A scenario-based enterprise optimisation of mixed farming units in the Hessequa district of the Western Cape Province, South Africa

by

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Declaration

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Abstract

Over the past 20 years, the farming environment has changed significantly, becoming much more integrated and complicated. Whereas the focus was primarily on farming before, it has become a business, where farmers have to plan and optimise to be sustainable and survive every single scenario presented to them. To operate in a financially feasible manner, farming systems in the Western Cape of South Africa are heavily dependent on external inputs. What makes the farming environment so much more complicated is the fact that it is influenced by external factors from the social, political, economic and climatic environment, over which a farmer has very little control. This study investigated farm-level profitability under a range of scenarios as a mechanism to utilise as a basis for a strategic tool for advising farmers in a specific geographical area about challenging weather and approaching perilous times.

This study used qualitative and quantitative methodologies to give farmers a strategic view of the future. Although the study's main theme is scenario development, data were collected and analysed through using surveys and modelling. The concept of the typical farm was applied within the framework of scenario building to simulate the impact that a change to the input cost structure and weather (rainfall) would have on the structure of mixed farming operations in the mountainous area of Riversdale, Southern Cape. Using the enterprise data collected within linear modelling, possible changes to the typical farm setup were studied and analysed to provide farmers with an optimal and sustainable solution.

From the results of the various scenarios, it is clear that mixed farming operations are important, as both livestock and cropping enterprises are needed to survive challenging financial periods. It can further be seen that the livestock component should be the flexible component of a mixed farming enterprise. By combining the linear model results from the four scenarios, an optimised average of a typical mixed farming operation is obtained. It is therefore suggested that, to survive three of the four scenarios, a typical farm should be split 70:30 in favour of cropping enterprises. Although the suggested mixed farming setup might not be optimal in years with favourable cropping conditions, the study aims to provide an optimal yet sustainable solution, and therefore a long-term optimised average profit would be obtained.

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Chapter 1:
Introduction

1.1 Background

In a world with many religions, traditions and beliefs, there is always one common need and that is food. With food security under threat because of the ever-expanding world population and climatic changes, agriculture is becoming more and more crucial to human survival. Although agriculture plays a relatively small role in the economy, especially in developing economies such as South Africa, it is very important to the Gross Domestic Product (GDP), as it forms indirect links to other sectors of the economy (Strauss, 2010). Agriculture not only plays a vital role in the GDP of the country, but also provides large-scale employment opportunities and rural development, which provide a source of livelihood and economic development (farmingportal, 2019).

In South Africa, summer crops are generally planted in the central to northern parts of the country, where rainfall is mostly received during the summer months, and winter crops in the Southern Cape and Swartland regions where, for example, 85% of all the winter wheat planted in the Western Cape is found (Hoffmann, 2010). Before the deregulation of agricultural marketing in 1996, the Wheat Board was particularly influential, as it set producer prices on a cost-plus basis, favouring producers under the protectionist government policy of self-sufficiency. As a result, wheat received preferential treatment in the era of controlled marketing, relative to other crops (Hoffmann, 2010). Following the liberalisation of the marketing of agricultural products and the removal of the commodity boards, through the political changes of 1994, the tide changed and the percentage contribution of wheat decreased, as an increasing variety of crops were introduced. The removal of the support programmes, together with the full exposure to market forces and the introduction of new crop varieties, including canola, barley and oats as supplementary crops to wheat, complicated the existing systems and, as a result, the decision-making by farmers in the context of the Western Cape became increasingly more complex (Liebenberg, 2013). Adding to

the complexity of the new systems are the uncertainty, volatility and unpredictability in which farmers operate, from an operating environment perspective (Planning, 2021).

The climatic conditions in the Southern Cape, including the study area, allow for multiple farming activities to be carried out, with grain and livestock comprising one of the most prominent activities. Farming in the area under study, the mountainous region of Riversdale in the Hessequa district of the Southern Cape, is productive and rewarding, yet challenging, as farmers have to deal with shallow acidic soils and low-quality natural veld (weatherspark, n.d.). To overcome this issue, farmers have to plant additional crops as feed for the sheep, reducing farmers' ability to optimise their use of farms. Adding to the challenging agro-ecological conditions, is the increasing frequency and extent of external shocks, with no more than three being experienced in the last decade. The first external shock was the 2017–2019 drought, followed by a foot and mouth disease outbreak, and lastly, the COVID-19 pandemic. Over and above the challenging conditions and external market forces, rising input prices are adding exponential pressure onto farmers to achieve profitability and sustainability (Sihlobo, 2021a). Input costs, for example, fuel, fertilisers, and chemicals for wheat and pest control are some of the most influential input costs. The constant increases in the prices of these products and resources are attributable to poor government regulation, poor management of resources, and high local manufacturing cost (Sihlobo, 2021a). The more frequent external shocks being experienced, the difficult farming conditions, and the constant decrease in margins are putting the sustainability of farmers under pressure, forcing them to rethink the way in which they structure their farming operations.

Farming is a very asset-specific operation and, as a result, any structural changes are generally long-term in nature, thus making optimisation a far more complex process (Qiang-qiang, 2023). To be sustainable and maintain profitability, farmers need to optimise their farming operation by identifying feasible strategies to use to overcome challenges, reduce risk, and sustain or increase profitability (Strauss, 2010). Scenario planning or scenario thinking is one such tool that would assist farmers in their decision-making processes to plan for a range of possible conditions that might arise. This study focused on creating a range of scenarios for farmers in the mountainous region of Riversdale, which encapsulates the range of uncertainties and challenges that farmers face and, at the same time, propose optimised structural outcomes to maintain economic viability.

To construct the scenarios, enterprise data collected from industry experts and farmers, within the study area, was analysed and different strategies were set up and compared through linear programming. Linear programming is a modelling tool that can be used to determine profit-maximising or cost-minimising using data from various enterprises to calculate an optimal combination. By identifying the most economically feasible combinations, farmers would be able see how they could restructure their farming operations within the context of the scenarios that they may face.

1.2 Research Problem and Research Question

In South Africa, agriculture plays an important role in the economy, as it forms part of the livelihoods of many South Africans, providing much needed job opportunities and income. Like many other developing countries, South Africa experiences several obstacles, such as economic recessions, political turbulence, and expropriation without compensation, to name a few, making it difficult for regular citizens to make a living. The evidence can be seen in the unemployment rate of the country, sitting at around 30.1% (Businesstech, 2020). Because of the country's resulting economic instability, external market shocks, such as droughts, floods, and disease outbreaks, have a much higher effect on the economy than they would in larger, better-equipped, developed countries (Cope, 2017).

Thanks to improved technology and information accessibility, farming practices have changed, over time, to address the problems and dangers brought on by changing surroundings, whether they be on the economic or agricultural side (TLU.SA, 2020). Although farming methods have changed and technology improved, some farming areas with poor soils and difficult terrain for livestock still find it difficult to maintain economic viability and sustainability, without creative and innovative farming practices (Ryschaway, 2012). One of these areas is the mountainous regions of the Southern Cape of South Africa. More specifically, the Riversdale area of the Hessequa district. This particular area of the Southern Cape is characterised by acid soils, and hot and dry summers, with long, cool and windy winters (weatherspark, n.d.). The problem is that to farm in an area like this is much more complex because of the high level of resources required to achieve the same level of output as those of farms in the Free State, with their deep, nutritious soils and semi-arid conditions (AgMip, n.d.). Margins are placed further under pressure, with areas of good quality, palatable natural veld being limited. The consequence of this limitation is that the

feed required for the small stock are mostly cultivated or bought. In 2019, agricultural input costs increased by 5%, whereas farm income only increased by 4.3% (Intelligence, 2020). In recent times, this trend of the input-output price squeeze has become more apparent, with input costs increasing at alarming rates (Intelligence, 2020).

Farmers operate mixed-farming practices with small stock and crops to offset risks, although this is not always the optimal way of farming (Ryschaway, 2012). To increase profitability and ensure sustainability, farmers are placed in a predicament, where they are unable to continue to use the same farming practices. Making decisions in farming, or any other business, is ultimately a choice that is made under conditions of uncertainty. Following ill-advice and making alterations might do more damage than good, as farmers have very little margin for error and could stand a chance of facing bankruptcy (Hoffmann, 2010). The lower margins being achieved, the risks associated with external forces impacting on the sustainability of mixed-farming operations, and the lack of current research comparing the implications of various external factors on mixed farming, prompt the main research question of how mixed-farming operations in the study area could be structured, given various scenarios, to ensure long-term sustainability and profitability of the farmers.

As a farmer, scenario planning would help to predict possible future outcomes and help to make informed structural changes. A scenario-based study, in which small stock farming and crop farming are compared will not be a set guideline for farmers to make profit, but will tie information together, which farmers could use to make decisions that are better informed. The study will, therefore, fill the gap in the existing knowledge and enable farmers in the study area to optimally structure their farming practices to potentially increase profits and maintain economic sustainability through difficult periods.

1.3 Aim and Objectives

The goal of this study is to determine the optimal enterprise mix for a mixed-farming operation in the Hessequa district of the Southern Cape given the growing complexity of the operating environment. This dissertation investigates a set of scenarios for possibly improving farm-level profitability, as well as to provide farmers with the tools to overcome difficult and risky periods. In other words, the study will allow farmers in the study area to structure their farming operations

in a way so as to improve their profitability and ensure sustainability in various future scenarios. The specific objectives of the study are as follows:

1. Characterise and identify the farming operation of typical farms in the study area.
2. To set up enterprise budgets and determine the margins for farms in the study area.
3. To identify the influential factors that play a role in the profitability and sustainability of farming in the mountainous region of the Riversdale area of South Africa in order to set up the different scenarios.
4. To Combine the identified influential factors and the margins of the various enterprises to create a linear programming model to determine the optimal enterprise mix of each of the four proposed scenarios
5. To find the sustainable and financially optimised enterprise combination for the range of possible future scenarios by combining the optimised enterprise mix for each individual scenario.
6. To make practical recommendations on the enterprise mix of farming operations.

The results of this research study will be valuable to farmers and industry leaders who are looking for a way of improving or intensifying their farming practices. This study will not aim to replace existing methods, but will act as an alternative or complementary tool to assist with the currently existing methods.

1.4 Research Preposition

Farmers operating a mixed farming system with sheep in the study area are facing challenges, including unpalatable natural vegetation, acid soils, frequent weather extremes, external market shocks and lower profit margins attributable to lower yields and the fact that input prices increase at faster rates than prices of output products do. Given the volatility of market prices, most farmers in marginal areas use a mixed system to reduce or spread risk, and therefore they operate in a "safe", but not optimal manner. The following research prepositions will guide this study:

- More effective and sustainable enterprise combinations do exist, which would offset risk during the prescribed scenarios. The scenarios are set up by using input cost levels and weather data in the form of rainfall.

- Profit margins could potentially be improved, if farmers were to follow the proposed scenario combinations.
- To be sustainable, a mixed-farming system should be followed.
- The future outcomes would represent a logical extension of the past and present, and would allow for accurate assumptions to be made.

1.5 Methodology

A scenario-based study, combining enterprise budgeting and linear modelling, was used to simulate and financially assess the effects that specific external influences have on farming in the Southern Cape and, more specifically, on mixed-farming in the mountainous area of Riversdale. To provide farmers with a strategic view of the future, the study focused on both qualitative and quantitative methodologies. Although the main theme of this study is scenario building, surveys and modelling were used to collect and analyse the data. This allowed for a combination of primary data and secondary data to be used in the study. The primary data were collected through surveys sent out to various industry experts, including farmers and financial advisors, and the secondary data were based on farming data collected from the local cooperative, reviews of current industry practices, and academic research. To model and analyse the data collected, the study is split into three main stages, as described below.

Stage 1

- The starting point and the very first step of the study were to identify the problems that farmers are facing within the study area. A qualitative approach was used in this step, as data were collected through means of a survey directed at industry experts and farmers. The data collected provided a holistic view of the farming environment in the study area, from which the common and main issues were identified.
- To be focused and direct, the data collected were further used to identify the most important production cost factors, as well as the two main influential factors of farming in the study

area. The two most influential factors, rainfall and input costs, were used as the focus point around which the scenarios in Stage 3 are built.

Stage 2

- After identifying the main production cost factors, a modelling approach was followed to ascertain the profit margins for each of the enterprises compared in the study. An enterprise budget was set up in Excel for both segments of the small stock sector, more specifically, the sheep and crop sectors, by using area-specific data collected from the local cooperation.

- According to an article published by wallstreetmojo, linear programming is perfect to use to estimate the relationship between two or more variables (Pandula, n.d.). Therefore, to compare and obtain the optimal and sustainable combinations between the enterprises, linear programming was used.

Stage 3

- Because the future is volatile and non-static, specific scenarios were set up, using the two most influential external factors identified in the first part of the study, to help the mixed farmers to plan and structure their operations in a profitable yet sustainable manner. Forecasting scenarios are classified as exploratory or descriptive scenarios, based on forward-looking approaches to the future (Maria Giaoutzi, 2012). The results generated through the modelling process, in Stage 2, were used within each scenario to obtain the respective profit margins and the optimal combination.

- The final method of analysis used within the study is ‘back casting’. The focus during this stage is not on what might happen in plausible futures, but rather on how the desirable future could be attained. To overcome and absorb the extremes in the market, an optimised average derived from the four scenario models was generated. As change in agriculture is long term and often difficult, an optimised average from the four scenarios was generated instead to help farmers to absorb and overcome the extremes in the market, whether they constitute price shocks or weather shocks.

Chapter 2:
Literature Review

Introduction

Chapter 1 introduced the need for this study by contextualising the problems that farmers are facing within the mountainous region of the Hessequa District of the Southern Cape, as well as introducing the goals and aim of the study. The chapter further explained the methods followed to achieve the specific goals of the study. The purpose of this chapter is to establish familiarity and understanding of previous literature and current literature on the topic of sustainability and profitability.

This chapter consists of four main key sections. Each reviews critical information and provides a literary backroad on the issues surrounding the agricultural environment. The first section addresses the diversity and importance of farming in South Africa. The second and third sections of the chapter explore the risks that farmers encounter in order to gain a better understanding of the need for risk management solutions. The third section reviews the product mix of farming in the Southern Cape and the research area, as well as the most prevalent farm set-up used to mitigate risk and uncertainty. The final section of the literature review examines previous research to gain an improved understanding of what research has been done on the topic of improving farming practices and what methods were used to conduct the research, and then to highlight the benefits of utilising a scenario-based approach to improve farm management and planning.

2.1 Overview of Agricultural History and its Role in Economic Development

> "what the classic economist could not foresee was the extent to which the state of the arts and methods of production would change. Some of the changes occurred in agriculture and other occurred in other sectors of the economy but had a major effect on the supply of food."
>
> (Johnson, 2019)

The history of agriculture shows that it has always played an important role in the development and wellbeing of economies. According to literature, the economic history of many advanced

countries started with agriculture, as it forms part of the backbone of economic advancement (economicsdiscussion.net, n.d.). It can therefore be seen that agriculture is an important element, as it has always played a vital role in the survival and development of people and countries. The extract taken from an article by Johnson (2019) shows that agriculture developed in such a way and became such an integral part of the economy that not even an economist could predict the path agriculture followed.

Agriculture is defined by Shawn McKenzie, at the John Hopkins Centre, as comprising the art of producing food and other desired products through the cultivation of plants and the production of domesticated livestock (McKenzie, 2007). What started as a means of survival, in which people followed a hunter-gatherer lifestyle, quickly developed, together with human society, into something stable and more permanent, in which people produced food according to the needs of society. The radical change in human lifestyle had a major impact on the environment, climate, and the development of economies. The resultant impact of the radical lifestyle changes that were made by humans largely defines why and how agriculture developed.

The need for a stable food supply, before and during the industrial revolution, gave rise to many small economies developing, as farming communities also developed. It is well documented that agricultural development and industrial development are complementary, as they both rely on each other in terms of inputs and outputs (economicsdiscussion.net, n.d.). As countries and economies developed, agriculture started to form part of one inclusive economy, forming backwards and forward linkages with the whole economy. To maintain the balance between population growth and food production, farmers must continuously adapt and find new ways of improving production. Increasing the size of farms and extending the land allocated to agriculture are some of the early solutions implemented to keep up with the rapid population growth (McKenzie, 2007). The limitation of available land as a resource brought about the introduction of new farming techniques, technologies and new ways of structuring farms. Although agriculture's percentage share of an economy is constantly dropping, as the latter expands and diversifies, it is still very important as it plays a vital role in the process of food supply, foreign currency earnings through imports and exports, employment, supply of raw material, creation of infrastructure and social stability (economicsdiscussion.net, n.d.).

The basic concept of agriculture has always been the same, although the environment in which farmers have to operate is continuously changing. The continuously changing environment is a result of climatic pressures, economic pressures and social pressures. Since food security forms part of the basis for life, an economy cannot grow without a well-developed and functioning agricultural sector. Literature shows that, throughout history, agriculture has always played an important role in the economic well-being of any country. Although its contribution to an economy decreases over time, it will always be important because of its direct and indirect linkages to the stability and growth of other higher contributing sectors.

2.2 Farming vs Non-farming Businesses

Farming is often misunderstood and taken as being no different from any other industrial business and, therefore, outsiders often criticise the treatment that farmers receive, and believe that they should be treated the same as non-farming businesses, ignoring some important differences and facts, for example, asset specificity, price determination and technological advancements (Harwood D. Schaffer, 2016). Farming, in general, is much more complex than non-farming businesses as it operates under high levels of uncertainty, volatility and unpredictability (Harwood D. Schaffer, 2016). To understand the differences between a typical farming operation and non-farming businesses, you have to consider various important factors, including pricing, land, labour, external force and risk (Girdziute, 2012).

2.2.1 Pricing

Pricing is an important factor in a business, as it determines the potential revenue of a product or service. The higher the price is, the greater the market value. According to literature, the key to maximising profit is through pricing and therefore, to be successful, emphasis needs to be placed on product-pricing strategies (Megan L. Brunch, 2011). Both farmers and non-farming businesses have very little say in the price of inputs, as suppliers are generally limited and products are specific. When considering pricing strategies, the first and main difference between farming and non-farming operations is the fact that farmers are price-takers on both the supply and demand sides, whereas non-farming businesses are mostly price-setters (Harwood D. Schaffer, 2016).

In a perfectly competitive environment, prices are determined by supply and demand. Non-farming prices are mostly determined by supply and demand, but the owner does have the final say in the setting of prices (Contributor, 2021). Farmers do not have the luxury of setting prices, as they are price-takers, and are in the hands of the market. For farmers, several factors, including supply and demand, exchange rates, weather conditions, input prices and international prices, influence commodity and livestock prices (Nigatu, et al., 2020). On the other hand, non-farming pricing is set through a combination of business marketing tactics and supply and demand factors, with very few external factors (Contributor, 2021).

Price volatility is another important difference to consider when comparing non-farming businesses with farming operations. Farming is often characterised by high levels of risk and uncertainty, caused by a variety of economic, natural and political factors, and as a result, farmers are often confronted by instability in the prices they receive for their produce (parliament, 2016). Non-farming prices are generally much more stable and quickly revert to equilibrium, as they mainly rely on supply and demand factors, and are easily corrected for as businesses could easily alter the structure of the business by increasing or reducing the supply of products in the short term (Contributor, 2021).

2.2.2 Land

Land as a production factor is extremely important, as it forms the basis of the existence of modern economics (Metzemakers & Louw, 2005). To farm or to start an industrial business, the first and most important step is to acquire land. Anthony Young, in a book on land as a resource, describes land as an important but limited resource that has always been undervalued in terms of its true potential. He goes on by explaining that human population growth is the main reason why land is such a valuable and scarce commodity to have (Young, 1998). Land availability is decreasing, year after year, as populations increase and areas of available arable soil decrease as a result of soil erosion and global warming, making it increasingly vital to emphasise management and sustainable farming practices (Lambin, 2011).

The difference between land as a resource in farming and non-farming operations is directly related to the availability, fertility and appropriate land use (Lambin, 2011). To be sustainable and to maximise profits, rational farmers preserve and utilise all their available arable land, as it forms

the bases of all income generated (Abera, 2017). Non-farming operations, on the other hand, use a lower percentage of their land (76.7%) for being economically successful and are not dependent on the fertility of soil to generate income (Harwood D. Schaffer, 2016). Unlike non-agricultural land that could be repurposed, when agricultural land is sold and a farmer decides to leave the industry, the land remains in the agricultural industry(Harwood D. Schaffer, 2016). Farmers are usually limited in what they can produce because of soil fertility and the topography of land. Non-farming businesses are not constrained by land and are able to adjust production in response to market demand, and are therefore not reliant on the physical characteristics of the land to create their goods (Metzemakers & Louw, 2005). Agricultural land, compared with an ordinary building used for non-farming operations, contains a much higher asset specificity, as the latter can be used for multiple purposes, whereas agricultural land will always remain agricultural land. Land is thus a far more important commodity in agriculture than it is in non-farming operations, as the quality and management of land determine a farmer's success (Metzemakers & Louw, 2005).

2.2.3 External forces and risk factors

Entering the business world is usually complicated and requires hard work, especially in a tough economy (Zurub, 2015). To be successful in starting up and running a business takes days of planning and careful management. External forces and possible risks are usually the most important factors to consider when starting or managing a business. Although risks and external driving forces are a part of any business, some sector experience these factors to a higher degree than other sectors do. Farming is one such sector (Duong, et al., 2019). Farmers are constantly managing risks, whether direct business-related risks, for example capital and labour, or risks from external forces, for example the weather and market shocks caused by diseases like foot and mouth disease. During some periods, farmers have to manage multiple risks at the same time (Duong, et al., 2019).

Looking back at 2007/2008, the world faced one of its largest food price crises in years. During this period, farmers were facing multiple risks, including production risks caused by severe droughts, market risks caused by the spike in prices, and institutional risks when governments decided to change policies (Adam Komarek, 2020). Compared with non-farming businesses, what sets farming businesses apart is the fact that farmers tend to face more risks, as they are dealing with natural processes, biological assets, and plant and animal diseases (Girdziute, 2012). With

climate change being an issue, farmers are highly exposed to adverse natural processes and extreme weather conditions, leaving farmers with the constant risk of large-scale economic losses (Girdziute, 2012). In addition to environmental concerns, farms are far more vulnerable to criminal activity than non-farming enterprises are. Because it is impractical to lock up all of the farming equipment and kraal all of the livestock every night, criminal activity in the farming environment is therefore very high (Clack, 2018). Although farming is a business and faces similar economic risks to non-farming businesses, it is the environmental component and level of external risks that separate farming operations from non-farming operations.

2.2.4 Discussion

Through the comparison made between non-farming businesses and farming operations, it is clear that farming is susceptible to sudden price changes, slow to react to price changes and contains higher levels of risk (Girdziute, 2012). It is true that all businesses are affected by external factors over which they have little to no control. The distinction lies in how they respond to these external forces and how quickly the economic environment may return to balance (Harwood D. Schaffer, 2016). This subsection has argued the point that to be successful as a farmer, emphasis must be placed on the management and structuring of farms, as farmers are dealing with a complex environment that is constantly changing and contains high levels of risks and uncertainties.

2.3 Product Mix of Farms in South Africa

2.3.1 Introduction

South Africa is a country with a wide range of climates, ranging from subtropical along the eastern coast to Mediterranean along the western coast, with large, semi-arid to arid areas in the interior (Daly, 2021). The diversity in terms of climatic conditions allows farmers throughout South Africa to farm with a large range of agricultural commodities (Daly, 2021). Literature on the climate variability in the social-ecological systems of the Southern Cape explains that the South African agricultural sector is the sector most vulnerable to climate change, and that events like severe droughts and floods will become challenges, if not already experienced, as seen in the 2017–2019

drought in the Western Cape (Ward, 2018). The structure of farms and cultivation methods are therefore continuously evolving to compensate for environmental changes.

Product mix, better known as product assortment, refers to the number of product or services offered by a company to its customers. A product mix comprises width (number of product lines), length (number of products in a product line), depth (varieties of one product) and consistency (use of the product) (Michael C. Cant, 2016). In agriculture, the product mix is different and is much more limited, compared with those of non-agricultural businesses. The reason for the differences is the fact that in agriculture, climatic conditions determine what farmers can produce and, as a result, farmers are limited to what they can produce in different parts of the country (Zwane, 2019).

The goal of this study is to improve management and to ensure sustainability, and therefore it is needed to gain a better understanding of the literature around the product mix of farms in South Africa, as it provides background and better insight into the issues, approaches followed to combat the issues, and limitations faced within the agricultural environment (AgriSETA, 2006).

2.3.2 Width of the product mix of farms in South Africa

Climate, natural vegetation, soil conditions and risk are some of the major role-playing factors in determining the size and width of farming operations, not only in South Africa but across the world (DAFF, 2020). In agriculture, farmers face high levels of risks and price volatility and, as a result, it can be seen that farmers specialise in livestock farming with lower risk, or follow a mixed farming system in which risk is reduced and spread, according to the 2017 Census Report released by Stats SA (StatsSA, 2017). Although focusing on a single commodity allows farmers to channel their resources and time in one direction, the risk of not having “eggs in other baskets” could lead to large-scale losses, when external factors like droughts or disease appear (Bellon, 2020).

In the high summer rainfall and winter rainfall areas, farmers diversify into mixed farming systems, with maize and wheat being the main summer and winter crops, respectively (DAFF, 2020). In the dryer, more arid regions, farmers are obliged by the condition to follow extensive livestock systems, with sheep in the Karoo and cattle in the bushveld (DAFF, 2020). In the Mediterranean and sub-tropical conditions, farmers venture into fruits, wines and citrus farming. Agricultural production width is therefore largely determined by the climatic conditions and the

water availability and, as a result, the production width of farms differs throughout South Africa (Zonneveld, et al., 2020).

2.3.3 Length of the product mix of farms in South Africa

The product mix length is defined as comprising the total number of products that a company produces within each product line (Michael C. Cant, 2016). The agricultural product mix length is much shorter, compared with non-agricultural businesses, for example the manufacturer of Coca-Cola, which produces and sells various types of sodas. Agricultural products are standardised and indistinguishable, and therefore compete with each other on the basis of price, as no other marketable characteristics exist (Crawford, 1997).

In South Africa, a large portion of the crops planted is planted with maize, followed by wheat and other smaller crops, like sunflower, soybeans, sugarcane and canola (DAFF, 2020). To reduce the impact of price volatility and to improve crop productivity, most farmers plant multiple crops on a rotational basis, for example maize and soybeans in the summer rainfall areas, and wheat and canola in the winter rainfall regions (Kooper, 2020). Although numerous breeds of stock and types of crops are cultivated in South Africa, the product lines of individual farmers are narrower because of restricting variables, such as climatic conditions, soil conditions and the structure of farms (Kahan, 2019). To be economically sufficient, commercial farmers choose the breeds and crops best suited for the conditions and the structure of the farms.

2.3.4 Depth of the product mix of farms in South Africa

Variations in farming products are determined by the type of production system, the market conditions, and market availability (Giller, 2021). Climate change has forced the agricultural sector to adapt and, as a result, many genetic variations, cultivars and breeds in crops and livestock exist (Oosthuizen, 2014). Unlike a non-farming operation, where companies can produce all sizes, shapes and flavours of a product at the same time, farming is a much more specialised operation, producing undifferentiated products according to climatic conditions (Harwood D. Schaffer, 2016). It can therefore be seen that, although different breeds and cultivars exist, the end product still remains the same, as wheat from a different cultivar remains wheat.

2.3.5 Consistency of the product mix of farms in South Africa

The production consistencies of farms are high and vary, given the production system followed. Beef and crop farmers have a consistent product line, whereas sheep farmers and dairy farmers have inconsistent product lines because they produce multiple products, with different uses (DAFF, 2020). Sheep farmers produce wool and meat for the textile and food industries, respectively, and dairy farmers produce milk and meat. Agricultural product lines can be considered as being consistent. Although a diverse range of products are being produced and farmed in South Africa, the end uses of individual crops and livestock are undifferentiated, as farmers deliver to the same market, receiving prices determined by international commodity markets and exchange rates, and by transport costs and many more factors, over which farmers have no control (Hoffmann, 2010).

2.3.6 Discussion

It can be seen from the literature that the South African agricultural product mix is diverse, yet narrow. Because South Africa has such a diverse set of climatic conditions, farming is not limited to a single production system, and therefore multiple product lines exist (Hoffmann, 2010). Although many cultivars, breeds and varieties of animals and crops exist, commercial farmers in South Africa specialise according to the area condition, climatic conditions and market availability, for example citrus in sub-tropical areas and extensive sheep production in the arid Karoo (Harwood D. Schaffer, 2016). Using a product mix approach to dissect the agricultural industry of South Africa, it can be seen that the agricultural environment is complex and that constant pressures on farm-level profitability exist (Kooper, 2020).

2.4 Product Mix of Farms in the Southern Cape

2.4.1 Introduction

The Southern Cape is an area in South Africa that forms part of the greater Western Cape Province. The specific area is distinguished by a Mediterranean climate, with rainfall distributed more evenly than in the rest of the Western Cape. Traditionally, the Western Cape receives most of its rain

during the winter months. The characteristics of the Southern Cape in terms of soil and climatic conditions make it suitable for a large variety of farming activities, including crop farming, dairy farming, fruit farming, and livestock farming (Hoffmann, 2010). As with the rest of South Africa, farmers in the area venture into multiple farming activities, following a mixed-farming operation, to reduce risk and to stabilise income during variable economic downturns (Kooper, 2020). Although many farming product lines do exist, as will be explained in the rest of the section, this study will focus on mixed farming, which is the most prominent product mix pursued within the area (Hayward, 2021).

2.4.2 Width of the product mix of farms in the Southern Cape

The all-year rainfall in the Southern Cape and the soil and climatic characteristics, traditionally, allow for a mixture of agricultural activities to be undertaken. Unique from the rest of the country with summer rainfall, agricultural activities include field-crop production, animal production, horticulture, forestry and mixed farming (Wilkinson, 2017). Although grain farming is the most popular farming activity in the Southern Cape, it is common to see livestock, predominantly sheep, being incorporated into farming systems because of the farmers' ability to produce sustainable food levels in the winter and summer months, and the advantage that this gives would assist in reducing farm-level risks through diversification (Hoffmann, 2010). Unlike most of South Africa, where livestock can graze on the natural veld, farmers are obliged to produce all feed for the livestock, as the natural veld is sour and unpalatable to stock animals (van der Spuy, 2002). Wheat, canola and barley are the most common cash crops cultivated in the Southern Cape, with the study area focusing less on barley, and more on wheat and canola. In rotation with the cash crops, lupines, oats, medics, and other pastures are planted and are mainly used as feed for the livestock. Moving closer to the Langeberg mountain range, the increasing availability of water allows for a variety of product lines to be pursued, including dairy farms with cattle grazing on irrigated pastures (van der Spuy, 2002).

2.4.3 Length of the product mix of farms in the Southern Cape

The lengths of agricultural product lines differ and change as the conditions throughout South Africa vary. In the Southern Cape, agricultural product lines are longer than those in the rest of the country (Hoffmann & Kleynhans, 2011). Although the area is prone to extreme climatic events

attributable to a combination of climatic conditions and global warming, the traditional 60:40 year-round rainfall of the Southern Cape provides agricultural conditions that make the crop mix and productive potential of the area unique (Kooper, 2020). The typical farming methods followed in the area under study are either intensive dairy farming under irrigation, or more commonly, mixed farming systems where cash crops and livestock (sheep) form part of the farming mix (David, 2022). Because farmers have to cultivate pastures for livestock, the farming systems are slightly more complicated, as farmers need to divide crop fields between cash crops and pastures for livestock (van der Spuy, 2002). As a result, farmers in the Southern Cape and in the study area plant a variety of different crops throughout the year, as opposed to the one or two crops planted in the summer rainfall areas with good, palatable natural vegetation.

2.4.4 Depth of the product mix of farms in the Southern Cape

Similar to the rest of South Africa, variations among crops and livestock farming in the Southern Cape are determined by climatic conditions, external factors, and water availability (Kooper, 2020). The Southern Cape, and more specifically the Hessequa district, is divided into the dryer 'vlakte' area and the wetter mountainous area, and as a result, farmers decide on, for example, the wheat or canola cultivars best suited for the soil and climatic conditions. As explained in describing the product mix of agriculture in South Africa, agriculture in general produces undifferentiated products. Although many cultivars exist, the agricultural product line depth is limited in the end products; for example, canola seed remains canola seed, no matter the cultivar (Crawford, 1997). Variation among crops is, therefore, more common owing to the range of soil and climatic conditions present in the area.

2.4.5 Consistency of the product mix of farms in the Southern Cape

As seen throughout the product mix, various factors influence the structure of farms, including the climate, soil conditions and external forces. The soil and climatic conditions within the region allow for various farming systems to be followed, and therefore farming in the Southern Cape is inconsistent. According to literature, it can be seen that livestock farming forms an integral part of farming in the Southern Cape; hence, mixed farming is one of the preferred farming systems (van Eeden, 2000). Because the natural vegetation is unpalatable to stock, with the result that farmers have to cultivate pastures for livestock, the product lines are much more reliant on each other,

rather than as seen in the rest of the country. Although product lines rely on each other, the variety of products produced within the mixture of farming systems resulted in the product lines being inconsistent.

2.4.6 Discussion

In conclusion, it can be seen that the Southern Cape is a very diverse regions, when it comes to farming, as climatic conditions are favourable for a variety of agricultural activities. Although global warming greatly influences farming operations and the way in which farmers structure farms, the product mix of farms in the Southern Cape represents some of the most integrated and complex farming systems in the country.

2.5 Previous Literature: Approaches for Estimating Profitability and Economic Sustainability

2.5.1 Expert group discussion & enterprise budget modelling

"For each area the expected impact of climate change, fluctuating product and input prices, and the possible impact of partial conversion to bio-fuel production were evaluated in terms of expected impact on profitability. Various area-specific strategies were identified that could enhance the profitability of grain production: most of the strategies focused on optimising machinery usage and expanding or intensifying the livestock enterprise. The repeated successful use of the model in support of the expert groups in all the chosen study areas illustrates the value thereof for identifying and evaluating plans to increase the profitability of small grain production." (Hoffmann, 2010).

Farmers operate in a very volatile environment, with constant pressures on product prices, caused by direct and indirect pressures, for example, market shocks, political risks and weather shocks (Kahan, 2019). A study was conducted by Hoffmann (2010) to establish methods and strategies that would contribute to the advancement of profitability in the grain sector. To identify the strategies, a combination of multi-period, whole-farm budgeting models and expert group discussions were used. An expert group discussion is a participatory research method used to combine the knowledge and experience of various industry experts to gather useful and meaningful

information (Hoffmann, 2010). In this particular 2010 study, the author combined the knowledge of experts in the fields of agronomy, soil science, entomology and plant pathology, in the agricultural chemistry industry, together with producers and agricultural economists to pool knowledge fragmented by specialised studies.

The models served as an instrument for viewing the financial impact of suggestions made by the expert group in the process of improving farm-level profitability. The study was conducted in various areas of the Western Cape to gain an inclusive view of the grain sector in the province. The assumptions and financial results for each area were calculated, analysed and adjusted together with the expert group, and it was found that the areas of the Goue Rûens and Koeber/Wellington were the most profitable. In the quoted extract from the article set out above, it can be seen that various area-specific strategies were identified that could improve profitability in the grain sector. Most of the strategies identified in the study revolved around improving the use of machinery or intensifying the livestock component of the farm.

A whole-farm budget is a very useful modelling technique to use in farm management, as it allows for a blanket view of problems to be formed (Kooper, 2020). Although it does not elaborate on the specific problems, it gives enough detail to make a well-informed farm management decision. The article explains that budgeting models, like all other methods of analysis, are not perfect and contain a degree of limitations. The most important limitation of whole-farm modelling is the fact that it might not identify the best/optimal solution (Hoffmann, 2010). To overcome this limitation, a linear model could be a useful addition, as it allows us to compare and create an optimal solution (Oosthuizen, 2014). Furthermore, it requires an excellent understanding of the farming system because of the various influential relationships present in farming. Expert group discussions are an excellent tool for gathering information, as it allows for the gathering of information about the same topic from different points of view (Hoffmann, 2010). Expert groups also allow for making better, more informed decisions, as it helps to stimulate creativity that is not possible to generate fully through questionnaires. The disadvantage of expert group discussions might be that the coordination of group discussions could be difficult and time-consuming to achieve (Reddy, 2013). The fast-tracking of technology would certainly have a positive impact on expert group discussions and the coordination of them.

2.5.2 The stochastic frontier approach

"The general objective of the study was to estimate the economic efficiency of the mixed crop-livestock farmers in two districts of north eastern Ethiopia. Cross-sectional data were used to analyse the economic efficiency of mixed crop and livestock production systems and identifying its determinants factors." "The parametric method stochastic frontier approach was employed to measure economic efficiency" (Hussien, 2012).

According to the quoted article and related literature, the stochastic frontier approach is a very useful approach to follow when looking at the efficiency of a business (Hussien, 2012). Although some analysts use output-over-input to measure performance, it is not an appropriate method to use in measuring efficiency, as it is most effectively determined by the input-output ratio (Gaviglio, et al., 2021). The stochastic frontier approach uses panel or random cross-sectional data to measure the efficiency while revealing inefficiencies, deviations from the mean, and white noise or random shocks. This method was used in the study by Hussien (2012) to examine the economic effectiveness of mixed crop-livestock production systems in the Ethiopian highlands.

The study used data obtained, through surveys, from 252 farmers and found that most farmers were not efficient and had room for improvement. The study further suggested that technology adoption, better education, and access to credit services would provide possible solutions to improving production efficiency. It was found that farmers who diversified within the livestock sector obtained a relatively better farm income, and as a result, the diversification of livestock was suggested as another possible solution.

Compared with other techniques used to study farm-level productivity, the stochastic frontier approach is a valuable method of analysis, as it unravels changes in productivity into a straightforward, understandable economic interpretation. When studying the inefficiencies of a firm or business, the stochastic approach accounts for random white noise (externalities) that might affect output (Asche, et al., 2009). However, one important limitation of the approach is that, when separating the inefficiencies and the white noise, factors with a large degree of assumptions on the error term are required, which could lead to heteroscedasticity, being the unequal spread of test results, leading to biased assumptions. The stochastic frontier approach is not considered to be a method of analysis in the current study, as it does not provide a financial view of the result, but an econometric view (Asche, et al., 2009).

2.5.3 Linear programming

"The profitability of changing farming enterprises can be examined by means of budgeting techniques. In this study the profitability of the inclusion of more home grown feed stuffs in the fodder flow program of dairies, currently run according to a zero feed lot grazing system, was investigated. The technique of Linear Programming (LP) was used in this regard." (van der Spuy, 2002).

According to the literature, linear programming is a modelling technique used to maximise or minimise solutions for a problem, subject to various constraints (Vidhya, 2017). Linear programming is often the preferred method of analysis to use because it is easy to use and it simplifies complex relationships and constraints to find optimal points or combinations. In the study by van der Spuy (2002) on the profitability of dairy farming in the Swartland area, linear programming was used to study the profitability profile of including self-cultivated feedstuff into the fodder flow of dairies.

According to the article, high feed cost is the single biggest factor influencing profitability in a zero-grazing dairy system. As a result, the optimal use, in terms of profit, of using self-produced crops, for example wheat, whether to sell or add as a supplementary in the feed system, was studied in the research paper. The results of the study showed that practices of dairy farmers in the study area were mostly effective, but contained some room for improvement. With lower input price levels, it is profitable to produce wheat as a supplement to maize, which is normally the preferred energy source in dairy feed. Farm prices are very volatile and as a result, the balance between producing wheat and buying maize is, and will, constantly shift (van der Spuy, 2002). The advantage of using linear programming is that it can be set up in a way to accommodate continuous price changes. It is also an important tool to use in farm management as it helps to optimise the use and allocation of resources (Oosthuizen, 2014).

Linear programming, as a method of analysis, will therefore form part of this study because it is relatively easy to use and understand. The constantly changing environment and the price volatility within agriculture are other reasons why linear programming is an important tool to use, since it allows farmers to operate optimally, while being flexible.

2.5.4 Financial cost-benefit analysis

"This investigation focuses on strategies aimed at reducing production costs as a means of improving competitiveness. The field of this study is the winter-grain producing sub-regions of the Southern Cape which are severely affected by the deteriorating situation." (van Eeden, 2000).

In this study by van Eeden (2000) on cost-saving production methods for grain producers in the Southern Cape, the financial cost-benefit method was used as the preferred method of analysis. Cost-benefit analysis is a tool used to support decision making without outside influences, for example opinion, politics or bias (Weller, 2016). A cost-benefit model is set up in a way to lay out the benefits of a decision, as well as the cost to achieve the given action.

In the quoted extract, it can be seen that the 2000 study intended to reduce the production cost of winter grain farmers in the Southern Cape by improving their competitiveness. To achieve the objective, the researcher used strategies from experts and knowledge gained from popular literature and compared them to current production practices by using cost-benefit analysis. Three different production methods, comprising reduced, minimum and no-tillage, were compared with the then current production methods. Based on the result derived from the various areas under study, it was concluded that reduced tillage was a more profitable way for producing grain and that the use of technology, for example GPS systems, would also be beneficial.

As an analytical tool, its simplicity is what makes cost-benefit a preferred method of analysis in many businesses (Hamel, 2018). The advantage of using this method is that it simplifies complex business decisions, as well as allowing businesses to compare completely different projects through a simple framework of total benefit minus total cost, equals net benefit. (Hamel, 2018). Although useful as a tool for decision-making, accuracy could be a limitation, as farming enterprises contain several hidden or unexpected costs. If all costs are not accounted for or biased opinions are given, the results would be skewed and inaccurate; therefore, when using the cost-benefit analysis, it is important to carefully consider all potential costs (Weller, 2016). The cost-benefit analysis allows for analysing proposed changes, rather than finding optimal combinations between existing practices, and therefore this method is not considered as a method of analysis to use in the current study.

2.6 Scenario Analysis as a Foresight Tool in Agriculture

Agriculture is a complex and risky sector to venture into because of the level of external forces and therefore, to be successful, it requires time, patience and planning. To deal with the complexity and uncertainty, researchers have conducted many studies to establish approaches that are more effective for examining the long-term developments of firms. The issue with the more traditional methods of analysis is that they generalise or assume that the impact of future events would be the same as experienced in past events (Giaoutzi, et al., 2012). One of the methods considered to be more effective or appropriate is scenario analysis. In business, and more so in farming, the 'what-if' questions are always a drawback in decision making, and as a result, scenario planning plays an important role in the planning and decision-making processes.

Scenario planning is a tool or method of analysis that allows farmers to predict future outcomes, based on the impact of certain variables, or to create outcomes that allow them to see what they would need to do to achieve those goals (Float, 2020). Scenario planning is used for long-term planning in largely unpredictable environments. In agriculture, the farming environment is constantly changing and, as a result, the risk and uncertainty involved leads to opportunities being easily missed (Olabisi, 2020). Failure to plan for certain scenarios might lead to disasters or large-scale economic losses; therefore, creating scenarios is important for survival in any farming environment. Scenarios are often regarded as useful tools to use because they:

- Allows for the gathering of intelligence on future developments;
- Provide insight into what possibly needs to be done to achieve future outcomes;
- Provide a platform for comparison;
- stimulate creative thinking; and
- Can be used as a method for learning about, rather than predicting, the best possible future scenario (Giaoutzi, et al., 2012)

Scenario planning comprises using two approaches, namely forecasting and 'backcasting'. According to Giaoutzi et al (2012), forecasting scenarios are defined as exploratory or descriptive scenarios. They are based on a forward-looking approach, in which the future is represented by using past and present trends. Forecasting is characterised by being problem-driven, from

quantitative to qualitative, deterministic, statistical and closed future. Backcasting scenarios, on the other hand, are defined as normative or prescriptive scenarios and are based on a backwards approach (Giaoutzi, et al., 2012). During this approach, the future goals are known, but the steps needed to reach the specific goals must still be determined. Backcasting is characterised by working backwards, from the future to the present, by using qualitative data. It also promotes creative thinking, is transparent, and allows for an open range of options. When setting up a backcasting scenario analysis, it is important to incorporate a participatory approach to build a common vision among participants, and to strengthen the content of the analysis (Giaoutzi, et al., 2012).

Scenario planning, whether it is used as a forecasting tool or used as a backcasting tool to see what steps are needed to reach specific farming goals, is always useful as it allows you to better manage your capital and identify areas where growth is possible (Axson, 2018). Scenario planning further provides flexibility, as it not only generates optimal outcomes, but also empowers farmers to plan for various economic conditions (Axson, 2018). It can, therefore, be seen that scenario planning will, and is forming, a crucial part of farming, since the agricultural environment is volatile and ever-changing.

2.7 Conclusion

The literature show that markets are continually changing, making it a complicated environment to operate in. The use of management and decision-making tools is thus significant in the agricultural setting since it is a useful, easy and understandable way of capturing complex interactions that allow for thorough planning and decision-making (Kooper, 2020). In the research area, where farming circumstances are difficult and margins are tight, tools such as linear programming and scenario building may be advantageous since they can improve decision-making and ensure potential future success. According to the literature analysis, such a study has never been conducted, indicating a gap that can be filled by incorporating a linear programming model into a scenario-based study.

Chapter 3:
Applying Farming Modelling to a Typical Farm in the Riverdale Area

3.1 Introduction

The main objective of this research study is to investigate the sustainability and profitability within the agricultural environment of the Southern Cape, and to create a scenario-based framework for farm management and planning. Modelling is a useful, easy and understandable way of capturing complex interactions within the farming environment, and for translating research knowledge to farmers (Kooper, 2020). In order to investigate the complex interactions, it is important to understand the environment and the challenges within the environment.

The first section of this chapter focuses on providing an understanding of the area, the Southern Cape of South Africa, and the specific challenges faced by farmers within the area, to provide the context for study. The second part of the chapter describes a typical mixed-farming system within the study area. The enterprise combinations, physical dimensions, and assumptions around the data are discussed. The last part of the chapter addresses how data was collected and how models are set up and constructed to answer the specific issues in question.

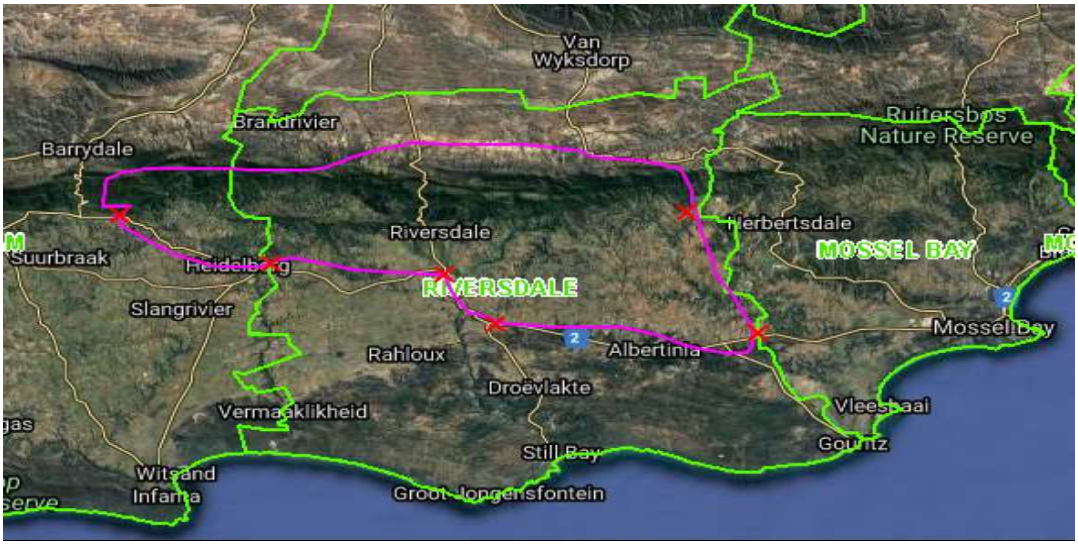

Figure 3.1: Location of the area under study

Source: Elsenburg CapeFarmMapper, 2020

Figure 3.1 above depicts the focus area of this study. It can be seen on the map that Riversdale covers a large area, including the study area within the pink borders, as well as the Droëvlakte on the southern side of the N2 highway, in the direction of Stillbay. Climatic conditions, demographics and the sizes of farms differ between the droëvlakte and the mountainous regions, and therefore, only the area within the pink borders were selected as the study area.

3.2 The Farming Environment in the Southern Cape

The Southern Cape is an area in South Africa that forms part of the greater Western Cape. It is situated southwest of the Karoo and to the east of Cape Winelands, with the Langeberg Mountain range in the middle of it (van der Spuy, 2002). Furthermore, it is divided into two areas, the dryer 'vlakte' area, named after the flat plains, and the mountain area with steep hills and valleys. Unlike the rest of South Africa with summer rainfall, the greater Western Cape, including the Southern Cape, predominantly receives rainfall in the winter months. Although the Southern Cape does get 60% of its rain in the winter months, 40% of the rain occurs during the summer months (van Eeden, 2000). The Southern Cape is characterised by cold, wet and windy winter months, and hot, dry summer months with scattered rain. The different climatic conditions and soil conditions make the Southern Cape perfect for a vast variety of grain and livestock systems.

A typical farm in the Southern Cape area grows wheat, barley, canola, lupines and oats in the winter months, with wheat and canola being the main crop. Crop rotation is a common practice, as farmers aim to conserve soil, prevent crop diseases like black stem in canola, and increase farm profitability by creating a more stable system (Kooper, 2020). To spread and reduce the risks caused by global warming, farmers follow a mixed-farming system that combines the main crop enterprises with livestock production. With droughts occurring more frequently, livestock production provides an extra source of income to complement income derived from cash crops and supplement the lack of income from cash crops during dryer years (David, 2022). Sheep are the most commonly found type of livestock in the area, while dairy cattle and ostriches are present in smaller numbers (Streigher, 2021).

The general farming environment of the Southern Cape is unique, as it deals with environmental, economic and political issues. Although the Mediterranean climate of the Southern Cape is suitable for a variety of farming activities, the unpredictable nature of the climate, with more frequent

floods, droughts and high winds, adds an element of risk to farmers' operations (Ward, 2018). The poor-quality natural vegetation throughout the Southern Cape is another challenge for farmers, as it obliges them to supplement animal diets with either planted pasture areas or purchased feed, for example. Having to supplement animal diets adds extra economic strain on to the cash flow and margins of farming operations (Kooper, 2020). The need for planted pastures in the particular conditions is a primary motivating factor for the study, as farmers have to deal with a balancing act between the utilisation of fields for cash crops and planted pastures for livestock. With increasing economic pressures arising from external factors, such as the closure of markets attributable to more frequent animal disease outbreaks, disruptions in supply chains, and rapidly increasing input costs, the emphasis is shifting to achieving further optimisation and sustainability of operations (Elsenburg, 2022). The particular challenge for Southern Cape farmers is to achieve long-term sustainability under challenging, uncertain and fluctuating circumstances in a complex system of economic, social and environmental sub-systems.

3.3 Description of a Typical Farm within the Research Area

The Southern Cape, as mentioned above, is divided into two broad regions, called the 'vlakte', with flat plains, and the mountainous region, with steep hills and valleys. Although many similarities are seen in terms of crops and livestock throughout the Southern Cape, many differences exist between these two distinct areas. Farmers within the study area deal with obstacles involving the sizes of farms, the topography of the area, the nature of the soil, and variable climatic conditions (Streigher, 2021). Although farming practices have evolved to overcome the obstacles, the obstacles still present farmers with unique challenges.

With these unique challenges in mind when conducting a optimisation study, a representative farm or research site should be identified as a proxy for a typical farm in the general area (Kooper, 2020). To gain a more inclusive and accurate representation of a typical farm in the study area, averages and assumptions were used, rather than data from a specific farm or trial site.

3.3.1 Climate

According to the SSK research group data, it can be seen that the area under study (depicted in Figure 2.1 above) is traditionally wetter than the remainder of the Southern Cape is, receiving 200–300 mm more rain than the flat plains known as the 'vlakte' do (Kooper, 2020). With rainfall of around 600 mm a year, the research area, traditionally, receives above-average rain, as compared with the rest of South Africa. As with the rest of the Southern Cape, the area receives 60% of its rain in the winter months, and 40% in terms of scattered showers in the summer months (Hoffmann, 2010). Although climatic conditions are favourable for crop and livestock farming, the unpredictable nature of the climate, brought about by global warming, makes it difficult for farmers to control diseases and parasites. Climatic conditions oblige farmers to spend more money on chemicals, as diseases and parasites are much more common when compared with the rest of the Southern Cape. A typical farm in the study area grows wheat and canola on rotational bases, and oats for animal feed to supplement or replace direct grazing during the winter months (Streigher, 2021). While there is a market for oats in the grain industry, the market size is limited and, therefore, oats are preferred for use as pasture. Barley is also a common grain in the Southern Cape, but the moist conditions within the study area make it difficult for crops to dry out, and therefore harvesting becomes a problem. The nature of the farms and the accessibility to water makes it possible for farms to irrigate pastures and crop fields. Although most crops and pastures are grown under dryland conditions, as seen in Figure 3.1 below, an average of 13.5 ha of land is irrigated or set up to for irrigation during the dryer summer period (Sentraal-Suid Koöperasie, 2021).

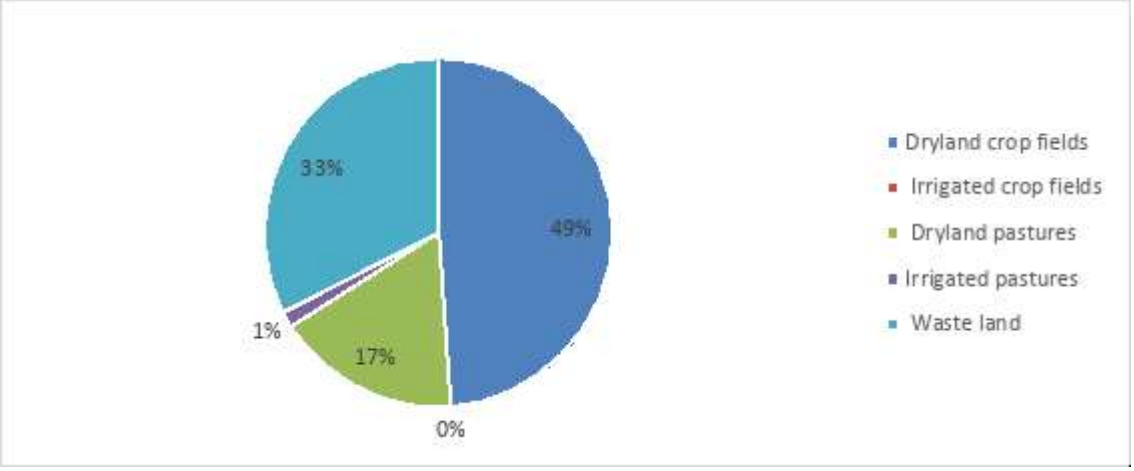

Figure 3.2: Average land distribution of a typical farm within the mountainous region of the Riversdale area

Source: Own calculations from data collected from the Sentraal-Suid Koöperasie study group (Sentraal-Suid Koöperasie, 2021)

3.3.2 Terrain

Typical farms within the study area are characterised by steep hills and valleys. Unlike the large, flat crop fields in the 'vlakte' region, crop fields within the study area are smaller with steeper gradients as a result of the farms being situated on the foothills of the Langeberg mountain range. A typical farm ranges between 200 ha and 1400 ha, with an average of around 932 ha. In Figure 3.1 above, it can be seen that a large portion of a typical farm comprises waste-land, which for the purpose of farming present a burden rather than an asset, as it is unworkable and unprofitable. The reason for such a high percentage of wasteland is that some areas are covered with protected shrubs and wetlands, other areas are overgrown with invasive trees, and large parts are inaccessible owing to steep gradients and riverbeds (Sentraal-Suid Koöperasie, 2021).

3.3.3 Soil

Soil is one of the most important factors in agriculture and must be properly managed to prevent losses. Well-managed soil is crucial to the success of any farmer, as good-quality soil produces healthier, higher-yielding crops (Kooper, 2020). In the Southern Cape, soil conditions and soil structures vary, and therefore soil management differs. Soil along the coast on the 'vlakte' area is sandy and shallow, and has low water infiltration ability. A typical farm in the study area contains shallow to medium-deep soil beds. The soil is typically much more acidic and prone to soil erosion,

with leaching of nutrients, owing to the steep nature of the fields (Hoffmann, 2010). To improve the soil and reduce acidity, farmers have adopted a rotational cropping system, together with frequent applications of lime. Crops that are included in the rotational systems are wheat, canola and/or pastures (David, 2022). Although canola can only be planted every third year, because of the risk of diseases, it is important for the rotational systems, as it improves soil structure, water infiltration and soil aeration (Kooper, 2020). To manage weeds and protect soil moisture for equal germination during dryer years, farmers spray herbicides during the off-season to kill all weeds and to leave the crop field bare. Although this approach increases input costs, farmers in the study area claim that the benefits of enhanced germination outweigh the additional costs.

Figure 3.3: Flow diagram of process followed to collect and model data

The picture above depicts an all-encompassing overview of the methodological approach, which includes an interconnected data collecting and analysis procedure. The first four processes, data compilation, data verification, enterprise budgeting, and linear programming, are covered in Chapter 3, while Step 5, scenario setup, and Step 6, modelling and outcomes, are described in Chapters 4 and 5, respectively.

3.4 Data compilation

When researching a specific issue or topic, it is important that the details gathered for data are relevant to the outlook of the study, and that data are analysed in time (Hayward, 2021). To render a study accurate and creditable, it is important to collect and compile data from sources that can

be trusted and are accurate. Primary data always constitute the best data to use, as the data are relevant and up-to-date, while secondary data details are not regulated and could be subject to bias. Constraints within the data collection process, for example the sample size, time and accuracy of the data, often make it difficult to collect primary data for farm modelling. Another possible limitation of farm simulation for an existing agricultural region, such as the study area, is that rough averages are used, and assumptions regarding production yields and prices need to be made (Hayward, 2021).

In order to overcome the issue of limited time and accuracy and to limit poor assumptions being made, the data and industry norms collected for this study was obtained through a mixture of secondary and primary data sourced from farmers and various industry role players (Table 3.1). Through connecting with the local farmer agribusiness, Sentraal Suid Kooperasie (SSK), secondary data was obtained from a study group that involved farmers around the Swellendam area and from agricultural experts in the cooperative. The study group focused mainly on production data, income and production costs of farmers, and aimed to improve and optimise cost and production within the serves area of SSK. The farmers from whom the data are collected were mainly in the Swellendam region in the Overberg district and, therefore, to relate the data to the study area, a Delphi technique was followed to “ground proof” the data.

A Delphi technique is a process in which expert opinions are used to obtain consensus on a specific topic with a large sample size, limited information and where there is no true or knowable answer (Dufresne, 2017). Farmers and specialists in the research area were given a questionnaire, pertaining to specific questions on a typical farm setup in the area, and interviewed as part of the process of reviewing and verifying the data and highlighting areas that needed to be adjusted.

Table 3.1: Sources of commodity prices and industry norms used within the analysis of the study.

Data	Source
Canola Price per ton	SSK study group farming records (Sentraal-Suid Koöperasie, 2021)
Wheat Price per ton	SSK study group (Sentraal-Suid Koöperasie, 2021)
Wool Price kg	OVK (Kaap, 2021)
kg wool per sheep	SSK study group (Sentraal-Suid Koöperasie, 2021)

3.5 Budgeting

Budgeting is a non-optimising financial and management tool used by farmers and business owners when making future decisions, based on expected income and expenses (Kooper, 2020). Budgeting is a quantitative simulation model that is based on accounting principles and methods (Hoffmann, 2010). The simplest form of budgeting uses a technique in which the expected expenses are deducted from the expected income to show the profit or loss achieved. Budgeting as a financial planning tool is one of the easiest and simplest tools to construct, and therefore it is frequently used in the literature (Hoffmann, 2010). It is also popular among farmers as it provides many advantages, including adaptability, user-friendliness, and the ability to accommodate large input–output variable relationships.

Enterprise budgets are a useful technique for splitting farm data and viewing the inputs and outputs per enterprise. The data obtained through these budgets not only describe a typical mixed-method farm in the study area, in financial terms, but it also allows for comparative analysis to be made between different farms and different enterprises. To model the various scenarios, the data from the enterprise budgets were combined, in Microsoft Excel, through a self-constructed linear programming model to obtain the optimal combinations in which profits are maximised.

3.6 Comparative Data on Input and Output Prices

The enterprise budget model is comprised of input and output data derived from farmers who are involved in the SSK study group. The data from the study group formed the basis of the enterprise

budgets, before the Delphi process was used to verify and adjust the data. During this process, the average farm-level income and expenses of the farmers in the study area were compared with the average data from the study group, where differences and similarities were identified. Fertilisers, chemicals, seed costs and fuel prices are identified as being the main contributors to the input cost structure of rain-fed winter grain enterprises. Although the above-mentioned factors are some of the main contributors, the sizes of the farms and hectares planted are also identified as being major differences. Farming practices, cost-saving, and the sizes of farms formed most of the differences observed.

- Hectares of canola and wheat planted: the numbers of hectares planted in the study area are much lower than those of the farmers in the study group are, and this is attributable to the sizes and the demographics of the farms. Although sizes differ, the prices that farmers received per ton were the same.

- Seed costs: seed costs are a major topic for debate, as some farms would withhold seed from a harvest for use in the next planting season. Although it is best to buy certified seeds, as many farmers do, some farmers withhold seed for 're-planting' in an attempt to save cost (Kriel, 2021). For this study, it was agreed to assume that all farmers bought seeds, hence the high per-ha. value for all seed costs.

- Fungicides: owing to the climatic conditions and the higher average rainfall, crops are prone to contract more fungal diseases, and therefore it was observed that farmers within the study area spend more on fungicides, compare with the dryer "vlakte" area with the lower average yearly rainfall.

The key differences noted in validating the data for the sheep enterprises, which include the planted pastures, were the area of pastures planted, the number of sheep kept, the direct income obtained from pastures, feed costs and veterinarian costs. The reason for the differences observed can be ascribed to the size differences, farming practices, and climatic conditions. Farmers in the mountainous area of Riversdale might be less concerned with soil moisture retention than farmers, for example in the 'vlakte' region, do because the temperature is cooler and wetter in the study area, with the average rainfall being substantially greater. As a result, farmers spray less frequently during the pre-season to keep fields weed-free. Farmers in the study area could also save money

that would be spent on supplementary feeds during the hotter summer months, because they receive sufficient rain for planting and sustaining pastures. Besides the above-mentioned differences, most of the data obtained are very similar and therefore the SSK study group data could be used as representative data for the Riversdale farmers. It is worth noting that the study data are based on five-year averages, which include both good and bad seasons. As a result, the data are slightly skewed, with lower year-on-year prices and yields attributable to the below-average years caused by a drought within the sample period.

3.7 Sampling Unit and Conversion

When analysing data, the unit of analysis usually refers to the main parameter or parameters being investigated in the study. When collecting data to be compared, different units of analysis are used, for example individual people, groups of people, area planted, and distance. From the unit of analysis, researchers can then determine the unit type of the study or dissertation (DiscoverPhDs, 2020). To compare data and to ascertain measurable data, it is important to convert data to a single unit, for example kilometres to metres.

This study aimed to find an optimal and sustainable combination, given various scenarios, between the grain and sheep enterprises of mixed farming systems in the study area. To compare the enterprises with one another, area planted was identified as the logical unit of analysis. The main problem identified within the study is that, to plant pastures, farmers have to sacrifice a portion of their cropping fields that could have been used to plant additional winter cash crops. The reason for using area planted as the unit of analysis is that the ratio of cash crops to planted pasture is being studied.

The data collected for the sheep enterprise were given in rand per ewe, whereas the data collected for the pastures planted and cash crop sector were given in rand per hectare. Naturally, to arrive at a measurable point and to ascertain the optimal area combination between pastures planted and cash crops planted, the rand per ewe values of the sheep enterprise were converted to rand per hectare values, as a rand per hectare value forms part of the general income and expenses of a sheep enterprise. When using linear modelling as a tool to find the optimal combination point of various enterprises, it is not necessary to have the units of variables at the same figure. For crops,

in linear programming, the physical units are hectares (land area of 10,000m^2), whereas for livestock, the physical units are number of animals or small stock units (SSU). Both hectares and small stock units are considered continuous and, as a result, the model processing is not compromised (Agusto Hauber Gameiro, 2016).

3.8 Linear Programming Set-Up

Linear programming is a modelling technique used to maximise or minimise an objective function, given a list of activities and identified constraints. Traditionally, a linear programming model is represented by:

- Maximising/minimising z (objective function) = a'b; in which 'a' represents the net profit and 'b' the quantities of each farming activity.
- Subject to $Xb \leq c$; $b \leq 0$; where X represents the technical coefficients and c the resources.

  (Agusto Hauber Gameiro, 2016)

This research aimed to find optimal combinations of crops and livestock land use that would promote the long-term sustainability of farms in the mountainous regions of the Southern Cape, under a range of future scenarios. Linear programming forms the basis of each scenario, where the outputs from the adjusted linear programming models are analysed, interpreted and compared with the base model of a typical farm. Linear programming is used within this study to maximise returns for a typical mixed-farming system using the average variable cost for the 2016–2020 seasons. A typical farm is described by the following activities and constraints:

A typical farming enterprise in the mountainous area of Riversdale specialises in the production of wheat, canola, and sheep for wool and feeder lambs. On average, a typical farm comprises 935 hectares. Some of the farming land is equipped for irrigation. Apart from the irrigation constraint, the combination of activities on the farm is also influenced by the availability of labour and capital. The four-year average production information concerning yield and prices are given in Table 3.2 below.

Table 3.2: Price and yields for the farming activities

	Wheat	Canola	Planted pastures
Yield (ton/ha)	2.18	1.5	
Selling price (R/ton)	R4161	R5900	
Variable cost (R/ha)	R4433	R5446	R2336

Source: Own calculations based on farmer interviews and data collected from the SSK study group (Sentraal-Suid Koöperasie, 2021)

On average, a typical farm comprises 630 hectares of arable land available for cropping activities at any given point in time, of which 15 hectares are available for planted pastures under irrigation. The remaining 305 hectares of land are either wasteland or form part of the farmyard.

According to the advised cropping rotation system conducted in the area, each hectare of arable land should only be planted under canola every third year. A farmer should furthermore not plant wheat more than two years in a row.

A typical farmer farms with an average of 680 sheep. Some 90% of the farmers in the area use a sheep production system where lambs are sold as feeder lambs when they weigh approximately 36 kg, for around R38/kg. Until the lambs are sold, they produce around 0.8 kg of wool, which can then be sold for R103/kg. On average, each ewe produces 1.1 lambs per year. Wool sheered per ewe amounts to approximately 7.5 kg per year. Sheep production systems in the area cull about 10% of the breeding flock a year and receive R23/kg per ewe, at a weight of 50 kg. Variable costs per ewe amount to R758. The average carrying capacity of planted pastures amounts to 3.25 small stock units (SSU) per hectare of planted pasture. The establishment variable cost of planted pastures is R2336/ha. Each ewe requires 1 hour of labour per year.

In the study area, farms have an average of four labourers, whose working capacities combine to number 8448 hours per year. On average, wheat and canola require 5 hours/ha, and planted pastures require 2 hours/ha, per year.

A typical farming enterprise in the study area has a credit facility at Sentraal-Suid Koöperasie, the local cooperative, of no more than R 4 million a year or R 6000/ha to cover production costs.

Fuel costs related to the production of wheat, canola and pastures amount to R475/ha, R485/ha and R474/ha, respectively.

3.9 Discussion

This chapter has focused on describing a typical farm in the study area, the processes followed to collect and refine data, and how the specific models were set up to answer the questions being investigated in the study.

It can be concluded from this chapter that the Southern Cape serves as one of the largest winter wheat and canola regions of South Africa (Hoffmann, 2010). Although a vast variety of farming activities occur within the region owing to the Mediterranean climate and the traditional 60:40 winter summer rainfall patterns, the agroecological conditions of farms in some areas make for more difficult farming conditions than in other areas. The farming conditions within the study area are characterised by steep hills and valleys, shallow acidic soil, and variable climatic conditions. Because of these characteristics, farmers in the study area have to deal with large portions of unproductive wasteland, the leaching of nutrients, and higher input cost levels. With economic pressures, the uncertain nature of farming, and the challenging farming conditions, farmers predominantly follow mixed-farming practices with winter grain and livestock to spread and reduce risk (Kooper, 2020). The main crops cultivated in the study area are wheat and canola, with sheep as the main livestock component.

To simulate a typical farm as closely as possible, enterprise data were collected from the SSK study group and compared with farmers in the study area. The usefulness of enterprise budgets to depict a typical farm is discussed in the chapter. Enterprise budgeting allows each farm activity to be viewed and analysed in terms of income, expenses and net profit. To model the various scenarios, the data from the enterprise budgets are combined, in Excel, through linear programming. Linear programming, as explained in section 3.8, is a profit maximisation or cost minimisation tool and, therefore, forms a key component of scenario planning within the study. In the next chapter, the development and set-up of the scenarios are explained. Chapter 4 is important as it describes the scenario setup process which provides a platform around which the results and conclusions are drawn.

Chapter 4:
Scenario Set-Up and Development

4.1 Introduction

In the current global economy, the farming environment is constantly evolving. Some changes such as in input costs are unavoidable, whereas others such as climate change take years before the effects are evident. Risk, uncertainty and constant changes (e.g. prices, weather, and markets) are unavoidable factors and influence the way in which farmers operate. In the farming environment, there will always be elements of risk. As a result, the key to sustainable farming is to manage risk and to endeavour to limit the effects of risk by focusing on what matters the most (Axson, 2018).

Scenario planning is one of many techniques available to farmers that could be used to ensure future readiness in an ever-changing farming environment. As previously mentioned in the literature reviewed in Section 2.6, scenario building is a technique used to combine various factors to create a range of outcomes that would help farmers to see how their behaviour and operations should change under different conditions. Being able to analyse multiple future outcomes allows farmers to plan their operations for avoiding a sets of future outcomes. To remain sustainable and maintain profitability, farmers need to be resilient, adaptive and innovative. It is therefore important to plan and evaluate farming operations on a regular basis in order to help to guide farmers towards a strategy that would ensure their ongoing, sustainable success (Axson, 2018).

Scenario planning is a valuable tool used in business planning, as it stimulates creative thinking and provides opportunities for development. In the agricultural industry, many influential factors exist and therefore the aim of using scenario planning in this study is to help farmers within the study area to plan for and avoid the negative implications of mismanagement. As mentioned in the literature study, agriculture has a much higher asset specificity than other businesses do, and therefore long-term planning is needed to make structural and operational changes (Edwards & Duffy, 2014). The need for long-term planning emphasises the importance of scenario planning.

During the process of farm management and scenario planning, it is important to identify these factors, to select the most influential factors, and to build strategies in order to overcome the effects of the variables. The rest of this chapter aims to describe the key variables, around which the scenarios are constructed, and to give an overview of each scenario.

4.2 Expected Impacts and Uses of Key Variables

To create scenarios for scenario planning, it is important to identify the key drivers or influential factors that are relevant to, or may cause risk and uncertainty within, the specific business environment. In the study area, after consulting with farmers and industry experts involved in the SSK study group, input costs, political uncertainty, economic uncertainty, soil conditions and variable climatic conditions were listed as being possible factors that are likely drivers of future uncertainty. The two most influential factors identified, around which the scenarios are structured, are input costs and climatic conditions (particularly rainfall), as these two factors largely determine the direction taken by any farming business.

According to Hoffmann (2010), fuel prices, chemicals for weed and disease control, and fertilisers are the major contributors to the input cost structure of winter grain enterprises in the Western Cape. Input costs are directly linked to profit and, as a result, play an important role in the sustainability of farming operations. In an academic study by Kooper (2020), it is noted that fertiliser and chemical prices are directly linked to international markets and exchange rates (R/US$) because the required commodities are imported, and not locally sourced or produced. Fuel prices, on the other hand, are volatile and unpredictable, as the prices rely on the crude oil price for pricing, which is used largely by the government for raising taxes and levies (Kooper, 2020). The cost–price squeeze effect is a term used in agriculture to describe the relationship between income and expenses, and the rate at which both variables increase (Brits, 2016). Farmers are price-takers, as illustrated by the above data, and thus the impact of a cost–price squeeze is always a reality in agriculture. In an article written by Wandile Sihlobo (2021), he explains that input costs, including fertiliser, agrochemicals, labour, fuel and energy, had increased drastically over the preceding 5 years, and more so in 2021, with glyphosate, on the agrochemical size, up by 99%, and potassium chloride, on the fertiliser side, up by 125%, respectively. One can see that the

sharp increases in input prices are squeezing profits because output prices are not following the trend of the input prices (Sihlobo, 2021b). Although not area-specific with all farmers having to deal with the pressures of input costs, the difficult nature of farming operations within the study area render input costs an ever more important variable to consider in terms of forward planning.

Rainfall, on the other hand, is the most influential factor in agriculture, as it largely determines what can be farmed, how farmers should operate, and how large harvests might be in any given year. In the study area, crop fields, although with a small percentage under irrigation, are generally cultivated on dry land, where farmers rely on sufficient rain for crop and pasture production. Rainfall in the study area is variable, ranging between 400 mm and 900 mm a year. Although the study area has an average rainfall of 650 mm, extreme weather events like droughts are becoming much more common, as mentioned throughout the study, and will become a prevalent factor in farming decision making. With input costs increasing, farmers rely ever more on good, consistent rainfall and therefore it is an important factor to consider.

4.2.1 Input costs

To model the effect of large scale changes to the input cost structure of farming operations, fuel prices are used as a proxy, across all variable input costs. Fuel is one of the most, if not the most, important factor in any commercial farming operation, as all mechanised equipment/machinery requires fuel to operate. Prices of fuel are often more volatile than other input costs and due to their importance to farming no substitute exist in South Africa as of yet. The percentage change to variable costs in Scenarios 2 and 3 are derived from the historical yearly inflationary increase in fuel prices. Over the 2020/2021 season, the volatility of fuel prices is made clear as the price of fuel increased by 65%, and therefore it is used as it represents the season with the highest inflationary increase (SAPIA, n.d.). Inflation is calculated from the base year of 2015 by using the following calculation (2021-2015) ÷ 2015 × 100. The change in variable cost is applied to the total variable production cost of each enterprise, and not only to one individual input price. The reason for investigating the total effect is that more than one influential input cost factor exists and cost prices increased across the board.

4.2.2 Climate

Climatic conditions within the Southern Cape, as mentioned throughout this study, are suitable for many farming activities, including winter grain, livestock, dairy, forestry and fruits. Although suitable for many farming activities, the unpredictability, uncertainty and variability in climatic conditions caused by the effects of climate change make climate a key variable to consider (Kooper, 2020). Climate has many components, including temperature and rainfall. For the study, climatic conditions are considered in terms of rainfall and are modelled through changes in yield. During optimal conditions in Scenarios 1 and 2, farmers harvest around 3.5–4 t/ha wheat and 2–2.5t/ha canola, whereas during below-average conditions, farmers harvest around 2 t/ha wheat and 800 kg-1 t/ha canola (Sentraal-Suid Koöperasie, 2021).

4.3 Scenario Overview and Framework

This section concentrates on and describes the most likely outcomes, given the key factors identified in the previous section of this chapter. As seen in the scenario framework, the first two scenarios focus on excellent climatic circumstances, with variable input costs remaining either constant or increasing at a high rate, whereas the last two scenarios focus on situations when climatic conditions are below average and input costs either increase drastically or remain constant.

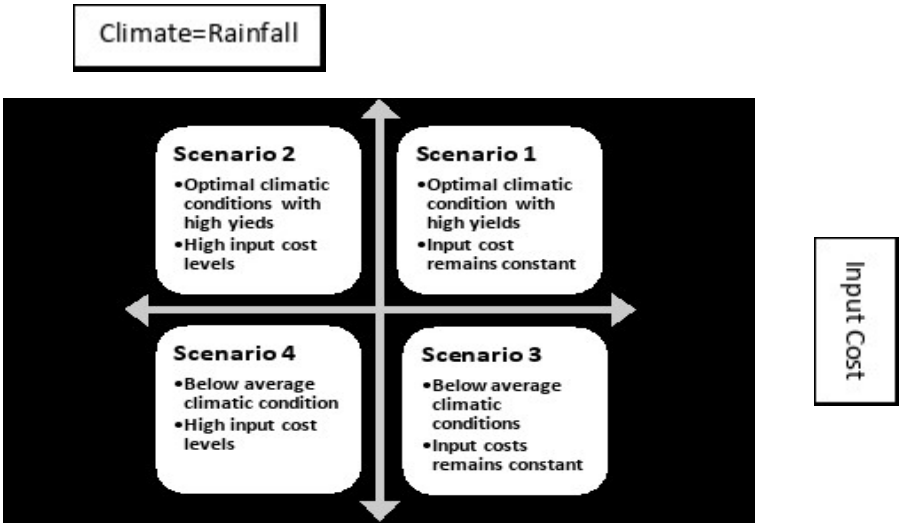

Figure 4.1: A graphic representation of the scenario framework

4.3.1 Scenario 1

Optimal climatic conditions and constant input costs are the dominating characteristics of this scenario. To model the best-case scenario, the average yields of the wheat and canola enterprises are increased to best describe optimal conditions. During this scenario, the average wheat yield of 2.18 t/ha and canola yield of 1.5 t/ha are increased to 3.5 t/ha and 2.5 t/ha, respectively (Sentraal-Suid Koöperasie, 2021). Variable costs are left constant, with no changes. Although the trend in prices of input costs suggests that this scenario is highly unlikely, input costs could possibly remain constant, with government support provided through subsidies, for example.

4.3.2 Scenario 2

The goal of a successful farmer is to maximise profit during above-average years, while remaining sustainable during below-average years. The main contributors to the input cost structures of the various enterprises under study are fuel prices, seed costs, fertiliser and agrochemicals (Hoffmann, 2010). This scenario, therefore, focuses on an increase in the costs of all enterprises, given above-average climatic conditions. To assess the true impact of a variable production cost increase, the increase is applied uniformly, across all enterprises. Given the variability of climatic conditions and the ongoing input-output price squeeze, this scenario is critical, as it would allow farmers to take advantage of above-average agricultural conditions.

4.3.3 Scenario 3

Agriculture is one of the few industries that are directly reliant on, and influenced by, climatic conditions. Climate change is a crucial component in agriculture, and this is becoming increasingly apparent, as weather patterns become more unpredictable. The frequency and longevity of extreme events like droughts and floods are increasing, as rainfall and temperature patterns are changing (Woetzel et al., 2020). In the recent past, during the 2017–2019 seasons, the Western Cape, including the area under study, experienced droughts, as a result of which crop yields were below-average. With lower crop yields, livestock play a large role, as farmers rely on the income from wool and meat to maintain positive cash flow.

This scenario focuses on how to structure a typical mixed farming business in the face of below-average weather conditions and constant production costs. As stated in the first scenario, unless the government implements significant policy changes, input costs are unlikely to remain constant in the near future.

4.3.4 Scenario 4

Scenario 4 combines what has been said concerning Scenarios 2 and 3 to form the worst-case scenario. This scenario features a substantial percentage rise in variable costs, combined with below-average climatic conditions. With yields at 1 t/ha for canola and 2 t/ha for wheat, and an increase in production costs of 65%, this scenario is critical in terms of sustainability, as survival is the focus during difficult periods. The primary goal is thus to produce an outcome that would potentially ensure sustainability by ensuring that farmers cover all variable costs. The importance of the income streams derived from the livestock component is highlighted in this scenario.

4.4 Conclusion

This chapter has focused on the development of the scenarios and the key components for each scenario. The first part of this chapter focused on identifying and describing the key variables within the study area. The chapter concluded by discussing the various scenarios and the mechanics within each scenario.

The farming environment is volatile and uncertain. Understanding complex interactions in the farm environment can be facilitated by the use of simulation and modelling, which are effective tools to use for academics and farm managers (Kooper, 2020). Scenario building, as used in this study, is one such tool. In order to set up the scenarios, key influential variables that produce financial uncertainty within the study area were identified. To best assist in safeguarding the sustainability of farmers, and to create the most influential scenarios, weather (rainfall) and input costs were identified as the two greatest uncertainties within the study area. From these two factors, the scenarios were built.

On the one end of the spectrum, are high yields (3.5 t/ha wheat and 2.5 t/ha canola) and high input costs (increase by 65%), and on the other end are low yields (2 t/ha wheat and 1 t/ha canola) during dry seasons and constant input costs. Within the first two scenarios, climatic condition are set to be above average, with above-average yields. Input costs are kept constant in Scenario 1, whereas in Scenario 2, input costs are elevated to above-normal levels. In Scenarios 3 and 4, climatic conditions are set below average, with constant input costs in Scenario 3 and high input cost levels in Scenario 4.

In Chapter 5, each of the described scenarios is simulated through using linear modelling to determine the most profitable combination of crop and livestock enterprises. The chapter will conclude by integrating the outcomes of each scenario to propose an approach that farmers could potentially implement to ensure their long-term sustainability.

Chapter 5:
Results

5.1 Introduction

To model and financially compare the implications of specific external factors regarding farming in the Southern Cape, and more specifically mixed-farming in the mountainous area of Riversdale, a scenario-based study using enterprise budgets and linear modelling was used. In Chapter 4, the structure of the scenarios was set out and described. The first step in this process was to identify the key variable and explain how it would be incorporated to generate realistic scenarios. The latter part of the chapter was devoted to explaining the scenario framework and the significance of the given scenarios to the context of the study.

The goal of this chapter is to model the scenarios, define the best and most sustainable combinations, and compare them with the control model. It is important to note that farmers in the study area encountered a mixture of above- and below-average conditions over the study period, resulting in average values that are slightly lower than the current data would indicate. In addition to the mixed conditions, there are current inflation levels that are not accounted for because of the set data range.

The first step and a very important part of this chapter would be to set up a base or control model that represents the average data of a typical farm. The base model plays a significant role in the chapter as it provides a platform to financially compare and observe the actual changes caused by each scenario. The results derived from each of the four scenarios created will be analysed and compared to the base model in terms of enterprise combinations, the status (binding or not binding) of each objective function, the resulting slack, and Lagrange multiplier values. The slack component indicates each objective function's surplus value, whereas the Lagrange multiplier represents how much the profit margin would rise or decrease, if one more Ha or SSU is planted or acquired. The results of each scenario will also suggest the best combination of enterprises in which earnings are maximised and inputs are minimised. The goal of the study is to find a sustainable combination of enterprises, therefore the results from each scenario will be combined in the final section of this chapter to provide an optimal yet sustainable combination that is flexible enough to withstand three of the four scenarios.

5.1.1 Base model

The first model of the scenario framework is the base model. The base model contains the average data of a typical farm in the study area. Setting up a base or control model that represents the average data of a typical farm is necessary in order to compare finances and track actual changes brought about by each scenario (Synario, 2021).

Table 5.1: Summary of a typical farm in the mountainous area of Riversdale

Cell	Objective function	Cell value		Status	Slack	Lagrange
F16	Planted Pastures	135	HA			
F10	Sheep production size LHS	440	SSU	Binding	0	-594
F11	Carrying capacity: sheep	0	SSU	Binding	0	2106
F12	Labour LHS	3033	Hrs	Not Binding	5415	0
F13	Production capital LHS	3 325 090	Rand	Not Binding	674 910	0
F7	Land: arable land LHS	630	HA	Binding	0	4036
F8	Rotational cropping: Canola	180	HA	Not Binding	30	0
F9	Rotational cropping: Wheat	315	HA	Binding	0	127

Source: Own calculations

Average variable costs, yields per hectare, and output prices were used to model a typical mixed-farming enterprise in the research area. Fixed costs would fall under the study's ceteris paribus conditions because they do not affect the enterprise combination of a farming operation. Fixed costs include levies, insurance, salaries, and banking costs, and do not vary with the scale or intensity of production (Kooper, 2020). Setting up a control is necessary for comparing data, since it offers a baseline against which the scenarios can be compared.

A typical farm in the study area, as seen in the results presented in Table 5.1 above, should be split to 50% wheat, 28% canola, and 22% pastures in order to achieve optimality. The percentage split between the enterprises is important, as it shows that each enterprise has its place and does contribute to the overall profit of a mixed-farming enterprise. The wheat enterprise contributes the most to total profit, at R1 311 339, followed by canola, at R724 927. Despite contributing less to total profit, the small stock enterprise, which includes sheep and planted pastures, still contributes R284 911, highlighting its importance within the mixed-farming setup. The Lagrange multiplier represents the value by which the farmer's total profit increases or decreases, should the binding constraint be increased by one unit. The binding constraints are sheep production, carrying capacity, arable land, and rotational cropping, as shown in Table 5.1 above. Looking at the binding constraints, it is clear that the principle of scale is important, as the model suggests that increasing

the farm size and the winter grain area planted, more specifically the wheat enterprise, would increase profit by R4036 and R127 per ha, respectively. Despite lower output prices, higher average yield of wheat, compared with canola, as well as the resulting higher average profit margins, contributed to a higher number of hectares being allocated to wheat. Sheep production, as mentioned, is binding, but shows a negative Lagrange Multiplier. This means that, although profitable, an increase in the flock size by 1 SSU would decrease profit by R594. It was agreed in the discussions with the industry experts that it takes too long and too much capital to rebuild a flock of sheep, and therefore the minimum value should represent the value of the farmer with the smallest number of sheep. It can therefore be seen that flock size must be kept at 440 SSU, which is the suggested minimum. The slack value shown in Table 5.1 above represents the surplus amount of the non-binding constraints. The results show that farmers have more than enough labour and capital to meet their needs. A farmer in the area under study needs roughly R3 500 000 in production capital to meet all of the variable costs of a mixed farming operation.

5.1.2 Scenario 1 (above-average conditions with constant variable input cost)

This scenario shows an outcome in which climatic conditions, in particular rainfall, are above average and input costs stay constant. In this scenario, wheat and canola yields are enhanced to above-average levels of 3.5 t/ha and 2.5 t/ha, respectively.

Table 5.2: Summary of scenario 1 showing the effects of above-average climatic conditions in a period of constant variable input costs

Cell	Name	Cell value		Status	Slack	Lagrange
F16	Planted Pastures	122	HA	-	-	-
F10	Sheep production size LHS	440	SSU	Binding	0	-2323
F11	Carrying capacity: sheep LHS	0	SSU	Binding	0	3836
F12	Labour Q1 LHS	3043	Hrs	Not Binding	5405	0
F13	Production capital LHS	3 356 143	Rand	Not Binding	643857	0
F7	Land: arable land LHS	630	HA	Binding	0	9655
F8	Rotational cropping: Canola	210	Ha	Binding	0	1025
F9	Rotational cropping: Wheat	285	Ha	Not Binding	30	0

Source: Own calculations

Agriculture is a high-risk, but rewarding, industry. In this scenario, the emphasis shifts to the above-average years when farmers could really maximise profit by taking advantage of near-perfect conditions. From the results shown in Table 5.2 above, it can be seen that, when compared with the base model, the difference in the ratio between the sheep enterprise and the cropping

enterprise has increased. The reason for the observed difference is that the above-average conditions not only have an effect on the yield of the various cropping enterprises, but also increase the carrying capacity of pastures, which allows farmers to carry the same amount of sheep on fewer hectares. In order to take advantage of the conditions, a farmer should allocate 19% of the available hectares to pastures, 33% to canola, and 45% to wheat. This means that no replacement ewes need to be kept, and the flock size needs to be kept at a minimum of 440 SSU. Although the sheep enterprise contributes considerably less profit, at R322 848, compared with R2 878 462 and R2 242 800 for wheat and canola, respectively, it is still very important, as it helps with cash flow throughout the year. Looking at the status of the constraints, it can be seen that the only constraints whose status changed are those of the cropping enterprises. As yields increase, the more that canola is favoured. From the results, it can therefore be seen that canola, under favourable conditions, is binding and that wheat is not binding. The resulting Lagrange multipliers, as in the base model, emphasise the principle of scale. As farm sizes increase, so do profit levels. A 1 ha increase in farm size would increase farm profit by R9655/ha.

5.1.3 Scenario 2 (optimal climatic conditions with high input cost levels)

To model this scenario, not only are yields increased to above-average levels, but input costs are also increased to above-normal levels. Because of the importance of fuel to the existence of farming, it was decided, as mentioned in Chapter 4, to use the maximum, historical yearly inflation rate for between 2015 and 2021 as a representative value for the increase in input cost levels. Input costs are therefore increased by 65%, and crop yields are elevated to similar levels as presented in Scenario 1.

Table 5.3: Summary of scenario 2 showing the effect of high input cost levels in a year with optimal climatic conditions

Cell	Name	Cell value		Status	Slack	Lagrange Multiplier
F16	Planted Pastures	122	HA			
F10	Sheep production size LHS	440	SSU	Binding	0	-2056
F11	Carrying capacity: sheep LHS	0	SSU	Binding	0	3075
F12	Labour Q1 LHS	3078	Hrs	Not Binding	5370	0
F13	Production capital LHS	3 384 468	Rand	Not Binding	615 532	0
F7	Land: arable land LHS	630	HA	Binding	0	6465
F8	Rotational cropping: Canola	210	HA	Binding	0	360
F9	Rotational cropping: Wheat	298	HA	Not Binding	17	0

Source: Own calculations

As mentioned above, most agricultural inputs are imported and, as a result, prices are directly linked to international markets and exchange rates. With the current economic state of South Africa and the volatility of exchange rates, high input costs are most likely to comprise one of the dominating concerns for farmers. This scenario focuses on increases in the costs of all variable inputs, given optimal climatic conditions suitable for high yields. From the results of the linear model summarised in Table 5.3, it can be seen that, to maximise profits, arable land should be split 47% towards the wheat enterprise, 33% towards the canola enterprise, and 19% towards pastures for the sheep enterprise. Although input costs have increased by 65%, profits for wheat and canola would grow significantly when compared with the base model, with wheat contributing R1 927 412 to the overall profit, and canola R1 433 355. In this scenario, the sheep enterprise must be reduced to the minimum level of 440 SSU, and maintained for the drier years to come. Looking at the status of the constraints, it is clear that the results are similar to those of the base model. The results show that labour hours and production capital are not binding, and therefore farmers would have more than enough labour and capital available to them to cover all the variable input costs. In this scenario, the economy of scale is once again emphasised, as the Lagrange multiplier shows that arable land should be increased and that profit margins would increase by R6 465 for every additional ha.

5.1.4 Scenario 3 (below-average conditions with constant input cost levels)

This scenario shows an outcome in which farmers would endure a drought, with lower-than-average yields and constant input costs. In this scenario, wheat and canola yields are reduced to below-average levels of 2 t/ha and 1 t/ha, respectively.

Table 5.4: Summary of scenario 3 showing the effects of below-average climatic conditions in a period of constant variable input costs

Cell	Name	Cell value		Status	Slack	Lagrange Multiplier
F16	Planted Pastures	315	HA			
F10	Sheep production size LHS	945	SSU	Not Binding	505	0
F11	Carrying capacity: sheep LHS	0	SSU	Binding	0	1512
F12	Labour Q1 LHS	2852	Hrs	Not Binding	5596	0
F13	Production capital LHS	3 147 480	Rand	Not Binding	852 520	0
F7	Land: arable land LHS	630	HA	Binding	0	1726
F8	Rotational cropping: Canola	0	HA	Not Binding	210	0
F9	Rotational cropping: Wheat	315	HA	Binding	0	1688

Source: Own calculations

The focal point of this scenario shifts towards the less-favourable climatic conditions, where sustainability becomes more important than profitability would be. From the results shown in Table 5.4 above, it can be seen that the emphasis needs to shift toward the sheep enterprise and the wheat enterprise. Although canola has a better recovery rate when exposed to below-average climatic conditions, data from the SSK study group showed that, during the dry 2018–2019 seasons, canola averaged around 1 t/ha, whereas wheat averaged around 2 t/ha. The difference in yield potentials is largely responsible for the results seen in the table. The results suggests that, when the scenario conditions are dominating, farmers should allocate 50% of arable land to wheat, and the other 50% towards pastures for the sheep enterprise. With 50% of arable land being allocated towards the pasture, the sheep enterprise should be increased to 945 SSU, depending on the carrying capacity, to maximise output and remain sustainable.

In the first two scenarios, the sheep enterprise helped with cash flow and the spread of risk. In this scenario, the sheep enterprise is one of the main income streams, as it contributes R543 822 to the total profit, while the wheat enterprise contributes R1 075 410. Looking at the Lagrange multipliers for the “Land” and "Rotational cropping: Wheat” constraints, it can be seen that, for every hectare added to arable land and wheat planted, profit margins would increase by R1726 and R1688, respectively. The economy of scale, therefore, plays an important role in sustainable farming practices. Except for the canola rotational cropping constraint, the slack value follows similar patterns to that of the base model.

The results show that there are more than enough labour hours available and that the farmer would have an excess of R852 520 to spend on unforeseen expenses. As demonstrated in the first three models, the sheep enterprise should be quite adaptable. This means that flock sizes should be able to increase or decrease, as the conditions dictate. The relevance and importance of the sheep enterprise are emphasised in this scenario, as farmers would rely on it to remain sustainable in years with below-average rainfall.

5.1.5 Scenario 4 (below-average weather conditions and high input cost levels)

As a result of dealing with external factors like the weather, international prices and the exchange rate, farmers would, for example, experience the “highs” and “lows” of farming, and would thus have to deal with periods where yields are low and input prices are high. The goal of this scenario

is to produce an outcome in which farmers could cover at least all variable input costs and survive the difficult period.

Table 5.5: Summary of scenario 4 showing the effects of below-average climatic conditions in a period of high input cost levels

Cell	Name	Cell value		Status	Slack	Lagrange Multiplier
F16	Planted Pastures	630	HA			
F10	Sheep production size LHS	1890	SSU	Not Binding	1450	0
F11	Carrying capacity: sheep LHS	0	SSU	Binding	0	1019
F12	Labour Q1 LHS	2682	Hrs	Not Binding	5766	0
F13	Production capital LHS	3 202 920	Rand	Not Binding	797 080	0
F7	Land: arable land LHS	630	HA	Binding	0	248
F8	Rotational cropping: Canola	0	HA	Not Binding	210	0
F9	Rotational cropping: Wheat	0	HA	Binding	315	0

Source: Own calculations

The results shown in Table 5.5 above show that, during a period of below-average weather and high input costs, the focus should shift completely to the livestock enterprise, with no hectares being allocated to cropping enterprises, and 100% of arable hectares being allocated to planted pasture. When profit margins are compared with the basic model, it is obvious that the R156 442 profit that farmers would make by focusing on the sheep enterprise is much lower than the profit margins achieved by including cash crops during more favourable conditions. Although profit margins are lower, focusing on the livestock industry reduces the likelihood of bankruptcy and would allow farmers to stay sustainable through difficult times.

The results further suggest that labour and production capital are not binding, and that farmers would have 5766 labour hours and R797 080 extra to spend on unforeseen expenses, or to buy extra feed. The Lagrange multiplier for the binding land constraint suggests that, for every hectare of arable land added to the existing 630 ha, the profit margin would increase by R248. Although profit margins would increase, the advantages gained are not worth the risk during the difficult conditions, and therefore farmers should not increase their use of arable land. From the results, it can be seen that focus and resources should be channelled towards the sheep enterprise and that expenses should be limited, as profit margins would be extremely low and the risk of bankruptcy would be extremely high.

5.1.6 Optimised average farm setup

The second and most important aim of the study is to find a combination of farming enterprises, using the scenarios, in which farmers would be assured to remain sustainable in three out of the four scenarios.

Table 5.6: Optimised average farm setup of a typical mixed farming enterprise

Name	Cell value		Status	Slack	Lagrange Multiplier
Planted Pastures	187	HA			
Sheep production size LHS	608	SSU	Not Binding	1450	0
Carrying capacity: sheep LHS	3.26	SSU	Binding	0	1019
Labour Q1 LHS	2991	Hrs	Not Binding	5766	0
Production capital LHS	3 296 030	Rand	Not Binding	797 080	0
Land: arable land LHS	630	HA	Binding	0	248
Rotational cropping: Canola	143	HA	Not Binding	210	0
Rotational cropping: Wheat	300	HA	Binding	315	0

Source: Own Calculations

By combining the results of each linear model, an optimised average of a typical farm in the study area is obtained. From the combined results shown in Table 5.6 above, it can be seen that, to increase the chances of remaining sustainable during the first three scenarios, farmers should allocate 70% of arable land towards cropping enterprises, and 30% towards pastures for livestock. When comparing the optimised typical farm setup with the base model, it can be seen that, while the emphasis swings somewhat towards the livestock industry, with planted pasture increasing to 187 hectares and sheep output increasing to 608SSU, less production capital and fewer labour hours are required. Although this combination of enterprises is not optimal and would not ensure maximum profit during optimal conditions, it would ensure greater stability and provide farmers with an optimised average, when combining the above- and below-average years. To become and remain sustainable, farmers need to be able to avoid the market extremes and therefore, by following the suggested optimised average farm setup, mixed farming operations would be able to absorb and fortify the effects of the plausible future scenarios.

5.2 Discussion

Typical enterprise budget models were constructed for each farming unit of a mixed-farming enterprise through using secondary data that were adjusted by using the Delphi technique, as explained in Section 3.5. The data used for the study ranged from 2016 to 2020, which included a couple of years where yields were above average, and a couple of years where yields were below average. Although the average data of a typical farm is not a direct guiding tool for management, once it is converted to a linear model, the data can be used to find the optimal and sustainable combination of any given scenario.

The study aims to find the sustainable and financially optimised combination for the range of possible future scenarios of a typical farm in the Hessequa district of the Southern Cape by combining the optimised enterprise mix for each individual scenario. As seen in the scenario framework described in chapter 4, the first two scenarios focus on excellent climatic circumstances, with variable input costs remaining either constant or increasing at a high rate, whereas the last two scenarios focus on situations when climatic conditions are below average and input costs either increase drastically or remain constant. According to the literature, one of the most important methods for managing risk is through diversification (Kooper, 2020). From the results of each scenario, it can be seen that there is a clear trend in favour of mixed farming with pastures for sheep and cash crops, which correlates well with literature and suggests that farmers need both crops and livestock at a 70:30 split to remain profitable and sustainable. It further shows that farming operations, especially in the study area, need to be flexible enough to accommodate adaptability, as each scenario required a different combination of enterprises to maximise profitability.

Chapter 6:
Conclusions

6.1 Overview of the research

Chapter 1 is important, as it gives background on the farming environment in the Southern Cape and highlights the specific issues that farmers, not only in the study area but all over South Africa, face on a daily bases. Farming as an industry largely relies on external inputs and various external factors to function in a financially feasible manner. Over recent years, the variability and volatility of these external factors and the effects of the cost–price squeeze have begun to place the profitability of farms in the Southern Cape under pressure. To prevail, farmers face a situation where change or improvement of their current farming operations is needed. The main objectives of this study were focused on improving the farm-level profitability of mixed-farming systems in the study area, being the mountainous area of Riversdale in the Southern Cape, while endeavouring to ensure a sustainable future.

To conduct any research, it is important to understand the industry and what sets it apart from other industries or businesses. The first part of the literature review in Chapter 2 was set out to explain the differences between the farming environment and other business environments. Farming, in general, is much more complicated, as it deals with natural processes, political issues, international markets and biological complications such as animal diseases and pets. What sets the agricultural environment apart from normal business environments is explained through the product mix of each sector. The natural and environmental components, over which farmers have very little control, ultimately comprise the main difference within the product mix of the two sectors. The last part of Chapter 2 explains the various approaches available and already used in literature to study the topic of profitability and sustainability. The scenario building approach used in this study is but one of many approaches available and explained in the chapter.

In Chapter 3, the farming environment is narrowed down by focusing on the study area, and more specifically, on a typical farm within the study area. With its Mediterranean climate, with 60% of its rainfall in the winter months and 40% in the summer months, the study area is suitable for a variety of grain and livestock systems. Although many similarities exist in terms of livestock and

crops throughout the Southern Cape, many differences exist, for example topography and availability of arable land. A typical mixed-farming enterprise within the study area consists of small stock, predominantly sheep, and winter crops. The chapter further explains the various data collecting and modelling techniques used to portray and study the profitability and sustainability of a typical mixed-farming enterprise. To model a typical farm in the study, the data collected in the form of enterprise budgets were combined in Excel through linear modelling. Linear modelling uses the data collected of a typical farm within a framework of area constraints, explained in the chapter, to set out the optimal and most profitable combinations for the various enterprises.

Chapter 4 is regarded as the scenario setup and development section of the study. The first step in setting up scenarios is to identify the key influential factors, around which the scenarios are built. The first part of this chapter explains that the farming environment is very volatile and that it contains a high element of risk attributable to rising input costs, political uncertainty, economic uncertainty, acid soil conditions, and variable climatic conditions. After interviewing farmers and industry experts, input costs and climatic conditions, represented as yield per hectare, were identified as being the two key variables, around which the scenarios would be structured. The second part of this chapter explained the conceptual framework. It goes on by explaining each scenario in greater detail. The first scenario is centred on optimal climatic conditions, with high yields and constant input costs. The second scenario covers optimal conditions, with high yields remaining and input cost levels being set to very high. For the third scenario, below-average climatic conditions, with constant input cost levels prevail, whereas for the fourth scenario, farmers would be dealing with below-average conditions and high input cost levels.

In Chapter 5, the results of the various linear models were discussed and suggestions were made on how to structure a typical mixed-farming operation in the study area. The purpose of the linear models is to measure and evaluate the impacts of the various scenarios on the structure of a typical farm in the research area in order to choose the best and most advantageous combination. From the results, it was clear that there is room for both the livestock and the grain enterprises within a mixed-farming operation in the study area. For each scenario, a different optimal combination exists. Although the results for each scenario prove that a more optimal combination might exist, it would not be sustainable for structuring a farm according to one specific scenario. The second part of the results chapter is used to set up a sustainable combination from the results of each

scenario. The results were combined to find an optimised average combination of enterprises. The goal was to ensure that farmers could farm sustainably by absorbing the extremes in the market, and ultimately be able to survive three out of the four scenarios.

6.2 Key findings

As agriculture becomes more important to human survival, global population growth and environmental changes threaten food security (Oosthuizen, 2014). To achieve the difficult task of meeting the demands of the growing population, farmers need to optimise their production and ensure their sustainability. Over the past 20 years, the farming environment has changed significantly, becoming much more integrated and complicated (Kahan, 2019). What makes the farming environment so much more complicated is the fact that it is influenced by external factors from the social, political and economic environments, over which farmers have very little control (Ward, 2018). Adding to the already complicated situation are the unstable climatic conditions caused by climate change. Planning is becoming increasingly important as the farming environment changes and expands, posing a threat to profitability and sustainability.

Agriculture in South Africa is divided into the summer grain production areas and the winter cereal production areas. The Southern Cape is one of the main cereal production areas of South Africa, and is characterised by a Mediterranean climate, with rainfall distributed 60% in the winter and 40% in the summer. These climatic conditions allow for a variety of economic activities to be pursued, including livestock, dairy and crop farming. Historically, farmers in the Southern Cape have followed continuous cash crop systems to maximise their profits. However, in recent times, the effect of external factors like disease outbreaks and weather extremes have become much more apparent, obliging farmers to spread risk and move toward mixed-farming operations (Kooper, 2020).

In the study area, comprising the mountainous area of the Hessequa district in the Southern Cape, farmers are dealing with unique environmental issues, for example unpalatable grass and low nutritious shrubs, obliging them to either cultivate pastures for livestock or to buy feed (Streigher, 2021). With rising external economic pressures from factors, such as market closures brought on by more frequent animal disease outbreaks, supply chain disruptions and fast-rising input costs,

the focus needs to shift toward operational optimisation and sustainability. To become sustainable and maintain profitability, farmers need to optimise their farming operation by identifying feasible strategies for overcoming challenges, reducing risk, and sustaining or increasing profitability (Oosthuizen, 2014). Scenario planning or scenario thinking is one such tool to use that could assist farmers in their decision-making processes.

Although many different tools for management and planning exist, scenario planning is a very useful tool, as it helps farmers to identify possible outcomes and allows them to structure their operations accordingly (Girdziute, 2012). Management tools, such as scenario planning, can also control the risks imposed by changes in key influential factors, for example input prices, by simulating the effect that these changes might have on the combination of enterprises within the farming environment.

In agriculture, the complex environment causes many external factors to influence profitability and sustainability, and therefore to set up the scenarios, the two most influential factors, climatic conditions and input costs, were identified through interviewing industry experts and various farmers. By combining the data of a typical farm in the study area with the identified factors, the scenarios could be modelled and viewed. The scenarios created ranged from above-average climatic conditions with high yields and constant input cost levels, to below-average climatic conditions with low yields and high input cost levels.

From the results shown and discussed in the chapter, several key elements could be identified, as described below.

- From the results of each scenario a clear trend exists in favour of mixed farming, which suggests that farmers need to implement both livestock and crops farming to be profitable and sustainable. When the results are compared with earlier research, similar outcomes in support of mixed farming exist. According to a study by Kooper on continuous cash-crop rotational systems, crop-pasture systems offered income stability and sustainability (Kooper, 2020).
- Farming operations need to be flexible enough to accommodate all three enterprises. According to the combined results shown in Table 5.6 above, farmers should dedicate 70%

of their arable land to cropping enterprises, and 30% to animal pastures in order to increase their chances of being sustainable during the first three scenarios.

- In the case of a mixed-farming operation, especially in the research area, the sheep enterprise should be the flexible component. During favourable farming conditions, the sheep enterprise should be kept at the equilibrium point, whereas during challenging conditions, it should be the main focus.
- Because each scenario has a different optimal combination, and the goal is for farmers to farm sustainably by absorbing market extremes, an optimal average is required to ensure sustainability in at least three of the four situations.
- Since the linear modelling results of each scenario indicate that increasing the size of the farm would increase profitability, the economies of scale constitute a crucial element of profit maximisation.

The research proposition of this study states that enterprise combinations that are more effective and productive do exist, and that long-term profits would improve because of the improved combinations. Through careful analysis of the results obtained from the linear models, it can be concluded that, in order to maximise profit during good years and to be sustainable during difficult years, the key should always be to diversify. Through optimisation and diversification with sheep and cash crops, wheat and canola farmers in the Hessequa district operating mixed enterprises would be able to absorb the extremes within the farming environment and remain sustainable.

6.2 Implications of the Study for the Agricultural Industry and Farming in the Study Area

Risk and uncertainty constitute a very influential and unavoidable part of any business, and therefore careful analysis and management are required to become successful, make a profit, and remain sustainable in the long term. The study of risk and uncertainty in agriculture is important as the risks associated with, for example input costs, weather, market access and government policies, could greatly influence farm-level income and ultimately the sustainability of farmers.

The agricultural environment is constantly evolving and is becoming increasingly difficult to manage therefore it is important to find new ways to improve management and decision-making. For farmers to survive the volatility in the agricultural industry it is important to find strategies to improve profitability while ensuring sustainability. Consequently, analytical tools like scenario building, used within this thesis, are necessary as it is simple to use and effective in their goal to improve operational management sustainably. From the results in chapter 5, it can be argued that the thesis theoretically benefits the agriculture industry by demonstrating that more effective farming combinations exist and that farmers should diversify to ensure sustainability.

6.3 Shortcomings of the Research

Research has limitations, and it is obvious that the study has several limits worth highlighting. The shortcomings relate to the sample size, specificity of the geographical area of the study and the generalisability of the data.

The first shortcoming that might potentially have an impact on the study is the sample size of the data. Sample size directly influences the research findings, and therefore the larger the sample size is, the more credible the results would be (Faber & Martins, 2014). The secondary data collected from the Swellendam Sentraal Suid Kooperasie study group ranged from 2016 to 2020. Although the data is from a similar but different area to the study area and included a drought spell between 2017 and 2019, which could potentially have skewed the data, the impact of the limitations on the outcome of the results is limited, because the data are ground proven and were verified through interviews with local farmers and industry experts. Although the impact of the sample size is limited, a larger sample size might control the risk of reporting skewed data.

The second important shortcoming of the study could be that the results of the scenarios, when applied to areas outside of the study area, would not be transferable. This shortcoming relates to the specificity of the area selected and arises because of the differences in carrying capacity, yields, topography, and sizes of farms. Although the results generated for each scenario are area-specific and might not be true for other regions with different farming dimensions and practises, the resulting principle and setup of the models would remain constant, allowing farmers in different regions to apply their data to the model.

The third shortcoming of the study relates to the generalisability of the data and the critical influential factors used within the set-up of the scenarios. This limitation arises from the complexity of the farming environment (commodities, livestock enterprises, variable input costs, yields, carrying capacities, etc.) and the many aspects (social, political, economic and environmental) influencing the profitability and sustainability of farmers. The Delphi technique, which was used to verify or ground proof the data acquired from the local cooperative, might have indirectly reduced the impact of the shortcomings because it not only helped to compound the data, but also increased the relevance and impact of the main variables on the study's outcome.

6.4 Recommendations and Implications for Further Research

The main aim of the current research project was to create a scenario-based modelling system, which could be used in farm management and planning. The research question thus asked was, given the lower margins caused by the cost–price squeeze and risks associated with external market forces, what combination of farming operations within a mixed system, in the mountainous area of Riversdale, would be sustainable and the most profitable? To answer the questions and portray the scenarios, a combination of enterprise budgeting and linear modelling was used. It is recommended that a close professional relationship should be maintained with farmers and industry experts in order to touch all bases and to ensure that data are fair and accurate.

Because of variations in rainfall patterns, crop yields and sheep breeds across the Western Cape, the general trend of results would be similar, but profit margins and specific combinations within different regions would differ, and therefore it is recommended that farmers in different areas should apply their own data to the models. The results could therefore be presented to study groups and other area-specific farmers to increase their awareness regarding the impacts of critical variables on the profitability of their farming operations and the long-term structure of their farming enterprises. This study not only benefits farmers in terms of management, but could also be used by industry professionals as a guide for future research projects and investments. Farm-level profitability is the main concern for producers, and therefore industry experts could use the results of this study to ensure sustainability during less-favourable years and profitability during favourable conditions.

Through the process of conducting the research and collecting the data, some specific issues and concerns were identified, which could be researched or explored further in future studies. Because of the time constraints that are associated with any research project, it was impossible to incorporate all of the influential aspects of farming enterprises, and thus only the most commonly found enterprises within a mixed farming setup were included in this study. It is recommended that future researchers could derive a more inclusive view by using the same methodology and methods, but including or adding other grain and livestock components, for example barley and cattle. It is further recommended that future studies should investigate optimal allocations of arable land by using different modelling techniques or different key variables.

The last area of recommendation focuses on topics for further research. It was found in this study that variable input costs, especially in the more recent seasons, increased at a much higher rate than production income did. It is therefore recommended that future studies should focus on cost-efficient ways to reduce input costs through, for example better and cheaper soil management techniques or cheaper sustainable fuel sources. In past studies, it was recommended that researchers should investigate methods of producing livestock in a cheaper, more efficient way to increase the options available to farmers in mixed-farming operations (Hoffmann, 2010). Certainly, there is still a need to look into more profitable livestock production methods, as these play an important role within mixed-farming operations by reducing risk, increasing cash flow during difficult farming periods, and most importantly, to increase profits.

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Annexure 1

Appendix 1

Questionnaire/Interview

1. What is the average size of farms in the mountainous area of the Hessequa district?

2. Rank the most preferred winter grains in the Southern Cape?

3. What are the top 5 limiting factors of farming in the mountainous region of the Hessequa district and rank them?

4. What happened with profit margins over the past 10 year?

   - What are the reason for the changes?

5. Identify and list, in order of importance, the driving forces/uncertainties impacting decision making in farming? Eg. Weather, political issues

6. List the production cost factors of wheat?

- Will the factors change over time or remain constant?
- If changes occur what causes the changes?
- Risks involved in producing wheat, from an investment point of view?

7. List the production cost factors of canola?

- Will the production cost factors change over time or remain constant?
- If changes occur what causes the changes?
- Risks involved in producing canola, from an investment point of view?

8. Number of mixed farming systems where sheep are integrated with crops?

9. List Sheep flock sizes in a mixed farming system?
   - Largest
   - Average
   - Smallest

10. List the production cost factors of sheep?
    - Will the production cost factors change over time or remain constant? Why?

11. In terms of cash crops and planted pastures for sheep (Mixed farming system):

    Cash crops
    - Largest area planted (ha)

- Average area planted (ha)

_____

_____

- Smallest area panted (ha)

_____

_____

Pastures planted

- Largest area planted (ha)

_____

_____

- Average area planted(ha)

_____

_____

- Smallest area planted (ha)

_____

_____

Appendix 2

Linear Programming Scenario 1 - Final Report							
Setup	Ha	Ha	Ha	SSU			
Constraints	Wheat	Canola	Planted Pasture	Sheep			
Objectibe function	9655,5	10680	-2810	1512,14	LHS	RHS	Max
Land: arable land	1	1	1		630	630	<=
Rotational cropping: Canola		1			210	210	<=
Rotational cropping: Wheat	1				298,1163	315	<=
sheep production size				1	440	440	>=
Carrying capacity: sheep			-3,61	1	0	0	=
Labour Q1	5	5	2	1	3078	8448	<=
Production capital	4908	5930	2810	758	3384468	4000000	<=
Changing cells	298,1163	210	121,8836566	440			
	2878462	2242800	-342493,0751	665341,6			
Target cell	5444111						

Linear Programming Scenario 2 - Final Report							
Setup	Ha	Ha	Ha	SSU			
Constraints	Wheat	Canola	Planted Pasture	Sheep			
Objectibe function	6465,3	6825,5	-4636,5	1019,44	LHS	RHS	Max
Land: arable land	1	1	1		630	630	<=
Rotational cropping: Canola		1			210	210	<=
Rotational cropping: Wheat	1				298,1163	315	<=
sheep production size				1	440	440	>=
Carrying capacity: sheep			-3,61	1	0	0	=
Labour Q1	5	5	2	1	3078	8448	<=
Production capital	4908	5930	2810	758	3384468	4000000	<=
Changing cells	298,116343	210	121,8836567	440			
	1927411,59	1433355	-565113,5744	448553,6			
Target cell	3244206,62						

Linear Programming Scenario 3 - Final Report							
Setup	Ha	Ha	Ha	SSU			
Constraints	Wheat	Canola	Planted Pasture	Sheep			
Objectibe function	3414	98	-2810	1512,14	LHS	RHS	Max
Land: arable land	1	1	1		630	630	<=
Rotational cropping: Canola		1			0	210	<=
Rotational cropping: Wheat	1				315	315	<=
sheep production size				1	945	440	>=
Carrying capacity: sheep			-3	1	0	0	=
Labour Q1	5	5	2	1	2852	8448	<=
Production capital	4908	5930	2810	758	3147480	4000000	<=
Changing cells	315	0	315	945			
	1075410	0	-885150	1428972			
Target cell	1619232						

Linear Programming Scenario 4 - Final Report							
Setup	Ha	Ha	Ha	SSU			
Constraints	Wheat	Canola	Planted Pasture	Sheep			
Objectibe function	223,8	-3756,5	-2810	1019,44	LHS	RHS	Max
Land: arable land	1	1	1		630	630	<=
Rotational cropping: Canola		1			0	210	<=
Rotational cropping: Wheat	1				0	315	<=
sheep production size				1	1890	440	>=
Carrying capacity: sheep			-3	1	0	0	=
Labour Q1	5	5	2	1	2682	8448	<=
Production capital	4908	5930	2810	758	3202920	4000000	<=
Changing cells	0	0	630	1890			
	0	0	-1770300	1926742			
Target cell	156441,6						