CLIMATE ADAPTATION AND WATER CONSERVATION DECISION-MAKING IN PASO ROBLES, CALIFORNIA VINEYARDS

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ABSTRACT

Climate Adaptation and Water Conservation Decision-Making in Paso Robles, California Vineyards

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This paper examines vineyard perceptions and adoption of climate change adaptation and water conservation measures in the Paso Robles American Viticultural Area (AVA). A survey was distributed to all 220 vineyards and vineyard management companies that operate in the AVA, with a 53.64% response rate. The objective of the survey was to determine vineyard manager and owner attitudes towards climate change and adaptation, as well as their perceptions of how these threats would impact their operation. A second objective was to document the current level of water conservation and climate adaptation while identifying the barriers and opportunities for further adoption of these practices. The third objective was to share a climate projection to assess perceived impacts, attitudes, and perceptions of the projection and capacity to adapt. The final objective was to develop a typology to assist targeted outreach of vineyards. Our results showed that the most important current climate impact is heat, with water regulations and supply being the biggest concern in the future. Vineyards were also found to be relatively unsure about their capability to further implement adaptation measures, with relatively low adoption of most practices already. Decision support tools, like the climate projection, were found to be useful and desired by vineyards for management. Results of our study showed that trust in the information source can be a barrier to use of these tools. We identified further barriers to adoption of practices and identified an outreach strategy using a typology of vineyards, which focused on smaller vineyards and those without wineries. These results can be used to increase efficacy of government and NGO programs that aim to support climate adaptation and water conservation in the region.

Keywords: Climate Adaptation, Water Conservation, Adaptation Decision-Making, Paso Robles, Viticulture, Vineyards

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Chapter 1

INTRODUCTION

Climate change is predicted to reduce agricultural yields, affect production, and increase costs for crops and meat (G. C. Nelson et al., 2009). These changes will be the result of more frequent extreme weather events, increased risk of pests and diseases, increased irrigation demands (Fraga et al., 2012), increased temperature worldwide (Fraga et al., 2012; Neethling et al., 2017; van Leeuwen et al., 2019; Webb et al., 2012), and change in frost occurrence and growing season lengths (Jones et al., 2005b). Agriculture is often the basis for rural economies which support communities' social, economic, and cultural wellbeing (Cradock-Henry et al., 2020), positioning climate change as a threat to these farmers and communities. Recognition that these threats to agriculture also mean threats to global food security has led to increased focus on agricultural climate adaptation (Arbuckle et al., 2013a).

Climate adaptation is widely recognized as a necessary step for farmers to reduce risks related to climate change (Roesch-McNally et al., 2017) and therefore also ensure their economic resilience (Cradock-Henry et al., 2020). Adaptation, on a basic level, consists of farmers adjusting their practices, infrastructure, capital, and processes to reduce risks posed by the environment, with climate change being a main driver of this environmental risk (Cradock-Henry et al., 2020; Roesch-McNally et al., 2017). Wine grapes are particularly sensitive to the environmental risk caused by climate change (Webb et al., 2008; Hannah et al., 2013) and vineyards are already seeing impacts from climate change, with the intensity of impacts only predicted to increase (Mira De Orduña, 2010; Santos et al., 2020; Jones et al., 2005b; Fraga et al., 2012; Webb et al., 2012;

Hannah et al., 2013). Climate change is projected to reduce area suitable for winegrowing in main viticultural areas (Hannah et al., 2013) and have direct impacts on the wine grapes such as changes to their microbiological makeup (Mira De Orduña, 2010). Wine grapes have a productive lifespan of 20-50 years, meaning that vines being planted now will experience the predicted increasingly intense climate impacts in future decades, often limiting adaptation options and requiring long-term planning (Babin et al., in press; Battaglini et al., 2009; Nicholas & Durham, 2012). Despite the predicted significant climate impacts to agriculture, our understanding of the factors influencing vineyard adaptation decision-making is underdeveloped (Roesch-McNally et al., 2017; Arbuckle et al., 2013a).

Agricultural adaptation to climate change has been previously studied by examining farmers' views on climate change, vulnerability, and adaptation decision-making (Rejesus et al., 2013; Santos et al., 2020; Roesch-McNally et al., 2017; Waldman et al., 2020; Cradock-Henry et al., 2020). In a study of six regions worldwide, the majority of farmers in all regions believed that climate change and its impacts weren't a threat to their local agriculture (Prokopy et al., 2015). Arbuckle et al. (2013b) found that a majority of Midwestern U.S. farmers believed climate change was occurring, although a small fraction of these believed that its main cause was human activity. They also found that concern about climate impacts and attitudes towards adaptation varied based on their belief in climate change, as farmers who believed in climate change and its human cause were significantly more likely to be concerned about climate impacts and support adaptation measures. Arbuckle et al. (2013a) found in a survey of Iowa farmers that climate risk perceptions were a substantially more important predictor of farmer

perceptions of adaptation than their belief in climate change. Lereboullet et al. (2013) applied a socio-ecological approach to compare French and Australian viticultural regions, reporting how system characteristics influenced their adaptive capacity in the long term. A small number of other viticultural adaptation research studies have been conducted, finding that wine grape growers are becoming more aware of climate impacts and adaptation measures to deal with them (Battaglini et al., 2009; Fraga et al., 2012), but that much of the focus and practice adoption has been for reactive and short-term individual vineyard practices (Neethling et al., 2017; Nicholas & Durham, 2012). However, the scarcity, scope, and focus of these studies leave the important question of how these vineyard characteristics influence vulnerability unanswered.

Agricultural adaptation to climate change has been researched from multiple perspectives, however there is still a lack of understanding regarding viticultural adaptation decision-making and how factors such as vulnerability, perceptions, and ownership style may affect it. The Paso Robles American Viticultural Area (AVA) provides an opportune research space to explore these factors, as it contains over 200 wineries and more than 37,500 acres of vineyards. Irrigation water is a main issue that Paso Robles viticulture already faces, which can be seen clearly in the severe annual overdrafting of their groundwater basin. The Sustainable Groundwater Management Act (SGMA) requires that a Groundwater Sustainability Plan be put in place for the Paso Robles subbasin, however this plan is projected to cause severe economic losses for wineries and associated industries (Hamilton & McCullough, 2020). Adaptation measures can help to reduce this economic impact, but funding and other barriers act as significant hurdles (Keenan, 2019). The climate impacts already affecting Paso Robles,

predicted water restrictions for the region, and long-term outlook of viticulture make the Paso Robles AVA a prime location for this study. The lack of research focusing on factors affecting viticultural adaptation decision-making presents a research gap which this study addresses.

The research project will focus on Paso Robles AVA viticulturalist perceptions of climate change, as well as vulnerability, resilience, attitudes, and barriers and opportunities for climate change adaptation and water conservation. We hypothesize that viticulture's long production periods, financial ability to experiment with adaptation (Nicholas & Durham, 2012), and climate-sensitive product may result in wine growers needing extreme forethought and planning, making them more likely to consider climate impacts and adaptation measures to address these impacts. Through the distribution and analysis of survey data collected from wine grape growers, vineyard owners, and vineyard management companies in the Paso Robles American Viticultural Area, this work shows how vineyards adapt to climate change through adaptation and water efficiency practices, attitudes and perceptions of adaptation and decision support tools, and how their characteristics influence these adaptations. The results of this study will aid in further understanding winegrowers' perceptions of climate and use of adaptation practices, providing knowledge to increase adoption by utilizing trusted sources for adaptation outreach and implementation programs and tailoring these to specific vineyard characteristics.

Our research questions (RQ) for this study were:

RQ1: What risks to the economic viability of vineyards are important/ already experienced?

RQ2: What are the perceived impacts of the climate scenario, attitudes towards scenario, and perceptions of capacity to adapt?

RQ3: What is the prevalence of adoption of water efficiency, soil conservation and climate adaptation measures?

RQ4: How are RQs 1-3 influenced by vineyard typology?

RQ5: What are the barriers and opportunities to water conservation practice and climate adaptation practice adoption in the Paso Robles AVA?

RQ6: What sources of information about vineyard soil and water management are most trusted in the Paso Robles AVA?

Chapter 2

LITERATURE REVIEW

2.1 Impacts of Climate Change on Viticulture

Viticulture is predicted to be significantly impacted by climate change (Mira De Orduña, 2010; Santos et al., 2020; Jones et al., 2005a; Fraga et al., 2012; Webb et al., 2012). Changing climate is influencing vine phenology, the grapevine yield, and berry and wine quality (Mira De Orduña, 2010; Santos et al., 2020). Studies targeting winemakers in Europe found that most described a changing climate and changes in vineyard factors such as grape composition, grape harvest dates, patterns of pests and diseases, and grape vine phenological stages (Santos et al., 2020). Many vineyards are not replaced for 25-30 years, with wine grapes productive for up to 50 years, meaning that vineyard owners and managers need to look far into the future when making decisions (Woodall et al., 2002; Nicholas & Durham, 2012).

The direct impacts of climate change on the wine grapes include advanced harvest times, grape aroma expression, the stability of the grape chemical and microbiological makeup, and altered sensory balance (Mira De Orduña, 2010). Air temperature is the largest influence on wine grape growth and productivity (Fraga et al., 2012), and growing season mean temperatures have already increased across several wine regions about 1.3°C from 1950-1999 (Jones et al., 2005b). The increasing temperatures are projected to combine with a shift of the ripening period towards earlier and usually warmer parts of the season. The earlier timing and reduction in growing season length can lead to grape ripening during excessive heat, which results in decreased acidity, increased alcohol, and change in the sensory profile of wine (Santos et al., 2020). For example, growing season

temperatures in Europe are predicted to warm by 2.1°C by 2050, which will advance grape ripening by about 10-20 days (Jones et al., 2005a). However, the Intergovernmental Panel on Climate Change (IPCC) projects global mean surface temperatures to be as much as 0.3°C-4.8°C higher by 2081-2100 relative to 1986-2005 (IPCC, 2014). These increases may push the climate beyond what is optimal for specific varieties, resulting in difficulties ripening balanced fruit and producing current wine styles from the existing grape varieties (Jones et al., 2005b). Winegrowers are aware of this issue and are particularly concerned about the impacts on regional wine typicality (Neethling et al., 2017).

Climate change may also result in drier conditions on vineyards (van Leeuwen et al., 2019) which has been shown to impact phenological development independently of temperature. Therefore, projections of changes to harvest dates may be underestimated in dry areas due to the impact of drier soils (Webb et al., 2012). It's not only the soil which will be drier, but water for irrigation will also be an issue in many areas. Water supply is already a major issue facing agriculture and viticulture already in many areas, with climate change projected to exacerbate shortages (Fraga et al., 2012). Heat waves are very likely to happen more frequently and for a longer duration (IPCC, 2014), which is one factor in the increased dryness.

There are projected climate impacts on viticulture which will negatively affect the industry, but there are also certain positive impacts. Winegrowers in Europe and France in two studies associated some of this opportunity with better conditions for wine quality and grape ripening (Neethling et al., 2017). The projected warming for Central and Northern Europe will result in longer growing seasons and more frost-free periods,

reducing fall frost damage, and likely leading to better wine quality. Higher concentrations of carbon dioxide in the future are projected to have a positive impact on grapevine development and attributes of yield (Santos et al., 2020). There are also projected to be newly suitable areas for viticulture as climate changes (Fraga et al., 2012). Lastly, the effects of elevated carbon dioxide levels are predicted to result in an increase of primary plant production (Fraga et al., 2012). The increased carbon dioxide levels have been studied for effects on grapevines, with most reporting small or absent changes and possible cancelling out of benefits by increased heat (Mira De Orduña, 2010). Impacts are mostly regionally dependent and will result in positives in some areas, however in most current wine producing regions there is a predicted negative overall impact on wine grape quality (Mira De Orduña, 2010).

2.2 Climate Adaptation

Adaptation measures will be required for agriculture to adapt to climate change and stay profitable and sustainable in the long term (Cradock-Henry et al, 2020). Due to the variation in agroecosystems and local nature of climate impacts on agricultural components, climate adaptations and barriers to their use are both locally and regionally linked to the environmental and cultural context (IPCC, 2019). Successful adaptation measures need to account for not only farm and climate but also their interaction with local social, economic, and other contexts that it exists within (Neethling et al., 2017; IPCC, 2019). Bryant et al. (2000) breaks agricultural adaptation into four components: characteristics of the stress, agricultural system characteristics, the multiple scales involved, and the adaptive responses.

In the short term, adaptations often tend to focus on building capacity, improving technology and knowledge transfer, designing early warning systems, managing risk, managing gaps in overall implementation (IPCC, 2019), and as a main protection against specific threats (Santos et al., 2020). Examples of short-term agricultural adaptation practices include pest control and soil management (Neethling et al., 2017). Long-term practices tend to be more of system transformations (Moser & Ekstrom, 2010), with an example of a practice being changing grape varieties grown for wine (Neethling et al., 2017).

Adaptation pathways planning is an increasingly popular approach to decision-making support, as it can help with the uncertainty and complexity associated with climate change impacts. This approach provides a flexible approach to allow for change and uncertainty within the adaptation planning process, providing a range of strategies over the short and long-term (Cradock-Henry et al., 2020). Adaptation pathways provide help for planning and making decisions about adaptation, but there are many other tools which can be used to aid adaption decision-making.

2.2.1 Decision Support Tools

Decision support tools (DSTs) are methods and resources for knowledge which can aid decision-making for climate change adaptation (Palutikof et al., 2019a). These DSTs can come in many different forms, complexities, and designs useful for various applications. For instance, DSTs can be packaged into an adaptation platform, which is a whole environment dedicated to providing decision-makers with the data, tools, guidance, and information needed for adaptation (Palutikof et al., 2019a). However, a

gap persists between the production of the DSTs and what decision-makers require, as well as what the funders of the projects expect (Lemos et al., 2012; Palutikof et al., 2019a).

A barrier to the effective use of DSTs and climate information is uncertainty in climate models and their interpretation (Mase & Prokopy, 2014). Uncertainties can be a barrier by further clouding the information gap between science and decision-makers (Palutikof et al., 2019a). Uncertainties abound and are acknowledged in both our understanding of future climate and our models designed to predict the future climate. Climate forcing and global climate models provide information at a broad scale and incorporate uncertainties, but downscaled projections provide a higher resolution projection at the cost of greater uncertainty due to the spatial scale (Mearns, 2010). There has been work done to increase confidence in global climate uncertainty, while probabilistic methods have been used on both global and regional scales to reduce uncertainties (Mearns, 2010). Progress has been made in quantifying uncertainties about future climate change, however research should continue until uncertainty is no longer a barrier.

Further barriers to climate information use for decision-making include farmer and advisor perceptions of the information or tools, lack of context for forecasts, and aspects of the information itself such as scale (Mase & Prokopy, 2014). Mase and Prokopy (2014) found in a review of 30 years of studies that the main barriers responsible for the underutilization of DSTs and other climate information were farmer perceptions of low accuracy information/models and concerns that the information/model was too large in scale to be useful. These are persistent barriers to the local use of DSTs, but

there are strategies to overcome these barriers and provide a useful tool to local decision makers.

Useful and effective scientific information needs to be viewed by users as salient, credible, and legitimate (Cash et al., 2003); in this pursuit, DSTs need to be designed and delivered in a way that promotes farmers' ability and willingness to use them (Mase & Prokopy, 2014). "Boundary work" is that which happens at the interface between expert communities and decision-maker communities, and this work has been shown to be important for useful scientific information and effective science advising (Cash et al., 2003). The level of interaction between science and decision-makers, which boundary work helps to cultivate, critically influences climate information use rates (Lemos et al., 2012). Co-development and co-production, which can be combined into coordinated development, brings DST developers and end users to work together, which increases relevance, accessibility, and trust in the final product (Palutikof et al., 2019b). Interaction between DST builders and users in the development of the DST is vital to effectively using climate information and can help to overcome the barriers to their use. These DSTs and climate projections, especially when developed in an effective way, can help decision makers adopt useful climate adaptation practices which help reduce their vulnerability to climate change.

Decision support tools have been designed for viticulture, however there are few specific to this purpose and sparse literature on the use and effectiveness of these. Brisson et al. (2003) designed STICS, a model using daily climate data to simulate crop growth, soil water, and nitrogen. STICS was adapted for and utilized on vineyards in several regions (Terribile et al., 2017). Terribile et al. (2015) designed a spatial decision

support system, SOILCONSWEB-GCI, which aims to connect farm and landscape levels better within agriculture, something important for sustainable and quality viticultural management (Terribile et al., 2017). The tool is web-based, dynamic, and multiscale, designed for use in decision-making for agriculture, forestry, and urban planning. Terribile et al. (2017) refined the SOILCONSWEB decision support system to the specific needs and applications of viticulture in the tool *GeoVit*. This tool aims to support vineyard management and planning from a landscape scale and provides options for user decisions rather than just giving the best solution. Vite.net is another decision support system designed for vineyard managers to aid in sustainability of their vineyards. The system functions using two parts: real-time monitoring of the vineyard characteristics and a web-based tool to analyze the data and provide decision support (Rossi et al., 2014). Cola et al. (2014) created a simplified crop growth model and calibrated it to wine grapes, which was found to be helpful for vineyard technical assistance as part of a decision support system.

Cal-Adapt has great potential as a decision support tool, as previous research has suggested. Cal-Adapt is a publicly accessible tool which vineyard owners and managers can utilize to understand future climate scenarios for their area. It is a web source developed by U.C. Berkeley and the state of California for downscaled climate change projections. Cal-Adapt is designed to aid in climate adaptation planning by providing an idea of the future impacts by using and providing the current climate data, making it a decision support tool (*Cal-Adapt*, n.d.). Babin et al. (in press) found in interviews with Paso Robles viticulturalists that their impressions of Cal-Adapt were positive, with personalized and narrative-based projections much more useful than broader, map-based

projections. It was found by the Babin et al. (in press) that creating the projections could be time-intensive and the interviews also revealed additional variables which would make Cal-Adapt a more effective DST for vineyards. Cal-Adapt has shown utility as a decision support tool, but its usefulness and applicability to viticulture should continue to be improved.

2.2.2 Viticultural Adaptation

Decision support tools are underutilized as a method of adaptation decision-making, but there are a variety of adaptation methods commonly practiced on vineyards. Common viticultural adaptation methods typically optimize grape production through plant material choice of variety, clone and rootstock or viticultural techniques like vineyard floor management and training system (van Leeuwen et al., 2019). Vineyard floor management has an influence on wine composition, soil conservation, weed management, grapevine growth, and disease attack (Dobrei et al., 2015). Understanding of the local environmental, social, economic, and other contexts and their interaction with the local climate are essential for winegrowers as they analyze adaptation measures (Neethling et al., 2017). Important adaptation practices include cover crops, dry farming, conservation tillage, frost prevention techniques, and long-term adaptation such as varietal selection.

Cover crops are a widely used and well-known adaptation measure throughout all of agriculture. They have been shown to increase environmental protection and vine earliness, reduce soil erosion and fungal pathogen risk, and increase soil fertility, structure, and tractability. The drawbacks of cover crops are that they compete with the

grape vines for resources: soil, water, and nutrients. This competition does result in reduced vine vigor and grape yield (Neethling et al., 2017). Conflicting research finds that cover crops contribute to improvements in the vine vigor or crop load, as well as contributing to the improvement in weed suppression, physical and chemical soil properties (Dobrei et al., 2015).

Dry farming is an adaptation to a lack of irrigation water but is also the method that most European vineyards utilize (van Leeuwen et al., 2019). Dry farming typically uses 1/3 as many vines as an irrigated vineyard, which spreads the vines out and allows the soil water to be increased to each vine. Additional changes are that the vines can be trained into free-standing trees or the moisture in the soil can be sealed in with a thin top layer of pulverized dirt. The drawback of the reduced vine density is reduced product per acre. This can cost many operations too much to be economically feasible, although if operating costs are cut, the producer owns the land, or the wine is sold for a premium for being water-friendly it could make up some of this loss (Walsh, 2019).

Conservation tillage is when more than 30% of the crop residues are left on the soil surface (Dobrei et al., 2015). It is a measure of soil management, with these management practices being critical for greenhouse gas emissions and storage, protection of plants and soil, and water fluxes (Santos et al., 2020). The benefits of conservation tillage include reduced soil erosion, less labor, less time and fuel usage, better soil tilth, more organic matter in the soil, trapping soil moisture which increases water availability to vines, and better water and air quality (Dobrei et al., 2015).

Wine grapes are very sensitive to frost (Fraga et al., 2012), however there are two different types of adaptation measures used to prevent damage. Passive measures are

indirect methods carried out in advance to prepare the vines for frost and are used more often, while active measures are direct methods used directly before or during frosts (Neethling et al., 2017). Neethling et al. (2017) details the different passive and active frost adaptation measures. The first passive measure is avoiding planting vineyards in areas susceptible to frost in the first place or planting late-ripening varieties to avoid the frost. Passive techniques consist of adjusting inter-row management, such as no till or mowing cover crops. Cover crops actually restrict heat absorption of the soil, which results in lower spring frost night temperatures. This can result in frost damage, and so vineyards in frost-prone areas counter this issue by mowing cover crops in early spring. Pruning management can also help reduce susceptibility of the vineyard to frost, as postponing winter pruning will delay bud break and vine growth which then won't be exposed to the frost. Active prevention techniques use direct methods to protect the vineyard from frost damage. Wind machines, heaters, or over-vine sprinklers which are applied during or just before the frost event are common examples.

Long-term adaptation strategies help a vineyard adapt to climate change throughout several growing seasons or before the vineyard is even planted. Three main practices utilized are changes in training systems, varietal/clonal and rootstock selection, and vineyard relocation. Training systems can be changed with differing aims: delaying the maturation period, lowering sugar accumulation, reducing radiation in the cluster zone, and higher water use efficiency (Santos et al., 2020). Previous research found shift in varietal selection as a prevalent potential adaptation to climate change among Paso Robles winery managers and advisors as higher temperatures, more days of extreme heat, and longer heat waves have led wineries to look for hardier grapes which grow well in

arid regions (Babin et al., in press). Much of the appeal to consumers of many popular wine areas is dependent on a specific variety or few varieties, so change of varieties can cause economic losses (Santos et al., 2020). Changing varieties can help wineries to maintain economic feasibility in a changing climate but may not be enough in some cases. Areas may simply become too hot or too dry for sustainable viticulture, and vineyard relocation is a last resort option in these cases. The new vineyard site should be chosen somewhere cooler, which tend to be in coastal zones, at higher latitudes, at higher elevations, or areas with less solar radiation overall (Santos et al., 2020).

2.2.3 Water Efficiency Practices

Water efficiency practices are some of the most vital components of viticultural adaptation for the Paso Robles area, given their current groundwater struggles and projected further reductions due to climate change or regulations. Paso Robles Subbasin groundwater pumping has continued to exceed the yield estimated to be sustainable for the future, meaning that measures will be needed to bring the Subbasin back to a sustainable yield level (Paso Robles Subbasin, 2021). Water use efficiency is being encouraged, as well as other measures under the GSP. Water use efficiency provides benefits such as improving crop yields and reducing costs for water and other applied inputs, as well as other off-farm benefits (USDA, 2019). Keys to water efficiency in agriculture are knowledge of how much water the crop needs and how much water in the soil is available for the crop, making measuring and monitoring soil water status essential (Charlesworth, 2005). Monitoring of plant water status is vital as well, as it is a key to growth, productivity, and overall development of vines (Agriculture Victoria, 2019).

This is partially due to high quality grapes needing controlled water stress during key points of the growing season (Semmens et al., 2016). The most important water efficiency practices include soil moisture monitoring, plant tissue sampling, evapotranspiration monitoring, distribution uniformity tests, and flow meters.

Soil moisture monitoring is used to schedule irrigation and consists of monitoring of the soil to understand when irrigation is needed (Charlesworth, 2005). Charlesworth (2005) details the three ways to describe soil moisture: gravimetric soil water content (SWC), volumetric SWC, and soil water potential. Gravimetric SWC measures how much water is in the soil by weight and is the easiest method, as a soil sample is weighed, dried, and then weighed again to find the weight of the water. Volumetric SWC takes into account the soil bulk density, making it the most popular measurement method. Volumetric water content measurement systems can consist of frequency domain reflectometry, neuron moderation, or heat dissipation. Soil water potential is the measure of the tension and energy needed to remove water from the soil. Soil water potential measurement systems can consist of porous media instruments (tensiometers or resistance blocks) or wetting-front detectors (Charlesworth, 2005).

Plant tissue sampling is irrigation scheduling based on methods such as a pressure bomb or sap flow sensors. Pressure bombs, or pressure chambers, measure the water tension (stem water potential) in plants by adding pressure to a leaf and stem in an airtight container (Agriculture Victoria, 2019; Semmens et al., 2016). Different measurement techniques include leaf water potential, predawn leaf water potential, stem water potential, and shaded leaf water potential (Fulchton et al., 2014). Sap flow sensors measure fluid movement within the plant's xylem, which can be used as an indicator of

transpiration. Sap flow readings can be compared to daily evapotranspiration or temperature of the air to determine when irrigation for the vineyard is needed. Another similar measurement device is a dendrometer, which measures changes in plant water content by measuring variations in stem diameter (Agriculture Victoria, 2019).

Evapotranspiration (ET) monitoring quantifies ET, the process of evaporation from soil and plant surfaces and transpiration from plants, and is used to schedule irrigation (Semmens et al., 2016; Burt et al., 1997). A common method is modelling as a function of potential evapotranspiration using local weather stations and vegetation cover fraction. More complex and in-depth Soil-Vegetation-Atmosphere Transfer (SVAT) models can estimate ET considering common vineyard soil management and the season. Other methods to calculate ET for vineyard include eddy covariance, weighing lysimeters, or energy balance. A last, more advanced approach is estimating ET using land-surface temperature from satellites (Semmens et al., 2016).

Distribution uniformity tests measure the uniformity at which irrigation is distributed to the areas of a crop field, which can help vineyards make sure water is uniformly delivered throughout vineyard blocks. This measurement is important because non-uniform distribution can leave some parts of the vineyard without water and over-irrigate others, leading to negative outcomes (Burt et al., 1997). Distribution uniformity can be measured using multiple uniformity parameters, but when measured on a drip irrigation system will require representative measurement of emitter discharge using further parameters (Camp et al., 1997).

Flow meters are used to measure irrigation flow and schedule irrigation, increasing effectiveness of water management. Types of flow meters include propellor

flow meters (most common), magnetic flow meters, portable ultrasonic flow meters, and the less common Doppler flow meters (Sheffield et al., 2013).

2.3 Barriers and Opportunities for Adaptation

Barriers to climate change adaptation are obstacles that reduce adaptation efficacy and may lead to missed opportunities or greater costs, although they can be reduced or avoided through individual or collective action (Moser & Ekstrom, 2010). Barriers have also been defined in many other slightly different ways in the literature (Eisenack et al., 2014). Ekstrom & Moser (2014) identified four main categories of barriers (by frequency): institutional governance, attitudes and perceptions, resources and funding, and politics. They also found other less frequently mentioned categories of barriers (by frequency): leadership, issues with adaptation process, lack of understanding of climate change or science, lack of expertise, and communication. While most of these categories interact or overlap, this study uses two of these categories as a focal point: perceptions and financial and knowledge capacity.

2.3.1 Farmer Perceptions

Farmers worldwide have been found to have widely varying views on climate change and on the possible adaptation measures to counter the impacts, which can have impacts on their use of these adaptation practices (Rejesus et al., 2013; Santos et al., 2020). A study across four states examining producer perceptions of climate change and adaptation found that there was little acceptance of climate change being scientifically proven among agricultural producers and little belief that climate change would affect

crop yields or variability (Rejesus et al., 2013). In two studies conducted in Europe, winegrowers were very uncertain about the future climate changes and perceived climate conditions to be mostly dependent on natural variability (Santos et al., 2020). Farmers worldwide were found to perceive climate change risk lower than their belief that climate change is occurring (Prokopy et al., 2015). This seems to indicate that belief in climate change is a prerequisite for believing in its risks. Arbuckle et al. (2013b) found in a survey of nearly 5,000 Midwestern U.S. farmers that 66% of these farmers believed climate change was occurring, although only 8% of these believed that its main cause was human activity. A key finding from this paper was that concern about climate impacts and attitudes towards adaptation varied based on their belief in climate change. Farmer perceptions and attitudes influence their beliefs and views, but also are predictors of behavioral intentions such as adaptation practice adoption (Roesch-McNally et al., 2017).

Arbuckle et al. (2013a) found that farmers' support for adaptation is influenced by their perceptions of potential risks from weather volatility related to climate change. A study of farmers in the US Corn Belt found that those already using the adaptation practices and those who visited other farms to see their practices were more likely to plan on increasing their use of adaptation practices in response to climate change. However, farmers highly confident in their practices were less likely to indicate that they would increase use of adaptation practices as a response to climate change (Roesch-McNally et al., 2017). Farmer perceptions of climate change and associated risk are possible predictors of their adoption of adaptation practices, which in turn could influence farm exposure to climate change and overall vulnerability.

2.3.2 Financial Capacity to Adapt

A main barrier to agricultural climate adaptation is often the financial capacity to implement the practices and knowledge, skill, or information about the practices (Ali et al., 2017; Bryan et al., 2009; Moser et al., 2018). Many costs related to adaptation are high, which can prevent adoption of practices. However, the data available suggests that adaptation is very cost-effective in comparison to doing nothing (Moser et al., 2018). Decision support systems and tools are an option to help farmers make adaptation decisions with an understanding of the costs of options and valuation of avoided impacts (Palutikof et al., 2019a). All actions related to adaptation – vulnerability assessment, planning, applying for a loan, using a decision support tool, researching the practice, implementing the practice, monitoring, possible maintenance – cost additional money which the vineyard may not be able to afford (Moser et al., 2018).

Financial assistance for adaptation can come in the form of either funding, where money does not have to be paid back, or financing, where money must be paid back with interest. Crop insurance is a third, less-used source of adaptation financial assistance (Moser et al., 2018). As an example of recent adaptation financial assistance rates, only 10% of U.S. farms who improved their irrigation systems in 2013 received public financial assistance (USDA, 2019). This exemplifies the limited public funding sources available for adaptation and raises the importance of private sector funding. However, the private sector has little incentive to invest in adaptation because there is usually no direct return on investment (Moser et al., 2018). These factors can leave those wanting to implement adaptation with very limited options financially, however there are some opportunities.

2.3.3 Opportunities for Adaptation

Public institutions can be an important part in building agricultural adaptive capacity to climate change. These institutions can encourage and support adaptation by providing technical, credit, and advisory support (Khan et al., 2020). Institutions influence climate adaptation and vulnerability by structuring vulnerability and impacts, shaping outcomes of adaptation between individual and collective action, and facilitate access to outside resources for adaptation (Agrawal, 2008). Public, private, and civic institutions are important to adaptation in both formal processes and by promoting informal processes (Agrawal, 2008). California has established the Integrated Climate Adaptation and Resiliency Program (ICARP), which helps with coordinating funding from other agencies for adaptation (Moser et al., 2018). ICARP can serve an important role in improving communication between adaptation providers and users, a key to moving adaptation forward (Nordgren et al., 2016).

Viticulture has an opportunity to be a leader in agricultural climate adaptation, especially with help from institutions. The wine industry has higher profits margins than most agriculture, allowing them to experiment with new and innovative climate adaptation measures. Viticulture can essentially be a testing ground for adaptation, with other agricultural sectors adopting practices which are found to be useful (Nicholas & Durham, 2012). The opportunity for new adaptation practices, or innovative changes to current practices, is something which the institutions should cultivate and invest in. New adaptations can help to further reduce agricultural vulnerability to climate change.

2.4 Vulnerability and Resilience

Vulnerability is a complex and highly context-dependent concept which is largely responsible for vineyards' implementation of adaptation practices (Hinkel, 2011). Vulnerability could be defined as the context of a person or group's situation which changes their capacity to prepare, prevent, and recover from the impact of a hazard. A combination of factors are involved, all of which determine the extent of risk which an event in nature or society subjects a person's life, livelihood, or assets to (Blaikie et al., 1994). Another way to look at vulnerability is as a combination of vineyard exposure to a stress, sensitivity to the stress, and adaptive capacity (Nicholas & Durham, 2012). Vulnerability to climate change in agriculture can vary widely between different regions based on local factors. Climate vulnerability on a local level is a complex process with future vulnerability significantly influenced by local non-climatic factors (Neethling et al., 2017).

2.4.1 Resilience

Resilience is a concept linked to vulnerability, as resilience is the ability to deal with the stresses which vulnerability indicates. The greater a system's adaptive capacity is, the greater the system's resilience is (Khan et al., 2020). An important aspect of resilience to understand, similarly to vulnerability, is that it is very context specific. Rather than being inherent characteristics of an individual, group or community, resilience is an indicator for the connection between risks created by a hazard and the skills, knowledge and resources used to prepare for or manage the risk (Buckle, 2006). The principles which the concept of resilience is built on are persistability, adaptability,

and transformability (Keck & Sakdapolrak, 2013). Resilience can be broken down into social and ecological resilience, two distinct but sometimes intersecting aspects. Agricultural communities are a good example of this link, as these communities are often very dependent on the ecological resilience of their farms for their own social resilience (Adger, 2000).

Social and ecological resilience have been defined and distinguished from each other by Adger (2000). Social resilience can be defined as group or community ability to manage external stresses through change on the sociopolitical or environmental fronts. The resource dependency of a community or individual means that their livelihood, social order, and stability are directly related to their local economy and production of resources. Ecological resilience can be defined as a fundamental characteristic of ecosystems to maintain themselves despite disturbance. Resilience provides natural systems the ability to cope with large changes. This can be further defined in different ways, such as how much change they can take or how quickly they can bounce back (Adger, 2000).

Keck and Sakdapolrak (2013) break social resilience down into three different types of capacities: coping capacities, adaptive capacities, and transformative capacities. Breaking these three capacities down based on four categories can help differentiate them: response to risk, temporal scope, degree of change, and outcome. Coping capacities are those which are reactionary, short-term, low impact, and which restore the present level of well-being. Adaptive capacities are anticipatory and long-term, making incremental change and securing future well-being. Transformative capacities are anticipatory, long-term, radical changes which enhance both future and present well-

being . These definitions can help to further define and describe within the construct of social resilience.

Elements which support individual resilience include information and advice about assistance and preparation measures, financial or physical resources, managing capacity for resilience activities, personal and community support, and involvement with others in the community (Buckle, 2006). Elements which support resilience at a community level include knowledge of hazards and community characteristics vital to adaptive capacity, shared community values, established social infrastructure, positive social and economic trends, partnerships between community groups, and resources and skills (Buckle, 2006).

2.5 Viticultural Vulnerability

Regional identity is a vulnerability which isn't specific to the wine industry, but which is especially visible in the industry. Regions known for their high quality of wines produced create unique physical and cultural environments which are an important part of local economies through their grape and wine production and processing, trade, and resulting tourism (Jones et al., 2005b). The regional identity is often based on the terroir of the area, which typically consists of cultivar, climate, and soil. The terroir interacts with other factors, such as cultural practices, to influence the quality of the grapes and resulting wine (Cheng et al., 2014; Webb et al., 2008).

If wine grape quality and resulting wine structure and flavor are altered due to climate changes, a concern of winegrowers (Neethling et al., 2017), this may negatively

alter terroir and regional identity for producers (Webb et al., 2008). This can lead to regional economic reductions due to the impact of wine on supporting industries such as hospitality and tourism (Hamilton & McCullough, 2020; Santos et al., 2020). In this way, terroir can be viewed as a vulnerability within the wine industry.

2.5.1 Paso Robles Viticultural Vulnerabilities

Paso Robles provides a great opportunity to examine factors affecting agricultural conservation decision-making due to its specific vulnerabilities, regional economic importance, and ability to implement adaptation practices. The risks facing viticulture in Paso Robles are likely to result in massive losses to the local economy, with these losses due to a few key vulnerabilities (Hamilton & McCullough, 2020; Babin et al., in press; McMillan, 2020). Paso Robles wine advisors and vineyard managers found water supply, labor, and market oversupply to be the largest short-term risks to viticulture in the area. The biggest risks identified long-term (3-10 years) by these advisors and managers included climate/weather volatility, water supply, and regulations (Babin et al., in press). Irrigation water, labor, and market oversupply will be discussed in detail in this section.

The Paso Robles AVA is a striking example of an area already struggling with supply of irrigation water before climate change is in full effect. The agricultural sector in this area is already struggling with irrigation, as the Paso Robles Subbasin is considered by the California Department of Water Resources to be “critically overdrafted”. The California Sustainable Groundwater Management Act (SGMA) of 2014 requires local regulation of groundwater and created Groundwater Sustainability Agencies to carry this out. These agencies must create Groundwater Sustainability Plans

(GSP) for high priority subbasins, and the Paso Robles Subbasin's GSP was completed in January 2020. The end goal is to have sustainable management of these subbasins, and the GSP must be successful in creating sustainable use by 2040 for the Paso Robles Subbasin. The GSP aims to reduce the amount of groundwater pumping through best management practices, voluntary land fallowing, or mandatory pumping limits for areas if needed. (Hamilton & McCullough, 2020). Reduced winery production due to the GSP alone will result in $183.4 to $458 million dollar loss to the local economy, or about 12-32% of their total value (Hamilton & McCullough, 2020). These figures are based on the GSP and before climate change, which is projected to reduce water available for irrigation even further.

Paso Robles' short-term risks of water, labor, and market oversupply combine with the fact that many Paso Robles AVA wineries are small or family-owned to result in greater economic impact (Rivera, 2020). Larger operations would better be able to withstand the costs these factors may incur, but smaller operations struggle with the added costs. Value-added is an important factor to consider when analyzing economics of the wine industry. Adding value is the process of taking a product and changing it to a more valuable state, and it allows producers to obtain some of the revenues and profits between the farm and consumers (Coltrain et al., 2000). Out of the Paso Robles wine industry's total direct, indirect, and induced output of $1.9 billion in 2015, about $924 million was value added (Matthews & Medellín-Azuara, 2016). One way value is added in viticulture with the production of wine from wine grapes, and the ability for a vineyard to produce their own wine from their grapes can be very important depending on the grape market. Before the onset of the Covid-19 pandemic, an analysis found an

oversupply across the entire supply chain. These market conditions for growers were found to be the worst since 2001, and possibly all time (McMillan, 2020). In combination with the Covid-19 pandemic shuttering wine tourism for the better part of the summer, Paso Robles vineyards have been economically challenged.

Local institutions, such as the Upper Salinas - Las Tablas Resource Conservation District (RCD) and Independent Grape Growers of the Paso Robles Area (IGGPRA), have put efforts towards making progress in implementing climate and water adaptation practices (Upper Salinas, n.d.; Independent, n.d.). The adoption rates of these adaptation practices are not well understood, however. The actual usage of climate adaptation practices in Paso Robles, especially water efficiency measures, has been studied only through interviews with a small sample of stakeholders (Babin et al., in press). There is therefore a need to gain understanding of prevalence of practice usage on vineyards, as well as the barriers which may be holding vineyards back from usage. These are important factors to understand moving forward as climate impacts only increase in frequency and severity, especially with the region already struggling for irrigation water. Understanding these factors can inform as to whether assistance programs are needed, and if so, how much assistance, what form or method would be most impactful, which vineyards need it most, and how to target them.

2.5.2 Paso Robles Viticulturalist Perceptions

Interviews of Paso Robles wine managers and advisors found that 90% believed that climate change is happening and will impact their operation, and the consensus was that extreme heat events and water would be their primary impacts felt (Babin et al., in

press). Farmer perceptions of climate change seem to vary quite widely, but prior research in Paso Robles seems to show that at least some of the viticulturalists in the area understand the potential impacts of climate change.

Previous research on this topic has consisted of interviews with Paso Robles American Viticultural Area (AVA) viticulturalists about agricultural conservation decision-making. Vineyards were found to be aware of climate change and effects to come but are for the most part not planning or adapting for it yet, mostly due to the year-to-year focus of the vineyards' operations (Babin et al., in press). Similarly, Guerrero (2020) examined conservation practices and found that agricultural producers were familiar with some of the adaptation practices presented to them but not others, showing that knowledge or information on practices may be a barrier. Due to local vulnerabilities and struggles already experienced with irrigation water, the Paso Robles AVA provides an excellent case study of conservation decision-making and how perceptions may impact this.

Chapter 3

METHODOLOGY

This study aims to gain understanding of the factors affecting agricultural conservation decision-making via a survey of vineyard owners and managers in the Paso Robles American Viticultural Area. The goal of our methodology is to make specific and highly relevant local information about perceptions and vineyard management decisions in the Paso Robles AVA available to policymakers, local stakeholders, and viticulturalists themselves. To achieve this, we conducted analyses on vineyard use of practices, barriers to adaptation practice use, perceptions of climate risk and adaptation, and the impact of a climate projection scenario; these factors were also further analyzed through the filter of a typology of vineyards.

3.1 Sampling

The sampling design chosen was a census of all 192 vineyards and vineyard managers in the Paso Robles American Viticultural Area (AVA). This sample allowed broad insight into the views, perceptions, and actions of the Paso Robles vineyard owners and managers.

Contact information (email, physical addresses, and phone number) for a total of 219 vineyards and wineries with estate vineyards located in the Paso Robles AVA were obtained from the Paso Robles Wine Country Alliance (PRWCA) and the Independent Grape Growers of the Paso Robles Area (IGGPRA). 27 of these ended up being addresses located outside the boundaries of the AVA, and were removed from the

sample, resulting in a total sample size of 192. The survey population was vineyard managers and owners, and instructions were included in all mail and electronic contact for the person who makes the most vineyard management decisions for the vineyard to take the survey.

3.2 Data Collection and Survey Design

Data collection was completed using a Qualtrics online survey. Survey data was then downloaded to Excel and analyzed using R Studio and Excel. This section will describe the survey design, data entry and archiving, and statistical analysis and modelling.

The survey was composed of four main sections: risk and views on SGMA, future climate projections (scenario) for both the east and west Paso Robles region, perception of climate change and adaptation measures considering the scenario, and demographics of the respondent and vineyard at the beginning and end. The survey codebook is attached to this document as Appendix B. There were 88 questions for the complete survey, and it was estimated to take 25 minutes to complete. The survey was a mixed-mode survey using multiple contact modes (mail, email, phone call) with responses only being recorded online using Qualtrics survey software. Design and implementation were based on Dillman et al. (2014) and Bernard (2013). Online-only responses were chosen for multiple reasons: reduction in data entry mistakes with automatic compilation, reduction in costs, and quicker return of the survey responses (Schleyer & Forrest, 2000).

Question types on the survey included Likert-type scales, multiple choice, rating, demographics, and open-ended questions. Skip logics were also implemented on specific

questions which were relevant to only certain respondents, another benefit of online surveys. These skip logics allowed a proper flow of questions for respondents, depending on their answers. For instance, there was a section asking questions specific to vineyard manager type. They were then sent to the correct follow-up question depending on their answer to the previous question, ensuring only the relevant respondents answer the questions. Lastly, the force response feature was used on certain questions which needed to be answered. This feature meant they were required to select an answer to move on to the next question. It was used for questions necessary for skip logics and also just for questions that needed an answer, for example consent to take part in the survey.

The future climate projections scenario section utilized projections for the Paso Robles area from Cal-Adapt, which provides downscaled climate projections (*Cal-Adapt,* n.d.). Scenarios were provided for both the east and west side of the Paso Robles AVA, with respondents being shown the one more applicable to them. Both scenarios would be shown if respondents selected that they managed evenly on both sides of the AVA. The scenario consisted of climate averages/statistics using Scenario RCP 8.5 and model CanESM2 for six different factors from 1961-1990 and projected averages/statistics for comparison for 2020-2039 and 2050-2070. The factors were: nights per year where minimum temperature didn't fall below 60°F, days per year above 95°F, days per year above 100°F, average occurrence per year of heat waves with 4 days in a row of 95°F temperatures, average annual longest stretch of consecutive days when daily maximum temperatures were above 95°F, and annual rainfall average with a year-to-year range as well.

A link to the survey was distributed through email, phone calls, text messages and mail using the vineyard and winery addresses collected. The first stage of distribution was conducted using a letter containing a link to the online survey, a $5 gift, and the form containing the survey information printed on Cal Poly Department of Natural Resources and Environmental Sciences stationary with a handwritten address on the envelope and stamp placed. The letter was followed four days after by an email with a personalized greeting, information about the survey, and the link to the survey. Nine days after the letter was sent, an additional reminder email was sent in the same format. A reminder call was made 21 days after the letter was sent, and a last reminder email was sent 30 days after the letter was sent. The survey was closed to new responses 10 days after the last reminder email and 40 days after the initial letter was sent. The process of personalized and repeated contact through different communication methods was designed for higher response rates (Dillman et al., 2014; Monroe & Adams, 2012). Along with the reminders, non-response bias checks were periodically completed by the researchers during the survey collection period. Evaluation of respondents who had not yet completed the survey was carried out to determine if there was a common factor which may have been preventing participation. These respondents would be contacted again to determine if there was a common non-response factor. None were found.

Incentives to take the survey included a $5 bill for simply opening the initial letter/email and a $40 Visa gift card for completion of the survey. Those who didn’t qualify for the survey because they didn’t own or manage a vineyard didn’t receive the gift card but still received the $5 bill. Another benefit listed on our initial survey

information page was the chance to make sure their voice was heard regarding the needs and concerns of Paso Robles AVA viticulturalists.

3.2.1 Dependent and Independent Variables

The dependent variable for the survey was current and likely future adoption of vineyard climate change adaptation practices. We asked respondents about their current use and barriers to use of 12 main viticultural climate adaptation practices. The 12 adaptation practices asked about were: soil moisture monitoring, evapotranspiration monitoring, plant tissue sampling, distribution uniformity tests, flow meters, drought tolerant rootstocks, heat tolerant varietals, dry farming, continuous no-till, cover crops, voluntary fallowing, and diversification into other crops. Roesch-McNally et al. (2017) conducted a similar survey on farmers in the United States Corn Belt with a focus on factors influencing adaptive decision-making in agriculture, albeit with a focus on only three main adaptation practices.

The independent variables for the survey were the vineyard typology, climate changes observed, perceptions of climate change and risk, perceptions of SGMA and groundwater risk, perceptions of the climate scenarios for east or west Paso Robles, respondent demographics, vineyard characteristics, and location in the Paso Robles AVA or sub-AVA.

3.2.2 Vineyard Typology

A hypothesized factor influencing climate vulnerability and adaptation decision-making was land ownership style. Land ownership style has been identified as a potentially significant factor in management decisions of adaptation implementation, with a suggestion that producers leasing the land may be less likely to be stewards of it (Reimer et al., 2012). Conservation or adaptation measures may be less likely on rented lands due to renter assumptions of landowner views, communication with landowners, and the leases often being verbal or year-to-year (Petrzelka et al., 2021). We hypothesized that small vineyards and non-estate vineyards would be more vulnerable to climate change due to reduced adaptive capacity. Czupryna et al. (2018) found in a study of Polish vineyards that 57% of small vineyards (less than 0.5 ha) were essentially a non-profit activity, with none of them treating it as a primary income source. We hypothesized that vineyards which don't have a profit motive and large revenues with which to implement adaptation, are less likely to do so. Adaptive capacity is one of the three main dimensions of vulnerability (Nicholas & Durham, 2012), and so investigating these factors influencing adaptive capacity, in this study carried out using a typology, may be very important for understanding vineyard vulnerability.

A vineyard typology was developed for further analysis with guidance from Collier et al. (2008). This typology was based on two factors: size of vineyard and whether it was an estate vineyard. Fleming et al. (2015) analyzed similar characteristics of climate adaptation between grape growers and wine producers, while Czupryna et al. (2018) has conducted analysis between small and large vineyards. For size of the vineyard, small vineyards were categorized as 0-20 acres and large vineyards as 21+

acres. The winery aspect was separated between vineyards without a winery and those with a winery. Typology placements were therefore based on a question determining whether the vineyard had a winery and a question determining the size of the vineyard. There were six respondents unable to be used in the typology due to lack of response on one of these questions.

The typology was constructed using these characteristics as a means to understand which vineyards should be targeted for climate adaptation outreach and assistance. Babin et al. (in press) found in interviews with Paso Robles viticulturalists that large estate vineyards may be more likely to have the time and resources to use decision support tools for comprehensive adaptation planning. The interviews also found that growers dependent on selling their grapes rather than making their own wine with them may be more vulnerable to the impacts of climate change. These insights from Paso Robles viticulturalists and other previous research has prompted the creation of this typology, which aims to determine if these factors of vineyard size and/or winery integration have an impact on vineyard perceptions, adaptation, and ultimately vulnerability to climate change.

Four different typology bins were created:

(1) small vineyard (0-20 acres) without a winery

(2) small vineyard (0-20 acres) with a winery

(3) large vineyard (21+ acres) without a winery

(4) large vineyard (21+ acres) with a winery

3.3 Data Entry and Archiving

Data entry was completed by survey respondents on the Qualtrics online survey platform. Response identification codes were created by Qualtrics upon beginning the survey and time stamps were automatically recorded for the start and end of the survey. When survey data collection was completed, data were downloaded and stored in a .csv file format. Data cleaning procedures were then conducted, consisting of filling empty answers with "-99" and removing test responses completed by the research team. Copies of the data at each stage of cleaning and analysis were maintained to ensure the integrity of the data. Next, a codebook was created to guide researchers and future users of the data. The codebook contains our methods related to data, helpful tips for interpretation of the data, and the codes for each question and answer. The codebook is available as Appendix B.

Project data was backed up and stored on a hard drive and university servers, with access restricted to only researchers. The data was deposited into the Sacramento State University Library's ScholarWorks platform to be publicly shared and preserved beyond the end of the project. ScholarWorks is Sacramento State's institutional repository, with all Sacramento State scholarship being free to access for anyone. The data stored in this archive is also protected with multi-tiered disaster recovery plan with fail-over servers and regular on-site and off-site backups.

3.4 Statistical Analysis and Modelling

Statistical analysis of the survey data was carried out using R version 4.0.3 (R Core Team, 2020) and the package “psych” (Revelle, 2021). The first step was importing the data into R, which was completed from the .xlsx file containing the cleaned data. The data was first analyzed for descriptive statistics. Next, bivariate analyses were conducted using the typology of different vineyards. This typology was used to analyze vineyard negative impacts experienced, severity of impacts, adaptation practice adoption, concerns, and perceptions of adaptive capacity and the projected scenario.

The next data analysis performed was Analysis of Variance (ANOVA) testing, which is a test for statistical significance in differences of means of different groups of scores (Tabachnick & Fidell, 2007). ANOVA was used to determine relationships between the grower typologies and their level of adoption of conservation practices. The four grower typologies were tested to determine if there was a correlation between typologies and their current or future adoption of adaptation or conservation practices. We employed a Tukey’s honestly significant difference (HSD) post-hoc test. This test is a pairwise mean comparison technique, which gives the exact sampling distribution of the biggest difference between two means coming from the same population (Abdi & Williams, 2010). Tukey’s HSD test provides an output for every possible pair of the difference in means, confidence levels, and adjusted p-values. The p-values allowed determination of which values were significantly different from each other. This information was then converted to a notation with a mean and letter/s for each group, with groups not sharing a common letter significantly different from one another.

Chapter 4

RESULTS

A total of 103 vineyard owners and managers responded to the survey, resulting in a response rate of 53.64%. Thirteen respondents were vineyard service employees, 12 were vineyard employees, and 73 were owner-managers. The amount of vineyard acreage managed ranged from 0.3 acres to 10,000 acres, with an average of 340 acres (SE=130, n=95). Demographics and basic vineyard characteristics (Table A-1) as well as other additional findings in the form of figures and tables are reported in Appendix A.

4.1 Current Vineyard Risks

Risks to vineyards (Figure 1) were ranked on a scale from 1 (Not at all concerned) to 5 (Extremely concerned). The risk with the largest level of concern was groundwater regulations (M=4.18, SE=0.11, n= 103), followed by water supply (M=4.04, SE=0.1, n= 103) and labor availability and/or cost (M=4.0, SE=0.1, n= 103). The least level of concern was for diseases and pests (M=3.37, SE=0.01, n= 103).

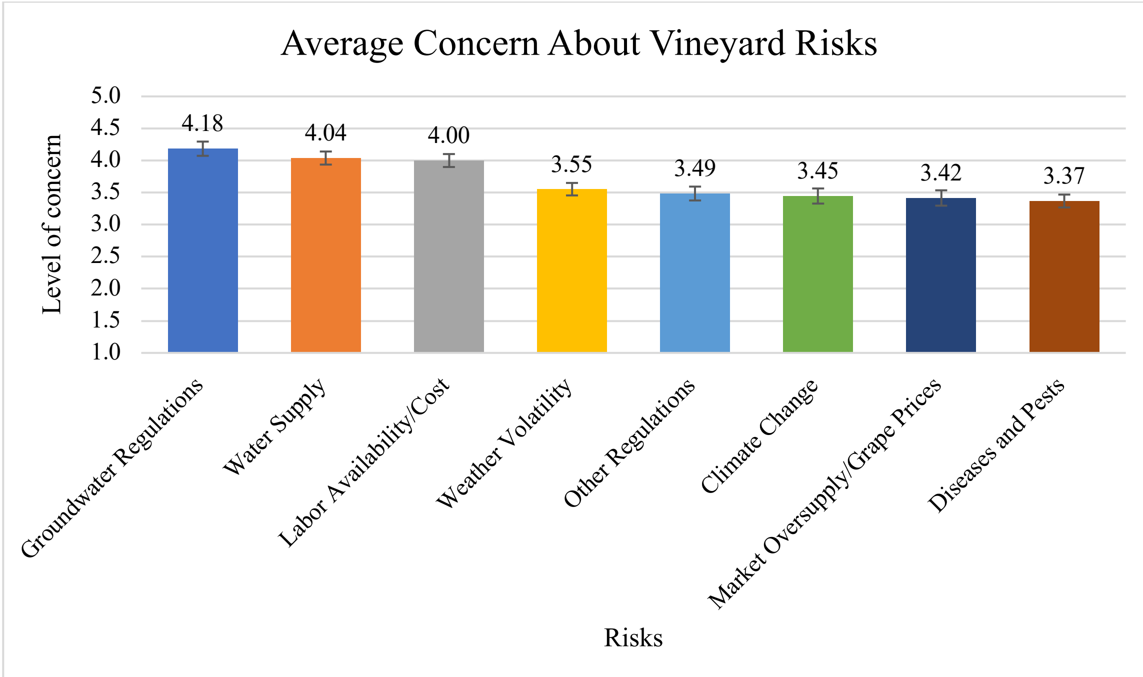


Figure 1. Average level of concern of different vineyard risks, scaled from 1 (Not at all concerned) to 5 (Extremely concerned), with standard error bars (n=103)

Impacts experienced by vineyards in the last five harvests (Figure 2) was ranked on a scale of yes (1) or no (2), with mean severity of these negative impacts in the last five harvests (Figure A-1) ranked on a scale of 0 (no negative impacts) to 4 (severe impacts). The most widely experienced negative impact in the last five harvests was vine stress due to extreme heat (74%, n=95), which was also the most severe negative impact experienced (M=2.66, SE=0.09, n=93). The next most widely experienced was disease (66%, n=92), which was also the second most severe impacts experienced (M=2.53, SE=0.11, n=88). Reduced water availability was the least experienced impact in the last

five harvests (32%, n=93) as well as being the least severity of impact (M=1.4, SE=0.12, n=77).

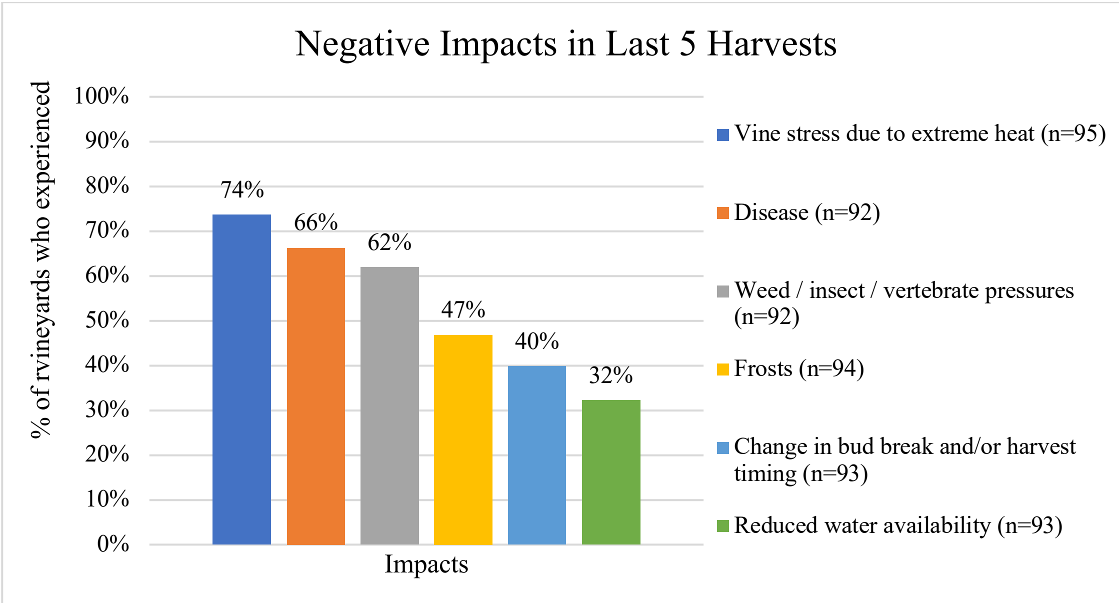


Figure 2. Reported negative impacts to vineyard in last five harvests, asked on a scale of yes (1) or no (2).

4.2 Perceptions of Climate Impacts, Climate Scenario, and Adaptive Capacity

The predicted impact on respondents' vineyards if the climate scenario were to occur (Figure A-2) was majority negative (80%), with a small minority neutral and only 2% of respondents expecting positive impacts (n=100).

Average concern about potential climate change impacts on the respondents' vineyards (Figure 3) was scaled from 1 (Not at all concerned) to 5 (Extremely concerned). Every climate impact was rated at least a 3.7, meaning they were at least between "Somewhat concerned" and "Moderately concerned" for every climate impact.

Reduced rainfall is the impact with the most concern (M=4.5, SE=0.09, n=98), with the next highest concern being extended heat waves (M=4.19, SE=0.09, n=98). Average concern about climate impacts was also analyzed by typology (Table A-2).

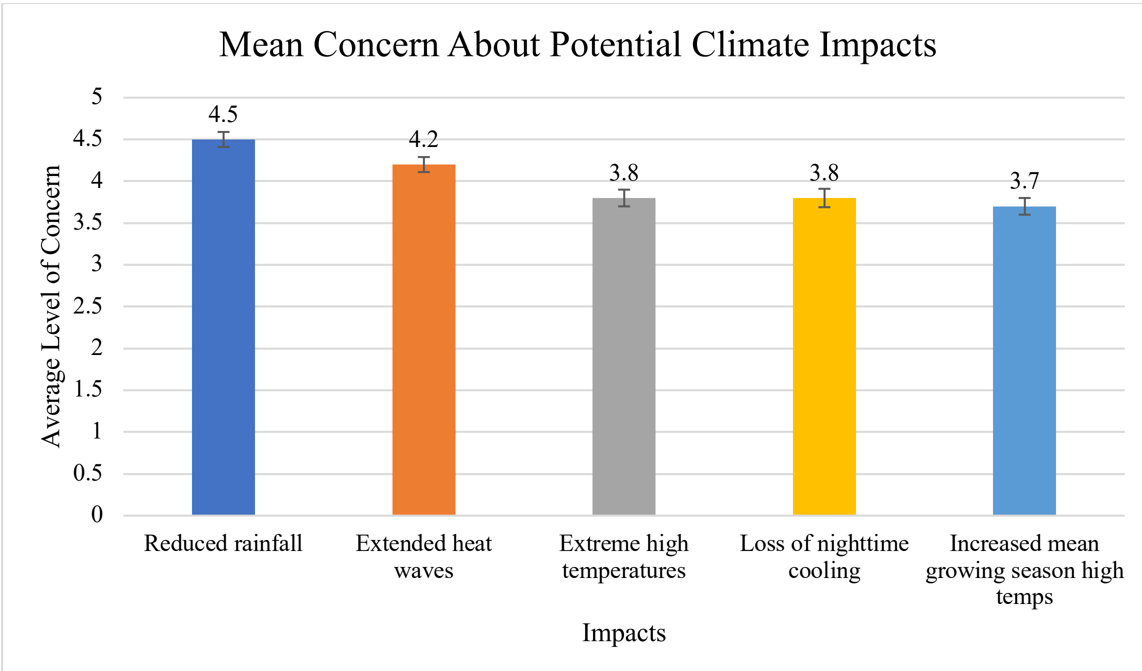


Figure 3. Average concern about climate impacts on vineyard on scale of 1 (Not at all concerned) to 5 (Extremely concerned), with standard error bars (n=98)

Perceived capacity for climate adaptation in the respondents' vineyards was scaled from strongly disagree to strongly agree (Figure 4). A higher percentage of respondents disagreed than agreed that they had the financial capacity required for adaptation. More than a quarter of respondents were uncertain of their financial capacity to adapt. We also found that 41% of respondents agreed that they had the knowledge and technical skill required to adapt, while 32% were uncertain of this.

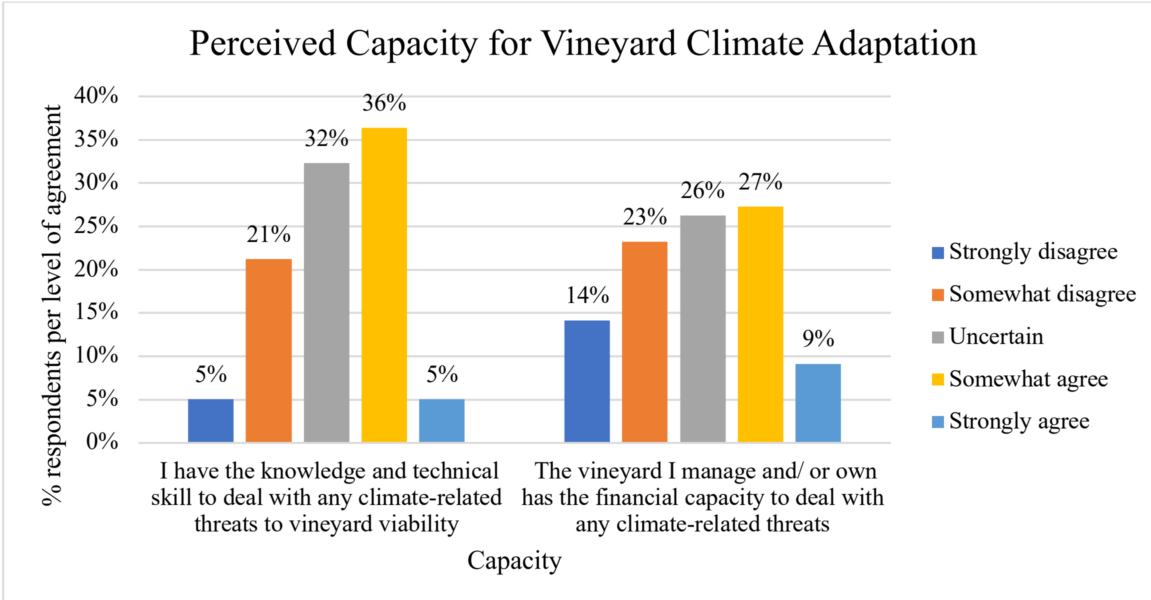


Figure 4. Perceived capacity for climate adaptation in vineyard by percent of respondents at each level of agreement with the capacity statements (n=99)

Climate change was very widely believed to be occurring (94%), with only 5% of respondents unsure of its occurrence due insufficient evidence and 1% believing that it's not occurring (Figure 5). The belief that climate change was occurring and was caused equally by natural changes and human activities was the most reported (44%), while belief that climate change was occurring and was caused mostly by human activities was a close second (41%).

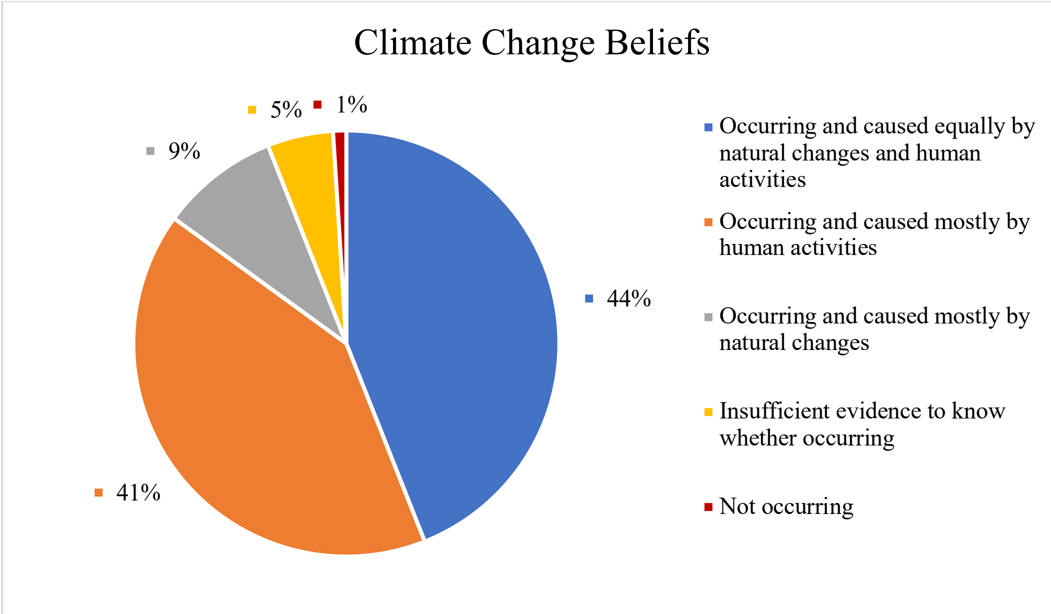


Figure 5. Climate change beliefs, respondents chose the one statement which best reflected their belief (n=98)

4.3 Prevalence of Adoption of Adaptation Measures

The adaptation practices with the highest percentage of respondents reporting current usage were cover crops and drought tolerant rootstocks, both at 87% usage (Figure 6). The next most widely used were flow meters (55%) and distribution uniformity tests (52%). There was also variation in the scale of usage of these practices even when they were used (Figure A-3). Some practices, such as continuous no-till, had somewhat low current usage rates (39%) but were used on a massive percentage of the land for vineyards that did use the practice (97%, n=38). The largest practice used by scale was cover crops, which were used on 100% of the land for vineyards that used them (n=84). The least used practices were diversification (13%, n=97) and dry farming (26%,

n=98), both of which were also used on relatively small amounts of the land even when they were used: 3% and 22% respectively.

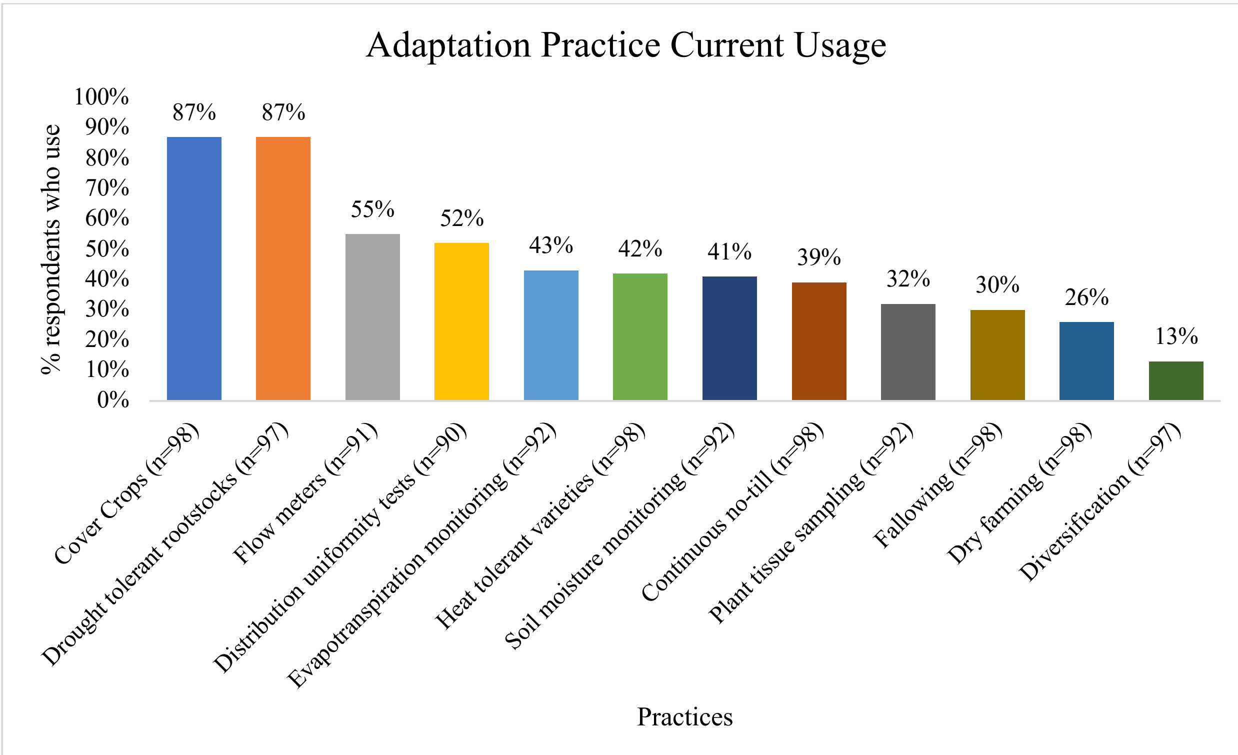
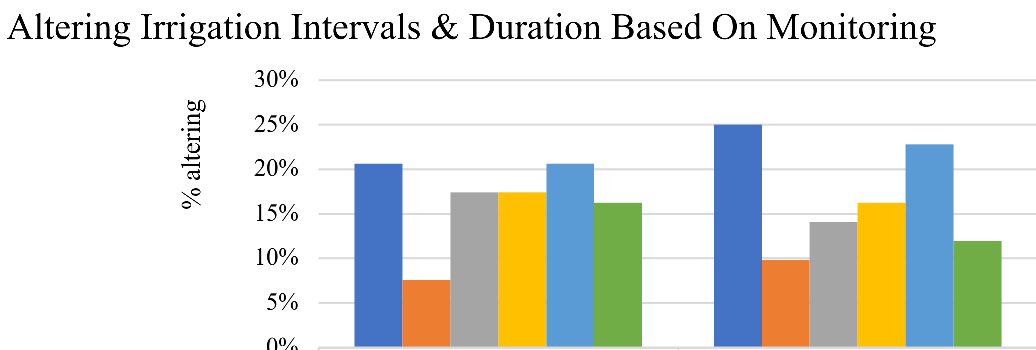


Figure 6. Current adoption of climate adaptation practices by respondents, asked as a yes/no.

Irrigation monitoring was used to alter both irrigation intervals and duration (Figure 7) for at least 50% of irrigation events by more than 50% of respondents. A large portion of respondents still do not use any irrigation monitoring to alter their irrigation, as monitoring is never used for intervals for 21% and duration for 25% of respondents. Responses were fairly spread out throughout the six prevalence categories, with “Never” the highest prevalence percentage for duration alteration and “Frequently (in about 70%

of irrigation events)” tied with “Never” for the highest percentage of interval alteration prevalence.



	How often do you alter irrigation intervals (time between irrigation sets) based off of soil, evapotranspiration and/or plant tissue monitoring?	How often do you alter irrigation duration (length of irrigation sets) based off of soil, evapotranspiration and/or plant tissue monitoring?
Never	21%	25%
Rarely (in about 10% of irrigation events)	8%	10%
Occasionally (in about 30% of irrigation events)	17%	14%
Sometimes (in about 50% of irrigation events)	17%	16%
Frequently (in about 70% of irrigation events)	21%	23%
Always (in at least 90% of irrigation events)	16%	12%

Figure 7. Percentage of respondents altering their irrigation intervals and duration based on irrigation monitoring, reported by prevalence of alteration (n=92)

4.4 Vineyard Typology Analysis

A vineyard owner/manager typology was developed: small vineyard without a winery (1), small vineyard with a winery (2), large vineyard without a winery (3), and large vineyard with a winery (4). Type 1 had 27 respondents, type 2 had 24 respondents,

type 3 had 14 respondents, and type 4 had 32 respondents. There were an additional 6 respondents who were unable to be used in the typology due to lack of response on questions used to develop the typology. The typology was used in one-way ANOVA tests to determine if there were significant differences in responses between the different types of vineyards.

4.4.1 Typology and Negative Impacts

Negative climate impacts to vineyards were evaluated by asking if specific impacts had been experienced and the severity of these specific impacts (Table 1). Small vineyards without a winery (type 1) had the least experienced negative impacts for 4/6 impacts.

One-way ANOVA testing and Tukey HSD post-hoc testing was used for the severity of impacts results. Severity of these climate impacts, when tested by typology in a one-way ANOVA, revealed that there was a statistically significant difference in severity of change of bud break and/or harvest timing impacts between two groups ($F(3,75) = [3.032]$, $p = .03$]). Tukey's HSD Test for multiple comparisons found that the mean value for severity of change in bud break and/or harvest timing impacts was significantly different between typology 2 (M=2.26, SE=0.17) and typology 4 (M=1.67, SE=0.13) (p=.03, 95% C.I. =[-1.15, -0.04]). There were no statistically significant differences in mean severity of change in bud break and/or harvest timing impacts between other vineyard typologies (ps>.1).

Table 1. Negative Impacts Experienced and Severity of Impacts. Reported as averages for all respondents and by vineyard typology (1=small without winery, 2=small with winery, 3=large without winery, 4=large with winery). Negative impacts experienced is on a yes (1) or no (2) scale, Severity of impacts on a No negative impacts (1) to Severe impacts (4) scale. Tukey HSD significance notation (typologies not sharing a letter are significantly different) reported only for the significant ($p<0.05$) ANOVA results for Severity of Impacts

	Typology	Vine stress due to extreme heat	Change in bud break and/or harvest timing	Reduced water availability	Frost	Weed / insect / vertebrate pressures	Disease
Negative impacts experienced	1	1.35	1.77	1.88	1.73	1.40	1.46
	2	1.36	1.57	1.77	1.55	1.24	1.43
	3	1.25	1.50	1.42	1.42	1.33	1.25
	4	1.13	1.50	1.54	1.45	1.45	1.20
	All	1.26	1.6	1.68	1.53	1.38	1.34
Severity of impacts	1	2.61	1.75 AB	1.59	1.68	2.55	2.65
	2	2.33	2.26 A	1.88	2.06	2.30	2.27
	3	2.93	2.0 AB	2.21	2.23	1.92	2.46
	4	2.84	1.67 B	2.08	2.23	2.16	2.72
	All	2.66	1.87	1.91	2.05	2.24	2.53

4.4.2 Typology and Practice Adoption

Current vineyard adaptation practice adoption was evaluated by asking if the practices were used with answer options of 1 (yes) or 2 (no). The current use rates in percentage are reported by typology [small vineyard without a winery (1), small vineyard with a winery (2), large vineyard without a winery (3), and large vineyard with a winery

(4)] for water efficiency adaptation practices (Table 2) and other adaptation practices (Table 3).

The small vineyards, type 1 & 2, have lower percentages of adoption for every water efficiency adaptation practice (Table 2) as compared to the large vineyards, type 3 & 4. Type 3 vineyards had the highest percentage of practice use for 4/5 water efficiency adaptation practices.

Table 2. Water Efficiency Practice Adoption. Reported as percentage for all respondents and by vineyard typology (1=small without winery, 2=small with winery, 3=large without winery, 4=large with winery) and for all respondents

Typology	Soil Moisture Monitoring (n=92)	Plant Tissue Sampling (n=92)	Evapotranspiration Monitoring (n=92)	Distribution Uniformity Tests (n=90)	Flow Meters (n=91)
1	38%	15%	35%	35%	35%
2	15%	20%	25%	37%	45%
3	64%	57%	50%	86%	86%
4	53%	43%	63%	63%	67%
All	41%	32%	43%	52%	55%

The adaptation practices with the highest percentage of adoption across typologies (Table 3) were drought tolerant rootstocks and cover crops. All typologies were over 75% adoption for both practices, although small vineyards (type 1 & 2) showed less adoption for both practices than large vineyards (type 3 &4). The largest difference in adoption of a practice between small and large type vineyards was fallowing, where the results were 19% for type 1, 8% for type 2, 64% for type 3, and 41% for type 4.

Table 3. Adaptation Practice Adoption Percentage. Reported for all respondents and by vineyard typology (1=small without winery, 2=small with winery, 3=large without winery, 4=large with winery).

Typology	Drought Tolerant Rootstocks (n=97)	Heat Tolerant Varieties (n=98)	Dry Farming (n=98)	Continuous No-Till (n=98)	Cover Crops (n=98)	Fallowing (n=98)	Diversification (n=97)
1	85%	33%	11%	37%	78%	19%	11%
2	83%	33%	38%	46%	79%	8%	13%
3	100%	50%	21%	21%	93%	64%	7%
4	88%	53%	31%	44%	100%	41%	19%
All	87%	42%	26%	39%	87%	30%	13%

4.4.3 Typology and Perceptions

The typology was next used to analyze perceptions about climate impacts, concern, and capability to adapt to these climate impacts (Table 4). The first factor analyzed was vineyard financial capacity to adapt to climate change. A one-way ANOVA was performed to compare the effect of vineyard typology on vineyard financial capacity to adapt. The one-way ANOVA revealed that there was a statistically significant difference in vineyard financial capacity to adapt between two groups ($F(3,93) = [5.33]$, $p = .002$]). Tukey's HSD Test for multiple comparisons found that the mean value of vineyard financial capacity to adapt was significantly different between vineyards of typology 3 (M=2.07) and typology 4 (M=3.47) (p=0.001, 95% C.I. =[0.47, -0.05]). There were no statistically significant differences in vineyard financial capacity to adapt between other vineyards typologies (ps>0.06).

The next factor analyzed with the typology was the perceived likelihood of the scenario occurring. A one-way ANOVA was performed to compare the effect of vineyard typology on perceived likelihood of the scenario occurring. The one-way ANOVA revealed that there was a statistically significant difference in perceived likelihood of the scenario occurring between at least two groups ($F(3,93) = [3.27]$, $p = .02$]). Tukey's HSD Test for multiple comparisons found that the mean value of perceived likelihood of the scenario occurring was not significantly different between vineyards of different typologies (*p*s>0.05).

Table 4. Perceptions of Climate Adaptation and Climate Scenario. Reported for all respondents and by vineyard typology (1=small without winery, 2=small with winery, 3=large without winery, 4=large with winery) on a 5-point Likert scale. Significant ANOVA results (p<0.05) are represented by *. Tukey HSD significance results are represented by significance letters, with typologies not sharing a letter for a practice being significantly different from each other

Typology	Have the knowledge and skill to adapt	Have the financial capacity to adapt *	Crop insurance will keep vineyard economically viable regardless	Likelihood of scenario occurring *	Impact if scenario occurs
1	3.04	2.85 AB	2.22	3.37 A	1.96
2	3.5	3.0 AB	2.54	3.92 A	1.92
3	3.14	2.07 A	2.29	3.36 A	2.07
4	3.03	3.47 B	2.0	4.0 A	1.94
All	3.15	2.94	2.23	3.73	1.94

4.5 Barriers to Climate Adaptation Practice Adoption

The most widely experienced barrier to adoption of conservation and climate adaptation practices was the financial expense to implement and manage the practices, which was the most important barrier for 88% of practices it was asked about for. Barriers to the use of the different adaptation measures were asked as a follow up for each practice for which adoption was examined, with only the respondents who answered that they did not use the practice answering the barriers questions.

Barriers to the use of soil moisture sensors, plant tissue sampling, and evapotranspiration monitoring (Figure 8) had financial expense as the most important barrier while insufficient benefit for the time spent and the need to learn new skills or techniques were secondarily important barriers. For barriers to the use of distribution uniformity tests (Figure A-4), financial expense was the most important while the need to learn new skills or techniques was second most important. The most important barrier to the use of flow meters (Figure A-5) was the financial expense, with the second most important being the need to learn new skills or techniques. Drought tolerant rootstocks (Figure A-6) had financial expense as a main barrier, with a second barrier being that they're still missing traits that are wanted. Heat tolerant varieties (Figure A-7) were found to have main barriers of their financial expense and a concern about lack of market for these varieties. Dry farming (Figure A-8) had a main barrier of lack of sufficient rainfall, which more than 70% of respondents reported. Reduced yields were also a barrier to dry farming. Continuous no-till (Figure A-9) had barriers of pest/weed concerns and compaction concerns. Cover crops (Figure A-10) had barriers of financial expense, pest/weed concerns, concerns about water use, and seeding timing challenges.

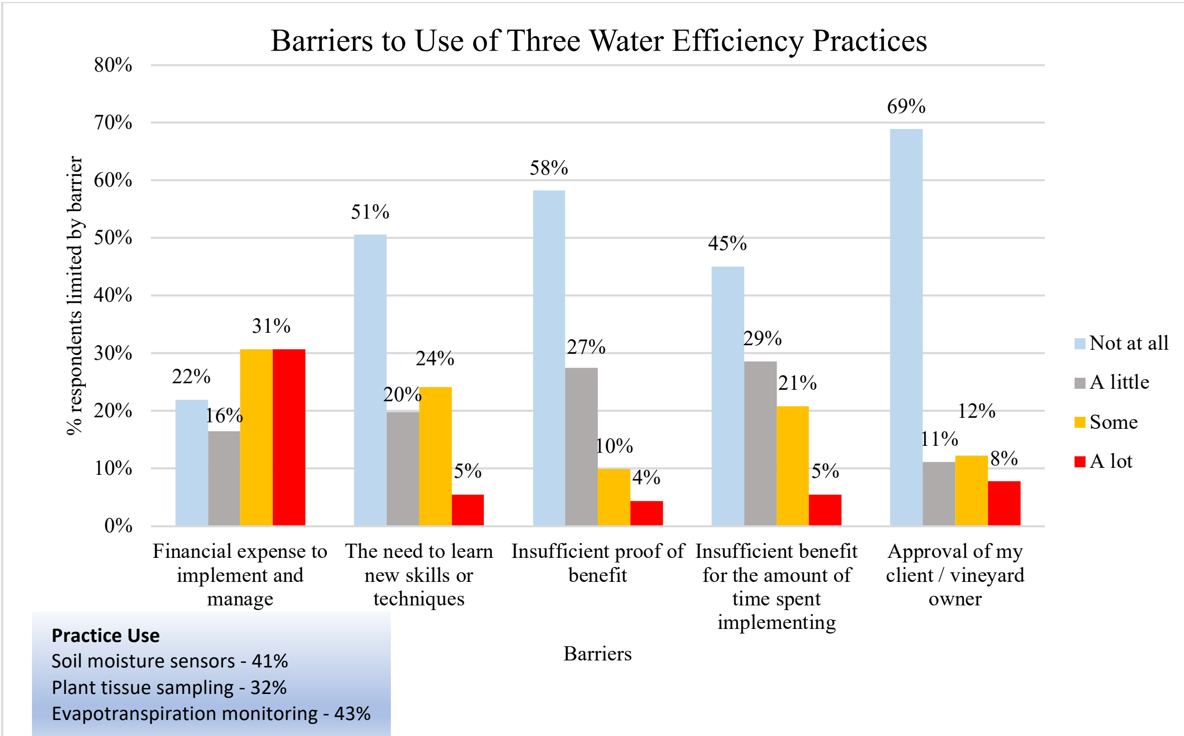


Figure 8. Barriers to the use of soil moisture sensors, plant tissue sampling, and evapotranspiration monitoring by percentage of respondents who were limited in their use of these practices by each barrier (n=91).

4.6 Information Sources

There was a large disparity in trust between different sources of vineyard soil and water management, as seen in Figure 9. The information sources which received the most percentage of "Very much" trusted answers were the UC Cooperative Extension (56%, n=97) and Cal Poly State University (45%, n=97). The next highest "Very much" trusted information sources were vineyard management companies or viticultural consultants (41%, n=97), Central Coast Vineyard Team (39%, n=97), and Independent Grape Growers of the Paso Robles Area (IGGPRA) (39%, n=98). The information

sources most “Moderately” trusted were the Paso Wine Country Alliance (40%, n=97) and other growers (40%, n=96)

The information source with the most percentage of “Not at all” trusted answers was the Upper Salinas – Las Tablas Resource Conservation District (22%, n=96). The Resource Conservation District also received the largest amount of “Not familiar” responses (17%, n=96). The next highest percent of “Not at all” trusted were Groundwater Sustainability Agencies (16%, n=97) and Agricultural Supply Retailers (15%, n=98). Agricultural Supply Retailers also received the most “Slightly” trusted responses (40%, n=98).

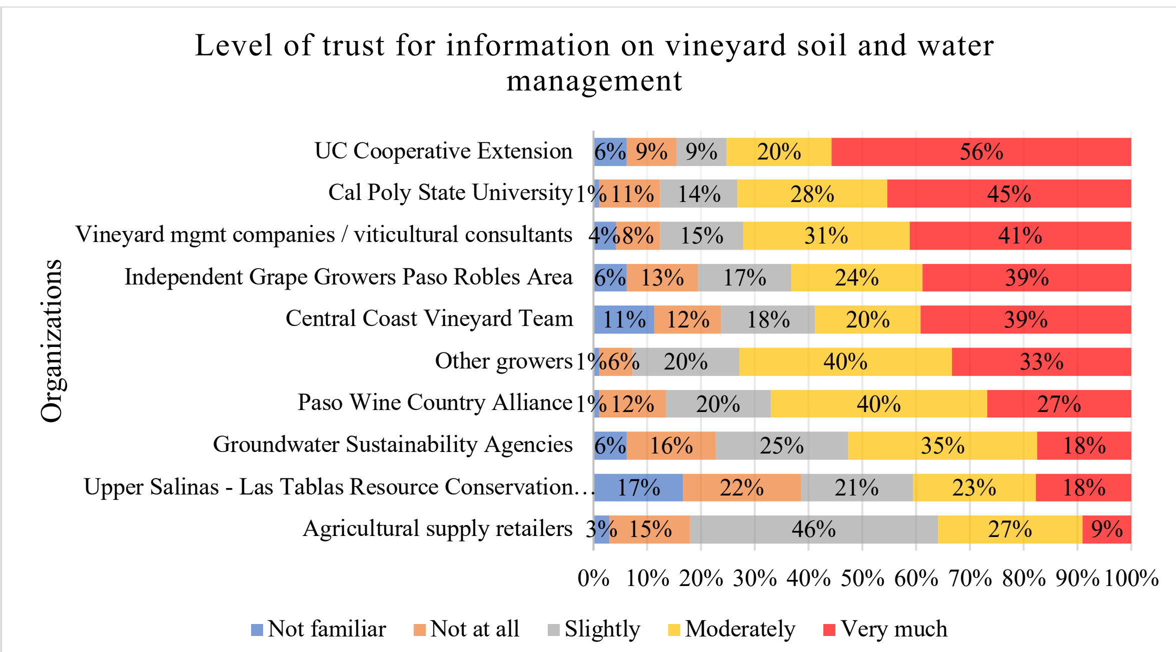


Figure 9. Level of trust for vineyard soil and water management information sources on a scale of “Not familiar”, “Not at all” to “Very much”

4.6.1 Decision Support Tool

Our projection of future climate impacts for east and west sides of the Paso Robles AVA functioned as our decision support tool (DST) for the survey (see projected scenario in Appendix B). 67% of respondents (n=99) found the projected scenario somewhat or extremely likely to occur (Figure 10), with only 11% finding the scenario somewhat or extremely unlikely to occur.

The majority of respondents also found that the projection was helpful (Figure 11) for vineyard risk management and adaption planning (80%) and that it was useful to know how temperatures and rainfall will change over the next 25 years and resulting impacts (83%). The projection was found to increase the concern of many respondents about climate change impacts on their vineyards (63%), although 27% were uncertain if the projection increased their concern. Only 11% disagreed that the projection increased their concern about these impacts.

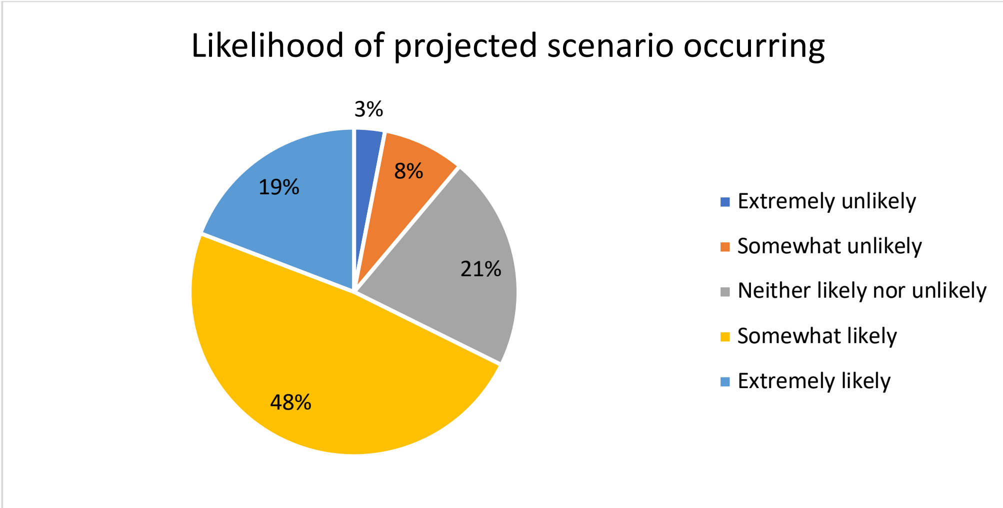


Figure 10. Likelihood of projected scenario provides to respondents occurring by percentage of likelihood category on a scale of "Extremely unlikely" to "Extremely likely" (n=99)

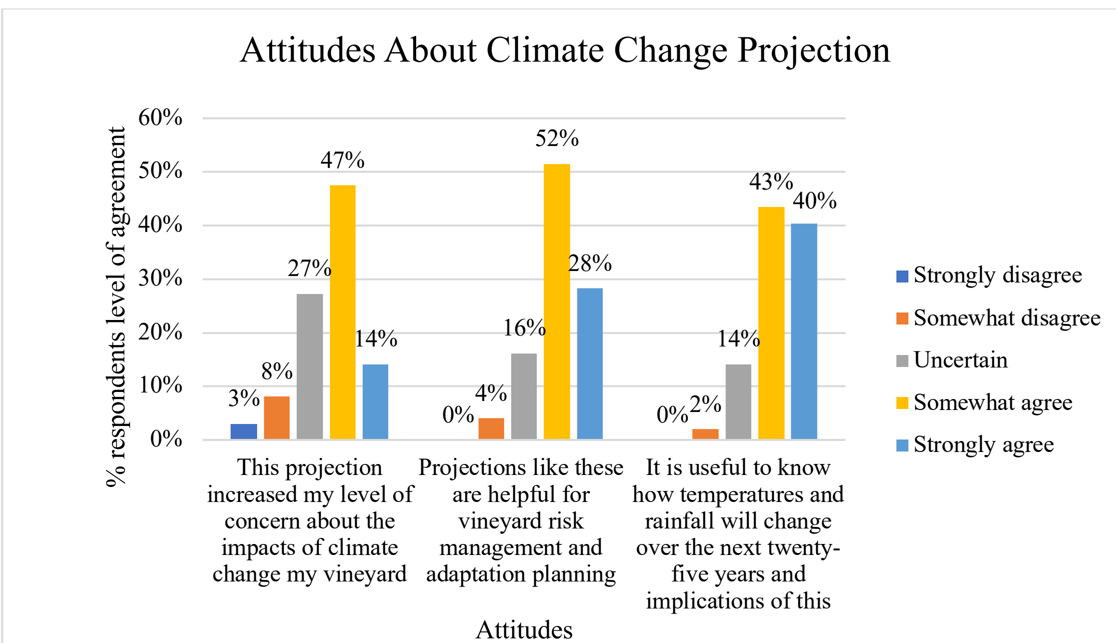


Figure 11. Level of agreement with statements associated with the climate change projection provided to respondents on a scale of "Strongly disagree" to "Strongly agree" (n=99)

Chapter 5

DISCUSSION

The purpose of our study is to gain increased understanding of the factors affecting viticultural adaptation decision-making, which will help government and local non-governmental organizations increase the efficacy of their climate adaptation education and implementation programs.

Our research questions (RQ) for this study were:

RQ1: What risks to the economic viability of vineyards are important/ already experienced?

RQ2: What are the perceived impacts of the climate scenario, attitudes towards scenario, and perceptions of capacity to adapt?

RQ3: What is the prevalence of adoption of water efficiency, soil conservation and climate adaptation measures?

RQ4: How are RQs 1-3 influenced by vineyard typology?

RQ5: What are the barriers and opportunities to conservation practice and climate adaptation practice adoption in the Paso Robles AVA?

RQ6: What sources of information about vineyard soil and water management are most trusted in the Paso Robles AVA?

Our findings illustrate that Paso Robles vineyards of smaller acreage as well as those without a winery are most vulnerable to climate change. Our results show that reduction in irrigation water has not been widely experienced by vineyards, but it is anticipated by vineyard managers to be the biggest risk for viticulture in the AVA moving forward. However, this has not yet led to high adoption rates of water conservation best management practices. We also found moderate uncertainty among vineyards about their capacity to adapt to climate change, with financial capacity being the leading cause for uncertainty and the leading barrier to implementation of adaptation practices. Lastly, source of information was found to be an important factor for vineyard trust in climate adaptation information. We suggest that adaptation outreach organizations coordinate to build trust, cater outreach to vineyard type, prioritize vineyards with lower adaptive capacity, and prioritize financial and water efficiency assistance in the short-term to decrease vineyard vulnerability and support adoption of climate change adaptation and water conservation best management practices.

5.1 Climate Adaptation Perceptions, Adoption, and Barriers

Paso Robles vineyard owners and managers were found to widely believe that climate change is occurring (94%), although they were split on whether it is mainly human-caused (41%) or equally natural and human-caused (44%), with only 9% believing it was occurring and mostly natural (Figure 5). These results compare to a

2012 survey in the United States corn belt, where 66% of farmers believed climate change was occurring, 8% believed it was mainly human-caused, 33% believed it was equally natural and human-caused, and 25% believed it was mostly naturally caused (Arbuckle et al., 2013b). Arbuckle et al. (2013b) also found that belief in climate change and its human cause increased concern about climate impacts and support of adaptation measures among these farmers. Our results of greater belief in climate change and its mainly or partly human cause should indicate that vineyards are supportive of adaptation, which based on previous research would hopefully lead to greater adoption of practices.

Most vineyards perceived that they were uncertain of or did not have the financial capacity for climate adaptation (Figure 6), highlighting the importance that financial assistance, or lack thereof, can have in the adoption of adaptation practices. The importance of financial barriers to adaptation and financial assistance has been shown consistently in the literature (Moser et al., 2018; Agrawal, 2008; Ali et al., 2017; Palutikof et al., 2019a). Addressing the issue of limited financial capacity, there are multiple sources of funding available from the public and private sector for adaptation, with California's Integrated Climate Adaptation and Resiliency Program as a resource to coordinate and display these funding opportunities (Moser et al., 2018). Technical skill to deal with climate change was perceived to have more capacity on vineyards than financial capacity, although a majority of respondents were still uncertain or disagreed that they had the knowledge or skill capacity to adapt. According to our results, for successful increase in adaptation practice adoption on Paso Robles vineyards, financial assistance is most needed, but technical assistance is a secondary and complimentary need. Local agencies and industry groups, such as the Upper Salinas – Las Tablas RCD,

already provide information on funding opportunities and technical assistance (Upper Salinas, n.d.). The access and uptake of this information, or the opportunities available, are insufficient and have maintained financial and technical assistance as the main barriers to adaptation in Paso Robles vineyards.

Adoption rates (Figure 7) were low for most other practices in addition to the water efficiency practices, and even the vineyards who utilized the practices often did so on a small percentage of their total vineyard acreage (Figure 8). We found that our adaptation practice use results were similar to the results of previous research done in the area. We found that 87% of respondents used cover crops and 39% used continuous no-till, while Guerrero (2020) found in interviews with 11 Paso Robles viticulturalists that 100% practiced cover crops and 45% practiced conservation tillage. There is a major opportunity for increased climate adaptation practice use in Paso Robles vineyards due to their current low usage rates.

We hypothesized that vineyards on rented land or managed by a vineyard management company may reduce the likelihood of adaptation practices being implemented. This was based on the premise that they may not see return on their adaptation investment depending on their contract and that communication with the landowner about these practices can be difficult (Petrzelka et al., 2021). Our findings suggest that this factor was not a major issue (Figures A-4 through A-10), as the approval of client or vineyard owner was answered majority “Not at all” a barrier for all barrier questions. These findings mean that adaptation outreach does not have to account for this barrier and can instead target all land ownership type of vineyards in a similar fashion.

5.2 Water and Efficiency Practices

Our results show that a majority of viticulturists in Paso Robles have not experienced reduced water availability (Figure 2), although they anticipate groundwater regulations and water supply to be the most important risk to the economic viability of their vineyards moving forwards (Figure 1). Water is clearly a major concern for viticulture in the area, particularly with the Groundwater Sustainability Plan (GSP) implementation on the horizon. The GSP contains possible mandatory pumping limitations for certain areas (Paso Robles Groundwater, 2019), which does make it a risk for vineyards, but also provides motivation to adopt efficient water practices. In addition, the climate impact most concerning to vineyards was reduced rainfall (Figure 5), which follows with their anticipation of water supply as a risk. These results can help the Paso Robles Groundwater Sustainability Agencies to better interface with vineyards to increase water efficiency practice use and as they implement the GSP.

Water efficiency practices (soil moisture monitoring, plant tissue sampling, evapotranspiration monitoring, distribution uniformity tests, and flow meters) have very low adoption rates in Paso Robles vineyards, with only flow meters and distribution uniformity tests used by at least half of respondents. In addition, only a small portion of vineyards altered their irrigation intervals and irrigation duration based on monitoring (Figure 7). Despite the Paso Robles groundwater subbasin being annually overdrafted, some vineyards having already experienced reduced water availability (Figure 2), major concerns about reduced rainfall, water supply, and resulting groundwater regulations (Figures 1 & 3), and the implementation of the GSP with possible mandatory pumping limitations on the horizon, most Paso Robles vineyards don't quantify their water use or

use BMPs for water efficiency. These practices would reduce individual vineyard vulnerability to climate change, as well as the vulnerability of every other vineyard and agricultural producer in the region.

The main barrier to vineyard adoption of all five practices were the financial costs to implement these practices. These results echo those of other research conducted on barriers to adaptation, which find that lack of funding is most important (Nordgren et al., 2016; Moser & Ekstrom, 2010). The second most important barrier was the need to learn new skills or techniques, which can also be partially attributed to the financial aspect of time and money spent learning these skills. A solution is therefore a funding and technical assistance program to help vineyards address both barriers preventing adoption of water efficiency practices. This program would only gain importance moving forward, as the current vineyard water concerns turn into widely and severely experienced impacts. The Paso Robles Groundwater Sustainability Agencies and other responsible agencies/entities should incorporate these results into planning for implementation of the Paso Robles Subbasin GSP, as they provide an understanding of what may limit their success. The next vital piece of information to increase effectiveness of water efficiency practices, and adaptation in general, is which vineyards or population needs the most focus for assistance.

5.3 Vineyard Typology

As hypothesized, our typology analysis showed that smaller vineyards adopted water efficiency practices at a far lower rate than larger vineyards. Small vineyards had the lowest water efficiency practice adoption rates, with vineyards of Type 1 & 2 having

the lowest adoption rates for every single practice. The small vineyards without a winery (Type 1) had the lowest adoption for 3/5 water efficiency practices, which suggest reduced resilience to the impacts of climate change and the groundwater challenges already facing the Paso Robles region. This reduced adoption of practices, however, has been largely offset by a large difference in experienced reduced water availability (Table 1) between the small vineyards and the large vineyards. Due in large part to the small vineyards' size, they don't require as much water and haven't experienced reduction in water as much as the larger vineyards, while also reporting less severity if they did (Table 1). These small vineyards have not experienced water impacts to the same extent, leading to reduced usage of water efficiency practices.

The vineyards without wineries had less perceived financial capacity to adapt than did the vineyards with wineries, indicating a clear need for adaptation assistance (Table 3). The vineyards without wineries likely have lower perceived financial capacity largely due to missing out on the large amount of value-added during wine production. Rather than gaining the value of selling wine, non-estate vineyards sell their grapes to the winemaking market, where varying prices due to market oversupply is a major concern for vineyards. Contracts with wineries can provide assurance to these vineyards without wineries, but 44% of the small vineyard without wineries also had no contract for the 2021 season (Table A-1). The lower perceived financial capacity for smaller vineyards can likely be largely attributed to their typically smaller capital source as compared to a large vineyard, making economic impacts of climate change more difficult to deal with (Rivera, 2020).

Interestingly, the large vineyards without wineries reported the lowest perceived financial capacity to adapt, lower than even the small vineyards without wineries. This may be attributed to their sources of income, as 64% of respondents from large vineyards without wineries received 76-100% of their income from viticulture as compared to 4% of small vineyards without wineries, 21% of small vineyards with wineries, and 60% of large vineyards with wineries (Table A-1). The vineyard owners and managers for smaller vineyards can maintain income diversification, while owners and managers of the larger vineyards are largely all-in on their vineyards as their source of income. Previous research has shown that income diversification is correlated with better ability to deal with shocks (Schwarze & Zeller, 2005), decreasing their vulnerability against risks such as climate change (Chambers, 1995).

Arbuckle et al. (2013b) suggests that perceptions, concerns, and beliefs about climate change and adaptation should be used to create effective outreach. The Groundwater Sustainability Agencies, RCD, and other entities encouraging or facilitating adaptation can take our results into account to create a targeted and effective outreach message for each of the types of vineyards in our typology. The outreach for small vineyards (type 1 & 2) needs to be greater due to their reduced perceived adaptive capacity and needs to include both financial and technical assistance. Outreach could be seminars through the Independent Grape Growers of the Paso Robles Area (IGGPRA) with assistance from the Central Coast Vineyard Team or local vineyard consultants about the practices and funding opportunities for them. Assistance with decision support tools could be carried out by Cal Poly or UC Extension and would be most useful for type 1, 2, and 3 vineyards, as Babin et al. (in press) finds that large estate vineyards are

more likely to already utilize decision support tools for adaptation forecasting. The outreach for small vineyards with a winery (type 2) should be financial based, but also one of the lesser priorities compared to type 1 and 3 vineyards. The outreach for large vineyards without a winery (type 3) should focus heavily on opportunities for financial assistance, which could consist of one of the trusted organizations, like UC Extension, sharing funding opportunities but also teaching how to find the funding opportunities through California's Integrated Climate Adaptation and Resiliency Program. The outreach for large vineyards (type 3 & 4) should also focus on water efficiency, as these vineyards use more water and therefore are more vulnerable to changes in water availability. The State Water Efficiency and Enhancement Program (SWEEP) should be highlighted for their financial assistance for irrigation improvements (Upper Salinas, n.d.). The Paso Robles Groundwater Sustainability Agencies and the RCD could take part in this outreach, with the RCD mobile irrigation lab providing a good opportunity to analyze and improve irrigation efficiency. Type 4 vineyards should not be the priority for adaptation outreach and programming but could use technical assistance which could be provided by UC Extension.

5.4 Information Sources and DSTs

Our results indicate that there is a wide disparity in trust between different sources of information on conservation and adaptation practices. Trust is critical for communication with farmers that aims to change their behavior (Mase et al., 2015), such as adopting adaptation practices. Unexpectedly, the Upper Salinas – Las Tablas Resource Conservation District (RCD), who would usually be responsible for managing

governmental cost share programs, was found to be one of the least trusted information sources (Figure 9). The most trusted sources were academic (UC Cooperative Extension and Cal Poly), which aligns with the findings of previous studies in Napa and Sonoma wine country (Nicholas & Durham, 2012). Vineyard management companies and consultants were also found to be very trusted, positioning these universities and companies/consultants as a best option for providing information about climate adaptation to Paso Robles vineyards.

Among the vineyard owners and managers we surveyed, financial capacity to adapt to climate change was very uncertain and presented the biggest barrier to implementation of adaptation measures. As a result, programs such as equipment grants and cost-sharing could be of massive importance to increasing adoption rates. Funding opportunities already exist for adaptation: State Water Efficiency and Enhancement Program for water efficiency adaptation and drought relief and the Healthy Soils Program for soil management practices (California Department of Food and Agriculture, n.d.). The Department of Food and Agriculture also offers technical assistance to accompany these funding programs and has future additional funding opportunities through the Conservation Agriculture Planning Grants Program.

The Upper Salinas – Las Tablas RCD is a main provider of technical assistance, irrigation evaluations, conservation evaluations and more services to the Paso Robles area (Upper Salinas, n.d.). However, with the low trust we found in them, it may not be the best organization to directly interact with the vineyards for adaptation. An opportunity for the RCD to address this issue presents itself in our finding that 17% of respondents were not familiar with the organization. Previous research has shown that strategies to

increase familiarity of information sources could increase trust in that source among farmers (Mase et al., 2015). Further outreach on the part of the RCD, optimally together with the highly trusted information sources, would be a good strategy to increase their trustworthiness and effectiveness in their work with vineyards.

We found that our Cal-Adapt climate projection, which functioned as our DST, was very well received and useful for vineyard managers. The projected scenario was helpful for respondents' risk management and adaptation planning, with the knowledge of how local climate will change and resulting impacts found to be very useful information. This confirmed the qualitative findings of Babin et al. (in press). These viticultural decision support systems and tools, with Cal-Adapt as a specifically useful version, can help vineyard managers to make better informed management and planning decisions, especially for adaptation. However, the scale, ease of use, and knowledge of these tools' existence and usefulness is an area which needs to be addressed.

Decision support tools need to be expanded in both their capabilities and their accessibility for vineyard managers and farmers in general. In addition, the tools need to be further refined by increasing resolution, which would make it easier to tailor projections to specific vineyards, and by increasing specificity of results. The Cal-Adapt downscaled projections utilized can provide projection at the relatively small-scale of 6 km squared (*Cal-Adapt*, n.d.). These projections can therefore provide a relative idea of local microclimates, which is needed for a truly effective DST. Additional features for Cal-Adapt use in vineyards have also been requested by managers, such as extreme cold events during the growing season and soil moisture or evapotranspiration (Babin et al., in press). There is an opportunity for trusted outreach organizations to work with vineyard

managers to generate more precise scenario projections, as well as incorporating more useful features that Paso Robles vineyard managers have stated their interest in. Projections which account for microclimates at an individualized, vineyard-specific level will be crucial for usage as a DST due to the many microclimates in the Paso Robles area (Babin et al., in press). Projections with a vineyard-specific scale and increased relevant features will increase their effectiveness and use as DST for Paso Robles vineyards.

5.5 Shortcomings

One possible limitation to our study was that both vineyard owners and managers were included in our survey sample, meaning that some respondents may not actually be responsible for the direct management of a vineyard. Landowners are still likely to have an influence on adaptation decision-making, especially in the long-term, but we have found that their approval is not a major barrier to use of most adaptation practices. Non-manager owners may have answered some questions which they didn't know about, but their feedback on other questions such as financial capacity to adapt was important, and so they were included.

Another limitation of our study is that only two projections were utilized, one for east and one for west Paso Robles. Only two were used due to the logistical challenges of creating an individualized projection for each vineyard within a widely distributed survey instrument. These projections therefore covered a relatively large area, resulting in microclimates not being accounted for. The projection was not vineyard specific, which could have affected the outcome of this survey significantly. However, Cal-Adapt can produce vineyard-specific projections, it was just not feasible for this study.

A last shortcoming is our choice of analysis procedures, as our combination of ANOVA and Tukey HSD post-hoc testing provided a conflicting result for one test. ANOVA found significant difference among groups for this test, while the Tukey HSD post-hoc test found no significant differences pairwise differences between groups. The Tukey HSD test is a conservative test, as the pairwise differences are analyzed using the sampling distribution for the largest difference (Abdi & Williams, 2010), which could explain why this occurred. The conflict between tests hinders analysis and understanding of the results, and therefore was a shortcoming of this study.

Chapter 6

CONCLUSION

This study has examined Paso Robles American Viticultural Area vineyard owner and manager perceptions, adoption of, and barriers to climate adaptation and water conservation practices. We found that financial and technical capacity are the most important barriers to adaptation to be addressed. Funding programs, optimally packaged with technical assistance, could be of massive importance to increasing adoption rates in the Paso Robles AVA. We suggest that the Upper Salinas – Las Tablas Resource Conservation District collaborate with other, more trusted information sources for vineyard adaptation outreach. The RCD can be the funding source, but the other organizations, such as Cal Poly or the UC Extension, may be the connection between the vineyards and the RCD to increase trust in the information and assistance. We suggest that vineyard adaptation outreach and support be implemented through trusted sources, focus on water efficiency, utilize decision support tools such as Cal-Adapt, tailor approaches to the characteristics of the vineyard, and focus on financial and technical assistance to increase vineyard capacity to adapt.

Further research should be conducted on the opportunities for adoption, such as the different methods of cost sharing or ways that the money could be directed to vineyard managers from trustworthy sources. Studies determining further vineyard vulnerability characteristics will be helpful to determine which types of vineyards should be prioritized for financial or technical assistance with adaptation. Tracking of attitudes about water and implementation of the Groundwater Sustainability Plan (GSP) is another area of importance for the vineyards in the Paso Robles area. Creating further

understanding of vineyard owner and manager attitudes and perceptions of SGMA and the GSP would be helpful for determining the most effective measures and methods of education and plan adoption.

From a broader perspective, much of the approach we have taken in this survey and the conclusions that we draw may be applicable to other sectors of agriculture as well. The survey itself could even be adapted to be used on growers of other specific crops which may be particularly vulnerable to the impacts of climate change. Viticulture is a good starting point for understanding climate adaptation decision-making, but implications, similarities, and differences between the processes and outcomes between viticulture and other types of agriculture could be impactful.

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APPENDICES

Appendix A
ADDITIONAL FINDINGS

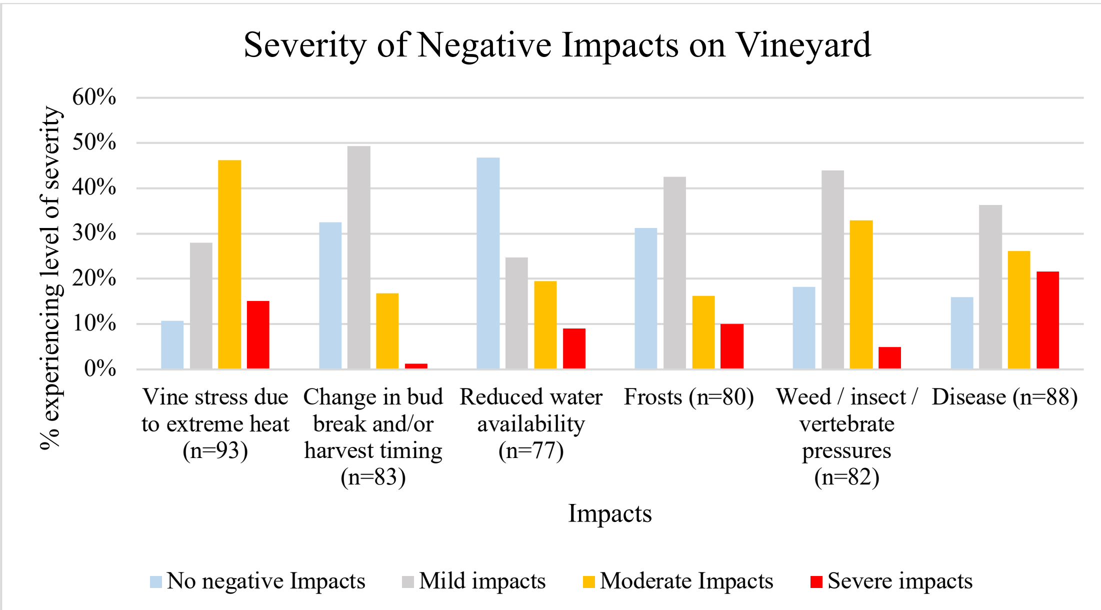

Figure A-1. Percentage experiencing level of severity of negative impacts on vineyards scaled from 0 (no negative impacts) to 4 (severe impacts)

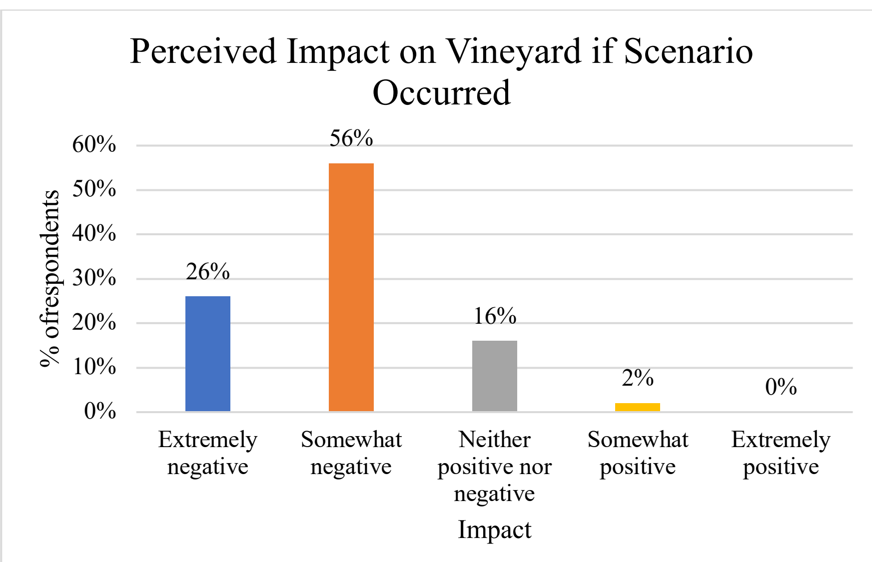

Figure A-2. Perceived impact of the projected climate scenario presented to respondents (n=100)

Table A-1. Demographics of Respondents and Characteristics of Vineyards. Reported overall and by vineyard typology (1=small without winery, 2=small with winery, 3=large without winery, 4=large with winery). Percentages rounded to nearest whole number.

Category	Characteristic	All	Type 1	Type 2	Type 3	Type 4
Highest Level of Education Completed (n=97)	Some formal schooling	0	0	0	0	0
	High school diploma / GED	2 (2%)	0	0	1 (7%)	1 (3%)
	Some college	10 (10%)	1 (4%)	6 (25%)	2 (14%)	1 (3%)
	2-year college degree	5 (5%)	1 (4%)	2 (8%)	2 (14%)	0
	4-year college degree	47 (48%)	11 (41%)	10 (42%)	6 (43%)	20 (65%)
	Graduate degree	33 (34%)	14 (52%)	6 (25%)	3 (21%)	9 (29%)
Proportion of income from Viticulture (n=97)	0-25%	43 (44%)	24 (89%)	12 (50%)	2 (14%)	4 (13%)
	26-50%	12 (12%)	2 (7%)	3 (13%)	3 (21%)	4 (13%)
	51-75%	8 (8%)	0	4 (17%)	0	4 (13%)
	76-100%	34 (35%)	1 (4%)	5 (21%)	9 (64%)	18 (60%)
Age	Mean year born (n=95)	1965	1955	1966	1966	1971
	Mean years in viticulture (n=97)	16.3	12.1	15.5	19.3	19.1
Number of Winegrape Varieties (n=97)	1	10 (10%)	8 (30%)	0	2 (14%)	0
	2	9 (9%)	5 (19%)	3 (13%)	0	0
	3	7 (7%)	2 (7%)	4 (17%)	0	1 (3%)
	4	9 (9%)	6 (22%)	2 (8%)	1 (7%)	0
	5	9 (9%)	2 (7%)	5 (21%)	2 (14%)	0
	6+	53 (55%)	4 (15%)	10 (42%)	9 (64%)	30 (97%)
Principal variety grown (n=97)	Cabernet sauvignon	47 (48%)	5 (19%)	9 (38%)	14 (100%)	19 (61%)
	Merlot	1 1%)	0	1 (4%)	0	0
	Zinfandel	9 (9%)	7 (26%)	1 (4%)	0	1 (3%)
	Syrah	15 (15%)	2 (7%)	4 (17%)	0	8 (26%)
	Petite Syrah	5 (5%)	4 (15%)	1 (4%)	0	0
	Cabernet Franc	1 (1%)	1 (4%)	0	0	0
	Grenache	12 (12%)	4 (15%)	6 (25%)	0	2 (6%)
	Mourvèdre	0	0	0	0	0
	Petit Verdot	2 (2%)	2 (7%)	0	0	0
	Chardonnay	1 (1%)	0	1 (4%)	0	0
	Sauvignon Blanc	0	0	0	0	0
	Pinot Noir	0	0	0	0	0
	Other red	4 (4%)	2 (7%)	1 (4%)	0	1 (3%)
	Other white	0	0	0	0	0
Contract Type (n=90)	No contract for the 2021 harvest	30 (33%)	11 (44%)	8 (35%)	1 (8%)	10 (34%)
	Secured for only for 2021 harvest	21 (23%)	5 (20%)	4 (17%)	2 (17%)	10 (34%)
	Secured for 2021 and 2022 harvests	7 (8%)	2 (8%)	2 (9%)	1 (8%)	1 (3%)
	Secured for next 3 or more harvests	32 (36%)	7 (28%)	9 (39%)	8 (67%)	8 (28%)
	Don't know	0	0	0	0	0
Certifications	Organic certified (n=97)	20 (20%)	0	4 (57%)	4 (31%)	7 (64%)
	SIP certified (n=98)	15 (15%)	4 (100%)	3 (43%)	9 (69%)	4 (36%)
Number of full-time employees (n=96)	0	24 (25%)	16 (64%)	5 (21%)	3 (21%)	0
	1-5	45 (47%)	8 (32%)	16 (67%)	7 (50%)	13 (41%)
	6-10	8 (8%)	0	2 (8%)	1 (7%)	5 (16%)
	11-25	8 (8%)	0	0	2 (14%)	6 (19%)
	26-100	8 (8%)	0	1 (4%)	1 (7%)	6 (19%)
	101+	3 (3%)	1 (4%)	0	0	2 (6%)

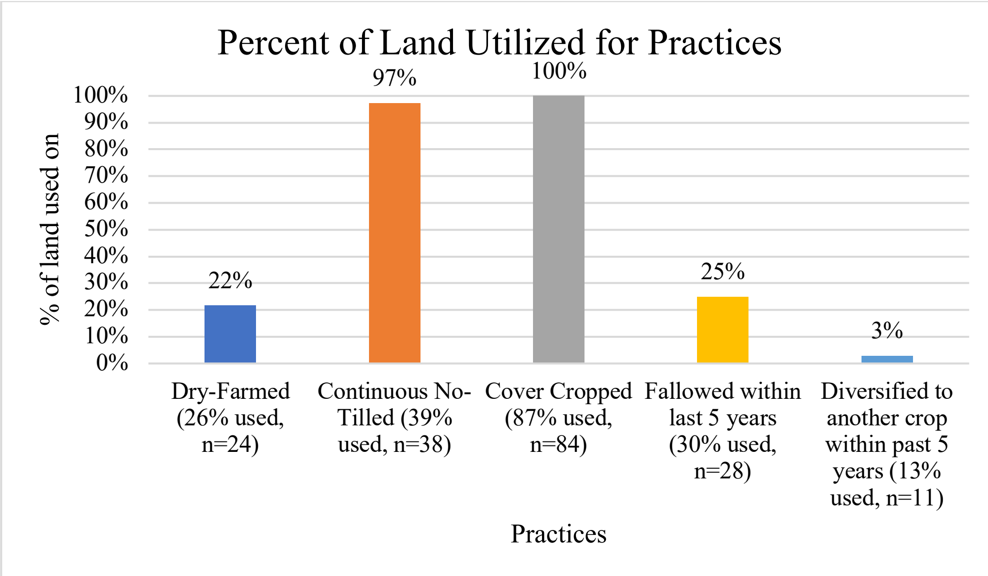

Figure A-3. Current percentage of land selected adaptation practices were used on for respondents who did use the practice

Table A-2. Vineyard Manager Concerns About Climate Impacts. Reported as average for all respondents and by vineyard typology (1=small without winery, 2=small with winery, 3=large without winery, 4=large with winery) on a scale of 1 (Not at all concerned) to 5 (Extremely concerned). n=98

Typology	**Concern about extreme high temps**	**Concern about extended heat waves**	**Concern about increased mean growing season high temps**	**Concern about loss of nighttime cooling**	**Concern about reduced rainfall**	**Projection increased concern about climate impacts**
1	3.81	4.19	3.74	3.59	4.27	3.59
2	3.67	3.83	3.42	3.78	4.5	3.58
3	4.0	4.29	3.64	3.64	4.43	3.5
4	3.84	4.38	3.78	3.84	4.69	3.66
All	3.8	4.2	3.7	3.8	4.5	3.62

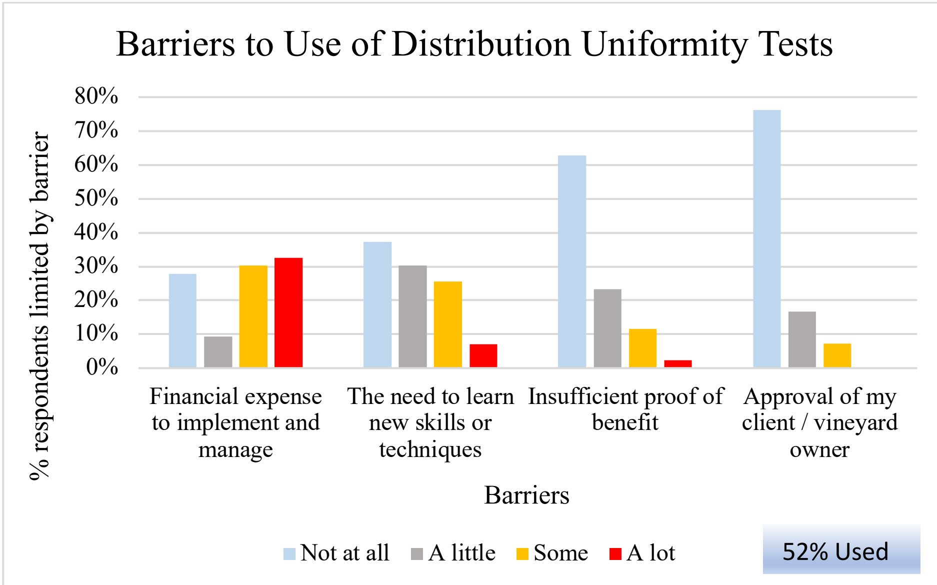

Figure A-4. Barriers to use of distribution uniformity tests in vineyard by percent of respondents experiencing the barrier on scale of "Not at all" to "A lot" (n= 43)

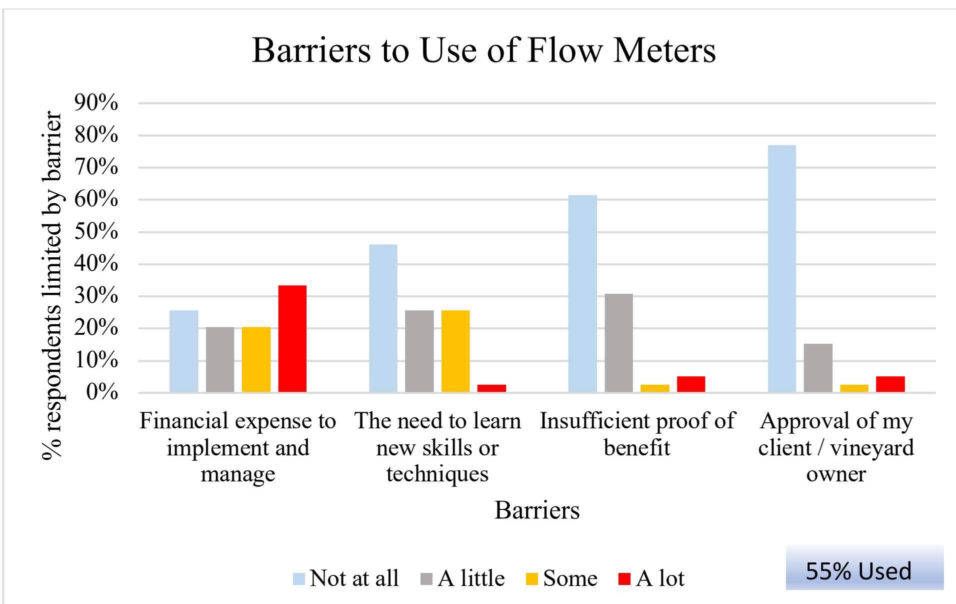

Figure A-5. Barriers to use of flow meters in vineyard by percent of respondents experiencing the barrier on scale of "Not at all" to "A lot" (n= 39)

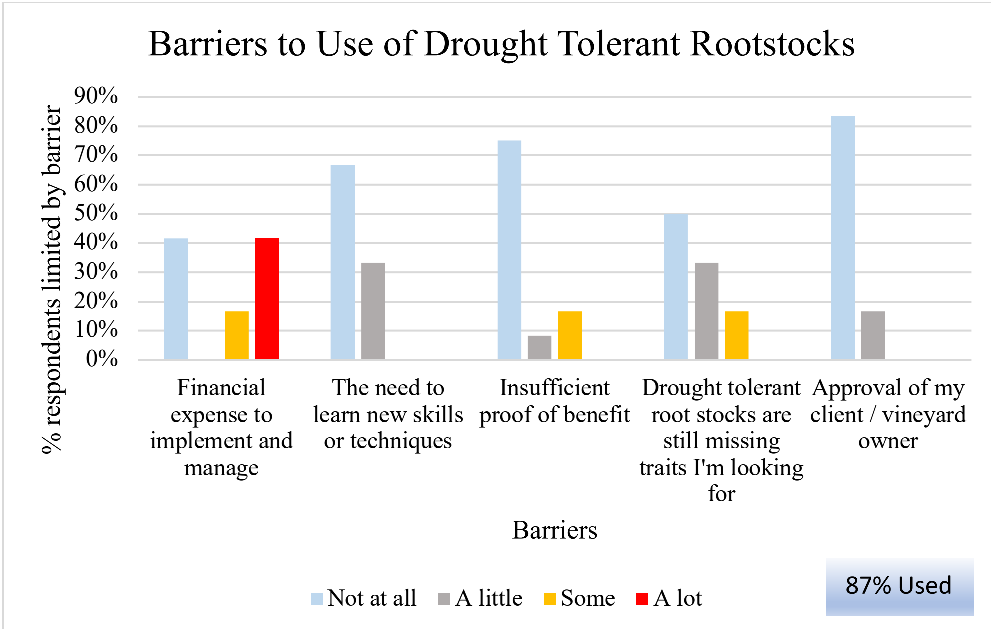

Figure A-6. Barriers to use of drought tolerant rootstocks in vineyard by percent of respondents experiencing the barrier on scale of "Not at all" to "A lot" (n= 12)

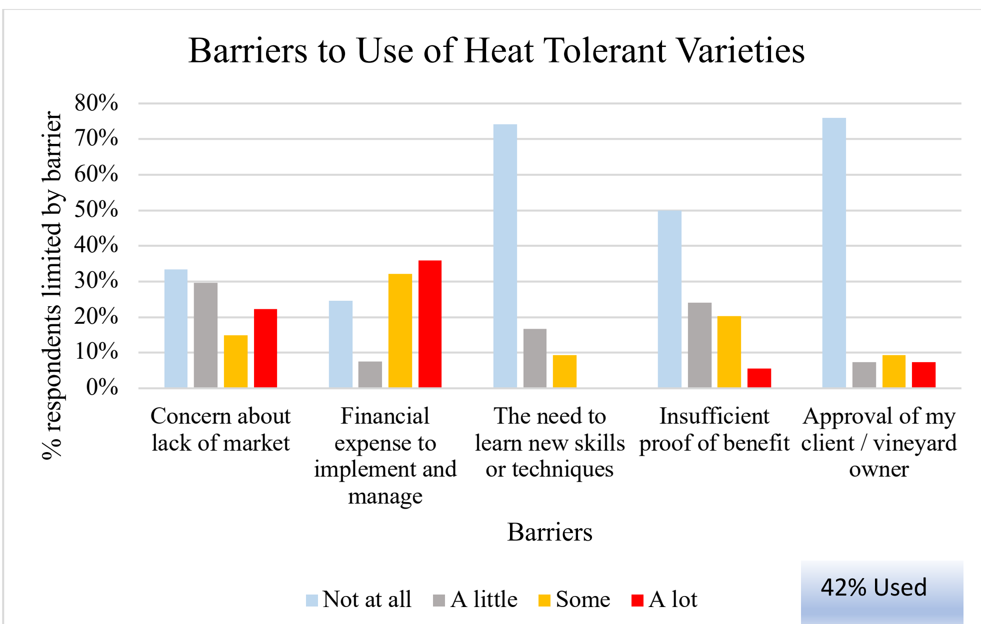

Figure A-7. Barriers to use of heat tolerant varieties in vineyard by percent of respondents experiencing the barrier on scale of "Not at all" to "A lot" (n= 54)

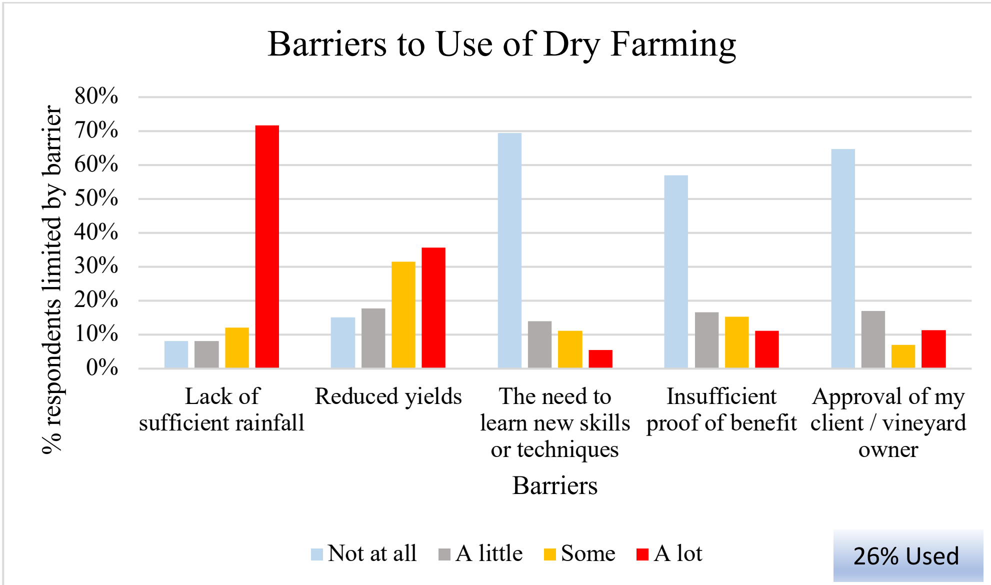

Figure A-8. Barriers to use of dry farming in vineyard by percent of respondents experiencing the barrier on scale of “Not at all” to “A lot” (n= 74)

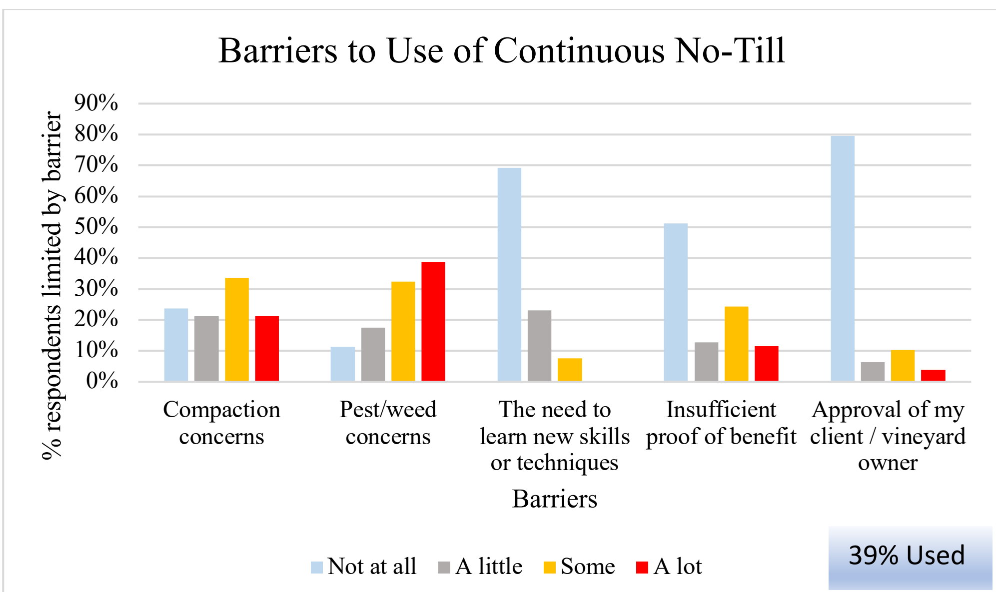

Figure A-9. Barriers to the use of continuous no-till in vineyard by percent of respondents experiencing the barrier on scale of “Not at all” to “A lot” (n= 78)

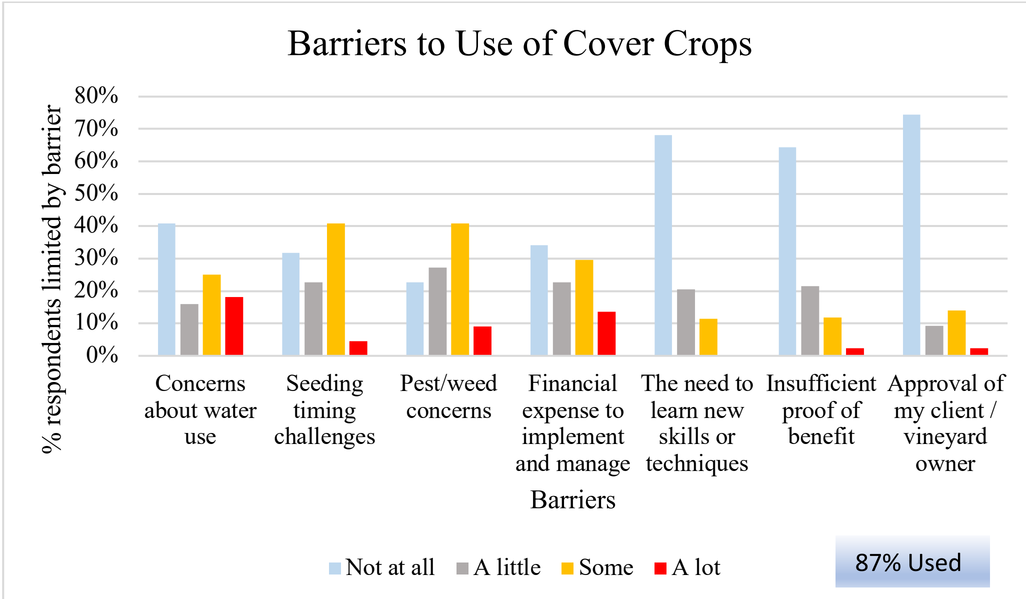

Figure A-10. Barriers to the use of cover crops in vineyard by percent of respondents experiencing the barrier on scale of “Not at all” to “A lot” (n= 44)

Appendix B
SURVEY CODEBOOK

Climate Adaptation and Water Conservation Decision-Making in Paso Robles, California Vineyards: 2021 Survey Codebook

This codebook was developed to provide the necessary information to use the data file (Vineyard survey data_4 28 21.xlsx) associated with the Climate Adaptation and Water Conservation in Paso Robles Vineyards 2021 survey.

General

- Q is an abbreviation for "question' and is used to correspond to a question on the survey
- Force response is indicated by an FR next to the question number and forces a response to the question in order to move forward with the survey. This was used throughout the survey on questions which needed to be answered in order to provide the proper survey flow to the next question.
- "-99" indicates a question which was not answered
- Surveys were received by respondents conducting the survey online through Qualtrics
- Not all survey questions were answered by all survey respondents. Some questions were skipped for respondents depending on their previous answers and most questions were able to be skipped by respondents without answering (those questions which were not force response).

Q1_graphic Map of the Paso Robles AVA.

Q1 Do you own vineyard property in the Paso Robles AVA? See map for AVA boundaries.

1: Yes

2: No

Skip Logic: If "Yes" is selected skip to Q2, if "No" is selected skip to Q3.

Q2_graphic Map of the Paso Robles AVA.

Q2 Do you make day-to-day management decisions on the vineyards you own in the Paso Robles AVA?

1: Yes

2: No

Skip Logic: Respondents that selected "Yes" or "No" skip to the End of Block (Q4).

Q3 Do you make management decisions on vineyards located in the Paso Robles AVA? See map for AVA boundaries

3: Yes

4: No

Skip Logic: If "Yes" is selected, skip to the End of Block (Q4). Respondents who don't skip to End of Block are directed to an End of Survey Block.

Q4 Cal Poly and Sacramento State Universities are conducting this survey in order to support non-regulatory strategies for increasing soil health and water use efficiency. If you make vineyard management decisions and/ or own vineyard property in the Paso Robles AVA, we'd greatly appreciate your input!

The benefits of your voluntary completion of this survey include: - A $50 eGift card   - Making sure your voice is heard regarding the needs and concerns of Paso Robles AVA viticulturalists - Helping document the commitment to water conservation within the Paso Robles AVA

This survey includes questions about your personal experiences and opinions and takes approximately 20 minutes to complete. You may skip any questions you choose not to answer. There are minimal risks anticipated with your participation in this study, as any information you provide is confidential and will not be linked to your name or company. They will only be released as summaries where answers cannot be linked to individual respondents. Anonymized project data will be deposited in the Sacramento State University Library's ScholarWorks platform to be shared with other researchers and preserved beyond the end of the project. The respondent must also be at least 18 years old.

This research is being led by Dr. Nick Babin in the Department of Natural Resources Management and Environmental Sciences at Cal Poly, San Luis Obispo. If you have questions regarding this study or would like to be informed of the results when the study is completed, please contact Dr. Babin at 805-756-2373, nbabin@calpoly.edu.

If you have any concerns about the conduct of the research project or your rights as a research participant, you may contact Dr. Michael Black, Chair of the Cal Poly Institutional Review Board, at (805) 756-2894, mblack@calpoly.edu, or Ms. Trish Brock, Director of Research Compliance, at (805) 756-1450 or pbrock@calpoly.edu.

If you agree to voluntarily participate in this research project as described, please indicate your agreement by clicking "I agree" below. You may stop and quit the survey at any time but your $50 eGift card will only be disbursed if you complete the survey. If you would not like to participate, please click "I disagree".

1: I agree

2: I disagree

Skip Logic: If "I disagree" is selected, skip to the End of the Block, which directs them to an End of Survey Block.

Q5_prompt How concerned are you about the impact of the following risks on the economic viability of the vineyards you manage and/ or own in the Paso Robles AVA?

Q5_1 Labor availability and cost

1: Not at all concerned

2: Slightly concerned

3: Somewhat concerned

4: Moderately concerned

5: Extremely concerned

Q5_2 Market oversupply / grape prices

1: Not at all concerned

2: Slightly concerned

3: Somewhat concerned

4: Moderately concerned

5: Extremely concerned

Q5_3 Diseases and pests

1: Not at all concerned

2: Slightly concerned

3: Somewhat concerned

4: Moderately concerned

5: Extremely concerned

Q5_4 Water Supply

1: Not at all concerned

2: Slightly concerned

3: Somewhat concerned

4: Moderately concerned

5: Extremely concerned

Q5_5 Regulations related to groundwater

1: Not at all concerned

2: Slightly concerned

3: Somewhat concerned

4: Moderately concerned

5: Extremely concerned

Q5_6 Regulations unrelated to groundwater

1: Not at all concerned

2: Slightly concerned

3: Somewhat concerned

4: Moderately concerned

5: Extremely concerned

Q5_7 Weather volatility

1: Not at all concerned

2: Slightly concerned

3: Somewhat concerned

4: Moderately concerned

5: Extremely concerned

Q5_8 Climate change

1: Not at all concerned

2: Slightly concerned

3: Somewhat concerned

4: Moderately concerned

5: Extremely concerned

Q6_prompt Do you agree with the following statements related to the vineyards you manage and/ or own in the Paso Robles AVA?

Q6_1 Finding a good market for grapes is becoming more difficult

1: Strongly disagree

2: Somewhat disagree

3: Neither agree nor disagree

4: Somewhat agree

5: Strongly agree

Q6_2 Finding adequate labor is becoming more difficult

1: Strongly disagree

2: Somewhat disagree

3: Neither agree nor disagree

4: Somewhat agree

5: Strongly agree

Q7_prompt Have the following factors *negatively* impacted either the quality or yield of the grapes produced in the vineyards you manage and/or own anytime during the past five harvests? If so, how severe were the impacts?

Q7#1 Negative impacts on any of last five harvests?

Q7#1_1 Vine stress due to extreme heat

1: Yes

2: No

Q7#1_2 Change in bud bread and/or harvest timing

1: Yes

2: No

Q7#1_3 Reduced water availability

1: Yes

2: No

Q7#1_4 Frosts

1: Yes

2: No

Q7#1_5 Weed / insect / vertebrate pressures

1: Yes

2: No

Q7#1_6 Disease

1: Yes

2: No

Q7#2 Severity of impacts

Q7#2_1 Vine stress due to extreme heat

1: No negative impacts

2: Mild impacts

3: Moderate impacts

4: Severe impacts

Q7#2_2 Change in bud bread and/or harvest timing

1: No negative impacts

2: Mild impacts

3: Moderate impacts

4: Severe impacts

Q7#2_3 Reduced water availability

1: No negative impacts

2: Mild impacts

3: Moderate impacts

4: Severe impacts

Q7#2_4 Frosts

1: No negative impacts

2: Mild impacts

3: Moderate impacts

4: Severe impacts

Q7#2_5 Weed / insect / vertebrate pressures

1: No negative impacts

2: Mild impacts

3: Moderate impacts

4: Severe impacts

Q7#2_6 Disease

1: No negative impacts

2: Mild impacts

3: Moderate impacts

4: Severe impacts

Q8_graphic Paso Robles Watershed Subbasin map

Q8 Do you manage and/ or own vineyards within the Paso Robles Watershed Subbasin? See map for Subbasin boundaries. The Paso Robles Subbasin is the area highlighted in greenish-blue.

1: Yes

2: No

SGMA_prompt The Sustainable Groundwater Management Act (SGMA) was passed in 2014 to help manage our groundwater in California. SGMA authorizes local stakeholders and institutions to form Groundwater Sustainability Agencies (GSAs) to manage groundwater basins and create groundwater sustainability plans. According to the 2020 Paso Robles Subbasin Groundwater Sustainability Plan, the basin is in an average annual overdraft of 17% and management actions will be necessary to eliminate this deficit.

Management actions identified by the plan include improved water-use monitoring and reporting, promoting water best management practices, promoting stormwater capture and groundwater recharge, promoting voluntary fallowing of irrigated crop land, mandatory pumping limitations in specific areas, and developing infrastructure for new water supplies.

The following questions solicit your opinions about SGMA, its implementation, and your participation in SGMA related activities.

Q9 Have you participated in the following activities related to the Sustainable Groundwater Management Act (SGMA)? Check all that apply.

1: I have never heard about SGMA prior to this survey

2: I have attended only one meeting or workshop

3: I have attended multiple meetings and workshops

4: I have provided feedback to a Groundwater Sustainability Agency (GSA)

5: I am a member of a Groundwater Sustainability Agency

6: I have heard about SGMA, but not attended any meetings or workshops

7: I do not have the time to participate, or the money to pay someone to participate on my behalf, in SGMA planning activities

Q10_prompt What is your level of support for the following management actions identified by the Paso Robles Subbasin Groundwater Sustainability Plan?

Q10_1 Improved water-use monitoring and reporting

1: Strongly oppose

2: Somewhat oppose

3: Neutral

4: Somewhat favor

5: Strongly favor

Q10_2 Promoting water best management practices

1: Strongly oppose

2: Somewhat oppose

3: Neutral

4: Somewhat favor

5: Strongly favor

Q10_3 Promoting stormwater capture and groundwater recharge

1: Strongly oppose

2: Somewhat oppose

3: Neutral

4: Somewhat favor

5: Strongly favor

Q10_4 Promoting voluntary fallowing of irrigated crop land

1: Strongly oppose

2: Somewhat oppose

3: Neutral

4: Somewhat favor

5: Strongly favor

Q10_5 Mandatory pumping limitations in specific areas

1: Strongly oppose

2: Somewhat oppose

3: Neutral

4: Somewhat favor

5: Strongly favor

Q10_6 Developing infrastructure for new water supplies

1: Strongly oppose

2: Somewhat oppose

3: Neutral

4: Somewhat favor

5: Strongly favor

Q11_prompt How much of a priority are the following management actions identified by the Paso Robles Subbasin Groundwater Sustainability Plan?

Q11_1 Improved water-use monitoring and reporting

1: Not a priority

2: Low priority

7: Medium priority

8: High priority

9: Essential

Q11_2 Promoting water best management practices

1: Not a priority

2: Low priority

7: Medium priority

8: High priority

9: Essential

Q11_3 Promoting stormwater capture and groundwater recharge

1: Not a priority

2: Low priority

7: Medium priority

8: High priority

9: Essential

Q11_4 Promoting voluntary fallowing of irrigated crop land

1: Not a priority

2: Low priority

7: Medium priority

8: High priority

9: Essential

Q11_5 Mandatory pumping limitations in specific areas

1: Not a priority

2: Low priority

7: Medium priority

8: High priority

9: Essential

Q11_6 Developing infrastructure for new water supplies

1: Not a priority

2: Low priority

7: Medium priority

8: High priority

9: Essential

Q12_prompt Please indicate your level of agreement with each statement about SGMA's impacts

Q12_1 If nothing is done, groundwater levels near my property will decrease over time

1: Strongly disagree

2: Somewhat disagree

3: Uncertain

4: Somewhat agree

5: Strongly agree

Q12_2 SGMA will reduce long-term risks associated with groundwater overdraft

1: Strongly disagree

2: Somewhat disagree

3: Uncertain

4: Somewhat agree

5: Strongly agree

Q12_3 SGMA will lead to additional regulation of my operation

1: Strongly disagree

2: Somewhat disagree

3: Uncertain

4: Somewhat agree

5: Strongly agree

Q12_4 SGMA is a threat to my operation

1: Strongly disagree

2: Somewhat disagree

3: Uncertain

4: Somewhat agree

5: Strongly agree

Q12_5 SGMA will increase the cost of grape production

1: Strongly disagree

2: Somewhat disagree

3: Uncertain

4: Somewhat agree

5: Strongly agree

Q12_6 SGMA will reduce the amount of water available to my operation

1: Strongly disagree

2: Somewhat disagree

3: Uncertain

4: Somewhat agree

5: Strongly agree

Q13_prompt Please indicate your level of agreement with each statement about SGMA implementation.

Q13_1 It is preferable that local Groundwater Sustainability Agencies implement SGMA rather than state regulators

1: Strongly disagree

2: Somewhat disagree

3: Uncertain

4: Somewhat agree

5: Strongly agree

Q13_2 I will participate in implementing SGMA activities

1: Strongly disagree

2: Somewhat disagree

3: Uncertain

4: Somewhat agree

5: Strongly agree

Q13_3 A majority of other growers will participate in implementing SGMA groundwater plans

1: Strongly disagree

2: Somewhat disagree

3: Uncertain

4: Somewhat agree

5: Strongly agree

Q13_4 Working with my community is a good way to address groundwater overdraft

1: Strongly disagree

2: Somewhat disagree

3: Uncertain

4: Somewhat agree

5: Strongly agree

Q13_5 Growers should participate in SGMA activities

1: Strongly disagree

2: Somewhat disagree

3: Uncertain

4: Somewhat agree

5: Strongly agree

Q14_prompt Please indicate your level of agreement with each statement about SGMA implementation.

Q14_1 Agricultural interests are taken into consideration by my local Groundwater Sustainability Agency (GSA)

1: Strongly disagree

2: Somewhat disagree

3: Uncertain

4: Somewhat agree

5: Strongly agree

Q14_2 My feedback will be taken into consideration by my local GSA

1: Strongly disagree

2: Somewhat disagree

3: Uncertain

4: Somewhat agree

5: Strongly agree

Q14_3 I am confident our operations will fare well regardless of changes to water access

1: Strongly disagree

2: Somewhat disagree

3: Uncertain

4: Somewhat agree

5: Strongly agree

Q14_4 It is better to wait until further changes to water conditions occur rather than anticipate and address them before they occur

1: Strongly disagree

2: Somewhat disagree

3: Uncertain

4: Somewhat agree

5: Strongly agree

Q15 Please select one statement that best reflects your beliefs about climate change.

1: Climate change is occurring, and it is caused mostly by human activities

2: Climate change is occurring, and it is caused more or less equally by natural changes in the environment and human activities

3: Climate change is occurring, and it is caused mostly by natural changes in the environment

4: There is not sufficient evidence to know with certainty whether climate change is occurring or not

5: Climate change is not occurring

Climate_Prompt A number of people and organizations are concerned about the potential impacts of climate change on California viticulture. In the next set of questions you will be asked to read and comment on a set of localized projections of future climatic conditions for the Paso Robles AVA. These projections were developed by the state of California to assist in adaptation and were obtained from: *https://cal-adapt.org/tools/*

Q16 Because of the wide-ranging differences in climate from the west to the eastside of the Paso Robles AVA, a projection from each area has been generated. Please indicate where the majority of the vineyards you manage and/ or own are located. Then read your corresponding projection carefully and be prepared to answer questions about vineyard adaptation.

1: East of Highway 101 is where the majority of the vineyards I manage and/ or own are located

2: West of Highway 101 is where the majority of the vineyards I manage and/ or own are located

3: Equally East and West of Highway 101 is where the vineyards I manage and/ or own are located

Skip Logic: If "East of Highway 101" is selected, skip to the East_prompt. If "West of Highway 101" is selected, skip to the West_prompt. If "Equally East and West of Highway 101" is selected, skip to the EastWest_prompt.

West_projection Westside Vineyards- Past Climate Averages and Future Projections

Westside vineyards averaged 4 nights per year when minimum temps did not fall below 60F° between 1961-1990.

Projected 17 nights/year between 2021-2039 **(+13 nights/year)**

Projected 41 nights/year between 2050-2070 **(+37 nights/year)**

Between 2021-2039, growing season average high temps are projected to be **3F° higher** than 1961-1990 baseline.
Between 2050-2070, growing season average high temps are projected to be **6F° higher** than 1961-1990 baseline.

Westside vineyards averaged 7 days per year above 95F° between 1961-1990.

Projected 20 days/year between 2021-2039 **(+13 days/year)**

Projected 35 days/year between 2050-2070 **(+28 days/year)**

Westside vineyards averaged 0 days per year above 100F° between 1961-1990.
Projected 5 days/year between 2021-2039 **(+5 days/year)**

Projected 12 days/year between 2050-2070 **(+12 days/year)**

Between 1961-1990, a heatwave of at least 4 days in a row of plus 95F° temps was recorded an average of once every two years.

Starting in 2021, heatwaves of 4 days in a row of plus 95F° are projected to occur twice every summer **(4X increase in frequency)**

By 2050, heatwaves of 4 days in a row of plus 95F° projected an average of 4 times per summer **(8X increase in frequency)**

Annual rainfall on the westside of the Paso Robles AVA averaged around 26 inches between 1961-1990 with a year to year range of 11-49 inches.

Projected 23 inches with range of 15-38 inches between 2022-2031 **(-3 inches/year)**
Projected 22 inches with range of 6-49 inches between 2050-2070 **(-4 inches/year)**

- Scenario RCP 8.5 and model CanESM2 (Average) were utilized to generate this projection at https://cal-adapt.org/tools/

Skip Logic: Skip to end of projection block if West_prompt is displayed

East_projection Eastside Vineyards- Past Climate Averages and Future Projections

Eastside vineyards averaged 4 nights per year when minimum temps did not fall below 60F° between 1961-1990.

Projected 12 nights/year between 2021-2039 **(+8 nights/year)**

Projected 36 nights/year between 2050-2070 **(+32 nights/year)**

Between 2021-2039, growing season average high temps are projected to be **3F° higher** than 1961-1990 baseline.
Between 2050-2070, growing season average high temps are projected to be **6F° higher** than 1961-1990 baseline.

Eastside vineyards averaged 16 days per year above 100F° between 1961-1990.
Projected 38 days/year between 2021-2039 **(+22 days/year)**

Projected 54 days/year between 2050-2070 **(+38 days/year)**

Eastside vineyards averaged 3 days per year above 105F° between 1961-1990.
Projected 13 days/year between 2021-2039 **(+10 days/year)**

Projected 25 days/year between 2050-2070 **(+22 days/year)**

Between 1961-1990, a heatwave of at least 4 days in a row of plus 105F° temps was recorded an average of once every ten years.

Starting in 2021, heatwaves of 4 days in a row of plus 105F° projected to occur once every summer **(10X increase in frequency)**

By 2050, heatwaves of 4 days in a row of plus 105F° projected an average of 4 times per summer **(40X increase in frequency)**

Annual rainfall on the eastside of the Paso Robles AVA averaged around 12 inches between 1961-1990 with a year-to-year range of 5-24 inches.

Projected 11 inches with range of 7-19 inches between 2022-2031 **(-1 inch/year)**
Projected 10 inches with range of 3-27 inches between 2050-2070 **(-2 inches/year)**

- Scenario RCP 8.5 and model CanESM2 (Average) were utilized to generate this projection at https://cal-adapt.org/tools/

Skip Logic: If East_prompt is displayed , skip to end of projection block

WestEast_prompt Westside Vineyards- Past Climate Averages and Future Projections

Westside vineyards averaged 4 nights per year when minimum temps did not fall below 60F° between 1961-1990.

Projected 17 nights/year between 2021-2039 **(+13 nights/year)**

Projected 41 nights/year between 2050-2070 **(+37 nights/year)**

Between 2021-2039, growing season average high temps are projected to be **3F° higher** than 1961-1990 baseline.
Between 2050-2070, growing season average high temps are projected to be **6F° higher** than 1961-1990 baseline.

Westside vineyards averaged 7 days per year above 95F° between 1961-1990.

Projected 20 days/year between 2021-2039 **(+13 days/year)**

Projected 35 days/year between 2050-2070 **(+28 days/year)**

Westside vineyards averaged 0 days per year above 100F° between 1961-1990.
Projected 5 days/year between 2021-2039 **(+5 days/year)**

Projected 12 days/year between 2050-2070 **(+12 days/year)**

Between 1961-1990, a heatwave of at least 4 days in a row of plus 95F° temps was recorded an average of once every two years.

Starting in 2021, heatwaves of 4 days in a row of plus 95F° are projected to occur twice every summer **(4X increase in frequency)**

By 2050, heatwaves of 4 days in a row of plus 95F° projected an average of 4 times per summer **(8X increase in frequency)**

Annual rainfall on the westside of the Paso Robles AVA averaged around 26 inches between 1961-1990 with a year to year range of 11-49 inches.

Projected 23 inches with range of 15-38 inches between 2022-2031 **(-3 inches/year)**
Projected 22 inches with range of 6-49 inches between 2050-2070 **(-4 inches/year)**

- Scenario RCP 8.5 and model CanESM2 (Average) were utilized to generate this projection at https://cal-adapt.org/tools/

Skip Logic: Skip to end of projection block if West_prompt is displayed

Eastside Vineyards- Past Climate Averages and Future Projections

Eastside vineyards averaged 4 nights per year when minimum temps did not fall below 60F° between 1961-1990.

Projected 12 nights/year between 2021-2039 **(+8 nights/year)**

Projected 36 nights/year between 2050-2070 **(+32 nights/year)**

Between 2021-2039, growing season average high temps are projected to be **3F° higher** than 1961-1990 baseline.
Between 2050-2070, growing season average high temps are projected to be **6F° higher** than 1961-1990 baseline.

Eastside vineyards averaged 16 days per year above 100F° between 1961-1990.
Projected 38 days/year between 2021-2039 **(+22 days/year)**

Projected 54 days/year between 2050-2070 **(+38 days/year)**

Eastside vineyards averaged 3 days per year above 105F° between 1961-1990.
Projected 13 days/year between 2021-2039 **(+10 days/year)**

Projected 25 days/year between 2050-2070 **(+22 days/year)**

Between 1961-1990, a heatwave of at least 4 days in a row of plus 105F° temps was recorded an average of once every ten years.

Starting in 2021, heatwaves of 4 days in a row of plus 105F° projected to occur once every summer **(10X increase in frequency)**

By 2050, heatwaves of 4 days in a row of plus 105F° projected an average of 4 times per summer **(40X increase in frequency)**

Annual rainfall on the eastside of the Paso Robles AVA averaged around 12 inches between 1961-1990 with a year-to-year range of 5-24 inches.

Projected 11 inches with range of 7-19 inches between 2022-2031 **(-1 inch/year)**
Projected 10 inches with range of 3-27 inches between 2050-2070 **(-2 inches/year)**

- Scenario RCP 8.5 and model CanESM2 (Average) were utilized to generate this projection at https://cal-adapt.org/tools/

Q17 If this scenario was certain to occur, what would the overall impact be on the vineyards you manage and/ or own?

1: Extremely negative

2: Somewhat negative

3: Neither positive nor negative

4: Somewhat positive

5: Extremely positive

Q18_prompt How concerned are you about the following potential impacts of climate change for the vineyards you manage and/ or own?

Q18_1 Extreme high temperatures

1: Not at all concerned

2: Slightly concerned

3: Somewhat concerned

4: Moderately concerned

5: Extremely concerned

Q18_2 Extended heat waves

1: Not at all concerned

2: Slightly concerned

3: Somewhat concerned

4: Moderately concerned

5: Extremely concerned

Q18_3 Increased average growing season high temperatures

1: Not at all concerned

2: Slightly concerned

3: Somewhat concerned

4: Moderately concerned

5: Extremely concerned

Q18_4 Loss of nighttime cooling

1: Not at all concerned

2: Slightly concerned

3: Somewhat concerned

4: Moderately concerned

5: Extremely concerned

Q18_5 Reduced rainfall

1: Not at all concerned

2: Slightly concerned

3: Somewhat concerned

4: Moderately concerned

5: Extremely concerned

Q19 In your opinion, how likely is it that this projected scenario could occur?

1: Extremely unlikely

2: Somewhat unlikely

3: Neither likely nor unlikely

4: Somewhat likely

5: Extremely likely

Q20_prompt Please select the answer for each statement which best reflects your attitudes about climate change and the vineyards you manage and/ or own.

Q20_1 This projection increased my level of concern about the impacts of climate change on the vineyards I manage

1: Strongly disagree

2: Somewhat disagree

3: Uncertain

4: Somewhat agree

5: Strongly agree

Q20_2 My vineyard operation will likely benefit from the projected climate change

1: Strongly disagree

2: Somewhat disagree

3: Uncertain

4: Somewhat agree

5: Strongly agree

Q20_3 Crop insurance will protect the viability of my vineyard operation regardless of weather

1: Strongly disagree

2: Somewhat disagree

3: Uncertain

4: Somewhat agree

5: Strongly agree

Q21_prompt Please select the answer for each statement which best reflects your attitudes about climate change and the vineyards you manage and/ or own.

Q21_1 Projections like these are helpful for vineyard risk management and adaptation planning

1: Strongly disagree

2: Somewhat disagree

3: Uncertain

4: Somewhat agree

5: Strongly agree

Q21_2 It is useful to know how temperatures and rainfall will change over the next twenty-five years and what this will mean in terms of future frosts, heat spikes, bud break dates and harvest dates

1: Strongly disagree

2: Somewhat disagree

3: Uncertain

4: Somewhat agree

5: Strongly agree

Q22_prompt Please select the answer for each statement which best reflects your attitudes about climate change adaptation in the vineyards you manage and/ or own.

Q22_1 I have the knowledge and technical skill to deal with any climate-related threats to vineyard viability

1: Strongly disagree

2: Somewhat disagree

3: Uncertain

4: Somewhat agree

5: Strongly agree

Q22_2 The vineyard I manage and/ or own has the financial capacity to deal with any climate-related threats

1: Strongly disagree

2: Somewhat disagree

3: Uncertain

4: Somewhat agree

5: Strongly agree

Q23 What is the average annual rainfall of the largest block you manage and/ or own in the Paso Robles AVA?

0-60: Value representing inches of rainfall

Q24 Do the vineyards you manage and/ or own in the Paso Robles AVA use irrigation?

1: Yes

2: No

Skip Logic: If "No" is selected, skip to Q43

Q25 What percentage of the vineyard lands you manage and/ or own are irrigated?

0-100: Percentage of vineyard lands irrigated

Q26: What proportion of this irrigation is from groundwater?

0-100: Percentage of irrigation from groundwater

Q27: Soil moisture monitoring refers to using sensors such as tensiometers to schedule irrigation. Do the vineyards you manage and/ or own currently utilize soil moisture sensors to schedule irrigation?

1: Yes

2: No

Q28: Plant tissue sampling refers to methods such as a pressure bomb or sap flow sensor to schedule irrigation. Do the vineyards you manage and/ or own currently utilize plant tissue sampling to schedule irrigation?

1: Yes

2: No

Q29: *Evapotranspiration monitoring* refers to methods such as weather stations or localized crop coefficients used to schedule irrigation. Do the vineyards you manage and/ or own currently utilize evapotranspiration monitoring to schedule irrigation?

1: Yes

2: No

Q30: How often do you alter irrigation *intervals* (time between irrigation sets) based off of soil, evapotranspiration and/ or plant tissue monitoring?

1: Never

2: Rarely (in about 10% of irrigation events)

3: Occasionally (in about 30% of irrigation events)

4: Sometimes (in about 50% of irrigation events)

5: Frequently (in about 70% of irrigation events)

6: Always (in at least 90% of irrigation events)

Q31: How often do you alter irrigation *duration* (length of irrigation sets) based off of soil, evapotranspiration and/ or plant tissue monitoring?

1: Never

2: Rarely (in about 10% of irrigation events)

3: Occasionally (in about 30% of irrigation events)

4: Sometimes (in about 50% of irrigation events)

5: Frequently (in about 70% of irrigation events)

6: Always (in at least 90% of irrigation events)

Q32_prompt How much do the following factors limit your ability to use soil moisture sensors, plant tissue sampling and evapotranspiration monitoring to schedule irrigation?

Q32_1 Financial expense to implement and manage

1: Not at all

2: A little

3: Some

4: A lot

Q32_2 The need to learn new skills or techniques

1: Not at all

2: A little

3: Some

4: A lot

Q32_3 Insufficient proof of benefit

1: Not at all

2: A little

3: Some

4: A lot

Q32_4 Insufficient benefit for the amount of time spent implementing

1: Not at all

2: A little

3: Some

4: A lot

Q32_5 Approval of my client/ vineyard owner

1: Not at all

2: A little

3: Some

4: A lot

Q32_6 Other (please fill in)

1: Not at all

2: A little

3: Some

4: A lot

Q32_6_TEXT Other (please fill in)

Q33: Distribution uniformity tests can ensure that a drip irrigation system delivers water uniformly throughout vineyard blocks. Do the vineyards you manage and/ or own currently utilize distribution uniformity tests?

1: Yes

2: No

Skip Logic: If "Yes" is selected, skip to Q35

Q34: How much do the following factors limit your ability to use distribution uniformity tests?

Q34_1 Financial expense to implement and manage

1: Not at all

2: A little

3: Some

4: A lot

Q34_2 The need to learn new skills or techniques

1: Not at all

2: A little

3: Some

4: A lot

Q34_3 Insufficient proof of benefit

1: Not at all

2: A little

3: Some

4: A lot

Q34_4 Approval of my client/ vineyard owner

1: Not at all

2: A little

3: Some

4: A lot

Q34_5 Other (please fill in)

1: Not at all

2: A little

3: Some

4: A lot

Q34_5_TEXT Other (please fill in)

Q35 *Flow meters* are utilized to monitor water usage and effectively manage irrigation. Do the vineyards you manage and/ or own currently utilize flow meters to monitor water usage?

1: Yes

2: No

Skip Logic: If “Yes” is selected, skip to Q37

Q36_prompt How much do the following factors limit your ability to use flow meters?

Q36_1 Financial expense to implement and manage

1: Not at all

2: A little

3: Some

4: A lot

Q36_2 The need to learn new skills or techniques

1: Not at all

2: A little

3: Some

4: A lot

Q36_3 Insufficient proof of benefit

1: Not at all

2: A little

3: Some

4: A lot

Q36_4 Approval of my client/ vineyard owner

1: Not at all

2: A little

3: Some

4: A lot

Q36_5 Other (please fill in)

1: Not at all

2: A little

3: Some

4: A lot

Q36_5_TEXT Other (please fill in)

Q37 Drought tolerant rootstocks allow for establishment of successful vines in conditions of drought. Do any of the vineyards you manage and/ or own employ drought tolerant rootstocks?

1: Yes

2: No

Skip Logic: If "Yes" is selected, skip to Q39

Q38_prompt How much do the following factors limit your ability to use drought tolerant rootstocks?

Q38_1 Financial expense to implement and manage

1: Not at all

2: A little

3: Some

4: A lot

Q38_2 The need to learn new skills or techniques

1: Not at all

2: A little

3: Some

4: A lot

Q38_3 Insufficient proof of benefit

1: Not at all

2: A little

3: Some

4: A lot

Q38_4 Drought tolerant root stocks are still missing traits I'm looking for

1: Not at all

2: A little

3: Some

4: A lot

Q38_5 Approval of my client/ vineyard owner

1: Not at all

2: A little

3: Some

4: A lot

Q38_6 Other (please fill in)

1: Not at all

2: A little

3: Some

4: A lot

Q38_6_TEXT Other (please fill in)

Q39 *Heat tolerant varieties* allow for vineyards to produce quality grapes in higher temperatures than most traditional French varieties are able to. Have the vineyards you manage and/ or own planted heat tolerant varieties in response to increased heat?

1: Yes

2: No

Skip Logic: If "Yes" is selected, skip to Q41

Q40_prompt How much do the following factors limit your ability to diversify to more heat tolerant varieties?

Q40_1 Concern about lack of market

1: Not at all

2: A little

3: Some

4: A lot

Q40_2 Financial expense to implement and manage

1: Not at all

2: A little

3: Some

4: A lot

Q40_3 The need to learn new skills or techniques

1: Not at all

2: A little

3: Some

4: A lot

Q40_4 Insufficient proof of benefit

1: Not at all

2: A little

3: Some

4: A lot

Q40_5 Approval of my client/ vineyard owner

1: Not at all

2: A little

3: Some

4: A lot

Q40_6 Other (please fill in)

1: Not at all

2: A little

3: Some

4: A lot

Q40_6_TEXT Other (please fill in)

Q41 *Dry farming* is the practice of growing grapes without irrigation. Do you dry farm any of the vineyard lands you manage and/ or own?

1: Yes

2: No

Skip Logic: If "Yes" is selected, skip to Q43?

Q42 What percentage of the vineyard lands you manage and/ or own are dry farmed?

0-100: Percent vineyard land dry farmed

Skip Logic: If answer not empty, skip to Q44

Q43_prompt How much do the following factors limit your ability to employ dry farming?

Q43_1 Lack of sufficient rainfall

1: Not at all

2: A little

3: Some

4: A lot

Q43_2 Reduced yields

1: Not at all

2: A little

3: Some

4: A lot

Q43_3 The need to learn new skills or techniques

1: Not at all

2: A little

3: Some

4: A lot

Q43_4 Insufficient proof of benefit

1: Not at all

2: A little

3: Some

4: A lot

Q43_5 Approval of my client/ vineyard owner

1: Not at all

2: A little

3: Some

4: A lot

Q43_6 Other (please fill in)

Q43_6_TEXT Other (please fill in)

Q44 *Continuous no-till* is the practice of growing grapes without ever disturbing the soil through tillage. Do you practice continuous no-till on any of the vineyard land you manage and/ or own?

1: Yes

2: No

Skip Logic: If "Yes" is selected, skip to Q46

Q45 On what percentage of the vineyard land that you manage and/ or own do you practice continuous no-till?

0-100: Percent vineyard land using continuous no-till

Skip Logic: If "100" is selected, skip to Q47

Q46_prompt How much do the following factors limit your ability to use continuous no-till?

Q46_1 Compaction concerns

1: Not at all

2: A little

3: Some

4: A lot

Q46_2 Pest / weed concerns

1: Not at all

2: A little

3: Some

4: A lot

Q46_3 The need to learn new skills or techniques

1: Not at all

2: A little

3: Some

4: A lot

Q46_4 Insufficient proof of benefit

1: Not at all

2: A little

3: Some

4: A lot

Q46_5 Approval of my client/ vineyard owner

1: Not at all

2: A little

3: Some

4: A lot

Q46_6 Other (please fill in)

Q46_6_TEXT Other (please fill in)

Q47 Cover crops are grown between vineyard rows for the protection and enrichment of the soil. Do you utilize cover crops on any of the vineyard lands you manage and/ or own?

1: Yes

2: No

Skip Logic: If "No" is selected, skip to Q49

Q48 What percentage of the vineyard land you manage and/ or own is cover cropped?

0-100: Percent of vineyard lands with cover crops

Skip Logic: If "100" is selected, skip to Q50

Q49_prompt How much do the following factors limit your ability to utilize cover crops in the vineyards you manage and/ or own?

Q49_1 Concerns about water use

1: Not at all

2: A little

3: Some

4: A lot

Q49_2 Seeding timing challenges

1: Not at all

2: A little

3: Some

4: A lot

Q49_3 Pest / weed concerns

1: Not at all

2: A little

3: Some

4: A lot

Q49_4 Financial expense to implement and manage

1: Not at all

2: A little

3: Some

4: A lot

Q49_5 The need to learn new skills or techniques

1: Not at all

2: A little

3: Some

4: A lot

Q49_6 Insufficient proof of benefit

1: Not at all

2: A little

3: Some

4: A lot

Q49_7 Approval of my client/ vineyard owner

1: Not at all

2: A little

3: Some

4: A lot

Q49_8 Other (please fill in)

Q49_8_TEXT Other (please fill in)

Q50 Fallowing refers to the practice of taking lands out of grape production and not planting them to another crop. Has any of the vineyard land you manage and/ or own been fallowed in the last 5 years?

1: Yes

2: No

Skip Logic: If "No" is selected, skip to Q52

Q51 What percentage of the vineyard land that you manage and/ or own has been fallowed during the last 5 years?

0-100: percentage of vineyard lands fallowed over the last 5 years

Q52 Diversification refers to taking lands out of grape production and planting them to another crop. Have any of the vineyard lands you manage and/ or own been planted to another crop in the last 5 years?

1: Yes

2: No

Skip Logic: If “No” is selected, skip to End of Block (Q56)

Q53 What percentage of the vineyard lands that you manage and/ or own have been planted to another crop during the last 5 years?

0-100: Percentage of vineyard lands planted to another crop over the last 5 years

Q54_TEXT What crop(s) have been planted?

Q55_prompt People get information about vineyard soil and water management from a number of different sources. To what extent do you trust the organizations listed below as a source of information about vineyard soil and water management?

Q55_1 UC Cooperative Extension

1: Not at all

2: Slightly

3: Moderately

4: Very much

5: Not familiar

Q55_2 Groundwater Sustainability Agencies

1: Not at all

2: Slightly

3: Moderately

4: Very much

5: Not familiar

Q55_3 Upper Salinas – Las Tablas Resource Conservation District

1: Not at all

2: Slightly

3: Moderately

4: Very much

5: Not familiar

Q55_4 Cal Poly State University

1: Not at all

2: Slightly

3: Moderately

4: Very much

5: Not familiar

Q55_5 Paso Wine Country Alliance

1: Not at all

2: Slightly

3: Moderately

4: Very much

5: Not familiar

Q56_prompt People get information about vineyard soil and water management from a number of different sources. To what extent do you trust the organizations listed below as a source of information about vineyard soil and water management?

Q56_1 Independent Grape Growers Paso Robles Area (IGGPRA)

1: Not at all

2: Slightly

3: Moderately

4: Very much

5: Not familiar

Q56_2 Central Coast Vineyard Team

1: Not at all

2: Slightly

3: Moderately

4: Very much

5: Not familiar

Q56_3 Vineyard management companies / viticultural consultants

1: Not at all

2: Slightly

3: Moderately

4: Very much

5: Not familiar

Q56_4 Agricultural supply retailers

1: Not at all

2: Slightly

3: Moderately

4: Very much

5: Not familiar

Q56_5 Other growers

1: Not at all

2: Slightly

3: Moderately

4: Very much

5: Not familiar

Q57 Are any of the vineyard lands you manage Sustainability in Practice (SIP) certified?

1: Yes

2: No

Q58 Are any of the vineyard lands you manage certified Organic?

1: Yes

2: No

Q59 In what capacity do you make vineyard management decisions?

1: As a management service employee

2: As a vineyard employee

3: As an owner-manager

Skip Logic: If "As vineyard employee" is selected, skip to Q61. If "As an owner-manager" is selected, skip to Q62.

Q60 Please select the statement that best reflects the clients you manage for.

1: Most of the acreage I manage is for vineyards without wineries (commission growers)

2: Most of the acreage I manage is for vineyards with wineries (estate growers)

3: The acreage I manage is about 50% commission growers and 50% estate growers

Skip Logic: If any answer is selected, skip to Q63

Q61 Please select the statement that best reflects the company you manage for.

1: The vineyard I work for does not have a winery (commission grower)

2: The vineyard I work for does have a winery (estate grower)

Skip Logic: If any answer is selected, skip to Q63

Q62 Please select the statement that best reflects your vineyard.

1: The vineyard I own does not have a winery (commission grower)

2: The vineyard I own does have a winery (estate grower)

Q63_prompt How many total vineyard acres in the Paso Robles AVA are managed by your company? Please estimate how many of these acres are owned versus leased.

Q63_1: # Vineyard acres managed by your company in the Paso Robles AVA

_____: vineyard acres managed by your company in Paso Robles AVA

Q63_2: Approximately how many of these acres are owned?

_____: Number of these vineyard acres owned by the company

Q63_3: Approximately how many of these acres are leased?

_____: Number of these vineyard acres leased by the company

Q64_prompt What is the total vineyard acreage in the Paso Robles AVA that you specifically manage? Please estimate how many of these acres are owned versus leased.

Q64_1: # Total vineyard acres you manage in the Paso Robles AVA

_____: Total vineyard acres you manage in the Paso Robles AVA

Q64_2: Approximately how many of these acres are owned?

_____: Number of these vineyard acres owned by the company

Q64_3: Approximately how many of these acres are leased?

_____: Number of these vineyard acres leased by the company

Q65 How many full-time employees does your company employ?

9: 0

4: 1-5

5: 6-10

6: 11-25

7: 26-100

8: 101+

Q66 What type of contract best characterizes the majority of the production for the vineyards you manage and/ or own?

1: No contract for the 2021 harvest

2: Contract secured only for 2021 harvest

3: Contract secured for 2021 and 2022 harvests

4: Contract secured for the next three harvests or more (at least through 2023)

5: Don't know

Q67_graphic Map of the Paso Robles AVA.

Q67 Which Sub-AVA contains the majority of the vineyard land you manage and/ or own? See map for Sub-AVA boundaries. Please choose only one.

1: Adelaida District

2: Creston District

3: El Pomar District

4: Paso Robles Estrella District

5: Paso Robles Geneseo District

6: Paso Robles Highlands District

7: Paso Robles Willow Creek District

8: San Juan Creek District

9: San Miguel District

10: Santa Margarita Ranch District

11: Templeton Gap District

12: York Mountain District

Q68: How many winegrape varieties do you manage and/ or own?

1: 1

2: 2

3: 3

4: 4

5: 5

6: 6+

Q69 Please select the grape variety that corresponds to the largest land area under your management and/ or ownership.

1: Cabernet sauvignon

2: Merlot

3: Zinfandel

4: Syrah

5: Petite Syrah

6: Cabernet Franc

7: Grenache

8: Mourvèdre

9: Petit Verdot

10: Chardonnay

11: Sauvignon Blanc

12: Pinot Noir

13: Other red

14: Other white

Q70 What year were you born?

####: Year born

Q71 What is the highest level of school you have completed?

1: Some formal schooling

2: High school diploma / GED

3: Some college

4: 2-year college degree

5: 4-year college degree

6: Graduate degree

Q72 How many years have you worked in viticulture?

0-70: number of years worked in viticulture

Q73 What proportion of your income comes from viticulture?

1: 0-25%

2: 26-50%

3: 51-75%

4: 76-100%

Q74_TEXT Please use the box below to share any additional comments about the survey.