THE IMPACT OF FUTURE CLIMATE CHANGES ON THE PRODUCTION OF SAUVIGNON BLANC WINES IN MARLBOROUGH, NEW ZEALAND

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1.0. Summary

Climate change is causing great concern amongst the world's wine producers as the viability of different wine-growing regions is challenged. Climate change has been forecast for the Marlborough region of New Zealand (NZ), and this is likely to have an impact on the region's ability to continue to produce the fresh, vibrant, and aromatic style of Sauvignon Blanc (SB) that has become world renowned.

A regionalised climatic forecast report provided by the National Institute of Water and Atmosphere (NIWA) in NZ projects that by 2100 the climate of the Marlborough region will be warmer with more heatwaves and an increased likelihood of drought (Pearce, 2018). These data have been available to producers in the area since their publication in 2018 and provides detailed information on climatic variables for periods around 2040 and 2090. This has provided producers with the information necessary to consider long-term and seasonal adaptation strategies for dealing with climate change.

This study completed a survey with nineteen Marlborough SB producers to determine their attitudes to these future climate forecasts. Their responses used to better understand what adaptation strategies they are considering or implementing already, and whether they believe that climate change will cause wide-scale change to viticultural practices and wine style.

2.0. Introduction

"Human influence on the climate system is clear and growing, with impacts observed across all continents and oceans. Many of the observed changes since the 1950s are unprecedented over decades to millennia." (IPCC, 2014, p.v)

There is strong evidence from scientists around the world that there are noticeable changes to global climatic conditions. Climate change has the potential to impact most forms of agriculture. Perennial crops, such as grapevines, where vineyards may last up to 50 years from planting, have the largest economic cost, and long-term investment in infrastructure can influence industry viability (Sturman, 2015). Consumers expect wine to reflect a sense of place and climate change has the potential to impact terroir. Jones (2015) argues that climate is the most critical aspect affecting viticulture and the resulting production of wine.

In 2018, to better understand the impact any future climate change may have on the production of wine grapes, the New Zealand Winegrowers Association (NZWG) commissioned the New Zealand National Institute of Water & Atmospheric Research (NIWA) to analyse specific climate model simulations. These simulations were sourced from the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment 2014 Report for different regions of NZ. The resulting reports allowed NZWG to focus on addressing climatic variables that may affect the production of wine in those regions.

One of the targeted regions, Marlborough, is the largest of the NZ wine regions accounting for 75% of the country's 2020 harvest (New Zealand Winegrowers, 2020). This same report shows the most widely planted grape variety is SB,

accounting for 80% of Marlborough's plantings. The forecast's significant temperature increases and reduction in total rainfall are likely to affect the region's ability to make the clean, fresh, strongly aromatic white wine on which it has built its reputation.

The NIWA Climate Change Projections for NZ Wine Regions, Marlborough report, (2018), was made available to all producers via the NZWG website, and its models have been presented by numerous climate scientists at NZWG seminars. This report provides clear information to all producers about the expected changes in climate out to 2100. Among other climatic variables, the model has predicted that mean growing season temperatures in Marlborough will rise over the next 10-30 years, but only to a level that would typically be seen in the variability between vintages. By 2100 this increase will be significantly higher and will sit outside current vintage fluctuation ranges.

This research paper seeks to understand the ability of the Marlborough wine industry to address the impact of future climate change on the production of SB through a TOWS[1] analysis examining the threats, opportunities, weaknesses, and strengths of several key dynamics. The main questions that this Research Paper addresses are:

- What are the attitudes of Marlborough winemakers and winegrowers to any future climate change?

[1] A TOWS analysis differs from a SWOT analysis as it focuses less on audit and analysis of this issue and more on the creation of a strategy to work towards. TOWS analysis looks at the relationship between the external factors of Threats and Opportunities against the internal factors of Strengths and Weaknesses. Therefore, Threats are examined against Strengths (ST)and Weaknesses (WT). Opportunities are also analysed against Strengths (SO) and Weaknesses (WO) (Friesner, 2021).

- What effect might future climate change have on the viticulture of SB in the region?
- What effect might climate change have on flavour profiles of Marlborough SB?
- How might Marlborough winegrowers adapt to the anticipated climate change to mitigate its impact on their industry?

3.0. Background

3.1. Marlborough and Sauvignon Blanc

The Marlborough region can be found on the north-eastern part of the South Island of NZ. As can be seen in Figure 1, Marlborough has three main grape-growing subregion areas: the Wairau Valley, the Southern Valleys, and the Awatere Valley.

Figure 1: Map of Marlborough subregions, New Zealand
Source: Wine Marlborough, 2021

The Wairau Valley vineyards are planted on old stony, free-draining riverbed soils left behind from the changing course of the Wairau River. The valley's climate is influenced by the Wither Hills to the south and the Richmond Ranges to the north. The vineyards of the Southern Valleys subregion rise into the hills to the south of the Wairau Valley to a maximum elevation of 520 metres. Many of the hills are north-facing giving them increased sun exposure, on this generally cooler and drier side of the Wairau Valley. The Awatere Valley is the driest, coolest, and windiest of Marlborough's three subregions. Bordered by the Black Birch and Kaikoura Ranges,

the Awatere Valley stretches south to the edge of Marlborough's geographical borders (Wine Marlborough, 2021).

Marlborough is the largest wine region in NZ accounting for 27,808 hectares of vines and 343,036 tonnes of grapes in 2020 (New Zealand Winegrowers Annual Report, 2020) representing 75% of NZ's 2020 harvest. First planted in 1973, SB has become, in the space of 50 years, the dominant variety planted in Marlborough, producing 295,301 tonnes of fruit, or 86% of the 2020 Marlborough vintage, and accounting for 22,369 hectares, or 82% of plantings (Wine Marlborough, 2021). Figure 2 illustrates the growth of SB throughout NZ and Marlborough since 2008. Marlborough now accounts for approximately 90% of all SB harvested in NZ.

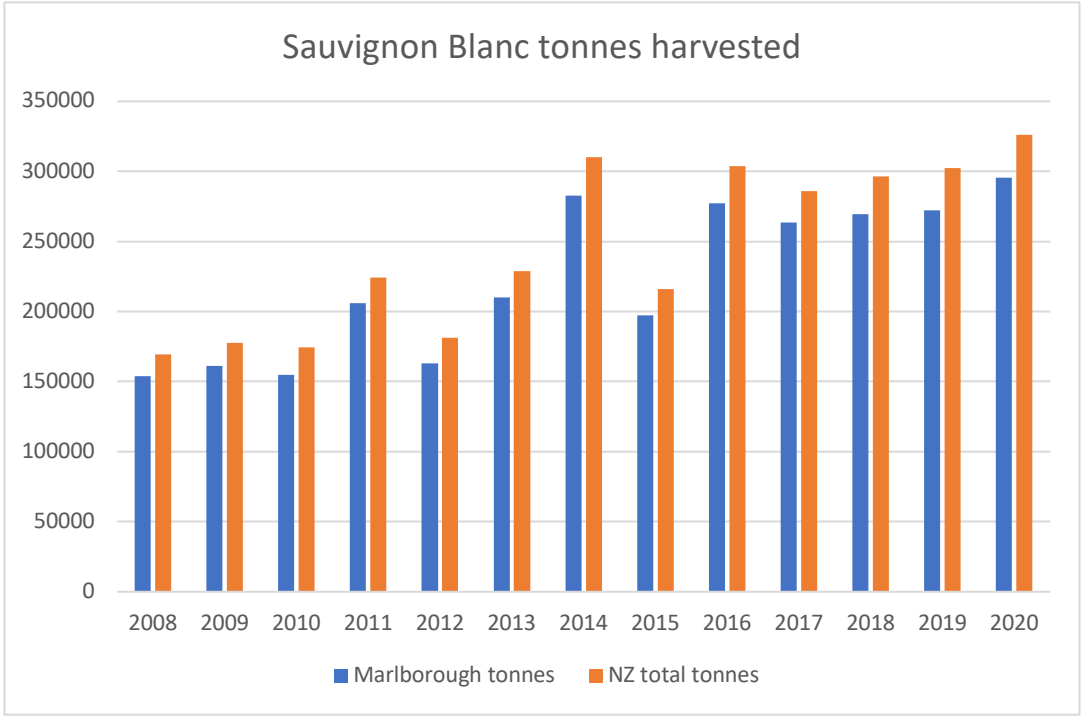

Figure 2: Total tonnes of Sauvignon Blanc harvested per year since 2008 for Marlborough and New Zealand.
Source: (Gregan, 2021, pers.comm)

International acclaim and demand have driven New Zealand wine exports from $1.093 billion to $1.922 billion in the past 10 years with SB now accounting for 87% by volume of these exports (New Zealand Winegrowers Annual Report, 2020). SB and the Marlborough wine industry are important contributors to the economy injecting $571 million and providing 6,088 full-time positions according to Wine Marlborough (2021). Plantings of SB are expected to increase by approximately 5,000 hectares by 2025. The threat of climate change and its impact on the production of Marlborough SB requires careful attention to ensure the ongoing viability of the industry.

3.2. Clonal Overview of Marlborough Sauvignon Blanc

According to Hoskins and Thorpe (2010), early plantings of SB in Marlborough trace back to a single clone from the University of California (Davis), now known as Clone 1 or Savvy MS (Mass Selection). “As the primary source of all plantings in Marlborough for close to 40 years, it has single-handedly produced the aromatic and well-balanced wines beloved by wine consumers everywhere” (Hoskins and Thorpe, 2010 p2). In 1992 three other clones were released in NZ. Clones 316, 317, and 5385 have all been used to make wines but none have had the same success as the MS clone and are much less widely planted. According to Hopkins and Thorpe (2010), clones 316 and 317 lost favour when they were found to be carriers of Grapevine Leafroll Virus 2. It is now believed that the Savvy MS clone makes up 90% of all plantings (White, 2015). NZWG thinks that this narrow genetic base presents a challenge to the industry when facing issues such as climate change, as temperature changes and drought conditions may challenge clonal suitability. (Loza, 2021, pers.comm)

3.3. Current winemaking

In Marlborough, SB is generally made in an intensely fruit-driven style. The majority of these wines are made from machine-harvested grapes. Parr et al. (2013) showed there is a higher concentration of volatile compounds in machine-harvested-fruit wines, creating a higher intensity of flavours. In general, these volatile flavour compounds are maximised during the winemaking process by maintaining a cool fermentation in neutral stainless-steel tanks and using cultured aromatic yeasts. White (2015) believes that by following this “recipe” the resulting wines are clean and varietally pure with consistent quality. The wines owe their reputation and

identification to the distinctive combination of ripe fruits and green vegetable flavours. “These pungent, aromatic wines that blend tropical fruit flavours with gooseberry and capsicum herbaceousness are probably the closest thing that NZ has to a national wine style” (Robinson, 1999, p489). In particular, the relative intensity of green characteristics such as green capsicum (often referred to as green pepper or bell pepper) appears to be the key to Marlborough SB’s distinctiveness (Green et al., 2011). In addition to the vibrant flavour profile, the wines typically show a high level of acidity that is easier to preserve in cooler climate regions.

3.4. Marlborough’s climate

According to Greven et al. (2007), Marlborough is well-suited for viticulture, typically having mild air temperatures during the growing season, cool nights during fruit ripening, and few spring frosts. In addition, there are sufficient sunshine hours to ripen the fruit. “What makes Marlborough special as a wine region is its unusual combination of long days, cool nights, bright sunshine, and, in good years, dryish autumns” (Johnson and Robinson, 2001, p318).

The complex terrain of the region provides spatial variations in temperature which make it challenging to summarise the climate. However, Marlborough, and in particular the Wairau Valley, is one of the sunniest parts of NZ, with an average number of sunshine hours of 2,475 per annum (Chappell, 2016). The climate is dominated by eastward-moving anticyclones which are generally accompanied by sunny and dry weather during the growing season. Anderson et al. (2012) found a median annual temperature (Tavg) during the growing season of approximately 15.1°C. Marlborough is one of the driest regions in the country as it is sheltered by a

mountain range, meaning most of the region is in a rain shadow. Summer droughts are frequent. The main viticultural areas in the Wairau and Awatere valleys are sheltered from the westerly, precipitation-carrying winds so according to Wine Marlborough (2021), average rainfall in these areas is normally less than 800mm per annum. Rain days mainly occur in winter, with the lowest number occurring during the key growing period between January and March (Chappell, 2016).

However, Marlborough's climate is changing. Greven et al. (2007) suggest that in the last 75 years the mean annual air temperature in Marlborough has risen from 12.4°C to 13.3°C. While there is limited historical data that show temperature trends from within the vineyard areas of the region, data obtained from Blenheim airport by Sturman and Quénol (2013), show that between 1941 and 2010, the range between mean maximum temperatures and mean minimum temperatures increased (Fig. 3). This has resulted in more hot days and frosts for the region.

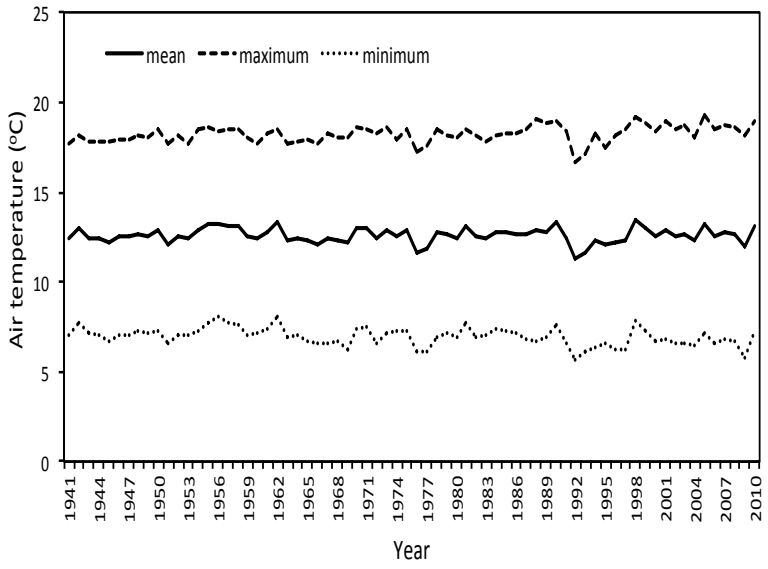

Figure 3: Annual mean daily maximum, mean, and minimum temperatures for Blenheim airport from 1941 to 2010.
Source: (Sturman and Quénol, 2013, p2611)

3.5. Climate forecasting for the future - background

According to Collins et al. (2013), forecasting future climate change is not the same as weather forecasts. They state that it is not possible to predict exactly how the climate will change over the next century and that forecasts of climate change are uncertain for several reasons:

1. They are dependent primarily on scenarios of future events that may or may not occur.
2. There is an incomplete understanding of how climate behaves and there are imprecise models of the climate system.
3. The existence of internal climate variability.

However, there is an expectation that rising greenhouse gases will continue to change climate systems. Models can then be used to make certain assumptions about future scenarios to define outcomes that allow understanding of future climate change (Collins et al., 2013).

The climate forecasts used for this research paper have been sourced from research undertaken by NIWA that was commissioned by the NZ Winegrowers Research Centre. The resulting 2018 report is heavily reliant on information and climate model simulations that are found in the IPCC Fifth Assessment (2014) report. The global scenarios in that report involved the development of 40 different emission scenarios covering the key greenhouse gases (carbon dioxide, methane, nitrous oxide, and chlorofluorocarbons) as well as the sulphate aerosols. They do not include specific initiatives to control greenhouse gas emissions, such as the Kyoto Protocol, but some of them assume a reduction in world population after a mid-century peak, and the rapid and widespread introduction of cleaner technology (NIWA, 2021). The

emission scenarios, called Representative Concentration Pathways (RCPs), were then modelled to determine the impact they would have on global climatic conditions. The following four pathways project different climate futures based on future greenhouse gas concentrations:

- RCP2.6 is a mitigation scenario where all greenhouse gases have been removed from the atmosphere
- RCP4.5 and RCP6.0 are for when greenhouse gases have stabilised by 2100[2]
- RCP 8.5 is modelled on increasing gas emissions or continuing in the current manner globally.

It is worth noting that the models did not allow for any unexpected climatic events that may be of influence such as major volcanic eruptions, changes in natural sources of methane or nitrous oxide or changes in total solar irradiance.

To forecast future climate change across NZ requires Global Climate Models (GCM's) to be statistically downscaled. (NIWA, 2021). This allows the introduction of local historical details and patterns to produce projections for the country, and then down to the region at a 5km x 5km resolution. The GCM's were selected based on their accuracy of results when compared to historical climatic data. The climate projections from the selected GCMs have been analysed in the NIWA report for the Marlborough region and are presented over a 20-year average of two periods, 2031-2050 (referred to as 2040) and 2081-2100 (referred to as 2090). The projections show climate changes relative to the period of 1986-2005.

[2] RCP4.5 and RCP6.0 are stabilisation scenarios but with differing atmospheric greenhouse gas concentrations. A higher pathway has higher radiative forcing by the gases.

3.6. Climate change forecast for New Zealand

NZ's climate is changing with long-term trends moving towards higher temperatures, more hot extremes, and shifting rainfall patterns (IPCC, 2014). The IPCC Fifth Assessment found that since 1900, the country has warmed by 0.9°C and more change is expected. The NIWA report forecasts, based on the introduction of stringent measures that limit the emissions of greenhouse gases, that temperatures will continue to rise by another 0.8°C by 2100 under the RCP2.6 emissions pathway. The emissions pathway, RCP8.5, suggests that if no limiting measures have been implemented this would increase to 3.5°C by 2100. Figure 4 illustrates these increases in temperature across the 20th and 21st centuries.

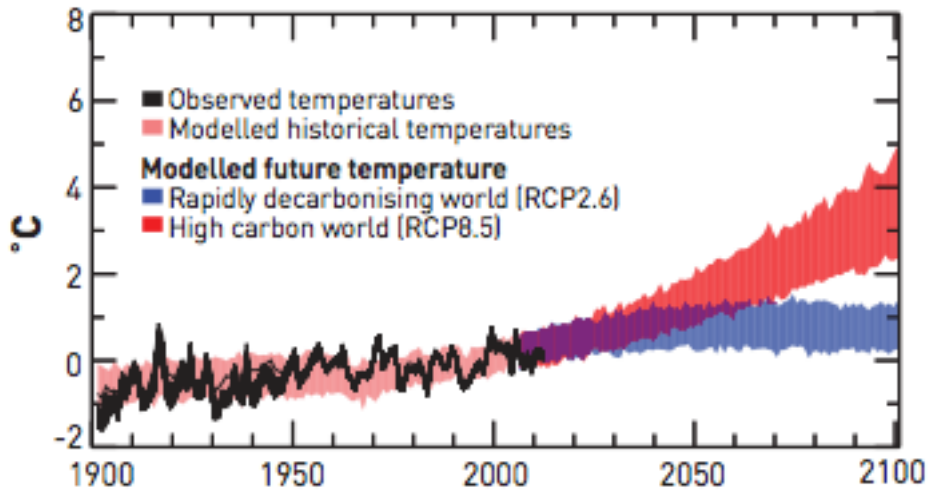

Figure 4: Temperature increase projections for New Zealand (IPCC, 2014)

The IPCC (2014) states that human greenhouse gas emissions are the dominant cause of recent global climate change and that further changes for NZ will be due to increasing amounts of greenhouse gases in the atmosphere. The rate of future climate change depends on the rate of increase of those gases (Pearce 2018).

3.7. Climate change forecast for Marlborough

The NIWA Report (2018) looked at possible climate change in Marlborough for different climatic variables in the 2040 and 2090 periods under the RCP4.5 and RCP8.5 pathways. These were chosen to present a pathway with no emissions controls in place (RCP8.5) and one that had some global mitigation against climate change, RCP4.5. The summarised results from the NIWA report (2018) of selected climatic variables over the growing season are as follows:

Mean temperature

By 2040, under both the RCP4.5 and 8.5 emission pathways, the mean temperature during the growing season will rise by 0.5-1°C across the whole region. The warmest months during the growing season will be March and April. The largest temperature rise of 2.5-3°C is predicted by 2090 under the RCP8.5 pathway.

Mean minimum temperatures

Otherwise known as night-time temperatures, mean minimum temperatures are forecast to rise by 1°C by 2040 and by 2-2.5°C by 2090 for RCP8.5. This is across the growing area of Marlborough and would mean a larger diurnal range.

Mean maximum temperatures

NIWA forecasts a rise of 0.1°C across the whole region by 2040, increasing to 3-4°C by 2090, under RCP8.5 with the greatest effect at higher elevations.

Hot days

NIWA considers temperatures over 25°C as “hot” when considering NZ’s temperate maritime climate. Currently, these occur in Marlborough between November and March. By 2040 there will be 8-20 more hot days (25-50% increase) under the RCP4.5 pathway and they will occur between October and April. Under the most

extreme RCP8.5 pathway, December and January will have 36-60 more hot days by 2090.

Frost days

The frost season will become shorter with 1-2 fewer frost days in September. At higher elevations, there will be less frost risk. Under the RCP8.5 pathway, it is expected that Marlborough will be experiencing less than half of the number of frosts it receives currently by 2090. Note: These forecasts around frost are contrary to what has been recorded by Sturman and Quénol (2013) over the past 20-30 years which has shown that frost events have increased over this period. Their studies have shown that an increase in a cold southerly flow of air has been affecting this part of the South Island differently than what is proposed by the NIWA scientists.

Growing Degree Days (GDD)

By 2040, GDD's will increase from 1,187 to 1,335. The 12% increase would be comparable to California's Central Coast and Loire Valley. There would be a 40% increase to 1,680 by 2090 under RCP8.5 making it comparable to Adelaide Hills and the Northern Rhone. The biggest increase would be for March.

Rainfall

There will be 20-30% less rainfall in November, at the start of the growing season, by 2090, however, rainfall in April will increase by 10-20% under RCP8.5. The heaviest rainfall events will happen in September and April. There will be an overall decrease in relative humidity with the biggest decreases in September and October around inland areas. There will be a small increase around coastal areas.

Summary of NIWA (2018) report

The Marlborough climate is forecast to warm under all climate change scenarios. Autumn will warm the most and Spring the least. By 2090, under RCP8.5 there will be a doubling of "hot days" from what is currently experienced. In contrast, the winter frost season will be shorter. Total rainfall will decrease from November to February and the region is projected to become more drought-prone during the growing season. Rainfall during the month of April will increase significantly.

3.8. Climate forecasts impact on viticulture

Climate has repeatedly been seen to be one of the most important factors in growing any high-quality crop with economically viable standards. “Climate arguably exerts the most profound effect on the ability of a region or site to produce quality grapes” (Jones, 2003, p2).

Temperature is central to all aspects of viticulture. Gladstone (2011) believes the evidence is now clear that, with only minor other influences, it alone controls vine phenology. Warmer temperatures will cause vines to flower earlier, go through véraison earlier, and reduce the length of the growing season due to quicker ripening. In addition to this, according to Jackson and Schuster (1994), high temperatures cause rapid development of sugars, loss of acids and high pH leading to unbalanced juice and lower quality of the finished wine.

The climate forecasts for the region are predicting less precipitation in the early parts of the growing season leading to an increased likelihood of drought in the area and therefore reduced abilities to irrigate the vines. Water stress before véraison will reduce yields and quality (Jackson and Schuster, 1994). They also state that

symptoms of water stress include short internodes, poor berry set and yellowing or loss of leaves leading to uneven ripening. Water stress due to drought during the key growing months of January and February affects growth and physiological development of the vine and damages those primary metabolites responsible for the flavours and acid in the wine thereby affecting style (Smith, 2019).

Less rainfall will create higher demands on vineyard irrigation systems and place further strain on the region's water resources largely derived directly from the Awatere and Wairau Rivers. Greven et al. (2007) state usage needs to be optimised to make sure there is enough water to meet demand. They found that mature SB vines in Marlborough can achieve optimum productivity using only half the amount of water previously thought. This research suggests that conventional above-ground irrigation practices are likely to be applying more water than needed for quality grape production. Biswas and McCarthy (2008) have shown that subsurface drip irrigation is more efficient and reduces above-ground evaporative losses and is therefore a useful adaptation tool for producers dealing with climate change.

3.9. Climate indices for viticulture

The importance of climate to viticulture has resulted in several climate indices that classify grape varieties and wine-growing regions according to temperature. These indices are used to determine the suitability of a variety within a region's climate and can therefore be used to illustrate how climate change will affect the viability of a region or variety.

The Huglin index uses the daily average temperatures and the maximum temperatures for a region over the growing season. Research by Sturman et al. (2015) found that future forecasted temperatures for Marlborough will change the region from cool with a HI value range of 1500-1800 to temperate (HI values of 1800-2100) by the end of the century. SB has a HI value of 1700 making it potentially less suitable to the region's climate by 2090.

Using the Winkler index, a classification based on growing degree days (GDD) Sturman et al. (2015) found that the forecast increase in GDD's to 1680 under RCP8.5 would move the Marlborough region from region I to the high end of region II by 2090.

The Jones's Average Growing Season (TGS) index below (Figure 5), illustrates that each grape variety has inherent climatic thresholds for optimum quality and production characteristics. For example, SB sits predominantly between the intermediate 15-17°C band. This matches with Marlborough's current average growing season temperature of 15.1°C. Under the more extreme pathway, RCP8.5, temperature increases due to climate change will result in the average growing

season temperature rising to a level deemed by the TGS criteria to be not suitable for the production of SB by 2090.

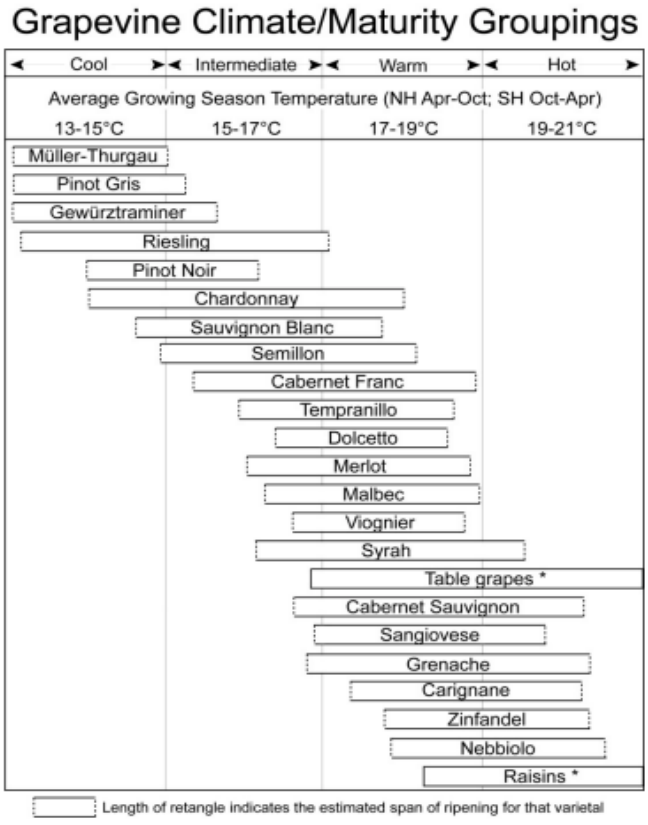

Figure 5: Climate-maturity groupings based on average growing season temperatures and the estimated span of varietal ripening potential that occurs within and across groups. (Jones, 2003)

The Latitude Temperature Index (LTI) divides varieties into distinct groups, based on their ripening requirements (Jackson and Cherry, 1988). SB sits in Group C which is described as warm (within a cool climate classification) with an LTI range of 270-380. Marlborough has an LTI of 327.5. A 3°C increase in temperature would increase the LTI of the region to above 380 (Trought, 2008). This index also supports the idea that SB would become less compatible with Marlborough's climate under new climate change forecasts.

Temperature-based phenology models, such as the Grapevine Flowering Véraison (GFV) model developed by Parker et al. (2011) determine the differences in vine development and fruit ripening over time. The GFV model evaluates a vine's phenological changes due to climate change as it focuses on the relationship between temperature and the stage of the grapevine phenology. This model allows for a change in management practices to slow phenology if required. The GFV model was used by Trought et al. (2016) to show that the véraison dates of the region have advanced by 0.4 days per annum from 1991 to 2015 suggesting phenological development is already advancing in the region. More research from Trought et al. (2015) proposed a 0.5°C increase in temperature will bring ripening or maturity for SB forward 5 days from what has been the average throughout 1987-2014. They further proposed a temperature increase of 2°C would bring ripening forward by 28 days. This research suggests a temperature increase of 2.5-3°C forecasted under the RCP8.5 pathway would have a significant impact on SB phenology.

3.10. Climates forecasts' impact on the flavour of Marlborough Sauvignon Blanc

Climate is a factor that influences both the region's ability to ripen a specific variety of grapes and the resulting wine style (Jones, 2003). The most easily identifiable differences in wine styles are based on the general characteristics of wines from a cool climate versus those from a hot climate (Jones, 2015). Johnson-Bell (2014) believes it is possible to taste the difference hotter temperatures can make in wine. SB thrives, around the world, in cool to moderate climates. Parker et al. (2011) state

that grapes that ripen in warmer climates contain less aroma or aroma precursors. In a warmer climate, SB loses its distinctive herbaceous, green characters. The methoxypyrazines compounds responsible for herbaceous aromas are now closely associated with the Marlborough region by the world's consumers. The methoxypyrazine flavour compounds are strongly influenced by climate and temperature (Allen et al., 1993). Plank et al. (2019) has found that higher temperatures reduce the amount of methoxypyrazine in grapes. Higher temperatures will also decrease the high acidity that is a defining character of Marlborough SB.

4.0. Methodology

4.1. Producer questionnaire and interviews

The key objectives of this Research Paper are to identify the threats, opportunities, weaknesses and strengths of the Marlborough SB industry with regards to addressing and adapting to future climate change forecasts. This was achieved by researching the attitudes of Marlborough SB producers to climate change and what they believe they can do to mitigate and adapt their production processes.

The literature review of the implications of potential climate change led to a qualitative survey questionnaire and the basis of the interview questions to understand what impact climate change may have on the production of Marlborough SB in the future. This interview questionnaire (Appendix 2) was developed with the help of Dr. Caroline Saunders of Lincoln University's Agribusiness and Research Unit. It was sent out to a cross-section of Marlborough SB growers and producers. Survey Monkey's online survey software was used to conduct the survey.

The questionnaire was sent to a total of 19 industry members representing 14 wine brands. Four recipients did not make wine under any wine brand but grow grapes for other producers. One recipient did not grow grapes or make wine. There are 518 growers and 158 wineries in Marlborough as per NZWG's 2020 Annual Report. Selection criteria were based on ensuring there was an accurate representative sample of the industry. It included representatives from the largest multi-national companies, large and medium-sized independent growers and makers and smaller growers and producers. Together they accounted for approximately 58% of the 2020 Marlborough SB tonnes harvested. NZWG classifies producers according to

production volumes. These categories are large (exceeding 4 million litres of sales annually), medium (200,000 to 4 million litres) and small (under 200,000 litres). Representatives from each category were targeted.

Growers from the Wairau Valley and the Awatere Valley provided a sub-regional grower perspective. Two smaller biodynamic producers and a medium-sized organic producer provided alternative methods of viticulture. Viticulturists/growers were selected for their opinions on possible impacts within the vineyard, winemakers for their knowledge on the impacts on production aspects, flavour and wine style. Ten winemakers and eight viticulturists/growers participated. Additionally, an independent consultant viticulturist who consults with multiple wine companies throughout NZ was interviewed. A summary of those surveyed follows:

- 5 winemakers (large)
- 2 viticulturists (large)
- 3 winemakers (medium)
- 1 organic viticulturist (medium)
- 2 winemakers (small)
- 1 Awatere Valley grower (large)
- 1 Wairau Valley grower (large)
- 1 Wairau Valley grower (medium)
- 1 Wairau Valley biodynamic grower (small)
- 1 Wairau Valley grower (small)
- 1 consultant viticulturist

Those selected have been involved in the production of SB in the region for over 15 years, providing a well-founded and broad level of experience to respond to any questions on the topic.

The questionnaire contained 20 questions designed to gather detailed responses around knowledge of NIWA's forecast climate changes, attitudes to these forecasts, what they viewed as being the more significant climate variables and whether changes in these variables would change the way they intend to grow or make SB. Time frames of the next 10 years, 10-30 years and over 50 years were used, as these aligned with the NIWA report time frames. Questions were asked to determine if the producers thought there would be a change in the future flavour profile or wine style of Marlborough SB, and if so, whether this would have a commercial impact on the industry by changing the cost of production or influencing consumer demand.

Once the questionnaires were completed, in-depth telephone interviews were conducted with respondents to provide more detailed input. These interviews were important because the respondents were able to expand further on the themes of the survey. Each interview lasted between 30 and 60 minutes.

Appendix 1 is a list of respondents. Due to commercial sensitivities the exact volume of grapes grown, or the number of cases produced by each respondent has not been provided.

Scientists and managers from the following organisations were also contacted and interviewed to provide some scientific context to survey responses and the NIWA data and to provide additional information.

- NIWA
- University of Canterbury (UC)
- Plant and Food Research
- New Zealand Winegrowers (NZWG)
- Bragato Research Institute (BRI)

The purpose of the questionnaires and interviews with winemakers, growers and scientists was to learn whether future climate change is an area of concern and to determine if there has been any consideration of ways to mitigate and adapt to the forecasts outlined by the NIWA report. In particular, questions were asked to determine if there will be a need to change the way SB is grown or made to produce a similar style of wine to the one that has achieved worldwide acclaim in a relatively short period[3].

For reporting results and analysis, the respondents were grouped into a large producer group and a small producer group. The small producer group included the small and medium-sized producers.

[3] During the analysis of the questionnaire results, an issue with Q15 was discovered. The original question had asked respondents to rank their concerns. While some answered correctly, the Survey Monkey software allowed others to incorrectly answer the question, making those data unusable. Rather than omit this key information, a decision was made to recontact all respondents. It was clear from the pattern of incorrect responses that employing a rating question would allow respondents to better express their concerns about projected climate changes. Thus, two follow-up questions were sent to respondents. The questions can be found in Appendix 4.

5.0. Results and Discussion

The results of the producer survey and interviews are being discussed using a Threats, Opportunities, Weaknesses and Strengths (TOWS) analysis framework. A TOWS analysis is different from a SWOT analysis as it emphasizes the external factors creating the Threats and Opportunities to Marlborough SB from climate change. Friesner (2017) states that a TOWS is for strategy generation and selection rather than for an audit. The following table summarises this analysis:

Threats • Short-term thinking • Increasing temperatures • Water availability • Changing flavour and wine style • Increasing costs of production • Frost • Industry reliance on single variety	**Opportunities** • Minimising the change in flavour and wine style • Irrigation • Canopy management • Rootstocks • Clonal improvements • Yeasts
Weaknesses • Water storage • Increasing costs impact on bottle price • Harvest infrastructure • Single varietal dominance	**Strengths** • Producer attitudes to climate change • Willingness to adapt • The blending of vineyards in the region

Table 1: TOWS analysis

5.1. Threats

5.1.1. Short-term thinking

Two of those questioned believed that climate change would not be an important issue in the production of SB within the next 10 years. Six others only found climate change to be moderately important. This means 8 respondents will not be doing anything to mitigate against or adapt to climate change in the next 10 years. The majority of those respondents were vineyard based. These responses may be due to a distrust of the forecasts for climate change. Hoare says the challenge is multi-faceted with many variables and no definite answers. Forrest believes that the research outcomes were inconclusive due to the spatial variation within Marlborough and therefore hard to give a blanket outlook for the region.

Figure 6 shows that 9 respondents believed it was an important issue and they were now working on plans to adapt to any future climate change. However, an anonymous respondent was comfortable thinking that there is little risk around the quality and style delivery of Marlborough SB in this time frame. Only 2 respondents, both winemakers for large producers, noted they have already implemented plans required for adaptation. Both mentioned they are already seeing the effects of climate change on vineyards and weather patterns.

The responses suggest there is little immediate concern from this cross-section of the industry, and in particular growers, that climate change will affect them in the next 10 years. Figure 6 shows the level of importance that respondents attribute to this issue rises over time, however, the threat is that the changing conditions due to climate change may not be addressed until it is too late.

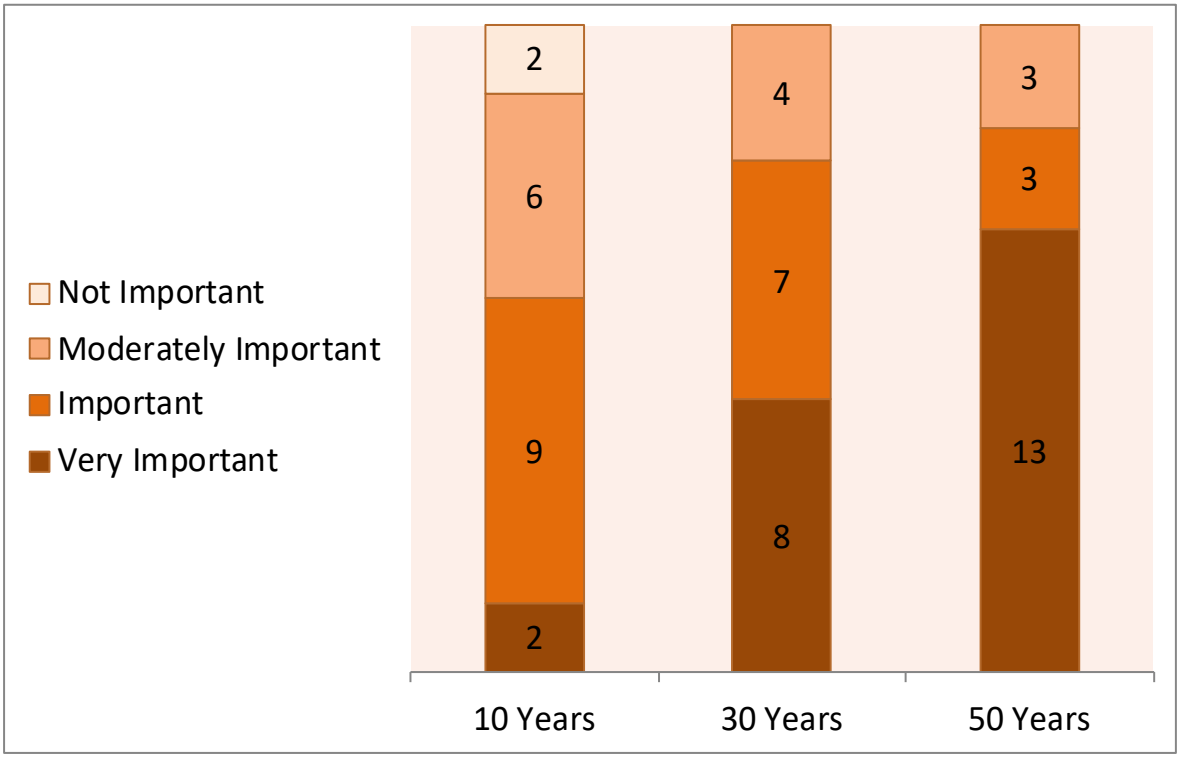

Figure 6- How important an issue do you believe climate change will be to the Marlborough Sauvignon Blanc industry in the next 10 years? In 10-30 years? In over 50 years? (n=19)

5.1.2. Increasing temperatures

The literature review has shown that temperature changes will impact the phenological development of the grapevine as well as wine style. Figures 7 and 8 illustrate the producers' levels of concern by 2040 and 2090 for temperature-related variables. Figure 7 shows the increase in temperature of 0.5°C-1°C by 2040 was somewhat or not very concerning for most respondents. This is likely because the quantum of change is not dramatic and any change is within the seasonal variation already experienced.

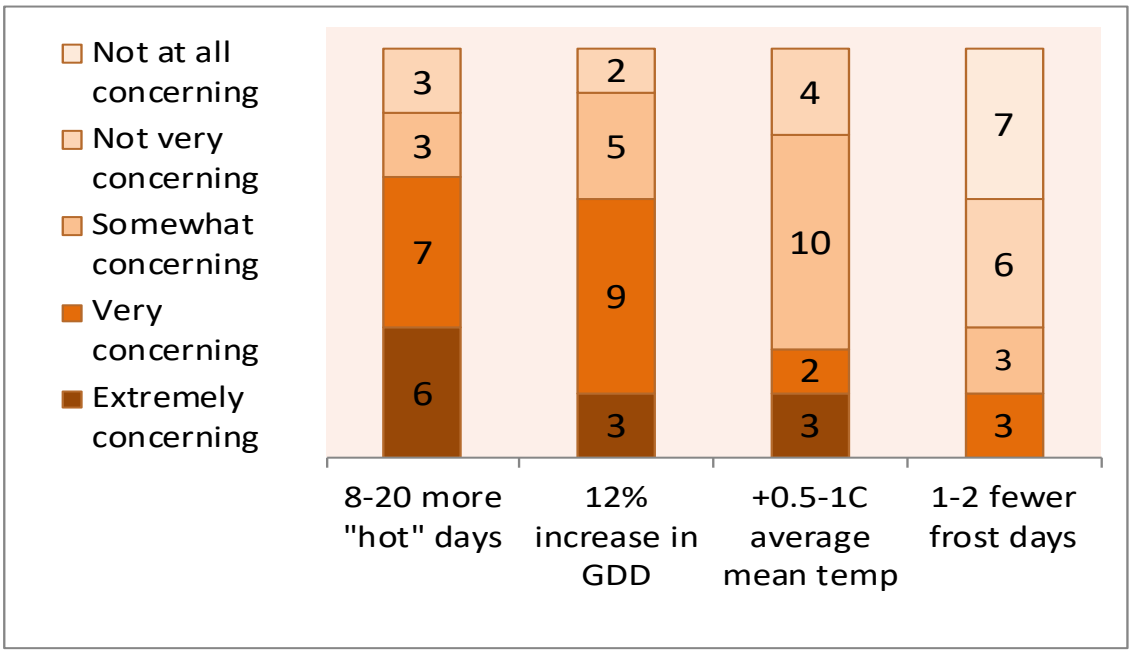

Figure 7: The NIWA forecast anticipates several climatic changes by the year 2040 for the Marlborough region. You may think some changes are more concerning and others are less concerning. Regarding your ability to grow and produce Sauvignon Blanc in 2040, how concerning are these projected changes? (n=19)

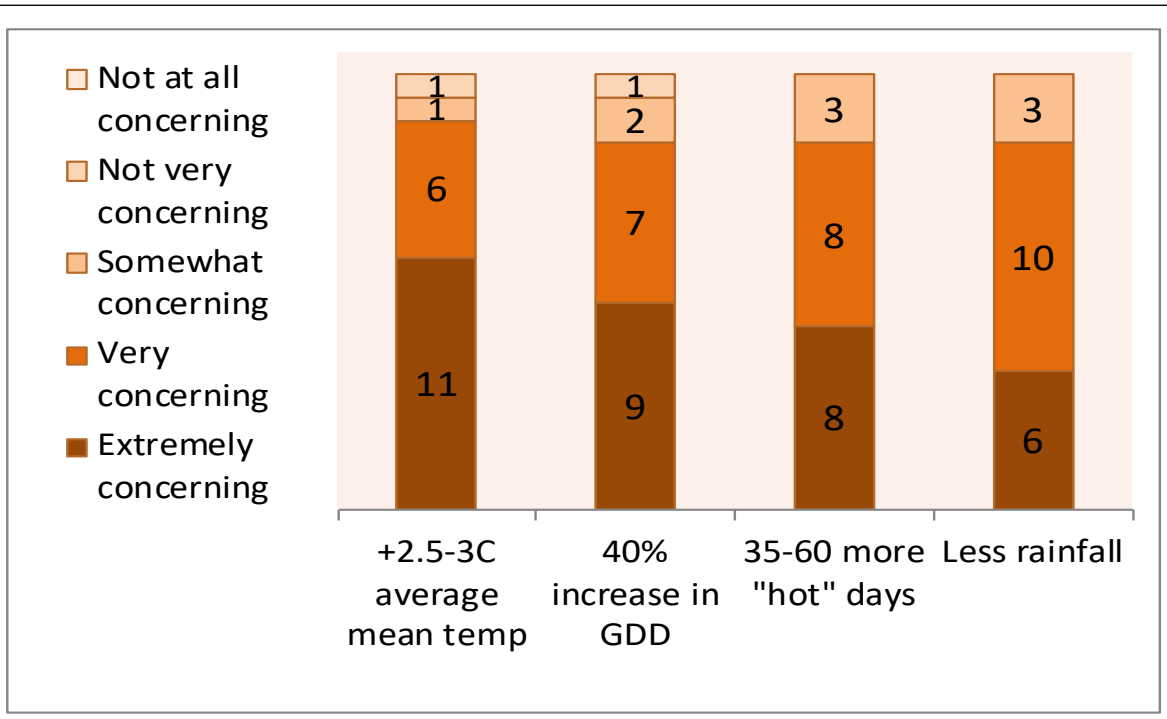

Figure 8: The forecast for 2090 includes more changes. Again, some changes will be more concerning to you than others. In your opinion, how concerning are these projected changes for 2090? (n=19)

However, Figure 8 highlights the forecast increase of 2.5°C-3°C by 2090 as very or extremely concerning indicating that respondents believe it will be harder to adapt to these temperatures. Weaver states that higher temperatures will decrease the levels of the methoxypyrazine compounds and Dunne predicts riper fruit with less acidity will alter the distinctive character of Marlborough SB while making the wines rounder with more alcohol.

Figures 7 and 8 also show the increase in hot days was very or extremely concerning for respondents by 2040 and even more so by 2090. The increase in temperatures will further advance SB's phenology. Sinnott says the temperature rise will affect vine phenology (growth stage development) and bring forward ripening into February-March. Anecdotal evidence from respondents stated that the increasing number of hot days during the growing season is speeding up grape ripening or sugar levels, but not the development of flavour. Sinnott comments that he is already seeing the effect of climate change on vineyards, their ripening patterns and flavour development.

Temperature links closely with Growing Degree Days calculations and a 40% increase by 2090 for the region is very or extremely concerning for most respondents. This would make Marlborough comparable in climate to renowned red wine regions such as Piedmont or the Northern Rhone. The ability to make "typical" Marlborough SB will be reduced under these conditions.

5.1.3. Water availability

The reduction of rainfall from November to January possibly leading to drought conditions was concerning for all respondents as seen in Figure 8. The lack of water

for irrigation is an obvious threat with Jordan saying the cost of water and providing irrigation would increase. The provision of enough water for irrigation during dry summer months will create a major limitation to the expansion of viticulture in Marlborough. Forrest comments that water availability will be the biggest hindrance to development and the ability to extend into newer areas.

All those interviewed voiced concern about the ongoing availability of water. The concerns raised centred around Marlborough becoming more susceptible to drought conditions and how this will affect river and aquifer flows and the ability to irrigate. This was especially the case for the smaller producers who currently access water from the river and aquifer and do not have the capacity for water storage solutions. Maling mentioned that SB is a variety that really needs water and does not yield well under dry conditions. Although access to water during the growing season is an identified threat, none of the respondents had an immediate solution. Flowerday said that the water in the area is already oversubscribed, and this will create issues when new water consents are applied for in the future. There is a recognised need to work with local government to find ways to mitigate the threat of a reduction in water availability.

5.1.4. Changing the flavour and wine style of Marlborough Sauvignon Blanc

Marlborough SB is a wine style that has been widely accepted by consumers. All respondents believe that climate change in the region will change the current flavour profiles and wine style of Marlborough SB. Known for its intense, herbaceous flavours and fresh acidity, any change may affect market acceptance. The only

respondent[4] who disagreed had the opinion that flavour profiles have been evolving and changing over the past 20 years and this evolution would continue regardless of climate impacts. In their view, style is changing due to the maturation of the industry, the age of the vineyards and technological developments. The main changes are thought to be that the wines will contain less of the herbaceous methoxypyrazine flavour compounds and will have a softer, more rounded acid structure due to rising temperatures. Jones mentioned there is potential for a riper, more tropical style with less herbaceous characters and the wines may hold less natural acidity. Shouler said there would be less of the green characters such as capsicum and tomato stalk and to expect less punchy characters and more weighty wines with lighter acidity. Smith believes that the biggest issue will be the clarity of flavour and aroma that will be affected due to the forecasted increases in hot days and drought stress.

5.1.5. Increasing costs of production

Twelve of the respondents believe the costs of growing SB would increase due to climate change. Rose states this would be due to the possible reduction in yields. Sinnott mentioned more extensive canopy manipulation would increase costs. Only 6 producers think the cost of making the wine in the winery would increase. The reasons given were predominantly linked to investment in infrastructure to harvesting the fruit more quickly. Smith believes there would be a 10-15% increase in bulk wine costs. Any increase in production costs is likely to flow through to the finished product where the consumer will be expected, yet be possibly reluctant, to pay more. Five respondents believe that climate change will have no impact on the costs of production for either growing or winemaking.

[4] The person surveyed requested that their name was not used in this research paper

5.1.6. Frost

The climate forecasts for the region suggesting a reduction in the likelihood of spring frost events was viewed positively by the industry as seen in Figure 8. Forrest saw this as a positive outcome as it would mean more stable cropping outlooks. Some of the producers believed that this variable is not correct, and the spatial variation found within the region will result in more frosts. Jordan and Sinnott both mentioned that other reports suggest more frost events are likely. This is supported by the studies on frost incidence from Sturman and Quénol (2013). Several respondents indicated that they are putting new frost fans into their vineyards. As the temperature warms it accelerates the early stages of the growing season, such as bud break, into the same time as frost season, making frost more of an issue. Further research is required to understand the impact frost may have on the region as this contradiction between the research and the forecasts will weaken the trust, or credibility, producers will put into the future climate forecasts.

5.1.7. Industry overreliance on Sauvignon Blanc

According to Wine Marlborough, over 80% of Marlborough vineyards are planted to SB. Marlborough has invested millions of dollars into winery and vineyard projects and built a global market around producing crisp, refreshing, aromatic SB. If this style of wine is not possible due to climate change, it would be a major threat to the region as the infrastructure, yields and market acceptance may be different for alternative varieties. There was a very mixed reaction amongst respondents when asked if there is a need to explore growing alternative varieties. Ten replied that it was not necessary with Rose commenting that the industry should continue to look

to improve what it currently produces. Maling believes that growers will not change given SB's demand, return and ease of growing. Most of the respondents who think there is a need to explore alternative varieties also mentioned the importance of SB. Sinnott, Shouler and Smith all believe that while it is still the industry driver, it is important that other options are in the market ready for production if climate change or market demand dictates.

5.2. Opportunities for adaptation

5.2.1. Minimising possible change of flavour and wine style of Marlborough Sauvignon Blanc

A shift in wine style due to climate change was not viewed as a concern by the majority of the respondents. Eleven respondents were neutral about whether the change in flavour profile would be accepted by the world's consumers and 3 thought consumers would be more positive about the wine style. Only 4 producers believed that a move away from flavours that have made Marlborough SB's reputation would reduce consumer demand. Forrest thought the change in flavour profile would be gradual, not dramatic, and SB drinkers will move with the offering rather than away.

There are, however, opportunities for maintaining some typicity of wine style. Studies by Parr et al. (2013), have shown it is possible to mitigate against any reduction in methoxypyrazines by changing the direction of the rows on a new vineyard from north/south to east/west, or by planting in cooler areas where these flavours are more prominent. In Marlborough, Awatere Valley wines made from grapes grown in rows orientated east/west have shown significantly higher concentrations of methoxypyrazine (Parr et al., 2013).

Multiple harvests of fruit at various ripeness levels can also assist in maintaining the current flavour profile. Maling suggests a winery can choose different times to pick blocks creating a good mixture of flavours to work with in the winery.

5.2.2. Irrigation

During the interviews, concern was shown over the issue of water availability. Smith stated that to survive, the vineyards require irrigation and investment is required in identifying and building a regional solution to securing fit for purpose, sustainable water resources for Marlborough. Rose mentioned that it was important to measure water use more accurately so that growers and producers can be educated about how much water is required. Subsurface drip irrigation (SDI) has been found to increase water use efficiency. Forrest has already moved to subsurface irrigation to deliver water more effectively and in doing so, has reduced the amount of water previously used by half. This suggests the implementation of subsurface irrigation when vineyards are replanted could be an effective way of reducing water usage in the future.

5.2.3. Canopy management

The need to change certain viticultural practices involving canopy was mentioned by most of the respondents as an obvious way to mitigate warmer temperatures and to maintain wine style. Jones commented that he would do less leaf removal to help retain acidity and may prune later to delay bud burst. This view was supported by Clouston, who thought there would be more canopy and less trimming in the future to provide more fruit shading and to retain acidity as light exposure and vine vigour both affect levels of methoxypyrazine character. Forrest talked about manipulating the leaf to fruit ratio to produce lower alcohol wines. Trimming the top third of the canopy after fruit set slows down sugar accumulation. Christensen has also undertaken trials with this technique to manipulate the canopy to slow the accumulation of sugar in the berry, thereby delaying harvest.

5.2.4. Rootstocks

The importance of the rootstocks was linked to water availability. Maling and Sinnott both suggested the need to use drought-tolerant rootstock. Smith mentions that rootstock choice could allow grapes to ripen two weeks later and require half the amount of water. Deep, explorative rootstocks such as 110 Richter will maximise the use of the soil water reserves (Trought, 2008). Flowerday and Jordan discussed the need to replant many of the older vines in the region that are suffering from trunk diseases such as Eutypa dieback and this would be an opportune moment to ensure the use of appropriate rootstocks.

5.2.5. Clonal improvement

The expected replanting of vineyards within the next twenty years will allow for the introduction of improved clonal material designed for the conditions. The narrow genetic base and overreliance on the MS clone of SB are seen as a major risk by NZWG when considering climate change in the region. The Bragato Research Institute (BRI) is now looking at ways to protect SB in the face of this issue. One respondent[5] said the introduction of new clones of SB through select breeding may help in climate change resilience. Introducing new clones from overseas is expensive and time-consuming with no guarantees they will be successful in Marlborough. Sinnott would like to see the creation of new clones of SB that would improve yield, be more tolerant of fungal attack, frost, high temperatures and drought while maintaining the grape's current flavour profile. New technology will accelerate natural diversity by using the plant's ability to alter its genetics in response to stress

[5] The person surveyed requested that their name was not used in this Research paper.

meaning that new clones could be available to producers within seven years of the start of the project.

5.2.6. Yeasts

The use of cultured yeasts to enhance varietal character, or to manipulate volatile compounds to make more “fruity” wines, is a technique used by winemakers such as Forrest. Careful yeast selection makes it possible to maintain aspects of the distinctive character of Marlborough SB, even in a warmer climate. Forrest believes that yeast science and research has the potential to develop products that could accentuate certain flavour compounds that would help to ensure consistency of style throughout the region.

5.3. Industry Weaknesses

5.3.1. Water storage

Smith predicts that the shortage of water will become extreme in some seasons. In his view, there are almost no long-term storage options available for the wine industry. The ability to find water in times of drought is crucial for the viability of SB. Dunne believes there is a greater requirement for alternative water sources that are not currently present. Jones said that there is currently no long-term community storage of water. Storage would enable producers to “bank” winter water for future use at times when access to water may be limited. Rose agreed that there is more need for backup water supplies such as dams or water tanks on vineyards.

5.3.2. Increasing costs impact on the bottle price

Thirteen respondents believed that climate change would increase the cost of producing SB. However, there is little perceived correlation mentioned between this extra cost and the impact it will have on the final price of the bottle. Flowerday mentioned they would need to focus on more, premium options to maintain margins with increasing costs. Smith states that he does not think many people would have thought about the impact climate change may have on the finished bottle price.

5.3.3. Harvest infrastructure

Warmer temperatures will bring forward the physiological ripening and therefore compress the harvest into a shorter time frame according to Flowerday. Wineries need to be equipped to deal with this and any extreme weather events without affecting quality. Machine harvesting gives the ability to harvest quickly if any extreme weather events appear within a 10-day forecast. Powrie mentioned the

region will need to invest in additional harvesting capability and winery receival infrastructure to bring fruit in quickly. Jordan agreed that picking and trucking capacity is crucial to protect quality. This was supported by a large producer[6] who said they currently need five and a half weeks to harvest their SB and the appearance of extreme weather events or compression of the harvest would place strain on existing infrastructure. Christensen mentioned that as weather patterns have become more extreme, they have changed some processing equipment to ensure fruit can be received and processed as quickly as possible.

5.3.4. Single varietal dominance

Although 6 respondents thought that alternative varieties should be explored none of those surveyed thought other varieties could take SB's place. Hoare commented that Marlborough SB is a style that new wine drinkers can easily recognise and enjoy. Other varieties cannot compete on a global scale. Sinnott stated that SB is the driver of the wine economy in New Zealand, and it needs to be protected. Growers such as Jones felt very strongly that SB is what Marlborough is known for and it makes no commercial sense to plant any other varieties. For him, this variety is easy to grow, gives consistent yields and is a more profitable option than growing other varieties. None of the respondents, therefore, believed that climate change impacts are significant enough to challenge the suitability of SB to the region.

[6] The person surveyed requested that their name was not used in this Research paper.

5.4. Industry Strengths

5.4.1. Attitudes to climate change

Nearly all of the respondents were aware of the NIWA climate change forecast report for the region and believed themselves to be either moderately informed or generally well-informed about climatic forecasts for Marlborough. Many of the producers had attended conferences where NZWG had highlighted the results of this work with presentations by recognised scientists including Andrew Lorrey and Petra Pearce of NIWA, Greg Jones, Mike Trought, Hervé Quénol and Amber Parker. Those involved in growing and viticulture consider themselves to be more informed regarding climate change forecasts than those working as winemakers.

Respondents have exhibited very little concern about a changing climate in the next 10 years. However, Figure 9 illustrates that in an extended time frame of 10-30 years concern increases with 15 respondents thinking it will be an important or very important issue for Marlborough SB. At this time, they believe they will be implementing adaptation plans and working to counter the impacts of climate change. It is worth noting that in this time frame there are no producers thinking that it is not an important issue that requires consideration.

Figure 9 also highlights that most respondents think climate change will be an important or very important issue in 50 years, and they will have implemented strategies to mitigate any effects. This long-term thinking is positive for an industry

that will need time to make significant changes. Maling mentions that long-term planning to minimise risk is key. However, in 50 years it can be assumed that the majority of those questioned will no longer be working in the industry so committing to addressing these issues while they are still able would seem sensible.

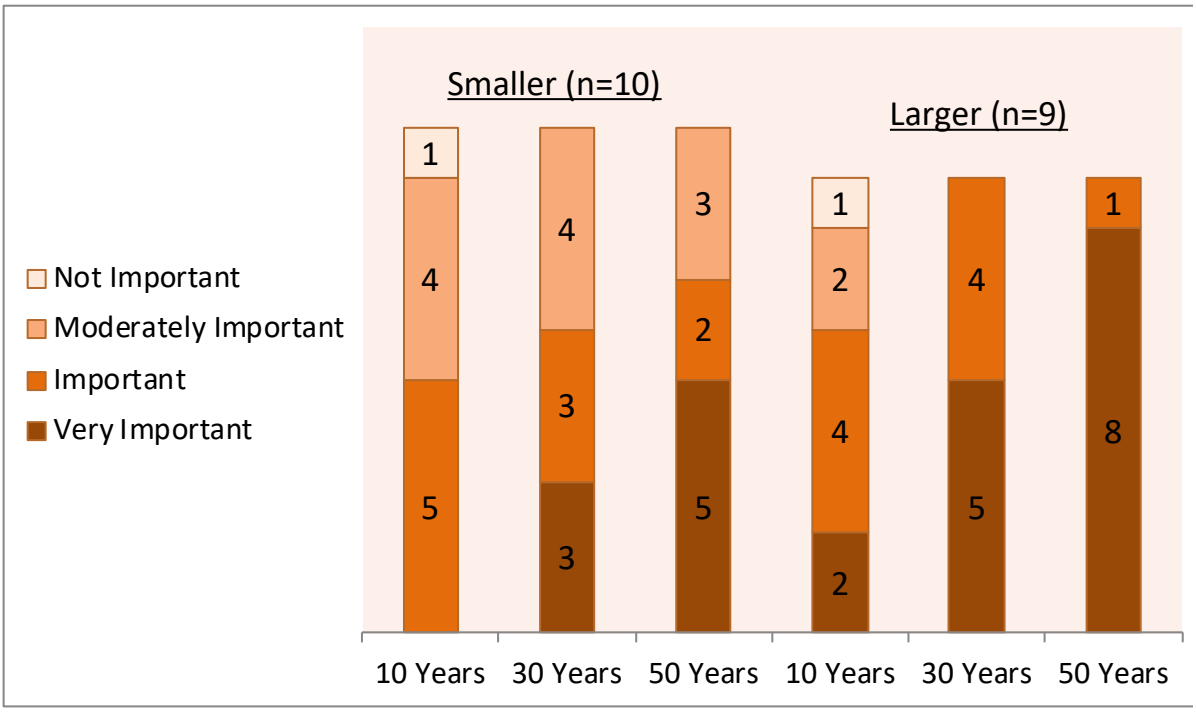

Figure 9: How important an issue do you believe climate change will be to the Marlborough Sauvignon Blanc industry in the next 10years? In 10-30 years? In 50 Years? For smaller producers and larger producers (n=19)

It is apparent from Figure 9 that larger growers and producers place more importance on the issue of climate change across all time frames. These larger producers account for half of the respondents but 95% of the production. It is likely they have a longer-term strategy due to the scale of their investment in the industry. The adaptation strategies they implement are likely to be eventually adopted by the smaller producers.

5.4.2. Willingness and ability for adaptation

All of the producers said the growing of SB would have to change as a result of climate change. The change in the vine's phenology as a result of a forecast increase in mean daily temperatures during the growing season would be the major driver for change. One respondent[7] mentioned the possibility of changing to east/west row orientation for new or redeveloped vineyards away from the currently planted north/south orientation. This is only a viable option for older vineyards that are being replanted or for new plantings in newer areas that are currently viewed as too cold but will become viable if temperatures rise. Forrest views the development of these new areas as a possible positive from climate change.

Thirteen of the 15 respondents who make wine believed they would change their production techniques. Six of them identified the change was related to ensuring acidity levels stayed appropriate for the wine style. Clouston thinks they will harvest earlier and possibly add acid when required.

The region's ability to adapt to climate change, unencumbered by legislative restrictions around planting areas, variety or winemaking is a real strength of the area.

5.4.3. Blending of vineyards and subregional diversity

Most of the respondents interviewed make wines that are blends between multiple vineyard sites. The reason they blend is the cooler sites in the Awatere Valley show

[7] The person surveyed requested that their name was not used in this Research paper.

more of the herbaceous characters with fresher acidity than fruit from the warmer stony soils in the Wairau Valley which show more body and more tropical fruit flavours. The use of blending between sites, and the addition of newer sites, will ensure that the region's wines can maintain a consistency of style. Flowerday suggested if temperatures increased, she would be looking at what subregions they source fruit from and change to those areas that provide her with the desired flavour profile. Rose believed the range of different subregions within Marlborough would allow for growers and winemakers to adapt and blend, thereby maintaining the wine style's uniqueness. It is widely accepted there is much spatial variability in temperature within the region and blending of warmer and coolers areas together would be a way to maintain wine typicity.

6.0. TOWS summary

	Strengths (S) 1. Producer attitudes to climate change 2. Willingness and ability to adapt 3. The blending of vineyards in the region	**Weaknesses (W)** 1. Water storage 2. Increasing costs impact on the finished product 3. Harvest infrastructure 4. Single varietal dominance
Threats (T) 1. Short-term thinking 2. Increasing temperatures 3. Water availability 4. Changing flavour and wine style 5. Increasing costs of production 6. Frost 7. Industry over reliance on Sauvignon Blanc	**S/T Strategies** (S1,T1) Invest in climate research to give a more detailed, accurate view of the region's complex terrain. (S2,T2) Explore vineyard adaption techniques for warmer temperatures. (S3,T4) Ensure style typicity by blending wines from warmer and cooler sites. (S2,T7) Invest in alternative varieties that suit new climate, soils and current infrastructure requirements.	**W/T Strategies** (W1,T3) Invest in community water storage solutions. (W3,T2) Invest in equipment needed for a condensed vintage. (W2,T5) Be more aware of climate changes impact on costs (W4,T4) Research focus on consumer taste requirements and monitor sales to ensure demand remains strong.
Opportunities (O) 1. Minimising change in flavour and wine style 2. Irrigation 3. Canopy management 4. Rootstocks 5. Clonal improvements 6. Yeasts	**S/O Strategies** (S3,O1) Use subregional flavour differences to maintain wine style. (S2,O3) Continue to develop new canopy management techniques (S2,O4) Explore the use of new rootstocks more suitable for future climate forecasts. (S1,O5) Industry investment in clonal improvement studies to create new clonal material suited to the region.	**W/O Strategies** (W1,O2) Use more efficient irrigation techniques that reduce the use of water. (W2,O5) Create better clonal material that maximises yield and quality. (W4,O1) Continue to make premium quality wines from Sauvignon Blanc.

Table 2: Threats, Opportunities, Weaknesses and Strengths (TOWS) matrix: Factors affecting the Marlborough Sauvignon Blanc industry, with possible adaptation and mitigation strategies, as a result of forecasted climate change.

7.0 Conclusion

The NIWA report on the forecasted climate conditions to 2100 for the Marlborough region shows significant changes that will have an impact on SB production. It is worth noting this report shows a very macro-scale picture of the whole region's climate, and further research is needed to give a more detailed picture of the atmospheric conditions that influence climate. The region's complex terrain provides significant variation in conditions. This must be better understood before further assessment of the possible impact of any climatic change on viticulture and winemaking in the region can happen.

1. ***What are the attitudes of Marlborough winemakers and winegrowers to any future climate change?***

The group of growers and winemakers who participated in the survey showed high awareness of the forecasted changes in the region's climate, but there was little immediate concern. In the short term, the majority believed that any change can be dealt with as seasonal variation. As Trought mentioned, the timeframe for significant climate change is very short for the world's climate but very long for someone working in a vineyard. Respondents believed climate change will have a more significant long-term impact and are looking for strategic adaption strategies to suit that timeframe. The larger producers are leading the industry in the creation and adoption of these strategies. More detailed climate research from the region will give smaller producers the confidence to follow those larger producers.

2. ***How might Marlborough winegrowers adapt to the anticipated climate change to mitigate its impact on their industry?***

One apparent strength was the willingness and ability of the producers to adapt to new conditions. A warming climate may make available new areas for planting with SB that were previously considered too cold. Additionally, most mature SB vineyards in Marlborough will be replanted within the next 20 years due to trunk disease. Unencumbered by any legislative barriers, this will be an opportunity to implement some long term-strategies such as changing row orientation to east/west on warmer sites, adding sub-surface irrigation and utilising drought-tolerant rootstock. New clonal plant material will also become available. Alternative varieties could also be introduced, however this is unlikely. While there would be some benefit in diversifying the region's offering, it appears that demand and economic viability of SB in Marlborough mean that the industry will remain heavily reliant on this one variety.

A forecasted, drier growing season is a great concern for a crop that requires irrigation to maintain yields and quality. Currently, the region's water is oversubscribed, and it is becoming more difficult in very dry years to access water supply from the Wairau and Awatere Rivers. The most obvious answer to this is to create storage solutions that provide irrigation water when the rivers run low. Ideally, this would be a regional solution, implemented in conjunction with local governments to provide sustainable water resources. In addition, growers could look to reduce their use of water by using the latest technology that measures the vine's water requirements as well as installing sub-surface drip irrigation to increase the efficiency of water use. As these strategies will take time to implement, they require attention in the present rather than the future.

3. ***What effect might future climate change have on the viticulture of Sauvignon Blanc in the region?***

Forecast increases in the maximum air temperatures will significantly impact the phenology of the grapevines in the region. A warmer climate will result in an earlier start to the growing season with early flowering and véraison. Positively, this will move harvest into March, away from a forecasted wetter April. Warmer temperatures at flowering will also improve fruit set and bunch initiation, leading to a possible increase in yields. Negatively, it will condense the season placing strain on existing infrastructure at harvest. This must be addressed to maintain quality. An earlier budburst increases frost risk although more research is required on whether frost incidences will decrease as per the forecast or increase as other research suggests. Pruning later may delay budburst away from the frost season but it will further condense the season. The advancing phenology of the vine will result in higher sugar levels, a reduction of acidity and a lack of flavour in the grapes at harvest. Seasonal strategies involving canopy manipulation need to be used to adapt. Techniques such as leaving more foliage to provide shade for the fruit or early trimming to remove young, vigorous leaves at the top of the vine can be used to slow sugar accumulation and maintain acidity. Research from other warm-climate wine growing regions will provide the Marlborough region with further adaptation strategies in the vineyard.

4. ***What effect might climate change have on flavour profiles of Marlborough Sauvignon Blanc?***

Marlborough producers already believe the flavour profile of Marlborough SB is different now compared to the 1990s. Over the past 10 years, export sales data from

the NZWG Annual Report (2020) show an increase of over 118 million litres of SB and this suggests there is now consumer confidence in the Marlborough name to produce quality wine. It is unlikely that a continual, slow and subtle change to wine style will affect global demand. However, as the climate warms, the level of methoxypyrazines found in the wines will decrease and the flavours will become more tropical and less herbaceous. That said, there is the potential that the refreshing and aromatic attributes that have made the wine style so popular with consumers can be retained by blending between warmer and cooler subregions. Timing of harvest and site selection will become increasingly important under future climatic conditions to maintain typicity. Ongoing research is required to monitor consumer preferences to ensure that any change to the style of Marlborough SB remains relevant and continues to generate global demand.

Focus on climate change in Marlborough is currently being led by NZWG through BRI. Both parties will provide a vital role in researching the issues and informing the industry of any developments. But research alone will not solve the problems that climate change has the potential to cause. Individual producers must, where possible, start to make and execute plans to ensure their businesses remain economically and environmentally sustainable in the face of climate change. Appropriate mitigation and adaptation strategies need to be identified and implemented before it is too late.

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9.0. Appendices

9.1. List of participating producers and scientists

Interviewee	Company	Position	Production size in hectares and/or cases	NZWG Company description
Melissa Tripe	JTC Viticulture	Viticulturist	>200hectares	Large Grower
Tim Rose	Rose Ag	Director	50-200hectares	Medium Grower
William Hoare	Novum	Owner	20-50hectares	Small Grower
James Jones	Starborough	Owner	>200hectares <25,000cs	Large Grower/ Small Winery
Sam Weaver	Churton	Owner	<20hectares <25,000cs	Small Grower/ Small Winery
Anna Flowerday	Te Whare Ra	Owner	<20 hectares <25,000cs	Small Winery
Steve Smith MW	Smith & Sheth	Director	<20hectares <25,000cs	Small Winery
Clive Jones	Nautilus	Winemaker	50-200 hectares 75-250,000c	Medium Winery
David Clouston	Two Rivers	Owner/ Winemaker	20-50hectares 25-75,000cs	Medium Winery
Beth Forrest	Forrest	GM/ Winemaker	50-200hectares 25-75,000cs	Medium Winery
Anna Dunne	Dog Point	Viticulturist	50-200hectares 25-75,000cs	Medium Winery
Alastair Maling MW	Foley Wines	Winemaker	50-200 hectares >250,000cs	Large Winery
Natalie Christensen	Yealands	Chief Winemaker	>200hectares >250,000cs	Large Winery
Tony Robb	Pernod Ricard	Operations Winemaker	>200hectares >250,000cs	Large Winery
Duncan Shouler	Giesen	Winemaker	>200hectares >250,000cs	Large Winery
Patrick Materman	Indevin	Winemaker	>200hectares >250,000cs	Large Winery
Jeff Sinnott	Constellation	Viticulturist	>200hectares >250,000cs	Large Winery
Oliver Powrie	Villa Maria	Viticulturist	>200hectares >250,000cs	Large Winery
David Jordan	Vine to Wine to Market Ltd	Owner	n/a	Consultant viticulturist
Philip Gregan	NZWG	Chief Executive		
MJ Loza	Bragato Research Insitute	Chief Executive		
Mike Trought	Plant and Food Research (retired)	Scientist		
Andrew Lorrey	NIWA	Report author		
Hervé Quénol	University of Canterbury	Climate Scientist		

9.2. Research Paper Proposal

IMW Research Paper Proposal Submission Form			
Student ID	**22900**	**Date of submission**	**20 Aug 2020**
RPP Version No	**7**	**Name of Advisor**	**Sheri Morano**

Note: RPPs must be submitted via your Advisor to the IMW

Proposed Title

The impact of future climate changes on the production of Sauvignon Blanc wines in Marlborough, New Zealand

Research Questions: Define the subject of your Research Paper and specify the specific research questions you plan to pursue. (No more than 200 words)

Marlborough accounts for 69% of New Zealand's wine hectarage and the production of Sauvignon Blanc accounts for 90% of all Marlborough plantings, as per the 2019 New Zealand Winegrowers Annual report. At a time when Marlborough Sauvignon Blanc is enjoying worldwide acclaim for a fresh, vibrant wine style, any changes to the growing conditions that may affect this should be of great interest to all involved. The New Zealand Winegrowers Bragato Research Centre (BRI) has commissioned the National Institute of Water and Atmospheric Research (NIWA) to provide a regional climate model to better understand the forecasted changes in climate to the region. The climatic forecasts from these studies will be outlined in this paper and will provide context for the research. These studies have highlighted changes in rainfall patterns and increased temperatures at crucial periods in the growing season. They have also shown a possible alteration in the frequency of extreme weather conditions.

This research paper seeks to answer the following questions in relation to the production of Sauvignon Blanc wines in Marlborough, New Zealand:

- What are the attitudes of winemakers and winegrowers to any future climate changes?
- What effect might climate changes have on the viticulture of Sauvignon Blanc in the region?
- What effect might the change in climate have on flavour profiles?
- How might winegrowers adapt to the anticipated climate change to mitigate the impact on their industry?

Background and Context: Explain what is currently known about the topic and address why this topic requires/offers opportunities for further research. (No more than 200 words)

Wine is a sensitive agricultural product that is expected to reflect and express where and how it is grown and climate change could transform many of the practices informed in its production.

The first Sauvignon Blanc grapes were planted in Marlborough in the 1970s. Since then the Marlborough industry has grown to 26,850 hectares hectares producing 305,467 tonnes in the 2019 vintage. The Marlborough Sauvignon Blanc wine style very quickly gained international recognition and is the main driver in New Zealand's industry, accounting for 85% of the industry's NZ$1.825 billion in exports (New Zealand Winegrowers Annual Report 2019) A wine style that is defined by its purity of flavor, energy and freshness is derived by the unique growing conditions such as high sunshine hours, large diurnal shifts, long but relatively cool growing temperatures with

minimum rainfall during vintage and free draining soils . Changes to these climatic conditions might threaten the ability of winemakers to continue to make a style that has become so widely sought after.

Sources: Identify the nature of your source materials (official documents, books, articles, other studies, etc.) and give principle sources if appropriate. (No more than 150 words)

Books and research studies on climate change and viticulture will be used as references to gain a full understanding of climate change impacts. These will include:

- Wine and Climate Change: Winemaking in a New World, (Johnson-Bell, 2014)
- Wine Terroir and Climate Change, (Gladstones, 2011)

Reports used will include but not limited to:

- Can a change in Vineyard Practice mitigate warming due to climate change? (Trought et al, 2015)
- Climate and Wine: Global trends and Influences Impacting Sustainable Wine Production (Jones, 2019)

New Zealand Winegrowers' online portal can provide data from the BRI and NIWA outlining the forecasted projections for the Marlborough region.
Reports include:

- Climate Change and the Marlborough Wine Region (Pearce, 2019)
- Climate Change Projections for New Zealand Wine Regions – Marlborough (NIWA, 2018)

Research undertaken at the BRI on the fundamental characteristics of Sauvignon Blanc clones, canopy management techniques, pest and disease susceptibility to indicate what impacts climate change may have. Other sources include:

- How Climate Change Could Influence Vine and Wine (Parker and Jones, 2019)

This literature review will be supplemented by qualitative research and interviews with the science community, leading viticulturists and winemakers in the region, and leaders within the industry (details in methodology below). The final sources selected will likely change as insights are gained through the literature research. These sources will also be used to understand what may have already happened and test the identified risk profile and potential suite of actions and solutions that come from this project.

Research Methodology: Please detail how you will identify and gather the material or information necessary to answer the research question(s) and discuss what techniques you will use to analyse this information. (No more than 500 words)

This research topic will require a two-stage approach.

Stage 1: Literature review.
This will provide the baseline information required to design a series of qualitative research initiatives and interviews to understand what implications climate change may have on viticulture, oenology and the business of growing, making and marketing Marlborough Sauvignon Blanc.

Scientists from the BRI, NIWA, Plant and Research, Lincoln University and the University of Auckland will be interviewed. The leaders of these divisions have agreed for their teams to participate and have agreed to connect the author to global science if relevant.

Stage 2: Survey and interview of select group, representative of the Marlborough industry as outlined below.
This process will be dependent on the insights from Stage 1 and therefore exact survey/ interview design cannot be declared at this stage. The questions asked however will be designed in a manner to specifically answer the questions outlined in the introduction. Dr Caroline Saunders at Lincoln University's Agribusiness and Economics Research Unit will provide assistance on survey and interview design.

The survey will be sent out using Survey Monkey protocols and followed by interviews specifically designed around the survey responses.

The following industry individuals have been approached to be surveyed and then interviewed. They have been selected as they present a wide representation of the region. Within this group there are some of the largest producers from multi-national companies as well as smaller private independent growers and winemakers. There is a selection of individuals who will be more focused on aspects to do with viticulture as well as winemakers who will be able to discuss the impact on wine style. Together this group of individuals represents some of the most internationally recognized wine brands to come from the region. In the course of the research it may become necessary to add to this list of survey recipients and interviewees.

Leading Marlborough viticulturists and vineyard managers.

- Ollie Powrie, Villa Maria Winery (large private producer)
- David Jordan, Vine to Wine (regional vineyard consultant)
- James Jones, Starborough (large Awatere Valley grower)
- Jeff Sinnott, Constellation (large publicly listed producer)
- William Hoare, Novum (small private grower)
- Anna Dunne, (medium sized organic producer)
- Melissa Tripe, (large Wairau Valley grower)
- Sam Weaver, Churton Vineyards (small private biodynamic producer)
- Tim Rose, Rose Ag (medium sized private grower)
- Steve Smith MW, Aotearoa NZ Fine Wine Estates (small private producer)

Leading Marlborough Winemakers

- Tony Robb, Pernod Riccard (Operations Director for large international company)
- Patrick Materman, Indevin (Global Director of wine for large private producer)
- Beth Forrest, Forrest Wines (medium sized private producer)
- Clive Jones, Nautilus (medium sized private producer) – Chairman of NZWG
- Alastair Maling MW, Foley Group (medium sized publicly listed company)
- Natalie Christensen, Yealands (large private producer)
- David Clouston, Two Rivers (medium private producer)
- Jason and Anna Flowerday (small private biodynamic producer)
- Duncan Shouler, Giesen (large private producer)

Wine sector leaders

- MJ Loza, CEO Bragato Research Institute
- Philip Gregan, CEO New Zealand Winegrowers
- Mike Trought – Scientist, Plant and Food Research
- Herve Quenol – Climate Scientist, University of Canterbury
- Andrew Lorrey – Scientist, NIWA

The results and analysis will then be presented in a TOWS analysis framework. This is similar to a SWOT analysis however greater emphasis will be placed on the external Threats and Opportunities that the Marlborough Sauvignon Blanc industry will experience due to forecast climate change. The TOWS analysis will generate strategy for mitigation and adaptation that can then be used by the industry when facing dramatic climate change conditions.

Potential to Contribute to the Body of Knowledge on Wine: Explain how this Research Paper will add to the current body of knowledge on this subject. (No more than 150 words)

The prospective effect of climate change on the Marlborough industry and in particular Sauvignon Blanc requires a focused path of research to identify the potential for disruption for the whole New Zealand industry. The forecasted projections for climate change is something that the BRI is currently researching however their studies do not focus exclusively on Marlborough and Sauvignon Blanc as they concentrate on the greater impact of climate change on viticulture within New Zealand.

The potential techniques that can be used to mitigate the effects of climate change will be hugely important for the continuing existence of this wine style. By collecting the observations and thoughts of leading individuals within the area with possible solutions can be communicated throughout the whole region as part of a wider plan to adapt to the effects of climate change.

Proposed Time Schedule/Programme: This section should layout the time schedule for the research, analysis and write-up of the Research Paper and should indicate approximate dates with key deliverables. *Dates of submission to both Advisors and the IMW must be those specified by the IMW.*

August 2020 – Submit Research Paper proposal to Advisor
August - October 2020 – Continue to do a document search for suitable climatic data and make changes to RP as directed by the Advisor
September 2020 - Submit Research Paper proposal to RP Co-ordinators
October 2020 –Document scientific research on effects of climate on viticulture to support or negate industry views.
November 20 -January 2021 - Interview Marlborough growers and winemakers.
1 May 2021– submit draft to Advisor
1 June 2021 – submit final draft to Advisor
12 July 2021 – submit to IMW

9.3. Survey/ Questionnaire

Q1. Do you grow/ make Sauvignon Blanc from Marlborough?

Q2. Name?

Q3. What is the name of your company?

Q4. What is your position within the company?

Q5. Are you happy for your name to be used in this Research paper?

Q6. How many years have you been working with Marlborough Sauvignon Blanc?

- Less than 10 years
- 10-15 years
- 15-20 years
- Over 20 years

Q7. How many hectares of Sauvignon Blanc do you own or lease?

- Less than 20 hectares
- 20-50 hectares
- 50-200 hectares
- Abover 200 hectares
- n/a – I do not own or control/ lease my own vineyards

Q8. How many total cases (in 9LE) of Marlborough Sauvignon Blanc do you produce?

- n/a – I do not produce wine under any label
- less than 25,000 cases
- 25,000 – 75,000 cases
- 75,000-250,000 cases
- Above 250,000 cases

Q9. Do you believe you are well informed about climatic forecasting within the Marlborough region?

- Yes
- No
- Neutral

Q10. Where do you find your information regarding possible future climate forecasts and how reliable do you believe that information to be?

Q11. NZWG commissioned NIWA to provide some climate forecasts for the Marlborough region. Have you read this information and do you believe there will be a change to the region's climate in the future?

- Yes
- No
- Not aware of the research

Q12. How important an issue do you believe climate change will be to the Marlborough Sauvignon Blanc industry in the next 10 years?

- Not important at all – it will not affect the production of Marlborough Sauvignon Blanc
- Moderately important – something to consider but not at a stage where anything needs to be done about it.
- Important – I have the information and I am currently working on plans to mitigate and adapt
- Very important – I am very conscious of this issue and I have already implemented solutions and plans to adapt and mitigate.

Q13. How important an issue do you believe climate change will be to the Marlborough Sauvignon Blanc industry in the next 10-30 years?

- Not important at all – it's not going to be an issue
- Moderately important – it will be something to consider and plan for
- Important – we should have plans in place by now
- Very important – we should be doing all we can to mitigate against climate change

Q14. How important an issue do you believe climate change will be to the Marlborough Sauvignon Blanc industry in over 50 years?

- Not important at all – it's not going to be an issue
- Moderately important – it will be something to consider and plan for
- Important – we should have plans in place by now
- Very important – we should be doing all we can to mitigate against climate change

Q15. Rank between 1-5, with 1 being the most important, how important each of the following aspects of NIWA's forecasted climate change for the Marlborough region would be to grape growing and winemaking of Sauvignon Blanc?

- A rise in average mean temperatures by 0.5-1 degree Celsius
- 10-15 more “hot” days over 25 degree Celsius – (this would double the current number of days)
- A reduction in rainfall between November and January leading to more drought
- An increase by 20% of April rainfall
- Reduction in the likelihood of frosts

Q16. Would you change the way you grew Sauvignon Blanc, and would that have an impact on the cost of production, if the regions climate changed in the ways outlined in the previous question?

- Yes- it would increase costs of production
- Yes- but it would have no increase in the costs of production
- No there would be no change
- n/a as I only make wine

If yes, what would you do differently?

Q17. Would you change the way you made Sauvignon Blanc in the winery if the regions climate changed and would it have an impact on the costs of production?

- Yes- it would increase the cost of production
- Yes- but it would have no impact on the cost of production’
- no- no changes
- n/a as I only grow grapes

If yes, what would you do differently?

Q18. Do you believe that a forecasted warmer climate in the region will change the current flavour profiles of Marlborough Sauvignon Blanc?

- Yes – How will it change?
- No

Q19. In your view do you think this change in the flavour profile will be positive or negative for regular consumers of Marlborough Sauvignon Blanc around the world?

- Very positive
- Positive
- Neutral
- Negative
- Very negative

Q20. Do you believe that the Marlborough region will need to explore growing alternative varieties to cope with climate change as well as changes in market requirements?

- No- Sauvignon Blanc from Marlborough will continue to be the prominent in international markets with a relatively balanced supply and demand so growing alternative varieties will not be necessary.
- Yes – there is a need to do this to meet market demands and to adapt to climate change.

9.4. Follow Up Questions on Climate Variables

Q1. The NIWA forecast anticipates several climatic changes by the year 2040 for the Marlborough region. You may think some changes are more concerning and others are less concerning. Regarding your ability to grow and produce Sauvignon Blanc in 2040 how concerning are these projected changes?

- 8-10 more “hot” (over 25°C) days during the growing season (An increase in “hot” days of 25-50%)
    - Extremely Concerning
    - Very concerning
    - Somewhat concerning
    - Not very concerning
    - Not at all concerning
- A 12% increase in the Growing Degree Days between October and April (comparable to GDD of Californian Central Coast, Loire Valley, Coonawarra)
    - Extremely Concerning
    - Very concerning
    - Somewhat concerning
    - Not very concerning
    - Not at all concerning
- A rise in growing season average temperature by 0.5-1°C
    - Extremely Concerning
    - Very concerning
    - Somewhat concerning
    - Not very concerning
    - Not at all concerning
- A shorter frost season (1-2 fewer frost days in September)
    - Extremely Concerning
    - Very concerning
    - Somewhat concerning
    - Not very concerning
    - Not at all concerning

Q2. The forecast for 2090 includes more changes. Again some changes will be more concerning to you than others. In your opinion how concerning are these projected changes for 2090?

- 35-60 more “hot” (over 25°C) days during the growing season (An increase in “hot” days of 100-175%)
    - Extremely Concerning
    - Very concerning
    - Somewhat concerning
    - Not very concerning

    - Not at all concerning
- Less rainfall from November through January with 20-30% less in November but 10-20% more for April
    - Extremely Concerning
    - Very concerning
    - Somewhat concerning
    - Not very concerning
    - Not at all concerning
- A rise in growing season average temperature by 2.5-3°C
    - Extremely Concerning
    - Very concerning
    - Somewhat concerning
    - Not very concerning
    - Not at all concerning
- A 40% increase in the Growing Degree Days between October and April (comparable to GDD of Adelaide Hills, Piedmont, Colombia Valley, Northern Rhone)
    - Extremely Concerning
    - Very concerning
    - Somewhat concerning
    - Not very concerning
    - Not at all concerning