.00	0.00	0.03	0.00	0.06	0.00	0.00	0.00	0.61	1.00
Sauvignon Blanc	0.00	0.00	0.11	0.00	0.35	0.09	0.05	0.31	0.30	0.00	0.00
Sweet melons	0.00	0.00	0.00	0.03	0.27	0.06	0.31	0.37	0.38	0.39	0.00
Citrus	0.00	0.00	0.03	0.01	0.00	0.09	0.00	0.00	0.00	0.00	0.00
Plums	0.00	0.05	0.08	0.06	0.07	0.09	0.06	0.06	0.05	0.00	0.00
Olives	1.00	0.95	0.77	0.73	0.16	0.10	0.27	0.12	0.11	0.00	0.00
	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00