The 3Ps (Profit, Planet, and People) of sustainability: A South African grape and wine perspective

by

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Thesis presented in partial fulfilment of the requirements for the degree of
Master of Science in Agriculture (Sustainable Agriculture)

at

Stellenbosch University
Sustainable Agriculture, Faculty of AgriSciences

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December 2021

Declaration

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Summary

Ever since the discovery of the environmental impacts of modern production in agriculture, sustainability and sustainable production has been at the forefront of efforts to reduce the external pressures on the system. The initial focus of the sustainability model was only on the environment and was later expanded to include the economic and social dimensions as evidenced in the millennium and sustainable development goals of the United Nations.

Industrial agricultural production produces its fair share of greenhouse gas emissions. However, the grape and wine sectors were traditionally not considered environmentally demanding. Regardless of this increased interest in sustainability and sustainable production, the question remains: What does sustainability mean? How to measure and achieve it? It is still hotly debated which is open to various subjective interpretations. This project was aimed at studying the three pillars of sustainability equally and together in the grape and wine sector in South Africa. The objectives of the project were to: (i) evaluate what sustainability and its three pillars mean and how climate change is affecting these three pillars, (ii) determine context-specific indicators for the three pillars of sustainability and (iii) finally assess the feasibility of balancing the three pillars in a farm.

The results of the first objective showed that sustainability is still highly subjective as all the respondents defined it differently and the environmental dimension still dominated their perceptions of sustainability in its importance, but they considered the social dimension the most difficult to achieve. In terms of climate change, extremes like drought, temperature and rainfall variations affected profits and the gains seen in other wine-producing countries are not present in South Africa. With regards to the environment, water demand was severely increasing irrigation pressure followed by increased reliance on chemicals for pest control. Spill-over effects of the economic dimension affected the social dimension in terms of limited work opportunities and stagnant wages for workers.

The results of the second objective showed that economic indicators selected as relevant speak to the precarious situation of grape and wine farmers. The environmental indicators considered relevant were interesting given that actual practices were different given various regional environmental contexts. While the social dimension showed that respondents believe in improving the welfare of workers but are limited in what they can do to improve this dimension given the economic situation of many farms.

The final objective showed that even though combined improved environmental and social practices reduced the profitability of farms, only improved social practices had the least effect. This showed that even significant improvement in the social dimension did not have to impact the bottom line of farms adversely. However, these results should be interpreted with caution as it involves simulating a complex system.

Finally, as this study was exploratory, more research is needed in terms of more diverse participants (foreign retailers and consumers), more rounds of indicator selection and simulating the entire farm and not just the production process.

Opsomming

Sedert die ontdekking van die omgewingsimpak van moderne produksie, is volhoubaarheid en volhoubare produksie aan die voorpunt van die pogings om die eksterne druk op die sisteem te verminder. Die aanvanklike fokus van volhoubaarheids model op slegs die omgewing is later uitgebrei met die ekonomiese en sosiale dimensies soos blyk uit die millennium en doelwitte vir volhoubare ontwikkeling van die Verenigde Nasies.

Industriële landbouproduksie produseer sy billike deel van kweekhuisgasvrystellings. Die druiwe- en wynsektore is egter tradisioneel nie as omgewingsvereiste beskou nie. Ongeag hierdie verhoogde belangstelling in volhoubaarheid en volhoubare produksie, bly die vraag: Wat beteken volhoubaarheid? Hoe om dit te meet en te bereik? Daar word steeds hewig gedebatteer wat oop is vir verskeie subjektiewe interpretasies. Hierdie projek was daarop gemik om die drie pilare van volhoubaarheid gelyk en saam in die druiwe- en wynsektor in Suid-Afrika te bestudeer. Die doelwitte van die projek was om: (i) te evalueer wat volhoubaarheid en sy drie pilare beteken en hoe klimaatsverandering hierdie drie pilare beïnvloed, (ii) konteksspesifieke aanwysers vir die drie pilare van volhoubaarheid te bepaal en (iii) uiteindelik die haalbaarheid om die drie pilare in 'n plaas te balanseer.

Die resultate van die eerste doelwit het getoon dat volhoubaarheid steeds hoogs subjektief is aangesien al die respondente dit verskillend gedefinieer het en die omgewingsdimensie steeds hul persepsies van volhoubaarheid in die belangrikheid daarvan oorheers het, maar hulle beskou die sosiale dimensie as die moeilikste om te bereik. Wat klimaatsverandering betref, het uiterstes soos droogte, temperatuur en reënval variasies die wins beïnvloed en die winste wat in ander wynproduserende lande gesien word, is nie in Suid-Afrika teenwoordig nie. Wat die omgewing betref, het die vraag na water die besproeiingsdruk ernstig verhoog, gevolg deur 'n groter afhanklikheid van chemikalieë vir plaagbeheer. Oorspoel-effekte van die ekonomiese dimensie het die sosiale dimensie beïnvloed in terme van beperkte werksgeleenthede en stagnante lone vir werkers.

Die resultate van die tweede doelwit het getoon dat ekonomiese aanwysers wat as relevant gekies is, spreek tot die benarde situasie van druiwe- en wynboere. Die omgewingsaanwysers wat as relevant beskou is, was interessant gegewe die werklike praktyke wat verskillend was gegewe verskeie streeksomgewingskontekste. Terwyl die sosiale dimensie getoon het dat respondente glo in die

verbetering van die welsyn van werkers, maar is beperk in wat hulle kan doen om hierdie dimensie te verbeter gegewe die ekonomiese situasie van baie plase.

Die finale doelwit het getoon dat selfs al het gekombineerde verbeterde omgewings- en sosiale praktyke die winsgewendheid van plase verminder, slegs verbeterde sosiale praktyke die minste effek gehad het. Dit het getoon dat selfs beduidende verbetering in die sosiale dimensie nie die onderste lyn van plase nadelig hoef te beïnvloed nie. Hierdie resultate moet egter met omsigtigheid geïnterpreteer word aangesien dit die simulering van 'n komplekse stelsel behels.

Ten slotte, aangesien hierdie studie verkennend was, is meer navorsing nodig in terme van meer diverse deelnemers (buitelandse kleinhandelaars en verbruikers), meer rondtes van aanwyserkeuse en die simulering van die hele plaas en nie net die produksieproses nie.

This thesis is dedicated to my late parents.
I wish they were here to see and reap the fruits of their hard-earned labour.

Acknowledgements

I wish to express my sincere gratitude and appreciation to the following persons and institutions:

- First and foremost, God almighty and his son Jesus Christ, for all love, care, protection, and provision all the duration of my MSc programme.
- My family and friends back home for all their prayers and support especially during the trying times of the research project and the programme.
- My co-supervisors: Dr Keesstra and Dr Hoffmann for their guidance and input all through the various stages of the research project.
- The management of Elim and Toni Tresdam for all their support and provision.
- Prof Dzama for providing financial assistance in the second year of my MSc programme.
- Mrs Malgas and Dr Phiri for all their guidance, advice, and mentorship all through the duration of the programme.
- Mrs Julia Harper, Anneke Muller, and Lee Saul for all their assistance in all academic matters all through the programme.
- The management and team at IPW, WIETA, VinPro, SATI and SIZA for all their knowledge, assistance and experience provided for this research project.
- Emma Bruwer and the management of Springfield wine estate for rallying around social media and assisting with my data collection and providing other relevant data and support.
- Mr Arno Mathyser for providing input, guidance, and data regarding the Robertson wine region.
- My MSc Sustainable Agriculture cohorts: Jabulani, Elsje, Mpho, Philasande, Mikhail, Dolly, Charity, and Taylor for all their assistance and support for the duration of our programme.
- I saved the best for last. My unending gratitude goes to my supervisor, Dr Blancquaert for all her guidance, mentorship, input, care, advice, patience, provision and assistance during the research project and the entire duration of my MSc programme. She has been unbelievably amazing, providing succour during trying times, going beyond the provisions of her duty, providing worldwide networking opportunities, and striving to bring out the best in me. Her belief in me has been one of my driving passions. She is the model of what supervisors should be. She has been wonderful, so much so that there are no words to describe what she means to me. Trying to describe what she has done for me is a fool’s errand. She simply is the best…….

Preface

This thesis is presented as a compilation of 6 chapters and 3 appendices. Each chapter is introduced separately, and referencing was done according to the style of the South African Journal of Enology and Viticulture except for chapter 2 which was published in the journal, *Sustainability*.

Chapter 1	**General Introduction and project aim**
Chapter 2	**Literature review** The 3Ps (Profit, Planet, and People) amidst climate change. A South African grape and wine perspective.
Chapter 3	**Research results I** Exploring stakeholders' perceptions of sustainability and climate change in grape and wine production in South Africa
Chapter 4	**Research results II** An exploratory participatory approach to developing sustainability assessment indicators for grape and wine production in South Africa
Chapter 5	**Research results III** Exploring the feasibility of the three pillars of sustainability: A wine farm case study
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Chapter 1

General introduction and Project aim

Chapter 1: General Introduction and Project aims

1.1 INTRODUCTION

Agricultural production increased, amongst other things, due to the increasing population (Woodhouse, 2010). The subsequent productivity resulted in an increasing reliance on synthetic inputs (herbicides, pesticides, and fertilizers) and mechanization (Altieri, 1992; Wojtkowski, 2006). Despite the advantage of an increase in food production, this resulted in unintended consequences such as soil erosion, pollution of water bodies, and biodiversity destruction amongst other things in the natural environment (Kendall & Pimentel, 1994; Dordas, 2009).

With increasing knowledge about the deleterious effects of modern agriculture, the United Nations created the World Commission on Environment and Development (WCED), which was also called the Bruntland Commission, named after the chairman of the commission (Keeble, 1987). This commission was tasked with coming up with a plan for sustainable development for the year 2000 and afterwards (United Nations, 1983). The commission in its report to the United Nations came up with one of the first definitions of sustainability and sustainable development. They defined sustainable development as "development that ''meets the needs of the present without compromising the ability of future generations to meet their own needs" (United Nations, 1987). Over time, the recommendations from the Brundtland report have been embraced by the United Nations first in the form of the 2015 Millennium Development Goals (MDGs). The MDGs existed from 2000 to 2015 and comprised of 8 development goals that ranged from poverty and education to health outcomes, environmental sustainability and global partnerships. Although many viewed the MDGs as the beginning of the step in the right direction, it was criticized amongst other things, for its limited scope, insufficient information for comparable performance analysis (UNGA, 2015). In 2015, the United Nations adopted the current 2030 Sustainable Development Goals (SDGs). These SGDs are a set of goals with universal consensus to end poverty and hunger, preserve everything that makes Earth hospitable and ensure that there is peace and prosperity for everyone now and in the future. The SDGs consist of 17 goals that are wider in scope and more detail-oriented than the MDGs, for example in looking at the main causes of poverty, the importance of a type of development that works for all people, involves goals to combat inequalities, human settlement, ecosystems, climate change, sustainable production and consumption, peace, and justice. Furthermore, the SDGs applies to all the countries in the World, unlike the MDGs that focused on developing countries only. Finally, there is a more directed focus on implementations of the goals (Morton *et al.*, 2017)

Over the years, different definitions of sustainability have risen as various researchers have embedded their definitions with different assumptions (So¨derbaum, 2011; Koohafkan *et al.*, 2012), to the extent that there is no one worldwide accepted definition of sustainability (Wei *et al.*, 2009; Ohmart, 2011). However, one of the widely accepted notions of sustainability adapted from the Bruntland report is the "Triple Bottom Line" or the "Three Pillars" (Elkington 1998) concept. This approach posits the idea that sustainability only occurs when there is significant responsibility towards the economic, environmental, and social aspects (Elkington, 1998). In other words, in this school of thought, an organization can only be sustainable if it is economically viable (profit), environmentally safe (planet) and socially responsible (people). Significant achieving towards this triple bottom line is usually viewed as changes along all three pillars simultaneously rather than one single that can be done (Peterson, 2013). However, sustainability as a concept is complex (Espinosa *et al.*, 2008; Dantsis *et al.*, 2009) and the three pillars are usually at odds with one another (Niles, 2013). Furthermore, the concept of sustainability is made even more complex by the difficulty in selecting between value-based and science-based and a lack of consensus about the exact location of farm boundaries (Ohmart, 2011). Consequently, many of the assessment methods for sustainability has focused on the environmental aspect (Binder and Feola, 2013) and the economic aspect to a lesser degree (Gray, 1992), while assessment methods that encompass the social aspect and/or all three pillars of sustainability are few and far between (Rigby *et al.*, 2001; Bélanger *et al.*, 2012). Finally, the lack of agreement about sustainability and how to measure it has not only led to a deluge of sustainability definitions, sustainability indicators and assessment methods but most importantly, an absence of comparability between sustainability assessment methods (Santiago-Brown *et al.*, 2015a)

Grapes are the 3rd most valuable horticultural crop in the world with a value of US$68 billion in 2016 which accounts for 7.4 million hectares of arable land planted with grapevine (Alston & Sambucci, 2019; OIV, 2019). These vineyards are used for: (i) wine production (57%), (ii) table grapes (36%) and (iii) dried grapes (raisins) (7%). Therefore, it has become an important sustainability concern as grape and wine-producing areas are very important for landscape preservation, tourism, and rural development (Soosay *et al.*, 2009; Tesco 2011). Sustainability has become an important concept in the grape and wine industries, especially in South Africa for reasons ranging from export legislation compliance, consumer's interests, market access and stakeholders' pressure (Hamman *et al.*, 2017).

South Africa is still among the largest producers and exporters of table grapes (6%) and wine (4.9%) in the world (OIV, 2019; Gbejewoh et al., 2021). However, exports have since plateaued since its high between 1994-2004 (Moseley, 2008). At the same time, there has been increasing competition from other grape and wine-producing countries for market share coupled with pressure from mainly consumers for more environmentally and socially sustainable products (Schaufele & Hamm, 2017;

BFAB, 2019; Produce Report, 2020). This has placed producers in an increasingly untenable position because a majority of farms are barely profitable (VinPro, 2020). This has prompted many to wonder if South African grape and wine farms can truly be sustainable. Indeed, the notion of sustainability being a "wicked problem" – a problem that cannot be solved, only managed – (Rittel and Weber, 1973; Conklin 2006) succinctly captures the dilemma of the South African grape and wine industries.

Consequently, this research project aimed to understand the sustainability of grape and wine production in the context of the three pillars of sustainability. The specific objectives of the research project were to:

- Objective 1: Define what sustainability means to the stakeholders of grape and wine production in South Africa.
- Objective 2: Determine appropriate and context-specific indicators for sustainability assessment of grape and wine production in South Africa.
- Objective 3: Assess the possibility of achieving the three pillars of sustainability in a case study wine farm in South Africa.

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Chapter 2

Literature Review

The 3Ps (Profit, Planet, and People) of sustainability amidst climate change. A grape and wine perspective

This manuscript was published in Sustainability 2021, 13, 2910.
https://doi.org/10.3390/su13052910

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Review

The 3Ps (Profit, Planet, and People) of Sustainability amidst Climate Change: A South African Grape and Wine Perspective

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Abstract: Conventional agriculture has made the search for sustainability urgent, more so with regards to climate change. This has extended to the grape and wine industry, an important industry in South Africa in terms of labor employment and foreign exchange. This paper aims to review the current state of knowledge with regards to the three pillars of sustainability and with regards to climate change. In order to understand sustainability in South Africa, a historical context is needed, because the welfare of farm workers still retains vestiges of past Apartheid. Ecological responsibility and higher profits are the main reasons for sustainable practices. Additionally, water use, chemical use, and soil erosion are important environmental sustainability concerns. With regards to climate change, in terms of economic sustainability, there will be winners and losers and social sustainability issues will intensify as changes occur in farms. Table grape producers are relatively more profitable than wine grape producers. Furthermore, pest, disease, irrigation pressure will worsen as the climate warms. However, there are long- and short-term adaptation strategies such as changes in viticulture practices and grape cultivars, respectively, to stem the effects of climate change, but this may be stymied by cost and farmers' perceptions of climate change.

Keywords: sustainability; dimensions; global change; South Africa; table grape; wine grape

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Citation: Gbejewoh, O.; Keesstra, S.; Blancquaert, E. The 3Ps (Profit, Planet, and People) of Sustainability amidst Climate Change: A South African Grape and Wine Perspective. *Sustainability* **2021**, *13*, 2910. https://doi.org/10.3390/su13052910

Academic Editor: Riccardo Accorsi

Received: 23 January 2021
Accepted: 22 February 2021
Published: 8 March 2021

1. Introduction

There has been an increased contemporary awareness about the environmental impacts of agricultural production and consumption; since the 1960s, agriculture has relied largely on synthetic chemicals (fertilizers, herbicides, and pesticides) and mechanization to achieve increased levels of production at the least possible cost [1,2]. This period, known as the "green revolution", while it increased food production, brought detrimental consequences to the world's natural resources [3]. Consequently, sustainability and sustainable development from the Brundtland Report "Our Common Future" [4] and the 1992 Rio Conference on sustainable development was placed at the center of international, national, and regional agendas [5]. Presently, there are many policies, agendas, and strategies that aim to transition to sustainable development at different levels for general or specific levels of activities, from the United Nations Sustainable Development Goals [6], to the European Union Green Deal [7], to African Union's "Agenda 2063—The Africa we want" [8], to various national and regional policy agendas.

Sustainability has become a very important word in the world today. However, a single universal definition has so far been out of reach [9]. One of the first definitions was provided by the United Nations as it formed the World Commission for Environment and Development (WCED). Their definition was: "sustainable development is the development that meets the needs of the present without compromising the ability of future generations to meet their own needs" [4]. However, since then different definitions have emerged, but it has since been a multidimensional concept built upon economic, environmental, and social principles [10,11] or the "triple bottom line" approach [12]. In the vision of the Sustainable Development Goals of the United Nations, true sustainability needs to address sustainability in the bio-physical environment, but also in the socio-economic environment. Solutions must be found in combining the needs for all three domains: biosphere, society, and economy [13].

The calls for sustainability have never been greater in the agro-food industry to address the environmental impacts and resource inefficiencies of the current system [14]. This call has extended to all sub-sectors of the industry, even the grape and wine industry that traditionally has not been viewed as a particularly environmentally inefficient industry [15]. Regardless, sustainability has been of great concern for the grape and wine industry particularly because of the risks associated with climate change. Numerous authors have reported on the importance of climate in grapevine physiology, growth (phenology), yield, and the subsequent fruit and wine quality [16–23].

In South Africa, sustainability and climate change are especially important concepts to the grape and wine industries because they are major contributors to the South African economy. South Africa is the seventh largest table grape exporter, commanding 6.2% of the export market share and employing almost 80,000 permanent and seasonal workers [24]. In terms of wine production, South Africa is the ninth largest wine producer (3.3% of world production), and sixth largest exporter of wine (4.9% of world exports) [25].

Considerable research has been conducted on the three individual pillars of sustainability and in the context of climate change in the South African grape and wine industry [25–30]. However, a major gap in these studies is the provision of a holistic overview of the three pillars in tandem. Consequently, this paper aims to review the state of current knowledge concerning the three pillars of sustainability in the grape and wine industry in South Africa in the context of climate change. In this review, the objective is to:

(i) analyze why sustainability is important to grape and wine farmers;
(ii) analyze current trends in the economic, environmental, and social sustainability of grape and wine production and how climate change is affecting these trends.

The framework for the analysis for the current trends in sustainability will be to discuss each pillar (economic, environmental, and social) of sustainability separately at first as a standalone concept. Thereafter, climate change will be introduced into these pillars; thus, the effects of climate change in each pillar (economic, environmental, and social) of sustainability will be further discussed separately. The outline of the paper is as follows: first, a description of the systematic review process; next is an explanation of the results of the selected papers from the review process. Thereafter, a discussion of why sustainability is important to grape and wine farmers and a historical context of grape and wine production in South Africa is provided to better understand sustainability trends in the country. Afterwards, a description of the economic, environmental, and social trends of grape and wine production in South Africa in the context of climate change. Finally, climate change adaptation strategies are discussed and areas where research is lacking and in need of further development is given.

To the best of our knowledge, this is the first review paper of its kind that focuses on all three sustainability pillars simultaneously in the context of climate change in the South African grape and wine industries.

2. Methodology

This review followed the guidelines set by PRISMA [31] for a structured review as shown in Figure 1. The review used a mixed-method approach which included quantitative and qualitative research. Web of Science and Scopus was used between April 2020 and June 2020 to obtain journal papers and conference proceedings. The search string words in Web of Science and Scopus Database were: TITLE-ABS-KEY (("sustainability*" OR "sustainability pillar*" OR "climate change*") AND ("viticulture*" OR "vineyards*" OR "wine*" OR "grape*")) There were no temporal limitations for this study. The papers were downloaded and exported to Mendeley Desktop where duplicates were immediately removed. The inclusion criteria were theoretical papers, and qualitative and quantitative studies. Book chapters, papers not in English, and conference proceedings were not considered for this review. The article titles and abstracts were screened, and papers not related to agriculture and parts of viticulture and winemaking deemed not relevant (e.g., wine chemistry, flavor chemistry, wine aroma, sensory evaluation, grapevine biology, wine microbiology, etc.) were removed. Furthermore, whole texts were analyzed and papers that dealt with other aspects of agriculture (e.g., crop and animal production) were removed except if they dealt explicitly in sustainability and climate change.

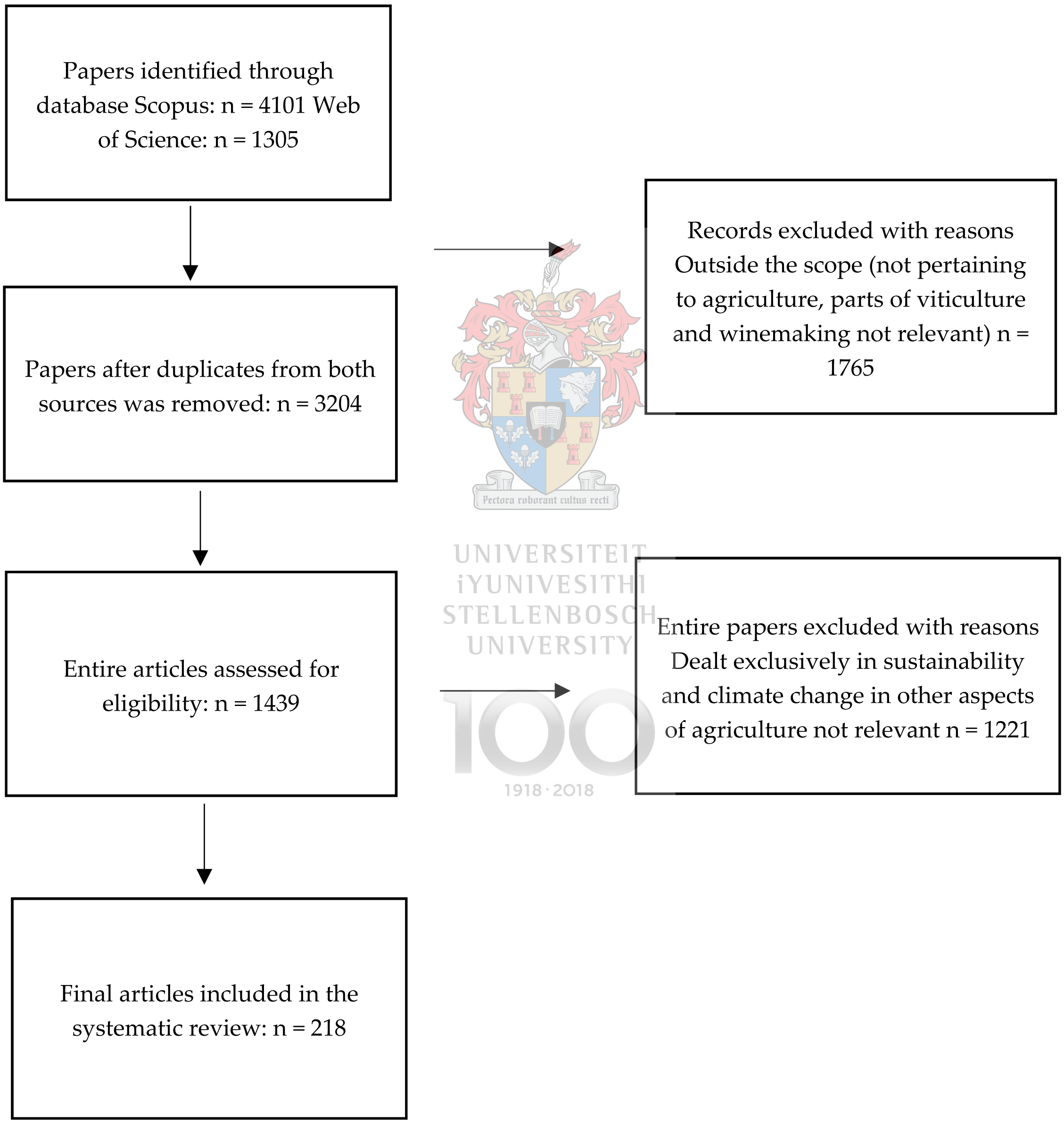

Figure 1. A PRISMA flowchart of the PRISMA systematic review process.

3. Results

An initial search of Scopus and Web of Science database yielded 4101 and 1305 papers, respectively. After duplicates were removed, this was reduced to 3204. Thereafter, after article titles and abstracts were examined, 1765 articles were excluded according to the aforementioned reasons, which reduced the number of articles to 1439. After that, the entire papers were examined and whole papers were removed according to the reasons given above. This gave a final paper count of 218. According to Figure 2, the majority of the selected papers were focused on the pillar of environmental sustainability (47.3%). This was followed by the pillar of economic sustainability (20.5%) and the pillar of social sustainability (13.2%). The number of research papers that dealt with all three pillars simultaneously was low (3.9%).

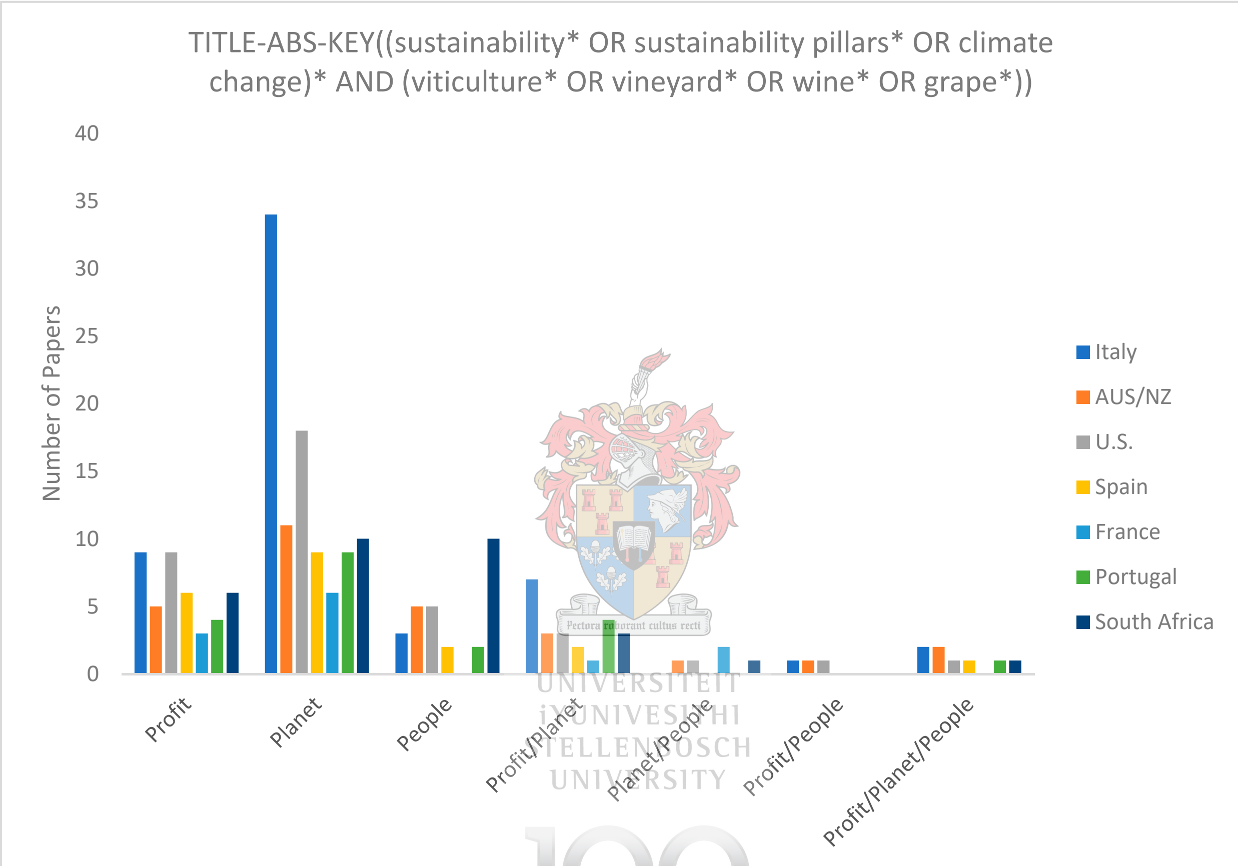

Figure 2. Bar graph showing the number of papers that dealt with the pillars of sustainability.

An overwhelming majority of the studies were conducted in Europe (Italy, France, Portugal, and Spain) followed by the United States, Australia, and New Zealand. Research in South America, Asia and Africa were abysmally low. The studies were published in a diverse range of journals, ranging from the *Journal of Cleaner Production*, *Sustainability*, *Journal of Wine Research*, *Journal of Wine Economics*, etc.

4. Discussion

4.1. Why Do Grape Farmers Become Sustainable?

Motivations for sustainability usually fall under ethical/personal/ecological responsibility, operation efficiency, marketing positioning/competitiveness, legitimacy/regulatory compliance, product quality/differentiation, higher profits, stakeholder pressure, and consumer demand [32–38]. Furthermore, business age, size, and ownership are factors that also play a role in the adoption of sustainable practices [39–41]. Hamman et al. [36] and other authors [42,43] found that in South Africa environmental responsibility is the major driver for sustainable practices and that legitimacy and competitiveness play a minor role. However, they emphasized that most sustainably proactive farms are characterized by environmental responsibility and a possible competitive edge. It was also reported that small- and medium-scale enterprises and family-owned businesses are more environmentally proactive, because managers can translate their personal environmental beliefs to organizational practices due to the high degree of control on operations [44,45] Finally, potential barriers to sustainability practices may include cost, time intensity, lack of information, abuse of the sustainability concept ("greenwashing") or a perception of how a good, well-maintained farm should look (clean and without weeds) [9,32,38,46]. Regardless, the adoption of sustainability practices usually depends on whether the perceived benefits outweigh the cost [47,48].

4.2. The Historical Context of Grape and Wine Production in South Africa

For a better understanding about sustainability in the grape and wine industry in South Africa, the historical and political context is important. Between 1917 and the mid-1990s, the regulatory system in the South Africa wine industry was presided over by the Koöperatieve Wijnbouwers Vereniging van Suid-Afrika (KWV), who instituted planting quotas, minimum prices, and methods of surplus removal, and were the sole exporter of wine. Wine production was dominated by co-operative cellars who pooled resources to sell grapes in bulk and farmers were paid according to tonnage delivered. These co-operatives were closely linked to the network of white power in the Western Cape, because rural civil society in the province was dominated by the white landed settler elites [49]. These co-operatives encouraged mass production and rewarded growers who could deliver high volumes of low-quality grapes (high sugar levels, unbalanced acids, pH, and low phenolic content—key determinants of wine quality). This orientation coupled with the imposition of international trade sanctions because of Apartheid policies in the country brought the industry to a halt, although it consequently survived through domestic consumption and exports of low-quality wine to Eastern Europe [50,51]. This mass production of grapes was dependent on cheap black labor which, until the 1980s, was characterized by racial hierarchy and authoritarian paternalism adapted from the earlier Cape slave society [52]. White settler elites controlled most of the commercial farming in the Western Cape and beyond, with values of white patriarchal mastery that shaped the relationship between farm owners and farm workers. Even with attempts in the 1980s to "modernize" labor relations (as a result of pressure on Apartheid policies) with workers' education and skill development, and even, ironically, research into fetal alcohol syndrome (which was largely caused by the "dop" or "tot" system), this notion of white mastery did not change but instead created a kind of "neo-paternalism" [53–55].

With the political transition of the early 1990s and a change in the economic and political power that had previously benefited the white elites, a slew of labor and employment legislation ranging from basic labor laws to minimum wage was passed to limit the control by farmers of workers' lives. Even though labor laws have significantly weakened the paternalist labor, it has not decisively transformed it; the state is most often too far away to enforce their laws, and farmworkers are reticent to fight for their rights because maintaining close and cordial relationships with farm owners are just as important [56].

With the lifting of trade sanctions and opening of the export markets following the political transitions of the 1990s, South African wine was thrust into an international market that was going through a lot of changes. Firstly, the global economic downturn was putting pressure on the global beverage industry, and global wine consumption was decreasing. Secondly, supermarkets were growing in importance as wine retailers which changed how wine was consumed and marketed, and lastly, was the increasing prominence of premium and super-premium branded wines and the falling prospects and consumption rates of low price, blended, and bulk wines which hitherto the country was focused on. All these had contradictory implications for producers. Although new markets meant new opportunities, these supermarkets had stringent purchasing requirements through strict phytosanitary, technical, and ethical requirements. Furthermore, deregulation and globalization meant an oversupply of wine coupled with competition within the country but also with other wine-producing countries for much sought-after supermarket contracts, placing producers at a disadvantage when bargaining with wine retailers [56]

For table grape producers, just like wine, supermarkets were becoming the dominant retailers of fresh produce. These supermarkets no longer purchased fruits in the open market but through integrated global value chains (GVCs). Supermarkets usually work with a close group of agents in the value chain to plan and preprogram their requirements annually to meet changing consumer needs. Their dominant position in the value chain allowed them to influence their agents and suppliers and exert increasing pressures on fruit growers to meet tight—albeit flexible—production schedules, and comply with quality, environmental and social standards. However, these supermarkets rarely have written contracts with suppliers that provide a guarantee of purchase, except for a verbal agreement. Furthermore, their purchase of fresh produce is mainly on a "consignment" basis, where prices are not agreed until very close to the point of final delivery. Additionally, even though they demand and dictate standards, the prices they pay are subject to the forces of demand and supply on the open market. Like wine, globalization and deregulation following the transition to a democratic government led to the dismantling of Unifruco, the single export channel of fruits. This resulted in increased competition within South Africa and between other exporting countries such as Chile, which exports fruits within the same "export window" as South Africa, leading to an oversupply and a subsequent decrease in prices [57].

Grape and wine producers consequently responded in ways that were still in their control, through the contraction, casualization, and externalization of labor [58,59]. However, it is important to note that this trend towards flexible employment is not unique to South Africa; research of the literature has emphasized the same trend worldwide, especially in the agricultural sectors of developing countries [60]. This is essential to understand the world that South African grape and wine producers entered in the early 1990s, and it is important to view any of the sustainability pillars through this lens.

4.3. Climate Change in Grape and Wine Production

Climate change is expected to impact viticulture through an increase in air temperature and a shift of the ripening period towards earlier and usually warmer parts of the season [61]. Mean temperatures for traditional viticultural zones have increased by 1.7 °C between 1950 and 2004 [62], and changes in grapevine growth and development have already been found [63–66], influencing grape yield and berry and wine quality [62,67] through a decrease in berry acidity [68,69] and increase in sugar content [63]. Furthermore, changes in temperature and rainfall patterns [70] may significantly modify viticultural zones in Europe [71,72] through severe dryness [73], organoleptic and organic acid degradation [20,64], and high potential alcohol content [74], although less modification is expected for South Africa [26,62]. Increased temperatures may also open new viticultural zones that previously were unsuitable for grape production in Northern and Central Europe [75,76], Western North America [77], and cooler and higher altitude regions in the Western Cape of South Africa [29,78].

4.4. Economic Sustainability of Grape and Wine Production

Economic sustainability in its simplest term means how farms in business stay in business. Economic sustainability is intricately linked to environmental and social pillars. Consequently, while only good economic performance might be beneficial in the short term, it is not necessarily so in the long term because neglecting the environmental and social dimensions may be a barrier to long term survival. Thus, effectively managing the environmental and social dimensions of businesses can also make farms economically sustainable [79]. Economic sustainability is usually viewed as economic viability, which means whether the farm can survive in the long term in changing economic contexts. These changes in economic contexts may be driven by changes in inputs and output prices, yields, governmental regulation, while the long term implies the entire working life of the farmer or even the working life of subsequent generations of successors of the farm. Economic viability is usually measured through profitability, stability, liquidity, and productivity [80].

However, economic sustainability sometimes extends beyond these indicators to others such as autonomy in various forms, examples are financial autonomy (less pressure from debts), diversification of income, and autonomy from subsidies [81].

Following the lifting of trade sanctions, South Africa's grape and wine exports increased four-fold between 1994 and 2004 but it has since plateaued. Additionally, tourism-related activities (tours, restaurants) have been an important source of income for South Africa's vineyards and cellars. However, South Africa's grape and wine farmers have fared better than other sectors in the agricultural economy [82]. For the last 10 years, South African wine farms have averaged a net farm income (NFI) that is less than what is required for sustainable grape production, but the situation is gradually improving. For example, in the 2018 vintage year, vineyards averaged an NFI of ZAR 14,957/ha compared to the ZAR 30,000/ha required for sustainable grape production. Moreover, for the 2019 vintage year, vineyards averaged ZAR 20,617/ha compared to the ZAR 34,000/ha required for sustainable production. However, these increases have been driven largely by yield increases, and over the past two years, this has been coupled with rising grape prices. While this is remarkable, it is also unsettling, given that future yield decreases are expected given the increasing percentage of aging and older vineyards. In fact, according to Figure 3, for the first time in 16 years, vineyards that were younger than three years old made up less than 10% of total hectares, and vineyards older than 20 years constituted over 20% of total hectares, which is contrary to the general knowledge that these figures should be 15% or more for vineyards aged three years or younger, and less than 15% for vineyards aged 20 years or older.

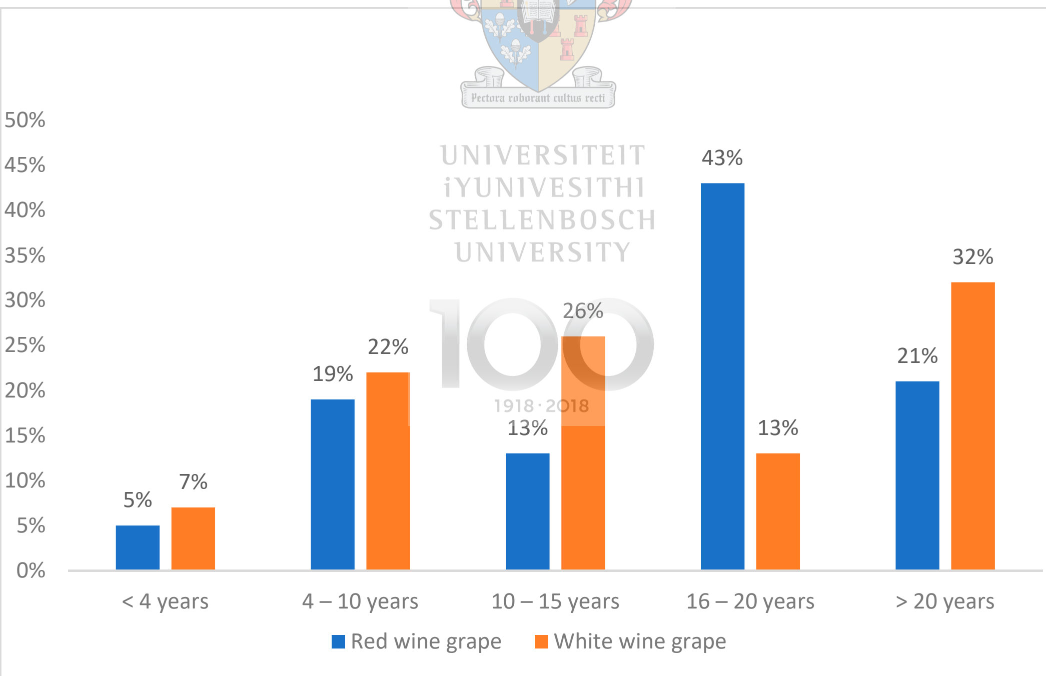

Figure 3. Age distribution of vineyards in South Africa [83].

Consequently, future increases in gross income, NFI, and profitability will largely need to come from a further increase in grape prices. However, it should be noted that the percentage of profitable vineyards (NFI > ZAR 34,000/ha) increased from 15% to 28% between 2015 and 2019, while the percentage of unprofitable vineyards decreased from 40% to 30% between 2016 and 2019 after an increase from 30% to 40% between 2015 and 2016; however, the majority of wine farms (40% in 2019) are still barely profitable, with an NFI between ZAR 20,000–34,000/ha [83]. Figures 4 and 5 show the increasing production costs of vineyards and the relatively modest profitability of vineyards in South Africa over the years.

Figure 4. Production costs of vineyards [83].

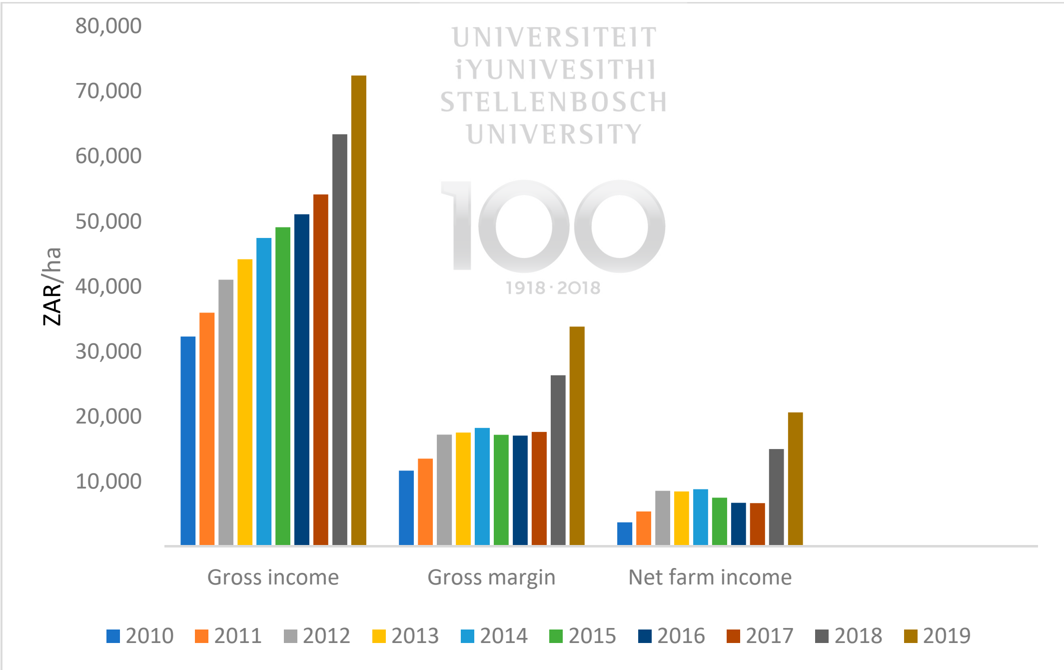

Figure 5. Profitability of vineyards on average [83].

For table grapes, the NFI income projection is roughly ZAR 46,000/ha. However, even though a projected increase in NFI is expected for table grapes, according to Table 1, the export outlook is worrying because of its dependence on the E.U. and U.K. markets. This is because even though production is expected to increase in South Africa, the population growth of the E.U. and the U.K. is worryingly slow and, in some countries, even negative, meaning that consumer demand will probably remain at current levels. Consequently, if market access is not expanded, further oversupply will be detrimental to the price of table grapes in the long term. Canada is an emerging export market to which table grape producers are looking to export, but there is also competition from other table grape producing countries looking to export there [84]. China is also another export market where South African table grape producers are looking to increase their footprint, because it has a growing economy and population with strong cultural importance for fruit consumption, complementary growing seasons, and both governments have pledged to increase bilateral trade [85].

Table 1. Regional table grape export market split 2019/2020 (4.5 kg Equivalent Cartons) [84].

Region	Export Market
European Union	31,400,602
United Kingdom	15,793,685
Canada	4,221,802
Far East	2,951, 997
Middle East	2,902,807
South East Asia	2,877,238
Russian Federation	1,193,984
Africa	877,039
United States	488,003
Indian Ocean Islands	275,262
Other	190,457

4.5. Economic Sustainability in Climate Change of Grape and Wine Production

The economic consequence of climate change on grape and wine as shown in Table 2 is generally hard to predict because variability is large, and the climate change process is non-linear [86]. Nemani et al. [87] showed that the increased temperature associated with climate change was an advantage to the wine industry in California, because frost occurrence reduced by 20 days and the frost-free period increased by 65 days. Adams et al. [88] corroborated these results, with a 90% and 65% increase in yield with and without CO_2 fertilization, respectively. However, a decreased yield for table grapes and relatively stable yields for wine grapes with increased temperature have also been shown [89]. Regardless, continued global warming may turn any possible gains into definite losses [90].

Higher yields are usually correlated with reduced wine quality [91]. However, even though this negative relationship between yield and quality is true most of the time [91], it is not always the case [92,93]. Furthermore, wine quality is also related to alcohol content, because higher temperature produces sweeter and stronger wines [91]. Even though many viticultural regions have been trending towards higher alcohol content, climate change is not fully responsible for this trend; consumer preferences and viticultural practices also play significant roles [93,94]. Wine quality has also been associated with higher prices. Alston et al. [95] showed a 61.6% increase in wine prices with a corresponding 1 °C increase in growing season temperature in Bordeaux. Similar results were found by Jones and Storchmann [96] and Chevet et al. [97]. These results may hold for cooler regions [91] but for warmer regions, there is a maximum peak in prices with regards to increased temperature, above which further increases in temperature reduces prices [98,99]. Based on current literature, evidence shows that there will be both winners and losers from climate change [91].

Table 2. Interaction of key economic sustainability indicators with temperature.

Economic Indicator	Temperature
Yield	90% and 65% increase in vine yield with and without CO_2 fertilization, respectively, corresponded with 3 °C increase in temperature [88]
Wine quality	0.23% increase in Brix levels per year between 1980 and 2005 [91]
Revenue	150–180% increase in revenue with a 3 °C increase in temperature [91]
Price	61.6% increase in price with 1 °C increase in temperature [95]

4.6. *Environmental Sustainability of Grape and Wine Production*

Grape and wine production have been subject to less regulation compared to other industries such as the manufacturing, chemical, and mining industries [33,100]. This is probably due to the preconception of grape and wine production as environmentally safe [101]. The most important issues related to environmental sustainability as shown in Table 3 are water use efficiency, use of chemical crop protection, and soil erosion.

Table 3. Environmental sustainability concerns of grape and wine production [15].

Environmental Indicators	Environmental Concerns
Water use	Inordinate water use coupled with inaccurate and/or absent data on water use
Organic and inorganic waste	Lack of data on waste generated coupled with limited and/or absent recycling programs
Synthetic chemicals use	Excessive use of synthetic chemicals with absent data on chemical use
Energy use and greenhouse gas emissions	Energy use in addition to CO_2 generated is an often-ignored environmental concern.
Ecosystem impacts	Soil erosion, destruction of local habitats, loss of biodiversity associated with vineyard monocultures, local pollution and contamination, and competition for water resources with other aspects of agricultural production

4.6.1. Water Use Efficiency

Water is a very important resource for grape and wine production, for which usage in viticulture and winemaking can vary according to the location and size of the farm [37]. For example, water footprint can provide important information on the water use of a specific portion of the farm, and strategies can be developed from this information to improve the water use efficiency. Water use is broadly categorized as blue, green, and grey water for agricultural use [102]. Generally, water use can be categorized as direct or indirect. Direct application of water refers to the application of irrigation, fertilizers, and herbicides, while indirect water use includes water use for agrochemical dilution [102]. In wine production, direct use of water in the cellar includes the washing of equipment (before and after crushing), winemaking, cold stabilization, and sanitation, while indirect water use in the cellar includes water for chemical dilution and water for waste removal [102]. Jarmain [102] reported that table grape and wine production in South Africa showed that on average, table grapes used 619 L of water for every 4.5 kg carton (industry standard) of table grapes produced; on average, 647 L of water was used for every 750 mL of wine produced [102]. Water use can consequently have important effects on the quantity and quality of water resources. Evidence suggests that vineyard and winery managers do not know or keep data on the quantity of water used and/or wastewater generated in their organization [15]. In a South African study, 80% of wine farmers could not accurately give their water use and even underreported the exact value by as much as 60% [103]. An Australian study showed that about 5% wine farmers still used over 8 L of water to produce a bottle of wine, regardless of the fact that research on the best management practices has reported the use of 0.4 L of water [104]. Concerns with the excessive use of water in viticulture and winemaking include the contamination of surface and groundwater sources, and the inappropriate disposal of wastewater [105,106]. Practices such as the use of drip line irrigation and partial root drying have been championed [19,107], and even reduced water use has been shown to be of benefit to wineries; a Canadian study showed a 6% increase in grape yield with a 30% reduction in water use [108], while a South African study stressed the importance of remote sensing and earth observations technology for quantifying water use over large areas [102].

4.6.2. Organic and Inorganic Waste

Organic and inorganic solid waste are unavoidable consequences of grape and wine production [15] and is one of the most important environmental concerns facing the industry [105,109]. Furthermore, just like water, there are a lack of data collected by farms [106]. Organic waste includes winery effluents such as grape marc, lees, and pomace stalk, some of which have the potential for reuse while others are of practically no value [110,111]. Inorganic waste, on the other hand, includes packaging materials and used chemical containers [37]. Landfills and incinerators are popular options for organic and inorganic waste disposal, and even though there is a growing market for organic waste and success with recycling programs, there is still room for further improvement [112,113].

4.6.3. Chemical Use

Similarly to other agricultural sectors, chemical use in vineyards includes fertilizers, pesticides, and herbicides, and in some countries chemically-treated timber is used for vineyard trellising [114,115]. Chemical use in wineries includes chemicals for cleaning operations, sanitation, and wine preservation [106,113]. The chemical use in vineyards is especially disconcerting; it has been shown that although European vineyards occupy only 3% of cropland, they use 15% of all synthetic pesticide applications [116]. Furthermore, just like other agricultural sectors, chemical use in vineyards is associated with contaminated run-off, spray drift, reduced soil fertility, reduced bee populations, damage of vineyards' natural defense networks, while chemical use in wineries affects the quality of wastewater making effective treatment before disposal cumbersome [117].

4.6.4. (Un)Sustainable Agronomic Management and Resulting Soil Loss

Soil erosion is an environmental risk that is particularly severe in vineyards because of soil tillage, poor organic matter content, and climatic conditions [118,119]. Consequently, this leads to a loss of soil fertility, soil quality, and loss of ecosystem services [120]. It should be noted, however, that extensive soil loss is not limited to vineyards; different authors have reported similar problems in various other crops [121–124]. Research has suggested that soil loss in vineyards is above the level that amounts to tolerable soil loss, less so for older vineyards with more organic matter content and higher bulk density in relation to younger vineyards [125] Moreover, accurately measuring soil loss in vineyards is fraught with difficulties, because different methodologies available tend to give different results. Thus, there is a need to improve the accuracy of measurements [126]. However, research has shown that there are various practices to mitigate the effects of soil erosion such as terracing, sediment fences, check dams, grass margins, contour farming, and the use of cover crops [127,128].

4.7. Environmental Sustainability in Climate Change of Grape and Wine Production

In the context of climate change, there is concern that increased temperature associated with climate change will cause increased pest and disease pressure on crops [129–131], and these changes are already taking place [132,133]. Increased temperature may cause the increased survival of pests and diseases during warmer winters and may cause the range of pests and diseases in a region to change because pests may move to cooler regions that were previously unsuitable for their development, as evidenced by the invasive spotted wing *Drosophilia* fruit fly, native to Southeast Asia, but has increasingly been spreading to Europe and the United States. [134,135]. Although pest movement to cooler regions is more likely due to globalization than climate change [136], their increased survival in these cooler regions is probably due to milder winters [135]. On the other hand, even though the increased temperature is likely to allow more pest generations in a growing season, as evidenced by the rice strip virus transmitted by the small brown planthopper [137,138], this may be offset by the early maturity and earlier harvest dates causing asynchrony and limiting pest damage [139]. However, results like this should be viewed with caution; pests may be able to maintain their synchrony with the target host [140] or adapt, and very likely restore, this synchrony [141].

The increased threat due to climate change is the increased erratic nature of the climate. Rainfall becomes more unpredictable and more intense when the climate warms. This causes higher soil erosion rates due to increased runoff in high intensity storms and higher soil detachment rates due to increased splash erosion [127]. Increased warming with associated increased evapotranspiration and increased frequency and intensity of extreme events such as droughts, wildfires floods, and heatwaves [142] will bring increased pressure for irrigation and less reliance on precipitation, more so for old world producers than new world producers [92]. For South Africa, this situation is especially dire because the country is one of the most water-scarce countries in the world, with large areas classified as arid or semi-arid [27].

Consequently, the expected increase in irrigation and water use in vineyards and wineries is likely to bring associated risks of erosion and silting of water bodies, especially as vineyards move uphill to areas of lower temperatures [30,42,106,143], salt build-up in soils which is detrimental to vines [93], and increased competition for water and land resources from other sectors of agriculture arguably deemed more important in terms of food production [15,144], and consequently pushing grape and wine production from traditional areas to more marginal areas with fewer resources [68]. Furthermore, the fynbos region of the Western Cape of South Africa where a significant portion of grapes are grown is fire-prone, and adaptation to frequent fires is a natural feature of the fynbos vegetation [145]. Even though studies are scarce, increased frequency of wildfires is expected with climate change [26,146] with effects of increased soil erosion after a fire [147].

Finally, the prospects of vineyard relocation with further warming are expected to bring biodiversity conservation concerns [77,148] especially in the Cape Floristic region of South Africa [78], one of the biodiversity hotspots in the world [149] and a major grape and wine producing region. Even though there are programs such as the Biodiversity and Wine Initiative (BWI) in South Africa to mitigate against the impacts of vineyard expansions and possible relocation through botanical audits, plans to preserve endangered and significant species, and setting aside land for biodiversity conservation [150,151] a large number of grape and wine farms are small- and medium-scale enterprises [152] without particularly large tracts of land; therefore, a majority of the reserved areas are likely to be small scattered fragments, making a formal reserve system particularly difficult [153,154].

4.8. Social Sustainability in Grape and Wine Production

The South African grape and wine production industries were infamous for some of the worst working conditions in Apartheid South Africa, and even though conditions improved following the political transition and the passing of legislation to improve workers welfare, transformation in the grape and wine industry still lags behind other sectors [150,155]. The casualization and externalization of labor especially after the transition to a democratic government was detrimental to farm workers. Research shows that almost three million farm workers were evicted from farms between 1950 and 2004 and then rehired as seasonal and casual workers, sometimes under worse conditions than before [156]. This change in labor structure has both pros and cons in terms of workers relationships with farm owners. On the one hand, while the "firm but generous" relationship, accommodation and discounted goods and services afforded to workers were gone, these farm workers were also free to unionize more easily and fight for their rights [157].

The neoliberal economic policies of the government have made them reticent to interfere in the relationship between farm owners and farm workers, so much so that apart from the lack of manpower, the government are reluctant to enforce their own labor laws. For example, it is possible for farm owners to apply for exemption from minimum wage labor laws [158]. In cases where farm owners have had to comply with labor laws, researchers argue that this has accelerated the rate of casualization and externalization of labor [159]. For example, one study found that when minimum wage was introduced in 2003, farm workers' wages increased by 17% but agricultural employment decreased by 13% [160]. It has also been found that agricultural employment reduced by 8.3% as minimum wage was increased by 52% [161]. However, this research and arguments for less intervention in farm owners and farm worker relationships by the government belies the fact that since the opening of the export markets following the transition to democratic government, exports and the income in commercial farms have increased exponentially [158]. Farm workers has always been viewed as expendable, regardless of the economic situation of the farm owner, and that is not going to change anytime soon.

Although their research was limited to female farm workers in Western and Northern Cape, because women are more likely to be casualized and paid less, as shown in Table 4, Devereux [158] found that more than half (55%) were not aware of the sectoral determination that deductions from wages should be limited to 10% of wages; 40% had not signed an employment contract; for those that signed, more 80% of seasonal workers did not receive a copy of their contracts; 41% were paid below minimum wage, more so for those paid fortnightly and monthly and less so for those paid daily and weekly; and almost 80% of workers had had deductions from their wages (some legitimately, others less so). In addition, 63% of farm workers did not have access to bathroom facilities, 62% were compensated for injuries incurred on farms and about half (51%) of these injuries were reported to the Department of Employment and Labour, 66% of farm workers were not provided with protective clothing from pesticides when spraying, membership in unions was abysmally low at 12%, 73% of farm workers claimed that farm owners do not allow union reps on farms, and 28% claimed the farms had never been visited by labor inspectors. It should be noted that violations of workers' rights are not limited to Western and Northern Cape; similar patterns of violations have been recorded in Eastern Cape [162], Limpopo [163], North West [164], and Free State [165].

Table 4. Violations of workers' rights in vineyards and wineries [158].

Social Indicator	Province		Workers	
	Western Cape	Northern Cape	Permanent	Seasonal
Did not sign a contract	29.4%	54.2%	23.9%	52.4%
Received a copy of their contract	16.2%	60%	37.2%	17.5%
Paid minimum wage	62.4%	59.6%	73.2%	51.6%
No access to facilities	57.2%	71.1%	52.2%	72%
Compensation for injury incurred at work	61.5%	60%	64.4%	61.2%
Injury incurred at work reported to the labor department	55.2%	37.1%	64.4%	36.7%
No protective clothing at work	52.7%	74.3%	54.5	73.3%
Exposed to pesticides	45.3%	95.8%	63.5%	69%
Trade union membership	13.6%	9.9%	13.8%	9.5%
Farm owner does not allow union reps on farms	64.7%	86.6%	68.6%	76.8%
Farm owner prohibits attending union meetings	49.3%	63.4%	47.8%	60.7%

4.9. Social Sustainability in Climate Change of Grape and Wine Production

Social sustainability research has been few and far between, and research on social sustainability in climate change has been even more so. Grape and wine production has strong cultural, social, and historical ties to a viticultural zone, and the concept of terroir embodies this [166]. Consequently, climate change will have different social consequences according to different contexts. In many old world viticultural zones, where terroir holds very strong meanings, changes in grapevine varieties, viticultural practices, and even possible vineyard relocation will affect regional, cultural, and social identities [166]. Furthermore, viticulture and winemaking are significant employers of labor in many viticultural zones and may be severely affected by changes in viticultural practices and vineyard relocation [167,168]. Additionally, the capacities of grape and wine farmers to adapt to climate change are influenced by social, economic, and political circumstances [169].

4.10. Climate Change Adaptation Strategies

Regardless of the various ongoing and expected effects of climate change in viticulture and winemaking, there are various short-term and long-term adaption strategies to reduce the effect of climate change in viticulture. Short-term adaptation strategies include viticultural practices to delay ripening [170], the use of sunscreen and shade nets to protect from sunburn and extreme heat [171,172], deficit irrigation practices as a water-saving measure and to take advantage of the relationship between vine–water status and yield [173], integrated pest management practices to adapt to the possibility of increased pest pressure, and soil management practices (conservation tillage, use of compost, mulches, cover crops) for soil and plant protection, carbon storage, and reducing greenhouse gases emissions [174]. Long term adaptation strategies include changes in training systems for higher water use efficiency, lower sugar accumulation, delay of the maturation period, selection of grape varieties and rootstock to those better adapted to the expected effects of climate change, genetic breeding for the development of climate change-tolerant varieties, and finally, usually as a last resort, vineyard relocation to cooler, higher altitude, higher elevation, coastal areas, and areas with lower solar radiation [174]. However, it should be noted that adaptation strategies that do not consider the economic, social, political, and cultural constraints at the farm, regional and national level are likely to be unsuccessful [168,175,176]. Furthermore, the decision to adopt an adaptation strategy will depend upon a farm or organization's capacity to change, the perception of their vulnerability to climate change relative to other risks, and the risks and opportunities associated with adaptation [177].

4.11. Knowledge Gaps and Future Research

This review has implicitly shown that an overwhelming majority of research in sustainability and sustainability in climate change has been conducted in Western countries. However, the historical context of the country presents a unique opportunity in sustainability research. Research in sustainability has essentially tackled one pillar at a time, and research in all three pillars is abysmally low. This needs to be remedied because grape and wine farmers battle all three pillars at the same time. Revenue from grape and wine production in South Africa has plateaued ever since the initial boon; therefore, farmers are constantly making decisions between increasing profits, investing in more environmentally friendly farming practices, or improving the welfare of farm workers, and any decision pits one pillar against the other. Research in sustainability should endeavor to ensure that it should not be an either/or situation between the three pillars of sustainability, and that even though it may appear as such, one pillar does not have to be sacrificed for the other. As shown in Figure 6, research should endeavor to make sure that the aim of sustainability is less to achieve all three pillars, but more to optimally balance and reconcile all three pillars relative to the resources of the farm and in the prevailing context of the country. The South African case study has shown that any effort at any time to place one pillar ahead of another, for any reason, belies the overall sustainability of the farm, and research in sustainability should make this clear.

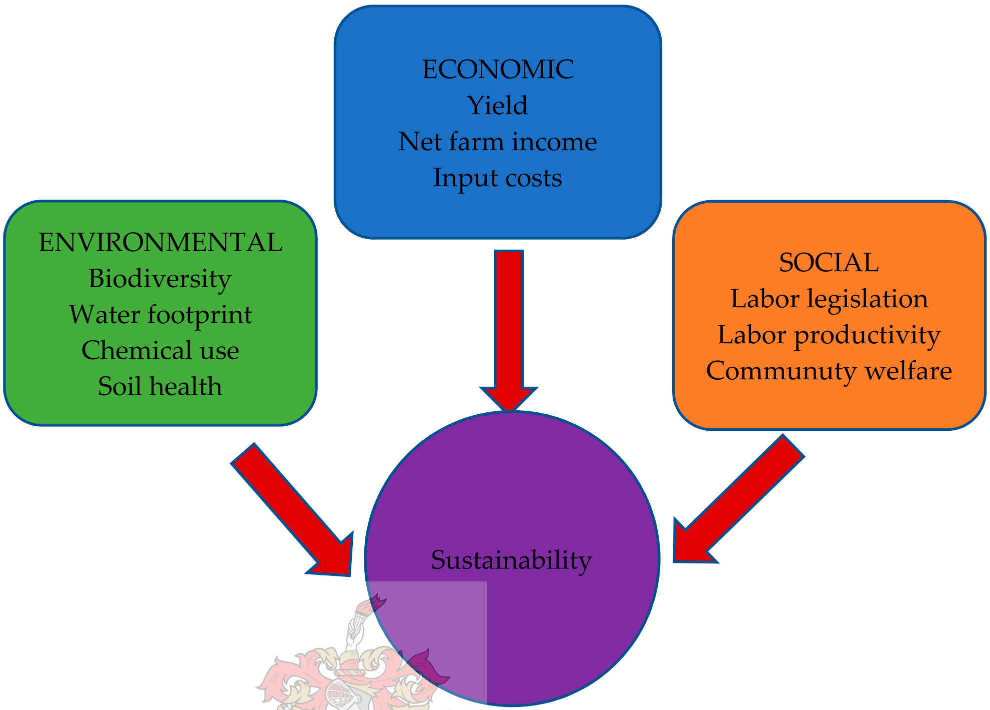

Figure 6. Graph showing the indicators of sustainability required to achieve overall sustainable grape and wine production.

Furthermore, even though there are a variety of assessment methods for the three pillars of sustainability, a comprehensive sustainability assessment of all three pillars simultaneously for the partial or entire value chain of grapes and wine are absent and sorely needed. Part of the reason for this lack of research is due to the paucity of the amount of data needed, especially for off-farm activities. Additionally, data for on-farm activities, especially for the non-productive stage of the grapevine, are not always available. This is disconcerting because it has been argued that a lack of quantitative data makes it difficult and even impossible to see and assess opportunities for improving performance and monitoring progress towards the end goal of sustainability [15]. Another reason is the lack of measurable context-specific indicators for economic, environmental, and social indicators for the South African grape and wine industry that would usually precede any sort of sustainability assessment.

In terms of the three pillars, considerable research gaps still exist. Firstly, in terms of economic sustainability for grape and wine production in the context of climate change, even though there theoretically exists a point where further increases in temperature will depress grape and wine prices, in practice, this point is not known [178]. Future research should aim to link increases in temperature with grape prices to understand where climate change starts being detrimental to grape and wine production, especially for warm category regions such as South Africa.

Regarding environmental sustainability amidst grape and wine production, only a handful of "noble" grape varieties are planted worldwide, relegating the other considerable numbers of varieties to very little limited hectares. This needs to be remedied, because many of these local or indigenous varieties may very well play a significant role in the future in the context of a warming climate; these "neglected" varieties could well be adapted to extreme and harsh climate due to years of "neglect". However, consumer acceptance of these varieties needs to be investigated simultaneously [179]. Furthermore, there is limited research on environmental problems that are very important and informative to farm managers. For example, because as detrimental as soil erosion is in all forms of crop production, research on it is still limited [180–182].

In the context of social sustainability in climate change, there is a need to assess the effectiveness of schemes such as the Wine and Agricultural Ethical Trade Association (WIETA), Fair Trade South Africa, and Sustainability Initiative of South Africa (SIZA) exclusively from workers' perspectives, because the effectiveness of these schemes are unconfirmed and largely up for debate; with the increased dominance of these schemes by retailers, the farm workers who they are supposed to support are ironically being left out of the conversation [109,112,113,183].

5. Conclusions

Sustainability has become a catch-all phrase for practically all efforts to remedy the detrimental impacts of conventional agriculture, even in the grape and wine industry that traditionally has not been viewed as a particularly environmentally impactful industry. The historical context of South Africa shows that sustainability amidst climate change is very important to the grape and wine industry, especially for reasons of environmental stewardship, higher profits, and stakeholders' pressure. Research has shown that table grape farms are more economically sustainable than wine farms, but the climate change effects on profitability is unpredictable. In addition to the inefficient use of water and chemicals, soil erosion, pest, diseases, and irrigation pressure are bound to intensify as the climate warms. Regardless of the various efforts to improve the welfare of farm workers, social sustainability at the level of the farm leaves a lot to be desired and this has no sign of changing anytime soon. However, there are various short-term (changes in viticultural practices, soil management practices and integrated pest management) and long-term (changes in training systems, changes in grape and rootstock varieties and vineyard relocation) adaptation measures to mitigate against the current and potential impacts of climate change in viticulture and winemaking, but these face barriers in adoption.

Author Contributions: Conceptualization, O.G. and E.B.; methodology, O.G.; formal analysis, O.G.; resources, O.G., S.K. and E.B.; investigation, O.G.; writing—original draft preparation, O.G.; writing—review and editing, O.G., S.K., and E.B.; visualization, S.K. and E.B.; supervision, S.K. and E.B. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Data Availability Statement: No new data were created or analyzed in this study.

Acknowledgments: The authors would like to thank Elsje Dippenaar from the Sustainable Agriculture Masters programme, Stellenbosch University, for her professional networking that laid the groundwork and that was instrumental in making this paper come to fruition.

Conflicts of Interest: The authors declare no conflict of interest.

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Chapter 3

Research Results I

Exploring stakeholders' perceptions of sustainability and climate change in grape and wine production in South Africa

Chapter 3: Exploring what sustainability means to grape and wine stakeholders

3.1 Introduction

Ever since sustainable development and sustainability was emphasized by the Brundtland Commission, it has always been a contentious topic (Wojtkowski, 2006; Espinosa *et al.*, 2008). This is mainly because sustainability as a concept is subjective and rooted in various personal ideologies and perceptions (Rinne *et al.*, 2013). As such, even though there are many accepted definitions of sustainability over the years, there has never been one universal definition that has drawn universal consensus (Wei *et al.*, 2009). However, there are a few explanations of sustainability that have drawn significant acceptance, one of which being the "triple bottom line" or "three pillars" concept proposed by Elkington (1998). This concept expanded from the Brundtland Commission's definition, proposes that sustainability is only possible when businesses show effort towards the economic, environmental, and social aspects of their production process (Elkington, 1998). This concept of sustainability has gained widespread acceptance in agriculture, especially in the field of viticulture and Oenology (Szolnoki, 2013; Gilinsky *et al.*, 2016)

Defining sustainability in the grape and wine production sectors means understanding principles, concepts, and practices (Flores, 2018). The International Organization of Wine and Vine (OIV) have provided definitions, guidelines, and general principles (OIV, 2004; 2008; 2016) for sustainable vitiviniculture. The OIV defines sustainable viticulture as a "global strategy on the scale of the grape production and processing systems, incorporating at the same time the economic sustainability of structures and territories, producing quality products, considering requirements of precision in sustainable viticulture, risks to the environment, product safety and consumer health and valuing of heritage, historical, cultural, ecological and aesthetic aspects" (OIV, 2004). With guidance from the OIV, different countries have been adapting this concept and framework to their respective countries (Flores, 2018).

Despite the imprecise nature of sustainability, the grape and wine industry has become attuned to its concerns such as climate change, water, chemical and energy use, and workers' welfare amongst other things (Gilinsky *et al.*, 2016). Furthermore, consumers are becoming knowledgeable about sustainability concerns of grape and wine production and are open to spending more for sustainable products, despite limited knowledge of what sustainability means (Sogari *et al.*, 2016; Schaufele and Hamm, 2017). In the recent Deloitte millennial report, climate change and protecting the environment ranked 3rd most important parameter (Deloitte, 2021).

This chapter, therefore, aimed to understand what the concept of sustainability and the concept of the three pillars of sustainability meant to the various stakeholders of grape and wine production in South Africa. Furthermore, this chapter aimed to find out how climate change is affecting these three pillars of sustainability and what the future holds for sustainable vitiviniculture in South Africa, should climate change continue to be a persistent concern.

3.2 METHODOLOGY

3.2.1 Study area

Grape cultivation in South Africa primarily takes place in the Western Cape with its Mediterranean climatic conditions. The Western Cape is in the southwest of South Africa and covers approximately 129,370 km^2. (Winter, 2002). The Western Cape is bordered by the Indian Ocean, Atlantic Ocean in the south and west respectively. The province of Western Cape is composed of 6 district municipalities which are West Coast, Eden, Cape Winelands, City of Cape Town, Overberg and Central Karoo. Western Cape accounts for about 11.3% of the country's population which translates to over 6.3 million people (Fanadzo *et al*., 2021). The topography is varied and complex and ranges from valleys to coastal plains and mountain ranges. The three obvious climatic regions are the South Coast, Karoo and the Mediterranean. The Mediterranean climatic region (of interest to viticulture) found in the southwestern and western part of the Western Cape, gets the majority of its precipitation during winter (May to August/September) (van Niekerk and Joubert, 2011). Even though the region has an average annual rainfall between 500mm and 150mm, higher than the average for South Africa, it is still a water-scarce region due to increasing urbanization and high-water demand for irrigation (Saldias *et al*., 2015). The average temperature ranges from 5^{o}C to 22^{o}C in the winter and 15^{o}C to 27^{o}C in the summer. The agricultural sector in the Western Cape is an important industry for the nation which includes wine grapes, deciduous fruits and vegetables. Western cape directly contributes about 3% to the national Gross Domestic Product (GDP), which is closer to 8% when the entire value chain is considered (Greyling, 2012). It accounts for over 60% of the country's agricultural exports (Murray, 2010). It is also a significant employer and seasonal and permanent labour in farming communities (Murray, 2010).

3.2.2 Research design

Research on what sustainability means for grape and wine producers in South Africa is practically non-existent (Gbejewoh *et al.*, 2021 – Chapter 2). Furthermore, sustainability research conducted in South Africa has been mainly on the environmental pillar of sustainability and only from the perspective of producers (Aslund 2013; Hamann *et al.*, 2016; Naude, 2019). However, the decision-making process of grape and wine production in South Africa is not solely in the hands of producers, but encompasses the entire value chain (academic institutions, industry professionals, governmental officials, retailers, and consumers). As a study population of the entire value chain of grape and wine production in South Africa has not been studied, explanatory theories cannot be created for this study. Consequently, an exploratory methodology was required. Given that so mare factors are unknown, it was essential to acquire many varieties and complexity of opinions within the population of the study as possible. As such, a semi-structured or open-ended questionnaire was suitable for this kind of research as it allows respondents to answer in their own words and give voice to their experiences (du Plessis, 2019).

3.2.3 Data collection instrument

A questionnaire that contained both semi-structured questions was created for this research (Appendix I). In addition to new questions, the questionnaire contained questions from previous studies done in other grape and wine-producing countries (Szolnoki, 2013; Santiago-Brown *et al.*, 2015a), but adapted to the South African context. The questionnaire was divided into three sections (Appendix I).

The first section dealt with the general information of the respondent and includes questions like job title, highest educational level, years of experience in the grape and wine industry of South Africa. Since the questionnaires were anonymous, the objective here was to get a general idea of each respondent.

The second section dealt with the perceptions of sustainability, perceptions of the three pillars of sustainability, what constitutes a sustainable farm/cellar etc. Since sustainability is a very much subjective concept, the idea here was to find out their meaning and interpretations of sustainability and its three pillars, their perceptions on the interactions and interrelationships between the three pillars of sustainability and the possibility of balancing and/or reconciling these three pillars in a farm/cellar.

The last section involved questions of the meaning of climate change, general effects of climate change in grape and wine production, how climate change was affecting the three pillars of sustainability. Even though there has been considerable research (Carter, 2006, Bonnardot and Carey, 2008) on the effect of climate change on environmental sustainability, the other pillars have been neglected. Therefore, the notion here was to assess the interactions between climate change and the three pillars of sustainability and find out what the future holds for sustainable vitiviniculture in the age of climate change.

3.2.4 Research participant selection and recruitment

As this was an exploratory qualitative study, the exact number of stakeholders in the value chain of grape and wine production in South Africa was unknown. As such, a convenience and snowball sampling procedure was employed for this research study. Potential research participants ranged from academic researchers, wine grape farmers, winemakers and cellar masters, industry professionals at VinPro and South African Table Grape Industry (SATI), sustainability certification personnel at Integrated Production of Wine (IPW), Wine and Agricultural Ethical Trading Association (WIETA), Sustainability Initiative of South Africa (SIZA) and government officials from the National Agricultural Marketing Council (NAMC). A lack of response on the surveys from table grape producers urged us to exclude them from the study. Therefore, this study only focused on wine and grape production perspectives. Participants were reached with the help of the study leader and those willing and able to participate in the study were recruited. The recruited participants were asked to recommend others that might be willing to participate in the study.

As the research participants were at the time of the study, all over the country and because of COVID-19 restrictions, face-to-face interviews were not feasible. For participants that indicated a willingness to take part in the study, an email was sent to them with details of the research project and a Uniform Resource Locator (URL) link was attached to the email that led to a Microsoft Form that contained the questionnaire. This was done between March 2021 and July 2021.

3.2.5 Data analysis

The captured research data was analysed utilizing the thematic analysis method. This method of data analysis is a general and convenient approach in examining qualitative data as its approach is recognizing patterns or themes in the data set (Wagner *et al.*, 2012). The use of the thematic data analysis method has been deemed appropriate when analyzing exploratory qualitative data (Naude, 2019).

3.2.6 Ethical considerations

Before the research commenced, ethical clearance was obtained from the Social, Behavioural and Education Research Committee at Stellenbosch University (REC-2020-15452). Per the ethical clearance, the identities of all research participants were kept secret and was only known to the research student and the supervisor. All research participants were willing and knew they had the right to withdraw from the study at any time. All data from the research project was stored in a password-protected laptop computer and backup at the researchers OneDrive folder at Stellenbosch University that is also password protected.

3.3 RESULTS AND DISCUSSION

3.3.1 Overview of Research Participants

The full list of the stakeholders in the grape and wine industry that participated in the study is described in Table 3.1. The list of stakeholders of the grape and wine industry that participated in this study were diverse and ranges from farm managers and viticulturist to winemakers and cellar masters to industry personnel at WIETA, SIZA, IPW, and SATI to wine merchants and wine marketers. The research participants all had sufficient experience in the grape and wine industry of South Africa with over half of the research participants having over 15 years of experience. Furthermore, all but two of the research participants had a minimum bachelor's degree which indicates that almost all the participants were highly educated.

Table 3.1: Description of Stakeholders of the Grape and Wine industry who participated in the study.

No	Highest Academic Qualification	Years of Experience	Job Title	Affiliation
1	Bachelors	18	Head of Wine and Viticulture	Farm
2	Masters	11	Junior Lecturer	Academia
3	Bachelors	6	Winemaker	Farm
4	Bachelors	6	Assistant winemaker	Farm
5	Bachelors	37	Cellarmaster	Farm
6	Masters	25	Technical Manager	Industry
7	Diploma	20	Marketing Assistant	Industry
8	Diploma	22	General Farm Manager	Farm
9	Bachelors	11	Winemaker	Farm
10	Bachelors	31	Group Viticulturist	Farm
11	Bachelors	20	Viticulturist/Senior Farm Manager	Farm
12	Masters	4	Environmental specialist	Farm
13	Diploma	26	General Farm Manager	Farm
14	Bachelors	15	Wine Accountant	Industry
15	Masters	16	Wine Merchant	Industry
16	Bachelors	15	CEO	Industry
17	Bachelors	20	PR, Wine judge and educator	Industry
18	Masters	15	Senior Economist	Government
19	Doctorate	13	Chief Economist	Government

3.3.2 Perceptions of Sustainability and its three pillars

Although different stakeholders participated in this research, there is still conformity concerning the responses. This section summarizes the results of the interviews using similar themes (see the data analysis subheading of the Methodology section) to give common answers.

Sustainability has always been a contentious concept, largely because its meaning and importance is subjective and open to various interpretations depending on the views, beliefs, and ideations of the respondents (Bebbington *et al*., 2007; Rinne *et al*., 2013). Our research shows that is the case as the participants all defined sustainability differently. A word cloud that was created from a word frequency is shown in figure 3.1 below.

"(Sustainability is) something (that) is able to be maintained at a certain rate or level" (Participant 6)

"*To put it in simple terms, that we can still be farming in 50 to 100 years from now*" (Participant 10).

"*Sustainability describes a state of being that allows processes and activities to continue into the future in the same way as it is now (or even in an improved way)*" (Participant 12).

Ohmart (2011) said that if you put 50 farmers in a room and ask them what sustainability means to them, you are going to get 50 different answers and our research confirmed this point of view. Sustainability is a complex concept, and this complexity seems to be the point of contention in defining it and therefore the lack of a universal and consensual definition (Dantsis *et al*., 2009; Casini *et al*., 2010). Gabzdylova *et al*. (2009) found that in New Zealand individual interests has a hand in how sustainability is perceived and eventually practised. While Szolnoki (2013) found sustainability to be a very peculiar and subjective term. Furthermore, there is no clear-cut way of saying what specific practice is sustainable or not. In that sense, what we believe is sustainable is what we think will be beneficial for the planet years from now.

Regardless of the various definitions of sustainability given by the research participants, it was found that the environment was at the forefront of the perceptions of sustainability.

"*Firstly; farming practices that are kind to nature and which focus on maintaining natural habitats and ecosystems amidst farming activities (environmental sustainability) Secondly: farming that is financially viable (financial sustainability)*" (Participant 2)

"*Sustainability towards our natural resources. using little to create a lot*" (Participant 3)

"*Farming for the next generations to come, ticking all the boxes of being beyond green. Striking the balance between nature and product*" (Participant 5)

This confirmed the findings of previous research that sustainability perceptions have focused on the environment and to a lesser extent, the economy (Santiago-Brown *et al*., 2015a). The environmental dimension has always been the focus of sustainability and sustainability practices (Saltiel *et al*., 1994). This focus largely came about because of the inherent conflict between finite natural resources and sustainable development (Darnhofer *et al*., 2010). For example, early instances of sustainability efforts like the Low Input Sustainable Agriculture (LISA) in the 1980s that focused on the limited use of synthetic inputs by using environmentally-based practices (Brouwer and Crabtree, 1999) and carbon footprints assessments which involves reducing carbon emissions with regards to climate change and the scarcity of natural resources (Koohafkan *et al*., 2010).

Figure 3.1: A word cloud of word frequency for the three pillars of sustainability.

With increased criticism about the focus on only the environmental pillar of sustainability, other dimensions were gradually being recognized. Consequently, Elkington (1998) defined the three-pillar concept of sustainability. As stated earlier, this widely accepted concept of sustainability espouses the view that sustainability is only possible when an effort is put towards the economic, environmental, and social dimensions of sustainability. However, respondents that defined sustainability using all three pillars were few and far between.

"*It refers to the long-term impacts of all activities on "people, planet, and profit" and the mitigation and offset of these activities to limit the negative and improve on the positive outcomes*" (Participant 11).

"*Considered use of a finite resource with a long-term vision - looking at environmental, economic, and social systems*" (Participant 15).

"*Meeting the social, environmental, and economic resource needs of the present without compromising those three needs for future generations*" (Participant 16).

This agrees with the findings of Santiago-Brown *et al*. (2015a) explained that perceptions that involved all three pillars of sustainability are rare. Consequently, regardless of the increased recognition of the economic and social dimension of sustainability, the environmental dimension is still the more prominent dimension. This is largely because the Brundtland report (UN, 1987) that popularized the concept of sustainability and from which every other definition of sustainability came from, focused mainly on the environmental pillar. As a result, this perception of the outsized importance of the environmental dimension of sustainability has been hard to shake.

Elkington (1998) defined the three-pillar concept of sustainability and explained that all three pillars are equally important for achieving sustainability. However, this has not been the case as some pillars have been deemed more important than others with regards to the push for sustainability (Santiago-Brown *et al*., 2015b).

"*Environmental sustainability. It is the largest of the three and sustains the other two pillars. In an ideal world, with considered and responsible environmental management, social and economic sustainability should follow*" (Participant 15).

"My experience lies mostly within the Planet pillar of sustainability. I believe that if the planet pillar is neglected too much, there will not be a people or profit pillar to uphold. Our planet provides us with everything we need to sustain life and to make life as comfortable as possible through the two supporting pillars" (Participant 12).

"*environmental. as a winemaker we are asking a lot from the soils, and we need to work accurately to preserve the resources given to us. once the soils are drained of nutrients and the ecosystem is removed, production of anything will be difficult*" (Participant 3).

"*Environmental and social. It may be a slight oversimplification and even idealistic - but I believe that if you achieve environmental and social sustainability, financial sustainability will follow. If you work in harmony with nature, your inputs will be reduced (over time) and by investing in your employees (training and social upliftment) the productivity and morale is improved*" (Participant 2)

Our research confirmed these findings but interestingly, the research participants regarded the environmental dimension as the more important pillar. As explained earlier, the outsize importance of the environmental pillar is hardly new. However, this importance of the environmental pillar over the others is noteworthy because it contrasts with research by Santiago-Brown *et al* (2015b) that found the economic dimension of sustainability to be deemed most important by research participants. While the research by Santiago-Brown *et al*. (2015b) involved only wine farmers, ours is more diverse and wide-ranging and involves other stakeholders of grape and wine production. This perhaps accounts for the contrasting results as producers may be more economically inclined, but other stakeholders not directly involved in grape and wine production may be more environmentally or socially inclined.

Just as contentious as defining sustainability, balancing and/or reconciling the three pillars of sustainability have always been rife with difficulties because the three pillars are interdependent and usually at odds with each other (Peterson, 2013). Regardless, the majority of the research participants believed in the possibility of achieving all three pillars of sustainability in a farm or cellar.

"*A paradigm for development, moving away from the current sectorial approach where social, economic, and ecological development are seen as separate parts. A transition toward a world logic where the economy serves society so that it evolves within the safe operating space of the planet. We have to redefine what we mean by growth. Instead of deriving this purely from the conclusion that the present global economy is flawed, we must make it possible to trace some historical trajectories which could emerge from the current poly-crises, culminating, possibly, in the evolution of a sustainable long-term development cycle*" (Participant 6)

"*Yes, I do believe it is possible, but not necessarily an easy task. It would definitely require dedication and resources and an active drive to achieve. I believe that the 3 pillars support each other when it is addressed through an integrated approach. By only focusing on one or two pillars, it will most likely negatively impact the third*" (Participant 12).

"*Definitely yes! But it will take time and will be difficult. Producers need to realize the importance of this balance and how their employees can also benefit i.e., that everything is not just about the farm, but also its people. The circle of interaction between the 3 pillars needs to be made clear (to) producers - everything is interlinked and by just watching Rands and cents you will not necessarily benefit the most. There is a deeper, philosophical link between the 3P's. Realising this requires a mind-shift - this will be the difficult part*" (Participant 2).

However, not all research participants were so sanguine about the possibility of achieving all three pillars of sustainability.

"*I would like to say yes even though the current outlook is often bleak. The relationship between the three pillars is unbalanced, priorities misaligned and therefore the system is skewed. Balance can be* *restored but would require massive economic and social input/energy and global cooperation (thus social cooperation across many systems)*" (Participant 15).

"*I'd like to think it is - yes. In theory, I know it is achievable. But I don't think it will ever be achieved on a large scale - not until there is a major paradigm shift in society's value pyramid. At the moment, money is the measurement of success, the critical driver. Until that changes on a global scale, until greed is displaced, yeah, well, not gonna happen*". (Participant 17).

While other participants believed in achieving the pillar(s) of priority before the others can be reasonably achieved.

"*Yes, if the economic pillar provides the other pillars will be able to comply. Without income Environmental and Social progress will be affected*" (Participant 8)

"*Yes, it is as they are all dependent on each other. The one cannot survive without the other, but some of them are more important for immediate survival, while others are needed for long term sustainability*" (Participant 14).

"*Only in economic markets where trade is fair. If you are not paid fair prices for your product, it may be difficult to support social sustainability*" (Participant 16).

Even though most research respondents believed in the possibility of achieving all three pillars of sustainability and deemed the environmental pillar is most important, it is obvious that the participants believed that economic sustainability is crucial in any push to achieving all three pillars of sustainability. Santiago-Brown *et al.* (201b) found that producers believed that environmentally friendly practices and social investments are contingent on the economic viability of vineyards. In this regard, our research agrees with that of Santiago-Brown *et al.* (2015b).

Given the intrinsic interrelationships and conflict between the three dimensions of sustainability, it is without note that there is bound to be trade-offs made regularly in trying to balance/reconcile all three dimensions.

"*Within the wine space, the wine will not be able to achieve profitable markets if the wine is not ethical and can demonstrate ethical attributes within the wine business. However, to achieve ethical and social sustainability, in other words to pay fairer wages and invest in skills development and capacity building, the business needs to be a profitable one.*" (Participant 16)

"*Sustainability is an integrated system. Countless amounts of trade-offs are possible between the three pillars. If a certain pillar is prioritised, it would be at the expense of another - thus trade-offs* *are a natural occurrence and inevitable. Economic gain is often prioritised over the integrity and health of social and environmental systems*" (Participant 15).

"*It is thought to be difficult to sustain all 3 pillars at once, as it is believed that ending world-hunger could come at a cost to the environment, whereas the "overprotection" of natural resources, could delay or reduce economic growth. It is also possible that ending poverty and increasing living standards could come at a cost of economic growth*" (Participant 12).

"*Trade-off between financial and environmental sustainability - less harmful products (organic/biodynamic/newer developed chemicals with lessened impacts on environment) are often more expensive than conventional products. Social sustainability is very often traded off for financial sustainability - reducing team size, only using contract labour in critical times and therefore limiting permanent staff. Investing in training of staff is also considered from a financial point of view and not in terms of what it could mean for the individual*" (Participant 2).

Santiago-Brown *et al*., (2015b) believed that trade-offs as an inherent part of sustainability encourage incessant conflicts between the economic, environmental, and social dimensions of sustainability. Our research confirmed these findings that producers have to deal constantly with these trade-offs between the three dimensions of sustainability. Sustainability involves complex variables such as the time of farm management decision, relevant context and perceptions of the stakeholder. Just as reasons for engaging in sustainable practices differ, farm management decisions also differ greatly. As such, bargains in decision making are hard to capture using a single time frame of reference. Advancements in a particular dimension may or may not have a deleterious effect in another dimension that did not receive attention during the same time. For example, a producer may forgo a wage increase for a new tractor in a particular growing season. Later, improved productivity due to improved mechanization may bring about an increase in the wages of workers. At the same time, the improved productivity due to the use of a tractor may bring about soil compaction and carbon emissions and thus reduced environmental sustainability.

Regardless of the trade-offs present in achieving all three pillars of sustainability, our research found that some pillars are indeed more difficult to achieve than others. Strikingly, the social dimension of sustainability was regarded by the respondents as the most difficult to achieve.

"*I believe the People pillar is the hardest to achieve. Measuring social sustainability in metric terms is quite difficult, as there are many qualitative factors that have an impact on it. As the Profit and Planet pillars have "key performance indicators", it is much easier to set targets for improvement and to track progress on the journey to sustainability. The "human element" in social sustainability* *makes it very difficult to measure and plan for improvement, and to ascertain when sustainability has been reached*" (Participant 12)

"Social. Producers are well aware of environmental sustainability and financial sustainability, but social sustainability is too often overlooked. There are industry bodies, such as WIETA, who are trying to address this, but many producers only comply by means of "tick-box" exercises for audits. It should be much more important than just window-dressing for a certificate. Producers need to BELIEVE in the principals of these compliance certificates and commit to DOING something about the problems in the industry" (Participant 2).

"*Social Sustainability because we still live in a world where people are exploited and deprived of their rights and human dignity*" (Participant 16).

The social dimension of sustainability has always been the more overlooked dimension of sustainability and years of criticism from social scientists has brought this dimension increasing recognition (Murphy 2012; Missimer *et al*., 2017), even more so in South Africa due to the history of the country and labour relations that has characterized the relationships between farm owners and farm workers (Ewert and Hamman, 1999; Kritzinger *et al*., 2004; Ewert and du Toit, 2005). South Africa has a storied history with regards to the relationship between the farm owner and farm workers and research has shown that agricultural workers are among the poorest and most discriminated workers of any sector (Linton, 2012). Research has found that amongst other things, the labour rights of farmworkers are still being violated irrespective of labour laws and various social certifications in place to prevent these types of violations (Devereux, 2020). The acknowledgement of the difficulty in achieving social sustainability in South African vineyards and cellars by stakeholders, while encouraging is just the first step in a very long way to redeeming the pilloried image of the treatment of farmworkers in South African vineyards and cellars.

3.3.3 Climate change and the three pillars of sustainability

Viticulture and winemaking are especially susceptible to climate change, even more so than any other agricultural produce. Significant research has been conducted on the effects of climate change on viticulture and winemaking (Santos *et al*., 2020). The effects of climate change in grape and wine production are expected to manifest through an increase in mean temperature and ripening in the warmer parts of the season (Molitor and Junk, 2019). Consequently, this is expected to bring changes in grape growth (Jones and Davis, 2000), grape yield (Jones *et al*., 2005), and wine quality (Kenny and Harrison, 1992). Research has shown that less viticultural modification is expected for South Africa than other wine regions (Jones *et al*., 2005). Regardless, climate change effects like drought, extreme temperature, wind/frost, and fire are already affecting grape yields and wine quality in South Africa. A word cloud of word frequency is shown in figure 3.2 below.

"*Our rain seasons have become erratic and difficult to predict. we have much less rainfall during the normal rain season and more in summer times when it is not favourable. our temperatures are also shifting, making it hard for the grapevines to bud equally and at the correct time. water quality from rivers and dams is decreasing*" (Participant 3)

"*More extreme weather conditions in both hemispheres. Droughts, fires, uncharacteristically high temperatures (from winter to summer), high rainfall, flash floods, hail, frost etc. These 'external' conditions then impact various processes in the cellar (change in glucose: fructose ratio, sluggish or stuck fermentations, higher conversion rates etc.)*" (Participant 15)

"*Temperature extremes, rain patterns that has led to increases in crop failures, insect and disease patterns has changed and ultimately the quality and profitability of the product is effected*" (Participant 6)

Depending on the region, climate change may be beneficial or harmful. For areas in Central and Northern Europe, an increase in temperature will lead to a longer growing season and reduced periods of frost which will reduce frost damage and increase wine quality (Bertin, 2009; Ashenfelter and Storchmann, 2010). For Southern Europe, increased temperature will lead to increased regularity of temperature and rainfall extremes with deleterious effects on yields of grape and quality of the wine (Hannah *et al*., 2013; Fraga *et al*., 2018). In South Africa, Naude (2019) found that drought reduced grape yields by as much as 30% in some regions in South Africa with an average yield reduction of 20%. Furthermore, temperature changes are having producers harvest earlier than ever before. While increased frost and wind damages especially in new leaves on vines are becoming increasingly present (Naude 2019). However, at the same time, there is expected to be an opening of new viticultural zones in higher altitude and cooler regions in the Western Cape (Fairbanks *et al*., 2004; Bonnardot and Carey, 2008). The biodiversity conservation concerns associated with these potentially new viticultural areas remains to be seen.

Figure 3.2: A word cloud of word frequency for climate change and the three pillars of sustainability.

The effects of climate change on the economic sustainability of vineyards and cellars have been the increased production cost (irrigation, pest, and disease control) and reduced yield and quality associated with changing climate patterns.

"*We are currently investing in a new water plant to treat our incoming water. we are increasing our irrigation schedules to manage our vines better, meaning more water usage also. rain during summer months may mean more sprays and chemicals to fight the infections/ pests. warmer day temperatures already have us harvesting at night to get the grapes in at a cool temperature*" (Participant 3)

"*Impact on yields and quality. Also, the cost of water and electricity impacts on this greatly as well as the actual availability of water resources - extraction of water from water schemes are heavily reduced during drought conditions.*" (Participant 2)

"*More rain in harvest (production and quality is impacted), Higher temperatures are giving more pest like FCM, Thrips and other insects that is causing damage on crops (production and quality is impacted*)" (Participant 13)

Previous research has estimated the increased quality of grapes and wine with increased temperature. Neimani *et al.* (2001) and Adams *et al.* (2003) showed that reduced frost-free periods and increased yield are associated with increased temperature. While Ashenfelter and Storchmann (2016) showed that the increase in alcohol content with increased temperature increased the quality and price of wine. However, these results are associated with cooler regions that have benefited from an increase in temperature. This does not necessarily apply to South Africa that falls in the warm region of climate classification for grape and wine production (Jones *et al*., 2005). Consequently, as our respondents explained, it is obvious that these benefits are not present in South African vineyards.

In terms of environmental sustainability with climate change, increased irrigation and water use have been the biggest impact of climate change in vineyards. To a lesser extent, increased use of pesticides due to increased incidence of pests and diseases is another effect.

"*Critically related to water. Extraction of water from water schemes are heavily reduced under drought conditions. Irrigation needs to be applied very precisely as well to avoid waste of this critical resource*" (Participant 2)

"*Our irrigation has needed to increase, meaning our nutrients are being washed out of the soils and need replenishing insecticides and fungicides are being used more when rain patterns change, and natural predators are being depleted*" (Participant 3)

"*For one, climate change is affecting the availability of natural resources such as water, but also contributes to erosion and loss of productive land. Climate change is also impacting natural ecosystems and their ability to function. Many farms are reliant on these ecosystems to assist with the management of pests. Additional resources required for pest management, once again has an impact on the profit pillar.*" (Participant 12)

Apart from modifying traditional viticultural zones (Fraga *et al*., 2016) rainfall and temperature extremes associated with climate change are expected to bring significant changes in viticultural practices, especially concerning irrigation and crop protection (Santos *et al*., 2020). South Africa as a dry region is already heavily reliant on irrigation for grape production (Araujo *et al*., 2016). This is expected to worsen as rainfall patterns become unpredictable (Robinson, 2006). Naude (2019) showed that during the recent drought in South Africa, producers explained that the heavy reliance on dams for irrigation severely impacted their yields as dam levels dropped and producers had to cut down on irrigation, ration their water use and rely on water of poor quality for irrigation. This agrees with what responses were given by our participants. On the other spectrum, increased incidence of pests and diseases is expected to increase reliance on synthetic chemicals and less on other pest management practices especially if pests move to new areas that were previously unsuitable for their development due to changes in temperature patterns (Olesen *et al*., 2011). Reineke and Thiery (2016) and Langille *et al*., (2017) found grapevine insects native to Asia surviving and rapidly producing in supposedly cooler regions of the United States and Canada. Research on the increased incidence of pests and diseases with climate change in South African vineyards is limited but global surveys that included South Africa has shown a moderate increase in the incidence of pests and diseases in vineyards (Bois *et al.*, 2017) which agrees with the responses by our respondents.

While climate change does not have a direct effect *per se* on social sustainability, effects of climate change from the economic and environmental dimensions may spill into the social dimension and have indirect effects in this area.

"*Climate change will impact the bottom line. Without profit it will not be profit(able) to continue without social programs.*" (Participant 14)

"*The over spilling impacts of the profit pillar being affected, will definitely also have an impact on the social sustainability of the business. Management may not have the needed financial resources available to implement practices that will uplift the social circumstances of the workforce*" (Participant 12)

"*People want to work for a daily living wage, if you can't pay them, they will not work for you*" (Participant 10)

"*Cashflow can come under pressure and that will have a negative effect on social development*" (Participant 13).

The limited research available has shown that climate will have indirect effects on the social dimension of sustainability. Lereboullet *et al*. (2013) found that changes in viticultural practices and even vineyard relocation had an adverse effect on grape and wine-growing communities in France and Australia. Grape and wine production are important significant employers of labour in local communities in South Africa with over 140,000 permanent and seasonal workers in the table grape and wine industry (SATI, 2020, VinPro, 2020). As our research respondents showed, changes in the production process brought about by climate change may reduce the number of workers employed and/or reduce the wages of workers. This is especially worrying as South Africa labour relations in the grape and wine industry currently leaves a lot to be desired (Linton, 2012; Devereux, 2020) and climate change may worsen these conditions.

Regardless of the various effects of climate change on the economic, environmental, and social dimensions of grape and wine production, the research respondents believed that it will still be possible to achieve all three pillars of sustainability, should the climate continue to change.

"*Yes. But responsibility of producers to make this happen is key. they need to acknowledge the impact their activities have and work towards mitigating these effects*" (Participant 2)

"*Yes, but our attention to detail will have to be great, and we will have to adapt a lot faster*" (Participant 13)

"*Yes. Climate change requires an attitude of resilience and adaptability. Any challenge can be overcome if one is willing to look for alternative, better solutions. Technology, resources and skills should be used to stay on the forefront of climate change science*" (Participant 12)

"*Yes, if we can slow down climate change or even reverse it, we could work on achieving balance*" (Participant 15).

"*Yes, but it will take more resources and knowledgeable inputs*" (Participant 9)

As the respondents mentioned, knowledge of resilience and adaptation strategies are key to lessening the impacts of climate change and achieving the three pillars of sustainability in grape and wine production. Concomitant to the adverse effects of climate change in grape and wine production has been adaptation strategies to lessen the effects of climate change in grape and wine production (Neethling *et al.*, 2016). These adaptation strategies are grouped into short term and long-term strategies depending on the severity of climate change effects on the location (Santos *et al.*, 2020) as shown in table 3.2 below.

Table 3.2: Climate change adaptation strategies in grape and wine production

Short-term adaptation strategies	Long-term adaptation strategies
Cultural practices – reduction in canopy size, changes in canopy geometry, shadow nets and earlier harvests (Hed *et al*., 2014; van Leeuwen and Darriet, 2016)	Changes in training systems - delayed maturation period, lower sugar accumulation, reduced radiation in cluster zone and higher water use efficiency. (Grifoni *et al*., 2008; Flexas *et al*., 2010; Stoll *et al*., 2014; Molitor *et al.* 2019)
Protection against heat and sunburn using shade nets and other inert chemical materials (Basile *et al.*, 2015; Bedrech and Farag, 2015).	Changes in varietal and clonal rootstock selection to heat tolerant and diseases resistant rootstocks (EECR, 2009; Schultz and Jones, 2010; Duchene *et al.* 2012)
Changes in irrigation practices by using various forms of deficit irrigation strategies (Ferreira *et al*.,2012; Koech and Langat, 2018).	genetic breeding for the development of climate change-tolerant varieties (Santos *et al*., 2020)
Continuous monitoring of changes in pests and diseases dynamic and sustainable soil management (cover crops, green manure, mulches, and compost) have all been found to suppress the incidence of pest of diseases in grapevine (Xi *et al*., 2010; Judit *et al*., 2011; Uliarte *et al*., 2013; Reineke and Thiery, 2016; Fraga and Santos, 2018; Garcia *et al*., 2018).	Vineyard relocations as a last resort to cooler and higher altitude regions (Moriondo *et al*., 2011; Karvonen, 2014).

However, as noted by our research respondents and previous research, the ability to adapt to climate change will depend on, amongst other things, farmers' perceptions of their vulnerability to change, opportunities and pitfalls connected with changes and their capacity to change (Mosedale *et al*., 2016).

3.4 CONCLUSION

Sustainability as a concept has always been complex and this study aimed to explore the perceptions of sustainability and climate change by stakeholders of grape and wine production in South Africa. As this was the first study of its kind in South Africa, a qualitative exploratory approach was used to get in-depth answers. In agreement with previous research, we found that sustainability definitions and the meaning differ among the various stakeholders, although the environmental dimension still dominates the perceptions of respondents. Furthermore, we found that farmers are having to make constant trade-offs between the three interrelated pillars, but most respondents believed in the possibility of achieving the three dimensions of sustainability. Consequently, we can define sustainability as "the continuous effort in trying to balance and/or reconcile the economic viability, environmental stewardship and social responsibility of a farm in the different economic, environmental and social context of the farm, farming region and country in any given time"

With regards to climate change, we found that even producers experienced effects ranging from droughts, temperature extremes, wind/frost damage associated with climate change having effects on grape yield and quality. Even though experts have estimated increased yield and quality associated with increased frost-free periods and increased alcohol content due to an increase in temperature, we found that these benefits did not necessarily apply to South African vineyards as the increased production costs and reduced grape yield and quality are affecting profit margins of farms. Furthermore, due to unpredictable rainfall patterns and increased temperatures, producers have had to depend more on irrigation and synthetic chemicals for water and pest control respectively, increasing the environmental footprint of grape and wine production. Even though they are no direct effects of climate change on social sustainability, producers have had to cut down on the social benefits of their production process due to the burden of climate change on the economic and environmental dimensions. Regardless, stakeholders are still optimistic about achieving all three pillars of sustainability should the climate continue to warm as there are various short term and long-term adaptation strategies to cope with the deleterious effects of grape and wine production in South Africa.

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Chapter 4

Research Results II

An exploratory participatory approach to developing sustainability assessment indicators for grape and wine production in South Africa

Chapter 4: Exploring a participatory approach to developing sustainable indicators for grape and wine production in South Africa

4.1 INTRODUCTION

Awareness of sustainability has been steadily increasing since the Brundtland report on sustainable development, the Millennium Development Goals (MDGs) and the current Sustainable Development Goals (SDGs) (Santiago-Brown *et al*. 2015a). Since then, a deluge of sustainable assessment methods has been developed (Milne & Grubnic, 2011), including those tailored specified for agriculture (Pannell & Glenn, 2000). However, all of these assessment methods are not encompassed and the focus on the environment pillar is emitted (Binder & Feola, 2013) to the detriment of the economic and social pillar (Bastianoni *et al*. 2001).

Just as there are a plethora of sustainable assessment methods, there has also been a cascade of sustainable indicators to be assessed and measured (Santiago-Brown *et al*., 2015a). Indicators are parameters that furnish data on other parameters that are difficult to measure. Indicators can also be used for farm management decisions (Munyaneza *et al*., 2018). However, this measurement of sustainability indicators is complex because sustainability is imbued in personal ideologies, political views, cultural backgrounds, and subjectivity (Rinne *et al*., 2013).

In agriculture, this dilemma is exacerbated by the choices between practice-based indicators and performance-based indicators as shown in table 4.1. In agriculture and more so in grape and wine production there is a lack of consensus between the use of practice-based and performance-based indicators for use in sustainability assessment.

Table 4.1: Differences between practice and performance-based indicators (adapted from Bockstaller *et al*., 2008; Whitehead *et al*., 2016; de Olde *et al*., 2018).

	Practice-based indicators	Performance-based indicators
1	Based on implementing a particular farming practice	Based on the effect of a particular farming practice
2	Assumes a particular farming practice improves sustainability	Measures the effect of a particular farming practice on the improvement of sustainability
3	Highly contentious and less scientifically rigorous	Highly scientifically adequate
4	Cheap, less time consuming and less complex	Expensive, time-demanding, and highly complex to measure
5	Examples include crop rotation, cover cropping and minimum wage	Soil erosion rates, surface water quality and workers' welfare.

The use of these sustainability indicators by businesses is essential to improve sustainability as it assists decision-makers to evaluate production practices and doing away with unsustainable practices (Bebbington *et al*., 2007; Fraser, 2012). As O'Brian and Colby (2008) said, "you cannot manage what you cannot measure". This chapter was aimed for an exploratory approach to develop a mixture and performance-based and practice-based indicators that can be used to measure sustainability in table grape and wine production in South Africa by participants in these sectors.

4.2 METHODOLOGY

This is an exploratory quantitative study in which two rounds of the Delphi technique (Hassan *et al*., 2000) was employed in developing appropriate and context-specific indicators for the sustainability assessment in grape and wine production in South Africa.

4.2.1 Delphi Technique

The Delphi technique, named after the oracle of Delphi, was created in the 1950s by the Rand Corporation (Hassan *et al*., 2000). It is a methodology employed in the sciences to collect views of experts and stakeholders of a particular research area for decision making and in reaching consensus (Carrera and Mack, 2010). For practical purposes, the Delphi technique does not employ a representative sample of a given population, but a range of experts and stakeholders from a particular field of research (Keeney *et al*., 2001).

The Delphi technique is usually carried out in an array of questionnaires sent in "rounds", sometimes interjected with feedback (Belanger *et al*., 2012). A questionnaire was sent to experts and stakeholders of a particular research area mostly via emails (Balasubramanian and Agarwal, 2013). Thereafter, follow-ups are done to elicit better responses. In previous research using the Delphi technique, at least two rounds of the process were deemed to be enough to get significant results (Trinh Hai *et al*. 2015; Fefer *et al*., 2016; Escribano *et al*., 2018; Ahmad and Wong, 2019; Munyaneza *et al*., 2019).

Questionnaires are an important instrument in the Delphi technique (Chang *et al*., 2011). These questionnaires are derived either from extensive literature reviews or suggested in consultation with experts (Quyen, 2014). When it comes to consensus or agreement, different degrees of consensus scores can be found in previous research. For example, Choi and Sirakaya (2006) selected at least 50%, Donohoe and Needham (2009) selected at least 60%, Chang *et al*. (2011) and Ahmad and Wong (2019) selected at least 75% and Labuschagne and Brent (2008) selected at least 80% as enough to reach an agreement. The agreement value determines which of the indicators of sustainability are to be included (Henning and Jordaan, 2016).

4.2.2 Delphi Experts

The Delphi technique expert is a person with appropriate knowledge and skill that is shown through his or her position in a professional organization, publications in reputable journals and/or in possession of graduate-level education (Lim and Anthony, 2016). Furthermore, the ability and willingness to take part in the study, sufficient time to take part in the study and sufficient communication skills are all important attributes for a Delphi expert (Rådestad *et al*., 2013). When it comes to criteria for Delphi experts, various researchers have used different criteria for Delphi expert selection. For example, Hsu *et al*., (2017) used working experience between 8 and 22 years, with or without graduate degrees. While Fefer *et al.* (2016) selected mainly experts with graduate degrees and limited industrial working experience. Musa et al. (2015) used experts with at least 5 years of professional experience with graduate degrees. Furthermore, experts may also be selected based on publication in reputable peer-reviewed journals (Donohoe and Needham, 2009). Miller (2001) and Choi and Sirakaya, (2006) selected experts with at least one peer-reviewed paper in a reputable journal.

Previous research has found a minimum size of 7 or 8 experts to be sufficient (Sourani and Sohail, 2015), with a size between 20 to 60 experts (Geist, 2010) for a mix of experts of various backgrounds (Hasson and Keeney, 2011). However, sizes from 9 to 13 have been deemed sufficient by various authors for the practical and timely development of a Delphi technique (Ahmad and Wong, 2019). Vatalis *et al*. (2012), Henning and Jordaan (2016) and Hsu *et al.* (2017) used nine experts, Labuschagne and Brent (2008), Barzekar *et al.* (2011) and Jato-Espino *et al.* (2014) selected 10 experts. Tseng *et al.* (2015) selected 11 experts while Quyen (2014) used 13 experts in their various studies using the Delphi technique.

4.2.3. Research Methodology

In this study, the Delphi technique was used to select appropriate and context-specific indicators for the assessment of sustainability in table grape and wine production in South Africa. The research methodology is depicted in Figure 4.1. For practical purposes, the first round of the Delphi technique was an in-depth review of sustainability and sustainability indicators in South Africa grape and wine production (Santiago-Brown *et al.*, 2015a; Hamman *et al*., 2017; Naude *et al*., 2019). The latter ultimately resulted in the publication of a review paper (Gbejewoh *et al.*, 2021) – Chapter 2 of this thesis.

In the second round, a questionnaire developed from the published review paper was sent out by email to various stakeholders and experts of table grape and wine production in South Africa. The questionnaire (Appendix II) includes indicators on the economic, environmental, and social indicators of sustainability and the Delphi experts were asked to rate each indicator in order of importance. The experts selected was based on recommendations from researchers, where experts were selected from their publication record in the field and referrals from industry professionals. Some of the selected experts were asked to recommend other experts to take part in the study. The experts were selected carefully with the criteria being: having graduate degrees with or without years of industry experience, industry experience with or without graduate degrees and viticulturist/cellar managers/farm managers/winemakers with or without graduate degrees, as explained in chapter 3 of this thesis. Finally, ethical clearance (REC-2020-15452) was obtained from Stellenbosch University for participants to participate in the study.

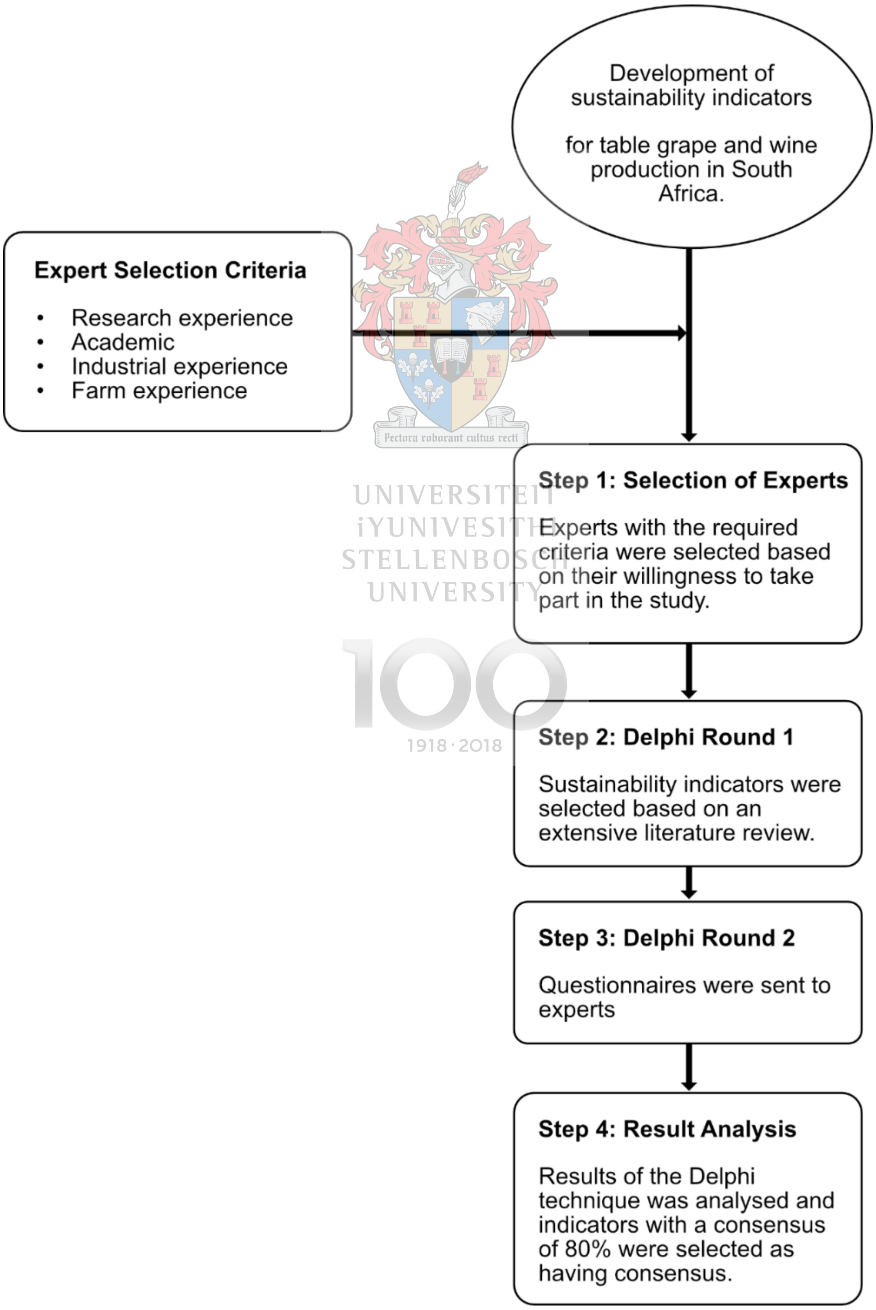

Figure 4.1: Flow chart of the Delphi technique process (adapted from Escribano *et al.*, 2018).

The questionnaire developed had a total of 60 indicators spread equally over the 3 pillars (economic, environmental, and social) of sustainability. The indicators selected from previous research (Santiago-Brown *et al*., 2015a) was adapted to a South African context, while new relevant indicators were also included. In relation with other Delphi technique research (Almansa and Martínez-Paz, 2011; Olaizola *et al*., 2012; Escribano *et al*., 2018), a 5-point Likert scale (from 0 - not important to 4 - very important) was used in the questionnaire to assess the level of importance of the various sustainability indicators as decided by the Delphi experts. Furthermore, open-ended questions were asked at the end of each pillar of sustainability where experts were asked to include and score (using the same Likert scale) sustainability indicators that were not included in the study. Finally, the mean, standard deviation, and consensus score (2/4 = 50%) of the scored sustainability indicators were calculated. A consensus score of 80% was selected to mean consensus. These values were gotten from previous research (Labuschagne and Brent 2008) that used the Delphi technique. Consequently, all indicators with a below the 80% consensus score were rejected.

4.3 RESULTS AND DISCUSSION

4.3.1 Delphi Experts

The Delphi experts for the study are listed descriptively in Table 4.2. The majority of experts had at least a bachelor's degree except for three experts who had diploma education. The Delphi experts all had adequate experience in the grape and wine industry of South Africa with a minimum of 4 years of experience with over half of the experts having at least 15 years of experience. The job descriptions of the experts ranged from farm managers; viticulturists; environmental specialists; winemakers; cellarmasters, to academics at Stellenbosch University. Naturally, farm professionals are over presented with over half of the experts being farm professionals.

Table 4.2: Description of the Delphi Experts who completed the questionnaire.

No	Highest Academic Qualification	Years of Experience	Job Title	Affiliation
1	Bachelors	18	Head of Wine and Viticulture	Farm
2	Masters	11	Junior Lecturer	Academia
3	Bachelors	6	Winemaker	Farm
4	Bachelors	6	Assistant winemaker	Farm
5	Bachelors	37	Cellarmaster	Farm
6	Masters	25	Technical Manager	Retail Industry
7	Diploma	20	Marketing Assistant	Industry
8	Diploma	22	General Farm Manager	Farm
9	Bachelors	11	Winemaker	Farm
10	Bachelors	31	Group Viticulturist	Farm
11	Bachelors	20	Viticulturist/Senior Farm Manager	Farm
12	Masters	4	Environmental specialist	Farm
13	Diploma	26	General Farm Manager	Farm
14	Bachelors	15	Wine Accountant	Industry
15	Masters	16	Wine Merchant	Industry
16	Bachelors	15	CEO	Industry
17	Bachelors	20	PR, Wine judge and educator	Industry
18	Masters	15	Senior Economist	Government
19	Doctorate	13	Chief Economist	Government

4.3.2 Sustainability Indicators

The final list of the selected sustainability indicators that showed an 80% consensus or higher are shown in Table 4.3. The complete list of all indicators with the varying means and consensus scores are shown in Appendix III. The first round of the selection of the sustainability indicators yielded an initial list of 60 indicators in total (20 for each pillar of sustainability). The list for the second and final round of selection of indicators that showed 80% consensus or higher was 39 indicators (12 for the economic dimension, 16 for the environmental dimension and 11 for the social dimension).

In this study, the first of its kind in South Africa, sustainability indicators were defined according to the "three pillars" concept. The first round generated an initial list of 60 sustainability indicators which was then further refined in a second-round to generate a final list of 39 indicators. The Delphi technique aimed to assist in achieving all the possible factors and solutions (Huge *et al*., 2010). A few limitations are necessary for the discussion of the Delphi technique results. First, the scientific validity of the Delphi technique depends in large part on the expertise of the experts (Munyaneza *et al*., 2019). In this study, the experts had sufficient experience with over half of the experts having at least 18 years of experience in the grape and wine sector of South Africa. Secondly, as farm professionals were overrepresented in the Delphi experts, we need to be cognizant of the fact that farmers sometimes rate indicators according to the goals that meet their pressing needs (Waney *et al*., 2014). Lastly, using a participatory method for sustainability indicator selection can provide a list of correlated indicators (Munyaneza *et al*., 2019). Even though this was considered during the selection of the initial list of indicators, correlations could remain thereafter. Researchers have advocated for correlation analysis (Paracchini *et al*., 2015) or weighting indicators (Yigitcanlar and Dur 2010) before making use of them. However, this was not considered in this analysis since this research is confined to just identifying the indicators

Dimension	Indicator	Consensus score (%)	Mean score (Out of 4)	Standard Deviation
Economic	Grape Yield	85%	3.4	0.6
	Grape and Wine Prices	90%	3.6	0.6
	Vine Health	90%	3.6	0.6
	Farm Net Income	89%	3.56	0.51
	Input costs	89%	3.56	0.72
	Financial Autonomy (Freedom from debts)	83%	3.31	0.60
	Labour Costs	81%	3.25	0.68
	Grape and Wine Demand	88%	3.5	0.52
	Grape and Wine Quality	90%	3.6	0.48
	Brand Value	88%	3.5	0.79
	Production and Quality consistency	93%	3.7	0.6
	Labour Productivity	93%	3.7	0.6
Environmental	Soil Health	99%	3.94	0.25
	Water use efficiency	97%	3.88	0.34
	Plant and Microbial biodiversity conservation	89%	3.56	0.63
	Environmental Record Keeping	83%	3.31	0.79
	Integrated Pest Management	92%	3.69	0.6
	Carbon Footprint	80%	3.2	0.91
	Soil Organic Matter content	88%	3.5	0.52
	Water Footprint	86%	3.44	0.81
	Precision Agriculture	86%	3.44	0.73
	Wastewater Management	83%	3.31	0.87
	Air and Water Quality	88%	3.5	0.52
	Organic and Inorganic Waste Management	83%	3.31	0.6
	Soil Conservation/Erosion Control	92%	3.67	0.48
	Energy Use Efficiency	88%	3.5	0.52
	Fertilizers, Pesticides and Chemical Use Efficiency	92%	3.69	0.48
	Soil Cover	89%	3.56	0.51
Social	Workers' education, training, and skills development	91%	3.63	0.62
	Safe and Healthy Work Environment	94%	3.75	0.45
	Workers' Welfare	91%	3.63	0.5
	Labour laws compliance	91%	3.63	0.89
	Farming Community's health and welfare	89%	3.56	0.51
	Workers' productivity	95%	3.81	0.54
	Labour Costs	86%	3.44	0.73
	Right to a Living Wage	97%	3.88	0.34
	Farming Community's benefits	81%	3.25	0.77
	Workers children's education, health, and welfare	95%	3.81	0.54
	Consumers' health and welfare	89%	3.56	0.63

4.3.3 Economic indicators

For the economic dimension, production quality/consistency and labour productivity were the indicators with the highest mean values and level of agreement as both indicators averaged a value of 3.7 (out of 4) with a consensus score of 93%. This was followed by grape/wine quality, vine health and grape/wine prices which averaged a score of 3.6 with a consensus value of 90%. Meanwhile, indicators with a consensus score below the accepted threshold were environmental and social certifications (78%), non-capital expenditures (78%), break-even price (78%), capital expenditure (75%), credit access (69%), income from off-farm activities (68%), age of vines (58%) and government subsidies (50%).

A spider graph of the economic indicators is shown in Figure 4.2. Interestingly, there was a consensus for the indicators of production/quality consistency, grape/wine quality, grape/wine prices and brand value as extremely relevant. This speaks to the dilemma that wine producers face in South Africa. The focus of the country was on bulk wine before the Apartheid era which set the country on a path and reputation of having "cheap and cheerful" wines which have been hard to shake ever since. As a result, South Africa wine has always been priced cheaply and branded wines in the country are few and are far between unlike other wine-producing countries (Ewert and Henderson, 2004). The relevance of these indicators for economic sustainability speaks to the knowledge of farmers and other stakeholders in the grape and wine industry even though research has shown that other indicators like input costs and labour productivity were ranked as also highly relevant and have been steadily increasing over the past decade (VinPro, 2020).

It is also noteworthy that environmental and social certifications were not regarded as particularly economically relevant. This is maybe because even though these certifications are required for access to important export markets, factors like the high cost of compliance mean that producers are not exactly seeing any economic returns for having these certifications. Research has shown that farmers weigh the costs of compliance and in many cases are only compliant because of export contracts (Moseley, 2008; McEwan and Bek, 2009). Our results contrast research by Santiago-Brown *et al.* (2015a) on wine production where experts found grape yield and profitability to be among the most relevant indicators for economic sustainability. However, the differences in sample size and research respondents may account for the different results as Santiago-Brown *et al.* (2015a) had a significantly larger sample size than ours and employed only wine farmers as research respondents while ours employed various actors in the entire value chain of grape and wine production. This is noteworthy because previous research has shown that farmers usually favour profits over other indicators (Santiago-Brown *et al.*, 2015b)

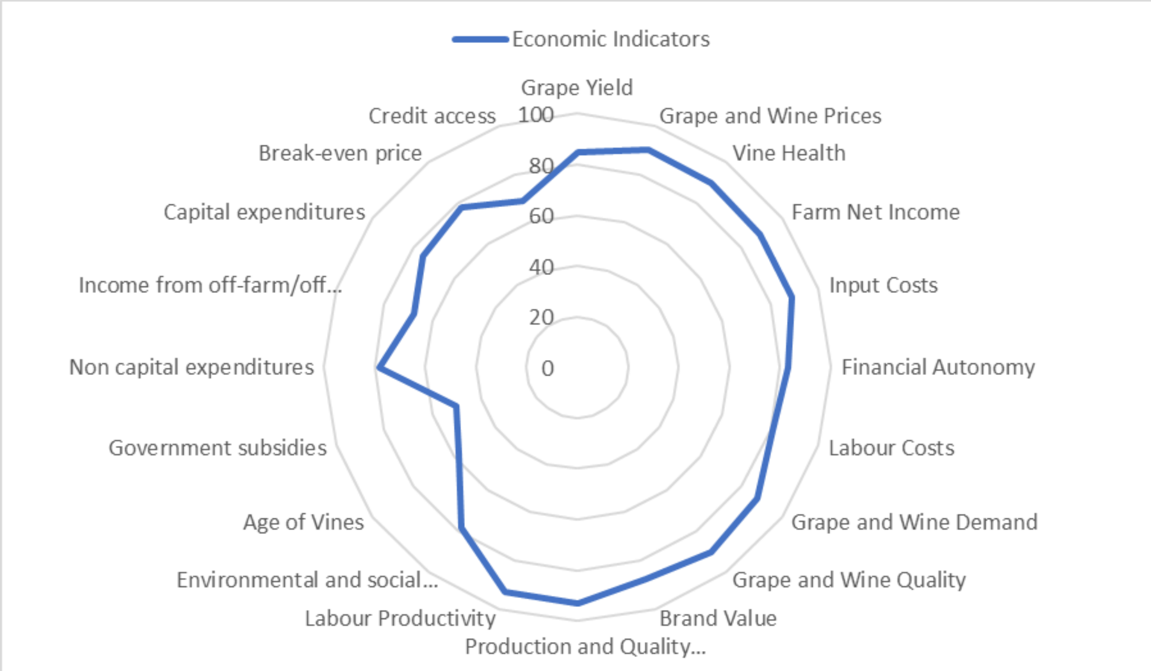

Figure 4.2: A spider graph of the economic indicators ranked by relevance levels.

4.3.4. Environmental indicators

With regards to the environmental dimension, soil health averaged the highest value with a mean score of 3.94 and a consensus score of 99%. This was closely followed by water use efficiency with a mean score of 3.88 and a consensus score of 97% and integrated pest management, soil conservation/erosion control and fertilizers/pesticides/chemical use efficiency with a consensus score of 92%. Indicators that scored below the threshold were environmental certifications (78%), percentage of a natural (untouched) area on the farm (75%), minimum soil disturbance (72%) and off-farm environmental impacts from farm/cellar (70%).

A spider graph of the environmental indicators is given in Figure 4.3. Even though environmental indicators like water use efficiency, wastewater management and water footprint were regarded as highly relevant by the experts, research has shown that farms still use more water than is necessary for grape and wine production or underestimate the quantity of water used in vineyards and cellars (Sheridan *et al*., 2005; Kumar *et al*., 2009). Recent research on the water footprint by the table grape and wine industry in South Africa shows that wine production has an average water footprint of 484L/kg while table grapes had an average water footprint of 619L/kg (WRC, 2020) with the global average being 707L/kg for wine grapes and 607L/kg for table grapes (Jarmain, 2020). While these figures show that the water use in South African vineyards and cellars is on par with international levels, it belies the deeper statistics. The water footprint in the coastal region was 842L/kg for wine and 714L/kg for table grapes, higher than the global average (Jarmain, 2020). The cognitive dissonance here is striking as experts agree on the relevance of these indicators for environmental sustainability but in practice, do something different. While this may be true, it should be noted that higher than average water demand in the coastal regions is due to different viticultural practices – vertical shoot positioning (VSP), which has been shown to increase water demand – which may account for the higher water use of these regions (Lebron *et al.*, 2006). The same situation applies to fertilizers/pesticides/chemical use efficiency and organic/inorganic waste management as these indicators were judged as highly relevant in our research, but limited research available has shown that indiscriminate use of these chemicals has been documented in vineyards (Forbes *et al.*, 2011) and inconsiderate disposal of organic/inorganic waste is a feature of vineyards and cellars (Musee et *al.*, 2007; Devesa-Rey *et al.*, 2011) but differences in pest population pressures in various regions play a role in the quantity of pesticides used.

Even though there are schemes like the Biodiversity and Wine Initiative (BWI) the low level of agreement for the indicator of a protected and untouched area of a farm is hardly interesting. Research has shown that most vineyards in South Africa are small to medium scale and even though conserving biodiversity is relevant, keeping an area of the farm completely natural and untouched is a step too far (Hussain *et al.*, 2008). Besides, the small and medium scale nature of vineyards in South Africa means that the conserved area is usually spotty and scattered (Kemper *et al.*, 1999; Reyers *et al.*, 2001). This probably explains the low level of relevance afforded to biodiversity conservation.

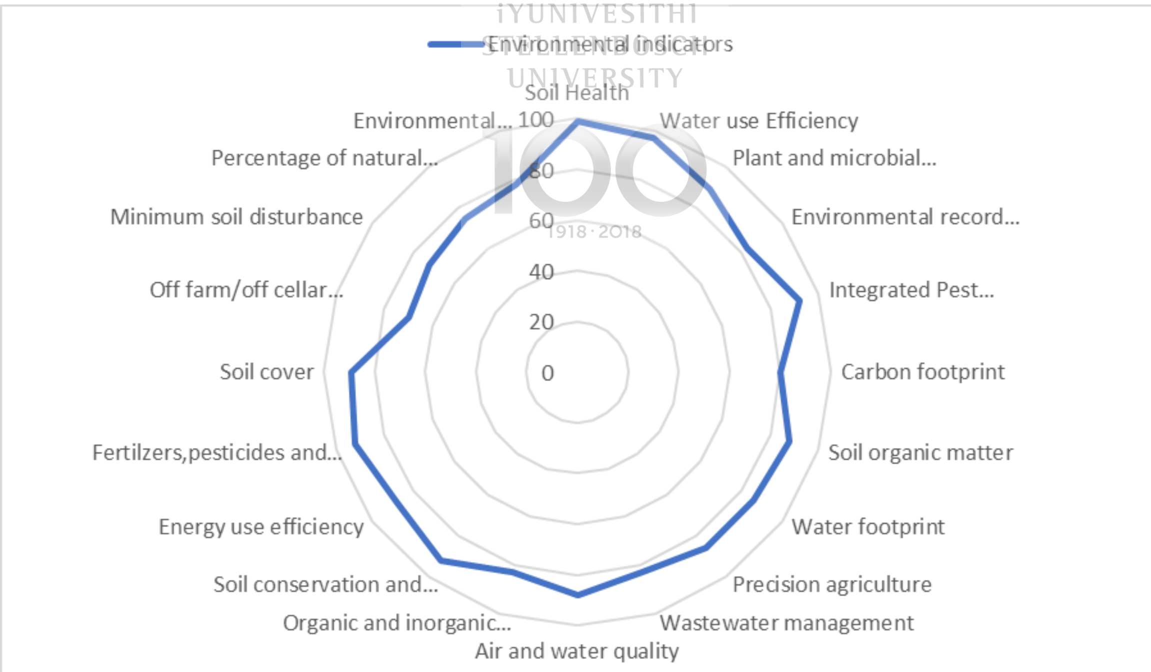

Figure 4.3: A spider graph of the environmental indicators ranked by relevance levels.

It is striking that experts deemed soil conservation/erosion control as highly relevant but minimum soil disturbance as not particularly relevant. This probably shows that minimum soil disturbance is not regarded as a particularly relevant option for soil conservation/erosion control. This could also be why soil cover was regarded as highly relevant as it provided a more practical option for soil conservation/erosion control than minimum soil disturbance. Regardless, soil conservation/erosion control in vineyards is worryingly limited as research has shown that soil loss in vineyards is above what is considered as manageable soil loss (Verheijen *et al*., 2009). Environmental record keeping is an interesting indicator. Even though there are adequate records on water use, fertilizers/pesticide/chemical use generated by farms and experts agree on the relevance of this indicator for environmental sustainability, previous research has shown that the presence of these records does not necessarily improve or change production practices (Christ and Burritt, 2013). What this means, remains to be researched.

Although it is not the first thing that comes to mind concerning environmental sustainability, grape and wine production uses a considerable amount of energy and emit a sizeable quantity of greenhouse gases. (Smyth and Russell, 2009). This does not even consider the quantity of energy used, and carbon emitted in bottle production, packaging, and distribution (Barber, 2010) given that previous research has shown that this stage of the value chain accounts for about 50% of the carbon produced (Point *et al*., 2012). It is also noteworthy that these indicators were regarded as relevant given that although they are tools for calculating greenhouse gas emissions (James, 2012), whether these calculations are used or even brings about change remains to be seen (Christ and Burritt, 2013). In terms of environmental sustainability, our research agrees with Santiago-Brown *et al*. (2015a) where soil health and water use were found to be the most relevant indicators for environmental sustainability.

4.3.5. Social indicators

Lastly, for the social dimension, the right to a living wage averaged the highest score with a value of 3.88 and a consensus score of 97%. This was followed by workers' productivity and workers children's education, health, and welfare with a mean score of 3.81 and a consensus score of 95%. Indicators below the consensus score were workers' complaints (79%), workers' retention rate, workers' housing/tenure security and work-related benefits with (78%), gender equality (75%), social certifications (74%), the ratio of permanent to temporary workers (72%), off-farm/cellar activities (67%) and aesthetics (66%)

A spider graph of the social indicators is shown in Figure 4.4. Strikingly, the right to a living wage was deemed as highly relevant with near-universal consensus because previous research has documented that farmworkers, especially in the Western and Northern Cape are paid below the living wage and sometimes even below minimum wage (Devereux, 2020). This shows that even though experts agree on the principle of the need to pay workers a living wage, the economic situation of most farms precludes farms from doing so. Research has shown that the majority of wine farms in South Africa are barely profitable (VinPro, 2020). Consequently, even though farmers believe in the need to pay a living wage, for financial reasons, most cannot. It is also noteworthy that social indicators like safe/healthy work environment and labour laws compliance were rated as highly relevant even though research has shown that farmworkers are not working in a particularly safe work environment or that farmers comply with all the labour laws (Devereux, 2020). Again, the financial situation of most farms precludes farmers from carrying out full health and safety precautions, which are usually expensive and have to be done regularly

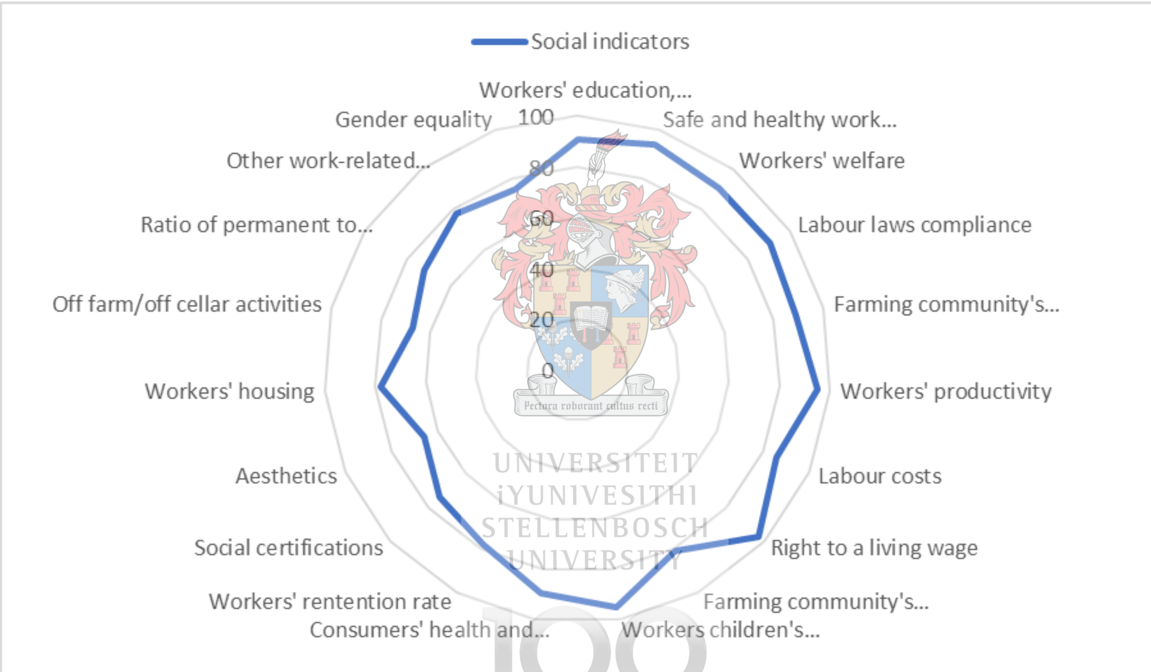

Figure 4.4: A spider graph of the social indicators ranked by relevance levels.

The low levels of relevance with regards to the indicators of workers' retention rate and the ratio of permanent to temporary workers are hardly noteworthy. Previous research has shown that a high turnover rate and the higher percentage of temporary workers are all efforts of producers to keep production costs down, costs that have been pushed down on them from retailers (Ponte and Gibbon, 2005). As such, it is not striking that experts do not rate keeping a fairer ratio of permanent to temporary workers or high retention rate as particularly relevant as farm workers have always been regarded as expendable (Barrientos and Kritzinger, 2003). Finally, it is important to note that in comparison to the economic and environmental dimensions, the social dimension received higher mean scores and consensus for its indicators. While this may mean the high relevance attached to these social indicators, it may also imply social desirability bias where respondents under or over report depending on what they perceive as being socially or culturally acceptable.

4.4 CONCLUSION

The Delphi technique is a method that is hardly used in sustainability research to select indicators and grade their level of relevance. However, this research has shown that the Delphi technique is a method that can be used in sustainability research given the fact that it provides a list of indicators that are easy to use with varying levels of consensus among experts. Unlike other research methods that involve indicators with a high level of complexity, the adaptation to a specific context and the bottom-up approach that involves important stakeholders is a strength of the Delphi technique. The indicators selected by the Delphi experts yielded interesting results as experts rated indicators like production/quality consistency, grape/wine prices, quality and demand and brand value as relevant for economic sustainability. This speaks to the untenable situation of bulk wine that the country majorly exports and to the fact that some sort of intervention is needed in the wine sector. What that will be, whether it be in form of government subsidies or financial assistance from foreign retailers remains to be seen. Furthermore, there appears to be some sort of implicit bias with regards to the environmental dimension as indicators related to water and chemical use shows a high degree of relevance but practices on farms tell a different story. However, region contexts may preclude producers from certain viticultural practices. Lastly, the high relevance of the social indicators shows that farmers are limited in what they can do to improve this dimension due to the economic situation of many grape and wine farms. Consequently, related to the economic dimension, interventions of some sort either from the private or government sector is needed.

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Chapter 5

Research Results III

Exploring the feasibility of the three pillars of sustainability: A wine farm case study

Chapter 5: Exploring the feasibility of the three pillars of sustainability

5.1 INTRODUCTION

Agricultural production systems, like all other production systems, are inherently complex. Agricultural systems are complex because it is composed of interrelated parts (Checkland, 1993). In agricultural systems, the production system, local, regional, national, and international systems are all connected in their relationship, thus increasing the complex process of decision making (Banson *et al.,* 2014). Furthermore, new technologies, variation in climate, product and input prices all contribute to the complex nature of agricultural production systems (Hoffmann, 2010). As a result, farmers are in the untenable position of having to make decisions and plan for the effects of these decisions, all without complete information about their production systems. This has prompted researchers to look for improved methods to analyse production systems. The systems modelling and simulation approach is one of those improved methods. This whole-farm systems approach assists farmers in comprehending the decision-making process of their farm management (Makhuvha, 2015).

The farm, by design, comprises physical, chemical, and biological components that change inputs into outputs (Makhuvha, 2015). The farm also contains a financial aspect where the farmer strives to make a profit. To study farm systems, require an understanding of the system and research methods that can appreciate the complexity of farming systems and show the consequences of making changes to this farm system. Studying direct interventions is time-consuming and not financially feasible. Moreover, it requires an actual farm. Thus, the use of models, which represents reality on the ground is an alternative (Legay, 1997).

Different types of modelling can be used in research, one of the most important being the budget model (Bruce, 2017). In creating a financial plan for a farm, the budgeting method is key in determining the financial implications of alterations in a farm. The creation of spreadsheet software like Microsoft Excel ® has made an impact on budgeting models being used for the farm decision-making process (Pannell, 1996). Thus, farm budgeting models can then be referred to as simulation models. Farm budgets include physical and financial input data that produces profit criteria like gross production value, gross margin, and net farm income (Dillon and Hardakar, 1984). Farm budgets work by quantifying and subtracting variable, fixed and overhead costs from the production gross value to get the net farm income. Farm budgets can be adapted to provide financial information that relates to returns on capital investments or the profitability of capital investments over a period longer than one financial year. Despite the criticism levelled at farm budgets- it does not provide the best solution, requires an expert understanding of the system and the accuracy of the budget model depends on the accuracy of the relationships identified in the system- it provides a thorough look at farm systems and allows for a multi-disciplinary approach in addressing issues related to farm management, including sustainability (Parker, 2020).

The three dimensions (economic, environmental, and social) of sustainability are interlinked, trade-offs are inherently present and any effort to address concerns in one dimension may result in an unavoidable loss in another dimension (Peterson, 2013). Consequently, farmers are always trying to balance and/or reconcile the natural interest to make a profit with their duty to the environment as custodians and their obligations to their workers and consumers for responsible practices. Farm budgets present an interesting way of simulating these farm management decisions that farms face with regards to the three pillars of sustainability. The incorporation of scientific and lay, but expert knowledge, into budget models is in the form of verified production parameters. The budget model is simply a financial reporting format but constructed on physical/biological processes and factors. Here these processes are carefully designed and manipulated to remain within ecologically sustainable parameters and the financial outcome of such systems is reported by the budget structure. Through manipulation of the input parameters of the budget model, predictive research questions related to sustainability can be addressed (Douthwaite & Hoffecker 2017). Furthermore, it acts as a tool for farmers to anticipate the consequences of their sustainable practices before any decision is made. An overview of the model is given in Figure 5.1 below.

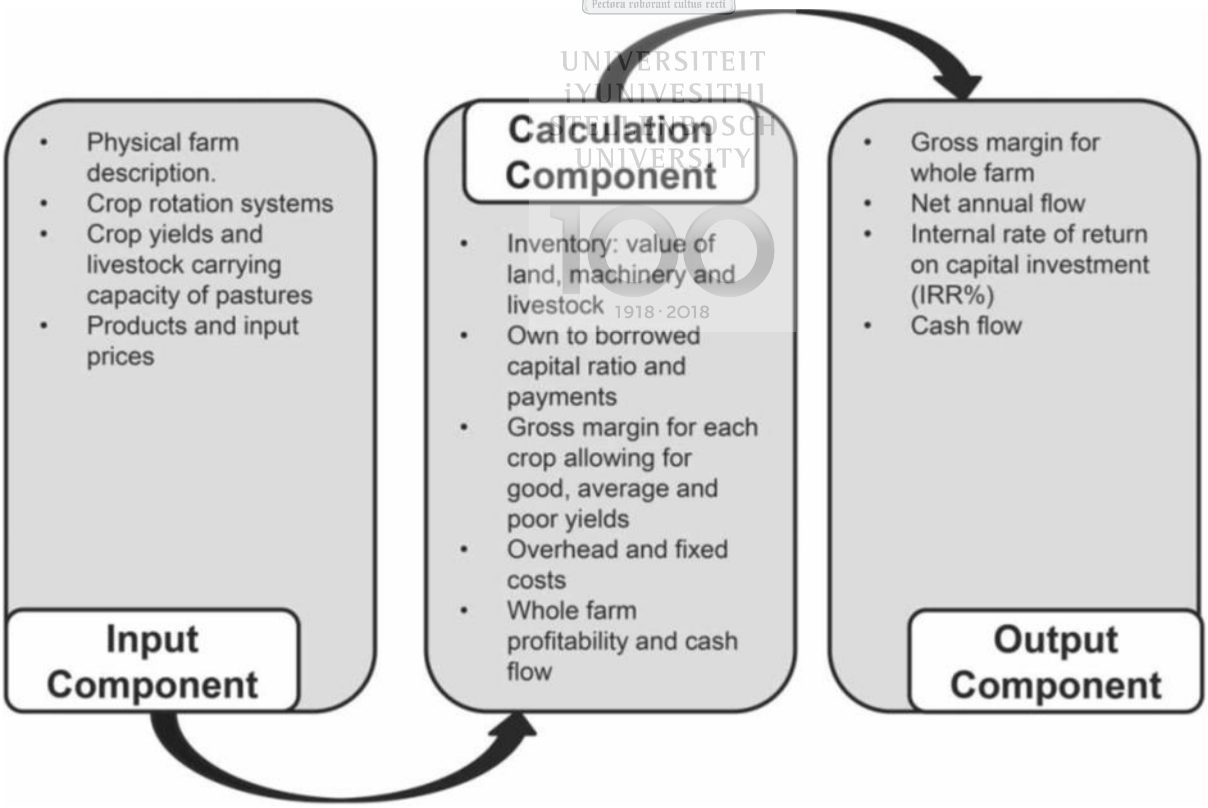

Figure 5.1: A graphical representation of a farm budgeting model (Hoffman, 2010).

Therefore, this chapter aims to use farm budget simulation to assess the possibility of balancing the three pillars of sustainability in a wine farm. In other words, this chapter aims to find out what effect environmentally and socially sustainable practices will have on the profitability of a wine farm.

5.2. METHODOLOGY

This research employed a partial farm budgeting method (enterprise budget) to analyse the expected profitability of more sustainable production practices. The partial budget model is especially useful in financial analysis in assessing the profitability of proposed changes in a production system, in this case, changes to a more sustainable system of production. The main benefit of partial budgets is the relative simplicity of the structure while it allows for the incorporating of much detail in the physical/biological and financial considerations. The partial budget is used the evaluate the average costs and benefits with regards to the adoption of an alternative production system (Chanza, 2016). In a partial budget, the calculation of a gross margin is the first step in the partial budgeting technique. This is because it allows for direct comparison of the profitability of similar production systems and thus enabling the farmer whether to keep or alter the production system. Gross margins were calculated for each production system using specific production practices and inputs over a production season. The gross margin is calculated by subtracting the variable costs from the gross output in each system of production (Chanza, 2016).

5.2.1 Study Area.

Robertson, located in the Breede River Valley region of the Western Cape, is one of the leading wines producing areas in South Africa. Robertson is classified as a coastal region under the Wine of Origin scheme (SA-Venues, 2020). It is composed of 9 wine production wards. Known for producing rich, intense, and fruit-driven white and red wines, it is the quantity-centre of wine production, well known for producing bulk wines since the yield of this region is relatively high due to the area being one of the hottest (rainfall is a meagre 400mm) wine-producing regions and daytime temperatures reaching 30^{o}C (Wine-Searcher, 2019). However, the evenings are much cooler since the region is roughly 96.56 kilometres from the ocean. This provides a winemaking possibility as the ocean breeze allows grapes to maintain a certain amount of acidity and prevent over-ripening (Vivino, 2019). The combination of various soil types (rich limestone, alluvial soils in the river valley and the red gravelly soil) are great for white and red wine grape production. Robertson is well known for white cultivars such as Chenin blanc, Chardonnay (for Methodé Cap Classique production and still wine production), Sauvignon blanc and red cultivars Pinot noir, Shiraz, Merlot noir, Cabernet sauvignon (SouthAfrica.net, 2020).

5.2.2 The partial farm budget model

The partial farm budget model contains input data, calculation and output components as shown in Figure 5.1 and explained in detail in Hoffman (2010). The input component contains physical farm description (hectares cultivated area under wine grape, number of permanent and seasonal labour, other fixed costs) and input and output prices data (fertilizers, chemicals, seasonal labour, grape yields, and prices). The input and output data are arranged in tables with columns for price and quantity for the calculation of the enterprise budget and quick selection of alternative products. The table also includes product unit prices, recommended application levels and value per hectare.

The partial farm budget model calculation component includes the various calculations and connections that connect the different input parameters to provide profitability results. The calculation component was created using standard accounting principles of gross production value, gross margin and net farm income. Gross margin and net farm income show the profitability of the whole farm.

5.2.3. Model alternative scenarios

A scenario is defined as an imagined or projected sequence of events (Therond *et al*., 2009). In this case, three scenarios were identified for simulation using the partial budgeting model. The three scenarios were as follows:

- Environmentally sustainable scenario (Scenario 1)
- Socially sustainable scenario (Scenario 2)
- Environmentally and socially sustainable scenario (Scenario 3)

The focus of this chapter was to assess these scenarios concerning the expected financial consequences. As earlier stated, a partial farm budget was constructed to model these three scenarios. It is necessary to note that four partial farm budgets were created, the three scenarios plus a baseline or status quo scenario which is the current farm production system. This was done to compare the financial feasibility of the current farm production system with the three alternative scenarios.

5.2.3.1 Environmentally sustainable scenario (Scenario 1)

The first scenario dealt only with the environmental pillar of sustainability. Here, the approach was to improve the environmental sustainability of the wine farm and using the partial budget model, simulate the financial effects of this improved environmental sustainability on the profitability of the wine farm. In terms of the partial budget, improved environmental sustainability involves the alteration of the input parameters of synthetic chemicals (fertilizers, herbicides, insecticides, and fungicides). In consultation with the Integrated Production of Wine (IPW) management team (the authoritative body for environmental sustainability certification in South Africa) and consultants for the Robertson wine farm region, an average recommended application rate of synthetic chemicals and water for the farm region was created. Thereafter, in consultations with experts at VinPro, the assumptions of the effects of these alterations on the wine grape yield were done.

5.2.3.2 Socially sustainable scenario (Scenario 2)

The second scenario dealt involved only the social pillar of sustainability. As with the first scenario, the approach was to use the partial farm budget to simulate the effects of improved social sustainability on the profitability of the wine farm. The inputs parameters in the partial budget that were altered included the wages of seasonal and permanent labour. These input data were gotten in consultation with the Wine and Agricultural Ethical Trade Association (WIETA) management team, the authorized body for social certification in wine farms in South Africa. As with the environmentally sustainable scenario, this scenario was created to simulate the financial implications of improved sustainable practices on the profitability of the wine farm.

5.2.3.3 Environmentally and socially sustainable scenario (Scenario 3)

Elkington (1998) defined the three pillars of the economy, environment, and society as necessary for true sustainability. In other words, any production system can only be truly sustainable if an effort is made towards these three dimensions. Consequently, the third scenario involves the environmental and social pillar of sustainability and assessing the financial consequences of improved environmental and social sustainability on the profitability of the farm using the partial budget model. Here, the first and second model was combined to model true sustainability and assess its effects on the bottom line of the wine farm.

5.3 RESULTS AND DISCUSSION

5.3.1 The physical farm

In this research, a case study farm was used as opposed to a typical farm that has been used in previous research involving a budget simulation model (Hoffman, 2010). While a case study farm is easier and quicker in data collection, its results are not necessarily generalizable which is a major limitation of using it (Hoffman, 2010). However, the same concept applies as it still allows for changes in data within the model to evaluate the effects of change in practices on the farm profitability. The total size of this case study farm is 190 hectares, with every hectare completely owned by the farmer, which means no portion was rented (Table 5.1). This farm size falls in the range of typical farm size in the Robertson region of the Western Cape as previous research conducted and subsequently validated by experts in the region estimated a typical farm in this region to be 200 hectares (Bezuidenhout, 2020). However, the value per hectare of this case study farm at R360, 000/ha for arable and planted land is considerably higher than that of a typical farm in the Robertson region as previous research estimated R129,650/ha (Bezuidenhout, 2020). This discrepancy is understandable given the fact that land prices increase considerably over time and differ substantially even in the same region.

Table 5.1: Description of the physical farm.

Farm Division:			
	Total Ha:	**Value/Ha:**	**Total Value:**
Arable Land (Planted)	151,13	R 360 000,00	R 54 406 800,00
Arable Land (Un-Planted)	10,87	R 300 000,00	R 3 261 000,00
Non-Arable Land	28,00	R 250 000,00	R 7 000 000,00
Totals:	***190,00***		***R 64 667 800,00***

5.3.2 Land Utilization

The land-use patterns of the case-study farm are described showing total hectares, percentage of arable land and percentage of planted land used by each cultivar (Table 5.2). The table shows that Chenin blanc and Cabernet Sauvignon have the largest percentage of hectares planted for the red and white wine varieties respectively. This agrees with the previous research by Bezuidenhout (2020) which shows that these white and red wine grape varieties have the largest hectares planted to it in a typical farm in the Robertson region.

Table 5.2: Land use description of the case study farm

Planted Land Division:			
Enterprise:	**Total Ha:**	**% of Total Planted Land:**	**% of Total Arable Land:**
White Cultivars:			
Chenin Blanc	24,30	16,08%	15,00%
Sauvignon Blanc	13,66	9,04%	8,43%
Muscat de Alexandria	6,20	4,10%	3,83%
Colombar	2,31	1,53%	1,43%
Chardonnay	1,53	1,01%	0,94%
Weisser Riesling	0,69	0,46%	0,43%
Verdelho	0,45	0,30%	0,28%
Roussanne	0,43	0,28%	0,27%
Semillon	0,42	0,28%	0,26%
Total White:	**49,99**	**33,08%**	**30,86%**
Red Cultivars:			
Cabernet Sauvignon	35,70	23,62%	22,04%
Shiraz	20,77	13,74%	12,82%
Merlot	18,05	11,94%	11,14%
Pinotage	11,88	7,86%	7,33%
Grenache	3,96	2,62%	2,44%
Cabernet franc	3,39	2,24%	2,09%
Cinsault	2,73	1,81%	1,69%
Petit Verdot	1,73	1,14%	1,07%
Petit Shiraz	1,31	0,87%	0,81%
Pinot noir	1,05	0,69%	0,65%
Malbec	0,57	0,38%	0,35%
Total Red:	**101,14**	**66,92%**	**62,43%**
Totals:	**151,13**	**100,00%**	**93,29%**

5.3.3 Variable costs

Variable costs are costs associated with the production process in a farm. These costs include chemicals costs, seed costs, fuel costs, transport costs, repair and maintenance costs, fertilizer costs, seasonal labour costs, water, and electricity. For this study, the only relevant variable costs are the fertilizer costs, chemicals costs (herbicides, pesticides, and insecticides) and seasonal labour costs as these are the costs that are altered to show changes in the production process. All other variable costs are assumed to be held constant. Table 5.3 shows the variable costs for all three scenarios plus the baseline scenario. The percentage of variable costs for chemicals in the baseline scenario is slightly higher than that given in previous research. However, the percentage of variable costs of fertilizers in the baseline scenario is lower than those given in previous research (Bezuidenhout, 2020). These differences are to be expected given the difference in farm sizes, regional contexts and even fertilizers and chemical spray programmes. Previous research has shown that even farms in the same region can have different environmental contexts and thus varying demands for fertilizers and chemicals. With improved social sustainability practices in line with recommendations from WIETA, the costs of seasonal labour increased from 25.74% of the variable costs in the baseline scenario to 36.28% of the variable costs in scenario 2 and 29.70% in scenario 3. The wages of workers are lower than the recommended levels from WIETA (Personal communication - Lipparoni, 2021). This is hardly interesting given farmworkers are among the most marginalized workers of any given sector (Devereux, 2020). On the other hand, with improved environmental sustainability practices with recommendations from IPW and consultants in the Robertson region, fertilizers increased from 6.75% of the variable costs in the baseline scenario to 21.59% in scenario 1 and 19.72% in scenario 3, while chemicals decreased from 27.76% in the baseline scenario to 19.74% in scenario 1 and 18.03% in scenario 3. This shows that in the baseline scenario, the fertilizers are lower than the recommended rate for the Robertson region, while the synthetic chemicals are higher than the recommended levels for the Roberson region (Personal communication - Mathyser, 2021).

Table 5.3: Variable costs for the case study farm

Scenario	Fertilizers (% of variable costs)	Chemicals (% of variable costs)	Seasonal labour (% of variable costs)
Baseline	6.75	27.76	25.74
Scenario 1	21.59	19.74	23.06
Scenario 2	6.75	27.76	36.28
Scenario 3	19.72	18.03	29.70

5.3.4 Overhead and Fixed costs

Except for the wages for permanent labour, the overhead and fixed costs are assumed to remain constant for the baseline and all three scenarios as these costs has no effects on the changes in the production process associated with this study (Table 5.4). Overhead and fixed costs include but are not limited to bank charges, property taxes, office equipment, accounting fees, licences, wages for permanent labour etc. Table 5.4 shows the fixed costs concerning permanent labour for the case study farm. In line with recommendations from WIETA, the costs of permanent labour increased from 25.32% of the fixed costs in the baseline and scenario 1 to 35.68% of the fixed costs in scenarios 2 and 3. Just like seasonal workers, this result shows that permanent workers are still being paid below the recommended levels (Personal communication - Lipparoni, 2021)

Table 5.4: Fixed costs with regards to permanent labour

Scenario	Permanent labour (% of fixed costs)
Baseline	25.32
Scenario 1	25.32
Scenario 2	35.68
Scenario 3	35.68

5.3.5 Gross production value

The gross production value of the case study farm is gotten by multiplying the quantity of the output (tons of wine grape cultivars) with the farm gate prices of these various cultivars. However, this gross production value is also affected by various factors like exchange rate, production volume, international prices, and export volume (Bezuidenhout, 2020). Table 5.5 shows the price per unit (in tons) of the various wine grape cultivars produced on the farm. The prices of white and red grape cultivars range from over R3,000 to over R6,000 with Chardonnay being the most profitable white wine cultivar at R6,234.53 per ton and Pinot noir, the most profitable red wine variety at R6,544.72 per ton. Even though the prices differ, results mostly agree with research by Bezuidenhout (2020) on Chardonnay and Pinot noir being the most profitable white and red wine grape cultivars in the Robertson region. The latter two grape cultivars do well in the limestone soils in the region. Therefore, premium quality grapes are produced and either used for still wine and Methodé Cap Classique production.

Table 5.5: The price per ton for all wine grape cultivars produced

Grape Incomes[3]:	
(White Cultivars)	**Value per ton:**
Chenin blanc	**Value per Unit:**
Sauvignon blanc	R 4 419,60
Muscat de Alexandria	R 5 367,60
Colombar	R 3 412,31
Chardonnay	R 3 287,06
Weisser Riesling	R 6 234,53
Verdelho	R 3 559,20
Roussanne	R 3 559,20
Sémillon	R 3 559,20
(Red Cultivars)	**Value per ton**
Cabernet Sauvignon	**Value per Unit:**
Shiraz	R 6 481,91
Merlot	R 5 061,85
Pinotage	R 5 031,95
Grenache	R 6 222,89
Cabernet franc	R 5 115,79
Cinsault	R 5 421,64
Petit Verdot	R 3 393,54
Petit Shiraz	R 5 115,79
Pinot noir	R 5 115,79
Malbec	R 6 544,72

Table 5.6 shows the gross production value for the entire farm and the gross production value per hectare. The gross production value per hectare decreased from R51,423.53 respectively in the baseline and scenario 2 to R48,600 in scenario 1 and scenario 3. This implies that with the improved environmental sustainability practices (in terms of fertilizers and chemicals done in consultation with IPW and fertilizers/chemical spray consultants) in scenarios 1 and 3, the yield of the white and red wine grapes reduced and thus the gross production value reduced. Furthermore, given that labour (seasonal or permanent) does not affect grape yield *per se*, the gross production value of scenario 2 remains unchanged from the baseline scenario. It is important to note that the gross production value per hectare for the baseline scenario of the farm is lower than that of the Robertson region (Personal communication - Schutte, 2021). This will unavoidably affect the environmental and social scenario given that the production levels are below average in the region.

Table 5.6: Gross production value for the case study farm

Scenario	R/farm	R/ha
Baseline Scenario	R7,771,637.89	R51,423.53
Scenario 1	R7,344,918	R48,600
Scenario 2	R7,771,637.89	R51,423.53
Scenario 3	R7,344,918	R48,600

5.3.6 Gross Margin

The gross margin is determined by subtracting the variable costs from the gross production value. The gross margin for the case study farm for the baseline and all three scenarios is given in Table 5.7 As earlier stated, the gross margin is the first accounting principle to be calculated when trying to determine the financial effects of changes in production practices as this value shows a change. The gross production value per hectare for the baseline scenario is R42,534.82. With alterations in the environmental and social dimensions, the increased costs of seasonal labour and the altered costs of fertilizers and chemicals which were assumed to impact the grape yield, the gross production value per hectare reduced to R32,385.58, R41,004.38 and R30,855.14 for scenarios 1, 2, and 3 respectively. Given reduced yield and reduced gross production value, the gross margin of the farm consequently reduced.

Table 5.7: Gross margin for the case study farm

Scenario	R/farm	R/ha
Baseline	R6,428,287.17	R42,534.82
Scenario 1	R4,894,433.21	R32,385.58
Scenario 2	R6,196,991.97	R41,004.38
Scenario 3	R4,663,137.57	R30,855.14

5.3.7 Total and net farm income for the case study farm.

The net farm income, essentially the profitability of the farm, is calculated by subtracting all the variable and fixed costs from all the farm income. The net farm income shows the actual profitability of the farm in a particular growing season. Table 5.8 shows the total farm income and the net farm income per hectare for the case study farm. Table 5.8 shows that with a net farm income per hectare of R25,573.40 in the baseline scenario, the case study farm is already in the low-profit range – R2,000 – R34,000 net farm income per hectare of wine farms in the Western Cape (VinPro, 2020). This is noteworthy given the fact that as earlier stated, the gross production value of the farm is below average for the Robertson region. However, the net farm income of the farm is still above the industry level average of R20,617/ha (VinPro, 2020). The changes in the social and environmental dimensions caused a reduction in the net farm income from the baseline of R25,537.40 to R17,091.95, R22,458.38

and R8,339.05 for scenarios 1, 2, and 3 respectively. Looking at the reductions, it is clear that combined improved environmental and social sustainability practices severely impacted the profitability of the farm while only improved social sustainability had the least financial consequence. These results are interesting in the sense that because of the complexity of agricultural production, alterations in the environmental dimensions are difficult to simulate. However, changes in the social dimension are rarely complex because it involves a change in factors like wages, housing, health, and safety etc., factors that have no effect on the actual production process and thus simulating the social dimensions are the closest to real-life situations. Consequently, the fact that the social dimensions had the least effect on the profitability of the farm is encouraging as farmworkers are in dire need of social upliftment (Devereux, 2020).

Table 5.8: Total and net farm income

Scenario	Total farm net income	Net farm income/ha
Baseline	R3,864,908.51	R25,573.40
Scenario 1	R2,583,107	R17,091.95
Scenario 2	R3,394,135.76	R22,458.38
Scenario 3	R1,260,281.36	R8,339.05

5.4 CONCLUSIONS

This research has tried to evaluate the possibility of balancing the three pillars of sustainability in a case study wine farm. Wine farms as agricultural systems are especially complex due to varying interconnected elements interacting in the system. Because of the need of farmers to anticipate the consequences of their decisions, simulation models have emerged as an efficient way to model production systems to assess the financial consequences of changes in production systems and assist farmers in making appropriate farm management decisions based on the best knowledge available to them. This research utilizes one of the various simulation models available, the enterprise budget by modelling only the production process of the farm. Three scenarios – environmental, social, and environmental/social – plus a baseline scenario was modelled to compare the effects of these changes in the profitability of the farm. The model environmental and social scenarios were developed in consultation with IPW, WIETA and farm consultants in the Robertson wine region. The results showed that alterations in the environmental dimension in terms of fertilizers and synthetic chemicals reduced the grape yield and consequently the gross production value. Even though the increased costs associated with alteration in the social dimensions did not affect the gross production value, along with the change in the environmental dimension, the gross margin and net farm income were reduced, with the combination of environmental and social sustainability having the most drastic effects. However, changes in the social dimension had the least effects and these changes show that even significant changes in the social dimension had only a modest effect on the profitability of the farm. However, these results should be read with caution as not all input parameters in the environmental and social dimensions were included and the model scenarios rest on reducing the complexity of an already complex system.

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Chapter 6

General discussion and conclusions

Chapter 6: General discussion and conclusions

6.1 GENERAL CONCLUSION

Following the Second World War, an increase in population went simultaneously with an increase in production and productivity in all sectors, including agriculture (Altieri, 1992). In agriculture, this increase in production was heavily reliant on synthetic inputs (Wojtkowski, 2006). Initially, it was a boon to agriculture and the population as food prices decreased dramatically (Hazell, 2002). Over time, however, the environmental impacts – pollution of air and water bodies, greenhouse gas emissions, increased pesticide resistance, soil loss etc – of this change in production systems were becoming increasingly apparent (Dordas, 2009). As a result, the concept of essentially "doing more with less", "preserving and increase the natural resource base" and "thinking of the future" was born and with time, sustainability became to go-to word for any efforts to reduce the environmental impacts of production systems (UN, 1983, 1987). This concept was eventually expanded to include the economic and social dimensions – through the millennium development goals and later the sustainable development goals – as intrinsically important for any effort towards sustainability (Elkington, 1998; UNGA, 2015; Morton *et al.*, 2017).

The various agricultural industries took up the concept of increased sustainability with fervour, even more so as agriculture began to feel the effects of climate change and given the fact that agriculture accounts for roughly 13% of greenhouse gas emissions (Chaudhury *et al.*, 2018). This even extended to the grape and wine industries as it became increasingly clear that grape and wine production was not so environmentally efficient as initially thought and given the fact that grape and wine production is especially susceptible to climate change, more so than any other agricultural sector (Christ and Burritt, 2013). With all this demand for sustainability and sustainable products, even from consumers, one would think a grounded and universal definition of the concept exists (Wei *et al.*, 2009). However, this is not the case as the idea or notion of sustainability was all experts had, but explaining what that idea meant, how to measure it and how to achieve it was fraught with difficulties, in large part because ideas are universal and thus everyone had their ideas of what sustainability entails (Pacini *et al.*, 2011; Koohafkan *et al.*, 2012). This is where this research comes in.

Even though there has been considerable research on the effort to explain, evaluate and measure sustainability, the focus has always been on the environmental pillar (Aslund, 2013; Naude, 2019). This research, a first of its kind in South Africa, has aimed to bridge that gap, but taking an equal look at the three pillars that constitutes sustainability, what they mean, how and what to measure for each pillar and evaluate the possibility of balancing all three pillars in grape and wine production in South

Africa. The importance of this research cannot be oversold because any effort towards sustainability needs to first understand what sustainability means to the stakeholders in charge of improving it, it must then figure how to measure and what to measure it to improve it. Without this approach, efforts in improving sustainability in South African grape and wine production is bound to be disjointed, incoherent, piecemeal, and individualistic.

EXPERIMENTAL LAYOUT

This study encompasses a combination of qualitative and quantitative research methods which employed a wide variety of research respondents: viticulturists, winemakers, cellar masters, academic lecturers, industry persons, regional consultants, and government officials to get a well-rounded group of experts tasked with making decisions about sustainability in grape and wine production in South Africa. The experts were a highly educated group with all, but two having at least a bachelor's degree and over half having at least 15 years of experience in the grape and wine industries of South Africa, which shows a highly experienced group.

GENERAL DISCUSSION

• Objective 1: Define what sustainability means to the stakeholders of the wine industry in South Africa.

A qualitative study aimed to establish what the three pillars of sustainability meant to the various stakeholders and how climate change affects them. In agreement with previous research, each one of the respondents defined sustainability differently and the environmental pillar dominated their perceptions of sustainability in its importance. However, the social pillar was deemed the most difficult to achieve as this speaks to the difficult history and relationship that has characterized labour relations in South African agricultural sectors. Furthermore, respondents confirmed that trade-offs are an inherent conflict in sustainability due to the interrelationship between the three pillars, but the majority believed it was possible to balance all three pillars. In the context of climate change, the effects of climate change have increasingly been felt through drought, rainfall extremes and sometimes, wind and frost. Even though previous research has shown positive effects of climate change through increased grape yield, increased sugar content and better wine quality, our study showed that that is not the case in South Africa, a warm region of grape and wine viticultural classification. Our research shows that increased water demand and increased reliance on synthetic chemicals for pest control is gradually becoming the norm and these reduced profits and increased production costs may spill into the social pillar and have vicarious effects in this dimension of sustainability. Regardless, the respondents believed that with knowledge of adaptation strategies, the effects of climate change can be managed and the three pillars of sustainability, adequately balanced.

Given the results of this study, we have come to define sustainability in agriculture as "the continuous effort in trying to balance and/or reconcile the economic viability, environmental stewardship and social responsibility of a farm in the different economic, environmental and social context of the farm, farming region and country in any given time". This definition of sustainability is apt because it is not just enough to consider the three pillars of sustainability, one must consider these pillars in the context where they exist. For example, water use practices that might be suitable for a wine farm in France or Italy, might not be the same for South Africa or the western United States as the low rainfall in these later countries might necessitate a higher irrigation water demand. Therefore, it would be controversial to consider the water use of farms in South Africa and the western United States as not environmentally sustainable as compared to France or Italy without considering the environmental context of South Africa and the United States, which is, for the most part, a semi-arid region. The same contextual factors apply to the economic and social dimensions. Furthermore, sustainability is defined as a "continuous effect to balance and/or reconcile" because there is not one thing that can be done to improve sustainability but rather a combination of decisions and practices over time, always changing as new knowledge and information is available and as the economic, environmental, and social context inevitably evolves. The idea should not be to achieve all three pillars *per se* but to "balance and reconcile". The onus on balancing and/or reconciling is because these three pillars will always be conflicting and thus striving for achieving all three in a farm is not feasible. The effort, therefore, is to consider the various contexts where these pillars exist in the farm and strive for a set of practices and decisions that tries to bring the best of out all three pillars given the various dimensional limitations. Lastly, the definition also considers time because any consideration of sustainability must take into account the time frame that it is considered. After all, what might appear sustainable in this growing season might not be so the next and vice versa (Chapter 3). In other words, the concept of improved or diminished sustainable practices is only as good as when it was considered.

Objective 2: Determine appropriate and context-specific indicators for sustainability assessment of wine production in South Africa.

A quantitative study was conducted on the idea that "you cannot manage what you cannot measure" (O.Brian and Colby, 2008) and thus tried to provide indicators of economic, environmental, and social sustainability can that be measured to be improved. Here, we used the Delphi technique, a method of achieving consensus or agreement in any given subject matter among experts in a given field. The results of the Delphi technique show in terms of economic sustainability, experts were acutely aware of the precarious situation of South Africa wine, which is one of the cheapest in the foreign markets due to the focus on bulk wine during the apartheid era and thus indicators like brand value, grape and wine demand, grape and wine prices and production and quality consistency were regarded as highly relevant. However, indicators like environmental and social certifications were deemed as not relevant which speaks to the fact that producers are not seeing the benefits of certification compliance and the costs sometimes outweigh the benefits. In terms of environmental indicators, indicators like water use efficiency, chemical use efficiency and environmental record-keeping were deemed as relevant but what this means remains to be seen as research has shown that even with knowledge of the excessive use of these inputs, production practices rarely change. However, regional environmental contexts may play a role in the high use of external inputs. For social sustainability, it appears that to a large extent, producers' hands are tied as even though they believed in the need for improved social conditions in the lives of farmworkers, the financial situation of most farms precludes farmers from making any meaningful or permanent change and whatever improvements are to the social dimension is bound to be piecemeal and subject to the prevailing economic situation of the farm. This research has shown that wine farmers are placed in an untenable position. The cheap and bulk wine that the country produces is what it is known for and for the most part, what foreign retailers expect. But the demand for this type of wine is decreasing and thus its profitability. Upscaling to brand wines is fraught with difficulties. For one, the term "brand" implies a certain amount of reputation for quality and quality wines is not what South Africa is known for. Thus, foreign retailers might be reticent to buy these types of wine given its untested reputation. At the same time, keeping the focus on bulk wines will, in time, be one of the death knells of the industry in South Africa. Governmental intervention in terms of subsidies for wine is an option but when one thinks of agricultural subsidies, corn, wheat, and soybeans are what comes to mind, not wine or table grape. This situation is even exacerbated when considering the social indicators because it is clear that producers can only do so much in improving the lives of their workers as the economic viability of many farms is a roadblock. Certifications that were meant to help producers have been dominated by the big retailers where they push the cost of certifications to producers and reap almost all the benefits (Moseley, 2008). Retailers assisting with the cost of certifications remains the most promising option but whether that is possible or even a long-term solution remains to be seen.

Objective 3: Assess the possibility of achieving the three pillars of sustainability in a wine farm in South Africa.

A quantitative study tried to find out the feasibility of actually balancing all three pillars of sustainability in a farm. Here, a partial budgeting model (an enterprise model) was used. This model only involves the production process of a farm and uses a case study farm, unlike previous research that employed a typical farm (Hoffmann, 2010). Four scenarios were simulated using the partial budgeting model: the baseline scenario, the environmentally sustainable scenario, a socially sustainable scenario, and the environmentally/socially sustainable scenario. The environmentally sustainable scenario with regards to fertilizers and chemicals was created in consultation with IPW, VinPro and consultants for the Robertson region where the case study farm is located. While the socially sustainable scenario with regards to workers' wages was created in consultation with WIETA. The results show that in the environmental scenario, the quantity of fertilizers increased while the quantity of chemicals decreased. This consequently affected the wine grape and reduced yield. For the social scenario, the wages of the workers increased in line with WIETA recommendations. Consequently, the gross production value, the gross margin and the net farm income decreased in all three scenarios. Even though the decrease in profitability was significant for the combined environmental and social scenario, the decrease in the social scenario only was marginal. Although these results should be read cautiously, it shows that considerable improvement in social sustainability practices can potentially reduce the profitability of farms, this reduction is not so significant as to prevent farmers from implementing them. These practices could potentially increase the profitability of the farm through an increase in labour productivity for example. It remains to be seen if farmers can take up these sustainable practices.

6.2 LIMITATIONS OF THE RESEARCH AND DIRECTIONS FOR FUTURE RESEARCH

As stated earlier, this research project is the first of its kind in South Africa that focused equally on the three pillars of sustainability. However, given the time constraints and the effects of the COVID-19 pandemic, there was only so much we could do. For the first objective, while we were able to get a somewhat diverse group of research participants, viticulturists and winemakers were over-represented in our sample. Future research should aim for better representation of the value chain as other actors like distributors, foreign retail industries (who import a sizeable quantity of South African grapes and wine), and consumers were not present in our study.

The importance of indicators of sustainability cannot be overstated as if something cannot be measured, it cannot be improved. If sustainability in grape and wine production is to be improved, it must first be measured and knowing what to measure is of utmost importance (O'Brian and Colby, 2008). This is the starting point in any push towards sustainable vitiviniculture. However, our second objective just focuses on identifying the indicators and not creating suitable assessment methods which is usually the crux of sustainability. Because of the interrelationships between indicators and context-dependency with thresholds and reference levels, creating an appropriate assessment method for sustainability indicators have been rife with difficulties (Astier *et al.*, 2011; Koohafkan *et al.*, 2012). Furthermore, the Delphi technique as a research methodology works better when used iteratively. Due to the constraints mentioned above, multiple rounds of the Delphi technique were not feasible. Previous research has recommended at least 2 rounds of the Delphi technique for more conclusive results (Escribano *et al*., 2018; Ahmad and Wong, 2019). Future research should aim for this.

Scenarios are depictions of possible futures (Therond *et al*., 2009). Scenarios allow us to ponder the question "what if". What if the quantity of fertilizers and chemicals are reduced to improve environmental sustainability? What if seasonal and permanent workers are paid a living wage? One of the sacrosanct principles of what-if scenarios is the principle of "ceteris paribus" (all things being equal) (Chiyangwa, 2018). In this context, it means all other things that might affect production and yield are held constant. This inviolable principle of what-if scenarios is its strength and its weakness. The strength is that it allows us to decomplexify production systems, briefly see into possible futures and make decisions accordingly. On the other hand, it also opens a significant limitation of this process, for the simple reason that all things are never equal given that production systems are complex and intricately related. Thus, making production decisions on model scenarios that depends on reducing the complexity of production systems is fraught with difficulties because there are countless elements in a system that might affect yield and keeping them constant is controversial, to say the least. Regardless, trying to account for them in the scenarios simply makes the model as complex as the system itself. Consequently, the results of the third objective should be interpreted with caution. Furthermore, in terms of the alterations in the environmental and social dimensions, not all input parameters related to these dimensions were included. For example, water and energy use were not accounted for in the environmental scenario and the social dimension, costs associated with worker's housing, health and safety tests, equipment safety tests etc. were also not accounted for. Water and energy use are especially difficult to quantify while other social costs related to worker's welfare are capital expenditures carried out every few years and thus not relevant for our study that focused on one growing season. Future research should aim to redeem this gap. Moreover, the scenarios did not consider the demand aspect of sustainable production as copious amount of research has been published that shows the willingness of consumers to pay more for environmentally and socially sustainable wine (Schaufele and Hamm, 2017). Adding this side will undoubtedly improve the profitability of farms. Lastly, while a partial budgeting model is useful in getting an initial picture of the financial consequences of alternative production systems, a whole farm, multi-year budget should be done in future research that includes capital requirements and inventory of farm holdings done for an extended time (usually 25 years) to get a complete picture of the financial effects of changing production. This whole-farm multi-period budget simulation should be done with a hypothetical typical farm of a region rather than a case study farm because a hypothetical typical farm involves a description of what constitutes an average farm in a particular region and thus is bound to provide more meaningful results than a case study farm that is unique in and of itself and may not represent production practices and systems in a given region (Hoffman 2010).

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APPENDIX I: Sustainability questionnaire

The three pillars (profit, planet and people) of sustainability amidst climate change: a South African table and wine grape perspective.

Dear participant,

I would like to invite you participate in a survey of what the three pillars (profit, planet, and people) of sustainability amidst climate change means in the South African table and wine grape context. This questionnaire will assist the researcher in identifying what the three pillars means to farmers, the trade-offs made daily, the decisions and choices that mediates these trade-offs and what are the current and future changes to the three pillars of sustainability in the context of climate change for the South African table and wine grape industry.

I meekly ask you to give me your earnest opinion to the best of your ability with regards to the questionnaire. Your participation is voluntary and anonymous, and I greatly appreciate your willingness to participate in this process.

Section A: What is sustainability?

1. What comes to your mind when you hear the word "sustainability"?
2. To you, a sustainable farm/cellar is ……………………?
3. What does economic sustainability mean to you?
4. What does environmental sustainability mean to you?
5. What does social sustainability mean to you?
6. Which pillar of sustainability is most important to you and why?
7. Which pillar of sustainability is usually the hardest to achieve and why?
8. According to your definition in (3), (4) and (5) above, what trade-offs are made, if any between these three pillars of sustainability?
9. What reasons mediates your answers in (8) above?
10. Do you think it is possible to achieve and balance/reconcile these three pillars of sustainability? Give reasons for either answers.
11. Would you say that your farm/cellar is economically, environmentally, and socially sustainable?
12. What are the reasons for your answers in (11) above?

Section B: The three pillars of sustainability in climate change.

1. What does climate change mean to you?
2. What effects of climate change in general are currently being felt in your farm/cellar?
3. Based on your definition of economic sustainability, how are the effects of climate change currently affecting the economic sustainability of your farm/cellar?
4. Based on your definition of environmental sustainability, how are the effects of climate change currently affecting the environmental sustainability of your farm/cellar?
5. Based on your definition of social sustainability, how are the effects of climate change currently affecting the social sustainability of your farm/cellar?
6. How do you see the future economic sustainability of your farm/cellar if the climate continues to change?
7. How do you see the future environmental sustainability of your farm/cellar if the climate continues to change?
8. How do you see the future social sustainability of your farm/cellar if the climate continues to change?
9. Which pillar of sustainability will become more important to you if the climate continues to change? Why?
10. Which pillar of sustainability will be harder to achieve if the climate continues to change? Why?
11. Do you it will be possible to achieve and balance/reconcile all three pillars of sustainability if the climate continues to change?
12. What practices (economic or otherwise) are you currently adopting to mitigate against the current effects of climate change on the economic sustainability of your farm/cellar?
13. What practices (environmental or otherwise) are you currently adopting to mitigate against the current effects of climate change on the environmental sustainability of your farm/cellar?
14. What practices (social or otherwise) are you currently adopting to mitigate against the current effects of climate change on the social sustainability of your farm/cellar?

APPENDIX II: Delphi technique questionnaire

The 3Ps of Sustainability in climate change. A South African grape and wine Perspective.

Questionnaire for the selection of appropriate context-specific sustainability assessment indicators for table and wine grape production in South Africa.

Dear prospective participant,

My name is Omamuyovwi Gbejewoh, a student at the South African Grape and Wine Research Institute (SAGWRI), Stellenbosch University and I would like to invite you to take part in a survey, the results of which will contribute to a research project in order to complete my MSc in Sustainable Agriculture. The study will be conducted under the supervision of Dr. Erna Blancquaert.

Please take some time to read the information presented here, which will explain the details of this project.

Your participation is entirely voluntary, and you are free to decline to participate. If you say no, this will not affect you negatively in any way whatsoever. You are also free to withdraw from the study at any point, even if you do agree to take part. Any and all information (including your identities) provided will be kept confidential and will only be known to the researcher and project supervisor.

The purpose of this questionnaire is to assist the researcher in selecting appropriate and context-specific sustainability indicators for the measurement of the three pillars of sustainability for grape and wine production in South Africa.

The questionnaire will take approximately 10 minutes to complete and will contain a combination of questions on which indicators of each sustainability pillar is important to you. The questionnaire is voluntary, and you will be able to terminate the questionnaire should you no longer wish to continue. The information will be deleted and will not be used for data analysis or any other research purposes

RIGHTS OF RESEARCH PARTICIPANTS:

You have the right to decline answering any questions and you can exit the survey at any time without giving a reason. You are not waiving any legal claims, rights, or remedies because of your participation in this research study. If you have questions regarding your rights as a research participant, contact Mrs. Maléne Fouché [mfouche@sun.ac.za; 021 808 4622] at the Division for Research Development.

Your information and response to the survey will be protected by a secure OneDrive Folder at Stellenbosch University and will only be accessed by only myself and my project supervisor.

If you have any questions or concerns about the research, please feel free to contact the researcher Omamuyovwi Gbejewoh (22338225@sun.ac.za) and/or the Supervisor, Dr. Erna Blancquaert (ewitbooi@sun.ac.za)

To save a copy of this text, take a screenshot of the consent letter on your device or send me a request via email (see email address above) and I will send the consent letter.

Instructions

1. The initial list of indicators was identified through literature review. Give scores to the listed indicators (from 1 to 5) according to the level of importance for the sustainability of table and wine grape production in South Africa.
2. Propose and score additional sustainability indicators that you think could be relevant for table and wine grape production in South Africa.

Definition: An indicator is defined as a variable which supplies information on other variables which are difficult to assess and can be used as a benchmark to make decisions.

Criteria: An indicator must be practicable (easy and cost effective to use and measure, comprehensible immediately and reproducible and data for it should be readily available) and useful (sensitive to variation, adapted to the context for the specific end user).

Personal Information

Highest education level:

Occupation:

Years of experience in the table and wine grape sector:

Identification of relevant indicators

Please, rate the listed indicators using a 5-point Likert scale:

1. Not important
2. Least or slightly important
3. Moderately important
4. Important
5. Very or highly important

You may add to the bottom of each table other indicators that have not been mentioned in this table that might also be relevant.

ECONOMIC INDICATORS

Measurable Indicator	**1**	**2**	**3**	**4**	**5**
Yield					
Grape and wine price					
Vine health					
Net income					
Inputs costs					
Financial autonomy (freedom from debts)					
Labour costs					
Grape and wine demand					
Brand value					
Fruit and wine quality					
Age of vines					
Production and quality consistency					
Labour productivity					
Environmental and social certifications					
Governmental subsidies					
Capital expenditure					
Non-capital related expenditure					
Break-even price					
Credit access					
Proportion of income from off-farm/off-cellar activities (e.g. Tourism)					
Add other indicators you think is relevant	**1**	**2**	**3**	**4**	**5**

ENVIRONMENTAL INDICATORS

Measurable Indicators	**1**	**2**	**3**	**4**	**5**
Soil Health					
Water use efficiency					
Plant, animal and microbial biodiversity conservation					
Off-farm impacts from vineyard and cellar					
Minimum soil disturbance					
Integrated Pest and disease management					
Carbon footprint					
Soil organic matter content					
Natural (untouched) area on farm					
Precision agriculture					
Environmental certification					
Air and Water quality					
Organic and inorganic waste disposal/recycling					
Soil conservation/Erosion control					
Pesticide/Fertilizer/Chemicals use efficiency					
Soil Cover					
Water footprint					
Wastewater treatment					
Energy use efficiency					
Record keeping					
Add other indicators you think is relevant	**1**	**2**	**3**	**4**	**5**

SOCIAL INDICATORS

Measurable Indicators	**1**	**2**	**3**	**4**	**5**
Workers' retention rate					
Workers' education, training and skills development					
Safe and Healthy work environment					
Workers' welfare					
Labour legislation compliance					
Social certifications					
Aesthetics					
Workers' housing and tenure security					
Farming community's health and welfare					
Worker's complaints					
Workers' productivity					
Labour costs					
Off farm/off cellar activities (e.g., Tourism, wine tours)					
Proportion of permanent to casual/seasonal workers					
Right to a living wage					
Farming community's benefits					
Workers children's education, health and welfare					
Consumers' health/welfare					
Proportion of male to female workers (Gender equality)					
Other work-related benefits (e.g., transportation, end of year bonus etc.)					
Add other indicators you think is relevant	**1**	**2**	**3**	**4**	**5**

APPENDIX III: Full list of sustainability indicators

Dimension	Indicator	Consensus score (%)	Mean score (Out of 4)	Standard Deviation
Economic	Grape Yield	85%	3.4	0.6
	Grape and Wine Prices	90%	3.6	0.6
	Vine Health	90%	3.6	0.6
	Farm Net Income	89%	3.56	0.51
	Input costs	89%	3.56	0.72
	Financial Autonomy (Freedom from debts)	83%	3.31	0.60
	Labour Costs	81%	3.25	0.68
	Grape and Wine Demand	88%	3.5	0.52
	Grape and Wine Quality	90%	3.6	0.48
	Brand Value	88%	3.5	0.79
	Production and Quality consistency	93%	3.7	0.6
	Labour Productivity	93%	3.7	0.6
	Age of Vines	58%	2.31	0.79
	Environmental and social certifications	78%	3.1	0.95
	Government subsidies	50%	2	1.5
	Capital expenditures	75%	3	0.89
	Break-even price	78%	3.1	0.99
	Credit access	69%	2.75	0.86
	Non-capital expenditures	78%	3.1	0.85
	Income from off-farm/off-cellar activities	68%	2.7	1.08
Environmental	Soil Health	99%	3.94	0.25
	Water use efficiency	97%	3.88	0.34
	Plant and Microbial biodiversity conservation	89%	3.56	0.63
	Environmental Record Keeping	83%	3.31	0.79
	Integrated Pest Management	92%	3.69	0.6
	Carbon Footprint	80%	3.2	0.91
	Soil Organic Matter content	88%	3.5	0.52
	Water Footprint	86%	3.44	0.81
	Precision Agriculture	86%	3.44	0.73
	Wastewater Management	83%	3.31	0.87
	Air and Water Quality	88%	3.5	0.52
	Organic and Inorganic Waste Management	83%	3.31	0.6
	Soil Conservation/Erosion Control	92%	3.67	0.48
	Energy Use Efficiency	88%	3.5	0.52
	Fertilizers, Pesticides and Chemical Use Efficiency	92%	3.69	0.48

	Soil Cover	89%	3.56	0.51
	Off-farm/off-cellar environmental impacts	70%	2.81	1.05
	Minimum soil disturbance	72%	2.88	0.81
	Percentage of natural (untouched) area on the farm	75%	3	0.89
	Environmental certifications	78%	3.13	1.02
Social	Workers' education, training, and skills development	91%	3.63	0.62
	Safe and Healthy Work Environment	94%	3.75	0.45
	Workers' Welfare	91%	3.63	0.5
	Labour laws compliance	91%	3.63	0.89
	Farming Community's health and welfare	89%	3.56	0.51
	Workers' productivity	95%	3.81	0.54
	Labour Costs	86%	3.44	0.73
	Right to a Living Wage	97%	3.88	0.34
	Farming Community's benefits	81%	3.25	0.77
	Workers children's education, health, and welfare	95%	3.81	0.54
	Consumers' health and welfare	89%	3.56	0.63
	Workers' retention rate	78%	3.13	0.72
	Social certifications	74%	2.94	0.99
	Aesthetics	66%	2.63	0.81
	Workers' housing	78%	3.19	0.83
	Off-farm/off-cellar activities	67%	2.69	0.79
	Ratio of permanent to temporary workers	72%	2.88	0.96
	Other work-related benefits	78%	3.13	0.62
	Gender equality	75%	3	0.89