The economic effect of mechanised harvesting technology on grape-producing farms in the Western Cape Province of South Africa

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DECLARATION

I, O'Brien Jonathan Perel, herewith declare that the master's degree dissertation submitted for the master's degree qualification *Master of Agriculture majoring in Agricultural Management* at the University of the Free State is my independent work, and that I have not previously submitted it for a qualification at another institution of higher education. I also with this relinquish copyright to the University of the Free State.

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O'Brien Jonathan Perel Date

DEDICATION

With great thanks, gratitude and humbleness, I would like to honour and dedicate this research work to my Father in heaven who gave me the strength and guidance to do this dissertation in Jesus' name.

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ABSTRACT

Mechanisation and technological development in agriculture is becoming increasingly apparent, not just in developing countries, but also in African countries, and more particularly in South Africa. The purpose of the research was to evaluate the economic impact of mechanical grape harvesting on wine farms in the Western Cape. Subsequently, it further determined the factors influencing the adoption of mechanical harvesting of wine grapes, as well as the factors influencing mechanical processes on labourers. The third objective was to determine if a farmer would consider mechanical harvesting and whether it would be profitable to use it. Therefore, the economic aspects are addressed by these objectives, whether it would be financially feasible and viable to make use of mechanical harvesting, would the reduction in labour cost strengthen adoption and which other economic factors would contribute to the adoption of mechanical harvesting.

The research comprised of both secondary and primary data; primary data stood mainly for determining factors that have an impact on adoption and labourers on these wine-producing farms. Secondary data were used to assess the profitability of employing a mechanical harvester for harvesting grapes. The number of farmers that participated in this study consisted of 91 producers of wine grapes.

The result clearly showed that increasing average yield of grapes in tons per year and hectares used for the production of wine grapes were negatively associated with farmers utilising mechanical harvesting for the harvesting of wine grapes. There were three different scenarios for harvesting grapes on wine farms with respectively 100 ha and 40 ha under wine grapes. The results also showed that it would be more profitable for wine grape producing farmers to make use of mechanical harvesters for harvesting grapes with a land size cultivation area of 100 ha instead of a wine grape cultivation area of 40 ha land.

The study revealed that permanent labour and hectares used for the cultivation of wine grapes do not significantly impact the adoption of mechanical harvesting of grapes. Farms with an average land size of about 75 ha to 100 ha, found mostly in the Breede Valley Municipality, would be more prone to mechanical harvesting than farms in the Stellenbosch area with an average wine grape land size of 40 ha, as investments in such machinery are profitable.

The study also showed that the increase in hectares used for the cultivation of wine grapes, the number of seasonal labour, permanent labour, the number of hectares used for wine grapes, mechanical harvesting, as well as the cost of mechanical harvesting did not decrease seasonal or permanent labour demand. It was clear that larger farming units with higher production output, especially in the Breede Valley Local Municipality would be more prepared to adopt mechanical harvesting. The results of the research revealed that mechanical harvesting would be profitable if adopted, and it would not reduce labour on the wine-producing farms. However, further research is needed for a comprehensive understanding of mechanisation at large to provide tangible interventions from government.

Keywords: Mechanical harvesting, adoption, labour, mechanisation, profitability, wine grapes, cost-benefit analysis, logistic regression, farmers

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List of Abbreviations and Acronyms

ALOh	Average labour output per hour
AYG	Average yield of grapes
BCR	Benefit-cost ratio
BFAP	Bureau for Food and Agricultural Policy
CBA	Cost-Benefit Analysis
CBC	Conservation biological control
EIRR	Economic Internal Rate of Return
FAO	Food and Agriculture Organisation of the United Nations
IGWS	Institute for Grape and Wine Science
IRR	Internal Rate of Return
LLs	Seasonal labour employment
LLp	Permanent labour change
MHout	Machine harvest output
NFI	Net farming income
NHecp	Number of hectares used
NPerL	Number of permanent labourers
NPV	Net present value
NSL	Number of seasonal labourers
RSA	Republic of South Africa
SAWIS	South African Wine Industry Information and Systems
WOSA	Wines of South Africa

CHAPTER 1
INTRODUCTION

1.1 Background of the study

In 1652, the first European settlers arrived in the Cape of Good Hope, now known as Cape Town, when the Dutch East India Company sent Jan van Riebeeck to set up a place on the trade route between Southeast Asia and Europe. Grapevines were among the plants that were planted together with other garden staples. The first vineyards were not successful, but vineyards planted in 1656, from Spain, France and Germany produced the first Cape wine, harvested in 1659. In 1679, Van der Stel arrived with plans to develop but also to produce good wine. He received a large land fund in 1685 and subsequently established the Constantia wine estate. The number of wine producers that crush grapes decreased by 2.58% from 581 to 566 between 2005 and 2015 and currently there are 3 232 primary grape producers and 104 bulk wine buyers in the wine sector (South African Wine Industry Information Systems [SAWIS], 2016). Most of the growth in production was on small, site driven properties; however, a large amount of production was managed by large cooperations. From 1990 to 2003, the share of grapes made for wine utilisation by the public rose from 30% to 70% (Breslin, 2011).

Previously, although also in some instances currently, vineyard activities are carried out both by hand and by utilising horse-drawn equipment before establishing any form of mechanisation. With the arrival of the first iron-wheel tractors, the grapevines needed to be rearranged by spreading the vines farther apart, so that the tractors could drive between the rows. Over the years, iron-wheel tractors have been replaced by rubber wheel tractors, where chain-wheel tractors have been used to aid in the preparation of the soil (Van Rensburg, 2016).

The FAO (2008) reported that the objectives of agricultural mechanisation are the reduction of human drudgery, to increase yields, put more land under cultivation and the enhancement of farmers' living standards. Aspects of agriculture that use technology include land preparation, as well as transportation and processing, which are vital in agriculture. Agriculture is the sector that dominates most African countries, placing significant reliance on the industry.

Mechanisation in agriculture is, in essence about the increase of power and the application of mechanical technologies in agriculture to improve labour productivity, as well as to achieve results past the ability of manual labour. Mechanisation in agriculture is not an ‘all or nothing’ process but considers various stages and types of enhanced mechanical technologies appropriate for compatibility with, for instance, socio-economic and industrial conditions. It also includes technologies such as irrigation systems, a system to process food and other related equipment (Food and Agriculture Organisation of the United Nations [FAO], 2008). Mechanisation, therefore, needs to be well developed to adhere to changing conditions and requirements.

The cost of manual labour has demanded a need for specialised management of vineyard equipment to have more activities done with the use of machinery. A system that is completely mechanised is likely to be the future for mechanisation for every operational activity in any given season. The mechanical operations should, however, not negatively affect the fruit or wine quality. The vineyard operations that have been mechanised are summer pruning and harvesting, dormant pruning, as well as fruit thinning. Mechanical harvesters and other mechanical operations have been used for some time, but no systems for the appropriate machine are used for the 12 major trellising systems (Morris, 2000).

The reason for looking at mechanisation in the wine-producing region within the Western Cape was mainly to establish what impact a wine grape harvester would have on the farm. New plantings did not replace the uprooted vines due to the financial burdens on the producers of wine since 2005. Therefore, new plantings were also unable to tolerate current rates of production. The financial pressure has not improved much if it was not for the export of wine to the overseas markets (SAWIS, 2009).

The cash expenditure, on the other hand, has remained unchanged since 2004, while labour remains the biggest section and constituted 40% of the production cost in 2013. The cost of labour compared to the total production cost is declining, regardless of wage changes during this period. This could either be due to an increase in mechanisation or improved productivity. However, mechanisation represented 20% of the expenditure, while direct cost and general expenditure amount to 17% and 19%, respectively, of cash expenditure (National Agricultural Marketing Council, 2014).

The cost factor, however, can fluctuate across several parts of production as a result of the degree of mechanisation, even though the overall cost of production does not vary dramatically from one region of production to another. There must be a balance between the areas of cost management, which include the objective of the wine style, input requirements for the vineyard, the competitiveness of the vines, as well as income improvement (Vinpro, 2016).

Higher efficiency is also vital, as it influences the cost-effectiveness threshold in the option between self-propelled and tractor-drawn wine grape harvesters. There is greater cost-effectiveness for self-propelled harvesters, with a broader area scale for smaller sections of flat vineyards than for steeper sloped vineyards. Present mechanical harvesters in the industry, ranging from very powerful and effective self-propelled versions with additional actions to trailed harvesters with reasonable procurement rates, make it easier to adapt to mechanisation. The preference amongst self-propelled and tractor-drawn automatic machines is often impacted by the vineyard and the topography of the field. In Italy, the implementation of self-propelled harvesters is more challenging than that of trailed machines in hilly areas for viticulture (Pezzi & Martelli, 2015).

In a study conducted by Hazarika (2015), the substitution of labour and the installation of machinery in agricultural properties is a common phenomenon that unlocks labour for jobs in other sectors of the economy. Mechanisation leads to higher productivity of land and labour; it prepares larger areas of land in less time compared to manual labour, and it brings about a larger output from the current land. There is also a push for labourers to move to urban areas for job opportunities because of economic growth and higher wages. Some implements and labour-saving technologies might positively affect the productivity levels of crops if adopted.

According to Goldammer (2015), a mechanical harvester for wine grapes are huge tractors that straddle grapevine trellises and remove fruit clusters from the vine. It softly separates the grapes from the stems by vibration. Once the fruit has been shaken loose, it is gathered by independently sprung ‘fishplates’ which close and open near the vine trunk. These plates are designed at an angle to divert berries to the conveyers. The grapes pass along a conveyor while the powerful hydraulic fans chew up and suck off leaves and debris. There are basically four types of mechanical harvesters, namely a multi-function harvester, a tow-behind harvester using a tractor, a dedicated self-propelled harvester and, the self-propelled unit, which is also used for operations such as hedging or spraying.

Goldammer (2015) also reported that a dedicated harvester, which was used for the study, are configured in two ways, namely when gondolas are full they transport the berries through the conveyor to the following trucks of gondolas and, secondly, they gather berries into on-board bins and offloads to trucks. The tow-behind harvesters are considerably less complicated and cost less than other dedicated harvesters but can achieve the same production as the self-propelled units. Modules for spraying, canopy management and pruning can also form part of the multi-function, self-propelled units and other practices in a reasonably short time.

1.2 Problem statement

Globally, research studies found that mechanisation in agriculture could contribute to production, limit production cost, and enhance production (Bates & Morris, 2009; Morris, 2007; Qiao, 2017; Yang, 2003; Wang et al., 2016; Zhang et al., 2018). The harvesting of wine grapes using a wine grape harvester is not a common practice in the Cape Winelands region, despite many farmers nowadays wanting to intensify mechanisation on farms.

Wine grape harvesters are one of the machines that farmers regard as useful to minimise the cost of production, but that needs to be evaluated and investigated thoroughly to determine the impact and effect. While the wine grape harvester would influence production, labour and the profit of the farm, it is questionable whether it would be practically feasible in the Cape Winelands given the variables, such as trellis systems, slopes, and soil that needs to be considered. According to Verma (2008), farm mechanisation can increase profitability and agricultural production because of timeliness of operation; it can also contribute to the quality of work done, as well as a more efficient input use. Furthermore, it could lead to a slight increase in on-farm labour, where off-farm labour (e.g., industrial production) could increase significantly.

Morris (2000) argued that mechanisation might require large capital investments and necessitates a very thorough effort from a management perspective. Thus, the technology used for mechanisation has regularly been applied long after it became frequently used by producers. The result in the enhancements in wages, health benefits, and education is due to the improvement in the conditions of migrant workers. These developments have resulted in the production costs for grapes increasing and leading to an interest in mechanisation for wine grape farmers in the United States of America to remain competitive globally. Trellising systems suited for mechanical harvesting together with other modifications are still major prerequisites for effective mechanisation of grapes.

Reid (2011) stated that there would be substantial challenges to meet the required level of agricultural productivity and world food demand by 2050. He also indicated that although agriculture has encountered significant challenges before, the industry needs to increase productivity, therefore, apply strict constraints on land and labour resources.

The effect of mechanisation could impact on labour by a more mechanised approach to wine production in the Stellenbosch and Worcester region. According to Singh (2006), mechanisation technologies keep changing with socio-economic advancement and industrial growth within a country. The unavailability of agricultural labour for field actions and the diminishing interest in agriculture can be major socio-economic problems in highly developed nations, where labour efficiency with integrity and improved land are the mechanisation criteria for developing nations. Technological developments within mechanisation are thus complex and location-specific. The land and labour productivity, as well as the quality of inputs of mechanisation may differ considerably.

Vivarelli (2012, 2013) in their research, addressed the long-term benefits and redistribution of the processes at work. Vivarelli (2013) found that the de-skilling and labour-saving consequences of capital-intensive technological developments were problematic since the Luddite revolution of the early nineteenth century. However, it also calls for consideration of a variety of insurance instruments that can alleviate these fears. The labour-saving impact of technological advancements can be offset by (i) enhanced competition for goods/services; (ii) increased revenue from redistribution; (iii) incremental jobs from the production of modern machines; (iv) additional investments made; (v) decreases in wages from price adjustments, and (vi) new products created using the latest technologies.

Many wine grape producers are continuously faced with internal and external farming factors such as increasing production costs, rising labour cost, political instability, economic constraints and technological advances, which impact the decision-making of the producers and profitability given the competitive international markets. Regions that produce wine grapes differ through rainfall, soil, climate, production systems, and topography, which place the farmer in a predicament and risk to change production techniques. This could influence the financial position of the business and the labour demand. A technique such as the mechanised harvesting of wine grapes could significantly impact the viability of the farm, and its labour usage.

The unique production regions and techniques used by wine farmers, present a unique set of topographical, practical and grape quality challenges for the use of a wine grape harvester to replace manual harvesting using labourers. The use of a wine grape harvester is controversial in relation to labour, profitability and the adoption thereof. Farmers and producers of wine grapes are using wine grape harvesters but do not seem to realise the impact thereof on labour. Also, they are uncertain of what impact it will have on profitability (e.g., would it decrease, increase or have no effect on labour use and will adopting a wine grape harvester be easier). Thus, against this background, this research is deemed necessary to determine and identify the economic factors that influence and impact labour use, including the profitability and adoption of the wine grape harvester.

1.3 Objectives of the study

The objective of the study was to investigate the economic impact of a wine grape harvester on how profitable it would be to mechanise harvesting, whether it would be economically feasible, and what impact would it have on labour demand and usage on wine grape producing farms within the Stellenbosch and Worcester regions of the Western Cape.

It was also critical and of much importance to identify the following sub-objectives, which contribute to the main aims of this research:

a) To identify and determine the factors that impact the adoption of a wine grape harvester by wine grape producers.
b) To determine and identify the economic factors that impact the profitability of using a wine grape harvester for harvesting grapes.
c) To identify and determine the factors that impact labour used for harvesting grapes.

1.4 Research question

The research aimed to answer the question whether the use of a wine grape harvester would be profitable, instead of using labourers for the activity, and what impact it will have on labour demand for harvesting grapes.

Three key questions emanated from the main research problem, namely:

- What factors will contribute to the adoption of mechanical harvesting of wine grapes?
- How will the profitability of the mechanical harvester affect the decision-making of producers?
- Which factors affect labour usage on farms that use mechanical harvesters for harvesting grapes?

1.5 Motivation of study

The South African wine sector has reached a fresh chapter on reinvestment, merging, and repositioning. Supply and demand are changing due to climate change, while financial constraints have caused the industry to force producers and wineries to reconsider their way of conducting business. Despite a rise of 11% in wine export volumes to R9.06 billion from 1 January to 31 December 2018, the numbers reflect an optimistic view of South African wine on foreign markets. Over the same period, the production fell by 6% to 420.2 million litres of wine consumed worldwide. Many farm businesses do require the volume to sustain their functions and actions, which thus necessitates the move towards premiumisation and higher prices.

Given the circumstances in the wine industry, there is undoubtedly pressure on these farm businesses, because of drops in sale volumes and smaller harvests, they, therefore, need to rethink the models and consider partnerships and mergers (State of South African Wine Industry, 2019). This study was inspired and motivated by the producer's tendency to use more machine-operated equipment to decrease the cost of labour. It is also motivated to clearly understand the impact and significance of using a mechanical harvester for harvesting grapes in place of labourers.

1.6 Hypotheses

The hypotheses are related to the objectives of this study:

a) Ho: Adoption of mechanical wine harvesters are more likely to increase in the intensive wine sector vs H1: Adoption of mechanical wine harvesters are likely to decrease in the intensive wine sector.

b) Ho: Mechanical harvesting of grapes is associated with a change in profitability and income vs H1: Mechanical harvesting of grapes is associated with a reduction in profitability and income.

c) Ho: Labour demand is lower with a more mechanised approach to the harvesting of grapes vs H1: Labour demand on farms is higher with a more mechanised approach to the harvesting of grapes.

1.7 Methodology and data use

In order to establish whether it would be feasible to adopt the mechanical harvesting of wine grapes, an evaluation had to be done to determine the factors influencing the adoption of a wine grape harvester. Primary and secondary data were used to gather information for the research. A multiple sampling technique was used to identify 91 farmers in the three local municipalities of Stellenbosch, Drakenstein, and Breede Valley (Worcester and Robertson). A data collection questionnaire was created and used for data about the producers' operational environment, socio-economic, institutional and production characteristics. Data included but were not limited to farm size, age, gender, production systems, labour use, and the method for harvesting grapes, degree of mechanisation, access to credit, advisory services, and farming income.

With the evaluation of whether the farmer would adopt a mechanised harvester for harvesting wine grapes or not, a binomial logistic regression model was used. The model is also used to classify factors that will impact labourers on the farm. A cost-benefit analysis (CBA) was used to determine if the use of a mechanical harvester for harvesting grapes would be profitable.

For the purpose of assessing the effect of the wine grape harvester on labour usage in the respective regions, primary data was used. In this study, labour and employment as the single biggest costs in agriculture will be affected by mechanisation and had to be evaluated to determine if it is going to remain the same, increase or decrease the employment in the wine industry. Primary data were collected from 91 farmers in each of the respective regions.

A structured questionnaire for primary data was used, as well as secondary data for this research. The data collected was used to determine the output per hour per hectare of the harvester, to obtain data about labour output and the cost for the wine grape harvester and the cost of labour use. Income generated from using labour and the harvester was obtained from secondary data, including man-hours and compared to that of the harvester per hectare per hour. The land–labour ratio was also determined per hectare.

1.8 Significance of the study

This research was inspired by Western Cape and South Africa's wine industry’s crucial role and contribution to the Gross Domestic Product (GDP) of South Africa. In the Western Cape economy, wine production plays a vital role and makes a significant contribution to unemployment. The wine industry is well-established in South Africa and is at risk of having a lesser impact on agriculture at large if steered in the wrong direction by advanced technologies. Therefore, the need arose to determine the impact of mechanisation and specifically the use of a wine grape harvester. Identifying and determining the factors that impact the adoption of a wine grape harvester, profitability of the farming business and labour use are of critical importance for commercial farmers, as well as emerging producers. Mechanisation is becoming more, and more of use in the modern agricultural sector, and producers need to know the effects thereof from various perspectives.

This study contributes to agricultural mechanisation literature with a specific focus on the use of a wine grape harvester by utilising an appropriate analytical methodology. The study will assist primary producers of wine grapes, cellars, agriculturalists and other producers in knowing the various factors impacting the adoption, profitability and labour of using a wine grape harvester. The findings from the study are expected to contribute towards knowledge about the advantages and disadvantages of using a wine grape harvester, as well as contextualise the impact on the socio-economic environment within agriculture. The findings will also be useful for extension officers, policymakers and government to make recommendations on sustainable agricultural production.

1.9 Outline of the study

This dissertation is organised in five chapters, including the present introductory chapter. Chapter 2 encompasses a literature review discussion that provides an overview of mechanisation and specifically the use of a mechanised wine grape harvester as a practice for harvesting grapes. It fundamentally explores various perspectives on mechanisation and more particularly, the impact thereof on labour and the profitability of mechanical harvesting. Chapter 3 will provide a systematic approach to the research design and methodology employed for analysis. It structures and provides a scientific premise for the respective models to be applied for analysing the data. In Chapter 4, the results will be presented rigorously to provide significant answers to the research question outlined in Chapter 1. It also discusses the results in a clear scientific manner to achieve the objective of the research. A summary of the findings, conclusion and recommendations will be presented in Chapter 5, which will be based on the rigorous results of the study.

CHAPTER 2
LITERATURE REVIEW

2.1 Introduction

This chapter entails a discussion about the appropriate literature on mechanisation and specifically the use of a wine grape harvester for harvesting wine grapes. Discussions and analysis of the wine grape harvester, the influence on labour and adaptability of the harvester will also be discussed. Furthermore, models for the analysis will be reviewed, namely the logistic regression model and the CBA. The CBA comprises calculating the Benefit-Cost Ratio (BCR), Net Present Value (NPV), as well as the Internal Rate of Return (IRR). Mechanisation in the wine industry seems to be complicated when looking at the external driving forces of agriculture. The wine industry, as a specialised industry within the agricultural sector, needs to adjust to the changing environments and existing economic situation. Mechanisation could contribute towards the industry at large or the industry could grow more mechanised if production methods and activities are adjusted.

2.2 Mechanisation in agriculture

Mechanisation in agriculture has always had a very comprehensive meaning. This comprehensive meaning includes utilisation, making and distribution of various tools, such as equipment and machinery for agricultural land advancement, harvesting and planting, as well as primary processing (Akinbamowo, 2013; Haruna & Junior, 2013; Mrema et al., 2014; Simalenga, 2000). The debate on agricultural processes and growth has become a conversation on the advancement of farm technology and the viability of the entire farm system (Mrema et al., 2014). There is a general consensus from the literature that mechanisation has an enormous bearing on rural landscape changes, the profitability of agriculture and on the demand and supply of farm labour. Mechanisation can be broadly described as the application of engineering technologies to improve efficiency and the work performance of labour (Schmitz & Moss, 2015). According to Emami et al. (2018), UNIDO and FAO concluded that the purpose of mechanisation in agricultural is to minimise labour use. Mechanisation allows the updating of processes for execution of operations leading to increased productivity as a move towards industrialisation, which in turn leads to increases in cultivated land, as well as the strengthening of local economic development resulting in improved livelihoods of farmers and producers (FAO, 2008 & 2010; Haruna & Junior, 2013).

In agricultural mechanisation, engineering technology is applied in agriculture, deliberately and consciously moving from subsistence to commercial agriculture, subsequently advancing agricultural output. Also, it takes into account the management and development of technologies for water control, the purpose of production, post-harvest operation, and material handling (Musa et al., 2012).

2.2.1 Challenges of agricultural mechanisation in Africa

The mechanisation of agricultural production in Africa has various challenges compared to other parts of the world. This section explores these challenges. The European Agricultural Machinery Association (2019) reported that the lack of change impacts value-adding improvement, while at the same time, a deficit occurs in the value chain as a result of inadequate funds for production. There are also inequalities in relation to where an uneven focus exists with lower-paid positions regarding gender. They also identified the lack of skills, training and management in agriculture as stumbling blocks to getting optimum yield per hectare for some areas of production. There is not adequate and sufficient storage to reduce food losses, a lack of knowledge about harvest and post-harvest activities, and the state is capacitated to direct regional, national, and international market linkages.

Narayanamoorty et al. (2014) found that faster ploughing operations in the crop seasons, scarcity of labour during peak agricultural operations, adoption of high-yielding varieties, cost-efficiency consideration due to a rise in wages, cheap credit and the availability thereof are factors that contribute to increased farm mechanisation.

2.2.2 Advantages of mechanisation in agriculture

With mechanisation, many advantages will be discussed. Advantages of mechanisation within a specific production season reduce the labour constraints when there are labour shortages. It enhances the livelihoods of farmers, advances production and lessens the physical drudgery requirement. Mechanisation can improve land productivity, enhance food security and expand the facilitation of cropping areas (Republic of Rwanda, Ministry of Agriculture and Animal Resources, 2013).

According to Chhun et al. (2015), mechanisation on farms serves as a driving force of development and transformation in agriculture. It could be contended that it is the most significant factor in reducing wage differences between the non-agriculture and agriculture industries and the improvement of farm productivity.

Ruttan (2002) also repeated this subject in his investigation on the growth of agricultural efficiency, indicating fast mechanisation in North America, while some countries in Asia and Europe revolt in the nineteenth century. However, over the last two decades, only a few developing nations have continued to mechanise their farming sectors and have moved to industrialised economies.

2.2.3 History of agricultural mechanisation and mechanical grape harvesting in Africa, Australia, United States of America and Europe

Mrema et al. (2008) reported that the use of tractors in the past in the whole of Africa could be divided into two sub-regions, namely the Southern African Customs Union nations (Swaziland, Botswana, Lesotho, South Africa, and Namibia), and the Southern Africa region, covering South Africa and Zimbabwe, which in earlier years had many settler people that influenced both the operations on the farm as well as the ownership of tractors. Furthermore, in South Africa, the industrial and large mining sector competed significantly for labour and increased tractor availability, including farm machinery, which was manufactured locally. In 1961, tractor numbers were already quite high for this region, with about 137 000 units, which were four times more than the rest of Sub-Sahara Africa. In the 1960s and 1970s, the number of tractors in use increased throughout and reached a high in the 1980s (200 000 tractors), and subsequently decreased to 111 tractors by 2000.

This was influenced by the fluctuations for units in this specific region. Large-scale producers caused the decrease and moved to advanced powered tractor units, which was the same in North America and Europe, thus requiring fewer units than before (Mrema et al., 2008). However, FAO (2008), in their study, reported that past efforts to accelerate the use of mechanisation inputs in numerous African governments and donors had produced mixed results. Africa has not had a large-scale agricultural investment in its inputs, irrigation and infrastructure, which is needed to intensify production, compared with other regions. This is partially due to Africa being fragmented into relatively small farming regions, compared to countries such as China, Brazil, and India, which on a subcontinental scale are large and capable enough to create a critical mass for investment.

Mrema et al. (2008) found that management was poorly trained and supported, while planning was very short-term, and in many cases, the state established tractor-hire structures to support small-scale farmers. Also, investment in mechanisation has been restricted to large commercial farms and government schemes. Some of these schemes failed miserably across the continent, and consequently damaged the image of agricultural mechanisation in general. According to Van Rensburg (2016), before any sort of mechanisation was developed, vineyard practices were conducted manually and with horse-drawn equipment. When the first tractors were introduced, the grapevines had to be planted farther apart for the tractors to fit between the rows. Such tractors have been replaced later with rubber-wheel and the chain-wheel tractors, which were used for soil preparation. The mechanisation of grape harvesting began in the Central Valley of California in the 1960s and led to more cost-effective harvesting of grapes for *vins ordinaires*. In this time, more expensive wines were harvested mechanically. In 1952, experimental mechanical harvesting of grapes started in California when a cutter bar and head harvester was used. However, the latter procedure was not commercially acceptable at the time.

Morris (1994) found that during the 1960s, a Cornell Grape Harvester was also used in a spindled wheel shaker, which was mastered for non-stop operation in an automated positioning over the row experimental unit. Chisholm-Ryder Corporation built a modified version of the Cornell Grape Harvester and adapted it to the first grape harvester launched commercially in 1963. In 1965, the configuration of the harvester for the Geneva Double-Curtain-trained wineries was further changed into a cross-row unit. Two other, more refined, production versions were produced for the harvest season of 1967.

Van Rensburg (2016) also reported that due to the lack of manual labour and because many new generations of harvesters are technologically advanced, automated harvesting in Europe started in the 1970s. However, only 23% of farmers in California grow their vineyards for the purpose of mechanisation. Around 80% of farmers in California's coastal area use automated harvesting compared to most farmers in the California Central Valley. Approximately 60% of Washington farmers use mechanical harvesting, while only 8% use mechanical harvesting in Oregon. Following the Second World War, mechanisation was originally adapted and used by these tractors in Australia before tractors, and horse-drawn alternatives arrived. Custom devices and instruments were later designed initially for tractors and manually harvested more than 85% of Australian wine grapes.

2.2.4 Agricultural mechanisation and mechanical grape harvesting in South Africa

A farmer's day organised in 1975 by the Institute of Enological and Viticultural Science of Nietvoorbij, which is now the Agricultural Research Council in Stellenbosch, started mechanical harvesting in South Africa in 1975. Around 700 farmers were introduced to the producers to test and show the harvesters themselves (Van Rensburg, 2016).

According to IGWS (2016), farmers are reliant on the mechanisation of their vineyard practices because of an increase in the competitiveness from other countries with labour available and the increasing labour cost to continue competitiveness in the market. In the 1960s, there was already certain mechanisation equipment available. However, the advancement of mechanisation was hindered, because of different grape varieties, labour availability, as well as training systems, and combinations thereof. Mechanisation requires an effective farm management system and large initial capital investments; therefore, the effective training of operators will determine the successful utilisation of these mechanical apparatus in the future. However, farmers, who farm with premium varieties, provided it is at a reasonable cost, prefer manual labour. National and international cost pressure will most likely advance mechanised vineyard application practices. Nonetheless, it should not adversely affect the quality of the wine.

Two types of harvesters, namely multifunctional and trailed grape harvesters, are used in South Africa:

- **Multifunctional harvesters:** Manufacturers started to design multipurpose harvesters, which can also be used for other practices, mainly to justify the large capital investment of a mechanical harvester that is only used for a short time during the year. For example, the harvesting chamber can easily be disconnected. The open zone can then be used by different equipment depending on the action, for example, disease control, pruning, and topping. Strong mechanical and hydraulic propulsion systems exist on the harvesters, which gives them the ability to be used for other practices throughout the year. However, it should be noted that harvesting grapes are the main reason why the machine was purchased. Prior to harvest, it should be ensured that the machines are in a perfect state using a timely maintenance schedule (Van Rensburg, 2016).

- **Towed grape harvesters:** Towed grape harvesters' harvesting capacity is lower but uses the same harvesting principles as that of self-propelled harvesters. In South Africa, the towed harvesters that are available use a horizontal canopy shaking action. Similar to self-propelled harvesters, the towed grape harvesters have either one or two conveyors, a conveyor arm that off-loads the grapes into a cart towed behind a tractor in the adjacent row, or with fans that remove the MOG (material other than grapes) from the grapes as well as receptacles on the machine. Sorting tables and de-stemmers are also available as new technological developments (Van Rensburg, 2016).

Manufacturers of mechanical grape harvesters are Pellenc, Nairn, Oxbo, Ero, New Holland Braud, Gregoire, and Trinova (IGWS, 2016). South Africa manufacture only about 5% of the total number of tractors, and its capacity is limited to produce implements and machinery for the agricultural sector. China and the United States of America (USA) are exporting the most considerable amount of agricultural equipment to South Africa (Esterhuizen, 2006). According to AFGRI (2009), equipment also holds South Africa's main franchise for service, part suppliers and sales of John Deere. AFGRI Agri Services is the leading agricultural service provider in South Africa and a provider of pre-owned and new mechanised equipment custom-made for the processors and producers in the agricultural sector; they also own John Deere franchises throughout Africa. To guarantee the effective management of an agricultural fleet, AFGRI Agri Services handles maintenance and services requirements on site. They also provide equipment such as Rovic and Leers, Kongskilde, Dormas, and Falcon Equipment amongst others, with a national agency agreement to provide farmers with these services.

The Institute for Grape and Wine Science [IGWS] (2016) reported that dealers of grape harvesters in South Africa had signed long-term arrangements with growers for mechanical harvesting. Longer harvesting hours are being reached because more than one operator is provided. To keep the process of harvesting uninterruptedly going, the farmer must guarantee the sufficient transport of grapes. Some producers in South Africa cooperatively buy harvesters together. In this way, they are also pooling their vehicles to carry the harvested wine grapes to their respective cellars. The partnership between the cellars and the growers allow each producer to have an equal and reasonable chance of harvesting their grapes at optimum ripeness. The training of the operator, as well as the maintenance and efficiency of the harvester determine the success of mechanical harvesting. The more experience the operator has, the more successful the mechanical harvesting of wine grapes will be.

2.3 South African wine industry

Since the 1970s, South Africa has seen a steady improvement in the application of agricultural mechanisation, with the result of job losses (Atkinson, 2007). A replacement of 70 employees per 12-hour shift is due to the use of grape harvesters (de Satge, 2010). However, in the 1990s, a rapid uptake of mechanisation took place in the wine industry, while the switchover is continuing (de Satge, 2010). Burnstein (2013) found that South African agriculture compared to the USA and Japan, is still more labour-intensive than the latter two countries.

The mechanisation of wine-producing farms in the Western Cape can only be done by large wine-grape growers as mechanical grape harvesters are costly (Visser & Ferrer, 2015). Mechanisation in the wine sector started approximately 10 years ago, roughly concurrently with minimum wage implementation for agriculture by the government. To prune vineyards with a pre-cutter is a new trend in the wine industry that reduces manual pruning. The pre-cutter operation can be carried out over 10 weeks by 15 labourers. Over the last 10 years, the sector association, known as VinPro, has not provided data on job growth or economic losses.

Visser and Ferrer (2015) also found that every province has its own employment patterns, which most likely mean that employment patterns differ depending on what the province produces in terms of agriculture, as well as the ease of mechanisation within the region. There has been an employment decline in the Free State, North West Province, and in the Western Cape and KwaZulu-Natal from 2008 to 2014, while in Limpopo it has increased. On the other hand, in provinces such as KwaZulu-Natal, Limpopo and Mpumalanga, employment increased as a result of machine and plant operators and assemblers. In contrast, it has decreased in Free State, the Northern Cape and the Western Cape. It is evident that from 2011 to 2012, the Mpumalanga and Limpopo provinces demonstrated a significant rise in on-farm job experience and a decrease in on-farm employment in the March 2013 minimum wage increase.

The wine industry in South Africa is supported by many organisations, such as the University of Stellenbosch’s Department of Viniculture, Elsenburg Agriculture College and the Nietvoorbij Viniculture and Oenological Institute, which is a pioneer in research in one of the world's most advanced wine companies (Wines of South Africa [WOSA], 2017a).

In a joint venture, the University of Stellenbosch, the Table Grape and the South African wine industries set up an Institute of Viticulture and Enology in a strategic attempt to boost their competitiveness. Freed up by independence, the wine industry in South Africa has grown substantially, and between 2005 and 2015 exports has more than doubled. There were more than 3 232 producers, and after South Africa had been liberated, the wine industry had grown stronger with the doubling of export in the mentioned period. The industry employs about 300 000 people directly and indirectly and, in 2015, had a yearly harvest of about 1 477 091, which is 1 154 million litres, where 84% went for winemaking. Approximately 1 405 401 tons (1 089 million litres), were harvested in the 2016 season, with almost 82% being used for winemaking (Wines of South Africa [WOSA], 2017a).

WOSA (2017b) reported that the amount of wine grape vineyard totals to almost 95 775 ha being under cultivation, stretching over a length of 800 km over South Africa. From the total national wine grape plantings, the red varieties cover about 44.8% of the entire vineyards, where Cabernet Sauvignon consist of approximately 11.1%, Merlot accounts for 5.8%, Pinotage, a South African variety, amounts to 7.4% and Shiraz consists of 10.4% of the total red wine grape varieties. There are about 55.5% white variety plantings, of which Chenin Blanc covers 18.6% of the total amount.

An export licence is required for all wines that are going to be exported. The Wine and Spirit Board at Nietvoorbij at Stellenbosch needs to receive samples of each batch of wine for export to overseas countries, which has undergone detailed chemical analysis, as well as tasting tests before licences can be granted. The Board verifies that the claims on the grape variety, origin, and vintage is true by providing an authorised seal to each bottle. The South African wine industry is also on the worlds' forefront in regulated production integrity and environmental sustainability. A new seal was launched in 2010 to track wine from the vine to the bottle in South Africa. It certifies the wine's sustainability and integrity and is also the worlds' first of its kind (WOSA, 2017a).

Concerning foreign wine production, the leading international wine producers per country is led by Italy with 19.1%, followed by France with 16.3%, Spain with 14.7%, and South Africa in seventh position with 3.9% (WOSA, 2017a).

WOSA (2017a) classifies wine producers in South Africa in four categories, namely:

- Previously under the original regulation estate winegrowers could make wine only from grapes that have grown on their own land, but since 2004, with a new dispensation more emphasis were placed on 'estate wine' being produced in and farmed as single units instead of the traditional 'estate'. However, to ensure that all processes are followed correctly up to the final certification, the units must consist of equipped facilities.
- Registered estates of the previous dispensation within the wine industry are automatically registered as Units for the Production of Estate Wine. They may now brand their production by using their names for the first time, but marketing and labelling can only be done for certified estate wine.
- Producer cellars, also known as the co-operatives, turn their members' grapes into wine, and they process about 80% of the total wine production of South Africa; they alone have invested vast amounts of capital in equipment for production.
- Independent cellars buy wine and grapes for bottling and branding under their name and brand, and they also make their own wine from grapes planted on their plantations.

2.3.1 Macro impact of the South African wine industry in South Africa and the Western Cape

PricewaterhouseCoopers (2015) found that increases in production, technological advances and manufacturing, including mechanisation, is making progress, especially after the labour unrest within the wine industry. Roughly 20% of cellars that produce wine grapes are considering mechanisation. It will, however, have far-reaching effects on the development of skills, retention of staff and human resource planning. Increased mechanisation would entail increased investment in the development of skills and training, thus shifting the position of current and new employees.

Top producers managed to realise that higher NFIs have resulted in expenditure reduction of 7% below average and yields of 25% above the average of the industry (Visser & Ferrer, 2015). To keep the production low, farms are notably making use of mechanisation. Labour cost is on average 5% lower than the industry average for the top 50 producers, due to their more mechanised operations. However, in the South African wine sector, the manufacturer of grape harvesters assert that the peak time for mechanisation was between 1995 and 1997, which explains why the total industry volume has been stable up to now.

According to Rabie and Marcus (2018), wine grapes are cultivated in various production regions within South Africa, with variations in production cost structures, cultivation practices, climate, as well as topography. Regarding the latter mechanisation and direct cost, including the cost of labour, it is viewed as the most considerable regional differences. The smaller harvest coupled with water scarcity and prolonged drought is also observed in the mitigated increase in mechanisation costs and general expenditure.

Table 2.1 illustrates that in addition to the Gross Domestic Product (GDP), the wine industry contributed R19 287 million to the economy of the Western Cape. This indicates that about 4.6% thereof contributed to the total GDP of the Western Cape. A substantial impact was made to the province's economy (± R33 458 million) when considering the wine industry's contribution. The total impact of the wine industry's GDP on the South African economy is R36 145 million, which is 53,4% more than the Western Province. The fiscal impact nationally is also more than double that from the Western Cape (R11 598). These figures provide an indication of the number of jobs that the wine industry supports, with 169 494 jobs in the Western Cape and 289 151 jobs in South Africa. This employment contributes about 7.5% and 2%, respectively of the overall jobs of the Western Cape and South Africa. The variations in the structures of labour and capital production intensities between the whole of the Western Cape and South Africa, explain why the percentages are higher than that of the GDP (SAWIS, 2015).

Table 2.1: Macro-economic impact of the wine industry on the South African economy

Macroeconomic Indicators	Western Cape (Rand in millions)	South Africa (Rand in millions)
Impact on GDP	19 287	36 145
Impact on capital investment	33 458	62 277
Impact on household income	11 511	23 579
Low income	2 050	3 994
Medium income	2 509	4 945
High income	6 952	14 640
Fiscal impact	4 809	11 598
National government	4 407	10 809
Provincial government	70	106
Local government	331	684
	Numbers	**Numbers**
Impact on employment	167 494	289 151
Impact on skilled employment	22 559	43 644
Impact on semi-skilled employment	49 857	84 769
Impact on unskilled employment	95 077	160 738

Source: SAWIS (2015).

In the wine industry, according to SAWIS (2015), backward ties constitute about 53% and nearly 47% of the industry's total influence in the Western Cape and the rest of South Africa. Table 2.2 presents the percentage of GDP in wine-producing and selling for the Western Cape compared to the rest of South Africa. Primary agriculture and manufacturing have the highest contribution of 66% and 72%, respectively, especially considering the rest of South Africa, which contributes 34% to primary agriculture and 28% to manufacturing. Wholesale and retail trade for the rest of South Africa (61%) is the only economic sector with a higher GDP than the Western Cape (39%). The principal explanation for the Western Cape's highest GDP in contrast to the rest of South Africa is that the Western Cape is the top producer of South African wine grapes.

Table 2.2: Total impact of different phases of the wine-producing and selling chain inside the Western Cape and outside the region (GDP)

Economic sector	Western Cape	Rest of South Africa
Primary agriculture	66%	34%
Cellars	53%	47%
Wholesale and retail trade	39%	61%
Tourism	54%	46%
Manufacturing	72%	28%
Total	53%	47%

Source: SAWIS (2015).

Table 2.3 illustrates the wine-producing and selling chain with regards to labour between the Western Cape and the rest of the country. The Western Cape has the most substantial contribution (79%) to labour compared to the rest of South Africa with 21% in terms of primary agriculture. Retail trade and wholesale are the only economic sector that has a higher contribution to labour (61%) compared to the Western Cape with 39%. The primary reason for the latter is that the rest of South Africa employs more labourers in the wholesale and retail trade than the Western Cape (SAWIS, 2015).

The impact on the Western Cape is considerably higher compared to that of South Africa as a whole in terms of labour and GDP, which is a direct indicator and demonstration of the importance of the Western Cape sector.

Table 2.3: Impact of different phases of the wine-producing and selling chain inside the Western Cape and outside the region (labour)

Economic sector	Western Cape	Rest of South Africa
Primary agriculture	79%	21%
Cellars	63%	37%
Tourism	59%	41%
Wholesale and retail trade	47%	53%
Manufacturing	72%	28%
Total	58%	42%

Source: SAWIS (2015).

2.3.2 Impact of mechanisation and the Fourth Industrial Revolution on agriculture

According to Verna (2008), mechanisation of the farm is viewed as sine-*qua-non*, meaning it is necessary to enhance agricultural productivity and reduce human drudgery. Farm mechanisation's impact on productivity and the production of agriculture during the post-green revolution period has been well recognised in India. Mechanisation has attained different levels in various states in India with the use of inputs such as chemical fertilisers, irrigation, pesticides, different high yielding seeds, and herbicides. Subsequently, four-fold increases occurred in agricultural productivity and production.

According to Yuan (2016), Africa had been the only continent worldwide since the 1960s where agriculture's production has been relatively slow. Its total cereal production in 2014 was 1.5 ton/ha, and worldwide a total of 3.6 ton/ha has been recorded. Latin America and Asian countries, on the other hand, showed that agriculture could be turned into a systematic marketing industry. Investment in machinery for agriculture has allowed farmers to increase sales, quality of life, and productivity. The rapid growth of demand for farm machinery in countries such as Turkey, China, India, and Brazil has stimulated growth in the production of local machinery.

FAO (2008) reported that Africa's agriculture, its agro-industries coupled with modernisation and development would largely depend on entrepreneurship and the transformation of policies for education. To sustain the development of Africa's agriculture needs, the key factors in driving the development should be to direct the focus to the creation of growth environments and entrepreneurship. There is also a need to develop policies for mechanisation that will inform sustainable agricultural growth, thus creating a path for commercialising farmers in Africa. Action is required, as too much time have been lost to adaptation.

Olaoye and Rotimi (2010) assert that the proper use, and the level and appropriate choice of mechanised inputs to agriculture has a substantial consequence on attainable levels of land, including labour efficiency, sustainability, environment, farm profitability, and quality of life within agriculture. Ajeigbe et al. (2010) found that mechanisation improves the capacity to generate income and efficiency of legume cereal systems in Nigeria.

The Fourth Industrial Revolution can change agriculture, as it could impact farm production positively, especially since many of the Association of South-East Asian Countries has enormous agricultural industries. The impact of linking agricultural producers to the internet has already resulted in well-documented enhancements in producer sustainability, efficiency, and profitability. The use of smartphones provides farmers with better access to knowledge about fertilisers, soil and seeds, weather forecasts, and market prices. These types of devices allow a "sharing economy," in which producers may rent mechanical equipment by using online sharing sites from other farmers. Furthermore, the Fourth Industrial Revolution could advance the traceability of products, overcome limitations of agricultural finance, and decrease the cost logistics. New technology can promote the generation of elite genetic material, as agriculture is a biological process and microbiology can be enhanced within agriculture (Menon & Fink, 2019).

2.3.3 Economic impact of mechanical harvesting on wine grapes

In Figure 2.1, and according to Domingues and Del Aguila (2016), the total cost of manual harvesting was meaningfully higher than the entire amount of mechanical harvest per hectare. However, the cost of manual harvesting was 133.3% more compared to that of mechanical harvesting. It was preliminary determined that the cost of harvesting grapes mechanically per hectare was lesser than the manual harvesting cost per hectare, while the vineyard areas of 41.92 ha validate the practice of the grape mechanics as a collective system.

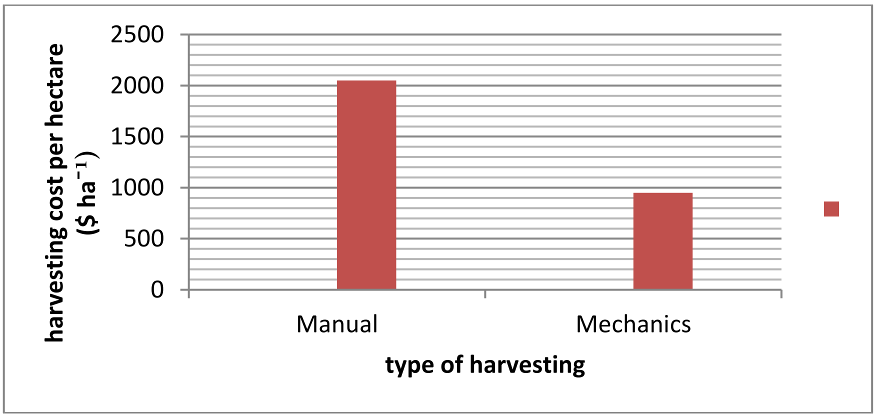

Figure 2.1: ***Cost of harvesting per hectare for harvesting grapes (manual and mechanical)***

Source: Domingues & Del Aguila (2016).

The mechanical harvesting of grapes is spreading rapidly in Italy, particularly in the central northern side where the vineyard area is projected to include between 20% and 30% of mechanisation (Corazzina, 2010). Even though it is far different from other countries in relation to the wine industries where the largest part of grapes is mechanically harvested (Clingeleffer, 2013), it indicates the progress of viticulture in Italy as they have sturdily updated the training forms, structures of farms, and organisation of vineyard work. Pruning and harvesting mechanically have been acquired due to suitable training systems that have been diffused (Gambella & Sartori, 2014; Intrieri & Poni, 2000). Bates and Morris (2009) indicated that the goal of limiting production cost is a primary feature that pushes wine producers toward mechanisation. Cost reduction, on the other hand, through the advancement of mechanised systems, and without compromising the quality of products, is best to survive the increasingly competitive market internationally (Morris, 2007; Pezzi, 2013).

Van Rensburg (2016) stated that it is very difficult to compare the cost of hand-harvest and mechanical harvesting, as there are different components to consider in both cases. Depending on the way of harvesting, costs may vary. However, various aspects of hand harvest can be mechanised, and it varies between farms, thus the cost of harvesting for every farm will be different. In Australia, machine harvesting costs were 45% of the cost of hand-harvesting in 1990 and 50% in 1991. Machine harvesting was between 70% and 79% cheaper per ton, depending on the yield per ha compared to hand-harvesting. The cost of mechanical harvesting is projected to be between 40% and 50% of the cost of hand-harvesting in California and the work of 60–70 hand-harvesting labourers are done by two to four harvester operators (Van Rensburg, 2016).

The cost-comparison of mechanical harvest and manual harvest is shown in Table 2.4. The Rand-per-ton value of mechanical harvest requires the cost of fuel and the amount of money used on labour in the case of manual harvest. The cost of mechanical harvests per ton was much higher in years with low yields, because fewer tons per hour had been harvested. The Table also indicates that for the first time in 2014, mechanical harvesting costs were less than hand harvest.

Table 2.4: Actual cost comparison between mechanical harvesting and harvesting by hand

Year	Mechanical harvesting		Harvesting by hand	
	Tons harvested	R/ton	Tons harvested	R/ton
2009	1 636	247	1 064	225
2010	700	417	602	265
2011	825	509	1 030	270
2012	634	612	826	290
2013	1 313	402	1 500	310
2014	1 840	280	1 388	330

Source: Van Rensburg (2016).

2.3.4 Cost comparison between the two types of harvesters

This evaluation is summarised in two tables, namely the self-propelled harvester and the towed-harvester. Table 2.5 illustrates that there is a distinct variance in the cost of the harvesters, where the towed harvester cost R1 600 000.00, 50% less than the self-propelled harvester (R3 200 000.00) (Van Rensburg, 2016). For the self-propelled harvester, a large amount of capital outlay is only justifiable when a large number of grapes are to be harvested. Many of the companies that sell harvesters rent it out and enter into long-term contracts with the farmers. The speed, however of the self-propelled machine is higher than that of the towed machine. Therefore, it is not always viable to purchase a machine. Farmers can lower the capital outlay on the machines by buying the harvesters together to effectively save costs.

Table 2.5: Self-propelled harvester

Purchase value	R3 200 000
Scrap value	R320 000 (10% of purchase value)
Lifetime	5 000 hours
Harvest capacity	10 tons/hour
Depreciation	(purchase value – scrap value) ÷ lifetime
Interest costs	9% of average investment ÷ hours per year
Fuel costs	Calculated at a diesel price of R13/litre
Repairs & maintenance	35% of purchase value ÷ lifetime
Fuel consumption	12 litres/hour
Insurance & licence	1% of average investment ÷ hours per year

Source: Van Rensburg (2016).

The towed harvester cost calculation, as illustrated in Table 2.6, are relatively inexpensive compared to the self-propelled harvesters. However, a tractor is needed to operate the harvester, although the tractor can also perform other production activities within the specific harvest year. A towed harvester has a minimum tractor size of 56 kW (75 hp) and needs a wider space to turn at the end of the row compared to the self-propelled harvester, thus it can also have a two- or four-wheel drive function (Van Rensburg, 2016).

Table 2.6: Towed harvester

Purchase value	R1 600 000
Scrap value	R160 000 (10% of purchase value)
Lifetime	5 000 hours
Depreciation	(purchase value – scrap value) ÷ lifetime
Tractor costs	Running costs (assuming that the tractor is already owned) calculated on 56 kW four-wheel drive at medium power
Insurance & licence:	1% of average investment ÷ hours per year
Harvest capacity	7 tons/hour
Repairs & maintenance	35% of purchase value ÷ lifetime
Interest costs	9% of average investment ÷ hours per year

Source: Van Rensburg (2016).

Table 2.7 and Table 2.8 demonstrate the cost calculation for the self-propelled and the towed harvester, respectively. The number of tons per harvester increased from 1 000 tons to 4 000 tons for the self-propelled harvester, and from 500 tons to 3 000 tons for the towed harvester. Therefore, the total costs decreased from R3 466 to R1 640 and from R1 947 to R 675 for the self-propelled and towed harvester, respectively. Depreciation, repairs and maintenance, and other variable costs are all constant for both harvesters. However, it can also be seen that as the number of tons harvested increase, there is a decrease in insurance and licences, interest costs, as well as a total fixed cost. It can thus be assumed that harvesting larger tonnage reduces variable and fixed costs (VinPro Agricultural Economic Services, 2017).

Table 2.7: Costs structure for a self-propelled harvester

Tons harvested	Annual usage	Depreciation	Insurance & licence	Interest costs	Total fixed costs	Repairs & maintenance	Fuel costs	Variable costs	Total costs
(tons)	(hours)	(R/hour)	(R/hour)	(R/hour)	(R/hour)	(R/hour)	(R/hour)	(R/hour)	(R/hour)
1 000	91	630	212	2 223	3 065	245	156	401	3 466
1 250	114	630	169	1 779	2 578	245	156	401	2 979
1 500	136	630	141	1 482	2 253	245	156	401	2 654
1 750	159	630	121	1 271	2 022	245	156	401	2 423
2 000	182	630	106	1 112	1 848	245	156	401	2 249
2 250	205	630	94	988	1 712	245	156	401	2 113
2 500	227	630	85	889	1 604	245	156	401	2 005
2 750	250	630	77	809	1 516	245	156	401	1 917
3 500	318	630	61	635	1 326	245	156	401	1 727
4 000	364	630	53	556	1 239	245	156	401	1 640

Source: VinPro Agricultural Economic Services (2017).

It is evident from Table 2.7 and Table 2.8 that the selection of a harvester must be carefully considered when determining which harvester to use. Factors to be considered in this regard include annual use, depreciation, insurance and licenses, overall fixed costs, repair and maintenance costs, the interest cost, variable costs, and total costs. The farmer also needs to consider the tons harvested and cost calculation, which need to be done in R/hour (VinPro Agricultural Economic Services, 2017).

According to Thomsen and Boen (2008), mechanical harvesters can work with a tractor or self-propelled unit; it could also include a driver's seat centred in the mechanical harvester, which moves over the vines for maximum visibility. The latest mechanical harvesters are proficient for picking around 32 metric tons per hour, for 20 hours per day during a period of 12 weeks of harvesting.

Edwards (2001), however, observed that the costs involved when purchasing the equipment are one of the disadvantages of mechanical harvesting. Factors such as higher prices for parts, new technologies, and larger machines have resulted in a rise in machinery cost. Therefore, it is important to evaluate whether investing in a mechanical wine grape harvester would be profitable or not. Thus, all costs associated with the mechanised wine grape harvester need to be determined to see if it is going to be a profitable investment.

Table 2.8: Costs structure for a towed harvester

Tons harvested	Annual usage	Depreciation	Insurance & licence	Interest costs	Total fixed costs	Repairs & maintenance	Variable costs	Total costs
500	71	303	133	1 393	1 829	118	118	1 947
750	107	303	88	929	1 320	118	118	1 438
1 000	143	303	66	697	1 066	118	118	1 184
1 250	179	303	53	557	913	118	118	1 031
1 500	214	303	44	464	812	118	118	930
1 750	250	303	38	398	739	118	118	857
2 000	286	303	33	348	685	118	118	802
2 200	314	303	30	317	650	118	118	768
2 400	343	303	28	290	621	118	118	739
3 000	429	303	22	232	557	118	118	675

Source: VinPro Agricultural Economic Services (2017).

2.3.5 Impact of mechanisation on labour

Rural labour markets and agricultural productivity have been the subject of several farm transition research on the effects of mechanisation. The Chinese scholarly community was split in the early 1950s in two opposing views on farm mechanisation (Hsu 1979). Duff (1978), as well as Johnston and Kilby (1975), disproved previous farm mechanisation studies, as most of these studies ignored their indirect effects, and also played a big part in the gains they believed had been achieved.

According to Busa and Nandi (2014), tractors, threshers, pump sets, harvester combine machines and power sprayers, are generally used in agriculture as machine power. However, mechanisation can assist labour in producing more and improving efficiency, thus it may not always replace labour. Farmers can improve their health conditions, their quality of life, and have enough time for other activities when using machines. Furthermore, it can reduce the time and cost for helping with a difficult task in agriculture, while at the same time improving the effective use of agricultural resources.

Hazarika (2015) emphasised that higher incomes, the rapid development of infrastructure, and fast economic growth are forcing farm labourers to move to urban areas or to seek alternative work opportunities. If introduced, innovations coupled with available technology to save labour may have a positive impact on crop productivity. Mechanisation, along with food crop management, may boost soil preparation and increase yields by enhancing water regulation. Production, design, and identification of mechanisation will go a long way within farming, especially for designed technologies appropriate for local crop structure and topography when considering social and environmental issues.

From the studies of Busa and Nandi (2014), as well as Hazarika (2015), both positives and negatives in employing mechanisation on farms should be considered. The positives refer to the improvement of productivity, and that labour can get more output. While mechanisation can reduce time and production cost, farmers can have enough time for other operations on the farm. However, the negative impact of mechanisation is that it can substitute manual labour (BFAP, 2012). Saayman and Middelberg (2014) assert that it can be costly to implement mechanisation as not all sectors are capable of structural changes. Studies have different perspectives on what mechanisation can bring, whether it is to the advantage or disadvantage of farmers.

When there is a labour shortage, mechanisation is essential. Labour is usually hired and denotes the same type of expenditures, as the cost of other factors within a commercially organised agricultural setup. In such circumstances, the producer may substitute mechanisation for labour if it contributes to the reduction of costs. Thus, where machinery and labour respectively reflect paid-out costs, the guiding theory would be driven by the usual logic of factor replacement based on relative costs and relative productivity (Busa & Nandi, 2014).

Singh (2006) reported that it is wrong to say that all sorts of mechanisation are unjustifiable and that it is not worth mentioning. The question, however, about unemployment and farm mechanisation, concerns tractor use, threshers, and combine harvesters. These machines reduce the unit cost of production, brings about timeliness and removes drudgery for farm operations, thus enhancing competitiveness. Therefore, countries such as China and South East and Far Asia currently using medium-size and improved low-level mechanisation should be recognised.

The South African agricultural sector is competing globally against subsidised agricultural producers, thus necessitating mechanisation. South African farmers must implement structural changes by considering moving away from labour-intensive farming (Sherry, 2013). Ramaila et al. (2011) specified that improved high-tech could lead to an increase in efficiency within agriculture. In addition, mechanisation can substitute manual labourers due to technologic advanced tractors, reducing the time it takes to harvest and cutting the cost of production (Bureau for Food and Agricultural Policy [BFAP], 2012).

However, Saayman and Middelberg (2014) state that mechanisation can be costly and not all the sectors can apply structural change implementation to the same degree, although the worth it adds to the value chain, is boundless. Therefore, producers will also measure the rise in output costs as a result of a rise in minimum wages relative to the capital costs of rearrangement processes.

A radical increase in the cost of labour is resulting in farmers not to cover operating expenditures, farmers, therefore, are looking towards alternatives, namely i) spreading risks by diversifying, ii) producing less labour-intensive alternate agricultural produce, iii) getting more, skilled workers rather than unskilled labourers and iv) mechanisation (BFAP, 2012; Hall, 2011).

BFAP (2012) reported that mechanisation should not be understood as an opportunity to increase the value added per farm worker, nor as a threat to employment. The agricultural industry in South Africa is quite comparatively labour-intensive, thus depends on physical labour that differs from the sub-sectors. With sales statistics of machine-driven implements from 2003 to 2012, a rise in mechanisation is evident with an increase from 3 200 to 7 800 units sold per year (Marketing & Media News South Africa, 2013; Sherry, 2013). The rise in these sales is due to substantial increases in the labour cost (BFAP, 2012; Marketing & Media News South Africa, 2013; Meyer, 2013; Sherry, 2013).

However, not only is a rise in income a justification for growth in prices, but it is also another contributor to the food price boom for agriculture from 2007 to 2012. During this time, agricultural product prices nearly doubled, leading to a significant rise in farmers' Net Farm Income (NFI). With these accessible surplus funds, farmers expanded investments in capital assets (Meyer, 2013).

According to the FAO (2008), most of the African countries and developing countries have an economic sector dominated by agriculture, which generates about 50% of the GDP and provides work for the majority of Africa’s people. Produce of about 40% is lost due to ineffective or poor processing and handling methods. Therefore, it pushes the need for enlargement of the sector at large at all levels and technology inputs are cited as one of the key limitations hampering the process of modernisation in agriculture within Africa.

Given the analyses of the FAO (2008) and the argument raised by Mitham (2011), the labour costs are the biggest expense, especially considering the dangers in terms of leave removing, risks of repetitive strain injuries on labourers, as well as leaving an exact number of shoots for the next season. This necessitates special individual vines attention. Employment and labour will be affected by mechanisation, specifically, the use of mechanised wine grape harvesters for harvesting. It will also be contrary to what the National Development Plan (Vision 2030) aims to achieve, namely as the prime economic rural area activity, agriculture has the potential to generate employment for around one million people by 2030 (Republic of South Africa [RSA], National Planning Commission, 2011).

2.3.6 Adoption of mechanical harvesting of grapes

Producers of high-quality wine grape cultivars conventionally used manual labour in vineyards. However, increased competitive global markets, complicated labour law, the expense of hand labour, as well as low-cost labour have caused commercial producers to seek approaches of mechanising vineyard operations. At the University of Arkansas, Fayette Ville has been conducting post-harvest work since 1966, adapting harvesters to various trellises and creating, adapting, and assessing machinery for the mechanisation of canopy management activities, such as dormant and summer pruning, removal of the leaves and shoots, and thinning of the shoots and berries (Morris, 2008).

Corazzina (2010) found that in comparison with other European countries such as Italy or France, Slovakia’s mechanised vine grape harvest is spreading at slow motion. Statistically, mechanised vine grape harvest is employed fully at a level of 20% to 30% of the total area used for vineyards in, for example, north Italy.

Due to several specific conditions, the utilisation and establishment of mechanisation in viticulture are limited. The main condition involves the selection of a suitable location for field landscaping. Also, on the areas which are characterised by a decent level of transverse slope together with the introduction of the appropriate landscaping techniques, it allows a non-problematic effort of machinery and, therefore, reduces the damage to the vines (Jobaggy & Findura, 2013; Johnson et al., 2003).

Greenspan (2007) determined the degree of adoption of mechanisation by producers and wineries and found that practices of mechanisation were more common for larger operations, which is defined to have more than 500 acres, than for the smaller ones. Greenspan accredited this trend to larger operations often producing fruit against lower price point wines, thus reducing costs substantially, while hand labour remains too time-consuming for these operations. Subsequenlty, they can make more extensive use of equipment, which easily justify investing in capital equipment.

Intrieri (2006) provided participants with insight concerning training systems and harvesters advancements in Italy. He also described work that has been done to develop training systems that are favourable for use in a mechanised vineyard and to improve and refine harvesters. Hays (2008) emphasised a necessity to shift to more mechanisation because of pressures on wine grape production, as well as mechanisation trends in Australia. He also predicted that new technologies, such as precision viticulture and nanotechnologies, including a Geographic Information System, will be merged with traditional ideas of vineyard mechanisation for broader methods to vineyard management.

Numerous studies (Da Costa Neto et al., 2017; Demalde & Spezia, 2006; Galletto & Barisan, 2007; Jobbagy et al., 2018; Pezzi & Martelli, 2015) have analysed cost-effectiveness between manual and mechanical harvesting and assessed the costs of mechanical harvest. The findings concluded that using mechanical harvesting of grapes over a certain number of hectares of corporate vineyards has an economic benefit. The limitation of the cost of production by a mechanised system without penalising the quality of the product could be a possible strategy to become more competitive globally.

According to Morris (2000), mechanised systems will permit for complete mechanisation of fully-grown grape vineyards. Vineyard activities that have been mechanised include a range of operations, for instance, dormant pruning, harvesting and summer pruning of existing vineyards. Morris (2000) also reasoned that mechanical harvesters and mechanical shoot positioners, as well as other operational devices, have been used, although no commercial systems exist for all of the 12 major trellising systems. Self-propelled harvesters can harvest over 245 acres (100 ha) in a season. Self-propelled units are usually used by grape farmers with more than 100 acres (40.5 ha). These producers custom harvesting as a side-line because of its larger capacity, while some other agribusinesses do nothing but custom grape harvesting in large, densely planted grape-producing regions (Morris, 2000).

Morris (2006) reported that an evaluation needs to be done in the research region when determining whether it would be practical to mechanically harvest wine grapes, especially regarding the vine row and alignment, vine spacing, vine height, soil conditions, vine row obstruction, and metallic debris. The total number of hectares also need to be determined to have an indication of the application per region.

2.4 Empirical methods

The different methodologies used in this study will be discussed in the following sub-sections. The discussion will start with the logistic regression model, followed by the cost-benefit analysis (NPV, BCR and IRR).

2.4.1 Logistic regression model

Part (2013) explained that the logistic regression, also known as the logit model or the logistical model, analyses the relationship between categorical dependent variables and several separate variables. The logistic regression models include the multinomial logistical regression and binary logistical regression. The binary logistic regression is used where the dependent variable is dichotomous, and the independent variables are either categorical or continuous. The study also indicated that the model could better illustrate the relative contribution of each independent variable to the dependent variable and estimate the significance of the dependent variable with the new values of the independent variables that influence the results of the other independent variables (Park, 2013).

Logistic regression determines the probability of an occurrence happening over the possibility of an incident not occurring. The result of these independent variables is regularly clarified in terms of odds. The mean of the response variable "p" of the logistic regression in terms of an explanatory variable "x" is modelled by connecting "p" and "x" through the equation $p=\alpha+\beta x$ (Park, 2013). According to Bhar (n.d.), most of the variables are quantitative within the logistic regression model, and estimation of the parameters is based on four basic assumptions. First, the dependent variable is linearly associated with the descriptive variables. Second, model errors are identically and independently distributed as a normal variable with common variance and a zero mean. Third, the descriptive variables are determined without errors, and the last assumption concerns the equal reliability of observations.

The sample size is widely considered to be associated with an estimator's precision (Claeskens et al., 2003; Mila et al., 2003). Determining large collections of data can be highly imprecise when used for logistic regression with small samples (Potter, 2005). Approximations could be prejudiced by evaluating small or medium samples (Maiti & Pradhan, 2009). The exact internal validity estimation of a quantitative logistic regression is especially troublesome for limited samples (Steyerberg et al., 2001).

Logistic models to include, for example, multinomial logistic regression and proportional odds models have extended categorical responses. They have been enhanced to consider the modelling of correlated and panel data, which include fixed and random effects, wide-ranging estimating equations, as well as mixed-effects logistic models (Hilbe, 2014).

The logistic regression model has two key focus areas, namely the probability and the odds ratio. According to Sperandei (2014), the probability ratio refers to the ratio between the number of events favourable to some outcomes and the total number of events. Odds, on the other hand, are the probability ratio: the likelihood of an occurrence favourable to a result, and the likelihood of an event against the same result. The probability is restricted between zero and one, and the odds are constrained between zero and infinity. Thus, the odds ratio is the odds ratio; a large odds ratio (OR) can represent a small probability and vice versa.

2.4.2 Empirical studies on adoption

Table 2.9 provides information about various empirical studies on adoption, of which many used the logistic regression model to analyse the data. Various authors used different approaches for measuring adoption. Vallone et al. (2019) introduced a vis NIR system to assess the berry properties in the field before mechanical harvest could be implemented. The research aimed to determine the viability of the non-destructive use of vis NIR spectroscopy on grapes cv. Jobbagy et al. (2018), on the other hand, assessed the total annual and partial unit losses, as well as the losses of grapes within a whole production area for three different varieties of grapes. Fabricio and Juan (2016) conducted the variance analysis (ANOVA), applying the Tukey comparative check with a 5% likelihood of overall manual and mechanical harvests per hectare, in an area of 41.92 hectares, as the point of equilibrium between mechanical and manual harvesting costs, over this area (41.92 hectares) is economically justified.

To determine and measure the economic and technical impact of a mechanical grape harvester on flat hill vineyards, Pezzi and Martelli (2015) used field tests, ANOVA and Statistica 10, and found that the aptitude of a cultivar and the topography of the vineyard influence the productivity of mechanical harvesters. Owombo et al. (2012) used the logistic regression, descriptive and budgetary model to determine the economic impact of agricultural mechanisation adoption. Raut et al. (2011) on their part applied the binary logistic regression model in which the outcomes showed that credit access, the distance to chemical fertiliser store and higher crop, yielded significant influences on adoption. Most of the research and studies mentioned in Table 2.9 are very applicable to this study, as they also seek to determine the factors that influence the adoption of mechanical harvesting of grapes. However, it is imperative to include other research that deals with the adoption of machines.

Table 2.9: Empirical studies on the adoption of mechanical harvesters and machines

Author/s	Objective	Method	Finding
Abbas et al. (2017)	Economic analysis of biogas adoption technology by rural farmers: The case of Faisalabad district in Pakistan.	Factors impacting adoption of biogas plants were analysed using the Logit model. Data were gathered from 160 respondents having biogas plants of 4 m3, 6 m3, 8 m3, 10 m3, 15 m3, 20 m3 and 25 m3 from villages in Faisalabad.	The study showed that the probability of a household embracing biogas technology rises with declining household head age, rising household size, rising conventional fuel prices, growing household income, and increasing cattle ownership.

Author/s	Objective	Method	Finding
Fabricio & Juan (2016)	The cost of grape mechanical harvesting is more economical than the manual harvest.	The study was carried out on viable vineyards, over four years (2013–2016), and154.9 ha were assessed on the mechanical harvesting of grapes. All costs were recorded for the mechanical harvesting of 154.9 ha as well as for the manual harvesting of 366.7 ha of grapes.	The study found that the average cost per hectare of mechanical grape harvesting was lower than the cost per hectare of manual harvesting and that vineyard areas were plausible where mechanical harvesting exceeded 41,92 hectares, justifying the use of grape mechanics.
Jobbagy et al. (2018)	Evaluation of the mechanised harvest of grapes concerning harvest losses and economic aspects.	The reflection of fixed and variable costs on vine grape harvester was evaluated as well as the non-direct costs. The annual partial unit and total costs, as well as the losses of grapes were assessed for three different selected variations of grapes for a whole production area.	The study found that a cost-effective way of mechanised harvest is attainable, thus considering increased harvest losses.
Mariano et al. (2012)	Factors influencing farmers' adoption of modern rice technologies and good management practices in the Philippines.	Poisson estimators and binary logit model have been used to classify organisational, socio-economic and environmental factors impacting approved seed and efficient crop handling.	Better production means a larger amount of income to share with their landlord for farmers-tenants. Intensive land planning, which can be done in due course by tractors, is required for the cultivation of transplanted rice.
Owombo et al. (2012)	Economic Impact of Agricultural Mechanization Adoption: Evidence from Maize Farmers in Ondo State, Nigeria.	The study used the logistic regression, the descriptive and budgetary model to analyse the data. Information on socio-economic characteristics, methods of conducting farming activities and organisational factors were collected.	It was found that education, access to machines, extension visits, equipment and age were significant determinants in mechanisation adoption through the use of the logistic regression model.
Pezzi & Martelli (2015)	Technical and economic evaluation of mechanical grape harvesting in flat hill vineyards.	They used Analysis of Variance (ANOVA), a field test and Statistica 10 for analysis. The evaluation of cost-effectiveness was done between the renting of a harvester and the purchase of a harvester by hypothesising different levels of an estimated maximum economic life of 15 years and annual use for both the trailed and self-propelled harvester.	The study revealed that the threshold of cost-effectiveness is influenced by greater productivity of flat vineyards between the two harvesters. The threshold of cost efficiency on smaller areas was reached by the self-propelled harvester, which has a greater field capacity in the flat vineyards.
Raut et al. (2011)	Determinants of Adoption and Extent of	The logistic regression model explored the special factors,	The food deficit situation, the availability of high yielding

Author/s	Objective	Method	Finding
	Agricultural Intensification in the Central Mid-hills of Nepal	organisational and socio-economic factors influencing the adoption of AI. There were two group discussions, data were collected from a survey of 310 households, and four key informant interviews took place.	varieties, the market value of the crops, access to pesticide and labour, and access to chemical fertilisers were factors that motivated households to adopt crops.
Tudisca et al. (2013)	The cost advantage of Sicilian wine farms.	The empirical study was conducted to determine the cost advantage of mechanical harvesting of grapes. Economic and technical data were collected from a Sicilian wine-producing farm while comparing rental harvesting with that of manual harvesting and farm property harvester.	The economic investigation conducted shows how the winegrowers could increase their income by implementing a mechanised harvest for both farm property and a leased grape harvester.
Vallone et al. (2017)	Acceleration Assessment During Mechanical Harvest of Grapes Using a non-Commercial Instrumented Sphere	They measured the acceleration of the plants during mechanical grape harvest with three separate trembling frequencies: 7.6, 7.9 and 8 Hz, and then calculated their effect on the key quality characteristics.	The discovery was that the amount of shaking increased as well as the accelerations and, as a result, the energy transferred from the shakers of the harvesting head to the farm.
Vallone et al. (2019)	Quality evaluation of grapes for mechanical harvest using visible near-infrared (NIR) spectroscopy	An Ordinary Least Square evaluation was used to evaluate the vis NIR prediction ability on grapes. Spectral acquisitions were rendered through the implementation of a handheld NIR system (600-1 000 nm). The predictive capabilities of a portable NIR system running in a wavelength range of 600-1000 nm were tested on white and red grapes of cv. Chardonnay and Syrah *Vitis vinifera* L. to assess berry characteristics in a non-destructive way before applying mechanical harvest.	The non-destructive technique was applied before the mechanical harvesting of grapes, which is important since it is essential to harvest at the appropriate time.
The various studies apply to the adoption of mechanical harvesters, machines and technology for the period from 2011 to 2019. There were a few studies on mechanical harvesting, where the focus was the cost of the mechanical harvesting or grapes, acceleration assessment during the mechanical harvesting of grapes and assessment of the mechanised harvest of grapes about harvest losses and economic aspects. Some of the investigations evaluated the adoption of other technologies. Most of the existing studies does not purely focus on the adoption of mechanical harvesting of grapes accept that of Fabricio and Juan (2016) and Jobbagy et al. (2018). This analysis is targeted and systematic in line with other work in this section, which uses the logistic regression model to analyse the use of technology. The data presented by the studies is also applicable because both economic and socio-economic factors are taken into account.			

Source: Author's compilation of different studies (2019).

2.4.3 Cost-benefit analysis model

The use of CBA as a model in this research was to determine the profitability of adopting the wine grape harvester for harvesting wine grapes. The following literature will be discussed with respect to CBA.

According to Hakansson (2007), in the CBA, several decision-making methods are applied that mathematically evaluate the disadvantages and advantages of the well-thought-out wine grape production system. For example, the consequences of various public decision alternatives in a typical CBA are compared. These consequences may be extremely varied but are allocated a collective metric in terms of financial value. The recommended choice is usually the one with the largest net benefit, although this neglects distributional aspects (e.g., the sum value is the decision criterion; who wins or loses does not matter).

Gains and losses occur at various times in CBA. Discounting is used to calculate the current prices for future costs and profits. Accordingly, the applicable decision-making provision in the CBA is that the current worth of the gains will be greater than or equal to the present value of the costs (Hakansson, 2007). Bumbescu and Voiculescu (2014) suggested that the cost-benefit analysis (CBA) is used as a way of evaluating (cost-benefit) expenditure programmes in agriculture, as well as the environmental and socio-cultural impacts of the initiatives. The effect must be calculated in relation to the expected goals. However, the goal of the CBA is to calculate and quantify the impacts of the venture in order to assess the relevant benefits and losses of the investment plan.

The costs and advantages are expressed in monetary and numerical terminology. CBAs use net advantages instead of overall advantages. Total benefits minus project expenses are net benefits. That allows investors to escape a "break-even" ratio, which is not deemed convincing by most decision-makers. CBA can be a tool for project evaluation to determine how far a project has accomplished its target (Buckley & Peterson, 2015).

According to Bumbescu and Voiculescu (2014), by investigating the appropriate gains and costs, the CBA has the goal of defining and quantifying the impacts of an intervention or initiative. Effects must be in line with the objectives, as well as with the economic, financial, social, and environmental circumstances. The 'incremental strategy' extends by observing the variations in the 'with project' scenario and the 'without project' scenario in terms of exposure to rewards and costs. After that, to assess if the proposal is acceptable and to define the net gains, the findings are combined and should be applied. Cost-benefit is also a decision-making method used to determine investment value.

Hirschey (2003) reports that the different criteria for decision-making could yield contradictory results, which could lead to the adoption of an undesirable project. Although the Benefit-cost Ratio (BCR), Internal Rate of Return (IRR), and Net Present Value (NPV) share a similar perspective on the current value of advantages and expenses, the option of project rejection or approval has a high degree of dependability.

The parameters for the CBA in this study will be the IRR, NPV, BCR, and a sensitivity analysis. When discounting a disparity in costs and profits, the NPV tests the competitive petition from competing ventures. The NPV is used as an integral measure of a project's desirability. In contrast, the BCR measures the cost-benefit ratio of a project and represents a relative measure of the project's desiredness. The NPV, therefore, favours large projects in terms of rankings; irrespective of project size, the BCR rankings projects the greatest benefit per cost (Beukes, 2013).

The IRR or NPV can also deliver the same outcomes if the freedom of the project remains, where a decision to refuse or approve a proposal does not hinder the decision to deny or commit to a specific proposal (College of Business Management, Pittsburgh University, 2011). The use of the IRR is favoured if only one project is measured (Beukes, 2013). However, in this research, an evaluation is done on the use of mechanical harvester, a mechanical harvester, and manual harvesting combined. Also, only manual harvesting is used as a different way of carrying out the harvesting activity on wine farms within the Western Cape Province.

According to Munda (2015), the evaluation rule or norm for a project’s economic acceptability concerning the NPV must be positive, in which a higher NPV is desirable. The IRR can be considered as the growth rate of returns that an economic project should produce, thus it is used with the meaning of an interest rate. The evaluation rule or norm is that it needs to be more than the discount rate or cost of the borrowed money. The evaluation rule for BCR of an economic project must be higher than one and a more desirable BCR for investment is one much greater than one.

The method to support the CBA for this particular study will be the NPV as it is preferred with mutually exclusive projects compared to the IRR, which evaluate individual projects. The NPV reinvest the cost of capital and is easy to calculate. Lastly, for analysing projects, it is the most used methodology in determining if the investment is worthwhile or not (Arshad, 2012).

2.4.4 Empirical studies on profitability

Various authors have used different approaches to the cost-benefit analysis (CBA) as a method and instrument to determine the profitability of an investment project. They used the method on a wide range of projects to evaluate if it will be profitable or not. The studies in Table 2.10 provide an overview of the use of the CBA on different projects. Levy et al. (2017) used the CBA to calculate the costs and advantages of an electrostatic precipitator pellet boiler over traditional biomass technology. The study showed that the pellet boiler was $190,000, powered by a better emission control system, as well as a higher cost of pellet fuel.

Grilli et al. (2017) also used the cost-benefit analysis to identify the most appropriate area for a power plant, starting with local wood resource obtainability and energy demand. In both cases, albeit with certain variations, the Net Present Value (NPV) has been proven positive. The lowest NPV existed only for the scenario with the financial flows.

Van der Bruggen et al. (2009) predicted the added impact of central softening by analysing the impacts on the drinking water industry, on the environment and their well-being, including on consumers and employment. The research showed savings to consumers that were higher than the drinking water company's expenses. Subsequently, a significant problem on the pricing of drinking water still exits. Lee (2016) made use of the CBA with economic incentive concepts of adjustment techniques and discounted benchmarks to support equitable investment choices on a biohydrogen farm. The research found that all financial indexes are commercially viable with biohydrogen, which can be successfully sold in other approved publications before the timelines.

These studies relate to the current research, based on investigating and evaluating the profitability of a project. More specifically, determining the cost and benefits provides an indication of the profitability of the project. The standard method to determine the profitability in these studies is by utilising the Cost-Benefit Analysis (CBA). The studies also indicate a positive or a negative outcome where the positive outcome suggest that the benefits exceed the cost, thus the project is profitable.

A negative outcome reveals that the costs are more than the benefits, which are an indication that the project is not profitable. Therefore, the use of the CBA is an applicable method to determine the profitability of a mechanical harvester.

Papendiek et al. (2016) conducted a cost-benefit study of three separate growth situations at two farm sizes to determine the growth of biomass from agricultural land in the federal state of Brandenburg. It was observed that the project had average productivity and that economies of scale were missing. Table 2.10 summarises the empirical studies that used the CBA as a tool for determining the profitability of investments or the comparison of two projects to determine which is the most profitable. The studies presented in Table 2.10 are applicable to this research as it shows the main mechanism for measuring profitability as the CBA; the CBA can be applied to various financial projects.

Table 2.10: Empirical studies on profitability using the cost-benefit analysis

Author/s	Objective	Method	Findings
Blumberga et al. (2015)	CBA of plasma-based technologies.	A CBA was performed for cold plasma processing for the separation of nitrogen oxides and flue gas sulphur.	The findings revealed that the use of plasma technology is not commercially feasible unless it covers both societal, environmental, and economic risks, as well as the advantages for all stakeholders participating in the project.
Cullen et al. (2008)	Economics and adoption of conservation biological control (CBC).	The CBA was used to compare 'with' and 'without' conditions to the CBC evaluation.	It was found that the CBC will theoretically offer a variety of advantages to landholders, including improved productivity, higher profits, and reduced cost of production.
Daujanov et al. (2016)	CBA of conservation agriculture implementation in Syrdarya Province of Uzbekistan.	The Cost-Benefit Analysis Model was used to determine a hypothetical scenario where the farm chooses to turn from Conservation Agriculture to traditional agriculture.	The study showed that if the advantages of Conservation Agriculture were monetised, investment in Conservation Agriculture would have favourable effects in marginal gains.
Grilli et al. (2017)	CBA with GIS: An Open Source Module for the Forest Bioenergy Sector.	For the estimation of the economic utility of a GIS the cost-benefit approach was used. In Italy, the technique was tested in the case analysis of the alpine valleys of Gesso and Vermenagna in the Piedmont region (North-West of Italy).	The NPV was found to be optimistic in all cases, albeit with some differences.
Groth and Scholtens (2016)	A comparison of CBA of biomass and natural gas CHP projects in Denmark and the Netherlands.	In evaluating the project plan in the Netherlands and Denmark, the cost-benefit approach was used.	The report showed that the cost of fuel and the price of emissions are behind the disparities. It was also found that the vulnerability of the CBA derives not just from legislative variations in countries, but also from variations in the methods used.

Author/s	Objective	Method	Findings
Lee (2016)	CBA, Levelised Cost of Energy (LCOE) and evaluation of financial feasibility of full commercialisation of biohydrogen.	The study used the CBA with economic incentives concepts, discounted indices, and adjustment techniques to back inclusive financial decisions on a biohydrogen plant investment project.	The study showed that biohydrogen is commercially sustainable for exploration and can be successfully commercialised.
Levy et al. (2017)	A CBA of a pellet boiler with electrostatic precipitator versus conventional biomass technology: A case study of an institutional boiler in Syracuse, New York.	CBA of alternative biomass technologies involves emission control technologies under study, as well as quantification of releases for each of the fuel-boiler.	The annualised average cost for the pellet boiler was $190,000 higher, resulting in a higher pellet fuel price and emission control equipment.
O'Mahoney et al. (2013)	A CBA of generating electricity from biomass.	It is believed that all farm-level prices should be included in the cost of biomass fuel supplied to the stations. The fuel savings in terms of turf and pollution mitigation are incentives to be considered.	The findings showed that while it might be theoretically feasible to reach the goal by mixing national resources with imported biomass, it is rarely the least cost alternative and, as a result, the objective of the State strategy will need to be reassessed.
Papendiek et al. (2016)	Assessing the economic profitability of fodder legume production for Green Biorefineries. A CBA to evaluate farmers profitability.	A CBA was conducted to assess the production of biomass from agricultural land in the federal state of Brandenburg (Germany) in three different growth scenarios at two farm sizes.	It was noted that there was a net productivity of the project and that there were no economies of scale.
Tangvitoontham and Chaiwat (2012)	Economic Feasibility Evaluation of Government Investment Project by Using CBA: A Case Study of Domestic Port A), Laem-Chabang Port, Chonburi Province.	To assess the worthiness of the government project, the Benefit-Cost Ratio, Net Present Value, and Economic Internal Rate of Return were used.	The findings show that the BCR was 1.27, the project's NPV was 618.705, and the EIRR was 16.81%. Tests suggest, however, that the Domestic Port A is worth investing in.
Van der Bruggen et al. (2009)	CBA of central softening for production of drinking water.	A CBA was used to quantify the added benefit of central softening by researching the effect on the drinking water business, safety, the economy, consumers, and unemployment.	Larger systems were found to have a lower cost per m^3 of saturated water. However, despite the size of the installation, the running expense would presumably not change as much.

Author/s	Objective	Method	Findings
The various studies in this particular table use the CBA as a methodology in calculating the profitability of a venture. The CBA can take many forms, but the most commonly used approach is the incorporation of the Benefit-Cost Ratio (BCR), Internal Rate of Return (IRR), and Net Present Value (NPV). Regarding the studies in this table, this research are investigating the profitability of an investment, where this study attempt to evaluate the profitability of a mechanical harvester for harvesting grapes. The methodology and data use are also in line with the above studies, where mostly financial aspects are being used to determine whether the mechanical harvesting of grapes would be profitable or not.			

Source: Author compilation of different studies (2019).

2.4.5 Empirical studies of the impact of mechanisation and technologies on labour

According to Ugur and Mitra (2017), the effect of technology implementation is employment-oriented, which can be seen more clearly when the implementation of technology favours product innovation. Adoption of technology is also less likely to be related to job development if the evidence refers to low-income nations and not low-mixed or middle-income countries, and (ii) if the proof relates to farm employment rather than jobs within a firm/industry.

The majority of evolving technologies are connected to a decrease in routine manual tasks, non-routine interactive, and routine cognitive tasks, while these new technologies increase in non-routine analytic tasks (Atalay et al., 2018). The socio-economic implications as a result of large-scale agricultural ventures, in general, have been extensively discussed in recent years. The degree of welfare benefits provided by major farm investments for the resident communities is, however, still challenged. Some warn that major farm investments pose a danger to the well-being of rural communities, although others indicate that this could be a significant catalyst for change in the neglected rural areas (Nolte & Ostermeier, 2017).

The sectoral analyses indicate that positive job impacts are only meaningful in the large and medium-sized industries but insignificant in the low tech industries (Van Roy et al., 2018). Djanibekov and Gaur (2018) reported that households are increasing their household energy usage patterns through the use of solar panels and that the use thereof is subject to the state subsidies for domestic and agricultural panels of 50% to 80%.

The empirical work has shown that innovation and investment practices negatively impact job development within energy-intensive industries after taking the position of the sectoral growth in production (Costantini et al., 2018). Many new technologies are correlated with decreased repetitive manual activities, non-routine multimedia actions, and repetitive cognitive tasks, whereas these new technologies boost non-routine analytical tasks (Atalay et al., 2018).

Table 2.11 provides a summary of empirical research done on the impact of technology on labour. There is a range of studies that indicate the effect of technology on labour, as conducted by Nin-Pratt and McBride (2014), who applied the descriptive investigation collectively with the empirical evaluation of the economic productivity of agriculture in diverse production methods, as well as agro-ecologies. They also revealed that the cost of labour still plays a key role in Ghanaian agricultural progress in controlling the adoption of labour-intensive machinery, even in moderately dense populated zones.

Busa and Nandi (2014) applied the Stochastic Frontier Production Function analysis to investigate the reasonableness of the use of labour in paddy production across states based on plot-level data under the Cost of Cultivation Scheme during 2009/2010. The study showed that there was no rational use of human labour in Indian agriculture. Djanibekov and Gaur (2018) explored two types of households distinguished by their socio-economic features and that are related through agricultural contracts, and the model used for the assessment was an agricultural household dynamic programming model. Households showed an improvement of energy consumption habits by using solar panels, even though the acceptance of these technical developments is conditional on state incentives of 50% to 80% for the purchase of solar panels for domestic to farm sector purposes.

Adu-Baffour et al. (2019) examined the impact on growers who obtain tractor services from the agricultural equipment producer John Deere to endorse smallholder mechanisation in Zambia; they utilised the Propensity Score Matching as an evaluation tool. The findings revealed that due to a move from family labour and land expansion, the demand for hired labour increased. Rotz et al. (2019) used labour-saving equipment and mechanisation as the core mechanisms of digital farming to organise the investigation. They focused on drones, mobile phones, sensors, robotics and precision-technologies, as opposed to transparency and communication technologies such as radio-frequency identification chips. The study showed that new technology advances extend both spatial and labour marginalisation, and it also intensifies exploitation.

Nolte and Ostermeier (2017) identified numerous scenarios based on crucial factors of the direct employment creation potential of Large-Scale Agricultural Investments (LSAIs), which included the production model, crop type, and the former land use; they developed a transition matrix to conduct the evaluation. The study revealed that adoption of technology on employment would be optimistic when the evidence is associated with the innovation of the product and skilled labour employment. Contrary to the latter, when the data related to unskilled-labour employment, the effect was negative. Many of the mentioned studies are applicable to the current research as researchers determined the impact of technology on labour, while at the same time identifying factors that influence labour in a given sector.

Table 2.11: Empirical studies on the impact of technology on labour

Author/s	Objective	Method	Finding
Adu-Baffour et al. (2019)	Can small farms benefit from big companies' initiatives to promote mechanisation in Africa? A case study from Zambia.	The research focuses on the impact of this programme on small-scale farmers providing tractor services using Propensity Score Matching.	The study showed that by farming greater sections of their land, farmers would double their profits. It also turned out that the job market expanded because of the transition from family to hired jobs.
Busa & Nandi (2014)	Examines the effective and efficient use of labour in Indian agriculture in the context of farm mechanisation.	The Stochastic Frontier Production Function analysis was applied to explore the reasonableness of the use of labour in paddy production across states founded on plot-level data under the Cost of Cultivation Scheme during 2009/2010.	The study found that in Indian agriculture, there was no fair use of human labour.
Djanibekov & Gaur (2018)	Analyses the nexus issues of energy use, agricultural production, income and employment among heterogeneous and interdependent rural households in Uttar Pradesh, India.	The model used for the evaluation was a dynamic model of household agricultural programming. It investigated two types of households differentiated by their socio-economic qualities and linked through agricultural contracts.	It was established that households improve energy usage by using solar panels, although technology advances are conditional on the state subsidies of 50% and 80% to acquire solar panels, respectively for domestic and agricultural purposes.
Fung (2006)	Are labour-saving technologies lowering employment in the banking industry?	The ordinary least square, with four distinct requirements, approximate labour demand.	The results of this study found that the spill-over of labour-saving technology is followed by higher firm-level jobs.

Author/s	Objective	Method	Finding
Nin-Pratt & McBride (2014)	Agricultural intensification in Ghana: Evaluating the optimist's case for a Green Revolution.	Through empirical assessment combined with descriptive analysis, the economic productivity of agriculture in various agro-ecologies and production systems were assessed.	The study showed that labour costs in Ghana also play a key role in agricultural production in restricting the implementation of labour-intensive technological developments, particularly in less densely populated regions.
Nolte & Ostermeier (2017)	Conceptually understand what effects the establishment of a large-scale farm has on the rural labour market in low- and middle-income countries.	A transition matrix was used to classify many possibilities focused on essential factors in the prospects for direct employment in large-scale agricultural investments.	The study concluded in the evaluation that large-scale agricultural investments hugely crowd out small-scale producers, which is marginally mitigated by the planting and execution of contract cultivation systems with concentrated labour crops.
Reddy et al. (2014)	The paper test the hypothesis that there are significant changes in the labour use, farm mechanisation and labour productivity across the states and crops by using the data collected from the comprehensive cost of cultivation scheme for the period 1997 to 2010.	Government of India's cost of cultivation data was used to assess indices of labour productivity, the use of labour, changes in crop profitability as well as the cost of labour.	The study results indicate that there has been a strong correlation between family labour movement, farm mechanisation and increased casualisation of labour, and it has been observed in many states and crops.
Rotz et al. (2019)	Automated pastures and the digital divide: How agricultural technologies are shaping labour and rural communities.	The research used labour-saving equipment and mechanisation as the key element of digital farming to organise the analysis. They focused on drones, mobile phones, sensors, robotics and precision-technologies, as opposed to transparency and communication technologies such as radio-frequency identification chips.	The study showed that new technology advances extend both spatial and labour marginalisation, and it also intensifies exploitation.
Ugur & Mitra (2017)	Technology Adoption and Employment in Less Developed Countries: A Mixed-Method Systematic Review.	The mixed-method combines the power of description synthesis with that of meta-regression analytic evidence to synthesise qualitative data that provides a quantitative overview of comparable effect figures in consideration of selection bias effects.	Both the description synthesis and the findings of the meta-analysis indicate that the effect of technological adoption on jobs appears to be favourable where the data is applied to professional software creation and work. Contrary, as figures refer to unskilled labour, the effect is negative.

Author/s	Objective	Method	Finding
White et al. (2005)	Technology adoption by resource-poor farmers considering the implications of peak-season labour costs: Peruvian Amazon	The research developed a substitutive method, known as the return to opportunity-costed labour (RTOCL), which defines seasonal-changing labour costs.	The results have shown that the early maturity trait helps rice to become more conducive to the peak-season labour requirements. It was also noted that there was a need to tackle heterogeneous seasonal labour demands.
Studies presented in this table evaluate the impact of labour by employing various technologies within agriculture. The studies assess how labour will be affected when technological changes are implemented on within agriculture, communities and organisations. Various methodologies are used to determine the impact on labour, although the methodology employed in this study will be the Logistic Regression model to determine the effect on labour. The Logistic Regression model is the suitable model in this particular study and is applicable to determine how labour in agriculture will be affected. Data gathered in this study is similar to some of the studies presented in the table, where cost, socio-economic factors, as well as descriptive analysis are taken into account within the evaluation.			

Source: Author's compilation of different studies (2019).

2.5 Summary

This chapter presented an overview of relevant literature on mechanisation and the use of a wine grape harvester for harvesting wine grapes. It provided insight into how mechanical harvesting of grapes as a production activity on farms affect labour, efficiency, adoption, and profit of the farming business. The chapter also presented the theories of mechanisation agriculture, more particularly, how it evolved over the years, including its impact and influence within the agricultural sector. It can be observed that agricultural mechanisation is gradually moving from subsistence to commercial agriculture and to advance agricultural output, faster ploughing operations in the crop seasons, scarcity of labour during peak agricultural operations, adoption of high-yielding varieties. It is also the driving force of development and transformation in agriculture and can improve farm productivity. However, mechanisation's impact on agriculture negatively influences labour, as the intensification of mechanisation could decrease labour operations, and subsequently, lead to a reduction of labourers on the farm. Furthermore, the chapter provided a framework and overview on how the wine sector of South Africa is structured, allowing for an understanding of the macro influence of the industry and more critically highlighting the economic impact of the use of a mechanical harvester for harvesting grapes within the industry. The empirical studies concluded that there is an economic benefit in employing mechanical harvesting of grapes over a certain amount of hectares for commercial vineyards.

Section 2.4 discussed a wide variety of theories on the methodological framework of the study. From the theories on empirical models, it is clear that the models discussed are very applicable to the study's questions and to address the objectives of the research. The models referred to are the logistic regression model and the cost-benefit analysis.

The next chapter will explore the background of the methodological framework and the actual procedure for the research analysis.

CHAPTER 3

RESEARCH DESIGN AND METHODOLOGY

3.1 Introduction

The previous chapter presented a detailed discussion about the literature to emphasise what this study aims to achieve. This chapter aims to contextualise and understand the research design, the collection of data, and explore the methodologies. The research area mentioned, which is the Western Cape's Winelands, where the study was conducted, are also described. The following section addresses the research methodology and the context for the conduct of the study. The last section in this chapter provides further clarification of the methods used for this particular study.

3.2 Study area

The land area in the Western Cape province amounts to 12 938 600 ha and is the fourth largest province in South Africa as a whole. The area consists of 2 454 788 ha (19%) potentially arable land, 730 731 ha (5.6%) nature conservation, forestry being 198 938 ha (1.5%), 9 105 821 ha (70.4%) grazing, with farmland of 11 560 609 ha (89.3%), and 448 322 (3.5%) other (Department of Agriculture, Forestry and Fisheries [DAFF] 2014); Statistics South Africa [StatsSA], 2012).

The Western Cape has five district municipalities, namely Eden, Overberg, Cape Winelands, West Coast and Central Karoo, as well as the Cape Metropolitan, which is the only metropole located in the province (see Figure 3.1) (Western Cape Government, 2014).

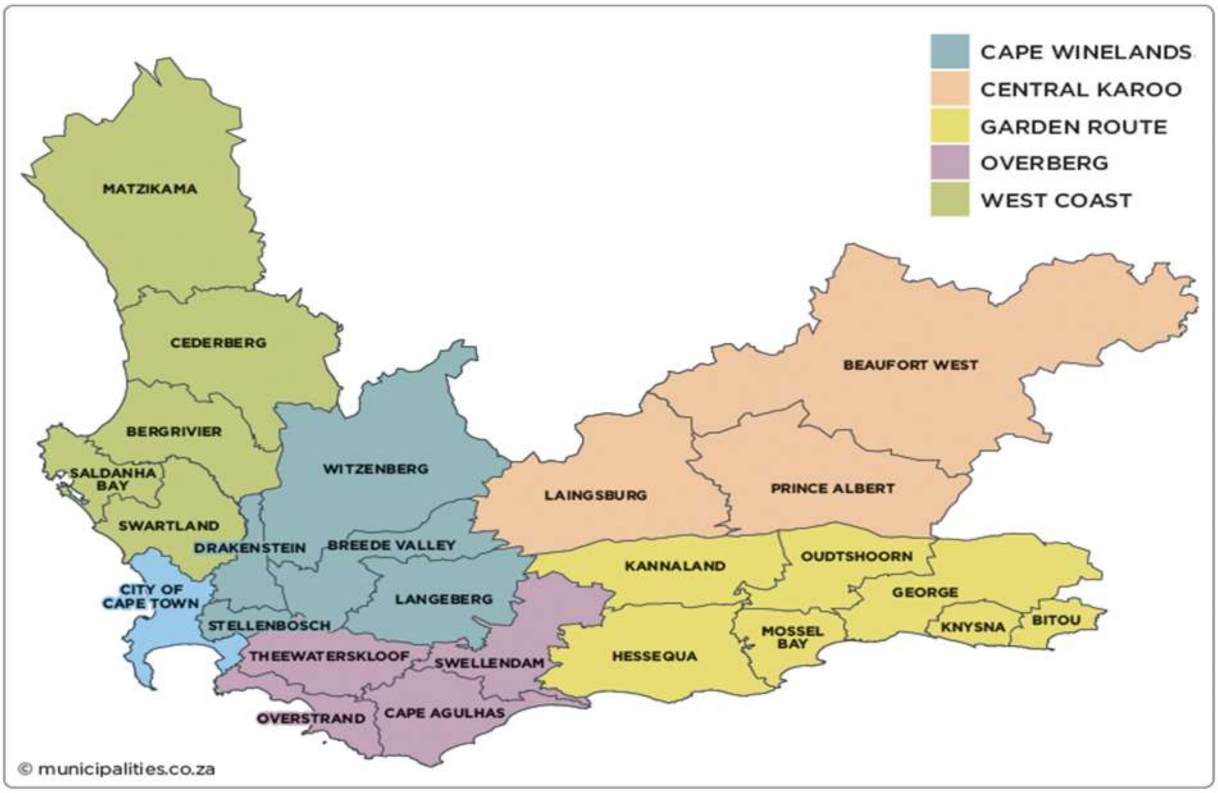

Figure 3.1: District and local municipalities in the Western Cape province.

Source: Municipalities of South Africa (2020).

Figure 3.2 indicates that the Cape Winelands district encloses 22 309 km² and is located next to the Cape Metropolitan. It is an interior to the Overberg and the West Coast coastal regions. The Cape Winelands consist of five local municipalities, namely Stellenbosch, Breede Valley, Witzenberg, Drakenstein, and Langeberg municipalities. The area has a relatively high and varied level of growth and is one of South Africa's sort after rural and small-town sub-regions (Cape Winelands District Municipality, 2017).

The research was conducted in the Cape Winelands, the largest wine-producing region in the Western Cape and South Africa. Many of the wine producers, wine cellars and producer cellars are found in the Cape Wineland region. About 74% of all private wine cellars are situated in the Cape Wineland district, thus ideal for conducting research. The producer cellars for this district amount to about 75% from all wine-producing areas.

Also, the data and information gathered are relevant, given the external factors that influence wine production in the area. The latter provide reasons why this area is applicable.

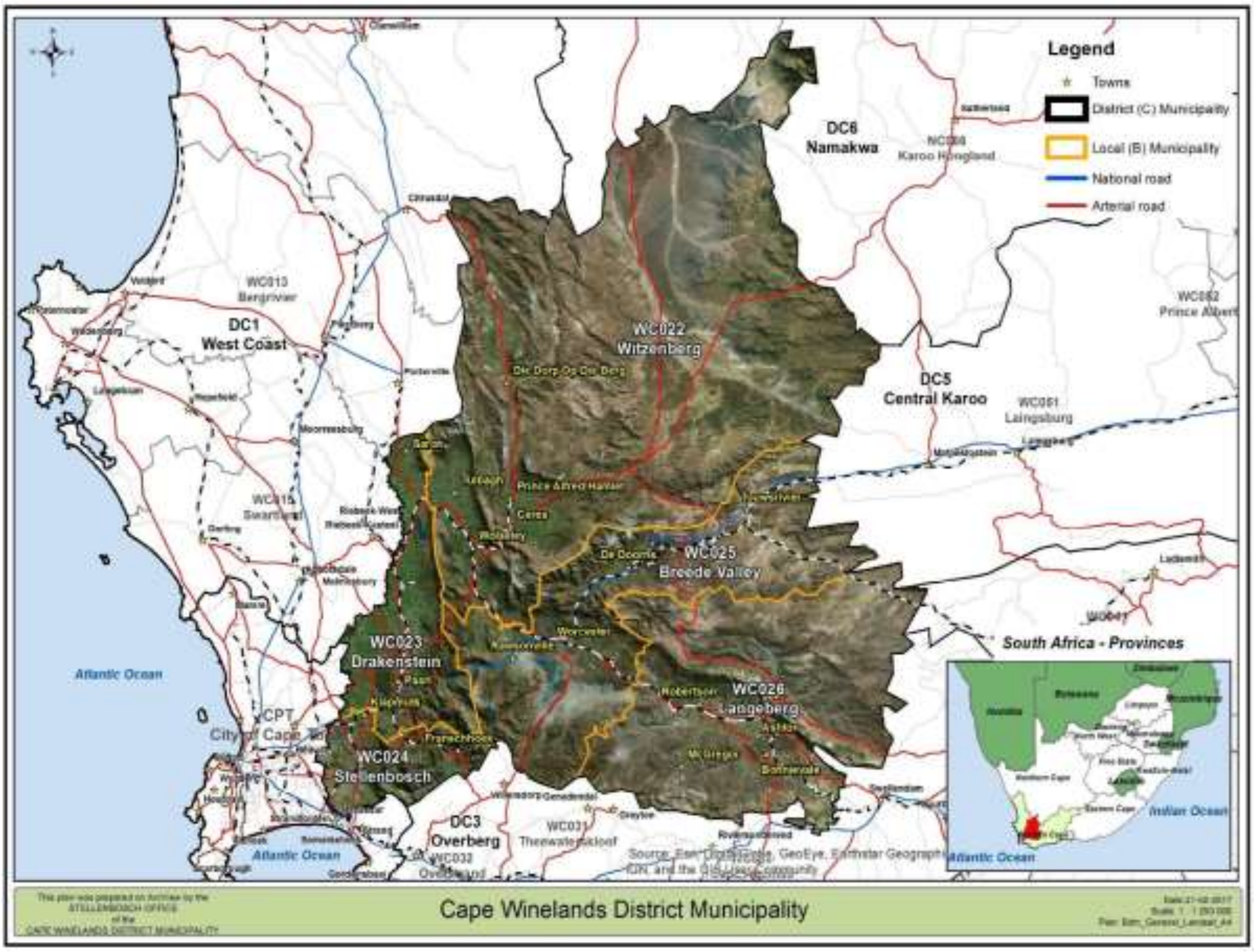

Figure 3.2: District and local municipalities in the Western Cape Province

Source: Western Cape Government (2014).

Table 3.1 illustrates the comparison between the producer and private cellars within South Africa. Stellenbosch and Drakenstein (Paarl) have the largest amount of private cellars with 172 and 120, respectively, followed by Robertson and the Klein Karoo. Breedekloof and Robertson, on the other hand, has the largest number of producer cellars with 11 and 9, respectively. It should be noted that for the purpose of this study, the three local municipalities will consist of Stellenbosch, Drakenstein (Paarl), and Breede Valley (Worcester and Robertson). Stellenbosch and Paarl have the largest number of private cellars due to the history of the Cape Winelands region; production dates back to the 1600s.

Table 3.1: Number of producers and private wine cellars in 2016

Producer cellars	2016	Private wine cellars	2016
Northern Cape	3	Northern Cape	14
Olifants River	3	Olifants River	12
Swartland	2	Swartland	31
Klein Karoo	4	Klein Karoo	22
Paarl	6	Paarl	120
Robertson	9	Robertson	43
Stellenbosch	2	Stellenbosch	172
Worcester	8	Worcester	13
Breedekloof	11	Breedekloof	19
Cape South Coast		Cape South Coast	47
Total	**48**	**Total**	**493**

Source: SAWIS (2016).

3.3 Research approach and design

3.3.1 The sampling technique

The multi-stage sampling technique was used in this study. This technique utilises a process where sample selection is conducted from increasing smaller samples of the study population (Barreiro & Albandoz, 2001; Whittemore, 1997). According to Sedgwick (2015), the multi-stage sampling technique considers two or more stages of random sampling based on a hierarchical structure. Different clusters (e.g., wards, schools or households) are randomly sampled at each stage, and in the final stage, a random sample of participants are selected. The first stage consisted of a purposive selection of the Cape Winelands as the region within the Western Cape where the study was conducted. The second stage comprised of selecting three districts, which included Stellenbosch, Drakenstein, and Breedevalley local municipalities. During the third stage, the selection of the specific farms around these three towns was done. The breakdown of the population is illustrated in Table 3.2, which included both private and producer cellars, with the sample size being identified from the respective towns and surrounding areas that produce wine grapes.

3.3.2 Research approach

Williams (2007) reported that three mutual methods exist to conduct research or studies, namely mixed-methods, qualitative, and quantitative methodologies. The person conducting the analysis forecasts the form of data expected to react to the research query. For example, whether textural, numerical, or both will be needed for the data. Based on the evaluation, the researcher selects one of the three methods listed above to conduct the research further. Researchers typically select a mixed-methods methodology for research questions needing both textual and numerical data. They select the quantitative method to respond to research questions necessitating numerical data, and the qualitative approach for research questions needing textural data. For the objective of this particular investigation, a mixed-method research approach was applied to analyse the data. According to Creswell et al. (2011), as cited by Wium and Louw (2018), mixed-methods studies analyse and collect data, draw inferences and integrate the findings using both qualitative and quantitative methods in a single study.

3.3.3 Research design

A questionnaire was developed and completed with the producers of the Worcester/Robertson, Stellenbosch and Paarl regions (Appendix A). Table 3.2 displays the data on the number of private cellars for the respective local municipalities (SAWIS, 2016). According to SAWIS (2016), there were 48 producer cellars and 493 private cellars in South Africa. For this research, only private cellars were approached, and the data collected from Stellenbosch only; Drakenstein (Paarl) and Breede Valley (Robertson and Worcester) consist of 348 private cellars.

The design of this research provides a scientific understanding and reason for data collection to clarify the initial objectives and questions of the investigation. The approach for this research design was both quantitative and qualitative data as a means of analysis for determining the objectives. Information was gathered from both primary and secondary sources to determine the aims of this study.

Table 3.2: Number of private wine cellars for the Cape Wineland's region

Local Municipality	Region	Number of private wine cellars	Number of sample
Stellenbosch	Stellenbosch	172	39
Drakenstein	Paarl	120	30
Breede Valley	Worcester and Robertson (combined)	56	22
Total		**348**	**91**

Source: Compiled from SAWIS (2016).

The sample size of 91 private wine grape producers totalled the number of respondents who agreed to participate in the questionnaire.

3.3.4 Data collection

The questionnaire consisted of closed and open-ended questions; it was prepared and pre-tested to ensure validity. The researcher sent the survey to the respondents between October 2018 and February 2019. Primary data collection is critical in determining a study's objectives. The questions of the survey were guided and adopted from similar research already completed (Mamman, 2015; Rahman et al., 2011; Raut et al., 2011).

Detailed information was collected from the producers, for example, information about their operational environment, socio-economic situation, institutional and production conditions (Appendix A). Secondary data were used to determine and identify the factors that impact the profitability of a wine grape harvester. This information was gathered from the South African Wine Industry Information System and VinPro; the key role players in the sector that supply data information and knowledge of the wine industry.

3.4 Conceptual framework for mechanical grape harvesting

The harvesting of grapes using a machine is becoming gradually important for the production of wine grapes in wine-producing regions. There are three aspects that form part of this conceptual framework: (i) The factors that affect the adoption of mechanical harvesting; (ii) the economic evaluation to determine if mechanical harvesting would be profitable; and (iii) the impact of mechanical harvesting on labour. The objective for introducing mechanised vine grape harvesting is to reduce annual cost and lower the need of manual labour, although the initial costs required to introduce mechanised harvesting are quite high (Bates & Morris, 2009; Jobbagy & Findura, 2013; Pezzi & Martelli, 2015).

Conventionally the harvesting of grapes was done completely by hand, starting from the early 1970s, but gradually extended to the harvesting of grapes through mechanical harvesting. Nowadays it is becoming evident that this method is a practice more diffused in the world of wine grape production; supported by the lower costs compared with hand-harvest, product quality is not compromised (Galletto & Barisan, 2007; Pezzi & Martelli, 2015).

Furthermore, according to Tangvitoontham and Chaiwat (2012), the Cost-benefit analysis (CBA) is an economic evaluation tool that can be used to decide whether a project is worth following or not. In order to assess the disadvantages of the alternatives, the study offers the costs and benefits of various situations. The cost-benefit study illustrates the net effect of a proposal on public well-being. Under this philosophical context, the CBA was used to determine whether or not it would be necessary to employ a mechanical harvester. There were three forms of appraisal: net present value (NPV), benefits-cost ratio (BCR), and internal rate of return (IRR). The assessment requirements comprised these three forms.

McGowan and Vasilakis (2019) reported that technological advances that increase crop productivity impact a less urbanised economy as economic activity shifts from the service and manufacturing sectors to agriculture. The implications are widely defined and driven by technical developments that raise the need for agricultural labour. Rotz et al. (2019), on the other hand, found that new technological advances increase exploitation and expand both spatial, as well as labour marginalisation. Ugur and Mitra (2017) stated that technology acceptance is more likely to have a beneficial impact on jobs where data is linked to product growth and the jobs of skilled employees. Contrary to the latter, the result is negative when the data relate to unskilled jobs.

Mechanical harvesting of grapes is a critical aspect on wine-producing farms in the Western Cape, and given the technological advances in agriculture, it necessitates a research perspective to determine the economics of such activity on these wine farms. Therefore, the research’s objective is to investigate the economic effect of mechanised harvesting technology on grape-producing farms.

Figure 3.3 illustrates four factors, namely high input cost, changes in production methods, technological advancements, and high labour cost; all contributing to the adoption of technology. The latter factors contribute to the adoption of mechanical harvesting of grapes on wine-producing farms. However, an evaluation is required to determine whether mechanical harvesting would be profitable or not. Employing mechanical harvesting can result in it either increasing or decreasing labour on farms. Therefore, this conceptual framework was adopted from Kumari and Patil (2017).

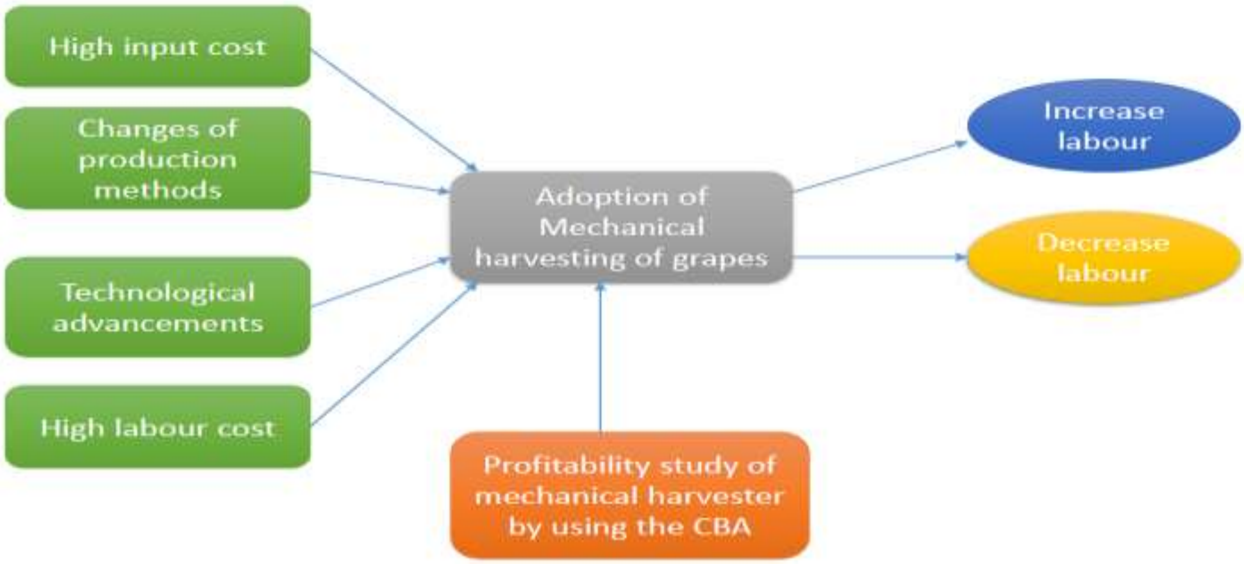

Figure 3.3: ***A conceptual framework for technology adoption.***

Source: Adopted from Kumari & Patil (2017).

3.5 Empirical models

The Logistic Regression model was initially identified to determine the factors that influence the adoption of the wine grape harvester, as well as the impact on labour. This study utilised binomial logistic regression for the analysis, although an explanation follows regarding the difference between the logistic regression and binomial logistic regression. Often referred to as the logistic model, logical regression analyses the relationship between several independent variables and a categorically dependent variable; it estimates the likelihood of event occurrence by fitting data in a logistical curve, thus two models exist, namely binary and multinomial logistic regression (Park, 2013).

According to Sweet and Martin (2011), the binomial logistic regression, which is the same as binary logistic regression analysis (BLRA), analyses the relation of a single binary response variable and multiple explanatory variables, thus a categorical variable of two categories. Hair et al. (2010) stated that the BLRA reflects a special case of linear regression analysis (LRA) used when the answer is not continuous in binary form, and the explanatory variables are quantitative or qualitative. The latter literature provides the basis for using the binomial regression model, therefore, an extensive theoretical background, as discussed in the literature review, was required. The binomial regression model provided a more focused method to analyse the data, and to identify and assess the influence of variables on the adoption of mechanical harvesting, as well as the mechanisation's impact on labour use. Thus the binomial logistic regression model proved more significant compared to the logistic regression model. The reason being that potential variables that were carefully selected from an extensive comparative non-parametric (Chi-square) analysis were well associated with the division of the respondent. The binomial logistic regression analysis was set up to investigate key potential variables associated with mechanical harvest adoption. These variables include: the average yield of grapes (AYG) in tons per year, Net Farm Income (NFI) measure, the average labour output (tons) for harvesting grapes in an hour on the farm (ALOh), number of hectares used for the production of wine grapes (NHecp), number of permanent labourers on the farm (NPerL), and permanent labour change (LLp (1)).

The binomial regression analysis was also used to investigate whether a farm will use less seasonal labourers because of mechanical harvesting of grapes. The strongest associated variables that were identified by means of an extensive comparative non-parametric (chi-square) analysis of how well individual variables were associated with the division of the respondent and used in the regression analysis: the number of hectares used for the production of wine grapes (Nhecp), the absolute number of seasonal labourers used on the farm during the year (NSL), farmer's age (FA), and the average labour output (tons) for harvesting grapes in an hour on the farm (ALOh).

The CBA was conducted to assess the profitability of the project by drawing a comparison between the mechanical harvesting of grapes and using only labour for harvesting grapes. The costs and the benefits associated were determined by using two different grape harvesters, namely the self-propelled harvester and the trailed harvester in the three distinct regions. The lifetime of the project is over five years, corresponding for each of the regions by using the different harvesters.

3.5.1 Determining the factors that impact adoption of mechanical harvesting and labour of wine-producing farms in the Western Cape

The binomial logistic regression model was employed to determine the factors that impact the adoption of mechanical harvesting of grapes, as well as labour. Owombo et al. (2012) used the logistic regression model, and the adoption function is specified as:

$$MH = f(\beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + \beta_8 X_8 + \beta_9 X_9 + \beta_{10} X_{10} + \beta_{11} X_{11} + \beta_{12} X_{12} + \beta_{13} X_{13} + \beta_{14} X_{14} + \beta_{15} X_{15} + \beta_{16} X_{16} + \beta_{17} X_{17} + \beta_{18} X_{18} \ldots\ldots 3.1$$

Where:

MH = adoption status measured as a dummy (MH_0 = non-adopters; MH_1 = adopters).

X = represents the independent variables.

FA = X1 = age of farmer, *Gend* = X2 = gender, *EduF* = X3 = educational level of farmer, *Exp* = X4 = farming experience in years, *NPerL* = X5 = permanent labourers, *NSL* = X6 = seasonal labourers, *SourIn* = X7 = source of income, *NHec* = X8 = number of hectares under wine grapes, *AYG* = X9 = average yield per year, *NFIL* = X10 = average farming income, *NFIM* = X11 = average net farming income (NFI) using labourers for harvesting,

NFILM = X12 = average NFI using a mechanical grape harvester, *AccCr* X13 = access to credit, *AdSer* = X14 = advisory service, *MarkPl* = X15 = distance to market, *STS* = X16 = suitable trellis system, *IdealT* = X17 = ideal topography, *AccMec* = X18 = access to mechanical grape harvester.

B0 = Coefficient of the constant term.

B1–B10 = Coefficients of the independent variables.

The following logistic regression was used to determine the factors impacting adoption:

MH = B0 + B1FA + B2Gend + B3EduF + B4Exp + B5NPerL + B6NSL + B7SourIn + B8NHec + B9AYG + B10NFIL + B11NFIM + B12NFILM + B13AccCr + B14AdSer + B15MarkPl + B16STS + B17IdealT + B18AccMec……………………………………………………(3.2)

The following logistic regression was used to determine the factors impacting seasonal and permanent labour:

$$LLp/s = f(\beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + \beta_8 X_8 + \beta_9 X_9 + \beta_{10} X_{10} + \beta_{11} X_{11} + \beta_{12} X_{12} + \beta_{13} X_{13} + \beta_{14} X_{14} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3.3)$$

Where:

LLp_0 / LLs_0 = Permanent status measured as a dummy (LLp_0 = decrease in permanent labour / LLs_0 = decrease in seasonal labour).

LLp_1 / LLs_1 = (LLp_1 increase in permanent labour / LLs_1 = increase in seasonal labour).

X = represents the independent variables

FA = X1 = method(s) of harvesting grapes, *NSL* = X2 = Number of seasonal labourers, *NHecp* = X3 = Hectares for production, *MethH* = X4 = Type of harvesting, *TypH* = X5 = Type of harvester, *DuraH* = X6 = Length of harvest season (number given - weeks), *Mchout* = X7 = Machine output, *ALOh* = X8 = Labour output, *LaHar* = X9 = Labourers for 1 ton, *CostHarM* = X10 = Cost of machine harvesting, *CostHarH* = X11 = Cost of labour harvesting, *Manhec* = X12 = Man-hours per ton , *AvgharMac* = X13 = Average machine duration, *Lalahec* = X14 = Average labour land ratio.

B0 = Coefficient of the constant term.

B1–B10 = Coefficients of the independent variables.

The following logistic regression formula was used to determine the factors that impact labour:

LLp / LLs = B0 + B1FA + B2NSL + B3NHecp + B4 MethH + B5TypH + B6DuraH + B7Mchout + B8ALOh + B9LaHar + B10CostHarM + B11CostHarH + B12Manhec + B13AvgharMac + B14Lalahec ………………………………………………………………(3.4)

Table 3.3 and Table 3.4 present the dependent and independent variables that were used in the study. Table 3.3 presents the dependent variable as adoption, and the dependent variable is Age (FA), Gender (Gend), Qualification (EduF), Experience (Exp), Permanent labourers (NPerL), Seasonal labourers (NSL), Sources of income (SourIn), Hectares for production (NHec), Average yield per year (AYG), Average NFI labourers (NFIL), Average NFI machine (NFIM), Average NFI labourers and machines (NFILM), Access to credit (AccCr), Advisory services (AdSer), Distance to market (MarkPl), Trellis system (STS), Topography (IdealT) and Access to mechanical harvesting (AccMec). The entire latter variables are critical in determining the adoption or non-adoption of mechanical harvesting of grapes.

The years of Experience (Exp), Age (FA) and qualifications (EduF) encompass the social composition of how farmers perceive mechanical harvesting and technology. The younger a farmer is, probably the more willing they are to adopt mechanical harvesting. The other fundamental variables from a production perspective which is critical to take into account are Permanent labourers (NPerL), Seasonal labourers NSL), Sources of income (SourIn), Hectares for production (NHec), Average yield per year (AYG), as well as NFI. These variables cannot be ignored as they inform to what degree or level a farmer would make use of mechanical harvesting and within what circumstances.

Table 3.3: Description of variables for adoption used in the logistic regression model

Variable	Description
Dependent variable	
Adoption (MH)	0 for increase adoption and 1 for decrease adoption
Explanatory variables:	
Age (FA)	Age in years
Gender (Gend)	0 if Male, 1 if female
Qualification (EduF)	1 No education, 2, Primary education, 3, Secondary education, 4 Diploma, 5 Degree and 6 Postgraduate studies
Experience (Exp)	Experience in years
Permanent labourers (NPerL)	Number of permanent labourers
Seasonal labourers (NSL)	Number of seasonal labourers
Sources of income (SourIn)	Amount of income in Rand (R)
Hectares for production (NHec)	Number of hectares under vines
Average yield per year (AYG)	Average yield in ton per year
Average NFI labourers (NFIL)	1 if R 35 000.00 or less, 2 if R40 000, 3 if R45 000, 4 if R50 000, 5 if R55 000, 6 if R60 000, 7 if R65 000, 8 if R70 000, 9 if R75 000 and 10 if R80 000 or more.
Average NFI machine (NFIM)	1 if R 35 000.00 or less, 2 if R40 000, 3 if R45 000, 4 if R50 000, 5 if R55 000, 6 if R60 000, 7 if R65 000, 8 if R70 000, 9 if R75 000 and 10 if R80 000 or more.
Average NFI labourers and machines (NFILM)	1 if R 35 000.00 or less, 2 if R40 000, 3 if R45 000, 4 if R50 000, 5 if R55 000, 6 if R60 000, 7 if R65 000, 8 if R70 000, 9 if R75 000 and 10 if R80 000 or more.
Access to credit (AccCr)	0 if Yes, 1 if No
Advisory services (AdSer)	0 if Industry consultants, 1 if Extension officers, 2 if Both.

Variable	Description
Market place (MarkPl)	0 if local, 1 if International and 2 if Both
Trellis system (STS)	0 if Yes and 1 if No
Topography (IdealT)	0 if Yes and 1 if No
Access to mechanical harvesting (AccMec)	0 if Yes and 1 if No

Source: Author compilation (2019).

Table 3.4 presents the dependent variable of the impact on labour. It can be for seasonal or permanent labour. The dependent variables include Age (FA), Seasonal Labourers (NSL), Hectares for production (NHecp), Type of harvesting (MethH), Type of harvester (TypH), Length of the harvest season (number given in weeks) (DuraH), Machine output (Mchout), Labour output (ALOh), Labourers for one ton (LaHar), Cost of machine harvesting (CostHarM), Cost of labour harvesting (CostHarH), Man-hours per ton (Manhec), Average machine duration (AvgharMac), as well as the Average labour land ratio (Lalahec). The latter variables all impact seasonal and permanent labour. The critical variables include Age (FA), Seasonal Labourers (NSL), Hectares for production (NHecp), Type of harvesting (MethH), Length of the harvest season (number given in weeks) (DuraH), Machine output (Mchout) and Labour output (ALOh). If farmers prefer using seasonal labourers, it can affect the number of seasonal labourers if mechanical harvesting is employed. Therefore, the greatest impact would be on seasonal labourers.

The labour output against the output of a machine would also influence if a machine is needed for harvesting grapes or not. If it is more cost-effective to harvest mechanically than using labourers, it can impact either seasonal or permanent labourers. Farmers also need to consider the cost of the machine and determine if the return on investment would be profitable in the medium or long run, given all the other variables.

Table 3.4: Description of variables for impact on seasonal and permanent labour used in the logistic regression model

Variable	Description
Dependent variable:	
Seasonal labour (LLs) Permanent labour (LLp)	LLs_0/LLp_0 = 0 decrease labour and LLs_1/LLp_1 = 1 increase labour
Explanatory variables:	
Age (FA)	Age in years
Seasonal labourers (NSL)	Number of seasonal working during harvest season
Hectares for production (NHecp)	Hectares under wine production
Type of harvesting (MethH)	1 if Mechanical harvester, 2 if Labourers, 3 if Both.
Type of harvester (TypH)	1 if Self-propelled, 2 if Tractor-drawn and 3 if Both
Length of harvest season (number given - weeks) (DuraH)	Length of the season in weeks/months
Machine output (Mchout)	1 if 4 tons/hour or less, 2 if 5 tons/hour, 3 if 6 tons/hour, 4 if 7 tons/hour, 5 if 7 tons/hour, 6 if 9 tons/hour, 7 if 10 tons/hour and 8 if 11 tons/hour and more.
Labour output (ALOh)	1 if 4 tons/hour or less, 2 if 5 tons/hour, 3 if 6 tons/hour, 4 if 7 tons/hour, 5 if 7 tons/hour, 6 if 9 tons/hour, 7 if 10 tons/hour and 8 if 11 tons/hour and more.
Labourers for 1 ton (LaHar)	How many labourers can harvest 1 ton
Cost of machine harvesting (CostHarM)	1 if R 75.00 or less, 2 if R 120.00, 3 if R 165.00 and 4 if R 210 and more
Cost of labour harvesting (CostHarH)	1 if R 138.51 or less, 2 if R 169.30, 3 if R 200.08 and 4 if R 230.86 and more.
Man-hours per ton (Manhec)	1 if 6 hours or less, 2 if 7 hours, 3 if 8 hours, 4 if 9 hours, 5 if 10 hours and 6 if 11 hours and more
Average machine duration (AvgharMac)	Duration of the machine
Average labour land ratio (Lalahec)	1 if 3 workers:1ha or less, 2 if 4 workers:1ha, 3 if 5 workers:1ha, 4 if 6 workers:1ha, 5 if 7 workers:1ha, 6 if 8 workers:1ha, 7 if 9 workers:1ha, 8 if 10 workers:1ha and 9 if 11 workers:1ha or more.

Source: Author Compilation (2019).

3.5.2 Cost-Benefit Analysis

The Cost-benefit analysis (CBA) is used to determine the profitability of the mechanical harvester. In the evaluation, the benefits and the costs are being compared to see whether the benefits exceed the cost, thus resulting in a positive assessment. Further steps in decision-making using the CBA in determining the profitability is the use of the Internal Rate of Return (IRR), Net Present Value (NPV), and lastly the Benefit-Cost Ratio (BCR). The NPV, BCR, and IRR are indicated as follows:

- **Net Present Value (NPV)**

$$NPV = \sum_{t=0}^{n} \left(\frac{(B_t - C_t)}{(1+r)^t} \right) \quad \text{..........} 3.5$$

Where:

Bi = benefits

Ci = costs

d = the discount rate

i = year of the project

- **Benefit-cost ratio (BCR)**

$$BCR = \sum \frac{B_t}{(1+r)^t} \div \sum_{t=0}^{T} \frac{C_t}{(1+r)^t} \quad \text{..........} 3.6$$

Where:

∑ = indicates the sum of values

Bt = income at time t

Ct = cost at time t

T = timescale of the project

t = 0 = starting time of project

r = discount rate

- **Internal Rate of Return (IRR)**

$$NPV = \sum_{t=0}^{n} \left(\frac{(B_t - C_t)}{(1+r)^t} \right) = 0 \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots 3.7$$

Where:

Bt = project benefit in period *t*

Ct = project cost in period *t*

r = discount rate

t = is the number of years

3.5.3 Data analysis

Jeffreys's Amazing Statistics Programme (JASP) and Statistical Package for Social Science (SPSS) as statistical packages were used for the statistical analysis of the data. JASP is a free graphical software package for simple statistical measurements, which include regression models, Analysis of Variance (ANOVA) and *t* tests. It also investigates contingency tables. JASP was used to present and measure the predictor variables and the confirmatory results that were run by the SPSS.

3.6 Summary

This chapter outlined the approach to the methodology used in this study. Firstly, this chapter explained the study area within which it was conducted. It illustrated the Western Cape as the province for the research, particularly the Cape Winelands District Municipality where the study took place. The various wine producers and private cellars are also indicated with the specific number per area. The chapter also included a discussion about the research approach and design. The research methodology included a description of the framework of the analysis, which, in this study, is a mixed-method research technique consisting of qualitative and quantitative studies. However, the research design also considers the questionnaire construction and the determination of the same size. The sampling technique, which is used in this study is the multi-sampling technique, and the data collection method is also explored.

Furthermore, the chapter set out an understanding of the conceptual framework. It explained the factors impacting adoption of mechanical harvesting, taking into account the evaluation on the profitability of such a machine, as well as how the adoption of mechanical harvesting influences labour. Also, the empirical models used in the study, particularly the logistic regression model, was presented. Independent and dependent variables were identified and explained in the context of the model. The CBA as a model for decision-making and data analysis together with the approach thereof were also discussed; providing an outline of the study’s approach.

The following chapter presents the results and the discussion of the analysis.

CHAPTER 4
RESULTS AND DISCUSSION

4.1 Introduction

This chapter presents the results and discussion from the analysis of the data that were collected to determine the economic effect of mechanical harvesting technology on wine-producing farms in the Western Cape. Two diverse methodologies were used to determine the effect of a mechanical grape harvester. First, a presentation of the logistic regression analysis on the adoption of a mechanical harvester, followed by the results for the Cost-benefit analysis in determining how profitable the machine would be. Lastly, a discussion about the impact of the harvester if labour were evaluated by using the logistic regression analysis. The chapter, therefore, explains how mechanical harvesting will impact wine-producing farms.

Discussions on the findings will pertain to how mechanised grape harvesting will not only influence this massive agricultural change but will also impact agriculture professionals – from policymakers via machinery manufacturers, farmworkers, to agriculture scientists and engineers – and finally to consumers and eaters and drinkers of the produce.

The prosaic questions that need to be determined include what factors impact the adoption of mechanical harvesting, how labourers will be affected on the farm and would mechanical harvesting of grapes be profitable if used. This chapter will present the results from the logistic regression model that was employed to determine the factors that impact the adoption of mechanical harvesting; the same model was used to determine the impact on labourers. Lastly, the CBA was used to determine the profitability of mechanical harvesting of grapes on the farm.

4.2 Socio-economic characteristic of respondents

This section encompasses a discussion about the socio-economic characteristics of the producers for the respective wine districts referred to in the study. Table 4.1 presents the results for wine grape producers regarding their socio-economic characteristics. The results showed that 98.9% of the producers are males, and only 1.1% are females; the wine grape production farms are clearly dominated by males. The results of the research are in line with of the findings of Mariano et al. (2012). They found that 89% of farmers who adapted to technology such as certified seed technology were males, thus more male farmers adapt new technological advances.

The marital status of the farmers is also a critical characteristic to consider. Approximately 93.3% of the farmers are married, and 6.7% are single. Since married people manage most of the farms, it indicates a great level of commitment and dedication. Coupled with being married, it also provides a sense of experience within the farming business. Paul et al. (2017) also found that marital status is a major factor in technology adoption. Findings from this research further revealed that based on their level of qualifications, the respondents are well educated. About 19.5% had a secondary education; only 5.7% had a Higher Certificate, while 28% and 33% of the respondents had either a Diploma or Degree, respectively. A total of 4.6% of respondents had a postgraduate qualification, which is not common for the producers of this study. However, most of the producers regard a post Grade 12 qualification as important for managing a farm.

With a P-value of 0.487, education is not a significant contributor when decisions are made on the adoption of technology (Raut et al., 2011; Musa et al., 2012). Raut et al. (2011) found that there was no significant change in socio-economic conditions between adopters and non-adopters of agricultural intensification (AI). Musa et al. (2012), on the other hand, found that the state rather than other organisations should create a platform for educating rural producers on how to accept and adopt modern technology within agriculture. Therefore, education in this study was not found to be a significant contributor to the adoption of mechanical harvesting of grapes.

Concerning the source and sources of income, the study revealed that 25% of the farmers had only wine as a source of income. About 19.3% and 13.6% had wine grapes and wine, and wine grapes as sources of income, respectively. The majority of the producers (approximately 28.4%) had wine grapes, coupled with other sources of income as income streams. According to Abbas et al. (2017), income raises the probability of acceptance, indicating that incentives for earning income need to be developed. Thus, in this research, it is evident that income from the primary production and or other income sources within the farming business is very important in the adoption of technology. Furthermore, most farmers in this study apply a relative level of diversification, which is critical to sustaining the farming business in the long run.

The number of farmers with access to credit was 89.2% compared to 10.8% of those without access. The results of this study are consistent with research conducted by Mariano et al. (2012) that found that credit was significant at a 1% level of significance, in which certified seed (CS) technology requires larger cash outlays; in this study credit is needed to switch to the mechanical harvesting of grapes. According to Uddin et al. (2014), there was inadequate access to credit to account for the income difference when moving labour from off-farm revenue generation to on-farm adaptation strategies. Mariano et al. (2012) also concurred with this finding that sufficient credit is needed for major mechanical investment within agribusinesses. Therefore, most of these farmers maintain a fair amount of viability within their industry and are capable of investing in mechanical harvesting of grapes.

Table 4.1 Socio-economic characteristics of wine grape farmers

Variable	Description of socio-economic characteristic	Sample size	The frequency	Valid percentage (%)	Cumulative percentage (%)
Gender	Male	91	90	98,9	98,9
	Female		1	1,1	100
Marital Status	Single	89	6	6,7	6,7
	Married		83	93,3	100
	Widow		-		
Qualification	Secondary	87	17	19,5	19,5
	Higher Certificate		5	5,7	25,2
	Diploma		28	32,2	57,4
	Degree		33	37,9	95,3
	Postgraduate		4	4,6	100
Source(s) of income	Wine	88	22	25,0	25,0
	Wine grapes		17	19,3	44,3
	Wine and wine grapes		12	13,6	57,9
	Wine and Other Sources		8	9,1	67
	Wine grapes and Other Sources		25	28,4	95.4
	Other sources		1	1,1	96,5
	Wine, wine grapes and other		3	3,4	100
Access to credit	Yes, have access	83	74	89,2	89,2
	No, have no access		9	10,8	100

Source: Author’s estimation (2019).

4.3 Empirical results and discussion

This sub-section entails a presentation of the results from the empirical models, namely the logistic regression analysis that was utilised to explore the association of mechanical harvesting on key potential variables associated with mechanical harvesting adoption. These potential variables were carefully selected from an extensive comparative non-parametric (Chi-square) analysis of how well individual variables were associated with the division of the respondents by mechanical harvesting. The most influential associated variables were used in the appropriate model; the final set shown was refined by the 'stepwise entry' method in the JASR software.

4.3.1 Binomial logistic regression analysis on the adoption of mechanical harvesting

Table 4.2 shows the results of the binomial logistic regression model. The dependent variables, namely MH_0, which refers to non-adoption, and MH_1 being the adoption of mechanical harvesting. The logistic regression was performed to attempt to predict the uptake of mechanical harvesting. The binomial logistic regression model was statistically significant [$X^2(37) = 73.495$, $p<.001$].

The results indicated that the number of hectares used for the production of wine grapes, NFI measure, average labour output (tons) for harvesting grapes in an hour on the farm, as well as the number of permanent labourers on the farm proves to be significant. A discussion on the analysis will be presented in the next section.

Table 4.2: Factors impacting adoption of mechanical harvesting

Variable	Coefficient	z	P-value
Regression model	73.495	-	<.001
Adoption (MH) (1)	2.674	3.658	< .001
Average yield per year (AYG)	3.158	0.657	0.511
Average (NFI)	-3.115	1.900	0.057**
Labour output (ALabO)	-1.193	-2.134	0.033***
Hectares for production (NHecp)	4.122	-1.998	0.046**
Permanent labourers (NPerL)	-1.816	2.436	0.015***
Permanent labour (LLp)	-2.022	-2.000	0.046**
Age (FA)	-0.101	-0.240	0.810
Gender (Gend)	-1.424	-0.006	0.995

Qualification (EduF)	-0.315	-0.695	0.487
Experience (Exp)	0.125	0.314	0.753
Seasonal labourers (NSL)	0.020	0.048	0.962
Sources of income (SourIn)	0.455	0.916	0.360
Access to credit (AccCr)	-4.370	-0.008	0.994
Advisory services (AdSer)	0.399	1.097	0.273
Market place (MarkPl)	-0.183	-0.468	0.640
Trellis system (STS)	0.004	0.009	0.993
Topography (IdealT)	-6.198	-0.007	0.994
Access to mechanical harvesting (AccMec)	-10.430	-0.010	0.992

**** = significant; *** = significant at the 1% level; ** = significant at the 5% level; * = significant at the 10% level.

Source: Author's estimation (2019).

The increase in the average yield of grapes in tons per year and hectares used for the production of wine grapes were associated with an increased likelihood of mechanical harvesting. Noticeably, both hectares for production (NHecp) and average labour output (ALabO) (tons), including permanent labourers (NPerL) with P-values of 0.046, 0.033 and 0.015, respectively, is significant for harvesting grapes in an hour. These were both associated with a lesser likelihood of mechanical harvesting being adopted; possibly because these were already high-yielding traditional economic farms.

The results suggested that an increase in yield of grapes in tons per year, labour output, and the number of hectares used for the production of grapes indicates that farmers would not be likely to adopt mechanical harvesting of grapes. It also suggests that with a large number of hectares and a higher volume of output the producers will adopt mechanical harvesting of grapes, which does not support the hypotheses of H_0 for the increase in the adoption of mechanical harvesting.

Farmers with an increasing NFI and a relatively good average labour output are less likely to adopt mechanical harvesting of grapes. The effect on permanent labour (NPerL) with a coefficient of -1.816 and -2.022, respectively proof also to be significant and positively correlated. The values of -1.816 and -2.022 suggest that farmers are not affected by permanent labour on the adoption of mechanical harvesting.

Therefore, it does not affect permanent labour and does not concur with the results of Adu-Baffour et al. (2019). They demonstrated that mechanisation could double income by farming a greater portion of their land. The demand for hired labour rises due to land expansion and as a result of a transition from family labour, including that of children, to hired labour. It is also not consistent with the findings of Reddy et al. (2014). They concluded that mechanisation increased casualisation of labour, which was observed through numerous crops and states. The results are also not consistent with that of Tudisca et al. (2013) who reported that winegrowers could increase their income by implementing a mechanised harvest for both farm property and a leased grape harvester.

4.4 Cost-benefit analysis

Conducting the CBA allowed for the assessment of the profitability of the harvester by comparing the mechanical harvesting of grapes and using only labour for harvesting grapes. The costs and the benefits can be associated by using two different grape harvesters, namely the self-propelled harvester and the trailed harvester in the three distinct regions. According to the VinPro Cost Guide (2018), the lifetime of the project is over five years corresponding for each of the regions using the different harvesters. More specifically, the benefits and cost have been calculated per hectare, utilising the Benefit-Cost Ratio. The cost, per region, in this investigation was calculated as follow: by only taking the capital outflow as the yearly payment of the investment for the period of five years from 2018 to 2023, for each of the harvesters. The benefits were calculated by using the targeted income in Rand/ha subtracting the cost of harvesting grapes manually and replacing it with the cost of harvesting mechanically in Rand/ha referring for the year 2018 in Table 4.3.

The latter refers to a situation, which used only the harvester for harvesting grapes. The second situation will be using both the harvester and labour for harvesting grapes. Based on the analysis in Table 4.3 that was done for a farm size of 40 ha and 100 ha, it is possible to compare the three regions in respect of the farm sizes and the use and non-use of the two different harvesters. Table 4.3 implies and indicates the target income and total expenditure, and the labour harvest cost and the machine harvest cost per hectare. It also indicates the average yield in ton per hectare, including the annual usage in hours per year for both the self-propelled and the trailed harvester. The labour cost per hectare is also indicated for all of the respective regions. This table, illustrating its income and cost calculations will form the bases for determining the CBA per region and the comparison between the regions.

Table 4.3: Income and cost comparison between regions

	Stellenbosch		Paarl		Robertson		Worcester	
Hectares	40	100	40	100	40	100	40	100
Target income / ha	77 379	69 459	66 659	58 775	76 217	68 297	74 695	66 775
Total expenditure/ha	51 411	51 411	39 415	39 415	48 937	48 937	47 414	47 414
Average yield (ton per ha)	8,78	8,78	11,07	11,07	21,61	21,61	21,25	21,25
Harvest of trellis (man-hours per ton). Max 11 hours	11	11	11	11	11	11	11	11
Self-propelled Harvester: Annual usage in hours / year (90 hours for 1 000 tons)	31,61	79,02	39,85	99,63	77,80	194,49	76,50	191,25
Trailed Harvester: Annual usage in hours / year (71 hours for 500 tons).	49,87	124,68	62,88	157,19	122,74	306,86	120,70	301,75
Labour harvest cost per ha (11 hours average - max @ R18.00)	198	198	198	198	198	198	198	198
Self-propelled harvester: Total cost per 1000 tons / 90 hours = R3 724.	1 307,87	3 269,67	1 648,99	4 122,47	3 219,03	8 047,56	3 165,40	7 913,50
Trailed Harvester: Total cost per 500 tons / 71 hours = R2 129.	1 495,41	3 738,52	1 885,44	4 713,61	3 680,62	9 201,54	3 619,30	9 048,25
Labour Harvest cost/ha (VinPro 2018)	19 659	19 659	14 227	14 227	13 462	13 462	13 273	13 273
Machine harvest cost / ha (VinPro 2018) convert calculation.	2 943	2 943	3 710	3 710	7 243	7 243	7 122	7 122

Source: VinPro Cost Guide (2018).

The financial performance was evaluated by using the following indicators:

- Net Present Value (NPV)
- Cost-Benefit Analysis (CBA)
- Internal Rate of Return (IRR)

The NPV, IRR and BCR have a shared perspective on the present value of benefits and costs; it has a high level of reliability in the choice to reject or accept the mechanical harvester (Hirschey, 2003). The latter three indicators give a clear and scientific analysis of the financial performance under various circumstance for each of the three regions.

Given the following calculations below that were used to determine the profitability of using the grape harvester to harvest grapes, the figures indicate the results. A comparison will be drawn between mechanised harvesting and harvesting grapes by only using labourers.

Figure 4.1 illustrates the impact that mechanical harvesting, and a combination of mechanical harvesting, together with labour harvesting, has on the profitability of a farm from 2018-2023.

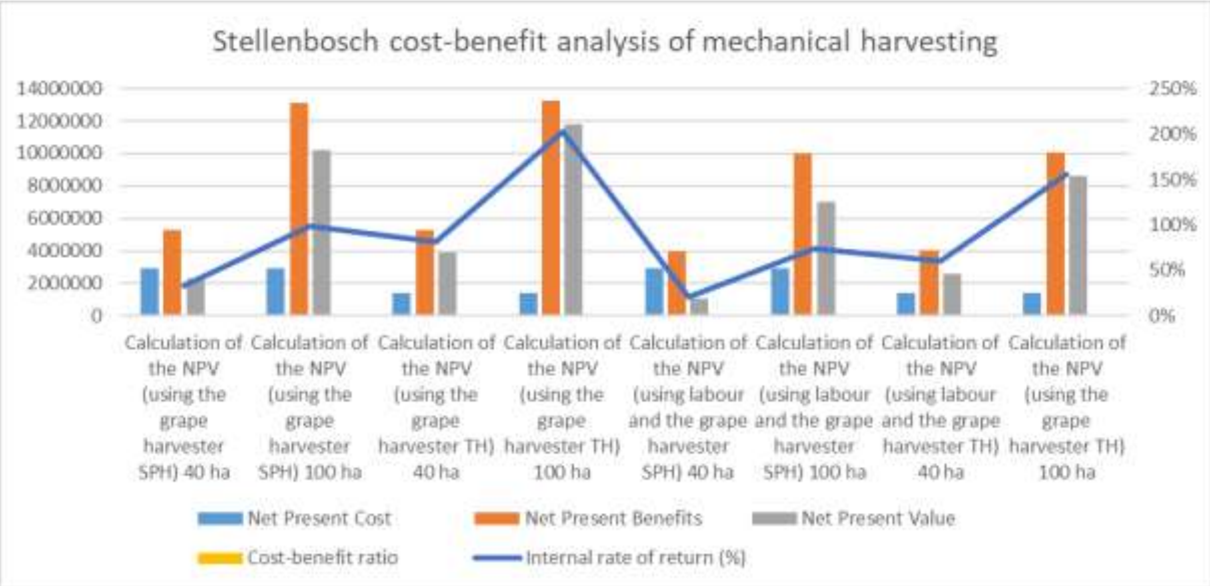

Figure 4.1: Stellenbosch cost-benefit analysis of mechanised harvesting from 2018-2023
Source: Author estimations based on secondary data

The NPV was calculated for five years from 2018 to 2023, using a self-propelled harvester on a 40 ha and 100 ha farm, as well as the use of a trailed harvester for the same farm sizes. The NPV was also calculated for the use of labour in combination with these mechanical harvesters. It can be seen that net present benefits and the NPV is higher when harvesting with the trailed harvester for a farm size of 100 ha and 40 ha. The IRR is also higher when harvesting 100 ha than harvesting 40 ha. However, the net present cost remains the same for harvesting 40 ha and 100 ha for the respective scenarios. It can also be seen that the cost-benefit ratio is higher when harvesting 100 ha than 40 ha when considering the cost and benefits. Thus, for farmers in Stellenbosch, they need to harvest at least 100 ha to employ mechanical harvesting of grapes profitably.

About 87% of farmers in Stellenbosch only use labourers for harvesting grapes, and 82% of the farmers do not have a farm larger than 100 ha. This means that for more than 80% of the farmers in Stellenbosch, it would not be profitable to make use of mechanical harvesting of grapes. This result is in line with that of Lee (2016), which revealed that all financial indices of biohydrogen are economically feasible of investing in Levelised Cost of Energy (LCOE) and will be commercialised successfully, although the study focused on LCOE as an investment. The results of the research are also supported in a study by Daujanov et al. (2016) where the findings propose that investment in Conservation Agriculture implementation have a positive incremental benefit if the advantages of Conservation Agriculture are monetised; the study focused on conservation agricultural as an investment opportunity.

Figure 4.2 illustrates the impact that mechanical harvesting and a combination of mechanical harvesting, together with labour harvesting, has on the profitability of a farm. The NPV was calculated for five years, using a self-propelled harvester on a 40 ha and 100 ha farm, as well as the use of a trailed harvester for the same farm sizes.

It can be seen that net present benefits and the NPV is higher when harvesting with the trailed harvester for a farm size of 100 ha and 40 ha. Furthermore, the IRR is higher when harvesting 100 ha compared to harvesting 40 ha. However, the net present cost remains unchanged when harvesting 40 ha and 100 ha for the respective scenarios. The cost-benefit ratio is higher when harvesting 100 ha than 40 ha, especially when considering the cost and benefits of mechanical harvesting. Therefore, farmers in Paarl need to harvest at least 100 ha to profitability employ mechanical harvesting for harvesting grapes. About 60% of farmers in Paarl only use labourers for harvesting grapes, and 40% uses both labourers and mechanical harvesting for harvesting grapes. Only nine farms in Paarl have a farm size of more than 100 ha. This means that for 30% of these farmers in Paarl, it would be profitable to utilise the mechanical harvesting of grapes. This is supported by an investment study by Tangvitoontham and Chaiwat (2012). They found that all indicators showed the project is worth investing in, and that the net present value (NPV) of the project was 618.705 million baht. Economic Internal Rate of Return (EIRR) equals 16.81%, and benefit-cost ratio (B/C) is 1.27.

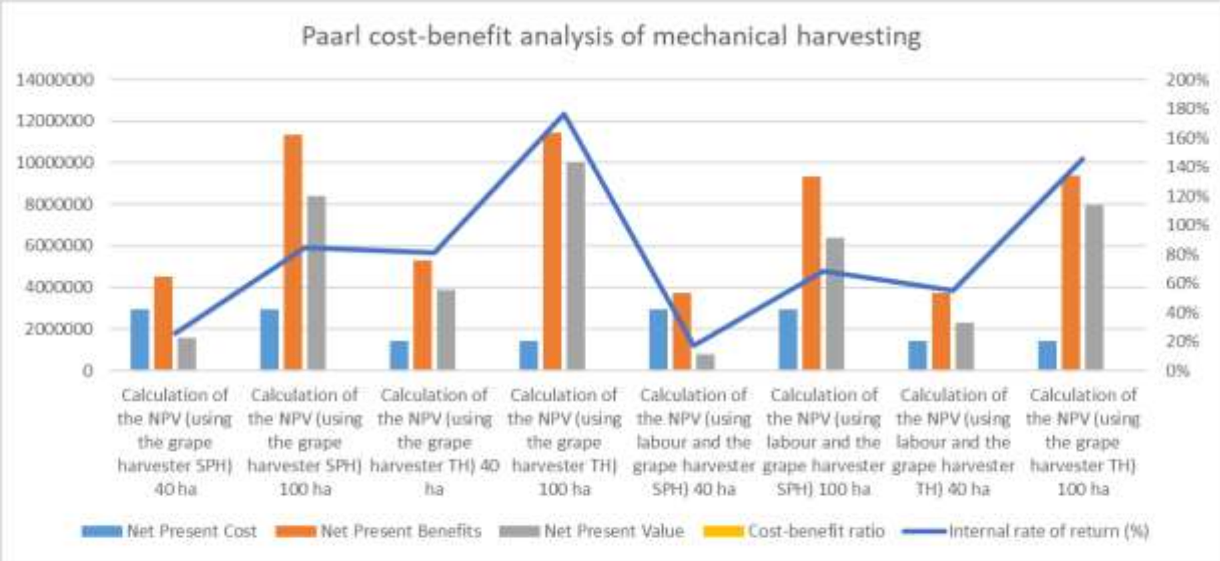

Figure 4.2: ***Paarl cost-benefit analysis of mechanical harvesting from 2018-2023***

Source: Author estimation based on secondary data 2019

Figure 4.3 and Figure 4.4 illustrate the impact that mechanical harvesting and a combination of mechanical harvesting together with labour harvesting have on the profitability of a farm.

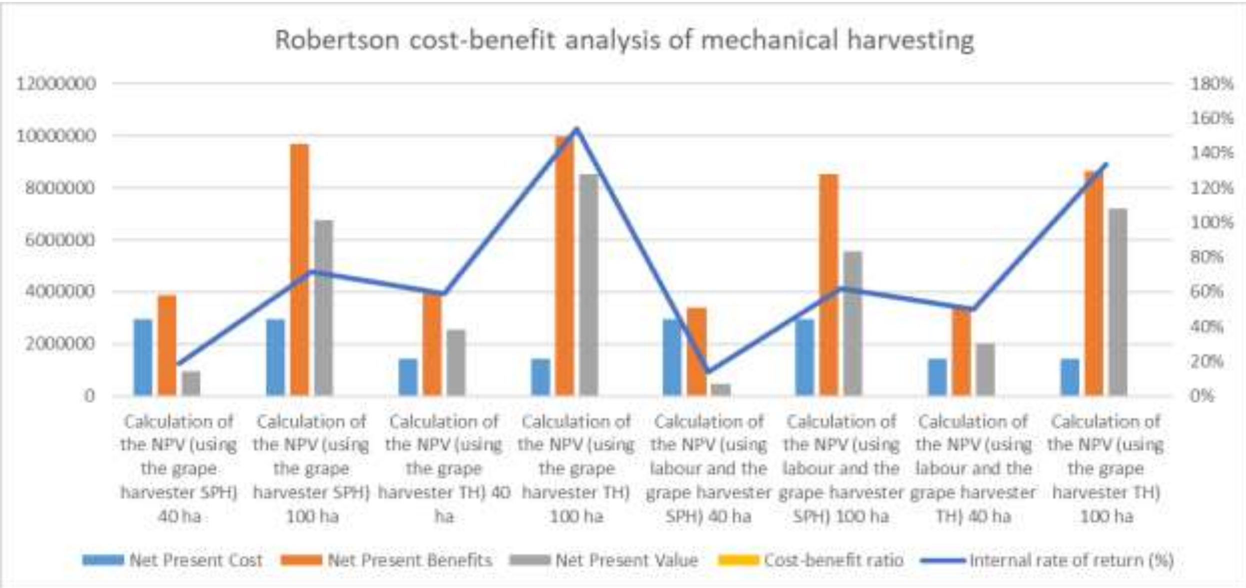

Figure 4.3: ***Robertson cost-benefit analysis of mechanical harvesting from 2018-2023***

Source: Author estimation based on secondary data (2019).

The NPV was calculated from 2018 to 2023, using a self-propelled harvester on a 40 ha and 100 ha farm, including a trailed harvester for the same farm sizes. In both figures 4.3 and 4.4 the net present benefits and the NPV were higher when harvesting with the trailed harvester for a farm size of 100 ha and 40 ha, with the same results for Stellenbosch and Paarl.

The CBR was also higher when harvesting 100 ha than 40 ha when considering the cost and benefits of mechanical harvesting in both figures. For farmers in Worcester and Robertson, at least 100 ha is required to harvest to profitability and employ mechanical harvesting for harvesting grapes. About 14% of farmers in Worcester and Robertson use mechanical harvesting of grapes, 36% only use labourers, and 50% uses both labourers and mechanical harvesting. Approximately 14 farms in the Worcester/Robertson region have a farm size of more than 100 ha. It would thus be profitable for 64% of these farmers to make use of mechanical harvesting of grapes. The results of the study in this particular part are also in line with studies conducted by Lee (2016) and Daujanov et al. (2016), which indicated a positive, successful investment opportunity on their research.

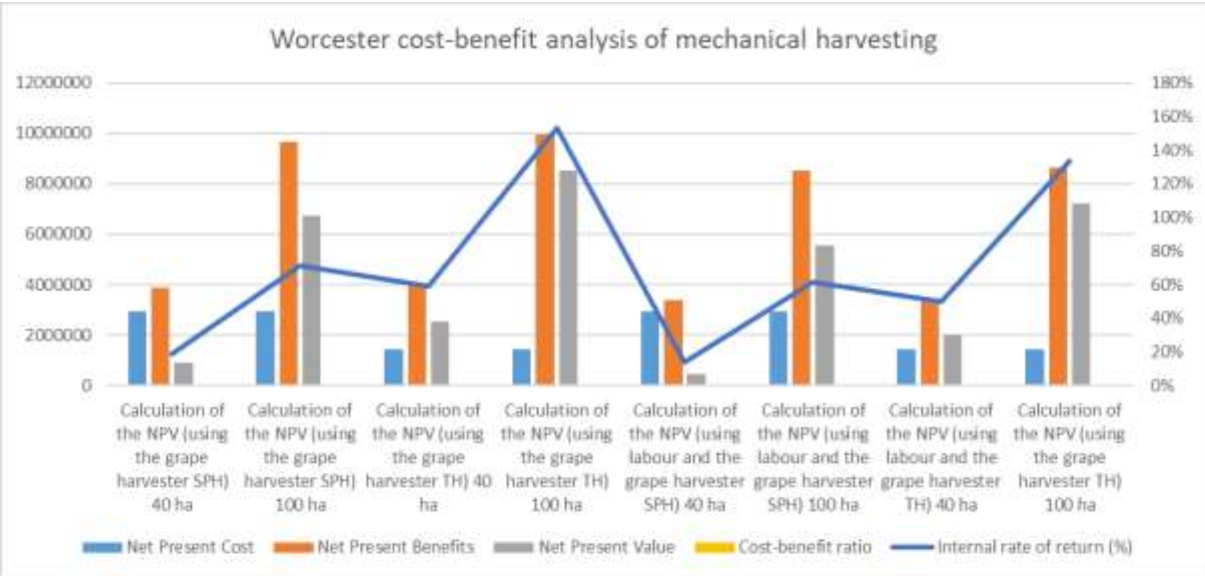

Figure 4.4: ***Worcester cost-benefit analysis of mechanical harvesting from 2018-2023***

Source: Author estimation based on secondary data (2019).

Figure 4.5 illustrates the NPVs from 2018 to 2023 of harvesting with labourers only for farms with a size of 100 ha and 40 ha for each specific region. Thus, for a production size of 40 ha in all the regions the NPV is about R2 500 000 and R6 000 000 for a production size of 100 ha. Harvesting grapes using only labourers would, however, still be profitable, if compared to harvesting grapes mechanically.

Comparing Figure 4.5 with figures 4.1, 4.2, 4.3 and 4.4, in all scenarios, the NPVs of harvesting with labourers are more profitable. Farmers in the respective regions that use only labourers for harvesting grapes would still be profitable and do not need to harvest grapes mechanically. Based on the results of this study, it is also supported by studies from Daujanov et al. (2016); Lee (2016), and Tangvitoontham and Chaiwat (2012), which all indicated positive and successful investments for projects, although it is within different fields but applied the same analysis of the CBA. The findings of this study are consistent with that of Da Costa Neto et al. (2017), Demalde and Spezia (2006), Galletto and Barisan (2007), Jobbagy et al. (2018), and Pezzi and Martelli (2015), which have concluded that there is an economic benefit in employing mechanical harvesting of grapes over a certain number of hectares of commercial vineyards. Therefore, changing from one method to another can be profitable if justified by a feasibility study such as the CBA.

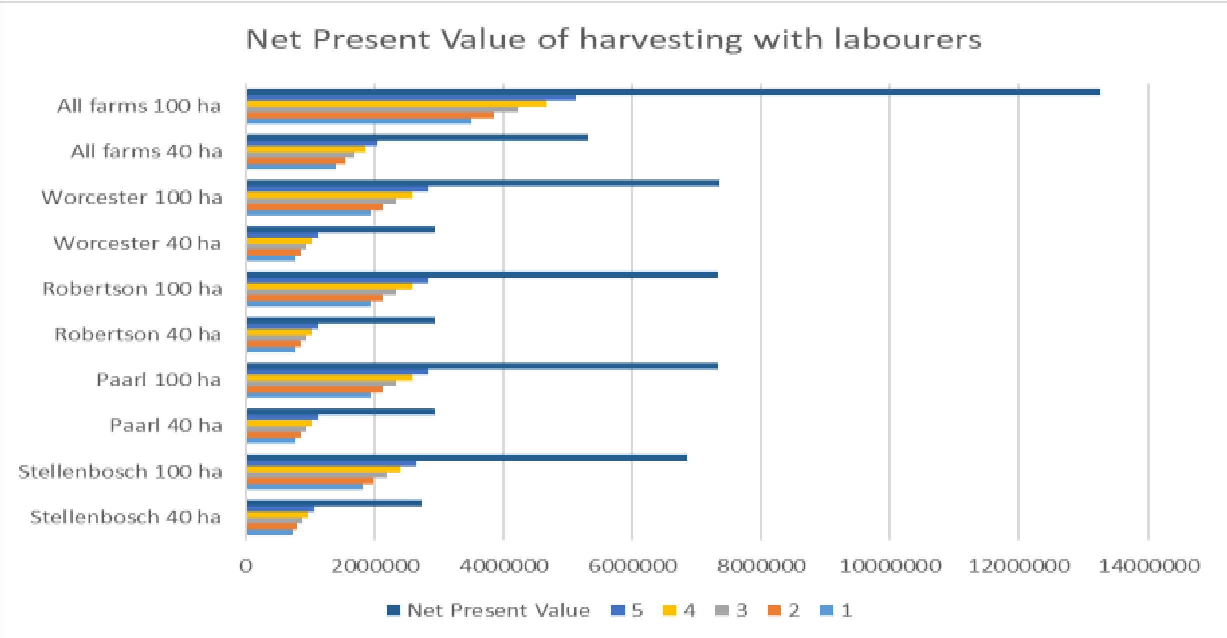

Figure 4.5: ***Net present value of harvesting with labourers from 2018-2023***

Source: Author estimation based on secondary data (2019).

4.5 Mechanical harvest impact on seasonal labour

A logistic regression was performed to attempt to predict whether a farm showed a lesser number of seasonal labourers (NSL) than the local mean level adjusted for the farm's grape-producing hectares. The computed binomial categorical was seasonal labour employment (LLs) (1 if the labour force was less than the average, 0 if otherwise).

This binomial logistic regression analysis was set up to investigate the association of this downward LLs on key potential variates. Those chosen were carefully selected from an extensive comparative non-parametric (chi-square) analysis of how well individual variables were associated with the division of the respondent by LLs. The strongest associated variables were used in the appropriate logistic regression module, which was refined by the 'stepwise entry' method in the JASR software.

In Table 4.4 both increasing hectares used for the production (NHecp) of wine grapes and the farmer's age (FA) were associated with an increased likelihood of the farm being below the local average for seasonal labourers. The remaining two variables, namely the number of seasonal labourers (NSL) used on the farm during the year and the average labour output (ALoh) (tons) for harvesting grapes in an hour on the farm, were associated with a lesser likelihood of the farm reporting a lesser than local average of seasonal labourers; being more prone to employ seasonal workers.

Table 4.4: Results on mechanical harvest impact on seasonal labour

Coefficients						
	Estimate	**Standard error**	**Standardised**	**Odds ratio**	**z**	**p**
Regression model	73.495	-	-	-	-	<.001
LLp (1)	1.442	0.308	-	-	4.677	< .001
NHecp	0.459	0.181	42.620	1.583	2.544	0.011****
NSL	-0.408	0.157	-11.808	0.665	-2.598	0.009****
FA	0.164	0.087	1.895	1.178	1.887	0.059****
ALOh	-0.497	0.373	-1.236	0.608	-1.332	0.183
MethH	-2.583	2.497	-1.295	0.076	-1.034	0.301
TypH	-10.017	6.272	-4.774	4.463	-1.597	0.110
DuraH	-8.065	6.030	-24.686	3.143	-1.337	0.181
Mchout	-0.739	0.750	-1.295	0.478	-0.984	0.325
LaHar	0.156	0.135	1.286	1.169	1.155	0.248
CostHarM	-239.860	15050.990	-145.894	6.763	-0.016	0.987
CostHarH	1.810	1.664	1.704	6.113	1.088	0.277
Manhec	-1.883	1.333	-3.115	0.152	-1.412	0.158
AvgharMac	-3.003	2.853	-2.562	0.050	-1.053	0.293

Lalahec	3.830	4.326	0.738	46.060	0.885	0.376

**** = significant; *** = significant at the 1% level; ** = significant at the 5% level; * = significant at the 10% level
⁺Standardised estimates represent estimates where the continuous predictors are standardised (X-standardisation).
LLs level '1' coded as class 1.

Source: Author's estimation (2019).

It was found that an increase in the number of hectares (NHecp) and farmers' age (FA) significantly affect the impact of seasonal labour. The increase in the number of hectares (NHecp) was significant at 0.011, and the farmer's age (FA) were significant at 0.059, thus positively correlated to an increase in seasonal labour (NSL). The results suggested that with an increase in the number of hectares (NHecp) and an increase in farmer's age (FA) seasonal labour will increase. With seasonal labour (NSL) at a significant level of 0.009, it also rejects the null hypothesis of lowering labour availability with an increase in mechanisation on the farm. This finding is coherent with other studies (Domingues & del Aguila, 2016), which found that the cost per hectare of mechanical grape harvesting is lower than the cost per hectare of manual harvesting. Mechanical harvesting is, therefore, justified when vineyard areas exceed 41.92 ha, and will also justify the use of a collection system of grape mechanics. This is particularly true for wine grape farms exceeding 42 ha.

The finding in this study does not correlate with similar studies conducted (Reddy et al., 2014; Adu-Baffour et al., 2019). They found that mechanisation would increase seasonal labour. The findings are also in contrast with Reddy et al. (2014) that suggest that farm mechanisation, displacement of family labour, and increased casualisation of labour is witnessed across numerous states and crops. The latter studies thus oppose the findings of this study, which indicate that mechanical harvesting or the employment of technological advancements on a farm does not imply that it will reduce labour.

Labour can thus be increased as the average labour output (ALOh) of harvesting increases, and as it increases, the mechanical harvesting can contribute to a rise in LLs. However, it could be that the possibility of this equation is 'over-specified' as the variates could be too closely associated with the modelled parameter (LLs); most likely because they have each already been affected by long-term farm factors, which influence the parameter and variates alike. This logistic modelling research has been done as a pilot exercise against the background of sound and potentially capable data already collected for the main CBA work. This constitutes a wider survey, specifically for these associated factors related to mechanical harvesting, and is thus worthy of further investigation.

4.6 Mechanical harvesting impact on permanent labour

A binomial logistic regression was performed to predict whether a farm showed a lesser number of permanent labourers than the local mean level adjusted for the farm's grape-producing hectare. The computed binomial categorical was LLp (1 if the labour force was less than the average, 0 if otherwise).

Table 4.5 shows the results of the effect of mechanical harvesting on permanent labour. The binomial logistic regression analysis investigated the association of this downward LLp on key potential variables.

Table 4.5: Results in mechanical harvest impact on permanent labour

	Estimate	Standard error	Standardised	Odds ratio	z	p
Regression model	73..495	-	-	-	-	<.001
LLp (1)	1.810	0.360	-	-	5.034	< .001
NHecp	0.218	0.065	20.202****	1.243****	3.362	< .001 **
NPer	-0.493	0.144	-9.987	0.611	-3.420	< .001**
MHout	-0.954	0.319	-1.672	0.385	-2.987	0.003****
Mh	-4.580	1.991	-4.580	0.010	-2.301	0.021**
DuraH	0.063	0.158	0.193	1.065	0.398	0.691
Mchout	-0.739	0.750	-1.295	0.478	-0.984	0.325
LaHar	-0.009	0.058	-0.077	0.991	-0.159	0.873
CostHarM	-2.747	1.281	-1.671	0.064	-2.145	0.032**
CostHarH	0.758	0.689	0.713	2.133	1.100	0.271
Manhec	0.467	0.316	0.773	1.595	1.480	0.139
AvgharMac	-0.118	1.051	-0.100	0.889	-0.112	0.911
Lalahec	-6.141	4.899	-1.184	0.002	-1.254	0.210

**** = significant; *** = significant at the 1% level; ** = significant at the 5% level; * = significant at the 10% level
+Standardised estimates represent estimates where the continuous predictors are standardised (X-standardisation).
LLp level '1' coded as class 1.
Source: Author's estimation (2019).

Table 4.5 shows that the variable NHecp, number of hectares used for the production of wine grapes and NPer has P-values of less than 0.001 that indicate a significance and strong evidence against lower labour availability when mechanisation increase. Variables MHout, for harvesting grapes in an hour have a P-value of 0.003, CostHarM having a P-value of 0.032, and the Mh at 0.021 P-value, which signifies the significance of the values and, therefore, would not have a lower labour availability with an increase in mechanisation as the null hypotheses suggest. The latter is consistent with the study of Busa and Nandi (2014) who reported that the use of machinery in agricultural production plays an important role in increasing productivity and reducing the unit cost of production resulting in profitability, making agriculture viable and not negatively impacting labour. The finding of the study is also in line with the findings of Ugur and Mitra (2017) who found that the impact of technology adoption on jobs is more likely to be favourable where data is linked to skilled-labour employment and product innovation. However, the latter support studies are dealing with a machine and technology adoption, respectively.

4.7 Summary

This chapter presented the socio-economic characteristics of the farmers and the empirical results of the effect of mechanical harvesting on farms in Stellenbosch, Drakenstein and Breede Valley local municipalities within the Western Cape. The results clearly show that increasing hectares used for the production (NHecp) of wine grapes were associated with farmers making use of mechanical harvesting (Mh) for harvesting wine grapes. It also revealed that variables such as Nhecp and NSL were significant against the null hypotheses on a decrease of seasonal labour availability when mechanisation increase. The Mhout, Mh, CostHarM, Nhecp, and Nper negatively correlated with the null hypotheses of lowering permanent labour with an increase in mechanisation. The results also showed that it would be more profitable for farmers to make use of mechanical harvesting for harvesting grapes with a land size of 100 ha compared to 40 ha. The study further shows that increasing hectares used for the production (Nhecp) of wine grapes and farmer’s age (FA), including the number of hectares used for the production (Nhecp) of wine grapes significantly impact the reduction on seasonal labourers (NSL), as well as permanent labour (NPer) of these farms.

The following chapter provides a summary of the conclusion and recommendations of the study.

CHAPTER 5
CONCLUSION AND RECOMMENDATION

5.1 Introduction

The aim of this study was to determine the economic effect of mechanised harvesting technology on grape-producing farms in the Western Cape Province of South Africa. The specific local municipalities included in this study were Stellenbosch, Drakenstein, and Breede Valley. The latter two were combined as the two regions have similar conditions. The research used the binomial logistic regression analysis to determine factors impacting the adoption of mechanical harvesting and factors affecting labour. The CBA was employed to determine the profitability of mechanical harvesting of grapes.

The study focused on how primary agriculture in wine-producing regions in South Africa will be impacted by the rapid increase in technological advancement and mechanisation in agriculture. The literature provides insight into how mechanical harvesting of grapes as a production activity on the farm affects labour, adoption and profit of the farming business.

Various techniques were employed to analyse the economic effect of mechanised harvesting on wine grape farms. However, no real concrete and satisfactory economic analysis have been conducted by specifically mechanised harvesting in the area of profitability, adoption and the effect on labour for the Western Cape. This study is unique as it investigates the economic effect of a mechanical harvester on wine productions farms within the Western Cape, which focus specifically on the impact it has on the profitability, the adoption of mechanical harvesting, and to what extend labour on the farm are impacted. The binomial logistic regression analysis was very applicable and appropriate to determine the factors affecting the adoption of mechanised harvesting, as well as to evaluate the factors affecting labour. The CBA was used to estimate the profitability of mechanised harvesting with particular focus on the NPV, CBA, and the IRR within the CBA.

5.2 Summary of findings

Findings regarding the adoption of mechanical harvesting revealed that farmers with large hectares of production units, labour output, including net farm income would not be more likely to adopt mechanical harvesting for harvesting grapes, as indicated by the binomial logistic regression analysis. The analysis also indicated that farms with a large number of hectares under wine grape production are not associated with the use of a mechanical harvester for harvesting grapes. The study also revealed through the Cost-benefit analysis (CBA) that by utilising mechanical harvesting for harvesting grapes would be profitable. Thus, changing from hand harvesting to mechanical harvesting can be justified by a feasibility study such as the CBA. The latter revealed that for a production size of 40 ha in all the regions the NPV is about R2 500 000 and for a production size of 100 ha it is more than R6 000 000. The study revealed that as the number of hectare for production increases, with the existing seasonal labourers on the farm, it will not increase mechanical harvesting of grapes, nor will it lower the availability of labour.

The study also revealed that the use of a mechanical harvester for harvesting wine grapes would be profitable, although using labourers only for harvesting grapes also indicated to be profitable. Furthermore, increasing hectares used for the production of wine grapes, cost of harvesting grapes, and mechanical harvesting were also factors associated with the hypothesis of lower permanent labour availability with an increase of mechanisation. Therefore, the use of mechanical harvesting of grapes do not reduce labour used for grape harvesting; some producers are using both mechanical and hand harvesting of grapes.

5.3 Conclusion and recommendation

The following sub-section of this research presents the conclusion and recommendations based on the results of the study. The conclusion will be discussed first.

5.3.1 Conclusion

After examining all the questionnaires and consequently, the analysis of the methodology that was used in the study, it is evident that mechanical harvesting of grapes in the Western Cape is a real and strong possibility. This dissertation investigated the economic effect of mechanical harvesting of grapes on adoption, profitability, and labour. Although some wine grape farmers already utilise mechanical harvesting of grapes, the increasing use of it throughout the province is unquestionable.

By employing mechanical harvesting of grapes based on the Cost-benefit analysis (CBA) or any technological advancement within agriculture, it will impact the investment of the project, delivery in terms of labour, and whether the machine or technology could be adopted or not.

Since there are several farmers already using mechanical harvesting of grapes, the result of this dissertation show that should the opportunity arise, many wine grape producers will be capable of adopting mechanical harvesting for harvesting grapes. The latter supports the adoption of mechanical harvesting of grapes as a profitable method for most farmers. Also, more research and studies show that the adoption of technologies and machines are becoming more evident in a global technologised environment, whether in agriculture or other industries. It is clear from the results of this study that certain criteria or requirements are needed for the economic implementation of mechanical harvesting of grapes. These requirements include the sufficient number of hectares for the production of wine grapes, as well as producing a certain number of yields, which are specific contributing factors for the mechanical harvesting of grapes. Thus, the NPV needs to be positive and needs to repay the investment in the medium term. In employing the binomial logistic regression model, the study shows that increasing hectares usage for the production of wine grapes, as well as seasonal labour wine grapes has proved significantly against the impact on the reduction of seasonal labourers. In the same binomial logistic regression model, the number of hectares for grape production, mechanisation output, permanent labour, and the cost of mechanical harvesting were all variables that did not support the hypotheses of lowering labour with an increase in mechanisation. It was found that seasonal labour and permanent labour will not be reduced when employing mechanical harvesting on an economical large wine grape farming unit.

However, the latter is not supported by all studies on technological adoption's impact on labour. This illustrates that when mechanical harvesting of grapes increases on wine grape farms in the Western Cape, it will not have a severe impact on labour reduction on these farms. In terms of the recommendations, the government would need to carefully monitor and evaluate labour on farms and put legislation in place to mitigate the effect on labour, as well as to sustainably promote mechanical harvesting of grapes.

Given the three objectives of this dissertation, it is evident that they are interlinked with each other. It is therefore important to view the outcomes coherently with each other to draw an informed conclusion, where a decisive decision can be made by the producer whether to adopt mechanical harvesting of grapes or not, based on the profitability of the investment, and the impact on labour. Many farmers and particularly wine grape producers face economic constraints, which makes it difficult to function and operate in. However, these farmers need to make important decisions on a daily bases to be profitable and sustainable. Some of these decisions include adopting to mechanical harvesting of grapes, and therefore, some answers are provided in this dissertation to inform producers better, before critical decisions are taken.

5.3.2 Recommendations

The section highlights the recommendations for policymakers, government, private stakeholders, and labour organisations that might formulate the impact of mechanical harvesting of grapes and technological advancement within agriculture. Some farmers in this study with many or few years of experience in the industry are already making use of mechanised harvesting as an adoption to more technological advance machinery. However, some farmers are not making use of mechanised harvesting because of topographical reasons.

Policymakers and government need to revise the adoption of mechanical harvesting of grapes, as well as the use of technology within the agricultural sector. Government will have to develop systems and mechanisms to address mechanisation to benefit both the producer and the labourer.

The study recommends that government should encourage producers to keep farm workers on the farm given the technological advance, by putting policies in place that prohibit the retrenchment of farmers without using mechanisation improvements as a reason for reducing labourers. Government can also incentivise producers that applied technology advancement but still kept farm workers on the farm.

The Western Cape and in particular the Cape Winelands are a wine grape production intensive region within South Africa, which has the potential to mechanise and improve technology on farms. However, it can also ensure an increase in employment within the sector. The latter recommendation could make sense because for a farm to invest in mechanical harvesting of grapes or any technological advances, it would have to grow bigger and increase its output.

Government should attempt to formulate a policy that motivates the integration of a modern agricultural system together with that of the current conventional systems. It will then inform benefits for both the producer as well as the labourers. The result will ensure profitability, but also enhance and maintain employment within the agricultural sector.

Stakeholders and wine industry organisations need to improve their data collection regarding mechanisation and new technological advancements and policies. These data, information and economic analysis need to be available on all levels within the industry and be accessible to emerging farmers. It is imperative for further research in this area to widening advice to policymakers on how to address mechanisation advances in agriculture.

5.4 Limitations and further studies

The objectives of the study were achieved. However, there were some limitations to the research. Firstly, the number of respondents that were used for the study could have been more, but due to difficulty in not getting the desired number of respondents, only those farmers that responded were used. It was difficult to get farmers to take part in the research, but those that did participate made it a little easier to complete the study.

There was also some limitation in the data collection as some producers did not share certain information due to reservation on personal and income information. Data had to be cleaned up to get a realistic indication of the data that were used for the analysis. Data analysis went through a rigorous process of fine-tuning to get a clear indication of the outcome of the objectives. There were also limitations within the area of literature for the specific outcomes of this study; an intensive effort was undertaken to align other similar studies to this research. Further studies can be conducted to determine the economic effect of mechanical harvesting in the Swartland district, which is also a wine grape growing area.

Future research can investigate the socio-economic impact of mechanisation outside farming and determine the effect within communities surrounding farming businesses. Research on the benefits for both the farming business and the labourers can be explored as mechanisation increase on wine-producing farms in the Western Cape. Research can also be conducted on how mechanisation can contribute to agro-processing and the impact thereof on employment within the Western Cape.

REFERENCES

Abbas, T., Ali, G., Adil, S.A., Bashir, M.K. & Kamran, M.A. 2017. Economic analysis of biogas adoption technology by rural farmers: The case of Faisalabad district in Pakistan. *Renewable Energy,* 107: 431-439.

Adu-Baffour, F., Daum, T. & Birner, R. 2019. Can small farms benefit from big companies' initiatives to promote mechanization in Africa? A case study from Zambia. *Food Policy*, 84:133-145.

AFGRI Agri Services. 2009. *Home page.* [Online] Available at: http://www.afgri.co.za (Accessed 14 November 2019).

Ajeigbe, H.A., Mohammed, S.G., Adeosun, J.O. & Ihedioha, D. 2010. *Farmers' guide to increased productivity of improved legume–cereal cropping systems in the savannas of Nigeria.* Ibadan. International Institute of Tropical Agriculture (IITA). Available at http://biblio.iita.org/documents/U10ManFarmersAjeigbeNothomDev.pdf-19b066d7456bd23a491c9559fd70c962.pdf (Accessed 25 May 2018).

Akinbamowo, R. O. 2013. A review of government policy on agricultural mechanization in Nigeria. *Journal for Agricultural Extension and Rural Development,* 5(8):146-53.

Arshad, A., 2012. Net Present Value is better than Internal Rate of Return. *Interdisciplinary Journal of Contemporary Research in Business*, 4(8):211-219.

Atalay, E., Phongthiengtham, P., Sotelo, S. & Tannenbaum, D. 2018. New technologies and the labor market. *Journal of Monetary Economics,* 97:48-67.

Atkinson, D., 2007. *Going for broke: The fate of farm workers in arid South Africa*, Cape Town: Human Sciences Research Council.

Barreiro, P.L. & Albandoz, J.L. 2001. *Population and sample. Sampling techniques*. Management Mathematics for European Schools. Available at https://docplayer.net/23889120-Population-and-sample-sampling-techniques.html (Accessed 14 November 2019).

Bates, T. & Morris, J. 2009. Mechanical cane pruning and crop adjustment decreases labor costs and maintains fruit quality in New York 'Concord' grape production. *HortTechnology,* 19(2):247-253.

Beukes, J. 2013. *An economic analysis of concentrator photovoltaic technology use in South Africa: A case study*. Master's dissertation, Nelson Mandela Metropolitan University.

BFAP (Bureau for Food and Agricultural Policy). 2012. *Farm sectoral determinations: An analysis of agricultural wages in South Africa*. Available at http://www.bfap.co.za/documents /research%20reports/BFAP%20farm%20sector%20determination%20report%20draft%2017 %20Dec.PDF (Assessed 25 May 2018).

Bhar, L. n.d. *Logistic regression.* New Dehli: Indian Agriculture Statistics Research Institute.

Breslin, J. 2011. *South Africa wine history*. Southern Starz Inc. http://www.southernstarz.com/images/edu_region_art/sa_wine_history.pdf (Accessed 10 August 2019).

Buckley, J. & Peterson, H.C. 2015. *Preliminary cost-benefit analysis for urban agriculture: An introduction.* Communty Food Systems Toolkit. Wisconsin State University. https://fyi.extension.wisc.edu/foodsystemstoolkit/files/2015/09/Buckley-Peterson-cost-ben-150904-more-index.pdf (Accessed 10 August 2019).

Bumbescu, S.S. & Voiculescu, A. 2014. Cost benefit analysis and its role in investment projects in agriculture. *Hyperion Economic Journal*, 2(4):44-53.

Burnstein, H. 2013. Commercial Agriculture in South Africa since 1994: Natural, Simply Capitalism. *Journal of Agrarian Change*, 13(1):23-46.

Busa, D. & Nandi, A. K. 2014. Farm Mechanisation and Rationality of Labour Use in Indian Agriculture: A Frontier Analysis of Cost of Cultivation Data. *Indian Journal of Agricultural. Economics*, 69(3):336-346.

Cape Winelands District Municipality. 2017. *4th Generation Integrated Development Plan*.

Chhun, C., Bora, B., & Sothy, E. 2015. *Effect of labour movement on agricultural mechanisation in Cambodia*. Working paper series No. 107. Phnom Penh: Cambodia Development Resource Institute (CRDI).

Claeskens, G.A., Aerts, M. & Molenberghs, G. 2003. Quadratic bootstrap method and improved estimation in logistic regression. *Statistics & Probability Letters*, 61(4):383-394.

Clingeleffer, P.R. 2013. Mechanization in Australian vineyards. *Acta Horticulturae*, 978:169-177.

College of Business Administration, University of Pittsburg. 2011. *Capital budgeting: Investment criteria*. BUSFIN 1030, Introduction to finance. Available at http://www.pitt.edu/~schlinge/fall99/l7.doc (Assessed 23 May 2018).

Corazzina, E. 2010. Agreement between producers and subcontractors for the mechanical harvest. *The Agricultural Informant*, 21:41-43.

Costantini, V., Crespi, F. & Paglialunga, E. 2018. The employment impact of private and public actions for energy efficiency: Evidence from European industries. *Energy Policy,* 119:250-267.

Creswell, J., Klassen, A., Plano Clark, V. & Clegg Smith, C. 2011. *Best practices for mixed methods research in the health sciences.,* s.l.: s.n.

Cullen, R., Warner, K.D., Jonsson, M. & Wratten, S.D. 2008. Economics and adoption of conservation biological control. *Biological Control,* 45(2):272-280.

Da Costa Neto, W. V., Izard , M. G., Elorza, P. B. & Domingues, F. 2017. First steps in the grape mechanization process in Brazil: quantitative features. *Agricultural Engineering International: CIGR Journal*, 19(2):110-119.

Daujanov, A., Groeneveld, R., Pulatov, A. & Heijman, W. J. 2016. Cost-benefit analysis of conservation agriculture implementation in Syrdarya province of Uzbekistan. *Visegrad Journal on Bioeconomy and Sustainable Development,* 5(20):48-52.

De Satge, R. 2010. Perspectives on change in the agricultural sector in the Cape Winelands District and its implications for farm workers and dwellers, s.l.: s.n.

Demalde, R. & Spezia, G. 2006. Quando conviene acquistare una vendemmiatrice. *Informatore Agrario,* 62(22):57-60.

Dixon, J.A. 2012. *Economic cost - benefit analysis (CBA) of project environmental impacts and mitigation measures: Implementation guideline,* s.l.: Inter-American Development Bank.

Djanibekov, U. & Gaur, V. 2018. Nexus of energy use, agricultural production, employment and incomes among rural households in Uttar Pradesh, India. *Energy Policy*, 113:439-453.

Domingues, F. & Del Aguila, J.S. 2016. *The cost of grape mechanical harvesting is more economical than the manual harvest?* Paper presented at the 39th World Congress of Vine and Wine. Brasil. BIO Web of Conferences 7, 01023. Available at https://www.bio-conferences.org/articles/bioconf/pdf/2016/02/bioconf-oiv2016_01023.pdf (Accessed 26 May 2018).

Duff, B. 1978. Mechanization and use of modern rice varieties. In: *Economic consequences of the new rice technology*, 145-164. Los Banos, Philippines: International Rice Research Institute. http://books.irri.org/9711040425_content.pdf (Accessed 26 May 2018).

Edwards, W. 2001. *Purchasing and leasing farm equipment*. North Central Farm Management Extension Committee. Available at https://ag.purdue.edu/commercialag/Documents/Resources/Farmland/RentalArrangements/2014_02_01_NCFMEC_Purchasing_Leasing_Machinery.pdf (Accessed 14 November 2019).

Emami, M., Almassi, M., Bakhoda, H. & Kalantari, I. 2018. Agricultural mechanization, a key to food security in developing countries: strategy formulating for Iran. *Agriculture & Food Security*, 7(24):1-12.

Esterhuizen, D. 2006. *An evaluation of the competitiveness of the South African agribusiness sector*. Doctoral thesis, University of Pretoria. Available at https://pdfs.semanticscholar.org/85b5/219712ad656b4a8ed213ed1d653b729546b4.pdf (Accessed 10 August 2019).

European Agricultural Machinery Association. 2019. Promoting Sustainable Agricultural Mechanization in Africa, s.l.: CEMA aisbl – European Agricultural Machinery Industry Association.

Fabricio, D. & Juan, S. D. A. 2016. The cost of grape mechanical harvesting is more economical than the manual harvest?. *BIO Web of Conferences 7*, 01023 (2016).

FAO (Food and Agriculture Organisation of the United Nations). 2008. *Agricultural mechanization in Africa: Time for action*. Vienna, Austria: United Nations Industrial DevelopmentOrganization.

https://www.unido.org/fileadmin/user_media/Publications/Pub_free/agricultural_mechanization_in_Africa.pdf (Accessed 5 June 2018).

Galletto, L. & Barisan, L. 2007. Economic evaluation of the alternatives to the manual harvest in Eastern Veneto. *The National Viticulture Convention in Ancona,* 14(3):270-274.

Gambella, F. & Sartori, L. 2014. Comparison of mechanical and manual cane pruning operations on three varieties of grape Cabernet Sauvignon, Merlot, and Prosecco in Italy. *American Society of Agricultural and Biological Engineers,* 57(3):701-707.

Goldammer, T. 2015. *Grape grower's handbook, A guide to viticulture for wine production*. 2nd edition. Apex Publishers. http://www.wine-grape-growing.com (Assessed 29 May 2018).

Greenspan, M. 2007. Mechanization of vineyards. The technology is there, but adoption is slow for U.S. growers. *Wine Business Monthly,* 14(11):34-36.

Grilli, G., Garegnani, G., Geri, F. & Ciolli, M. 2017. Cost-benefit Analysis with GIS: An Open Source Module for the Forest Bioenergy Sector. *Energy Procedia,* 107:175 – 179.

Hakansson, H. 2007. *Cost-benefit analysis and valuation uncertainty: Empirical contributions and methodological developments of a study on trade-offs between hydropower and wild salmon*. Doctoral thesis, Swedish University of Agricultural Sciences. Arkitektkopia, Umeå.

Hair, J., Black, W., Babin, B. & Anderson, R., 2010. Multivariate data analysis. Seventh Edition ed. s.l.:Pearson Prentice Hall.

Hall, R. 2011. *The next great trek? South African commercial producers move north.* Working Paper 19, presented at the International Conference on Global Land Grabbing, Bridgeton, UK, 6-8 April 2011. https://www.africaportal.org/documents/9292/WP19.pdf (Accessed 29 May 2018).

Haruna, I. M. & Junior, J. A. 2013. Mechanization practice: a tool for agricultural development in nigeria: a case study of Ifelodun local government area of Kwara State. *International Journal Basic Applied Science,* 2(3):98-106.

Hays, P. 2008. Status and future of vineyard mechanisation in Australia and New Zealand. *Proceedings of the Justin R. Morris vineyard mechanization symposium*, Midwest Grape and Wine Conference, Osage Beach, Missouri, February 2-3, 2008. https://mospace.umsystem.edu/xmlui/bitstream/handle/10355/2219/JustinMorrisVineyardMecahnizationSymposium.pdf?sequence=1 (Accessed 29 May 2018).

Hazarika, C. 2015. Labour scarcity in agriculture and farm mechanisation. *Indian Journal of Agricultural Economics*, 70(1):109-111.

Hilbe, J.M. 2014. Logistic regression. In: Lovric, M. (Ed.), *International encyclopedia of statistical science*. Arizona State University.

Hirschey, M. 2003. *Managerial economics*. 10th edition. Ohio: Thompson.

Hsu, R.C. 1979. Agricultural mechanization in China: Policies, problems, and prospects. *Asian Survey*, 19(5):436-449.

IGWS (Institute for Grape and Wine Science)/ 2016. *IGWS*. [Online] Available at: http://igsw.co.za/article/fact-sheet/mechanical-harvesting/10-cost-of-mechanical-harvesting-and-harvesting-by-hand.

Intrieri, C. 2006. *Italian advancements in training systems and harvesting machines to improve vintage quality*. Christchurch, s.n.

Intrieri, C. & Poni, S. 2000. Physiological response of winegrape to management practices for successful mechanization of quality vineyards. *Acta Horticulturae*, 526:33-48.

Jobaggy, J. & Findura, P. 2013. Mechanization of viticulture. 1st ed. Slovak: Slovak University of Agriculture in Nitra.

Jobbagy, J., Kristof, K., Schmidt, A., krizan, M. & Urbanovicova, O. 2018. Evaluation of the mechanized harvest of grapes with regards to harvest losses and economical aspects. Agronomy Research, 16(3):426-442.

Johnson, L.F., Roczen, D.E., Youkhana, S.K., NHemani, R. & Bosch, D.F. 2003. Mapping vineyard leaf area with multispectral satellite imagery. *Computers and Electronics in Agriculture*, 38(1):33-34.

Johnston, B.F. & Kilby, P. 1975. *Agriculture and structural transformation.* London: Oxford University Press.

Kumari, S. & Patil, Y. 2017. A conceptual framework for technology adoption towards sustainability in agro based industry. *International Journal of Innovative Research in Science, Engineering and Technology,* 6(4):2347-6710.

Lee, D-H. 2016. Cost-benefit analysis, LCOE and evaluation of financial feasibility of full commercialization of biohydrogen. *International Journal of Hydrogen Energy*, 41(7):4347-4357.

Levy, J.I., Biton, L., Hopke, P.K., Zhang, K.M. & Rector, L. 2017. A cost-benefit analysis of a pellet boiler with electrostatic precipitator versus conventional biomass technology: A case study of an institutional boiler in Syracuse, New York. *Environmental Research,* 156:312-319.

Love, J., Selker, R., Marsman, M., Jamil, T., Dropmann, D., Verhagen, J., Ly, A., Gronau, Q.F., Smira, M., Epskamp, S. Matzke, D., Wild, A., Knight, P., Rouder, J.N., Morey, R.D., & Wagenmakers, E.J. 2019. JASP: Graphical statistical software for common statistical designs. *Journal of Statistical Software,* 88(2):1-17.

Maiti, T. & Pradhan, V. 2009. Bias reduction and a solution for separation of logistic regression with missing covariates. *Biometrics*, 65(4):1262-1269.

Mamman, I. 2015. *Influence of Agricultural Mechanization on Crop Production in Bauchi and Yobe States*. Nigeria, Zaria: s.n.

Mariano, M.J., Villano, R. & Fleming, E. 2012. Factors influencing farmers' adoption of modern rice technologies and good management practices in the Philippines. *Agricultural Systems*, 110*:*41-53.

McGowan, D. & Vasilakis, C. 2019. Reap what you sow: Agricultural technology, urbanization and structural change. *Research Policy,* Volume 48:1-17.

Menon, J. & Fink, A. 2019. The Fourth Industrial Revolution and its implications for regional economic integration in ASEAN. *Journal of Asian Economic Intergration,* 1(1):32-47.

Marketing & Media News South Africa. 2013. Farm workers lose jobs after wage hike. *Bizcommunity*, 05 February. http://www.bizcommunity.com/Article/196/475/88918.html (Accessed 25 May 2018).

Meyer, F. 2013. Grain producers’ labor cost in South Africa [Telephonic interview]. 06 June, Potchefstroom, North West, South Africa.

Mila, A.L., Yang, X.B. & Carriquiry, A.L. 2003. Bayesian logistic regression of Soybean Sclerotinia stem rot prevalence in the U.S. north-central region: Accounting for uncertainty in parameter estimation. *The American Phytopathological Society*, 93(6):758-764.

Mitham, P. 2011. Mechanization of vineyards: Manual labor's difficulties push growers to mechanized work. [Onlinne] Wines & Vines Analytics. https://winesvinesanalytics.com/features/article/82327/Mechanization-of-Vineyards (Accessed 10 August 2019).

Morris, J.R. 1994. Mechanical harvesting and vineyard mechanization. https://pdfs.semanticscholar.org/a82b/7172fba322cc852d708cdf713582aec972d2.pdf (Accessed 10 August 2019).

Morris, J.R. 1996. *A total vineyard mechanization system and its impact on quality and yield*. Proceedings of the 4th International Symposium Cool Climate Viticulture & Enology, 16-20. https://pdfs.semanticscholar.org/4dc3/0c669341598e53135369f81cc4f89bcce2ea.pdf (Accessed 31 May 2018).

Morris, J.R. 2000. Past, present, and future of vineyard mechanization. *American Journal of Enology and Viticulture*, 51(4):155-163.

Morris, J.R. 2007. Development and commercialization of a complete vineyard mechanization system. *HortTechnology*, 17(4):411-420.

Morris, J.R. 2008. Commercialization of the Morris-Oldridge vineyard mechanization system. Presented at the Justin R. Morris Vineyard Mechanization Symposium, Osage Beach, Missouri, 2 February. Available https://mospace.umsystemat.edu/xmlui/bitstream/handle /10355/2219/JustinMorrisVineyardMecahnizationSymposium.pdf?sequence=1 (Accessed 31 May 2018).

Mrema, G.C., Baker, D. & Kahan, D. 2008. Agricultural mechanization in sub-Saharan Africa: Time for a new look. Agricultural management, Marketing and Finance Occasional Paper 22. Rome: Food and Agriculture Organization of the United Nations. http://www.fao.org/3/a-i0219e.pdf (Accessed 31 May 2018).

Mrema, G., Soni, P. & Rolle, R. S., 2014. *A regional strategy for sustainable agricultural mechanization: sustainable mechanization across agri-food chains in Asia and the Pacifc region,* Bangkok: FAO.

Munda, G., 2015. An Assessment of Discount Methods for Evaluating Efficiency of Investments in Education, s.l.: EUR 27589 EN.

Musa, D.S., Musa, J.J. & Ahmad, D. 2012. Mechanization effect on farm practices in Kwara state, north central Nigeria. *IOSR Journal of Engineering (IOSRJEN),* 2(10):79-84.

Narayanamoorty, A., Bhattarai, M., Suresh, R. & Alli, P. 2014. Farm mechanisation, MGNREGS and labour supply nexus: A state-wise panel data analysis on paddy and wheat crop. *Indian Journal of Agricultural Economics,* 69(3):321-334.

National Agricultural Marketing Council. 2014. Cost of wine grape production and producer profitibility. Markets and Economic Research Centre.

Nin-Pratt, A. & McBride, L. 2014. Agricultural intensification in Ghana: Evaluating the optimist's case for a Green Revolution. *Food Policy,* 48:153-167.

Nolte, K. & Ostermeier, M., 2017. Labour Market Effects of Large-Scale Agricultural Investment: Conceptual Considerations and Estimated Employment Effects. *World Development,* 98:430-446.

Olaoye, J.O. & Rotimi, A.O. 2010. Measurement of agricultural mechanization index and analysis of agricultural productivity of farm settlements in Southwest Nigeria. *Agricultural Engineering International: CIGR Journal,* 12(1):125-134.

Owombo, P.T., Akinola, A.A., Ayodele, O.O. & Koledoye, G.F. 2012. Economic impact of agricultural mechanization adoption: Evidence from maize farmers in Ondo State, Nigeria. *Journal of Agriculture and Biodiversity Research*, 1(2):25-32.

Papendiek, F., Tartiu, V.E., Morone, P., Venus, J. & Hönig, A. 2016. Assessing the economic profitability of fodder legume production for Greene Biorefineries – A cost-benefit analysis to evaluate farmers profitability. *Journal of Cleaner Production,* 112(5):3643-3656.

Park, H.A. 2013. An introduction to logistic regression: From basic concepts to interpretation with particular attention to nursing domain. *Journal of Korean Academy of Nursing*, 43(2):154-164.

Paul, J., Sierra, J., Causeret, F., Guindé, L. & Blazy, J. 2017. Factors affecting the adoption of compost use by farmers in small tropical Caribbean islands. *Journal of Cleaner Production,* 142(4):1387-1396.

Pezzi, F. 2013. Reduce cost without penalizing product quality. *Il Corriere Vinicolo*. 6 October. Available at http://www.uiv.it/archiviohtml/ridurre-i-costi-senza-penalizzare-la-qualita-del-prodotto/ (Assessed 31 May 2018).

Pezzi, F. & Martelli, R. 2015. Technical and economic evaluation of mechanical grape harvesting in flat and hill vineyards. *American Society of Agricultural and Biological Engineers,* 58(2):279-303.

Potter, D. 2005. A permutation test for inference in logistic regression with small- and moderate-sized data sets. *Statistics in Medicine,* 24(5):693-708.

PricewaterhouseCoopers, 2015. *The South African wine industry insights survey,* s.l.: PricewaterhouseCoopers.

Qiao, F. 2017. Increasing wage, mechanization, and agriculture production in China. *China Economic Review,* 46(C):249-260.

Rabie, P.A. & Marcus, E. 2018. *The 2018 Vintage: A Watershed Year for the South African Wine Industry,* s.l.: VinPro Production Plan survey.

Ramaila, M., Mahlangu, S. & Du Toit, D. 2011. *Agricultural productivity in South Africa: Literature review*. Directorate: Economic Services, Production Economics Unit. Available at https://www.daff.gov.za/docs/GenReports/AgricProductivity.pdf (Accessed 14 November 2019).

Raut, N., Sitaula, B.K., Vatn, A. & Paudel, G.S. 2011. Determinants of adoption and extent of agricultural intensification in the central mid-hills of Nepal. *Journal of Sustainable Development*, 4(4):47-60.

Reddy, A.A., Rani, C.R. & Reddy, G. 2014. Labour scarcity and farm mechanisation: A cross state comparison. *Indian Journal of Agricultural Economics*, 69(3):347-358.

Reid, J.F. 2011. The impact of mechanisation on agriculture. *The Bridge on Agriculture and Information Technology,* 41(3):22-29.

Republic of Rwanda. Ministry of Agriculture and Animal Resources. 2013. Strategic plan for the transformation of agriculture in Rwanda Phase III. Kigali: Ministry of Agriculture and Animal Resources. Available at http://www.amis.minagri.gov.rw/documents/strategic-plan-transformation-agriculture-rwanda-phase-iii#main-content (Accessed 14 November 2019).

RSA (Republic of South Africa). National Planning Commission. 2011. *National Development Plan 2030 – Our future make it work*. Pretoria: The Precidency.

RSA (Republic of South Africa). Department of Agriculture, Forestry and Fisheries. 2014. *Abstract of Agricultural Statistics*. Pretoria: Directorte Statistics and Economic Analysis. Available at http://www.daff.gov.za /Statistics %20and%20Economic%20Analysis /Statistical% 20Information/Abstract%202014.pdf (Assessed 18 September 2018).

Rotz, S., Gravely, E., Mosby, I., Duncan, E., Finnis, E., Horgan, M., LeBlanc, J., Martin, R., Neufeld, H.T., Nixon, A., Pant, L., Shalla, V. & Fraser, E. 2019. Automated pastures and the digital divide: How agricultural technologies are shaping labour and rural communities. *Journal of Rural Studies,* 68:112-122.

Ruttan, V.W. 2002. Productivity growth in world agriculture: Sources and constraints. *Journal of Economic Perspectives,* 16(4):161-184.

Saayman, L. & Middelberg, S.L. 2014. The effect of higher wages on production cost and mechanization: A South African maize sector study. *The Journal of Applied Business Research,* 30(2):341-352.

SAWIS (South African Wine Industry Information and Systems). 2009. *Macro-economic impact of the wine industry on the South African economy (also with reference to the impacts on the Western Cape).* Final Report. Compiled by Conningarth Economists, Pretoria. http://www.sawis.co.za/info/download/Macro_study_2009.pdf (Assessed 5 June 2018).

SAWIS (South African Wine Industry Information and Systems). 2015. *SA Wine Industry Statistics Nr. 39*. Paarl. South Africa. Available at http://www.sawis.co.za/info/download/stats/2015/July/Eng/files/assets/common/downloads/publication.pdf (accessed 14 November 2019).

SAWIS (South African Wine Industry Information and Systems). 2016. *SA Wine Industry Statistics Nr. 40*. Paarl. South Africa. Available at http://www.sawis.co.za/info/download/Book_2016_engels_final_web.pdf (Assessed 24 May 2018).

Sperandei, S., 2014. Understanding logistic regression analysis. Biochemia Medica, 24(1):12-18.

Sherry, S. 2013. Farming mechanization: Not an easy switch. *Financial Mail*, 50, 28 June – 3 July.

Simalenga, T. 2000. Entrepreneurship in mechanized agriculture technology oriented operations. *Agricultural Mechanisation Journal (AMA)*, 31(3):61-88.

Singh, G. 2006. Estimation of a mechanisation index and its impact on production and economic factors: A case study in India. *Biosystems Engineering*, 93(1):99-106.

Singh, J. 2006. Scope, progress and constraints of farm mechanization in India. In: Indian Agricultural Statistics Research Institute (Eds.), *Status of farm mechanization in India*. New Delhi: Indian Council of Agriculture Research, pp. 48-56.

Schmitz, A. & Moss, C. B. 2015. Mechanized agriculture: machine adoption, farm size, and labor displacement. *AgBioForum*, 18(3):278-96.

Sedgwick, P. 2015. Multistage sampling, London: BMJ Publishing Group Ltd 2015.

State of South African Wine Industry. 2019. *Smaller Streamline Ready to Go*, s.l.: s.n.

Statistics South Africa. 2012. *South African statistics, 2012.* Available at http://www.statssa.gov.za/publications/SAStatistics/SAStatistics2012.pdf (Assessed 18 September 2018).

Steyerberg, E.H., Harrell, F.E. Jr., Borsboom, G.J.J.M., Eijkemans, M.J.C., Vergouwe, Y. & Habbema, J.D.F. 2001. Internal validation of predictive models: Efficiency of some procedures for logistic regression analysis. *Journal of Clinical Epidemiology*, 54(8):774-781.

Sweet, S. & Martin, K. 2011. Data analysis with SPSS: A first course in applied statistics.. Fourth Edition ed. s.l.:Pearson publisher.

Tangvitoontham, N. & Chaiwat, P. 2012. Economic feasibility evaluation of government investment project by using cost benefit analysis: A case study of domestic port (Port A), Laem-Chabang Port, Chonburi Province. *Procedia Economics and Finance,* 2:307-314.

Thomsen, M. & Boen, C. 2008. The economics of vineyard mechanization. *Proceedings of the Justin R. Morris vineyard mechanization symposium*, Midwest Grape and Wine Conference, Osage Beach, Missouri, February 2-3, 2008. https://mospace.umsystem.edu/xmlui/bitstream/handle/10355/2219/JustinMorrisVineyardMecahnizationSymposium.pdf?sequence=1 (Accessed 24 May 2018).

Tudisca, S., Di Trapani, A. M., Sgroi, F. & Testa, R. 2013. The cost advantage of Sicilian wine farms. *American Journal of Applied Sciences,* 10(12):1529-1536.

Uddin, M. N., Bokelmann, W. & Entsminger, J. S. 2014. Factors Affecting Farmers' Adaptation Strategies to Environmental Degradation and Climate Change Effects: A Farm Level Study in Bangladesh. *Climate,* 2: 223-241.

Ugur, M. & Mitra, A. 2017. Technology adoption and employment in less developed countries: A mixed-method systematic review. *World Development,* 96:1-18.

Van der Bruggen, B., Goossens, H., Everard, P.A., Stemgée, K. & Rogge, W. 2009. Cost-benefit analysis of central softening for production of drinking water. *Journal of Environmental Management*, 91(2):541-549.

Vallone, M., Alleri, M., Bono, F. & Catania, P. 2019. Quality evaluation of grapes for mechanical harvest using vis NIR spectroscopy. *AgricEngInt: CIGR Journal*, 21(1):140-149.

Van Rensburg, H. 2016. Origin and development of mechanical pruning. Stellenbosch: Institute for Grape and Wine Sciences. Available at http://igws.co.za/article/fact-sheets/mechanical-pruning/1-origin-and-development-of-mechanical-pruning (Accessed 14 November 2019).

Van Roy, V., Vertesy, D. & Vivarelli, M. 2018. Technology and employment: Mass unemployment or job creation? Empirical evidence from European patenting firms. *Research Policy,* 47(9):1762-1776.

Verma, S.R. 2008. Impact of agricultural mechanization on production, productivity, cropping intensity income generation and employment of labour. In: Indian Agricultural Statistics

Research Institute (Eds.), *Status of farm mechanization in India*. New Delhi: Indian Council of Agriculture Research.

Vinpro. 2016. *Cost guide 2016/17*. Paarl: VinPro Agricultural Economic Services.

VinPro Agricultural Economic Services. 2017. *Cost Guid 2017/18,* s.l.: Vinpro.

Vinpro. 2018. *Cost guide 2018/19*. Paarl: VinPro Agricultural Economic Services.

Visser, M. & Ferrer, S. 2015. *Farm Workers' Living and Working Conditions in South Africa: key trends, emergent issues, and underlying and structural problems*. Pretoria: The Pretoria Office of The International Labour Organisation.

Vivarelli, M. 2012. *Innovation, employment and skills in advanced and developing countries: A survey of the literature*. Discussion Paper Series IZA DP No. 6291. Bonn, Germany: Institute for the Study of Labor. Available at http://ftp.iza.org/dp6291.pdf (Accessed 14 November 2019).

Vivarelli, M. 2013. Technology, employment and skills: An interpretative framework. *Eurasian Business Review,* 3:66-89.

Wang, X., Yamauchi, F. & Otsuka, K., 2016. Wage Growth, Landholding, and Mechanization in Chinese Agriculture. *World Development*, 86:30-45.

Western Cape Government. 2014. *Western Cape provincial profile*. Report WCPP2014. Compiled by the Agricultural Economic Services: Marketing and Agribusiness. Available at http://webapps.daff.gov.za/AmisAdmin/upload/Western%20Cape%20Provincial%20Profile%20-%2005Aug14.pdf (Assessed 18 September 2018).

White, D.S., Labarta, R.A. & Leguı´a, E.J. 2005. Technology adoption by resource-poor farmers: considering the implications of peak-season labor costs. *Agricultural Systems,* 85:183-201.

Whittemore, A.S. 1997. Multistage sampling designs and estimating equations. *Journal of the Royal Statistical Society: Series B (Statistical Methodology)*, 59(3):589-602.

Williams, C. 2007. Research methods. *Journal of Business & Economic Research,* 5(3):65-72.

Wium, A.M. & Louw, B. 2018. Mixed-methods research: A tutorial for speech language therapists and audiologists in South Africa. *South African Journal of Communication Disorders*, 65(1):2225-4765.

WOSA (Wines of South Africa). 2017a. *Overview*. [Online] Available at: http://www.wosa.co.za/The-Industry/Overview/ (Accessed 14 November 2019).

WOSA (Wines of South Africa). 2017b. *Statistics*. [Online] Available at: http://www.wosa.co.za/The-Industry/Statistics/World-Statistics/ (Accessed 14 November 2019).

Yang, M. 2003. *Study on Agricultural Mechanization and the Enhancement of Agricultural International Competitiveness in China.* Doctoral thesis, China Agricultural University, Beijing, China.

Yuan, Z. 2016. *Agricultural mechanization in West Africa,* s.l.: Syngenta Foundation for Sustainable Agriculture.

Zhang, M., Duan, F. & Mao, Z. 2018. Empirical study on the sustainability of China's grain quality improvement: The role of transportation, labor, and agricultural machinery. *International Journal of Environmental Research and Public Health,* 15(2):271-393.

Appendix A

QUESTIONNAIRE

Vraelys / ***Questionnaire***

Afdeling A. Sosio-ekonomiese, ekonomiese en produksie-inligting oor die boerderybedryf. ***Section A. Socio-economic, economic and production information about the farming business*****.**

Beantwoord asseblief die vrae hieronder en, waar nodig, dui die toepaslike opsie aan met 'n (X) / *Please respond to the questions below, and where required, indicate the appropriate option with an (X)*

Vrae aan die boer of produsent. / *Questions to the farmer or producer*.

1. Wat is u ouderdom? / *What is your age*?

   ………………………………….

2. Wat is u geslag? / *What is your gender*?

a)	Manlik / *Male*	
b)	Vroulik / *Female*	

3. Wat is u huwelikstatus? / *What is your marital status?*

a)	Enkellopend / *Single*	
b)	Getroud / *Married*	
c)	Wedewee / *Widowed*	
d)	Geskei / *Divorced*	

4. Wat is u huishoudelik grootte (hoeveel persone bly by u)? / *What is the size of your household (how many persons are living with you)*?

   …………………………………………….

5. Wat is u hoogste kwalifikasie? / *What is your highest qualification*?

   ……………………………………………

6. Hoeveel jaar ondervinding het u in hierdie boerdery? / *How many farming experience in years do you have in this type of farming*?

   …………………………………………

7. Hoeveel permanente arbeiders is op die plaas? / *How many permanent labourers are on the farm*?

   …………………………………………

8. Hoeveel seisoenarbeiders word gedurende die jaar op die plaas gebruik? / *How many seasonal labourers are used on the farm during the year*?

…………………………………………

9. Dui asseblief die plaas se bronne van inkomste aan. / *Please indicate the farms' sources of income*.

…………………………………………

10. Hoeveel hektaar word gebruik vir die produksie van wyndruiwe? / *How many hectares are used for the production of wine grapes*?

…………………………………………

11. Wat is die gemiddelde opbrengs van druiwe in ton per jaar? / *What is the average yield of grapes in tons per year*?

………………………………………..

12. Wat is die gemiddelde netto boerdery inkomste per hektaar per jaar wanneer arbeiders gebruik word vir oes? / *What is the average net farming income per hectare per year for wine grapes using labourers for harvesting*?

a)	R 35 000.00	
b)	R 40 000.00	
c)	R 45 000.00	
d)	R 50 000.00	
e)	R 55 000.00	
f)	R 60 000.00	
g)	R 65 000.00	
h)	R 70 000.00	
i)	R 75 000.00	
j)	R 80 000.00 and more	

13. Wat is die gemiddelde netto boerdery inkomste per hektaar per jaar wanneer masjinerie gebruik word vir oes? / *What is the average net farming income per hectare per year for wine grapes using machinery for harvesting*?

a)	R 35 000.00	
b)	R 40 000.00	
c)	R 45 000.00	
d)	R 50 000.00	
e)	R 55 000.00	
f)	R 60 000.00	
g)	R 65 000.00	
h)	R 70 000.00	
i)	R 75 000.00	
j)	R 80 000.00 and more	

14. Wat is die gemiddelde netto boerderyinkomste per hektaar per jaar wanneer masjinerie en arbeiders gebruik word vir oes? / *What is the average net farming income per hectare per year for wine grapes using machinery and labourers for harvesting*?

a)	R 35 000.00	
b)	R 40 000.00	
c)	R 45 000.00	
d)	R 50 000.00	
e)	R 55 000.00	
f)	R 60 000.00	
g)	R 65 000.00	
h)	R 70 000.00	
i)	R 75 000.00	
j)	R 80 000.00 and more	

15. Het die plaas toegang tot krediet? / *Does the farm have access to credit*?

a)	Ja / *Yes*	
b)	Nee / *No*	

Rede/
Reason…………………………………………………………………………………………
…………………………………………………………………………………………………

16. Word die plaas adviseer deur bedryfskonsultante of voorligtingsbeamptes? / *Is the farm advised by industry consultants or extension officers*?

a)	Industrie konsultante / *Industry consultants*	
b)	Voorligting beamptes / *Extension officers*	
c)	Beide / *Both*	

17. Hoe ver is die plaas van die mark (uitvoer, plaaslike of beide) afstand? / *How far is the farm from the market (export, local or both) distant*?

………………………………………….

18. Het die plaas die opleistelsel vir meganiese oes? / *Does the farm have the trellis system for mechanical harvesting*?

a)	Ja / *Yes*	
b)	Nee / *No*	

Rede/
Reason…………………………………………………………………………………………
…………………………………………………………………………………………………

19. Het die plaas die geskikte topografie om die druiwe meganies te oes? / *Does the farm have the suitable topography for harvesting grapes mechanically*?

a)	Ja / *Yes*	
b)	Nee / *No*	

Rede/
Reason……………………………………………………………………………………………
……………………………………………………………………………………………………

20. Het die plaas toegang tot meganiese oes van druiwe? / *Does the farm have access to mechanical harvesting of grapes*?

a)	Ja / *Yes*	
b)	Nee / *No*	

Rede/
Reason……………………………………………………………………………………………
……………………………………………………………………………………………………

21. Dui die plaassituasie aan op die volgende aktiwiteite? / *Indicate the farm situation on the following activities*?

Beskrywing / *Description*	**Ja / *Yes***	**Nee / *No***	**Verduidelik hulle indien ja / *Explained them if yes***
Buite-boerdery aktiwiteite / *Off-farm activities*			
Eie grond / *Owned land*			
Marktoegang / *Market access*			
Familie arbeid / *Family labour*			
Besproeiingstoegang / Irrigation access			
Kunsmistoegang / *Fertiliser access*			

Afdeling B: Inligting oor praktyke en metodes gebruik vir die oes van druiwe

***Section B: Information on practices and methods used for harvesting grapes*.**

Vrae aan die boer of produsent. / *Questions to the farmer or producer*.

1. Gebruik die boerdery 'n meganiese oesmasjien of arbeiders of albei vir die oes van druiwe ? / *Is the farm using a mechanical harvester or labourers or both for harvesting grapes*?

a)	Meganiese oesmasjien / *Mechanical harvester*	
b)	Arbeiders / *Labourers*	
c)	Beide / *Both*	

2. Indien a) in Vraag 1 beantwoord is, maak die plaas gebruik van van 'n self-aangedrewe of trekker-trek tipe meganiese-oesmasijien? / *If a) is answered in Question 1, is the farm using a self-propelled or tractor drawn type of mechanical harvester?*

a)	Self-aangedrewe / *Self-propelled*	
b)	Trekker-trek tipe / *Tractor-drawn*	

3. Hoe lank duur dit om die druiwe-oesseisoen te voltooi? / *How long does it take to complete the grape harvesting season*?

……………………………………weke/maande / *weeks/months*

4. Wat is die masjien oes uitset (ton) vir die oes van druiwe in 'n uur op die plaas? / *What is the machine harvest output (tons) for harvesting grapes in an hour on the farm*?

a)	4 ton/uur / tons/hour	
b)	5 ton/uur / tons/hour	
c)	6 ton/uur / tons/hour	
d)	7 ton/uur / tons/hour	
e)	8 ton/uur / tons/hour	
f)	9 ton/uur / tons/hour	
g)	10 ton/uur / tons/hour	
h)	11 ton/uur / tons/hour	
Ander / other	……………. ton/uur / tons/hour	

5. Wat is die gemiddelde arbeids-uitset (ton) vir die oes van druiwe in 'n uur op die plaas? / *What is the average labour output (tons) for harvesting grapes in an hour on the farm*?

a)	4 ton/uur / tons/hour	
b)	5 ton/uur / tons/hour	
c)	6 ton/uur tons/hour	
d)	7 ton/uur / tons/hour	
e)	8 ton/uur / tons/hour	
f)	9 ton/uur / tons/hour	
g)	10 ton/uur / tons/hour	
h)	11 ton/uur / tons/hour	
Ander / other	……………. ton/uur / tons/hour	

6. Hoeveel arbeiders kan 1 ton druiwe in een uur oes? / *How many labourers can harvest 1 ton of grapes in one hour*?

……………………………………….

7. Wat is die gemiddelde koste om druiwe meganies per uur te oes? / *What is the cost for harvesting grapes mechanically per hour?*

a)	R 75.00	
b)	R 120.00	
c)	R 165.00	
d)	R 210 and more	
Ander / other	R…………………………	

8. Wat is die gemiddelde totale arbeidskoste vir die oes van druiwe per dag per arbeider? / *What is the cost of labour for harvesting grapes per day per labourer*?

a)	R 138.51	
b)	R 169.30	
c)	R 200.08	
d)	R 230.86 en meer / *and more*	
Ander / other	R…………………………	

9. Wat is die gemiddelde man-ure per ton vir die oes van druiwe? / *What are the average man-hours per ton for harvesting grapes?*

a)	6 ure / *hours*	
b)	7 ure / *hours*	
c)	8 ure / *hours*	
d)	9 ure / *hours*	
e)	10 ure / *hours*	
f)	11 ure en meer / hours and more	

10. Wat is die gemiddelde masjien duur vir die oes van druiwe per hektaar? / *What is the average machine duration for harvesting grapes per hectare*?

……………………………………………ure / *hours*

11. Wat is die gemiddelde arbeider/grondverhouding per 10 hektaar op die plaas? / *What is average labour land ratio per 10 hectares on the farm*?

a)	3 werkers / workers:10ha	
b)	4 werkers / workers:10ha	
c)	5 werkers / workers:10ha	
d)	6 werkers / workers:10ha	
e)	7 werkers / workers:10ha	
f)	8 werkers / workers:10ha	
g)	9 werkers / workers:10ha	
h)	10 werkers / workers:10ha	
i)	11 werkers / workers:10ha	
Ander / other	R…………………………	

12. Word produksiepraktyke beïnvloed deur die effek van droogte? / *Are production practices influenced by the effect of drought*?

a)	Ja / Yes	
b)	Nee / No	

Rede/
Reason………………………………………………………………………………………………
………………………………………………………………………………………………

13. Watter tipe impak het droogte op die boerderyonderneming? Merk relevante afdelings. / *What impact does drought have on the farming enterprise? Mark relevant sections.*

a)	Minder opbrengs / *Less yield*	
b)	Minder grondwater / *Less soil water*	
c)	Verlies van inkomste / *Loss of income*	
d)	Swak druifkwaliteit / *Poor grape quality*	
e)	Swak plantgesondheid / *Poor plant health*	
f)	Beskadiging van grondstruktuur / *Damaging of soil structure*	
g)	Risiko om nie krediet te kry van finansiële instansies / *Risk of not obtaining credit from financial institutions*	
h)	Kan lei tot afleggings van werkers / *Can lead to workers being discharged*	

14. Word produksiepraktyke beïnvloed deur die effek van waterskaarste? / *Are production practices influenced by the effect of water scarcity*?

a)	Ja / Yes	
b)	Nee / No	

Rede/
Reason……………………………………………………………………………………………
………………………………………………………………………………………………

15. Watter impak het waterskaarste op die boerderyonderneming? Merk relevante afdelings. / *What impact does water scarcity have on the farming enterprise? Mark relevant sections*.

a)	Minder water vir besproeiing / *Less water for irrigation*	
b)	Beperking op munisipale gebruik / *Limit on municipal use*	
c)	Minder water vir huishoudelike gebruik / *Less water for household use*	
d)	Beperking op boerdery uitbreiding en groei / *Limit farm expansion and growth*	
e)	Verlaag produksie van gewasse / *Decrease production on crops*	

16. Is daar aksie geneem om aan te pas by droogte en waterskaarste? / *Have action been taken to adapt to drought and water scarcity*?

a)	Yes	
b)	No	

17. Indien ja geantwoord in Vraag 16, watter stappe is gedoen om aan te pas by droogte en waterskaarste? Merk relevante afdelings. / *If answered yes in Question 16, what actions been taken to adapt to drought and water scarcity? Mark relevant sections.*

a)	Het fasiliteite vir stoor bv. watertenke / *Have facilities for storage, for example, water tanks*	
b)	Maak gebruik van grondwater / *Make use of ground water*	
c)	Maak gebruik van herwinbare water / *Make use of recycled water*	
d)	Maak gebruik van watermetings / *Make use of water metering*	
e)	Tegnologie vir effektiwiteit vir besproeiings doeleindes / *Technology for efficient use of irrigation consumption*	
g)	Beperking op daaglikse huishoudelike gebruik / *Restrict daily use of water by households*	
h)	Het versekering op droogte en waterskaarsheid / *Have insurance on drought and water scarcity*	
i)	Vermindering van die hoeveelheid wingerd / *Reduce the number of vineyards*	
j)	Bou van nog ‘n dam op die plaas? / *Building another dam on the farm*	
k)	Verandering van boerderyvertakking / *Change of farm enterprise*	
l)	Besproeiingsopsies / *Irrigation options*	
m)	Diversifikasie op die plaas / *Farm diversification*	
n)	Implementering van droogtebestande kultivars / *Implementation of drought resistant cultivars*	
o	Ander / Other	

Beleidsaspekte / *Policy aspects*

18. Hoeveel jare van erge droogte het die boerdery ervaar? / *How many years of severe drought have the farm experienced*? _______________

19. Spesifiseer die droogte jare in volgorde van prioriteit (bv. 2000, 2005 en 2014, 2015, 2016) / *Specify the drought years in order of priority (for example 2000, 2005 and 2014, 2015, 2016)*
____
____

20. Wat verwag jy van die regering ten opsigte van droogteverligting? / *What do you expect from government in terms of drought relief*?
____
____

21. Dui die rol van die regering aan op droogtevermindering / droogteverligting: / *Indicate the role of government on drought reduction /drought relief:*

Stelling / *Statement*	**Ja/*Yes***	**Nee/*No***	**Verduidelik indien ja / *Explained if yes***
Regerings het ons suksesvol deur droogte in die verlede gelei / *Governments have successfully led us through drought in the past*			
Die regering is geïnteresseerd in droogtekwessies en -impakte in ons gemeenskap / *Government is interested in drought issues and impacts in our community*			
Regering lei die gemeenskap op, gee kennis en vaardighede om effektief beheer van droogte te gee / *Government train the community, give knowledge and skills to effectively take charge of drought*			
Die regering bied befondsing vir landboudoeleindes / *Government provide funding for agricultural purposes*			
Die regering stel ons in kennis van nasionale / streeksdroogtebeleide of inisiatiewe wat ons gemeenskap kan beïnvloed / *Government inform us of national/regional drought policies or initiatives that may impact our community*			
Die regering voorsien hulpbronne wat ons nodig het om droogte te hanteer (bv. voere, water, kospakkette) / *Government provides resources we need to cope with drought (for example Fodder, water, food parcels)*			
Ek vertrou die regering om ons te lei as daar weer droogtegevaar is / *I trust government to lead us in the event that there is drought hazard again*			

22. Hoe het vorige droogte jou sosiale aktiwiteite / sielkundige stres beïnvloed? / *How did previous drought affect your social activities/psychological stress*?

a)	Geen effek / *No effect*	
b)	Matige effek / *Moderate effect*	
c)	Erge effek / *Severe effect*	

23. Het u skuld? Verduidelik die skuldsituasie? / *Do you have debt? Explain the debt situation*?

a)	Ja / *Yes*	
b)	Nee / *No*	

a)	Sukkel jy om jou skuld te betaal gedurende droogte / *Are you struggling to repay your debt during drought*	
b)	Droogte verhoog die skuldvlak op die plaas / *Drought increase level of debt on the farm*	
c)	Dit is moeilik om krediet te kry tydens droogte / *It is difficult to get credit during drought*	

24. Wat is die skuldvlak van die plaas min of meer? / *What is the debt level of the farm more or less*?

....%

25. Wat is die bronne van droogte vroeë waarskuwing? / *What are the sources of drought early warning*?

	Beskrywing / Description	**Stem saam / *Agree***	**Stem nie saam nie / *Disagree***
a)	Department van Landbou, Vissery en Bosbou / *Department of Agriculture Fishery and Forestry*		
b)	Hoor by ander / *Word of mouth*		
c)	Boerderygenootskap / *Farmers Association*		
d)	Suid-Afrikaanse Weerdiens / *South African weather service*		

26. Wat is u bron(ne) van inligting vir die volgende kategorieë? / *What is/are your source(s) of information for the following categories*?

	Beskrywing / *Description*	**Droogte vroeë waarskuwing *Drought Early warning***	**Produksie / *Production***	**Mark inligting / *Market information***
a)	Koerant / *Newspaper*			
b)	'n Radio / *A radio*			
c)	'n Televisie / *A television*			
d)	Internet / *Internet*			
e)	Voorligters / *Extension officers*			
f)	Bedryfskonsultante / *Industry consultants*			
g)	Gemeenskapsleier / *Community leader*			
h)	Buurman/vriend/familie / *Neighbour/friend/family*			
	Ander/Other			

27. Watter gewasmeganismes gebruik u boerderyonderneming tydens droogte? / *What cropping mechanisms does your farming enterprise get/make use of during drought*?

	Beskrywing / *Description*	
a)	Besproeiingsopsies / *Irrigation options*	
b)	Boerderydiversifikasie / *Farm diversification*	
c)	Implementering van droogtebestande gewasse/kultivars / *Implementation of drought resistant crops/cultivars*	
d)	Ander / *Others*	