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Assessing Seasonal Forecast Use in Western Cape Viticulture:  
A Risk Framework Approach

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*By*

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Submitted to the University of Cape Town in fulfilment of the requirements  
for the degree

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GradMonth Year



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*Psalms 9:1*

# Abstract

Viticulture refers to the practice of cultivating grapevines for winemaking. With a rapidly changing climate and rising global temperatures, this type of farming is under significant threat. Seasonal forecasts (SF) offer the potential to reduce farmer's vulnerability to climate risks by offering advanced climate information. This study aims to use a risk management framework to identify and compare the level of risk involved in using or not using seasonal forecasts in viticulture.

The study's primary data was collected through self-administered semi-structured interviews with viticulturists, agricultural consultants, and farm managers at different wineries within the Western Cape province, South Africa (SA). Wine grape farmers were interviewed to learn about their adaptation strategies in response to climate variability and their use or no-use of SF. The interviews explored the nature and types of risks that exist when climate conditions are above and below normal conditions, with and without the use of SF.

A risk management framework, designed for this study's context, was used as a reference point, giving common ground to analysing the responses thematically and produce evidence toward each study objectives. The results show that climate variability poses a significant threat to the yield and quality of wine produced and has a negative impact on the labour and finances involved in running a vineyard. Analysing the responses showed that forecast uncertainty is the main driver of low SF uptake thus correlating with a lack of risk precautionary decision-making measures by farmers. Making them more vulnerable to unexpected climate impacts and risks. Farmers who make use of SF are mainly commercial who work with consultants and whose main income is made from selling grapes.

The evidence presented suggests that the adoption of a risk framework could potentially aid farmers in making better decisions to help them identify, mitigate and/or avoid risks using SF technology to inform risk identification for present and future climate scenarios of their vineyards.

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# Abbreviations

AN	Above Normal
AR	Assessment Report
BN	Below Normal
CPT	Cape Town
ENSO	El Nino Southern Oscillation
DEFF	Department of Environment, Forestry and Fisheries
GCM	Global Climate Models
GDP	Gross Domestic Product
IPCC	International Panel on Climate Change
N	Nitrogen
N <sub>2</sub> O	Nitrous Oxide
NDP	National Development Plan
OIV	International Organization of Vine and Wine
PRD	Partial Root Drying
RCP	Representative Concentration Pathways
SA	South Africa
SAWS	South African Weather Services
SF	Seasonal Forecast
SPEI	Standardized Precipitation Evaporation Index
WoSA	Wines of South Africa

# Chapter 1 – Introduction

## 1.1 Background

### 1.1.1 Difference between table and wine grapes

Grapevines are a type of fruit crop used to make a variety of fresh, dried, and processed products such as wine, jam, and juice. They are of significant economic value worldwide with an estimated average of 48% of the world's grape production used for winemaking (Alston and Sambucci, 2019). Although all grapes belong to the same species *Vitis Vinifera*, wine grapes and table grapes are selectively bred for different characteristics that distinguish their appearance and size for their different uses. Table grape berries are larger in size compared to wine grape berries and have uniform colouring, no seeds, and thinner skin to appeal to the consumer market (Rasulov, 2017). In comparison, wine grapes berries are smaller in size with thicker skin and contain seeds which enhances the colour and flavour of wine. The difference between the two types of grapes is depicted in Figure 1.1.

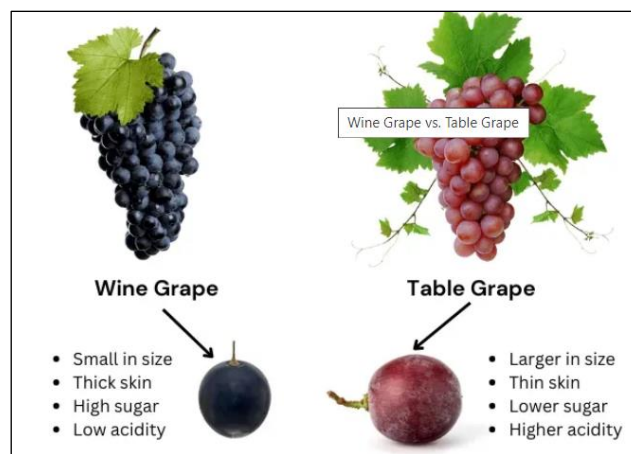


Figure 1.1 Differences between table grapes and wine grapes (Edwards, 2023).

Due to their specific growth requirements, grapevines are grown predominantly in narrow geographic and climatic regions characterized by Mediterranean, maritime or continental climates. These climates provide conditions best suited for optimum wine grape quality and production. Individual wine grape cultivars have even narrower climate ranges which limits areas suitable for its cultivation. Narrow niches jeopardise the cultivation of wine grapes more

than any other crop due to short term climate variability and long-term climate changes (Jones and Webb, 2010).

A typical grapevine requires between 635 and 890 mm of water during its growing season to avoid stress and produce high-quality wine (VinPro, 2022a). The distribution of rainfall is particularly important for dryland vineyards, as excessive or insufficient water at critical stages of the vines growth process can negatively affect the quality of the wine (Goldammer, 2018). In recent decades Southern Africa has experienced frequent and severe drought events which have consequently threatened the long-term sustainability of the wine industry (Baudoin et al., 2017). Climate variability and water scarcity challenges in the region make it difficult for wine grape growers to produce high quality grapes with an adequate balance of sugar and alcohol content. To deal with this, farmers have adopted management strategies such as canopy and crop control (i.e. vine thinning) and the use of appropriate trellising systems to ensure the production of high quality grapes (Yin et al., 2022).

A trellis system is a structure that is established when planting a vineyard. It helps to train and support vines and other climbing plants as they grow. It usually comprises a network of vertical and horizontal supports such as stakes and wires that guide the plant and keep it off the ground. The benefits of use for grapevines include better light penetration that promote photosynthesis, better air circulation that reduces the risk of fungal diseases, optimization of space in the vineyards and simplification of harvesting and crop protection such as pruning and vine thinning (Sun et al., 2023). A vertical trellis system, as shown in Figure 1.2 below is suitable for wine grapes as it allows growers to control the vigour of the grapes and their exposure to sunlight (Yin et al., 2022). Comparatively, a “T-shaped” trellis system, as shown in Figure 1.3, is suitable for table grapes as it minimizes contact between the grapes, allowing them to hang freely and thus maintain their appearance (Yin et al., 2022).



*Figure 1.2 Vertical trellis system*



*Figure 1.3 “T-shaped” trellis system*

### ***1.1.2 Characteristics of grapevines in SA***

The wine-growing regions in South Africa (SA) are diverse and extend across several provinces, including the Western Cape, KwaZulu Natal, and Northern Cape. Due to the Mediterranean climate in the Western Cape, regions such as Stellenbosch, Franschhoek and Paarl are known for producing some of the best wines in the world. The country is also known

for producing wine grapes in unconventional climates such as the Northern Cape which is characterized by semi-desert climate conditions, cool nights and very little rain (Lottering, 2024). The quality of the wine differs significantly from that of grapes grown in Mediterranean climates due to the difference in terroirs and the lack of the cool sea breezes which prevails in the Western Cape. Cooler climates are best suited for the cultivation of white and sparkling wines whilst red grape varieties are more resistant to hot and dry conditions (Jones et al., 2012).

### ***1.1.3 Importance of wine grape production in the Western Cape***

The history of wine and wine making in SA dates to the year 1655 when the first vines were planted in Cape Town by Dutch Settlers at the Cape of good hope. South Africa is considered a “new world” wine producer which refers to wines that are planted in warmer climates compared to “old world” producers which were mainly found in Europe and Middle East regions (Fraga, 2019). Since then, the industry has grown exponentially, contributing billions to the national GDP. South Africa accounts for 4% of wine produced globally and is ranked amongst the top ten biggest wine producers internationally, marking it as a significant economic driver in the country (Araujo et al., 2016). Furthermore, the industry is estimated to supply close to 270 000 jobs throughout the wine value chain in the country and an approximate 90% of all wine produced in SA is grown and manufactured in the Western Cape, making it a vital component of the agricultural output of the province (Araujo et al., 2016). The industry is important for its contributions towards the GDP and employment in a country with otherwise one of the highest recorded unemployment rates in the world (Statistics South Africa, 2023).

### ***1.1.4 Use of seasonal forecasting in viticulture***

“The cultivation of grapevines for winemaking known as viticulture is widely cited as a climate-sensitive agricultural system that has been used as an indicator of historic and contemporary climate change” (Mosedale et al., 2016). Many studies have posed the question of whether existing wine-growing regions will continue to be suitable for cultivation in the future given the rapidly changing climate. The literature reveals that climate change is expected to have both positive and negative effects on different wine-growing regions around the world (Mosedale et al., 2016). It is anticipated that vineyards may need to adopt new grape varieties, relocate to new regions and/or higher altitudes to adapt to these changing conditions (Santos et al., 2020). One such way to adapt to climate variability is by introducing and encouraging the use of tools

and technologies such as seasonal forecasting, which offer weather predictions of an upcoming season a few months in advance.

Seasonal forecasts refer to climate model predictions created using complex hydrodynamic equations about the weather and climate through the use of computer models (Hansen et al., 2011). The models are assembled using equations that simulate the behaviour of the atmosphere, ocean and land surface over a certain period (Hansen et al., 2011). Due to viticulture's vulnerability to local climatic conditions and annual rainfall patterns various forecast models have been tested to enhance the resilience of the sector to varying climatic conditions (Moeletsi et al., 2013). Early forecasting of meteorological risks has proven to enable farmers to establish appropriate mitigation measures to minimize production losses in SA. Similar advances in technology have made it easier to accurately predict weather and climate abnormalities at temporal intervals ranging from days, seasons and in some instances, years (Moeletsi et al., 2013).

Seasonal forecasts have the potential to reduce farmer's vulnerability to climate risk by offering advanced climate information that encourages efficient use of resources (e.g. water for irrigation and agrochemicals application) thus enhancing farmer's ability to manage production volatility. It is possible to reduce the impact of climate risks on agriculture and improve food security in SA through effective management of farms/vineyards and adoption of forecasting technologies. The improved accessibility of climate information and technology has made it easier for new-age farmers to intensify production, replenish soil nutrients and adopt climate resilient strategies that protect farms/vineyards against harsh long-term consequences of extreme events (Hannah et al., 2013). Farmer's accessibility to climate information enables them to plan for anticipated climate hazards and avoid or mitigate effects before impact (Chisadza et al., 2020).

## **1.2 Climate challenges in South Africa**

South Africa (SA) is predominantly semi-arid and faces challenges related to the lack of effective rainfall, leading to devastating impacts on agriculture, water availability, ecosystems, the economy and society. The region is also influenced by a variety of factors that exacerbate drought events such as the El Nino Southern Oscillation (ENSO). ENSO represents an interplay between the earth's global atmosphere and the Pacific Ocean which results in fluctuations in

the ocean-climate patterns (Sazib et al., 2020). ENSO phases (El Nino vs La Nina vs Neutral) are driver of weather conditions and can cause a variety of disasters such as floods and droughts in various location around the world (Cai et al., 2021, Ibebuchi, 2021). In SA El Nino phase often bring hot and dry conditions, conducive of heatwaves and droughts that have a devastating impact on agriculture. These rainfall changes combined with human-induced global warming, increase the severity of drought episodes on South African agriculture due to the high amounts of water lost via evapotranspiration. Human-induced climate change also leads to an increased probability of extreme weather events in the country including heatwaves and droughts (King et al., 2020, Manatsa et al., 2017).

Cape Town's 'day zero' was a result of a prolonged drought period that began in autumn of 2015 and extended through the winters of 2016 and 2017 (Cash et al., 2019). By the summer of 2018, the impacts of the consecutive droughts were felt across the country leading officials to the decision to implement water restrictions in major cities in the country like Cape Town (Wolski, 2018). Being the second largest city in the country, 4.6 million Cape Town residents were then limited to using 50 litres of water per person per day. The water restrictions were further extended to water-dependent industries such as agriculture, where the amount of water typically allowed for irrigation purposes were cut by up 90% in an attempt to conserve water during the drought (VinPro, 2022a). In May 2018, the Western Cape government announced that the province's largest dam, Theewaterskloof, which supplies its residents with potable drinking water and irrigation, sat at a worrying capacity level of 21.4% thus triggering the call for day zero (VinPro, 2022b). Consequently, this prolonged drought period that brought the Western Cape to the brink of day zero resulted in devastating impacts on the wine industry.

### **1.3 Problem statement and rationale**

The increasing frequency of climate variability and severity of extreme climate events in SA poses a significant threat to the long-term sustainability of the wine industry of the country (Araujo et al., 2016, Bahta, 2021, Dube et al., 2022, Naik and Abiodun, 2020, Naude and Naude, 2019). Any adverse impact on wine grape production and the subsequent wine supply chain could result in severe economic and social consequences. Research has shown that low grape yields and poor wine quality are the most widely recorded challenges faced by viticulturists and farm managers due to climate variability and change. These impacts are likely to persist with a rise in prolonged heat and water stress challenges being faced in the

country. The region has already begun to feel the impacts of climate change with a steady decline in rainfall projected to occur even more so as the level of global warming increases (Englebrecht and Monteiro, 2021).

There is a lack of research that evaluates the nature and types of risks that influence the use or non-use of SFs by grape growers. The knowledge gained from this research can help farmers make informed decisions about the use of SFs as an adaptation strategy to cope with the changing climate and improve their overall resilience. The results can potentially serve as a model for other wine producing regions facing similar climatic challenges. They will not only provide novel information for the agricultural industry, but it also promotes and supports the adoption of climate smart agriculture, build farmer capacities and foster a deeper understanding of crop adaptation pathways. The lack of research that addresses the integration of risk management and seasonal forecasting in viticulture as a tool for sustainability highlights the originality of this study.

#### **1.4 Aim and objectives**

The aim of this study is to investigate the level of risk involved in the use and non-use of seasonal forecasts (SF) in viticulture, in the Western Cape Province. The key objectives of this study are to:

1. To categorize and analyse the different types of hazards and risks associated with growing grapes in the Western Cape to understand their sensitivity to climate hazards.
2. To examine current grower strategies in response to climate variability and compare practices with and without SF use.
3. To apply a risk assessment framework to compare the risk between using SF in viticulture and not using them.

#### **1.5 Thesis structure**

The thesis consists of six chapters. Chapter 1 outlined the purpose of the study, research problem, study aim and objectives. Chapter 2 presents a review of the relevant literature focusing on the relationship between climate variability and viticulture. It also explores

common adaptation strategies used to address the impacts of climate variability, discusses agricultural risk management and examines the role of seasonal forecasting in mitigating climate risk. A brief description of the research design, research structure and data collection methods employed in the study are provided in Chapter 3. Chapter 4 presents the results of the study while Chapter 5 offers a detailed analysis and discussion of the findings. Finally, Chapter 6 concludes the research aim and objectives with a summary and recommendations for future research.

# Chapter 2 - Literature Review

## 2.1 Introduction

The climate greatly influences and shapes agricultural systems particularly in viticulture where the vine is sensitive to fluctuating rainfall and temperature conditions. Understanding the relationship between climate and the vine is essential for managing climate impacts on grape production. This chapter explores this relationship and reviews existing literature on adaptation responses aimed at enhancing grapevine resilience. Among these strategies the use of SF emerges as an underutilised but critical tool in viticulture due to its potential to inform timely agricultural decisions with a rapidly changing climate. The chapter details the relevant literature on the role of SF in viticultural risk management.

## 2.2 Climate and the vine

Historically, climate has proven to be a pivotal factor to the success of all agricultural systems (Ramos *et al.*, 2015). It determines the geographical suitability of a crop system in a given location and significantly influences crop quality and drives economic sustainability. However, agricultural systems in the present day are under unprecedented pressure due to the rapidly changing climate. These impacts are easier to spot in viticulture where the climate's influence is most critical for optimum fruit ripening in order to produce a desired wine style (Theron and Hunted, 2022). The selection of grapevine cultivars and viticulture practices is influenced by various factors including climatic characteristics, soil properties and human factors. Grapevine cultivars have specific soil preferences that impact the characteristics of the resulting wine style (Jones *et al.*, 2012).

The relationship between soil, plant and climate (also known as terroir) largely determines the characteristics and outcome of a vineyard. The concept of terroir encompasses the relationship between the physical and biological environment, viticulture and oenological practices, soil, topography, climate, landscape characteristics and biodiversity features (Naude and Naude, 2019, Riedo, 2019, Van Leeuwen and Destrac-Irvine, 2017). Grapevine development is also highly influenced by weather thereby making them particularly vulnerable to short and long term climate changes (Sun *et al.*, 2023). Climate variability is a natural phenomenon that occurs because of natural and periodic changes in the circulation of the air, ocean and other factors.

Climate variability has an impact on agriculture and although climate change and variability are natural phenomena, man's contribution exacerbates the rates of both long and short terms climate change and related agricultural impacts. While grapes can thrive under unconventional climates, prolonged extreme temperatures, and highly variable climate will greatly affect the yield and quality of produce in the long term which will affect the profitability of the industry at farmers level and the country at large (Araujo et al., 2016).

A Mediterranean climate is characterized by warm, dry summers and cool, wet winters providing optimal conditions for growing wine grapes. The average temperature range in this type of climate is between 13°C and 20°C during the critical phases of the growing season (Riedo, 2019). Climate projections indicate that temperatures are likely to continue to rise in the current century, posing possible detrimental impacts on viticulture (Araujo et al., 2016, Moriondo et al., 2013, Venios et al., 2020, Ollat et al., 2017). Various consequences of this are outlined in the literature ranging from immediate impacts like a change in the quality of wine to long-term impacts like a change in vine suitability regions and reduced resilience of grape cultivars grown in traditional wine regions.

Historical temperature trends for all main viticulture regions in the world have shown an increase in the average temperature during the growing season of 1.3 degrees between the years 1950-1999 and an increase of 1.7 degrees between the years 1950 to 2004 (Riedo, 2019). Grapevines are easily affected by rainfall and temperature variability. The most apparent impact being the accelerated bud break, flowering and fruit maturation phases which are now taking place earlier in some parts of the world like France and Germany. These regions have reportedly begun harvesting nearly three weeks earlier than they did in the 18<sup>th</sup>, 19<sup>th</sup> and early 20<sup>th</sup> centuries (Naude and Naude, 2019). While the effects of global temperature rise on other continents such as Africa are manifesting differently. For example in SA, wine grape harvesting is seeing a delay of up to 14 days compared to previous seasons (Mosedale et al., 2016).

### ***2.2.1 Impacts on phenological cycle***

Grapevines require varying levels of water at different growth stages and during different periods of the year. Their distinct annual growth cycle begins with budbreak. In the Southern Hemisphere this occurs between September and October. Continuing with flowering which is where early shoot and leaf growth takes place between September and November. After this, fruit-set begins where berries are formed between November and December. Then veraison,

which marks the start of grape ripening (January-March), harvest follows (March-April) then finally the grapevine goes through winter dormancy (July-September) to help the vines cope with the cold temperatures and ensure normal spring growth (Anderson, 2010). The duration of each phenological growth stage is dependent on the type of grape which is influenced by the temperature conditions specific to each region.

The impact of high temperatures on vine and berry development varies depending on the vine's phenological stage (growth stage) (Goldammer, 2018, Venios et al., 2020). A significant impact of temperature variation is seen through phenological shifts of the grapevine lifecycle (Venios et al., 2020). According to Van Leeuwen and Destrac-Irvine (2017), berries are generally more tolerant to high temperature during the start of ripening which is between fruit set and veraison however as the grapevines phenological cycle progresses, prolonged periods of high heat can be detrimental to the grapevine by restricting berry growth and consequently reducing yield (Oczkowski, 2016).

Moriondo et al. (2013) revealed that high temperatures (e.g., 40 degrees and above) can reduce vine photosynthesis and slow sugar accumulation during ripening. This affects the overall quality of the wine as slow sugar accumulation increases malic acid respiration which reduces berry acidity thus affecting the style, balance and alcohol content of wine (Koundouras, 2018). The temperature's influence on wine acidity and sugar accumulation was verified by Sadras et al. (2012) in a field experiment study in Australia. The researchers separated the temperature effects by comparing the fruit of vines subjected to high temperatures with a control group that was not. They confirmed that higher temperatures expedite the wine development process by changing the openness of its leaf pores (stomata) and decrease the overall acidity of its sap in response to environmental changes. This adaptation allows the crop to cope better with different conditions like temperature, humidity and/or nutrient availability in the soil.

### ***2.2.2 Impact on berry development and wine quality***

Wine grapes are made up of several hundred chemical compounds including but not limited to; water, fermentable sugars, organic acids, phenolic and aromatic compounds. High temperatures affect grape metabolism and the biosynthesis of these compounds. Elevated temperatures lead to sugar accumulation, organic degradation and an imbalanced sugar-acid ratio resulting in higher alcohol content and reduced freshness and aromatic complexities in the wines (Ramos et al., 2015). Warmer conditions also decrease total acidity and affect the levels of malic acid

and amino acids in grapes. Temperature affects the synthesis of anthocyanins which are responsible for berry coloration in red wines. Research has shown that anthocyanins accumulate better between 20°C and 30°C ranges, anything above that affects the accumulation process (Jones and Webb, 2010). High temperature exposure also affects the colour of ripened berries and impacts the aroma development of the wine (Mosedale et al., 2016). High temperature exposure during maturation can alter the concentrations of aroma compounds and affects the balance of the aroma profile in wine (Ramos et al., 2015). Intense heat waves tend to increase bitterness of the berries and even damage to the skins caused by sunburn (Araujo et al., 2016). Temperature variations have proven to accelerate the vine growth rate. Sun *et al.* (2023) found that high temperature in the early growing stage resulted in premature veraison which affects enzyme activation and causes poor ripening. The increased temperature also shortens the growing season, accelerating berry ripening.

Conversely, low temperatures during the growing season interrupt sugar accumulation and lead to organic acids breakdown in the grape berries. Literature shows that vines require a temperature that is consistently above 10°C during budbreak and anything between 20°C and 25°C during flowering and fruitset. As the grape matures warmer temperatures are needed (between 25°C and 30°C) for grape ripening (Jones et al., 2005). When temperatures consistently fall below these averages during the respective growth stages, the grape berries are unable to mature making them unsuitable for wine making. Heavy rains also reduce grape yield and affect berry evolution. Cold, wet weather during flowering for instance has been reported to reduce harvest quality and yield (Mosedale et al., 2016). Quality is most affected when the heavy rains fall four-to-six weeks before harvest. Heavy rains during this stage create a favourable environment for bunch rots and pest and disease infestations. Excessive rains also dilute sugars in the berries making the wine less flavourful.

Climate impact on wine quality is a contentious point debated in the literature. Some scholars argue that wine grape quality is subjective and a decrease in grape ripening due to climatic conditions does not necessarily diminish the quality of the wine. In support of this claim, Riedo (2019) found that climate change impacts vary among grape varieties and wine regions and these impacts do not necessarily prove to be harmful to the quality of wine. Ashenfelter and Storchmann (2016) challenge this notion and contend that lower temperatures do not guarantee higher wine quality and vice versa. Their study found that cooler climate regions like Bordeaux in France or Mosel in Germany, with consistently low temperatures, have produced below

average wine quality due to the grapes inability to fully ripen under such temperatures. They observed that wines produced in hotter climate regions such as the United States' Pinot Noir or Australia's shiraz wines may exhibit better quality due to the warm climate conditions being more favourable to the grape ripening processes providing fuller bodied and flavourful wines (Ashenfelter and Storchmann, 2016).

### **2.2.3 Impact on grape yield**

Harvest 'yield' refers to the number and size of grape clusters produced at the end of a season. Berry weight is used to calculate the yield of a vineyard. Optimal yields are achieved with moderately high temperatures, sufficient light, nitrogen and water (Theron and Hunter, 2022). In some cool climate regions, an increase in temperature can help improve grape yields and berry quality by reducing the occurrence of frost and extending the growing season as is the case in the Napa and Sonoma valleys (Sun *et al.*, 2023). However, in other regions higher temperatures can cause yield reductions of up to 35% due to drought conditions causing closure of the grapevine's stomata thus disrupting the photosynthesis process. Temperature fluctuations associated with climate change can contribute to yield variability as warmer weather has been linked to increased yield fluctuations in grape varieties such as Sangiovese and Cabernet Sauvignon in Italy (Sun *et al.*, 2023).

Vegetative and reproductive developmental cycles make up grapevine phenology (Torregrosa *et al.*, 2015). They are complex cycles responsible for fruit and vine growth in the current and future seasons. The growth of a grapevine is strongly influenced by environmental factors such as daylight length, heat, water, soil and light. Challenges such as increasing temperature and carbon dioxide coupled with water stress are direct impacts of climate change and these impacts significantly alter grapevine growth patterns.(Torregrosa *et al.*, 2015) For example, increased carbon dioxide levels reduce the production of important plant hormones such as ethylene and jasmonic acid that grape vines require for defence responses (Torregrosa *et al.*, 2017).

Water shortage or deficits during berry growth particularly after bloom can have a significant impact on grape yield. Grimes and Williams (1990) noted that grapevine water stress experienced during bud break could not be remedied by supplemental irrigation inputs during the bloom-veraison and veraison-harvest periods. The authors explained that as soil water depletes to the point that the vine experiences stress, the yields decrease due to the lack of sufficient water being absorbed by the plant to adequately produce larger yields. Sun *et al.*

(2023) argues that water shortage is only a problem if the shortage occurs during the early growing season of the vine, this is because water is needed early on to sustain bud fertility during which time the buds are sensitive. However, after the bud break phase the grapevine's growth will still be relatively unaffected by the lack of water as a grapevine is only most sensitive to water stress during the early and late phases of their growth cycle (Ramos *et al.*, 2020). Evapotranspiration increases because of increased temperature and unpredictable rainfall leading to water deficits. According to Ramos *et al.* (2015) water deficits have no impact on grape yield until crop evapotranspiration threshold limit of 50% is reached. This phenomenon is confirmed by Ramos and Martinez-Casasnovas (2010) who observed that the years where the water deficit during the growing period in the Penedes region (located in northeastern Spain) was above 50% ET<sub>c</sub>, lower grape yields were achieved compared to wet years, with a difference in yield of up to 53% (Ramos *et al.*, 2015).

#### **2.2.4 Pests and diseases impact on vine**

Climate change is having a significant impact on grapevine health by increasing pest and disease risks in vineyards. The defence system of a vine can normally resist or combat potential attacks from pests and pathogens during specific stages of the vine's lifecycle, however, climate change can alter the timing of plant exposure to pathogens making the vine more susceptible to diseases (Sun *et al.*, 2023). High temperatures associated with climate change can promote pathogen development and increase their survival rates leading to changes in the host plant's susceptibility to pests and diseases (Theron and Hunted, 2022). Studies have found that plant diseases can be used as climate change indicators. Fungal disease infestations such as downy or powdery mildew, are more prevalent in vines stressed by warmer climates especially when the timing of the vine's growth stage matches the period when the fungi are most active. The phenology of both pathogens and grapevines may be altered by climate change which leads to changes in insect survival and feeding patterns. These pathogens rely on grapevine phenology timing for their emergence and survival (Ramos *et al.*, 2015). Their impacts result in damage to grape, making them unsuitable for winemaking.

Grape mealybug species *P. maritimus* and *P. ficus* are examples of two key pest species that cause great economic losses in SA, California, Spain, Pakistan and South American vineyards (Sun *et al.*, 2023). They are small soft bodied insects with piercing sap-sucking mouthparts. They contaminate grapes through their waxy secretions, egg sacs and honeydew production which encourages the growth of sooty mould on the grapes (Sun *et al.*, 2023). They are

considered severe agricultural pests as they reduce grape production and spread various plant viruses rendering grape unmarketable and unsuitable for wine production (Sun et al., 2023). A continued rise in hot and wet climatic conditions will accelerate the distribution of mealybugs and many other pest and pathogen species (Sun et al., 2023).

### **2.3 Review of climate adaptation strategies**

The impacts of climate change are highly variable across different cultivars, regions and vineyards. Effects will depend on a combination of grape varietal and the specific cultivation strategies employed within a particular terroir (Fraga, 2019, Theron and Hunted, 2022). Some cultivation strategies are employed to avoid and/or mitigate against the detrimental effects of changing climatic conditions and improve overall resilience. According to Theron and Hunted (2022) cultivation strategies, both short term and long term, play a role in managing climate impacts on the grapevine and avoid/reduce inconsistencies in wine style and typicity. Various approaches can be employed such as utilizing different grape varieties and rootstocks, implementing efficient irrigation methods, practicing delayed pruning considering row orientation and training systems (these refer to the methods used to prune, shape and support grapevines as they grow), manipulating canopy, using plant tissue films, adopting sustainable vineyard floor management and implementing sequential harvesting. Adaptation strategies differ in nature and effectiveness in the short, medium and long term as depicted in Figure 2.1. Each strategy is described below with examples of implementation on vineyards across the world.

In order to be effective, adaptation strategies need to be vineyard specific taking into account a factors such as topography, environmental conditions, grape variety, desired wine style and timeline, ranging from immediate climate threat to long term sustainability (Rogiers et al., 2022). It is imperative to also consider the grower community, consumer values and pressures, available labour force and other socio-economic factors when implementing these strategies. Adaptation strategies should also take into consideration all potential short and long term impacts on the environment, social and financial aspects of running a vineyard in order to achieve sustainable productivity.

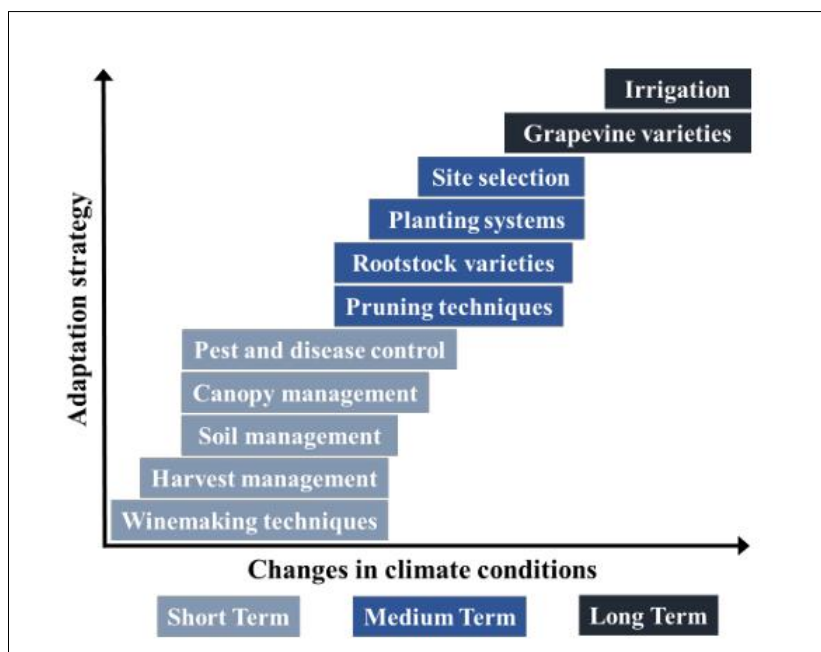


Figure 2.1 Suitable adaptation strategies to changing climatic conditions over the short, medium and long term (Neethling *et al.*, 2017)

### 2.3.1 Irrigation and fertilisation

The literature shows that grapevines are a lot more tolerant to drought compared to any other fruit crop (Sun *et al.*, 2023). However, they do require water for specific vine growth phases such as berry development. Future climatic conditions are consistently hotter, leading to higher evaporative demand, and increased rainfall variability, which will in turn increase the irrigation needs of vineyards. There are a few irrigation techniques that can be adopted in viticulture to adapt to rainfall and temperature variability (Sun *et al.*, 2023). Drip irrigation has proven to have positive effects on water usage compared to sprinkler systems although it has been reported that initial transition from sprinklers to drip irrigation may lead to yield reductions.

Some farmers in the Western Cape province have recalled experiencing yield losses of up to 64% in the first year of switching to drip irrigation due to changes in water supply, followed by a 40% decrease in the second year however, records show that yields eventually stabilize above previous levels in subsequent years (Riedo, 2019). Deficit irrigation is a method that involves the implementation of soil drying and wetting cycles to help enhance water efficiency. Another technique called Partial Root Drying (PRD) alternates the dry and wet parts of the root system which increases the grapevine's water resistance. A study by Myburgh (2013) explored the impact of different drip irrigation methods by characterising vegetative growth, yield and

quality of a Merlot variety in the Western Cape found that conventionally irrigated vines are over-irrigated compared to those that are irrigated through techniques like PRD. Irrigation methods can also be enhanced through the use of technology such as soil probes and remote sensing that monitor grapevine stress physiology and encourage efficient use of water (Riedo, 2019). Ongoing research is being conducted in SA in response to legislative requirements on the improvement of wastewater usage for vineyard irrigation. This research will aid in enhancing the use of technology in treating winery wastewater which will ensure safety in terms of nutrient toxicity and fruit quality (Riedo, 2019).

In terms of nutrient management, inappropriate addition of Nitrogen (N), especially on heavier soils can lead to excessive supply and waste as vine uptake, shoot growth and yields tend to plateau with increasing soil N levels (Sun et al., 2023). There is a risk of leaching when soils contain an excessive amount of nitrate (NO<sub>3</sub>) which could potentially cause eutrophication in nearby water sources like rivers and streams. In regions with predominantly acid soils like the Western Cape, an excessive presence of N combined with significantly saturated soils can negatively affect the environment by contributing to the production of nitrous oxide (N<sub>2</sub>O) and other greenhouse gas emissions (Theron and Hunter, 2022).

### ***2.3.2 Alternative cultivar/rootstock selection***

According to Theron and Hunter (2022), the International Organization of Vine and Wine recorded over 4000 wine grape cultivars in 2013 signifying the large extent of genetic variability and plasticity of the grapevine genome. Viticulture offers a wide range of cultivars suitable for different climates from cool to hot. This makes it possible for the conservation of existing viticultural regions by modifying the genotypes of grapevines to incorporate desirable traits that can withstand changing climate conditions however this is not without its challenges. Rogiers et al. (2022) states that finding the right cultivar or a specific location is complex as it depends on the cultivar's niche and desired wine style. Cooler climates produce lighter, fresher and crispier wines with higher acidity, while warmer climates produce wines with more body, colour, higher alcohol content and darker fruit characters. Under normal circumstances growing cultivars outside of their climatic range can decrease productivity, quality and consistency in wine styles, however more studies are revealing that investing in grapevine breeding programs for genetic improvement of cultivars both scion (upper part of the vine) and rootstock (lower part of the vine) may be beneficial for wine industries in the long term to foster sustainable wine production systems (Torregrosa et al., 2017, Jones and Webb, 2010).

Some countries like Australia have already begun evaluating the growth, productivity and wine production potential of cultivars from other countries like Italy. The assessments include evaluating the distinctive characteristics of cultivars and conducting consumer preference studies to gauge their potential for premium wine production (Rogiers *et al.*, 2022). Moreover, ongoing research is being done on breeding cultivars in both warm and cool growing regions. Some cultivars already demonstrate their ability to perform well specifically in either warm or cool climates and other cultivars showing good adaptability to both climates (Rogiers *et al.*, 2022). While climate change may incite changes in cultivars, adoption may take a while as certain wine producing countries like France, Italy and Germany must comply with legislation and tradition regulating cultivars according to regional cultivar/quality classification. Meanwhile countries like Australia, United States, China and SA do not have such restricting legislative requirements (Rogiers *et al.*, 2022).

### ***2.3.3 Vineyard site selection***

Cultivating wine grapes at higher altitudes has been reported to mitigate the effects of climate change. The increased exposure to ultraviolet light and lower temperatures provide suitable conditions for the production of high quality grapes and premium wines (Sun *et al.*, 2023). This was evidenced in Southern Brazil, where vineyards situated at higher altitudes produced more mature Cabernet Sauvignon berries compared to those cultivated in lower altitudes (Sun *et al.*, 2023). As a result, emerging wine farmers are seeking areas with more suitable climate conditions to establish their vineyards. Higher altitudes offer low temperatures during the night which has been proven to result in increased wine aromas and lower alcohol content (Rogiers *et al.*, 2022).

### ***2.3.4 Changes in vine row orientation***

Previous studies have indicated the potential of row orientation as a viticulture adaptation technique to combat climate change impacts. Vine row orientations impact vine physiology, growth cycle, crop yield as well as the quality of berries and wine due to climate and temperature disparity between the Northern and Southern Hemispheres which create distinct climate conditions (Sun *et al.*, 2023). In the Northern Hemisphere, north-facing slopes tend to be cooler compared to south-facing slopes because of sun exposure. However, the opposite is experienced in the Southern Hemisphere, for example, in SA, grapes grown in a northwest-southeast (NW-SE) row orientation showed higher levels of skin anthocyanins in their Shiraz

cultivars compared to those grown in a NW-SE and NE-SW orientation rows which displayed higher aroma and flavour characteristics (Sun et al., 2023).

### ***2.3.5 Training systems and canopy management***

As climate conditions change the need to adjust how vines are trained and supported may also be required. For example, in warmer regions characterized by high vine vigour such as SA, it has been observed that the implementation of taller trellis systems, where the bunch zone is positioned further away from the soil, is helpful in creating a more favourable microclimate inside the grapevine canopy by reducing the average leaf and bunch temperature (Myburgh, 2013). In contrast, shorter grapevine trunks achieved through training systems like Guyot or goblet systems may help the vines use water more efficiently and improve the vine's resistance to drought which is likely due to the vine's smaller size (Santos *et al.*, 2020). Guyot and goblet training systems enable the efficient use of water by keeping the vine small. The Guyot system helps the vine channel its energy towards a fewer number of fruit bearing shoots, meaning less water is lost through leaves improving their drought resistance.

Similarly, the goblet system's low bushy shape reduces evaporation and shields the soil in return retaining soil moisture and reducing evaporation. Less water is required for hydration when the vine's canopy is kept small making both these systems optimal during drought periods (Santos et al., 2020). To manage the growth of the vines and ensure good yields and quality, vineyard owners also need to understand the balance between shoot and root growth as well as vegetative and reproductive growth. Techniques such as young vine training, choosing the right spacing between vines, selecting appropriate trellis systems and adequately arranging the rows in the vineyards will optimize the microclimate within which the leaves perform photosynthesis and the grapes ripen (Yin et al., 2022).

Proper canopy management practices also play a crucial role in creating the right conditions for grape quality. Neglecting or improperly executing these practices can result in underutilization of the vineyard's potential for grape growing and wine quality (Theron and Hunter, 2022). Canopy management is an increasingly acknowledged adaptation approach to enhancing vineyard water management due its influence on vine leaf area index and transpiration rate (Yin et al., 2022). Various canopy management methods can be implemented throughout the year to help mitigate against adverse climate impacts. One such example is that of shoot trimmings. A

few studies have reported that shoot trimmings or topping is a canopy management strategy that is used to delay berry ripening and de-accelerate sugar accumulation (Sun *et al.*, 2023).

### **2.3.6 Soil preparation and management**

In viticulture, soil management is used as an adaptation tool to prevent the loss of water in vineyards throughout the growing season (Sun *et al.*, 2023). Proper soil management prevents degradation and erosion whilst improving the physical, chemical and biological properties of the soil (Theron and Hunter, 2022). Research has found that deep soil preparation improves the healthy growth of the vine both below and above ground (Fourie and Freitag, 2010). Soil management practices mainly include soil tillage techniques and cover cropping which aids in supplying the grapevine with water, controls its vigour and avoids soil erosion (Neethling *et al.*, 2016). Abad *et al.* (2021) advocates for the covering of vineyard soils with green vegetation (cover cropping) especially during the rainy season to improve soil structure, water infiltration and retention. Cover-cropping also helps with carbon sequestration unlike clean cultivation which increases the presence of carbon dioxide in the atmosphere as more organic matter is broken down especially with an increase in rainfall. Greater care should be taken in drier regions that implement cover cropping to ensure that grapevines still receive sufficient water and nutrients from the soils to avoid competition with the cover crops.

Biochar application is also a widely researched adaptation strategy that is known to improve and enhance soil structure. Biochar is a fine-grained charcoal high in organic carbon that is resistant to decomposition. It is created after biomass is heated in the absence of oxygen and has a microscopically porous structure that enables it to hold more water (Rogiers *et al.*, 2022). Observations have found that when biochar is added to soil, the water holding capacity of the soil increases from about 11 wt% (weight percentage) to 22 wt%. It further increases microbial activity in the soils and helps with the retention of nutrients (Sun *et al.*, 2023). This is supported by a four-year study conducted in a non-irrigated vineyard in Tuscany, Italy, where it was found that the effects of biochar application improved the soil properties and saw an increase of soil water content which resulted in a crop load increase from 16% to 66% without an effect on berry quality (Sun *et al.*, 2023).

More studies in recent years are looking at technology application as an adaptation strategy in soil management. Technologies such as geographic information systems (GIS) and remote sensing can improve the management of vineyards as they are able to provide information a lot

faster than manual data collection and input. Remote sensing can show areas of water stress on a vineyard (large scale view) and soil sensors can verify whether the stress is due to moisture levels at specific location on the ground. The combined use of both technologies offers farmers the option to accurately assess where water deficits occur and in turn help them fine-tune their irrigation strategies (Sun *et al.*, 2023). Mulching is also considered an agricultural technology that is affordable for sustainable soil and land management. Mulches can be made of organic or inorganic products which are usually placed on the soil surface. Mulches reduce soil compaction, retain soil moisture, regulate soil temperature and reduce evaporation (Fraga, 2019). Previous studies have observed that vineyards with mulch are less affected by heat and water stresses and are able to maintain decent yield levels even amidst adverse climatic conditions whilst combating pests and reducing soil erosion (Fraga, 2019).

#### **2.4 Use of seasonal forecasting**

Seasonal Forecasts are similar to weather forecasts in that they are both informed by historical weather observations. Unlike weather forecasts, SF provide a wider range of climate predictions on possible climatic conditions that can be expected on a larger time scale ranging from a few weeks to a few months ahead (Doblas-Reyes *et al.*, 2013). They are produced using complex climate models that simulate the relationship between the atmosphere, ocean and land using detailed numerical equations (Yang *et al.*, 2023). To produce this information, the models run multiple times with slight variations to create a range of different outcomes (Yang *et al.*, 2023). All forecast systems have limited capabilities in providing accurate information beyond a certain time-frame, for example weather forecasts can be relatively precise in the short term (i.e. seven-day forecast) but uncertainties increase as predictions extend into longer time frames (i.e. two weeks). (Yang *et al.*, 2023, Hansen *et al.*, 2011). However, even with their limitations weather forecasts are helpful in informing daily decision making in many areas including agriculture. In contrast, seasonal forecasts focus on broader more general climate trends and consider additional environmental factors such as sea surface temperatures that have an influence on seasonal climate patterns (Yang *et al.*, 2023). Although less precise, SF can provide valuable insights into general climatic conditions over several months with varying degrees of accuracy depending on the time frame and region of interest.

Future climate projections are predicting a likely increase in severe drought events in SA. According to Hannah *et al.* (2013) this prediction will poses a risk to the suitability of wine grape farming in certain SA regions such as the Olifants and Swartland areas in the Western

Cape. Hannah et al. (2013) observed an expected decline of suitable areas for viticulture within main wine producing regions globally of 23% to 27% by the year 2050. Figure 2.2 below illustrates the decrease of suitable wine producing regions in the world, including in SA's Western Cape Province (cell C). These include the Central Big Bay area, internal Swartland District area, the Stellenbosch area and partially the Paarl area. Farmer adoption of SF use presents the opportunity for them to increase agricultural production during droughts, floods and other extreme weather shocks by providing timely agrometeorological information that aids in farmers' strategic and tactical decision making. Several studies have suggested that one way to increase agriculture production and reduce farmer vulnerability to climate and weather shocks is by incorporating the use of SF in agricultural decision making (Chisadza et al., 2020, Peng et al., 2018, Hansen et al., 2011, Doblus-Reyes et al., 2013).

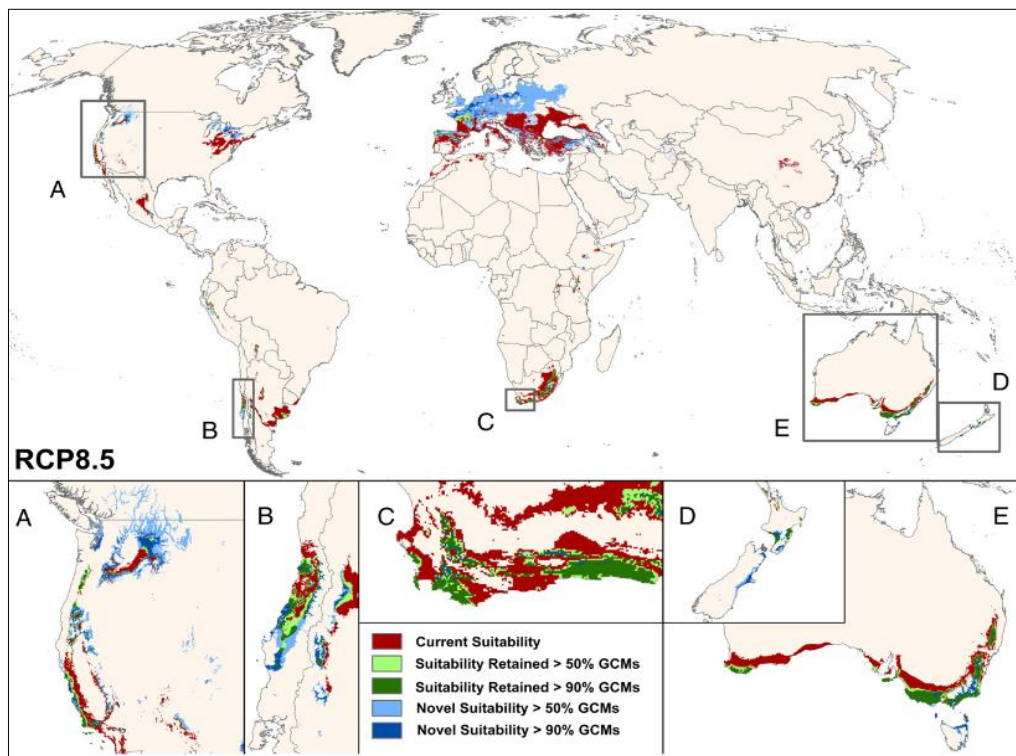


Figure 2.2 Depicts a global decrease of suitable wine producing regions in the Western Cape (Hannah et al, 2013).

The use of SF is not without some challenges. For one, the variability of Southern Africa's climate, including weather events driven by large scale ENSO phases (e.g. El Nino or La Nina), stresses food security. ENSO phases significantly influence seasonal weather patterns, resulting in rainfall and temperature variations that impact SF predictions. Recent studies have confirmed

the poleward movement of the Hadley circulation which affects global wind and rainfall patterns. This shift is expected to increase intense rainfalls in the Northern latitudes and have the inverse effect for subtropical regions like SA (Riedo, 2019). The combined impact of ENSO and the shifting Hadley circulation further increases the uncertainty of SF predictions.

Furthermore, the challenge farmers encounter in using SF is making decisions based on indigenous knowledge and/or personal experiences versus using SF as a measure or indicator of the decision-making process (Chisadza et al., 2020). Hansen *et al.* (2011) revealed that the probabilistic nature of SF is where scepticism from farmers stems from. Seasonal forecasts are models that provide formal probability outcomes and oftentimes farmers lose faith in models when they provide information that they perceive as poor (Dube et al., 2022, Chisadza et al., 2020). According to Santos et al. (2020) this can be remedied by communicating and educating farmers on such technologies and their benefits of use. This was true for a case study conducted in Burkina Faso, Kenya, Zimbabwe and Ethiopia, where forecast information was packaged with education and technical guidance and distributed to farmers in the form of a workshop with researchers who taught on the management and interpretation of forecast implementation, to aid in the acceleration of the learning process. It was discovered then that risk of disappointment and discontinued use of SF by farmers was reduced when farmers were trained on how to interpret data and make use of the models even if an early forecast was initially perceived as 'poor'.

Sufficient comprehension of annual climate variability and associated influences on agricultural practices is crucial for the utilization of advanced climate information in the form of SF in viticulture (Naude and Naude, 2019). Climate variability's impacts on agriculture go beyond direct shocks on production such as droughts and floods. Limited evidence suggests unexpected climate impacts on associated opportunity costs may outweigh the direct, post event costs of such shocks (Hansel *et al.*, 2011). In agriculture, the value of seasonal climate forecasts is attributed to the total incurred benefits to the farmer dependent on the farmer's eagerness to change old farm management practices. The literature reveals that a lot of smallholder farmers experience an increase in income through the use and availability of easily accessible seasonal climate forecasts in collaboration with Indigenous Knowledge Systems (IKS) (Arunrat et al., 2017, Klemm and McPherson, 2017).

Climate-adaptation reluctance is generally linked to economic and social standing of farmers, which directly influences their appetite for risk. While long term-climate change adaptation is

important, immediate risk-taking decisions shape how farmers respond to short term climate variability. Studies show that lower educational attainment among farmers can limit the use of advanced knowledge, especially when it comes to adopting new technologies such as SFs and similar (Arunrat et al., 2017). Farmer access to resources and profit gain also significantly influences farmer's willingness to take risks, guiding their choices in adopting short term adaptation measures. According to Habiba et al. (2012), farm income determines climate adaptation adoption, they found that the higher the farm income, the higher the possibility of investing in more risk adaptation measures and agricultural innovation adoption.

## **2.5 Risk management in agriculture**

Risk is defined by a situation or circumstance that may result in exposure to a hazard. Hazards are defined by things that have the potential to cause harm, loss or injury upon exposure (De Salvo et al., 2019). In the context of climate variability and change, hazards may refer to temperature and rainfall extremities and events that are out of the norm and possibly result in negative impacts on agriculture and livelihoods at large (Adger et al., 2018). Risk assessment and management are established as scientific fields and provide important contributions to decision making in practice. The key factor to consider when understanding risk is first determining who and what is exposed to the hazard and whether or not that exposure will result in detrimental impact (Aven, 2016). However, applying the notion of risk assessment to natural hazards is difficult because natural systems cannot be viewed or understood in isolation but rather as integrated wholes. A significant challenge in managing agricultural risks is the need to address and coordinate management goals, labour, finances and cultivation activities simultaneously (Leppälä, 2016).

Risk management in wine production is gaining more attention due to the clear indication that risks have significantly increased in various aspects of food production in recent years, including the wine sector (Naude and Naude, 2022). Similar to other agricultural systems, viticulture is susceptible to a range of risks stemming from different factors like human behaviour, climate production processes, inflation, institutional and policy frameworks as well as economic and financial factors (De Salvo et al., 2019). When faced with risks, wine producers can experience partial or complete production loss in a short space of time (seasonally) which would lead them to severe financial challenges. In the long term, climate change impacts on the vine will be affect grape yield and quality which subsequently influences

wine production costs, prices, revenues and profits of grape growers and winemakers (Alekbberova et al., 2023). This has sparked an interest in research that looks at understanding the risks that grape growers and winemakers face in the current (seasonal) and future climate change conditions. Previous studies have concluded that the best way to deal with climate variability and change in the wine industry is through mitigation and adaptation strategies.

Farmers face numerous agricultural risks that require risk management that is tailored specifically to an individual farmer's context. In a study that assessed the use of risk tools in a group study it was observed that 40% of farm owners cited risk identification as being most useful to mitigating risks especially on larger farms (Leppälä, 2016). Risk management is defined as the process of identifying risks, assessing their probability of occurrence, analysing potential impact and developing strategies that will help mitigate, monitor and/or control them (Naude and Naude, 2022). It is one step in the process of risk assessment and management that offers decision makers (i.e. farmers) with the necessary knowledge to identify strategies that may help improve their overall business performance (Connelly et al., 2018). However, the complex and multifaceted nature of risks require their management to be context specific in order to be effective (Naude and Naude, 2022). Figure 2.5 below depicts the risk management process and main steps that can be applied to viticulture.

The role of risk in science is to address global challenges. However, with the complex nature of the natural environment, the concept of risk is continually being refined with the emergence of new approaches to address new challenges (Simpson et al., 2021). Risk management can be considered an important part of sustainable agriculture. Its future oriented and holistic systems perspective is crucial to the maintenance and management of a sustainable business.



Figure 2.3 Standardized risk management process (ISO 31000) (Leppälä, 2016).

Naude and Chiweshe (2017) proposed an operational risk management framework that focuses on the four risk management phases (risk identification, risk evaluation, risk response and risk monitoring and control) that underpins this study. This framework was introduced to the wine industry in the Western Cape regions as a potential sustainability tool that can be used by wine grape farmers in response to the inherently risky nature of the wine industry. The processes that the framework follows are described as follows;

### 2.5.1 Risk identification

For risks to be managed they need to be identified along with their source and nature. According to Naude and Chiweshe (2017) it is difficult to develop strategies and adaptation methods to mitigate impact without identifying and understanding the risk first.

### 2.5.2 Risk assessment and analysis

Once a risk has been identified, the nature and source of the risk is assessed, the identified risks are then assessed and analysed to predict their probability of occurrence and severity of impact

using risk matrices that combine probability and severity to understand risk impact (Leppälä, 2016). Figure 2.6 shows an example of the use of risk management used as a tool to help farmers analyse risk and their impacts. During this analysis stage, the extent of impact is also determined. Multiple, cumulative and/or concurrent risks are dissected and analysed individually in order to devise appropriate strategies that will help minimize failure during mitigation (Naude and Naude, 2022).

**Table 1: Risk analysis example (Leppälä, 2016).**

<b>FARM - RM - FARM RISK MANAGEMENT ANALYSIS</b>				Page : 1
Farm name: xxxx				Made by: JP
Further Information:				Date: 17.8.2006
<b>Risk event</b>	<b>Consequences</b>	<b>Present risk control</b>	<b>Risk value</b>	<b>Improvement actions</b>
Energy use	Energy costs, loss of energy, non-renewable resource waste	Monitor and check electricity use, manual milking	3	Providing backup energy sources, repairing electricity wires and centres, new lamps, modernizing the cattle shelter, energy planning
Order in cattle shelter	Injury and fire risk is increasing	-	3	cleaning and improving the order in the cattle shelter
Fire safety, wood oven in the cattle shelter with the animal dust	Fire accident, dust explosion	Fire door, one fire extinguisher, routine	4	Fire and electricity check with rescue authorities, fire plan, add fire extinguishers, locate oven outside the building, cleaning
Schedules and working alone	Work strain, stress, health risk, injuries, dependence on one person	Healthy lifestyle, food and routines, parents and husband	4	Scheduling, monitor working time, substitute and relief workers, work delegation, breaks, rest, hobbies
Efficiency and ergonomics	Work disorders, process failures, work strain, stress, working costs, injuries	Routines and good physical health	4	Improving feeding process, provide helping tools for lifting, repair fodder storage system

### ***2.5.3 Risk response and mitigation***

During the third stage of the risk management process, strategies are devised for a series of possible outcomes and alternatives are considered based on solution merits. There are a variety of solutions that are likely to be taken into consideration depending on the extent, severity and likelihood of the risk and risk impacts (Aven, 2016). These solutions include strategies that can either reduce or avoid risk. Risk reduction measures are those that aim to lower potential loss or severity of impact should loss occur. Sometimes, depending on the nature, risks can be accepted by the party exposed to it if the cost of mitigation is higher than that of the loss or impact itself (Leppälä, 2016). Other solutions include risk elimination where steps are taken to ensure that factors that are likely to result in risk are removed (Naude and Naude, 2022).

### ***2.5.4 Risk monitoring and evaluation***

This step is continual and involves the process of overseeing and monitoring the implementation of strategies and their effectiveness. This stage also involves the establishment of decision triggers. Decision triggers are indicators that are able to alert when critical thresholds have been crossed and trigger the call for action (Cook et al., 2016). According to Cook et al. (2016) it is essential to employ evidence-based adaptation and mitigation measures that leverage the best available evidence to trigger and direct action when a system begins to transition into a high risk scenario.

## **2.6 Role of seasonal forecasting in risk management**

The approach of blending forecasting with another tool to inform decision making has been proven to improve the ability to predict key climate indicators like temperature and rainfall. Chou et al (2023) combined the use of SF with actual weather observations using a method called blending. They found that this strategy enhanced the reliability of the SF. Since SF are not always accurate there is potential for them to be incorporated into risk management to improve usefulness. Merging SF in the risk management structure could enable farmers to identify risks earlier which could reduce yield or affect wine quality (risk identification). Farmers would also be able to make decisions such as changing their planting time depending on the information provided by SF. During risk assessment, farmers will be able to quantify the likelihood of occurrence of a particular climate event such as a probability of a drought or flood and therefore plan their operational costs. It will also enable the farmer to prioritise risks according to severity and impact thus allocate resources accordingly. Thereafter farmers will

be able to make the necessary adjustments to vineyard management schedules, plant more climate resilient varieties or even adjust production methods (i.e. reduce water consumption on vineyard, change harvest time) to match the shifts in climate conditions (risk response and mitigation). Seasonal forecasts will enable the continuous improvement of mitigation strategies that have been adopted for a particular season. Through the aid of real time weather and updated SF data farmers will be able to assess the effectiveness of mitigation strategies, track climate trends over successive seasons to continually refine these strategies with each year and improve their resilience against climate variability and change.

## **2.7 Conclusion**

The literature reveals a growing body of work on climate adaptation measures in viticulture with particular attention on climate variability and its impacts on viticulture. However, despite these contributions there are still gaps in the literature regarding the use of forecasting as an adaptation measure in viticulture. Few research has explored risk management in the context of viticulture and those that do often lack subsequent exploration of SF as a mitigation tool in predicting changes in temperature and rainfall on a seasonal time scale. This study seeks to address this limitation by investigating the level of risk involved in the use and non-use of seasonal forecasts (SF) in viticulture and further propose a risk framework to serve as a cost-effective tool to wine grape farmers that will help them avoid, mitigate or control their risks towards long term sustainability. The insights from the literature have shaped the formulation of the research questions and have guided the selection of an appropriate methodological approach detailed in the next chapter.

# **Chapter 3 – Methods and Materials**

## **3.1 Introduction**

This chapter provides a comprehensive description of the research methods and materials used to conduct this study. It details the chosen research design and justifications for it. It begins with an outline of the study area followed by a description of the participant sampling process with the criteria of inclusion to the study. The chapter further discusses the methods followed and materials used during data collection. Lastly, the chapter concludes with a summary of the ethical considerations implemented to achieve the objectives of the research.

## **3.2 Research Philosophy**

This study followed a structured research process beginning with the identification of the research problem, formulation of research questions and a review of relevant literature leading into data collection and analysis. The study is guided by the interpretivist research philosophy which acknowledges the uniqueness of individual experiences and seeks to gain deeper understanding of their perspective on a topic. This philosophy set the framework to which the interview questions were formulated to understand the subjective experiences of wine grape farmers in dealing with and responding to climate variability. Therefore, a qualitative research approach was adopted to allow for in-depth exploration for farmers' knowledge of and experiences with the use of SF as adaptation measure in viticulture.

## **3.3 Research Design**

A qualitative research approach was chosen to produce more nuanced, comprehensive and robust explorations of the research questions (Bryman, 2006; Creswell & Clark, 2011). The study's primary data was collected through self-administered semi-structured interviews. Interview questions consisted of a mix of closed-ended and open-ended questions to gather qualitative information. Ten participants were interviewed, and the interviews were audio recorded. The recordings were transcribed verbatim and further cleaned for accuracy and analysed thematically and presented accordingly. The interview sessions were conducted over the suckering period which is the growth stage in the grapevine growing season. It is considered

one of the busiest times of the growing phase, requiring a lot of the farmer's time and attention. As a result, access to a larger number of farmers who were willing and able to participate in the study was difficult. A total of 20 farmers were contacted to participate in the study but only ten responded.

### **3.4 Sampling Selection**

Due to the limited availability of farmers, a snowball sampling technique was used to identify and select the wine grape farmers to participate in the study. Snowball sampling is a non-probability sampling method used when trying to gain access to a population that is otherwise hard to reach. The process involves identifying key participants (or informant) with direct experience in a niche topic, in this case the study was seeking to interview viticulturists, wine grape farmers, farm owners, wine makers or a person with measurable experience in cultivating grapes or making wine. Key informants then offer referrals of other individuals within their network whom they know and meet the study's inclusion criteria. This method was most fitting as it helped reach participants who would have not been easy to reach through online searches especially in the case of reaching smallholder farmers.

### **3.5 Study Area**

The study area is situated in the Western Cape and targets wine grape farmers as the population of interest. Ten wine grape farmers were interviewed across four wine growing regions namely, Cape Town, Stellenbosch, Grabouw and the Swartland as shown in Figure 3.1. The research participants of this study were made up of viticulturists, wine grape farm managers, agricultural consultants and any persons who have/had expertise or experience in growing wine grapes. The sample population was made up of both commercial and small-scale farmers.

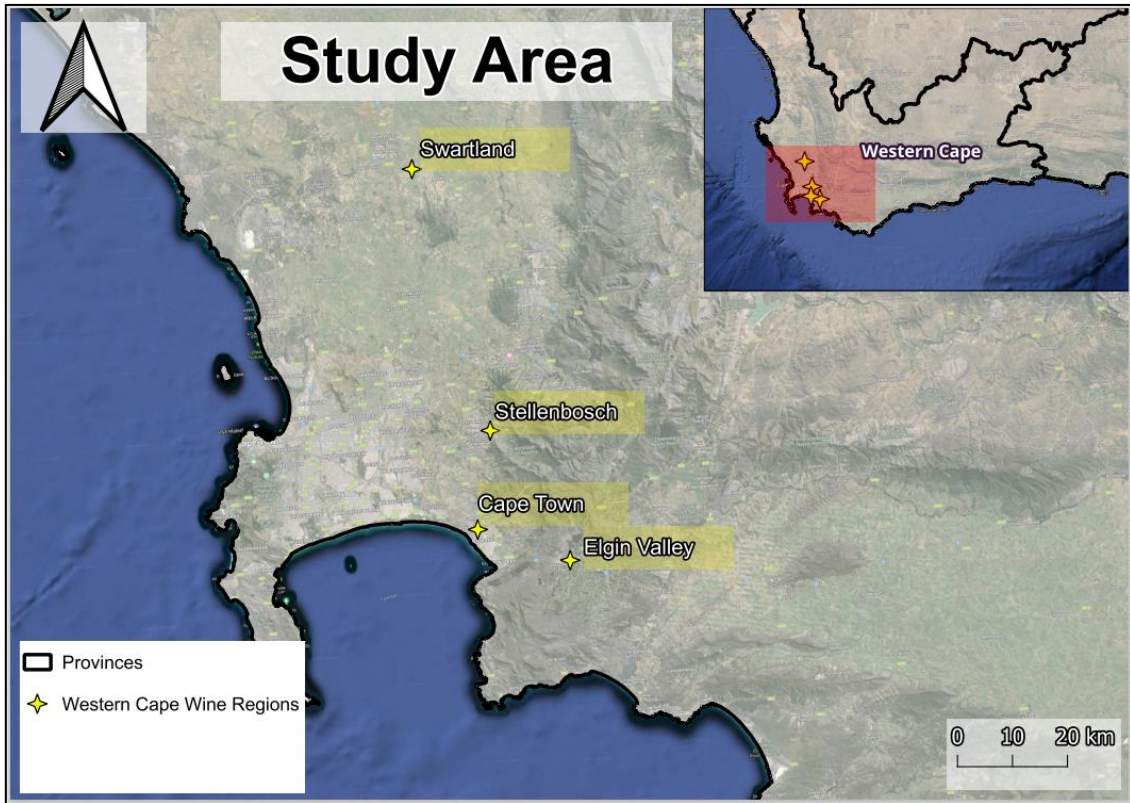


Figure 3.1 Vineyard locations of participants (Source: Own).

### 3.5.1 Cape Town

The Western Cape ( $33.2278^{\circ}$  S,  $21.8569^{\circ}$  E) is the third most populated province in SA accounting for 11.9% of the national population (Githahu, 2022). The majority of SA's wine industry is situated in this province which is also home to the country's most renowned wine regions such as Stellenbosch, Franschhoek and Paarl. Cape Town is the capital city located at the heart of the winelands. Cape Town has a Mediterranean climate that experiences the most rainfall (70%) between May and October (Araujo et al., 2016). The average annual rainfall within this city ranges from 400mm per year on the west coast to 2000mm in the surrounding mountains. The city experiences high winter rainfall with the wettest month being in June receiving an average of 112 mm. February receives the lowest rainfall at 16 mm. The average temperature conditions in the city rise to a high of  $20.1^{\circ}\text{C}$  in February and a low average of  $13.0^{\circ}\text{C}$  in July.

### ***3.5.2 Swartland***

Swartland (33.3307° S, 18.7126° E) is the most populated municipal area in the West Coast District with a total 137 567 people recorded in 2021 (Wine searcher limited, 2023). The population is expected to rise to 146 940 people by 2025 indicating an average growth rate of 1.7% for the period (Western Cape Government, 2021). A mild Mediterranean climate characterizes the region with warm dry summers and mild wet winters. The average annual rainfall is 500 mm where 80% of the rain falls between May and October (Riedo, 2019). The average temperature is 17°C with January being the hottest month of the year reaching an average temperature of 22.4°C. The region is traditionally known for wheat farming but now specializes in growing wine grapes particularly from the Shiraz, Chenin Blanc and Pinotage grape varieties.

### ***3.5.3 Stellenbosch***

Stellenbosch (33.9321° S, 18.8602° E) is the second most populated municipal area in the Cape Winelands District with a total of 196 036 people recorded in 2021 (Western Cape Government, 2021). The population is expected to grow to 209 854 people by the year 2025 equivalent to an average growth rate of 1.7% for the period (Western Cape Government, 2021). The area is characterized by hot dry climate with a cool ocean breeze from False Bay making it an ideal location for wine cultivation. The hot dry climate makes for good quality red wine grapes such as Cabernet Sauvignon, Cab blends, Shiraz, Pinotage and Merlot which are the most produced varieties in the area (Naude and Naude, 2022). In terms of white grapes, Chenin Blanc is the most common cultivar in the area due to the cool False Bay Ocean breeze that creates a suitable climate for growing white grapes followed by Colombard, Sauvignon Blanc and Chardonnay. This area also receives more rainfall in winter than summer with an average yearly temperature of 16.2 °C and an annual rainfall of 600 mm - 700 mm (Riedo, 2019). Most of the rain falls in June with an average of 141 mm and the driest month is February with an average of 20 mm. In terms of temperature, February is the warmest month with an average of 21.6°C and July is the coolest with an average of 10.9°C.

### ***3.5.4 Elgin Valley (Grabouw)***

Grabouw (34.1533° S, 19.0101° E) is a town located approximately 65 km south-east of Cape Town. Falls under the Theewaterskloof Municipality and serves as the primary commercial hub of the Elgin Valley (Western Cape Government, 2021). Renowned as the largest single export fruit producing region in Southern Africa, the town has experienced a surge in population size inhabiting an estimated 44,593 people. The climate is characterized by warm and temperate conditions with the most rain falling during the winter season. The mean average temperature is recorded at 15.5°C and average rainfall of 1010 mm.

## **3.6 Risk Framework**

A risk framework was used as a tool to gather data to achieve objectives one and two of the study. The framework was presented to the farmers during the interview session, and they were asked to populate the framework as part of the interview. The original risk framework was obtained from Naude and Chiwese (2017) and has been adapted to this study's context and presented in Table 2. The framework comprises four risk management processes which form the basis of the assessment. These processes are risk identification, risk assessment and risk response and mitigation, and risk monitoring and control, presented by the headings. The risk framework examined the potential effects of climatic hazards (temperature and rainfall) on the cultivation of wine grapes under above normal (AN) and below normal (BN) climate conditions.

### ***3.6.1 Risk identification***

Locating and understanding the source of risk is the first step in the risk management process. The risk framework is divided into two subcategories: Category and Probability. The category describes the temperature and precipitation risks and their impact on farmers' yield, quality, labour, and finances by highlighting the AN and BN conditions. Probability refers to the likelihood of an AN and BN temperature and rainfall event from occurring in a season ranging from 'rare' to 'almost certain' as presented in Table 2 below.

### **3.6.2 Risk assessment**

The risk assessment section of the framework was divided into two scenarios namely severity **with** seasonal forecasting (SF) information (1-5) and severity **without** seasonal forecasting information (1-5) to compare climate impacts on the yield, quality, labour and finances under these scenarios. All participants were asked to fill ratings for both **with** and **without**. For example, in the instances where farmers were already using SF, they were asked to give this rating according to their knowledge and experience of farming in a hypothetical case or if they could remember back to before they started using SF. In the case where farmers were not using SF, they were asked to rate according to their use of short-term forecasting (e.g. AccuWeather). In this section the risk levels are ranked and populated using a Likert scale. A Likert scale is a rating system often used in questionnaires designed to understand the opinions and perceptions in a more nuanced way (Taherdoost, 2019).

Likert scales vary from seven-point scales, five-point scales to three-point scales depending on the type of research being conducted. It has been proven that participants prefer seven-point scale due to the variety in answers that can be provided. However, this variety in scores also means that participants avoid selecting extremities in their responses thus resulting in ambiguous answers (Taherdoost, 2019). With seven-point scales, participants also struggle to differentiate between scores that are only subtly different resulting in further ambiguity. Conversely, three-point scale although they offer lower variety, their shortfall is that they do not offer enough distinction for-or-against a statement or argument (Pescaroli et al., 2020). Therefore, this study employed five-point scales as it meets and addresses the challenges of the two former scales. In this study, farmers rated climate impact on yield, quality, labour and finances from a scale of one to five. Where 1 = low risk level and 5 = catastrophic risk level.

**Table 2: Proposed risk framework**

Risk identification						Risk assessment										Risk preparatory measures	Risk monitoring and control
Category	Probability					Severity rating with SF (1-5)					Severity rating without SF (1-5)						
	No Impact	Low Impact	Moderate Impact	High Impact	Very High Impact	Yield	Quality	Labour	Finances	Other	Yield	Quality	Labour	Finances	Other		
<b>Rainfall Risks</b>																	
BN																	
AN																	
<b>Temperature Risks</b>																	
BN																	
AN																	

### ***3.6.3 Risk response and mitigation strategy***

The third section of the framework represents the third step in the risk assessment and management process. This step helps the grower to identify risks according to the grapevine growth stages and implement measures to avoid, mitigate or manage them accordingly.

### ***3.6.4 Risk monitoring and control***

The final step is risk monitoring and control. Here the farmers described the measures they put in place. This step is essential as it allows farmers to respond to changes more efficiently and provides early warning of increasing risk levels. The purpose of this step is for farmers to highlight indicators to monitor and establish decision triggers.

## **3.8 Data collection**

The data collection process began on the 1 November 2023 to 30 November 2023. The process was guided by a set of interview questions (refer to Appendix A) that were compiled in accordance with the study objectives. The interview guide/questions were split into five sections. Section A was acquiring baseline/background information about the farmers, their group types and years of experience. Section B sought to learn about the impact that climate variability has had or continues to have on farmers' vines according to their experience. Section C explored the adaptation methods and strategies employed by the farmers. Farmers gave their accounts on their understanding of SF and their use (or non-use) of this as an adaptation measure in wine grape growing. Lastly, Section E focused on risk management as a concept in wineries and the approaches employed thereof.

One-on-one semi-structured interviews were conducted with each of the wine farmers. The demographics of the interviewees is presented in Table 3. A pilot test was conducted with three different individuals who did not form part of the research participants. The pilot test ran through all the interview questions and risk framework that was to be presented to the farmers during the interview. This was done to assess the approximate length of the interviews and confirm the relevance of the questions to refine and remove irrelevant questions. All interviews were conducted in English which was not a problem for any of the participants. The average duration of each interview was approximately 1 hour. Photographs were taken where relevant

to depict climate impacts on the grapevines, adaptation materials employed and also the use of forecasting software or applications (apps) by the farmers to serve as supporting evidence to the study. Lastly, the risk framework described in 3.3 above was presented to each farmer during the interview where they were asked to populate the information in the framework based on their experiences with climate variability impacts on grape yield, quality, labour and finances with and without the use of SF.

### ***3.8.1 Ethical Consideration***

Before interviews were conducted ethical approval was obtained (**FSREC 082-2023**) from the University of Cape Town's Science Faculty Research Ethics Committee to ensure that the research is transparent and protects the participant (Attached as Appendix B). Information on the provinces' climate history, farming strategies and use of SF in viticulture was sourced from peer reviewed papers, working papers and conference presentations.

Participants were under no obligation to participate in the study. They were briefed before each interview about the purpose of the research, their role as participants and their rights were explained including their right to withdraw from study at any point and to freely ask questions at any time. No monetary compensation was offered for participation and participation was voluntary. Consent was acquired from each participant in writing.

All participants' identities were kept confidential and anonymous throughout the processes of data collection, storage, retrieval, transfer and disposal. All research findings were be presented in a manner that is not damaging to the participants lives, reputations and those of their respective communities. There were no potentially harmful risks related to participation in this study be it physical, social or psychological.

### **3.9 Data analysis technique**

Qualitative data is often extensive, unstructured, rich in information, and subjective. According to Martin (2010), the role of the researcher when it comes to analysing such data is to make sense of the dense information by sifting through it to find similarities or differences that will aid in the formulation of themes, ideologies and categories. The approach to data analysis for this study was thematic coordination for ease of interpretation.

The analysis process followed a step-by-step process which began with the transcription of all interview recordings using an online transcription website. Thereafter, the transcribed data was manually cleaned to remove irrelevant and incorrectly transcribed words. Data was then arranged according to themes. The research objectives were used as the point of reference for each piece of information collected. These pieces of information were then linked to the corresponding research objective. All data was grouped and coded, common themes were noted and differences highlighted. This process was repeated multiple times to ensure data validity and maintain study integrity. Any irrelevant data was eliminated from the study. The only software used to analyse the qualitative data of this study was Microsoft Excel due to the relatively small sample size. All analyses were done manually by the researcher on Microsoft Excel and Word. The results from the closed-ended questions are recorded and presented in graphs. Text analysis was used to present the open-ended data in the form of quotations, descriptive text and tables.

### **3.10 Data quality control**

Data validity in qualitative research refers to the accuracy of the scientific findings. To ensure trustworthiness of qualitative data great care in methodological processes were taken following Guba's four criteria – credibility, transferability, dependability and confirmability (Guba, 1986). Similarly, data reliability refers to the findings of a study being dependable and true. Meaning if the researcher were to conduct the research several different times under the same conditions, time and using the same data collection instruments the findings should be similar or the same each time. Methodological triangulation was used by collecting data in different locations to maintain credibility and confirmability of findings. Triangulation is a qualitative research strategy that tests validity through the convergence of information collected from different sources, locations or tools to provide relevant data to achieve the objectives of a study. Thick descriptive accounts of wine farmer's experience with climate variability and grape growing have been provided for data transferability. Semi-structured interviews were used to guide the data collection process. No bias was used in the formulation of these questions, no personal assumptions were made about the participants and questions were set with an unbiased tone.

### **3.11 Conclusion**

The chapter outlined the methods followed and materials used to investigate the level of risk involved in the use and non-use of SF in viticulture. Interviews were conducted to collect qualitative data. The methods and materials described in this chapter provide a robust foundation for the analysis and presentation of the results in the following chapter where the findings are discussed in detail.

# Chapter 4 - Results

## 4.1 Introduction

The previous chapter detailed the methods used to collect data for the study. This chapter will present the empirical findings of the study collected through face-to-face semi-structured interviews with wine grape farmers in the Western Cape. A risk framework was presented to the farmers during the interviews and was populated using the information they provided. The interview questions were designed to gauge the nature and types of climate hazards faced by farmers and the threat that these hazards have on wine grape yield, quality, labour and finances. The framework was used to compare risk levels with and without SF use. The chapter begins by depicting the baseline data followed by a description of climate hazards faced by wine farmers and their use (or non-use) of SF. The chapter further details the risk framework results for rainfall and temperature variability. To conclude, the risk preparatory measures, practices and strategies used by farmers in response to the risks are detailed.

## 4.2 Baseline data

### 4.2.1 Demographics

Table 3 shows the demographic composition size of the study population. Nine out of ten interview participants were male. Five out of ten owned their vineyards whilst the other five were either technical advisors, farm managers or viticulturist. All participants had a considerable amount of experience with the least number of years being 5 and the longest being 40. Most of the participants were located in the Swartland region, namely: P1-P4 and P6.

**Table 3: The demographic of the participants**

<b>Participant ID</b>	<b>Job title</b>	<b>Gender</b>	<b>Experience (in years)</b>	<b>Wine region</b>
P1	Farm Owner	Male	24	Swartland
P2	Farm Owner	Male	26	Swartland
P3	Farm Owner	Male	23	Swartland
P4	Farm Owner	Male	26	Swartland
P5	Technical Advisor	Male	28	Elgin Valley
P6	Farm Owner	Female	11	Swartland
P7	Technical Advisor	Male	45	Cape Town
P8	Farm Owner	Male	15	Elgin Valley
P9	Viticulturist	Male	23	Stellenbosch
P10	Farm Owner	Male	15	Stellenbosch

The vineyards managed by the participants differ in terms of their size, the variety cultivated, the age of the vines, the use of irrigation systems and forecasting technologies, among other things, which serve as a basis for management decisions (Table 4). For example, the largest vineyard of the sample size is 100 ha located in Cape Town. This vineyard also grows the oldest vines among the study group with 50-year-old vines. The smallest vineyard is 5 ha located in the Elgin Valley which also contains the youngest vines (5 years' old).

#### ***4.1.1.1 Irrigation***

All irrigated vineyards (6) under study were established using drip irrigation (Table 4). After the long drought that ended in 2017 in the Western Cape, these farmers moved from sprinkler irrigation to drip irrigation to conserve water. It was through this drought event that the farmers learnt just how resilient their vines are and as a result opted to make use of as little water as possible. For bigger commercial vineyards, technology such as continuous logging irrigation probes are used to monitor soil moisture content to optimise water usage on the vineyards. Other water-saving strategies adopted by farmers include the establishment and use of an onsite wastewater treatment plant that purifies black and grey wastewater produced on the farm and is reused to irrigate lawns and vines. All the farmers are water conscious more especially after experiencing frequent dry periods and droughts in the region in recent past.

**Table 4: The characteristics of the vineyards**

<b>Participant</b>	<b>Size (ha)</b>	<b>Cultivar/s</b>	<b>Irrigation (Y/N)</b>	<b>SF Tool/s or Climate Information</b>
P1	6	Mourvedre, Shiraz	Yes	None. (use weather app on phone).
P2	18	Cinsault, Chenin, Shiraz, Cabernet, Viognier, Barbera, Malvasia Nera, Zinfandal	No	None. (use weather app on phone and information from TV)
P3	10	Shiraz, Mourvedre, Cabernet	No	None. (use weather app on phone)
P4	14	Chenin, Chardonnay, Viognier, Pinotage, Shiraz, Mourvedre, Sangiovese, Cabernet	No	None.
P5*	Unspecified	Unspecified	Yes	RimPro, iLeaf, Daycom
P6	14	18 cultivars (unspecified)	Yes	Yr.no weather forecaster
P7	100	Shiraz, Pinotage, Sauvignon Blanc, Chardonnay, Barlow, Cabernet, Cabernet Franc	Yes	iLeaf (synced with weather station) technical advisor consults with Peter Johnston on forecasting information
P8	5	Unspecified	No	Rimpro
P9	21	Chenin, Shiraz, Merlot, Cabernet	Yes	iLeaf (synced with weather station)
P10	21	Chenin, Shiraz, Merlot, Cabernet	Yes	iLeaf (synced with weather station)

\*this participant is a consultant that works mostly with table grapes and other fruit crops but does not work with wine grapes. He was interviewed for his expert insight on forecasting in agriculture particularly fruit crop.

#### ***4.1.1.2 Crop Types and Cultivars***

According to P7 (who holds a doctorate in horticulture and has 45 years' industry experience), the average lifecycle of a vine is 20-25 years, after which the vine is considered unproductive and therefore new vines need to be planted. Some farmers opt to keep vines beyond this age for financial or sentimental reasons. According to the farmers, SF is most important for farmers when they are about to plant new vines as well as determine which cultivars to plant in a season. Among the Swartland region, a lot of red grape cultivars are grown as they are said to be more resilient to warmer temperatures than white cultivars. Mouvedre being the most common in the Swartland.

Commercial farmers grow a larger range of cultivars the highest being P6 with 18 different cultivars cultivated on the vineyard of both white and red grapes (Table 4). About 3 of the farmer's farm other crops along with wine grapes. The most common types of crops farmed in these regions include olives, apples and citrus fruits. It was noted that these farmers put a lot more energy into growing these other crops than they did with vines. This is due to financial gain when comparing production input with profit and crop type and the degree of resilience of the crop to climate impacts.

#### ***4.1.1.3 Forecasting Use***

A range of forecasting information is used by the participants (Table 4). The forecasting technology is mainly short term. Weather forecasting is used by all participants daily to make day-to-day management decisions such as contracting extra labourers for the day. Weather forecasts are used on a weekly basis to assist when farmers need to decide on whether to spray vines for preventative treatment. SF is used when farmers need to plant new vines, decide on cultivars to plant for a season or when they do their financial planning for the season.

#### ***4.2.2 Climate hazards experienced by farmers***

The climate risks experienced by the farmers in the past 10 years is summarized in Figure 4.1 below. Of the 10 respondents (n=10), 8 have experienced climate impacts that have affected the cultivation of wine grapes on their vineyards. While they all admitted to experiencing some major climate events over the past 10 years, the rest of the respondents (2) stated that these events had no detrimental impact on the growing of the vine itself.

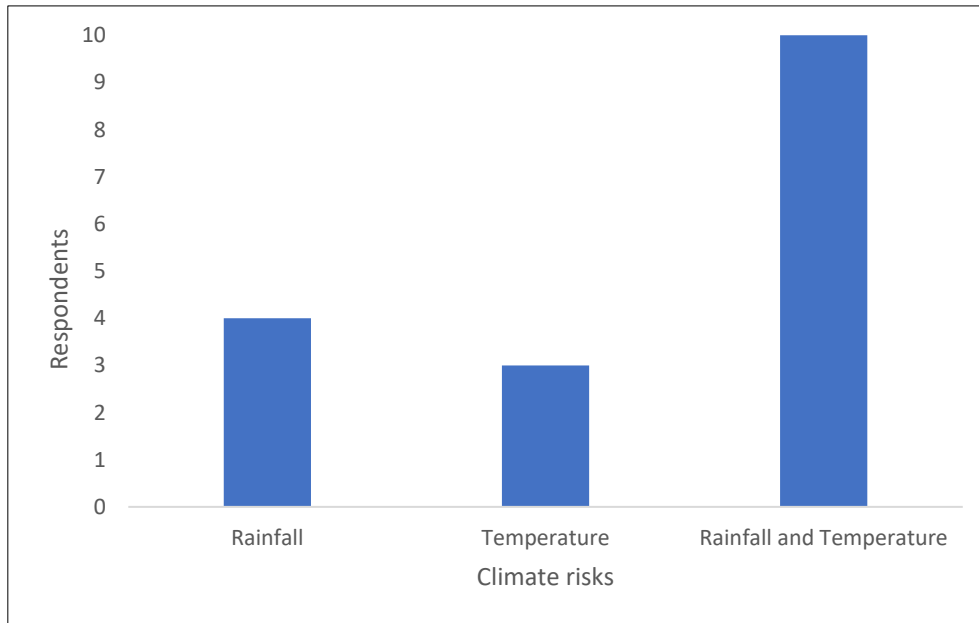


Figure 4.1 Climate risks experienced by respondents.

#### 4.2.3 Use of seasonal forecasts by farmers

All the farmers expressed difficulties in accessing SF. As a result, the most commonly used one was from SAWS. The use of SF information varied amongst the respondents. Specifically, 4 out of 10 of the farmers reported to using SF to guide their management decisions while the other 6/10 do not. The SF users use SAWS to inform their future forecasts as they mentioned this is the most easily accessible. The results reveal that most of these farmers rely more on short term weather forecasting than long term forecasting. Motivated by the greater accuracy of short-term forecasting which enables them to make better daily management decisions compared to SF. However, farmers also recognized the importance of long-term forecasting (such as SF) to their industry for various reasons like knowing where to plant vines and how to prepare for pest infestation. One of the respondents (P5) who has been a fruit crop (including wine grapes) consultant in the Elgin Valley for various farmers for 28 years explains;

*“So, a lot of growers make use of forecasting and I don't want to talk on behalf too much of grape growers, but all farming needs forecasting when it comes to climate or weather. Short and long term, but specifically short term in the early part of the season because we've got a lot of fungal diseases, slightly different in grapes, for instance they have downy mildew.”*

Challenges expressed by wine grape farmers which relate to the use of SF are presented in Table 5. Other challenges include the low profitability of the industry as expressed by farmers in the

interviews. Lastly, it was observed that smallholder farmers made less use of SF models primarily due to accessibility and a lack of knowledge on the technology and what it offers.

**Table 5: Challenges of using seasonal forecasts**

<b>Categories of Challenges</b>	<b>Challenge</b>	<b>Impact on farmers</b>
<b>SF Product/Access/Content</b>	Forecast accuracy;	Alters the influence/relevance of forecasting on farmer decision making.
	Low skill	
<b>Scale of business/vineyard</b>	Low yield	Low uptake among smallholder farmers. Some farmers grow vines as a side business venture because they have the extra land.
	Side hustle	
<b>Crop type/Cultivars</b>	Old vines	Certain cultivars are more resistant to climate impacts which influences uptake.
	Drought resistant cultivars	
<b>Revenue</b>	Vine resilience	Input cost and extra effort to monitor climate is not worth the money made from grape growing.
	Low profits	

**4.2.4 Farmer capacities (yield, quality, labour & finances)**

**4.2.4.1 Yield**

Table 6 presents the yield quantities provided by farmers in good versus bad climate years. Not all farmers were open to sharing their figures (such as P9 and P10) and other participants (i.e. P5 and P7) did not have figures to share as they are both agricultural advisors who do not grow wine grapes and do not own vineyards of their own. P4 did not have grape yield records to share but gave number of bottles they sell instead.

**Table 6: Participant grape yield records**

<b>Participant ID</b>	<b>P1</b>	<b>P2</b>	<b>P3</b>	<b>P4</b>	<b>P5</b>	<b>P6</b>	<b>P7</b>	<b>P8</b>	<b>P9</b>	<b>P10</b>
Good year (yield tonnage)	50	85	5	1500*	N/A	9	**	10	***	***
Bad year (yield tonnage)	24	16	2.5	5*	N/A	7/8	**	1	***	***

*\*The farmer did not have tonnage records so they gave no. of bottles of wine they are able to produce and sell instead*

*\*\*Desired profit is R40,000 per hectare*

*\*\*\*Did not provide records only mentioned that yields have been steadily increasing since 2009*

Commercial farmers had less accurate yield records to share compared to smallholder farmers. This is likely due to the fact their units of measure for yield are based on turnover rather than quantity. P7 explains further;

*“So we don't actually specifically look at the yield. We look at our turnover per block. So our desired profit is R40,000 a hectare. There are certain blocks that go much over that expected profit and some that go below that profit” (P7)*

#### **4.2.4.2 Quality**

Table 7 summarizes the impact of climate (temperature and rainfall) on the quality of grape produce as identified by the farmers during the interviews. Similar experiences were recorded during the interviews and have been presented in Table 7 according to the climate impact.

**Table 7: Climate impacts on wine quality**

<b>Climate Impact</b>	<b>Interview Result</b>	<b>Supporting quote</b>
<b>Temperature</b>	Rising temperatures = more expense	“Farming has become more costly because when we started it was good enough to just put a cover crop but for the last five years we’ve been putting in the bunkies (mulching with straw) where the vines actually grow. It’s an extra expense but it’s what we have had to do to keep the vines cool.”
<b>Rainfall</b>	The more rain the better the crop	“The unseasonal rainfall patterns (in January and December) have been helpful in letting us keep more grape bunches on the vine and enables the vine to deal with the stress better so it’s positive in that sense.”
		“I’ll never say there’s too much rain. We’ve never had that problem, not in the years that I’ve been farming.”
<b>Temperature and Rainfall</b>	A little stress is good for the vine	“All vines are pretty resilient. In the drought period, it was so dry we did lose some vines and we’ve lost portions of a vine. The plant did not die but we lost quite a few segments of it in those drought years.”
		“Because we are organic, all our vines have very deep roots so we have not lost any to drought but we have lost some to fire.”
	Favourable for pest infestation	“Downy mildew in particular has got a climate curve that triggers sporulation.”

#### **4.2.4.3 Labour**

Figure 4.2 presents the results of how the use and non-use of SF by farmers affects the seasonal employment/ contracting of labourers under variable climate conditions. The results reveal that with SF farmers can maintain a low and almost steady work force as they are able to space out when the vineyards require extra hands. Without SF the contractors tend to vary greatly. Some

farmers may need an urgent supply of labourers to assist during an unexpected weather condition to save the vines. Figure 4.2 below depicts the difference in the number of labourers are need on a vineyard when farmers make use of SF (blue) and when they do not (orange). The x-axis shows the difference in number of employees need by each participant when they are use SF versus when they are not and the y-axis shows how many employees are needed with SF and without SF.

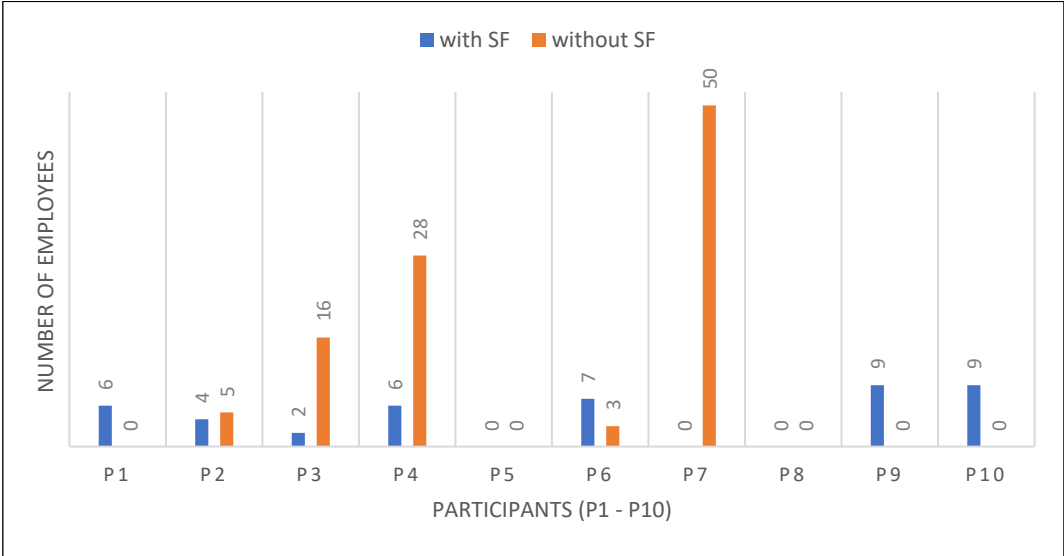


Figure 4.2 How SF use and non-use affects labour resource on vineyards.

**4.2.4.4 Finance**

The challenges encountered by farmers during grape cultivation are summarized in Table 8. Challenges such as competition in the industry especially for smallholder farmers means farmers need to supplement grape growing with another income just to survive in the industry. Other accounts of a decline in wine consumption were made. This decline has been noticed since the COVID 19 pandemic, when alcohol was banned in SA but wine drinkers continue to decrease since. The cost of wine growing and wine making were a recurring theme in the interviews where farmers explained that the business requires high input costs offering low return.

**Table 8: Financial challenges faced by wine grape farmers**

Challenge	Interview Result	Supporting Quote
Competition	6 out of 10 farmers opt to only sell/export grapes and not to manufacture and sell wine themselves.	“It's a very difficult market to get in, very competitive. You probably have to invest another R100,000,000 to put up a seller and then manage all the teams, all the marketing, all of that and that's an entity that has to run on its own.”
Wine consumption decline	7 out of 10 of farmers mentioned the biggest threat to the industry is the steady decline of wine consumption in the country.	“We're seeing a decline in wine users about 20% to 30% this year and we're expecting a decline of about 15% each year after that.”
		“They're not many South African wine drinkers. The truth is, there's less than a million. That's what I've been hearing and so there is not really a market.”
		“Weather wise there is no need to panic quite yet. But the main factor is the consumer market and trends.”
Input costs	9 out of 10 farmers were not comfortable to share their finance figures except one participant. The general response here was that production costs are high compared to profit gain in the industry.	“We spend about R 3-3.5 million just on tractors each year. That's only a portion of the production costs. Excludes chemicals, excludes fertilizer, excludes electricity and water.”

Figure 4.3 below depicts the various industries, and business ventures the farmers are involved in to supplement their wine grape growing. Depending on the farm size some farmers opted to grow other crops to make more money. Another service provided by farmers was accommodation services especially commercial farmers. They also offer tasting and rent out the vineyard for special events and occasions like birthdays and weddings. Participants P4 and P7 explain;

Participant P7 - *“Now wine grapes do not make a lot of money. Wine grapes are actually a very, very profit-restricted plant. All these vineyards that you see around here, the income will be supplemented by one or other industrial activity. Most of it is lifestyle. This is not a lifestyle farm. This is a commercial farm. But the owner of this farm owns seven other farms and has got a huge involvement with some other factories in and around Cape Town. And he can afford to push in more and more money. So it is very difficult to make good money in production costs. In the vicinity of 80,000 rand a hectare. Our return on investment is around about 100,000 rand a hectare. So we only have 20,000 rand that we can play with. If you talk about 20,000 hectares, around 100 hectares, we're talking about 2-million-rand income. From that 2-million-rand income, you've got to pay the contractors, you've got to pay the drivers, you've got to pay the big people.”*

Participant P4 - *“The visitors are more profitable than the wine.”*

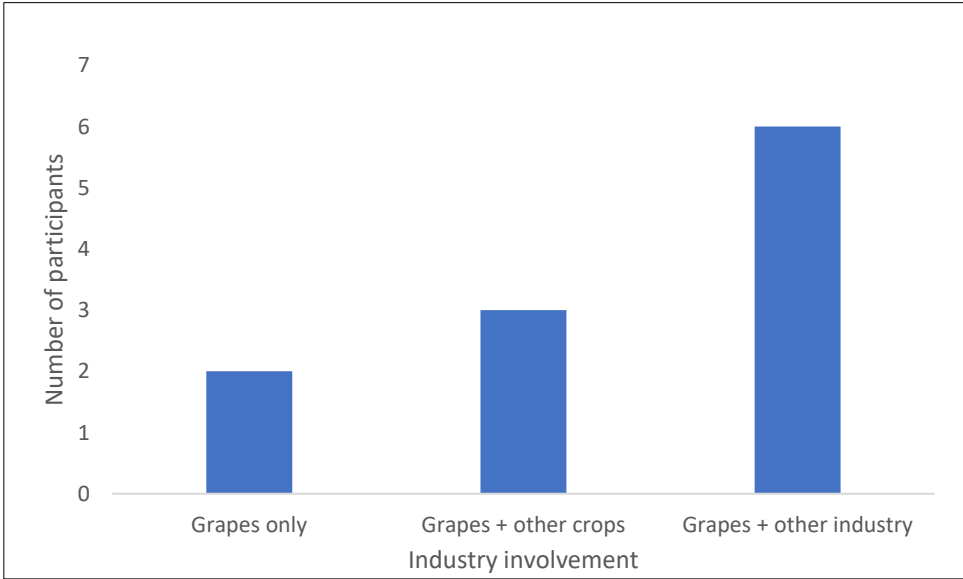


Figure 4.3 Farmer supplemental income.

### **4.3 Rainfall risk assessment**

Tables 9 and 10 below present the rainfall risk assessment analysis. They combine the likelihood of above and below normal rainfall events and the potential impact that these climate events may have on wine grape farmers' yield, quality, labour and finances to evaluate and compare how seasonal forecast use and non-use affects risk evaluations. The tables are represented by columns and rows. The columns represent the different levels of impact that the respective climate event is likely to have on yield, quality, labour and finances upon exposure, where 1 = 'no impact' and 5 = 'very high impact'. The rows represent the likelihood of the climate event (i.e. AN or BN rainfall) from occurring, ranging from 'rare' to 'almost certain'

#### ***4.3.1 Impact and risk of above normal rainfall***

Notably, 5 participants indicated that yield, quality, labour and finances are not negatively impacted by above normal rainfall events despite the probability of occurrence being 'likely' across P4, P5, P8, P9 and P10's vineyards. Moreover, the severity of impact remains the same with or without SF use. Low risks were recorded by 3 of the participants on yield, quality and finances by farmers who make use of SF however, 2 of the 3 rated low impact without SF use. Suggesting that there is an increase in impact severity in the absence of SF use when the likelihood of AN rainfall is 'possible'. Under the same probability, 3 of farmers have indicated an increase in risks on labour and quality especially, when they do not make use of SF. Overall, as probabilities increase from 'rare' to 'almost certain' the severity impact distribution shifts closer to higher impact levels especially on labour and finances, highlighting a possible correlation between higher probability of AN rains posing greater impact severity overall on yield, quality, labour and finances when SF is not being used.

**Table 9: The impact and probability of AN rainfall on yield (black), quality (blue), labour (red) and finances (green) when participants (P1-P10) use (with) or do not use (without) SF**

Impact →	No Impact (1)		Low Impact (2)		Moderate (3)		High (4)		Very High (5)	
	With SF	Without SF	With SF	Without SF	With SF	Without SF	With SF	Without SF	With SF	Without SF
Probability ↓										
Rare										
Unlikely										
Possible			P2, P3, P3, P6 P2, P3	P2, P3, P3, P6	P2, P3, P1	P3	P6, P1, P2, P6, P6	P2, P1, P2	P1, P1	P1, P6, P1, P6, P1, P2, P6
Likely	P4, P5, P8, P9, P10, P4, P5, P8, P9, P10, P4, P5, P8, P9, P10, P4, P5, P8, P9, P10	P4, P5, P8, P9, P10, P4, P5, P8, P9, P10, P4, P5, P8, P9, P10, P4, P5, P8, P9, P10			P7, P7	P7, P7	P7, P7	P7, P7		
Almost Certain										

**Table 10: The impact and probability of BN rainfall on yield (black), quality (blue), labour (red) and finances (green) when participants (P1-P10) use (with) or do not use (without) SF**

Impact →	No Impact (1)		Low Impact (2)		Moderate (3)		High (4)		Very High (5)	
	With SF	Without SF	With SF	Without SF	With SF	Without SF	With SF	Without SF	With SF	Without SF
Probability ↓										
Rare										
Unlikely										
Possible										
Likely	P5, P8, P5, P8, P5, P8, P5, P8,	P5, P8, P5, P8, P5, P8, P5, P8								
Almost Certain	P4, P9, P10, P4, P9, P10, P4, P9, P10, P4, P9, P10	P4, P9, P10 P4, P9, P10, P4, P9, P10, P4, P9, P10	P1, P2, P6, P1, P3, P6, P1, P3, P6, P1, P3, P6,	P1, P6, P1, P3, P6, P1, P3, P6, P1, P3, P6	P7, P7, P2, P7	P7, P7, P7, P7	P3, P7, P2	P2	P2	P2, P3, P2, P2

### **4.3.2 Impact and risk of below normal rainfall**

Like AN rainfall, no risks have been identified by 5 of the farmers for BN rainfall event on yield, quality, labour and finances despite the probability being ‘likely’ or ‘almost certain’. Also the use of SF at the lower impact ranges is not evidenced to increase or decrease severity. Increased risks begin to appear when SF is not used by 1 participant however still with a low impact rating primarily affecting grape quality. The moderate rating is experienced when the likelihood of BN rainfall conditions are almost certain. P7 experiences moderate risks on yield, labour and finances with SF use and escalates further including labour when SF is not used. High impact severity is experienced by 3 of the participants and of the 3 the use of SF is observed to reduce risks of 1 of the farmers’ yield. Very high risks persist for P2’s grape quality even with the use of SF signalling this farmer’s vulnerability to ‘almost certain’ BN rainfall conditions. He explains:

*“If I knew a season ahead what the climate was going to do, then I would be able to prune the vine differently. So if a drought is coming I would know to reduce yield so the vine is less stressed during the drought. Because if there is not enough rain then all your grapes are going to be sub-standard which will have a detrimental effect on the vine. The opposite of that is also useful, if you know that it’s going to be a wet winter and not such a hot summer you would be able to prune the vine in a certain way for a bigger yield.”*

P6 elaborates on the reason why using SF does not appear to make any difference on risk severity and impact as similarly reported by 3 the other respondents:

*“We make these decisions based on information in the field. So in terms of this lot here, we wait until a day in January say the 5<sup>th</sup> or the 8<sup>th</sup> and if we do not receive those unseasonal showers then we will get the guys in and we will cut off the vine (thinning). At our level, I don’t think seasonal forecasting is a great influence because the decision-making process is so close.”*

The last 2 of the respondents gave varying ratings, P2’s ratings increased on average without the use of SF compared to non-use. Signally importance of SF in maintaining their yield and finances. Comparatively P7’s rating was low for all categories except quality. This demonstrates that for these farmers (P2 and P7) below normal rain poses moderate to high risk on grape quality whether they make use of SF or not.

Overall, the use of SF does not escalate or de-escalate the overall risk of BN rainfall on grape yield, quality, labour and finances for 5 of the participants in this study even with an ‘almost certain’ likelihood of occurrence. The probability of BN rainfall also does not pose significant threat to the categories as most ratings fall within the ‘no impact’ to ‘low impact’ severity range. Highlighting the resilience of the grapevine and the effectiveness of farmer mitigation strategies.

When asked whether SF would be useful to wine grape farmers despite their uncertainty, all respondents unanimously agreed that it would be. However, with great hesitance due to accuracy concerns. Respondent P2 elaborates:

*“Yes it would, but they (SF) have to be very accurate for you to make management decisions for you to change your farming activities. So, because they are so unpredictable, I just always prepare for drought by buying as much straw as I can afford and pack on the vine strips to keep as much moisture in the ground as possible and reduce evaporation. If it’s a good season, then I still win.”*

#### **4.4 Temperature risk assessment**

Tables 11 and 12 below present the risk assessment results for temperature. They also combine the likelihood of above and below normal temperature events in a season and the potential impact that these climate events may have on wine grape farmers’ yield, quality, labour and finances, to evaluate and compare how SF use and non-use affects risk evaluations.

##### **4.4.1 Impact and risk of above normal temperature**

The responses from the farmers indicate that 4 experience risks with low impact on all categories but at high probabilities. For these farmers SF use does not escalate or de-escalate risks. Respondent P4 highlighted that though they may still produce good quality wines under high temperatures the reduction in yield will have a larger impact on finances and to some degree the quality of the produce. Emphasizing that even if the grapevine is resilient to high temperatures, if natural water reserves are not replenished the survival of the vine is also limited.

Participants P9 and P10 also face low impacts at a lower probability than the previous 4. For these farmers, temperature related risks remain minimal regardless of their use of SF. They attribute this low risk to their soil management techniques, particularly their efforts in increasing carbon in the soil which they claim enables them to maintain vines that are healthy through all climate conditions (except hail). Ultimately that will mean no significant threats to grape yields, quality, labour or finances of the vineyard provided they stick to maintaining healthy soils. Respondent P10 explains:

*“What matters is what are you doing with your soils because remember, one gram of organic matter holds eight grams of water. If every farmer was farming regeneratively, you wouldn't have dongas, you wouldn't have brown rivers, you wouldn't have an ecology that's destroyed. And therefore, if there's changes in climate, it wouldn't be a problem. So my view is that the regenerative farmers who are building their soils, not only increase resilience but build healthier soils and healthier plants no matter what the climate does.*”

Participant P9 highlights that the supplementary use of mulching enables them to maintain a steady environment for their vines because of the nutrients and water holding capacity the mulch can provide the soils which in turn stabilizes the vine, P9 continues:

*“Okay, so mulch is a soil cover, right? Where I knew mulch up to four years ago was it was just a biological medium and sort of inert medium like, you know, old wood chips or something that people would put down. We now mulch with chicken feathers. A UCT student actually did the research report on it, just to look at what is the actual impact of the chicken feathers is on soils. She looked at the microbes in the soil, the coolness of the soil, all those kinds of things. Needless to say, we've been continuing for four years to put out chicken feathers because it's so amazing. It's not just a mulch which keeps the soil cool, but it breaks down and feeds the soil. So, the plant growth is much more vigorous. So, we are doing everything we can to make our farm more resilient to an ever-changing climate.”*

**Table 11: The impact and probability of AN temperature on yield (black), quality (blue), labour (red) and finances (green) when participants (P1-P10) use (with) or do not to use (without) SF**

Impact →	No Impact (1)		Low Impact (2)		Moderate (3)		High (4)		Very High (5)	
	With SF	Without SF	With SF	Without SF	With SF	Without SF	With SF	Without SF	With SF	Without SF
<b>Probability ↓</b>										
<b>Rare</b>										
<b>Unlikely</b>										
<b>Possible</b>	P5, P7, P8 P5, P7, P8 P5, P7, P8 P5, P7, P8	P5, P7, P8 P5, P7, P8 P5, P7, P8 P5, P7, P8	P9, P10 P9, P10 P9, P10 P9, P10	P9, P10 P9, P10 P9, P10 P9, P10						
<b>Likely</b>										
<b>Almost Certain</b>	P1, P2, P3, P6, P1, P2, P3, P6, P1, P2, P3, P6, P1, P2, P3, P6,	P1, P2, P3, P6, P1, P2, P3, P6, P1, P2, P3, P6, P1, P2, P3, P6,	P4, P4 P4, P4	P4 P4 P4 P4						

**Table 12: The impact and probability of BN temperature on yield (black), quality (blue), labour (red) and finances (green) when participants (P1-P10) use (with) or do not to use (without) SF**

Impact →	No Impact (1)		Low Impact (2)		Moderate (3)		High (4)		Very High (5)	
	With SF	Without SF	With SF	Without SF	With SF	Without SF	With SF	Without SF	With SF	Without SF
<b>Probability ↓</b>										
<b>Rare</b>										
<b>Unlikely</b>	P1, P2, P3, P6, P1, P2, P3, P6, P1, P2, P3, P6, P1, P2, P3, P6,	P1, P2, P3, P6, P1, P2, P3, P6, P1, P2, P3, P6, P1, P2, P3, P6,	P4 P4 P4 P4	P4 P4 P4 P4						
<b>Possible</b>	P7 P7 P7 P7	P7 P7 P7 P7	P9, P10 P9, P10 P9, P10 P9, P10	P9, P10 P9, P10 P9, P10 P9, P10						
<b>Likely</b>	P5, P8 P5, P8 P5, P8 P5, P8	P5, P8 P5, P8 P5, P8 P5, P8								
<b>Almost Certain</b>										

#### **4.4.2 Impact and risk of below normal temperature**

Seasonal forecast use is less noticeable at lower impact levels as 7 of the farmers rated no impact on yield, quality, labour and finances regardless of their use of SF. Probability ratings were similar for farmers who were located in the same wine region. For example, 5 of the farmers who said BN temperatures are unlikely to occur are located in the Swartland, the 2 that said 'likely' are located in the Elgin Valley. Stellenbosch farmers (2) along with the Cape Town farmer (1) both said BN temperatures are 'possible'. Higher severity ('moderate to 'very high') impacts were not reported for this climate condition.

Respondent P4 from the Swartland region explained the reason why temperature poses minimal risk to their vine's health is due to the depth of their vines root network and the ample supply of groundwater found in the region. He explains:

*"This farm is peculiar for two reasons. Reason number one is it's got a huge amount of underground water. It's probably unique to have so much underground water. And good quality. So that's advantage number one. Advantage number two is that in good rain years, we probably get slightly more than average for the area."*

The respondent further noted that while they have lost some vines to fire in 2012, they haven't lost any vines to drought since acquiring the farm in 1997 despite being dryland. He also expressed anticipation of potential drought in coming years but remains confident in the resilience of his vines due to his experience of planting vines on the farm since 1997. He also attributes the resilience of the vines to a south-easterly wind that flows down the valley every day at 4 o'clock and cools the farm and the vines down no matter how hot the temperature gets during the day. The respondent elaborated:

*"I think next year is going to be bad and the year after is going to be bad. I think we've got two years of drought coming ahead and I know that we can survive it because the ground water allows us to do that."*

Farmers from the Swartland region indicated that they typically experience high temperatures in the area and are thus unconcerned when the temperatures fall below normal. In some instances, this is preferred in the region to avoid pest and disease infestation, as well as to prevent raisining and sun burning of grape skins. Table 13 groups the most recurrent responses to the impact of above and below normal temperature conditions on the grapevine.

**Table 13: Impacts of temperature on grapevines**

Temperature risk	Supporting Quote (Reasons)
Above normal	“You can expect sunburn, especially if it occurs during bloom. Sunburn later in the season, could affect the berries. Sometimes the winemakers like smaller berries because they think it is more concentrated and better tasting, better quality. If the grapes suffer a little bit, then it will definitely be a better quality, but lower volume.” (Cape Town region).
	“More beneficial for red varieties than on the white varieties because the white varieties can easily lose a bit of flavour under very hot conditions. (Cape Town region). Although, having said that, some of our best white and especially white varieties are made in the Robertson area, it's very hot in summertime and also very dry.”
	“We can’t plant Sauvignon blanc because it requires cooler climate and a lot more rainfall. We might get a yield but the quality will be terrible which means we can’t sell it” (Swartland).
	“High temperature, high humidity, and a lot of nitrogen in the air is like a party for fungus infections because for the fungus to thrive they need moisture and temperature.” (Swartland)
Below Normal	“2015 was excellent harvest. It was quite cool. We made a lot of wine of very high quality, all of it.” (Swartland region)

#### 4.5. Combined rainfall and temperature risks

A significant threat reported by all respondents was that of pest and disease infestation particularly downy mildew and powdery mildew. Generally, these infestations are a result of temperature and rainfall conditions that create an environment suitable for their growth within the field. Respondent P7 explains:

*“Berries are excessively sensitive to downy mildew and downy mildew which is an interesting disease. It has a sweet spot in terms of climate. It needs free water to start the growth, to start the spores and then secondly, it needs a temperature of between 12 and 15 degrees and it needs a vine leaf of about 10-centimetre diameter. These leaves are specifically sensitive to downy*

*mildew (Figure 4.4). If the conditions occur that will affect the infection in this part, it will generate a lot of spores. The spores will spread and if you have an excess of spores, obviously it becomes more and more difficult to control. The medicine that we prescribe is effective, but like all medicine, it's only partially effective and then eventually you end up with an epidemic and the epidemic causes huge, huge loss to the grower. The bunches are particularly sensitive when it flowers.”*



*Figure 4.4 Type of leaf that is susceptible to downy mildew infestation (source: own)*

The medicine/s the respondent is referring to are agrochemicals which are sprayed on the vine prior to infestation. The respondent further explains that there are various other diseases that form and spread under varying climate conditions:

*“Another disease called powdery mildew. It's not the same disease, it's two totally different diseases, and the conditions under which they develop are totally different. In the case of downy mildew, it develops under wet conditions and humid, or free water for the initial start, and then humidity for the eventual development and in the case of powdery mildew, it wants dry conditions. Downy mildew also starts the infection at the bottom of the leaves, and powdery*

*mildew starts at the top of the leaves. It's two different, totally two different species of diseases. But powdery mildew can be just as devastating as downy mildew.” (Respondent P7)*



*Figure 4.5 Signs of downy mildew infestation.*

#### **4.5 Farmer adaptation measures in response to climate variability**

Adaptation measures varied slightly among the respondents, 40% reported to using mulch as a method to cope with climate variability. Of that 40%, half of the respondents reported to using straw as mulch while the other half reported the use of compost and 20% reported to laying chicken feathers on the ground to grow the cover crop. Figure 4.6 below shows what the soil looks like when it has been mixed with the chicken feathers.

Other adaptation measures include the installation of drip irrigation (60%) as opposed to sprinkler irrigation (e.g. P6). Sprinkler irrigation has been reported to use up too much water in comparison to drip irrigation which only uses a fraction of that amount therefore being the preferred alternative especially after the long drought experience in 2015-2017. Only 10% of the vineyards with irrigation are smallholder and 50% are commercial vineyards. The other 40% of respondents farm dryland. These farmers opt to farm dryland due to the higher quality

of wine that is produced when vines are farmed this way and for others it is because of the high costs involved in acquiring and installing irrigation infrastructure. P10 elaborates;

*“My own personal view is you shouldn't be irrigating vines. It's not cheating but it's like it's artificially keeping them going. Maybe in the beginning you want to give them a little bit of water, but the expression of the vine and the true taste is when it's suffered and it has the ability to push its roots 20, 30, 100 meters down. The vine is an amazing plant. But because most vines are farmed conventionally, they feed them at the surface. So the vines are like, I'm going to get water and food. What am I going to have to work for? Just sit back and ask open, just feed me. Our vines have to work a bit harder.”*

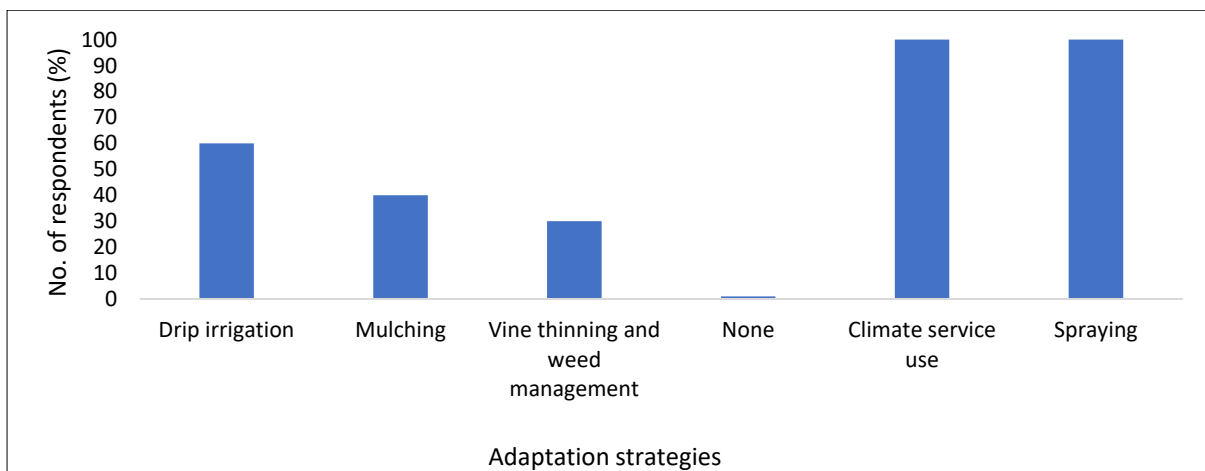


*Figure 4.6 Farmer showing soil mulch that includes a mix of organic waste and chicken feathers.*

As a way to cope with variable climate, farmers also rely on different types of technology and climate services to help them adapt. Use of climate information such as AccuWeather on mobile phones as well as weather forecast broadcasted on television to make day-to-day

management decisions. When asked how they knew which cultivars of grapes would survive the climate conditions of their area one of the respondents mentioned the use of historical climate information and one participant (P4) referred to reading published climate report from credible sources like the United Nations to ‘forecast’ for themselves what the future climate of their farm location would be like to inform those types of decisions. Another respondent who farms commercially said he did not make use or implement any adaptation measures related to the cultivation of vines which has worked out fine so far, they have only lost a season’s worth of produce to hail once in 2012 but not to other climate and weather conditions since and before then.

Three respondents mentioned vine thinning and weed management as an adaptation measure especially when the vine is under significant stress. Other adaptation measures implemented by farmers on their various vineyards are presented in Figure 4.7. Like general climate service use, all the respondents listed spraying as their number one go-to adaptation measure. The organic farmers which make up 60% of the sample size spray copper and sulphur fungicides to control diseases such as downy and powdery mildew while non-organic farmers (40%) make use of conventional agrochemicals.



*Figure 4.7 Percentage of farmers who make use of various adaptation strategies on farm in response to climate variability.*

When asked whether the farmers believed these adaptation strategies have implemented have improved their vines’ resilience and whether they are sustainable measures that can be applied and implemented long term all respondents answered yes. However, mixed responses were received when the question; “*Is there a notable difference between grape varietal response to the*

*adaptation strategies?”* was posed. With 50% of respondents saying yes and the other 50% saying not really.

Examples of responses:

**Smallholder farmer:** *“A year or two ago I put in drip irrigation and that’s made a hell of a difference because before I was only getting like 4 tons a hectare. Now in a good year I make 50 tons off 6 hectares, so I’ve doubled it basically just by putting in irrigation.”*

**Commercial farmer:** *“It’s a difficult question to answer because I have never farmed conventionally, I have always farmed organically. When I joined this farm, these vineyards were not managed organically for the first 10 years of their lives, so I made the conversion to organic, and the yields dropped initially but the quality was the same. Now the yields are picking back up and the quality of wine is even better. So, we’re making more money from the vineyards now, despite having had this conversion cost.”*

## **4.6 Risk preparatory measures**

### **4.6.1 Practices**

What was interesting to note in this study was that when asked whether the farmers conducted risk assessment on their vineyards all of them answered no. This does not necessarily imply that they lacked preparedness for specific risk scenarios encountered in vineyard operations or grape cultivation. Rather, it suggests that they did not perceive their control and monitoring protocols as necessitating a formally structured approach.

For example, P1 installed irrigation on his farm after the drought in 2015 and since then has seen his yield double in tonnages. It may be argued that a risk assessment was conducted by the farmer which led to the decision of the drip irrigation installation on their vineyards however they farmer does not consider this an assessment per se. Another noteworthy strategy is the technique of increasing the carbon found in the soil as was reported by Stellenbosch farmers P9 and P10. This strategy is a way for these farmers to proactively prepare the vines for climate impacts that could be detrimental. While not every farmer used the method of

chicken feathers to increase carbon in the soils, other farmers also agree that maintaining soil health is a good way to buffer the effects of climate on vines.

#### 4.6.2 Strategies

70% of the participants are owners of the vineyards who have owned them for years some have inherited the vines and vineyards from their families and therefore farm according to lived experiences with the climate, growing methods passed down from their elders and doing what their neighbours are doing. In terms of risk strategy implementation, the responses were split evenly as depicted in Table 14 with half the study size implementing measures and the other half not implementing anything.

**Table 14: Number of respondents employing risk management strategies**

Respondents who have employed risk strategies	5
Respondents who have not employed risk strategies	5

The five respondents who do not employ risk strategies are a mix of commercial (2) and smallholder (3) farmers. The 5 who do are commercial farmers whose risk strategies include;

1. Belonging to a Fire Protection Association (FPA).
2. Allocating up to 40% of farm profits to maintenance of farm infrastructure and systems to ensure infrastructure and resources needed to grow vines is available and working (i.e. irrigation pumps).
3. Detailed block plan for each block of vines with a corresponding irrigation program, fertilizer program and suckering program. This is checked and monitored on an ongoing basis by the farm manager.
4. Increase carbon in the soil (i.e. composting, putting down chicken feathers, cover cropping).
5. Irrigation scheduling especially before heatwaves.

The implementation of the above strategies serves as examples of wine grape farmer response to climate variability and change in the Western Cape. These generally have been implemented by farmers after experiencing some damage or loss due to negative climate impact on vines and vineyard overall. These climate impacts range from fires due to heatwaves and droughts in

the wine regions over the past 10 years of farming. Each participant elaborates further on their decision to opt for a specific adaptation measure as it relates to their individual experiences in Appendix C.

#### **4.7 Conclusion**

This chapter has presented the key findings of the study based on data collected through interviews. The results presented indicated the climate impacts experienced by wine grape farmers according to farmers' experiences. The risk levels of impact on wine grape quality, yield, labour and finances were presented by means of a risk framework which was rated by the farmers. These findings provide a focal point for the following chapter where they are discussed in detail in relation to the study's objectives and relevant literature.

## Chapter 5 - Discussion

### 5.1 Climate hazards associated with growing wine grapes

Climate risk combines three elements namely, hazard, vulnerability and exposure. In this context climate hazards refer to negative impacts caused by climate variability and change. Hazards therefore refer to events such as floods, droughts, hailstorms and so on. Vulnerability refers to the state and likelihood of being harmed and exposure is the degree to which an entity is unprotected from harm. For example, a grapevine is vulnerable if a heavy hailstorm event (hazard) is experienced during veraison. At this stage of the phenological cycle, the grapes are close to maturation as the development from flower to fruit has taken place and the grapes are exposed to physical damage. Therefore, risk is the chance that the grapevine will be harmed if exposed to a hazard such as a flood or drought.

The study assessed the types of climate hazards that exist in viticulture and the degree to which they pose potential risk to wine grape growing in the Western Cape. It was found that the wine regions have begun to experience consistently drier winters which have directly resulted in a reduction of grape yields. Grapevines, as previously mentioned, grow best in Mediterranean climates which are characterised by cool wet winters. However, farmers experience in recent years is that the winters are not always cool and wet. In the Swartland warm winters have resulted in drier soils with poor nutrient availability and organic matter making the vine susceptible to disease. Participant 2, located in the Swartland mentioned that farmers in the region have begun harvesting earlier than usual because the dry conditions accelerate the vine's development. This is problematic because if the grapes ripen during the hottest time of the year for instance, the high temperatures may reduce acidity and ultimately wine quality.

Flash floods and unseasonal rains are also a result of climate variability and have become more common in recent years. Farmers experience with this has been an effect on grape quality. When flash floods are experienced during warm winters the temperature and rainfall combinations create an environment favourable for downy and powdery mildew infestations. Warmer winters disrupt the dormancy cycles of pests and diseases resulting in increased pressure during the growing season. All farmers in the study rated pest infestation as the biggest threat to grape growing because of how regularly the floods are occurring and how much warmer winters are becoming with time. Farmers account that wine quality is also affected

when excessive rains are received between veraison to harvest as this is the stage when the grapevine ripens. If rains are received during this phase the berries are at risk of losing sugars as the rainwater is absorbed by the roots of the vine as well as through the skin of the berries. This dilution impacts the alcohol levels and thus the overall wine quality.

Hailstorms have also been identified as hazardous to grape growing. Although not as frequently and commonly experienced as heat stress or flooding. The impact of hail stones can severely impact the vine by shedding its leaves, knocking off grape clusters or even breaking the cane. This not only compromises the fruit quality but also reduces yield. For example, P4 experienced a total loss of vines due to a hailstorm in 2012. He is the only farmer in the study to have lost vines this way and while not very common, still highlights the unpredictability of climate risks. The wine industry has seen a noticeable decline in the number of wine drinkers in the country since COVID 19. Resulting in a growing concern among wine grape farmers about the future of wine in SA and the profitability of the wine industry in future. The decline in wine drinkers is causing direct negative impact on the financial aspect of the grape growing business. Farmers are selling less tonnages of grapes per season because buyers are purchasing less. Farmers also reported that there is more supply than demand for wine grapes in the market now, giving buyers an advantage in price negotiation. Thus, putting more pressure on production. Farmers are further demotivated by their low-income earnings from cultivating wine grapes. As reported by Participant 7 who said that wine grapes are a “profit restricted plant” because of the high costs that go into production compared to the amount of profit gained. Other farmers agreed with this statement as nearly all of them expressed challenges with making sufficient money from growing and selling grapes, often requiring them to take on other business ventures to supplement their earnings. More than half (60%) of the interviewees shared that their main source of income did not come from growing and selling grapes alone but from supplemental income such as offering accommodation, wine tastings or growing other crops like apples. This supports the claims of a similar study that was done in the region that showed how the choice (or lack thereof) of adaptation methods by wine grape farmers in the Western Cape is mostly influenced by the low profitability of the industry (Riedo, 2019). Similar observations were drawn from grape farmers in Tanzania that listed the top constraint to grape farming as low revenue compared to input costs due to restricted access to grape markets (Lwelamira et al., 2015).

## 5.2 Farmer response to climate hazards

Climate variability affects both smallholder and commercial vineyards alike. Each having their own set of strategies that they implement when needing to adapt or cope. The set of adaptation strategies employed by each farmer was mainly determined by the scale of the business, the microclimate of the vineyard and the farmer's risk appetite. As a result, there were commonalities and differences in strategies and decision triggers, which is a certain event or circumstance that prompts an action to be made, employed by both small-scale farmers and commercial farmers respectively.

In the Swartland the temperatures are generally high, averaging 25°C to 35°C, over the ripening season. The immediate response to temperature variability by farmers in this region includes using mulch to reduce heat stress on the vine. Mulching is seen as an effective way, by both smallholder and commercial farmers, to keep the vine cool under high temperatures which has been especially useful in the Swartland because of the region's recent experience with prolonged drought (i.e. 2015 – 2017). Before the drought, Swartland farmers (like P2) relied mostly on cover cropping to protect their vines from high temperatures but since the drought, P2 and others in the area began to supplement this method by mulching with straw to further buffer their vines against high temperatures over prolonged periods. Cover cropping was also implemented by commercial farmers P7, P9 and P10. Cover cropping is great if the goal of the farmer is to reduce erosion and increase biodiversity. This method also works well in areas that have sufficient water available during the growing season. Mulching on the other hand is suitable for water conservation and weed management and maintenance. Mulching is normally used in areas with limited rains and high temperatures like the Swartland. Moreover, cover cropping can also act as a pest and disease control measure as certain cover crops attract insects that prey on vineyard pests or act as a habitat for pest predators, naturally reducing pest pressure.

Farmers also use mulching to retain moisture content in the soils. Taking care of the soils is deemed by 30% of farmers to be another important mitigator of climate impact on vines. In the Stellenbosch region, farmers mixed their mulch material with chicken feathers and added compost to their soils to feed nutrients into and build the soil's carbon. Building carbon in soils has been reported to boost the resilience of the vines under variable rainfall and temperature conditions which has been the experience of P9 and P10 both based in the Stellenbosch region. According to these farmers, the severity of the climate's impact on vines is reduced when their

soils are healthy. Healthy soils enable the crop to withstand a myriad of temperature and rainfall variations plus enhance the soils water holding capacities which supports the vine through very dry conditions. These farmers view the soil as an important buffer against harsh climate conditions which was different from the response by farmers in the Elgin Valley. In the Elgin valley vines were neglected on the basis that they are strong enough to withstand rain and temperature variability therefore not requiring adaptation implementation. Only one farmer from the Elgin Valley had no adaptation measures put in place (such as mulching or cover cropping) for their vines.

The study concurs with the vast literature that highlights water availability as a major contributing factor towards grape yield especially for mass produced wines (Riedo, 2019). Irrigation was raised as the second most important adaptation strategy used by farmers in the Western Cape. It was observed that farmers who produce wines for mass consumption (commercial) tended to irrigate their vines to meet supplier demands, while boutique wineries and smallholder non-commercial growers usually prefer dryland farming. According to the farmers the dryland method produces lower yields but with higher quality wines compared to wines produced by irrigated vines. Interestingly, 60% of the participants indicated that the dryland farming method allows for the vine to undergo some stress which enhances the quality of the wine. Even large commercial farmers allocate certain hectares of their vines to dryland farming (e.g. P7) despite having other hectares of vines under irrigation. In such instances the dryland vines are kept and sold at a premium price because of the high quality of wine they produce.

Water shortages in the Western Cape has also influenced farmers to find ways to still irrigate their vines but with greater care to save water. For example, P6's decision to switch from sprinkler irrigation to drip irrigation was motivated by the 20-2017 long drought period. A byproduct of the drought was that it also demonstrated how resilient the grapevine is to farmers. So, although commercial farmers relied more on irrigating their vines for mass production in the past, the drought showed them that the vines produce better quality wines when they are stressed a bit. This then encouraged farmers like P9 and P10 to use less water when irrigating thereby reducing their irrigation consumption by up to 80% predrought levels.

### **5.3 Barriers and enablers of seasonal forecast use in Western Cape viticulture**

The use of SF by the farmers in the study area was relatively poor especially among smallholder farmers. Farmers at a smaller scale tend to rely on indigenous knowledge (e.g. strategies they learnt from the generations before them) to inform their management decisions and less reliance on technology-based information such as SF. In comparison, commercial farmers make more use of technologies such as drones and SF information obtained from platforms like the South African Weather Services, AccuWeather and Yr. Participant 7 is an example of this, with a 100 ha vineyard, the farmer does not work in isolation, he has connections with horticulturalists and climate scientists which he consults regularly which enables him to have knowledge of and access to technologies and information from climate and other industry experts which was a big difference from smallholder farmers who tended to work alone.

Although the uptake of SF by smallholder farmers was low, the results reveal that these farmers were not opposed to using them. Their responses elicited their interest in how to better interpret the information obtained from SF to help in their decision making. With more exposure and education there is opportunity for the uptake to increase. The challenge, as stated by P2, is knowing what to do with the information especially when the forecast accuracy is uncertain. Similar research also found that limited SF uptake among farmers has more to do with access and scientific understanding rather than accuracy of the forecast skill (Mushore, 2013, Chisadza et al., 2020). Low uptake can also be directly related to the type of crop being cultivated. In this case, it was found through the interviews that the crop (grapevine) is among the most resilient crop-types in agriculture compared to other crops that farmers were also growing (e.g. apples, olives and pears). Farmers in the Stellenbosch region emphasized the importance of the vine to undergo some level of stress (e.g. temporary drought period) to produce high quality wine.

This seemed to be the general stance held by most of the farmers, worrying less about the vine due to its resilience to rainfall and temperature variability. This makes their need for- and reliance on- SF lower than for other crop types. This was for instance observed in Elgin Valley where the participants also grow apples, which is the top selling fruit crop in the area. Participant 5 who is a farmer in this region was a lot more enthusiastic about speaking about the impacts of the climate on apples than vines. This was further evidenced by the various infrastructure and technology they use (soil probes and apps like RIMPro that advise on types of chemicals to spray based on infield weather predictions) to monitor and manage

environmental risks especially, climate related ones, to lower the severity of impact on apples and vines.

An additional barrier to uptake is because there were not many success stories directly related to SF use by wine grape farmers in the various regions. Therefore, less farmers (especially smallholder) were inclined to use it. This was also observed by Diouf et al. (2020) who interviewed climate experts in Europe to elicit their knowledge on the reasons for low SF uptake in Europe. Through this study they confirmed that when the potential benefit of SF use is not demonstrable to end-users, it was deemed irrelevant by the farmers to make use of. Moreover, farmers tend to be more reluctant to change their practices and systems which have worked for them and their families for generations. Resulting in a heavy reliance on indigenous knowledge to help them cope with unexpected climate events. During data collection, it was observed that older farmers, who did not make use of SF, were less reluctant to use it provided that the technology is used collaboratively with the strategies and methods they have used for decades (indigenous knowledge) and if they are introduced to it about by another farmer in the industry (somebody they know and trust). Risk preference and personality are a determinant of the uptake of technology by the farmers beyond just the scale of business (i.e. small vs commercial scale). Risk averse farmers are unlikely to rely of SF to inform their decisions compared to loss averse farmers.

It was expected that different farmers will perceive risk differently depending on their demographics, experience and the scale of their business. However, it was interesting to note how mostly the smallholder farmers only implement risk measures when they see or hear that another farmer in their area has done the same. During the interviews P1 mentioned that they began mulching with straw because they had seen their neighbour do the same. So instead of assessing risk based on individual experience, farmers in closer geographic proximity assessed risk severities in a similar way. This is a phenomenon known as the “neighbour effect” which explains that the proximity of wine growers affects their perceptions on the likelihood and severity of risk as was also observed with north-eastern Italian wine farmers (De Salvo et al., 2019).

Farmers recognize the value of technology at large to enable them to make decisions. They do make use of short-term forecasts, and software’s on their smartphones which connect to weather stations on their farms to help them monitor climate hazards and decide when and what type of chemicals to spray on their vines. Farmers reliance on short term weather forecasts (e.g.

Accuweather) was most prevalent by all participants to inform daily management decisions. Daily management decisions can include deciding how many labourers to call in when experiencing flash floods or unseasonal rains for example. Commercial farmers have very few permanent labourers who work on the vineyard so access to and use of weather forecasts are instrumental in this way. Even though they have a set number of seasonal labourers, this number fluctuates greatly depending on the levels in which temperature and rainfall varies. Without weather forecasting this number can rise from six labourers to 28 in a space of a day, which was the case for Participant (P4) who needed to make this call after receiving a rainfall warning from weather forecasting to avoid powdery mildew infestation during budbreak the previous season.

#### **5.4 Risk comparison with and without seasonal forecast use**

The results from the risk assessment reveal that the level of severity is higher in instances where forecasting is not used across both temperature and rainfall scenarios. The results also reveal that SF is not a crucial instrument to growing high yield and good quality grapes. Over 5 of the responses for AN and BN temperature reported little to no impact ratings with and without SF use. This shows how little difference the use of SF makes to wine farmer decision making. This low rating could be a result of many things. The first is that of SF access and how farmers interpret and use the predictions given by SFs. Many farmers, especially smallholder expressed their frustrations with SF accuracy and challenges with access. Another is that of the vine's resilience. All the farmers repeatedly expressed that the vine is a climate resistant crop, able to cope under variable temperature and rainfall conditions. In such a case some farmers may not see the value in using prediction models to plan for climate variability.

## Chapter 6 - Conclusion

### 6.1 Key Findings

The first objective of the study was to categorize and analyse the types of climate hazards and risks associated with growing grapes to understand their sensitivity to climate. The results suggest that the impacts of climate variability are being felt by farmers across the various wine regions however responses varied because of a difference in the perception of risk. The Mediterranean climate found in the Western Cape makes it suitable for grape cultivation. However, its deviation in temperature and rainfall from this standard climate consequently affects wine grape quality and yield. As a result, the region has begun to see a steady decline in harvests over the years.

Farmers (especially rain-fed farmers) are increasingly pressured by consistently drier winters and droughts particularly in arid regions like the Swartland, resulting in lower grape yield compared to cooler wine regions. The increase in flash floods and unseasonal rainfall in the country greatly threatens wine regions especially when rains are received before or during the harvest season as the soils are too dry to retain water. Some of the effects include diluted sugars in the grapes and pest infestation which decreases the quality of the grapes and ultimately the wine they produce. Similarly, hailstorms although rare, have previously caused complete crop destruction to vineyards in the Swartland and remain a looming threat as the climate continues to change rapidly. These findings underscore the urgent need for adaptive responses and strategies in the wine industry to avoid, minimize and/or mitigate the adverse effects of climate variability and change.

The second objective of the study was to examine the strategies used by wine grape farmers in response to the variable climate and compare their adaptation strategies with and without the use of SF. Mulching and irrigation emerged as the most preferred adaptation strategies used by farmers to cope with climate variability. Since the severe drought experience in 2015-2017, all the farmers began to implement measures to prepare for drought and dry conditions each season to take precaution. These measures included mulching and/or irrigation to keep their vines as cool as possible under extreme temperatures and ensure a sufficient supply of water to irrigate the vines with during the growing season.

The use of technology was an additional adaptation measure. Particularly smartphone applications that can be synced with the weather stations on the vineyards to keep farmers

informed and up to date on real time weather conditions. RimPro for instance is a decision support tool originally used to monitor and manage apple scab. Wine farmers adopted this app due to its ability to recommend the type of chemicals farmers should spray their vines with based on the information acquired from the weather station on the vineyard (Mian et al., 2021). When compared, commercial farmers made more frequent use of technology, including seasonal forecasts (e.g. Yr) than non-commercial farmers. However, the desire, interest and need by both commercial and non-commercial farmers to access and make use of such technology to help them cope and adapt to climate variability was similarly high. This was evidenced by their collective use and subscriptions to mobile and other web-based apps to predict the long-term variability and changes of the climate so they can make informed farming decisions. Thus, highlighting the usefulness of short- and long-term forecasting in viticulture, including SF.

The uptake of short-term (weather) forecasting (e.g. Accuweather) by the farmers compared to long term (seasonal) forecasting was relatively higher due to the degree of skill and accuracy of the short-term forecasting. The use of short-term forecasting however presents limitations such as deciding the type of cultivars to plant in a season or to know which adaptation measures to accurately implement to mitigate seasonal risks. A lack of awareness of various types of SF models that are readily available (preferably free) and accessible to the farmers is another hindrance to uptake. Farmers knew little about existing SF, especially in SA, and additionally felt the information available is too ambiguous and difficult to interpret, resulting in reluctance to use. Furthermore, it was observed that farmers who did not make use of SF, also lacked decision triggers, which they could implement to monitor environmental events/hazards and were therefore more vulnerable to climate impacts than farmers who do use forecasting.

The third objective of the study was to apply a risk assessment framework to compare the risk between using SF in viticulture and not using them. The risk assessment results of the framework demonstrated that without the use of forecasting severity ratings highlighted a greater impact on grape yield, quality, labour and finances. Use of weather forecasting proved to be instrumental in the day-to-day decisions that farmers make regarding climate. It meant that farmers were better prepared to handle unexpected climate impacts that would affect labour and resources which they have more control. The proposed framework was presented as a tool for farmers to refer to and identify patterns and previous responses to impacts which can help refine their responses to future climate impacts. The framework makes it possible for farmers to identify and prioritize risks based on the severity of impact ratings, it enables farmers of all

contexts, ages and educational backgrounds to plan and strategize measures to mitigate risks with its simple design. The use of the framework itself does not require SF per se as it can be adapted to any context if farmers diarize their experiences and responses to variable climate and their subsequent impacts

## **6.2 Concluding summary**

The aim of the study was to investigate the level of risk involved in the use and non-use of seasonal forecasts by wine farmers in the Western Cape. This was achieved by closely examining farmer adaptation practices and response to climate variability. The results have highlighted the significant differences in risk exposure between those who use SFs and those who do not. The findings further demonstrate that farmers who actively use forecasts in their decision making tend to be better prepared for seasonal fluctuations in climate, allowing them to anticipate adverse conditions and implement preventative measures more efficiently. In contrast, farmers who do not use forecasts are more likely to adopt a reactive approach responding only after damage or loss has occurred thereby increasing their vulnerability to climate related risks. The study provided further insights into the barriers that prevent broader SF adoption, such as reliance on indigenous knowledge and subjective risk perception, which further clarifies why some farmers remain hesitant to use the tool. The research also outlines how the integration of SF with a structured risk management framework can enhance farmers; ability to identify, prioritize and mitigate financial (input costs, sales, revenue), environmental (climate impacts, pest and disease control), and social (human resources) risks. While SF presents a valuable opportunity for improved risk management in viticulture, its non-use exposes farmers to greater uncertainties and potentially higher levels of climate risks. This study therefore effectively investigated and presented both the risks and potential benefits associated with using SF contributing to a deeper understanding of how SF can be strategically used to support resilient viticultural practices in the Western Cape.

## **6.3 Suggestion for future studies**

Seasonal forecasting in combination with the proposed risk framework could be used as a useful tool by wine grape farmers to identify, prioritize and mitigate risks. The framework is robust, and the listed categories (quality, yield, labour and finances) used in the framework only serve as a theoretical example of risk categories that can be inputted. In practice these

categories may be changed to suit the preference of an individual farmers and specific vines. The framework is also not limited for use by wine grape farmers but farmers of all crop types. If given the opportunity to redesign the framework adjustments could be made to enhance its applicability to individual farms, making it a more practical tool for all farmers. The decision-making power it equips farmers with means they stand a better chance at being able to make a living and cater to the demands of the country so that SA can remain food secure. It is suggested for future research that this study be extended to more wine grape producers in the country and more so with farmers who also make use SF in comparison to those who make use of one of these tools or none to quantify the value of use. The contributions of the study are twofold. The framework serves to provide a cost-effective tool to wine grape farmers that will help them avoid, mitigate or control their risks to remain sustainable in the industry long term. Secondly, the study and framework are expected to contribute towards the existing body of knowledge on risk management and SF research in the literature.

Risk assessment and management may enable farmers to not only monitor the climate impacts on the various growing stages of the vine but also to plan and better prepare other input costs and prioritize risks according to the severity. Providing farmers with access to and knowledge of more tools like the proposed risk framework could aid them in categorizing and visualizing risks thus enabling them to make strategic decisions that can optimize their systems. The literature highlights farmer reluctance towards adopting risk management measures, often citing concerns about the costs associated with crop insurance, particularly among small holder farmers especially in regions like Africa (Njue et al., 2018, Ntukamazina et al., 2017, Madaki et al., 2023). This underscores the need for accessible and affordable solutions to encourage broader adoption within the agricultural community.

The proposed framework also holds potential as a cost-effective tool that can be implemented and used by farmers across all scales regardless of their income levels. The framework provides a platform for operation risk planning and management to achieve sustainability. Since risk management involves the incorporation of previous events and experiences, this framework will enable farmers to formally identify, prioritise and manage future climate risks that may occur. The design of the framework can be easily adapted to different scales according to the context of the farmer. It also does not require monetarily investment to use as it can be drawn up and used by individual farmers to implement structured risk assessments and management processes for themselves. Sustainability in agriculture can be complex because it encompasses

risks from cultivating grapes, climate impacts, human resources and the finances that go into growing and running a vineyard. Therefore, as a tool, the framework encompasses the environmental (climate variability, pest and disease control), the social (seasonal employment) and the financial risks (sales, profits and liabilities) which are considered vital to the long term viability and sustainability of wine producers and the industry at large.

## References

- ABAD, J., DE MENDOZA, I. H., MARÍN, D., ORCARAY, L. & SANTESTEBAN, L. G. 2021. Cover crops in viticulture. A systematic review (1): Implications on soil characteristics and biodiversity in vineyard. *Oeno One*, 55, 295-312.
- ADGER, W. N., BROWN, I. & SURMINSKI, S. 2018. Advances in risk assessment for climate change adaptation policy. The Royal Society Publishing.
- ALEKBEROVA, M., ASLANOVA, F. & ENGINDEENIZ, S. 2023. RISKS IN GRAPES PRODUCING AND ALTERNATIVE RISK MANAGEMENT FOR VITICULTURISTS: A STUDY CASE FROM AZERBAIJAN. *Scientific Papers Series Management, Economic Engineering in Agriculture & Rural Development*, 23.
- ALSTON, J. M. & SAMBUCCI, O. 2019. Grapes in the world economy. *The grape genome*, 1-24.
- ARAUJO, J. A., ABIODUN, B. J. & CRESPO, O. 2016. Impacts of drought on grape yields in Western Cape, South Africa. *Theoretical and applied climatology*, 123, 117-130.
- ARUNRAT, N., WANG, C., PUMIJUMNONG, N., SEREENONCHAI, S. & CAI, W. 2017. Farmers' intention and decision to adapt to climate change: A case study in the Yom and Nan basins, Phichit province of Thailand. *Journal of cleaner production*, 143, 672-685.
- ASHENFELTER, O. & STORCHMANN, K. 2016. The economics of wine, weather, and climate change. *Review of Environmental Economics and Policy*, 10.
- AVEN, T. 2016. Risk assessment and risk management: Review of recent advances on their foundation. *European Journal of Operational Research*, 253, 1-13.
- BAHTA, Y. T. 2021. Perception of agricultural drought resilience in South Africa: A case of smallholder livestock farmers. *Jàmhá: Journal of Disaster Risk Studies*, 13, 1-11.
- BAUDOIN, M.-A., VOGEL, C., NORTJE, K. & NAIK, M. 2017. Living with drought in South Africa: lessons learnt from the recent El Niño drought period. *International journal of disaster risk reduction*, 23, 128-137.
- CAI, W., SANTOSO, A., COLLINS, M., DEWITTE, B., KARAMPERIDOU, C., KUG, J.-S., LENGAIGNE, M., MCPHADEN, M. J., STUECKER, M. F. & TASCETTO, A. S. 2021. Changing El Niño–Southern oscillation in a warming climate. *Nature Reviews Earth & Environment*, 2, 628-644.
- CASH, B., BURLS, N., BLAMEY, R. C., SWENSON, E., AL FAHAD, A., BOPAPE, M. J. M., STRAUS, D. M. & REASON, C. J. C. The Cape Town “Day Zero” drought and Hadley cell expansion. AGU Fall Meeting 2019, 2019. AGU.
- CHISADZA, B., MUSHUNJE, A., NHUNDU, K. & PHIRI, E. E. 2020. Opportunities and challenges for seasonal climate forecasts to more effectively assist smallholder farming decisions. *South African Journal of Science*, 116, 1-5.
- CHOU, C., MARCOS-MATAMOROS, R., GARCIA, L.P., PÉREZ-ZANÓN, N., TEIXEIRA, M., SILVA, S., FONTES, N., GRAÇA, A., DELL'AQUILA, A., CALMANTI, S. AND GONZÁLEZ-REVIRIEGO, N., 2023. ADVANCED SEASONAL PREDICTIONS FOR VINE MANAGEMENT BASED ON BIOCLIMATIC INDICATORS TAILORED TO THE WINE SECTOR. *CLIMATE SERVICES*, 30, p.100343.
- CONNELLY, A., CARTER, J., HANDLEY, J. & HINCKS, S. 2018. Enhancing the practical utility of risk assessments in climate change adaptation. *Sustainability*, 10, 1399.
- COOK, C. N., DE BIE, K., KEITH, D. A. & ADDISON, P. F. 2016. Decision triggers are a critical part of evidence-based conservation. *Biological Conservation*, 195, 46-51.
- DE SALVO, M., CAPITELLO, R., GAUDENZI, B. & BEGALLI, D. 2019. Risk management strategies and residual risk perception in the wine industry: A spatial analysis in Northeast Italy. *Land use policy*, 83, 47-62.
- DIOUF, N. S., OUEDRAOGO, M., OUEDRAOGO, I., ABLOUKA, G. & ZOUGMORÉ, R. 2020. Using seasonal forecast as an adaptation strategy: Gender differential impact on yield and income in Senegal. *Atmosphere*, 11, 1127.

- DOBLAS-REYES, F. J., GARCÍA-SERRANO, J., LIENERT, F., BIESCAS, A. P. & RODRIGUES, L. R. 2013. Seasonal climate predictability and forecasting: status and prospects. *Wiley Interdisciplinary Reviews: Climate Change*, 4, 245-268.
- DUBE, K., NHAMO, G. & CHIKODZI, D. 2022. Climate change-induced droughts and tourism: Impacts and responses of Western Cape province, South Africa. *Journal of Outdoor Recreation and Tourism*, 39, 100319.
- EDWARDS, W. T. 2023. *Wine Grape vs Table Grape Comparison* [Online]. Williams Minneapolis. Available: <https://williamsminneapolis.com/wine-grape-vs-table-grape/> [Accessed 2 June 2024].
- ENGLEBRECHT AND MONTEIRO. 2021. *The IPCC's latest assessment report on the climate crisis: Five 'take-home' messages for South Africa* [Online]. Available: <https://www.dailymaverick.co.za/article/2021-08-16-the-ipccs-latest-assessment-report-on-the-climate-crisis-five-take-home-messages-for-south-africa/> [Accessed 2 October 2023].
- FIELD, C. B. & BARROS, V. R. 2014. *Climate change 2014—Impacts, adaptation and vulnerability: Regional aspects*, Cambridge University Press.
- FRAGA, H. 2019. Viticulture and winemaking under climate change. MDPI.
- GITHAHU, M. 2022. *Western Cape is the third most populated province with 11.9% of SA's population* [Online]. Available: <https://www.iol.co.za/capeargus/news/western-cape-is-the-third-most-populated-province-with-119-of-sas-population-2ab1b611-be8b-4b45-af77-e8264e730fd6> [Accessed 4 October 2023].
- GOLDAMMER, T. 2018. *The Grape Grower's Handbook: A Guide to Viticulture for Wine Production*, Apex publishers Centreville, VA, USA.
- HABIBA, U., SHAW, R. & TAKEUCHI, Y. 2012. Farmer's perception and adaptation practices to cope with drought: Perspectives from Northwestern Bangladesh. *International Journal of Disaster Risk Reduction*, 1, 72-84.
- HANNAH, L., ROEHRDANZ, P. R., IKEGAMI, M., SHEPARD, A. V., SHAW, M. R., TABOR, G. Z., L., MARQUET, P. A. A. & HIJMANS, R. J. 2013. Climate change, wine, and conservation. *Proceedings of the National Academy of Sciences*, 110, 6907-6912.
- HANSEN, J. W., MASON, S. J., SUN, L. & TALL, A. 2011. Review of seasonal climate forecasting for agriculture in sub-Saharan Africa. *Experimental agriculture*, 47, 205-240.
- IBEBUCHI, C. C. 2021. Revisiting the 1992 severe drought episode in South Africa: the role of El Niño in the anomalies of atmospheric circulation types in Africa south of the equator. *Theoretical and Applied Climatology*, 146, 723-740.
- JONES, G. V., REID, R. & VILKS, A. 2012. Climate, grapes, and wine: structure and suitability in a variable and changing climate. *The geography of wine: Regions, terroir and techniques*, 109-133.
- JONES, G. V. & WEBB, L. B. 2010. Climate change, viticulture, and wine: challenges and opportunities. *Journal of Wine Research*, 21, 103-106.
- JONES, G. V., WHITE, M. A., COOPER, O. R. & STORCHMANN, K. 2005. Climate change and global wine quality. *Climatic change*, 73, 319-343.
- KING, A. D., PITMAN, A. J., HENLEY, B. J., UKKOLA, A. M. & BROWN, J. R. 2020. The role of climate variability in Australian drought. *Nature Climate Change*, 10, 177-179.
- KLEMM, T. & MCPHERSON, R. A. 2017. The development of seasonal climate forecasting for agricultural producers. *Agricultural and forest meteorology*, 232, 384-399.
- KOUNDOURAS, S. 2018. Environmental and viticultural effects on grape composition and wine sensory properties. *Elements: An International Magazine of Mineralogy, Geochemistry, and Petrology*, 14, 173-178.
- LEPPÄLÄ, J. 2016. Systematic risk management on farms.
- LOTTERING, C. 2024. *Northern Wine Regions* [Online]. Available: <https://southafrica.co.za/northern-wine-regions.html> [Accessed 29 May 2024].
- LWELAMIRA, J., WAMBURA, P. & SAFARI, J. G. 2015. Grapevine farming and its contribution to household income and welfare among smallholder farmers in Dodoma Urban District, Tanzania.

- MADAKI, M. Y., KAECEHELE, H. & BAVOROVA, M. 2023. Agricultural insurance as a climate risk adaptation strategy in developing countries: a case of Nigeria. *Climate Policy*, 23, 747-762.
- MANATSA, D., MUSHORE, T. & LENOOU, A. 2017. Improved predictability of droughts over southern Africa using the standardized precipitation evapotranspiration index and ENSO. *Theoretical and applied climatology*, 127, 259-274.
- MIAN, G., BUSO, E. & TONON, M. 2021. Decision support systems for downy mildew (*Plasmopara viticola*) control in grapevine: short comparison review. *Asian Research Journal of Agriculture*, 14, 12-20.
- MOELETSI, M. E., MELLAART, E. A. R., MPANDELI, N. S. & HAMANDAWANA, H. 2013. The use of rainfall forecasts as a decision guide for small-scale farming in Limpopo Province, South Africa. *The Journal of Agricultural Education and Extension*, 19, 133-145.
- MORIONDO, M., JONES, G., BOIS, B., DIBARI, C., FERRISE, R., TROMBI, G. & BINDI, M. 2013. Projected shifts of wine regions in response to climate change. *Climatic change*, 119, 825-839.
- MOSEDALE, J. R., ABERNETHY, K. E., SMART, R. E., WILSON, R. J. & MACLEAN, I. M. 2016. Climate change impacts and adaptive strategies: lessons from the grapevine. *Global change biology*, 22, 3814-3828.
- MUSHORE, T. D. 2013. Uptake of seasonal rainfall forecasts in Zimbabwe. *IOSR J Environ Sci Toxicol Food Technol*, 5, 31-37.
- MYBURGH, P. A. 2013. Effect of shallow tillage and straw mulching on soil water conservation and grapevine response. *South African Journal of Plant and Soil*, 30, 219-225.
- NAIK, M. & ABIODUN, B. J. 2020. Projected changes in drought characteristics over the Western Cape, South Africa. *Meteorological Applications*, 27, e1802.
- NAUDE, M. J. & CHIWESHE, N. 2017. A proposed operational risk management framework for small and medium enterprises. *South African Journal of Economic and Management Sciences*, 20, 1-10.
- NAUDE, M. J. & NAUDE, R. T. 2022. A proposed risk framework as a tool for sustainability for the South African wine industry. *South African Journal of Economic and Management Sciences*, 25, 4235.
- NAUDE, R. & NAUDE, M. 2019. Impact of Climate Change and Extreme Weather Conditions on wine growing within the Stellenbosch region. *Journal of Contemporary Management*, 16, 111-134.
- NEETHLING, E., PETITJEAN, T., QUÉNOL, H. & BARBEAU, G. 2017. Assessing local climate vulnerability and winegrowers' adaptive processes in the context of climate change. *Mitigation and Adaptation Strategies for Global Change*, 22, 777-803.
- NJUE, E., KIRIMI, L. & MATHENGE, M. 2018. Uptake of crop insurance among smallholder farmers: Insights from maize producers in Kenya.
- NTUKAMAZINA, N., ONWONGA, R. N., SOMMER, R., RUBYOGO, J. C., MUKANKUSI, C. M., MBURU, J. & KARIUKI, R. 2017. Index-based agricultural insurance products: challenges, opportunities and prospects for uptake in sub-Saharan Africa.
- OCZKOWSKI, E. 2016. The effect of weather on wine quality and prices: An Australian spatial analysis. *Journal of Wine Economics*, 11, 48-65.
- OLLAT, N., VAN LEEUWEN, C., DE CORTAZAR ATAURI, I. G. & TOUZARD, J.-M. 2017. The challenging issue of climate change for sustainable grape and wine production. *Oeno One*, 51, 59-60.
- PENG, B., GUAN, K., PAN, M. & LI, Y. 2018. Benefits of seasonal climate prediction and satellite data for forecasting US maize yield. *Geophysical Research Letters*, 45, 9662-9671.
- PESCAROLI, G., VELAZQUEZ, O., ALCÁNTARA-AYALA, I., GALASSO, C., KOSTKOVA, P. & ALEXANDER, D. 2020. A Likert scale-based model for benchmarking operational capacity, organizational resilience, and disaster risk reduction. *International Journal of Disaster Risk Science*, 11, 404-409.
- RAMOS, M., JONES, G. & YUSTE, J. 2015. Phenology and grape ripening characteristics of cv Tempranillo within the Ribera del Duero designation of origin (Spain): Influence of soil and plot characteristics. *European Journal of Agronomy*, 70, 57-70.
- RASULOV, A. 2017. Growing of high-qualitative table grapes for storage and transportation. *Annals of Agrarian Science*, 15, 439-442.

- RIEDO, G. 2019. *Drought Response Mechanisms and Adaptation: An Analysis of Strategies Adopted by Wine Grape Farmers in the Western Cape*. MSc Climate Change and Development, Faculty of Science.
- ROGIERS, S. Y., GREER, D. H., LIU, Y., BABY, T. & XIAO, Z. 2022. Impact of climate change on grape berry ripening: An assessment of adaptation strategies for the Australian vineyard. *Frontiers in Plant Science*, 13, 1094633.
- SADRAS, V., BUBNER, R. & MORAN, M. 2012. A large-scale, open-top system to increase temperature in realistic vineyard conditions. *Agricultural and Forest Meteorology*, 154, 187-194.
- SANTOS, J. A., FRAGA, H., MALHEIRO, A.C., MOUTINHO-PEREIRA, J., DINIS, L. T., CORREIA, C., MORIONDO, M., LEOLINI, L., DIBARI, C. & COSTAFREDA-AUMEDES, S. A. K., T., 2020. A review of the potential climate change impacts and adaptation options for European viticulture. *Applied Sciences*, 10, 3092.
- SAZIB, N., MLADENOVA, L. E. & BOLTEN, J. D. 2020. Assessing the impact of ENSO on agriculture over Africa using earth observation data. *Frontiers in Sustainable Food Systems*, 4, 509914.
- SIMPSON, N. P., MACH, K. J., CONSTABLE, A., HESS, J., HOGARTH, R., HOWDEN, M., LAWRENCE, J., LEMPERT, R. J., MUCCIONE, V. & MACKAY, B. 2021. A framework for complex climate change risk assessment. *One Earth*, 4, 489-501.
- STATISTICS SOUTH AFRICA. 2023. *Beyond Employment - Time Related Underemployment in the SA Labour Market* [Online]. Available: <https://www.statssa.gov.za/?p=16312> [Accessed].
- SUN, Q., GRANCO, G., GROVES, L., VOONG, J. & VAN ZYL, S. 2023. Viticultural Manipulation and New Technologies to Address Environmental Challenges Caused by Climate Change. *Climate*, 11, 83.
- TAHERDOOST, H. 2019. What is the best response scale for survey and questionnaire design; review of different lengths of rating scale/attitude scale/Likert scale. *Hamed Taherdoost*, 1-10.
- THERON, H. & HUNTED, J. 2022. Mitigation and Adaptation Practices to the Impact of Climate Change on Wine Grape Production, with Special Reference to the South African Context. *South African Journal of Enology and Viticulture*, 43, 10-25.
- TORREGROSA, L., BIGARD, A., DOLIGEZ, A., LECOURIEUX, D., RIENTH, M., LUCHAIRE, N., PIERI, P., CHATBANYONG, R., SHAHOOD, R. & FARNOS, M. 2017. Developmental, molecular and genetic studies on grapevine response to temperature open breeding strategies for adaptation to warming. *Oeno One*, 51, 155-165.
- TORREGROSA, L., VIALET, S., ADIVÈZE, A., IOCCO-CORENA, P. & THOMAS, M. R. 2015. Grapevine (*Vitis vinifera* L.). *Agrobacterium Protocols: Volume 2*, 177-194.
- VAN LEEUWEN, C. & DESTRAC-IRVINE, A. 2017. Modified grape composition under climate change conditions requires adaptations in the vineyard. *Oeno One*, 51, 147-154.
- VENIOS, X., KORKAS, E., NISIOTOU, A. & BANILAS, G. 2020. Grapevine responses to heat stress and global warming. *Plants*, 9, 1754.
- VINPRO 2022a. SA Wine Harvest Report.
- VINPRO. 2022b. *SA wine industry ready to grow* [Online]. Available: <https://vinpro.co.za/sa-wine-industry-ready-to-grow/> [Accessed 28 September 2023].
- WESTERN CAPE GOVERNMENT 2021. Socio-Economic Profile Swartland Municipality. South Africa: Western Cape Government.
- WINE SEARCHER LIMITED. 2023. *Swartland Wine* [Online]. Available: <https://www.wine-searcher.com/regions-swartland> [Accessed 15 September 2023].
- WOLSKI, P. 2018. How severe is Cape Town's "Day zero" drought? *Significance*, 15, 24-27.
- YANG, C., CEGLAR, A., MENZ, C., MARTINS, J., FRAGA, H. & SANTOS, J. A. 2023. Performance of seasonal forecasts for the flowering and veraison of two major Portuguese grapevine varieties. *Agricultural and Forest Meteorology*, 331, 109342.
- YIN, Y., LI, M., JIA, N., SUN, Y., HAN, B., LIU, C., LIU, S., ZHAO, S. & GUO, Z. 2022. Effects of trellis system and berry thinning intensity on vine performance and quality composition of two table grape cultivars under protected cultivation in northern China. *Scientia Horticulturae*, 299, 111045.

# Appendix A – Interview questions

## Interview Questions

**Research Title:** Exploring the risk profile of seasonal forecast uptake in viticulture.

### Section A: Background Information

1. Vineyard location (District)
2. Age of vineyard (years)
3. How many years have you been farming (experience)?
4. Farm size (hectares)
5. Farm type:
  - Subsistence
  - Small holder
  - Commercial
  - Other (specify):
6. What types of grapes do you grow?
7. On average how much yield do you produce in a good season vs a bad one?
8. How many labourers are employed (both permanently and seasonally)?

### Section B: Grapevine Vulnerability to Climate Variability

9. Has your farming been affecting negatively or positively by climate variability in the past? In what ways?
10. Are any of your grape varieties more resilient than others?
11. If yes, do you know why that is the case?
12. How does climate variability affect seasonal employment on the farm?
13. In your opinion what does the future of wine grape farming look like for SA?

### Section C: Current Adaptation/Management Strategies

14. What irrigation system do you use?
15. Are there any adaptation strategies that you have employed on the farm in response to climate variability?
  - Yes
  - NoIf yes, what are they?
16. Would you say these strategies have improved grape resilience to climate variability?

- Yes
- No

17. Is there a notable difference between grape varietal response to the adaptation strategies?
18. Have you noticed a difference in yield quality and quantity since adopting the strategies?
19. Do you believe these strategies are sustainable long term?
- Yes
  - No
- Please explain your answer further
20. How have your past season grape yields been affected by climate variability?

#### **Section D: Seasonal Forecasting**

21. What do you know or understand about seasonal forecasting?
22. Is your reliance/ non-reliance on seasonal forecasting influenced by your water storage (irrigation system)? Please elaborate.
23. Do you make use of any seasonal forecasting models?
- If yes, which ones and why?
  - What has been the management benefit of using seasonal forecasts on your vineyard?
24. If no, why not?
- Have you used forecasting models in the past? Where was it detrimental?
  - Do you think forecasting information is still useful despite them being uncertain?
25. How have you overcome the negatives? / Any ideas on how these negative outcomes can be overcome?

#### **Section E: Risk Management Structures and Systems**

26. Are there any risk management strategies employed on the farm?
27. Do you conduct formal risk assessment of vineyard activities?
28. If yes, how often?
29. If no, why not?
30. Do you have any environmentally related emergency preparedness measures?
31. If yes, what are they?
32. If no, what do you do in the face of an unexpected environmental hazard?

## Appendix B – Ethical clearance



**UNIVERSITY OF CAPE TOWN**  
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18 September 2023

Lihle Khumalo  
Environmental and Geographical Sciences

**Investigating the Potential of Seasonal Forecast Use in Mitigating Drought Effects on Wine Grape Production in the Western Cape: A Risk Assessment Approach.**

Dear Lihle Khumalo

I am pleased to inform you that the Faculty of Science Research Ethics Committee has approved the above-named application for research ethics clearance, subject to the conditions listed below.

- Implement the measures described in your application to ensure that the process of your research is ethically sound; and
- Uphold ethical principles throughout all stages of the research, responding appropriately to unanticipated issues: please contact me if you need advice on ethical issues that arise.
- If you are planning to do research with students or staff, you are required to request permission from the appropriate parties, see <https://uct.ac.za/research-support-hub/integrity/accessing-uct-staff-or-students-research-population>

Your approval code is: **FSREC 082-2023**  
Expiration date: **31 December 2024**

I wish you success in your research.

Yours sincerely

Signed by candidate

**A/Prof Melissa Densmore**  
Chair: Faculty of Science Research Ethics Committee

## Appendix C – Adaptation measures

Table 15: Farmer reasons for adaption

Participant	Reason for Chosen Adaptation Measure
P1	Installed drip irrigation 2 years ago which was motivated by the drought in 2015
P2	Growing cover crops to increase the water holding capacity of the soil to get mass plant material that is then rolled flat. It feeds the microorganisms in the soil, reduces evaporation and helps with water retention.
P3	Thin the vine under high temperature conditions and make use of straws for mulching. The extension officer recommended that we plant with drought resistant rootstocks so we ordered the vines from nursery and all our vines are on Richter 99 or Ruggeri.
P4	Weather app, UN reports and historical climate information
P5	Forecasting (Rimpro, fruitlook, Terra Clim, iLeaf, Daycom)
P6	The farm has moved away from overhead sprinkler irrigation back in the day (which uses way too much water) to drip irrigation (which only uses a fraction of overhead sprinkler irrigation) Weed management in times of drought are important and need to be done on time Planting cultivars that can take the drought and heat better than others
P7	Thinning channel (drainage) and cover cropping
P8	In terms of sprays, we've got a disease model, a software model that we use on the apples but also on the grapes. It's called RIMPRO, Relative Infection Measure. It's a software model that was developed in the Netherlands. And we've been using it the past five years or so in South Africa where we use a weather station and also the weather forecast to know what the disease pressure or possible disease pressure will be. And that is what informs whether or not you need to spray. That's what informs us in terms of what the disease pressure risk is. So, we take that information and it draws a graph for us and then we know how we should treat the specific conditions in that specific time slot.
P9	We compost all our grape waste. We compost seed wines as a grape waste. So we put the compost down. It's also mulch, but it's also food for the microbes and for the plant. We cover crop, because we've got all these feathers in the vineyard, there's so much food, so the cover crop grows very aggressively and so at a certain time of the year, we just roll it flat. And then there's a mat, nice thick mat that's covering the soil. So that in time breaks down, but it keeps the soil cool.
P10	establish good cover crops in the winter we flatten them so they will smother the new seeds germinating in the summer