COMMITTEE MEMBERSHIP

TITLE: Influences of conservation farming practice adoption amongst vineyards on the central coast of California

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COMMITTEE CHAIR: Nicholas Babin, Ph. D., Assistant Professor
ABSTRACT

Influences of conservation farming practice adoption amongst vineyards on the central coast of California

Jazlyn Guerrero

Farming practices will require changes to reduce crop sensitivity to climate change, which is projected to cause extreme heat events, variable precipitation, extended periods of drought, and increasing presence of pest and disease. Conservation agricultural practices build farm resiliency to climate impacts by improving soil health, reducing erosion and sediment runoff, and improving water infiltration. Literature on the adoption of conservation agriculture practices find no universal factors that indicate adoption of practices but suggest that the adoption of practices can be better understood by investigating practices specific variables and farm level characteristics and their implications on adoption. Our objective is to gain insight into the experiences with three conservation practices: cover crops, conservational tillage and set aside lands. Semi-structured interviews with wine producers and advisors from the Paso Robles AVA in California were conducted and analyzed to identify variables affecting adoption, these variables were then quantified to assess the prevalence of this variables amongst this sample. Cover crops was acknowledged to have more observable benefits than conservation tillage and set aside lands, the most notable benefits of cover crops experienced by producers were improvement to soil health and reduction of erosion. Producers who had not adopted conservation tillage experience suggested the practice was incompatible with their soil structure and soil needs. There was little awareness on the benefits and barriers to set aside lands, suggesting more information is needed about this practice. The results of this research will be used to inform a survey that will quantify the barriers and opportunities to adoption to these conservation practices experienced by producers in the Central Coast of California.

Keywords: Conservation practices, adoption, agriculture, vineyards
ACKNOWLEDGMENTS

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Chapter 1

INTRODUCTION

Changing climatic conditions and increasing global populations will cause increased pressure on global agriculture systems (Dawson et al., 2016; Tilman et al., 2011). Agriculture production is sensitive to weather conditions and climate change is projected to cause extreme heat events, variable precipitation, extended periods of drought, and increasing presence of pest and disease (Meehl et al., 2007). Farming practices will require changes to reduce sensitivity to climate while meeting global food demands and preventing further environmental degradation (Hobbs, 2007). In an effort to improve soil quality and the sustainability of agriculture, the Food and Agriculture Organization of the United Nations and the United States Department of Agriculture recommend the use of practices known as "conservation agriculture" which are practices that promote soil health and involve practices such as cover crops, reduced or no tillage, and crop diversification (FAO, 2013; Wade et al., 2015). These improvements can increase the resiliency and sustainability of farms against climate impacts (Knowler & Bradshaw, 2007), improve soil health, and increase carbon sequestration (Garcia-Torres et al., 2013).

The implications of sustained conventional farming practices on soil productivity and environmental quality has prompted researchers to study the underlying motivations of adoption or non-adoption of conservation practices. While government programs, agencies and extension organizations provide incentives, information, and assistance to encourage adoption of conservation practices, participation in all conservation programs is voluntary (Stubbs, 2011), meaning the adoption of conservation practices relies on the discretionary decision-making by farm management. Although advantageous, these optional practices have low rates of adoption. In the US, for example, a report from 2015 showed that 21% (98 million acres) of all crop land acreage used no-till, and less than 2% (6.8 million acres) of all cropland used cover crops (Wade...
et al., 2015). Improving the rates of adoption will require further understanding of the thought process, underlying factors, motivations, and barriers that determine adoption.

Review of global adoption literature (Knowler & Bradshaw, 2007) and meta-analysis of practice adoption in the United States (Baumgart-Getz et al., 2012; Prokopy et al., 2019) find no outstanding influences correlated to adoption. In an analysis of 170 variables (Knowler & Bradshaw, 2007), no universally significant factors were found to have an influence on adoption. However, some factors such as environmental awareness (Baumgart-Getz et al., 2012), farmer motivation, attitudes towards practice, prior experience with a conservation practice, and expected effect on yield (Prokopy et al., 2019) have been identified as potential indicators of adoption. Prokopy et al (2019) and Knowler and Bradshaw (2007) emphasized the need for research that is localized to include experiences with conservation practices, farm-level characteristics, informational and technological resources, financial capacity, institutional factors, and environmental stress (Smit & Wandel, 2006). This research will apply mental models to examine how producer’s understanding of farm-level factors influence managemental decision-making. Mental models represent an individual’s understanding of a system, this research will utilize mental models to compare producer’s and advisor’s perception of external environmental risk facing wine production and their opinions and experiences in using conservation practices for mitigating these risks.

This research project focuses on wineries in the Central Coast of California and aims 1) to assess perception of future risk to vineyard operations under the context of climate change and 2) to evaluate the motivations and barriers to the adoption of conservation practices amongst vineyard managers and advisors in the Paso Robles American Viticultural Area (AVA). The area is projected to experience prolonged heat waves, variable precipitation and shifts in growing season, with the severity of climate impacts drastically different between eastern and western vineyards located in this AVA (See Table 1). There are more than 200 wineries located in the
40,000 acres of the Paso Robles AVA (Taranto, 2019), of which 70 have been certified through Sustainability in Practice (SIP), a rigorous winery certification requiring the use of sustainable practices such as soil conservation and water quality management practices that are independently audited (About SIP Certified, 2020).

Using semi-structured interviews of 11 local vineyard managers and 9 viticulture advisors, together with downscaled scenarios of the future climate outlook for the area, Dr. Babin, Diego Rivera and I gathered data on perception of climate as a risk to operation and the implications of conservation tillage, cover crops, and natural set aside lands on future wine production. By evaluating the difference and similarities between manager and advisor mental models surrounding risk perception and management, we hope to identify variables or needs (i.e. information or resource needs) that are inhibiting practice adoption. The results of this research can be used to improve advisors’ and resource managers’ risk communication strategies and targeted outreach for practice adoption. The purpose of this research is to 1) increase our understanding of producer/advisor perceptions of agricultural and environmental risk and identify information gaps between groups, 2) develop influence diagrams that represent the prevalence of wine producer perceptions of environmental risks and likelihood landowners will adopt conservation practices, 3) inform survey content and design that will quantify the prevalence of risks perceptions amongst central coast farmers and determine how risk perception affects likelihood of conservation practice adoption under external environmental risks.
Chapter 2

LITERATURE REVIEW

Agricultural production will be especially vulnerable to the affects brought on by climate change (Meehl et al., 2007). To reduce sensitivity to the effects of climate change, meet global food demand (Tilman et al., 2011) and prevent further environmental degradation (Hobbs, 2007), methods used in agriculture will have to shift to methods that promote soil health. Agricultural practices that improve soil health have been found to increase farm resiliency to climate impacts by improving water infiltration, reducing erosion and nutrient runoff, increase soil organic matter and carbon content, regulate soil temperatures and reduce vulnerability to disease and pest (Hobbs, 2007). Conservation agriculture is a type of farming that is promoted by the Food and Agriculture Organization of the United Nations and the United States Department of Agriculture with the main goal of increasing soil health. Although there are many government programs that incentivize conservation practices, employing these practices is entirely voluntary (Stubbs, 2011), and in the US rates of conservation practice adoption are low (Wade et al., 2015). Review of global adoption literature (Knowler & Bradshaw, 2007) and meta-analysis of practice adoption in the United States (Baumgart-Getz et al., 2012; Prokopy et al., 2019) investigate several factors and their relationship with influencing adoption, these studies find no clear universality of factors that influence adoption and recommend that further research on practice adoption focus locally to incorporate farm-level (Smit & Wandel, 2006), and practice-specific factors (Reimer et al., 2012) that may have stronger indication of adoption.

Under this context, the research presented here focused on the risk perception of climate change and perceptions of conservation practices held by vineyard managers and viticulture advisors in the Paso Robles AVA, and the subsequent influence of these perceptions on adoption of conservation practices. To understand reasoning and motivations that influence adoption of conservation practices amongst members of this population we review the concept of
conservation agriculture, the theories that explain behaviors and actions; the role of mental models in managerial approaches; and the determinants of adoption studied in previous work.

2.1 Conservation Agriculture

Conventional agriculture is a method of farming characterized by the tilling of soils and application of synthetic inputs, such as fertilizers, herbicides, and insecticides (Wander et al., 1994). The implications of these farming practices are degrading soils (Wander et al., 1994), polluting water ways (Quality & Watersheds, 2016), threatening biodiversity (Mattison & Norris, 2005), and emitting greenhouse gases (Stuart, 2010). In an effort to improve soil quality and the sustainability of agriculture, the Food and Agriculture Organization of the United Nations and the United States Department of Agriculture recommend the use of practices known as "conservation agriculture" that involves many practices, some examples include reduced tillage, cover crops (CC), and natural set aside lands (FAO, 2013; Wade et al., 2015). The Natural Resource Conservation Service (NRCS) defines reduced tillage (NRCS Practice Code 345) as “managing the amount, orientation, and distribution of crop and other plant residue on the soil surface year-round while limiting soil-disturbing activities used to grow and harvest crops in systems where the field surface is tilled prior to planting” (NRCS, 2011). This research will use the term conservation tillage (CT), which has been used in the literature to encompass the varying degrees of tillage such as no-till, reduced tillage, minimum tillage, mulch tillage and ridge tillage (Busari et al., 2015). Cover crops (NRCS Practice Code 340) are defined as “grasses, legumes, and forbs planted for seasonal vegetative cover” (NRCS, 2014). There are numerous types of natural set aside lands defined by the NRCS such as hedgerow planting (NRCS Practice Code 422), filter strips (NRCS Practice Code 393), and buffer strips (NRCS Practice 332) which are permanent areas of vegetative cover that provide off-farm water and air quality improvements and increase wildlife habitat (NRCS, 2003b, 2003a, 2016).
Conservation practices have been found to increase farm resiliency and sustainability to climate impacts by improving water infiltration, reducing erosion and nutrient runoff, increase soil organic matter and carbon content, regulate soil temperatures and reduce vulnerability to disease and pest (Hobbs, 2007). A review of the benefits of various cover crops finds that the cover crop system can offer different benefits such as reduced erosion, reduced nitrate leaching, improve soil structure, improved soil water holding capacity, increased cash crop yield, reduced soil compaction, and reduced disease and pest susceptibility (Snapp et al., 2005). A review of the impacts of conservation tillage finds that the benefits vary with the type of tillage used, but when compared to convention tillage systems, conservation tillage systems had improvements on physical, chemical, and biological soil properties, crop performance and crop yield, off-farm water quality, reduced greenhouse gas emissions and increased carbon sequestration (Busari et al., 2015). A review of various types of vegetative buffers finds that these areas of land can provide increase soil carbon concentrations, improve infiltration capacities, increase soil microbial activity, and improve surface and subsurface water quality by trapping and treating sediment and contaminant runoff (Dabney et al., 2006). Despite these known benefits, adoption rates in the US are low, approximately 21% of all crop land acreage operated under no-till systems and less than 2% of all crop land used cover crops (Wade et al., 2015).

2.2 Influences of Behavior

According to the Theory of Planned Behavior, behavior is influenced by “attitudes towards the behavior, subjective norms and perceived behavioral control” which combine to create the perception of behavioral control and the intention of performing the behavior, potentially leading to the engaging in the behavior (Ajzen, 2012). The conceptual model of this theory is shown in Figure 1. The behavior here is the use of conservation practices, which according to this theory, are influenced by the attitudes towards the practices, social norms regarding the practice and the capability to adopt the practice. This theory suggests that positive
attitudes towards these conservation practices and positive social acceptance of these practices along with the capacity to carry out the practices will strengthen the intention of actually engaging in conservation practices and increases the likelihood of engaging in conservation practices. Ajzen (1991) explains that the theory can suggest behavioral tendencies and cannot predict actual behavior and that it serves only as a simple model to understanding behavior constructs.

![Conceptual model representing the theory of planned behavior.](image)

**Figure 1** Conceptual model representing the theory of planned behavior.

The *Reasoned Action Approach* expands on the *Theory of Planned Behavior* by adding additional elements that influence attitude, norms, and perceived control. This theory identifies several variables that influence a person’s behavior, shown in Figure 2, of those the variables most relevant to farming attitudes are education, experience, knowledge, age and gender, income and global attitudes (Fishbein et al., 2007). These additional components offer insight into the background factors that create a person’s disposition towards a behavior. Other studies, discussed below, have also identified attitudes, education, income, experience, and knowledge as key
factors associated with conservation adoption (Prokopy et al., 2019 and Baumgart-Getz, Prokopy, and Floress, 2012).

Figure 2 Conceptual model of the reasoned action approach including the various influential background factors.

2.3 Mental Models

In cognitive and psychological sciences reasoning, decision making and behavior are constructed by the use of mental models which are internal cognitive structures that form a person’s understanding of the world or systems (Jones et al., 2011; Lynam & Brown, 2012). In essence, mental models represent a person’s understanding of a system’s function and can be used to explain subsequent decisions, reasonings or behaviors. Mental models are important in natural resource management because they can be used to understand a person’s own perceptions of a system and how those perceptions influence their behaviors, which is important for facilitating better management and conservation (Lynam & Brown, 2012). Mental models are used in research to evaluate the process thinking used to predict outcomes and determine action.
Research on the mental models of pastoralists, academics and extension agencies found that pastoralists have more simplified mental models of agricultural systems as compared to mental models from researchers and extension agents who had more dense, detailed mental models which they argue can affect management decisions (Abel et al., 1998). Mental models will be used here to evaluate the variables mentioned by participants when considering climate risks and the management decisions to address those risks. This research will apply mental models to examine how producer’s understanding of agronomic systems influence management decision-making. By evaluating the difference and similarities between manager and advisor mental models surrounding risk perception and management, we hope to identify variables or needs (i.e. information or resource needs) that are inhibiting practice adoption. To our knowledge there are no examples of previous research that applies a mental model’s approach to adoption of conservation practices under climate stressors.

2.4 Determinants of Adoption

A meta-analysis on 93 studies of best management practice (BPM) adoption in the U.S. found that there are few distinct factors related to adoption of BMP (Prokopy et al., 2019). The few variables that had slightly higher influence of adoption then other variables were farmer identity and motivation, attitudes towards the environment and attitudes towards practice, previous experience with conservation adoption, information and awareness, vulnerability, farm characteristics, income, education, expected yield, and engagement in marketing (Prokopy et al., 2019). The study concludes by emphasizing the need for addition research that incorporates individual and institutional factors that may be facilitating or constraining adoption (Prokopy et al., 2019).

In a meta-analysis by Baumgart-Getz et al. (2012), social factors were found to have a small role in effecting adoption, and identified income, information, and social networks as factors that all impact adoption (Baumgart-Getz et al., 2012). Some factors that were found to have an insignificant effect on adoption were education, knowledge of ecosystem quality, and
contrary to Prokopy et al. (2019), they found risk perception had no effect on adoption because it was shown to diminish with time. Both Prokopy et al. (2019) and Baumgart-Getz et al. (2012) find that access to information, awareness to programs, and farm characteristics as having an effect on adoption. Baumgart-Getz et al. (2012) concluded by suggesting further research look at practice-specific behavior rather than conservation behavior in general.

A study by Brodt et al (2004) applied the theory of planned behavior to examined how farmer beliefs, values and goals are influential of a farmer’s management styles and found that the management style was influential of conservation practices adoption. Although, Brodt et al. (2004) did not find a significant relationship between information sources, the use of practices and awareness of conservation programs on practice adoption, the study suggests that adoption of conservation practices is determined by the practice’s alignment with producer’s style of management, personal goals, and business goals. Therefore, adoption of practices may not only be influenced by external factors like the variables studied in Prokopy et al. (2019) and Baumgart-Getz et al. (2012), but that internal factors, such as those examined in Brodt et al (2004), may also be influencing management decisions.

A review and synthesis of 23 studies on the factors that influence adoption of conservation agriculture amongst farms of varying temperate zones, from both developing and developed countries (Knowler & Bradshaw, 2007), identified 170 factors correlated with adoption. The review finds farmer awareness of soil problems to be positively correlated with adoption; conservation attitudes was found to have a positive and insignificant correlation to adoption; and education and age was found to have an inconclusive correlations with adoption (Knowler & Bradshaw, 2007). The review finds that the presence of erosion to be positively correlated with adoption of conservation tillage (Knowler & Bradshaw, 2007). Farm profitability, income, and gross income was found to have an inconclusive correlation with adoption (Knowler & Bradshaw, 2007). Information on conservation practice and its availability was found to correlate with adoption, but dissemination effectiveness may hinder adoption; state intervention
was found to have negative impacts on adoption but participation in subsidy programs had positive correlations and some insignificant correlations to adoption (Knowler & Bradshaw, 2007). The study concludes that universally significant factors leading to adoption are unlikely, and suggest that region-specific factors be investigated (Knowler & Bradshaw, 2007).

As opposed to Prokopy et al. (2019), Baumgart-Getz et al. (2012), and Knowler & Bradshaw (2007), which studied external variables like farm characteristics, institutional factors and demographics, one study explored characteristics specific to the conservation practice, like relative advantage, compatibility, observability, trialability, complexity, and risk, and how these characteristics made them more or less acceptable to producers (Reimer et al., 2012). This study found that a producer’s perception of a practice was influential on their decision to adopt. Specifically, relative advantage, compatibility and observability were found to be the most influential on adoption, and relative disadvantage and incompatibility were most deterrent to adoption (Reimer et al., 2012). These characteristics were taken from Rogers’ (2010) diffusion of innovation theory, in which relative advantage is defined as the perception of a practice to be more advantageous than what it replaces; compatibility is defined as the practice’s alignment with experiences, values and needs of adopters; and observability is defined by the practice’s observable results (Rogers, 2010). This study shows a connection between perceived practice characteristics and adoption, suggesting that individual understanding of practice specific factors have influence on adoption.

2.5 Conclusion

Conservation agriculture involves practices that have been found to increase the farm resiliency to climate impacts. Conservation practices have also been found to have on-site benefits such as improved soil health, increased water conservation and increase in yields, as well as off-site benefits such as improved water quality and reduce greenhouse gas emissions (Busari et al., 2015; Dabney et al., 2006; Hobbs, 2007; Snapp et al., 2005). Current literature on conservation practice adoption finds few factors that are universally significant to adoption
(Baumgart-Getz et al., 2012; Knowler & Bradshaw, 2007; Prokopy et al., 2019), and suggest future research focus locally to incorporate farm-level characteristics (Smit & Wandel, 2006) and practice-specific factors (Reimer et al., 2012) that may have stronger indication of adoption. This research focuses on wine producers and viticulture advisors local to the Paso Robles AVA in California and investigated producer’s experiences with and advisor’s observations of conservation practices to determine factors that facilitate or inhibit adoption in this area. Interviews will use future climate scenarios to discuss climate impacts on wine production and methods for mitigating impacts and elicit producer’s experiences with conservation practices and their perceived benefits and barriers to these practices, specifically cover crops, conservation tillage and natural set aside lands.
Chapter 3

METHODOLOGY

3.1 Overview of Methods

In this research project, we sought to understand the farm-level circumstances and vulnerabilities of wineries local to the California Central Coast; therefore, our sampling frame and participants were located within the Paso Robles American Viticulture Area (AVA) Figure 3. The Paso Robles AVA is in Northern San Luis Obispo County and is a large income source for the county, bringing in an estimated $1.9 billion annually (Matthews & Medellín-Azuara 2017). The region contains more than 250 wineries farming a total of 40,000 acres of wine grapes from over 40 different varietals (Taranto, 2019). The wines produced from this area experiences a diversity of weather conditions, topography, and soils type (Taranto, 2019), this variation within the region create a unique setting for assessing potential impediments to the implementation of conservation practices. The vineyards from this AVA experience very different weather conditions and the projected climate scenarios for this area show noticeable differences from western vs. eastern vineyards, demonstrated in Table 1.

Interview participants were selected using a snowball sampling method that worked off an initial list of contacts and additional contacts were solicited from participants following each interview (Etikan, 2016). The initial list of contacts was obtained through a local grape grower organization and the list consisted of three vineyard managers and three advisors. Managers were either owner-operators, estate employees or management company employees. Advisors were comprised of cooperative extension advisors, irrigation and pest control consultants, university researchers and grower organization representatives. Managers and advisors were chosen as key informants because their knowledge of and experience with agricultural management decisions (Christopoulos, 2009). Advisors are a liaison for farmers to the scientific community and will provide researchers with contacts of similar characteristics, such as social group or experience
Figure 3 This map shows the outline of Paso Robles AVA and the 11 sub AVAs or districts.

Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

level (Christopoulos, 2009; Etikan, 2016). The use of a snowball sampling method may accelerate the point at which saturation is reached, meaning no new ideas or themes emerged when a new participant was interviewed (Prokopy 2011). Despite this, the method allows for direct connections to people with the knowledge and experience relative to our research questions, more importantly, the method will ensure the research direction and findings meet the needs of stakeholders and offers valuable contributions to the body of knowledge informing decision making and natural resource management. Additionally, the data gathered through this research will be used to inform the content and design of a future survey. The survey will be distributed to
operating landowners in Monterrey, San Luis Obispo, and Santa Barbara counties, to gather data to be used to assess the prevalence of farmer perceptions of environmental risk and the likelihood of conservation practice adoption amongst landowners in the central coast of California.

<table>
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<td></td>
<td>Projected 2020-2039</td>
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<tr>
<td></td>
<td>Projected 2050-2070</td>
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<td>Annual Average Nights Minimum Temp &gt; 60°F</td>
<td>Observed 1961-1990</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Projected 2020-2039</td>
<td>17</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>Projected 2050-2070</td>
<td>41</td>
<td>36</td>
</tr>
<tr>
<td>Annual Average Maximum °F</td>
<td>Observed 1961-1990</td>
<td>71.5</td>
<td>76.1</td>
</tr>
<tr>
<td></td>
<td>Projected 2020-2039</td>
<td>74.2</td>
<td>79.2</td>
</tr>
<tr>
<td></td>
<td>Projected 2050-2070</td>
<td>77</td>
<td>82.1</td>
</tr>
<tr>
<td>Annual Average Minimum °F</td>
<td>Observed 1961-1990</td>
<td>40.3</td>
<td>42.1</td>
</tr>
<tr>
<td></td>
<td>Projected 2020-2039</td>
<td>42.9</td>
<td>45.1</td>
</tr>
<tr>
<td></td>
<td>Projected 2050-2070</td>
<td>45.4</td>
<td>47.6</td>
</tr>
<tr>
<td>Annual Average Inches Rain</td>
<td>Observed 1961-1990 (Range)</td>
<td>26.1 (11-48.5)</td>
<td>11.9 (5.3-24.2)</td>
</tr>
<tr>
<td></td>
<td>Projected 2020-2030 (Range)</td>
<td>27.9 (9.4-58.7)</td>
<td>13.6 (4.7-26.2)</td>
</tr>
<tr>
<td></td>
<td>Projected 2050-2070 (Range)</td>
<td>27.2 (5.1-84.4)</td>
<td>13.1 (2.2-40.9)</td>
</tr>
</tbody>
</table>

Table 1 Climate variables temporal frame utilized in vineyard-level projections. Includes data from two participant vineyards. Source: Author calculations from Cal-Adapt.org

An interview guide was developed by my advisor Dr. Babin (See Appendix A) and focused on these main topics: general risk perceptions, methods for reducing risk, climate risks, methods for reducing climate risks, climate projections, and conservation practices. The interview was structured to 1) elicit manager and advisors unprompted risks facing viticulture with no mention of climate change, and their methods for addressing or minimizing these risk, 2) elicit manager and advisor thoughts on the risks facing viticulture due to climate change and their methods for addressing or minimizing risk, 3) introduce climate projections and assess any changes in manager and advisor perception of risks facing viticulture, 4) and finally, discuss the
practices of conservation agriculture. The purpose of the structure was to understand advisor and managers foremost concerns and explore the potential of climate projections for risk assessment and climate adaption. Climate projections were created using Cal-Adapt, a free online tool created by the Geospatial Innovation Facility (GIF) at University of California, Berkeley that provides data and information on climate change scenarios (Cal-Adapt, 2020). For our purposed, Cal-Adapt was used to create vineyard-scale climate forecast for interview participants that included information on “Annual Averages”, “Extreme Heat” and “Extended Drought” (CAL ADAPT 2019). These projections were introduced halfway through the interview to elicit producer and advisor perception of climate change risks to production and their opinions on conservations practices for managing those risks.

There interviews were conducted in-person by Dr. Babin, they took approximately 1 to 2 hours and were digitally recorded with the participants consent. Twenty interviews were completed between June and November 2019: 11 with vineyard managers and 9 with advisors. The interview recordings were sent to a third party to be professionally transcribed which converted the voice recordings into text documents compatible with the analysis software, NVivo. NVivo is a qualitative analysis software program (NVivo, 2020) that was used for coding the interviews. The interviews underwent two phase of coding analyses. The first phase of analysis was a collaborative effort with another master’s student, Diego Rivera, and I. In this initial phase, we examined perception of current, future and climate risks facing viticulture operations, the methods used to manage risks and information needed to aid in management decision-making. The results of this first phase have been written into a manuscript submitted for publication and is not the focus of this research paper. This research paper will present the findings from the second phase of analysis conducted by myself under the guidance of Dr. Babin. This secondary analysis focuses on the motivations and barriers to the adoption of cover crops, conservational tillage and set aside lands.
3.2 Initial Analysis Coding

The initial analysis coding began with developing a codebook. Researchers reviewed transcriptions to find the themes to create the primary codebook. The focus of the primary codebook was to identify general risks, climate risk, response to climate projections, and practices used to manage risks. First researchers individually coded the same four interviews which helped refine the codebook (Glaser, 1965) and test intercoder reliability (NVIVO, 2020). The intercoder reliability measures coding agreement between users, which was calculated using the Kappa Coefficient through the NVIVO software (NVIVO, 2020), which found a coding agreement of 80% (Lombard et al., 2002). With a better refined codebook, researchers then conducted a second round of coding which resulted in a coding agreement of 95%. Using this final codebook (Table 2), all interviews were coded with one researcher coding all advisor interviews and another coding all manager interviews.

<table>
<thead>
<tr>
<th>Risks (short and long-term)</th>
<th>Climate Change Risks</th>
<th>Downscaled Projections</th>
<th>Practice for Management of Climate Risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Labor</td>
<td>Water availability</td>
<td>Overall response</td>
<td>Current practices to reduce risk</td>
</tr>
<tr>
<td>Water</td>
<td>Extreme heat</td>
<td>Risks/ adaptations</td>
<td>Potential practices to reduce risk</td>
</tr>
<tr>
<td>Market</td>
<td>Growing degree change</td>
<td>Improvements</td>
<td>1. Short term farming and</td>
</tr>
<tr>
<td>Regulations</td>
<td>Erosion</td>
<td></td>
<td>winemaking adaptations</td>
</tr>
<tr>
<td>Disease or pests</td>
<td>Grape quality</td>
<td></td>
<td>2. Long-term diversification</td>
</tr>
<tr>
<td>Input costs</td>
<td>Pests</td>
<td></td>
<td>and vineyard design adaptations</td>
</tr>
<tr>
<td>Climate or weather</td>
<td>Phenology</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Yields</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Frosts</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Table 2** First coding framework used to perform primary analysis of the general risks, climate risks, response to projections, and practices employed to manage risk.
3.3 Secondary Analysis Coding

Similarly, for the second analysis, four interviews were reviewed to find general themes regarding the benefits and barriers to adoption of each conservation practices, these themes were then used to establish the second codebook (Glaser, 1965). The focus of secondary codebook (Table 2.) was to categorize benefits and barriers to each of three conservation practices: conservation till, cover crops and set aside lands. The codes were based on emerging themes found while reviewing the interviews. Some codes are less straightforward and defined here as:

*Soil Health:* Encompassed any mention of soil physical, chemical and biological properties.

*Soil Type/ Structure:* Instances where soil type/structure was specifically identified

*Erosion Prevention:* Encompassed any mention of erosion, sediment runoff or soil loss

*Water Conservation/Infiltration:* Encompassed any mention of reduced water use or demand, improved water holding capacity, or improved rainfall efficiency

*Seeding Precision:* References any mention of the timing of seeding application

*Climate Resiliency:* References any mention of reduced sensitivity or vulnerability to climate impacts

*Information Need:* Used to code instances when participants requested or required additional information, or when participants lack information on a particular subject

*Equipment Cost/Labor:* Used to code any mention of the cost of a practice’s or the practices impact on labor

*Incentives/Funding:* Refers to any mention of external financial support

*Weed Management:* References an instance when practice was use as a method for managing weeds

*Invasive Weeds:* Refers to any mention of difficult or persistent weeds

*Gazing:* Instances where implication on grazing use
<table>
<thead>
<tr>
<th></th>
<th>Cover Crops</th>
<th>Conservation Tillage</th>
<th>Set Aside Lands</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benefits</td>
<td>Barriers</td>
<td>Benefits</td>
<td>Barriers</td>
</tr>
<tr>
<td>Soil Health</td>
<td>Cost or Labor</td>
<td>Soil Health</td>
<td>Invasive Weeds</td>
</tr>
<tr>
<td>Erosion Prevention</td>
<td>Seeding Timing</td>
<td>Weed Management</td>
<td>Soil Type or Structure</td>
</tr>
<tr>
<td>Water Conservation/Infiltration</td>
<td>Incentives/Funding</td>
<td>Water Conservation/Infiltration</td>
<td>Rodents Or Pests</td>
</tr>
<tr>
<td>Grazing</td>
<td>Information Need</td>
<td>Carbon Sequestration</td>
<td>Information Need</td>
</tr>
<tr>
<td>Wine Quality</td>
<td>Water Use</td>
<td>Erosion Prevention</td>
<td>Water Infiltration</td>
</tr>
<tr>
<td>Carbon Sequestration</td>
<td>Tillage Need</td>
<td>Climate Resiliency</td>
<td>Other</td>
</tr>
<tr>
<td>Climate Resiliency</td>
<td>Other</td>
<td>Other</td>
<td>Other</td>
</tr>
<tr>
<td>Weed Management</td>
<td></td>
<td>Wine Quality</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Table 3** Final codebook used in secondary analysis for assessing variables correlated to adoption.

Once the secondary codebook was complete, the codebook was used to code transcripts to determine the benefits and barriers to a conservation practice. Every instance in which participants discussed anything relevant to a code’s description was tabulated under than code (Glaser, 1965). This method resulted in the ability to quantify prevalence of each benefit and barrier to a practice amongst our sample.
RESULTS

A total of 11 grape producers and 9 advisors were interviewed to understand the motivations and barriers to the adoption of conservation practices amongst vineyard managers and advisors in the Paso Robles American Viticultural Area (AVA). Producers were of various positions such as 1 owner-operators, 3 estate employees, and 7 management company employees. Ages of producers interviewed ranged from 33 to 73 years; amount of experience ranged from 3 to 25 years; and scale of managed acreage ranged from 7 acres to 2500 acres with 7 producers managing large-scale, 400 or more acres, and 4 producers managing small-scale, 100 or less acres. Advisors were comprised of 1 cooperative extension advisor, 4 irrigation and pest control consultants, 2 university researchers and 2 grower organization representatives. Of the 11 producers we interviewed, all practiced cover crops (CC), 45% actively practice conservation tillage (CT), and 81% actively manage natural set aside lands on their property (Table 4).

<table>
<thead>
<tr>
<th></th>
<th>Cover Crops (%)</th>
<th>Conservation Tillage (%)</th>
<th>Set Aside Lands (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N=11</td>
<td>N=11</td>
<td>N=11*</td>
</tr>
<tr>
<td>Actively Practicing</td>
<td>100</td>
<td>45</td>
<td>81</td>
</tr>
<tr>
<td>Not Practicing</td>
<td>0</td>
<td>55</td>
<td>0</td>
</tr>
</tbody>
</table>

Table 4 Percentage producers cover crops, reduced tillage, and set aside lands amongst producers. *Two of the producers interviewed were not asked about set aside lands use or about their perceived benefits and barriers.

4.1 Cover Crops: Benefits and Barriers

When specifically discussing motivations and benefits to using CC in the vineyard, the top three reasons identified by producers were soil health (100%), erosion prevention (91%) and climate resiliency (73%), while advisors similarly identified erosion prevention (77%) and climate resiliency (66%) (Table 5). Slightly less common was the mention of water conservation
and or infiltration as a benefit to using CC, mentioned by 45% of producers and 55% of advisors. Within the Other category producers often mentioned the utility for CC as dust control (36%), for vineyard aesthetics (9%), and for beneficial insects (9%), while advisors mentioned the improvement to fishery habitats or biodiversity (22%), utility of CC as an additional source of income (11%), vineyard accessibility (11%) and the benefit of an environmental image on vineyard public relations (11%).

“[Cover crop]’s getting nitrogen and life in our soil. Building healthy soil, I guess is the big score with the cover crops. And yeah, through that, forage for the sheep, nitrogen for the soil, hopefully a little more nitrogen for the vines, mitigate erosion.” – Producer 1

“I don't want an erosion, and I don't want any dust and I feel like having ground cover conserves water. And I also think that having ground cover is better for soil health.” – Producer 2

“We're concerned about fixing nitrogen and healthy soils and the microbiome and nematodes for God's sakes. We got to have healthy nematodes.” – Producer 4

“To put nutrients back into the soil for erosion control. I think their idea is the-- because what they'll do is, they'll cover crop it. I think that helps to build topsoil and I think that's really what we're after. And then getting and then disk ing it and getting that organic matter back in soil. So, building organic matter in the soil is one of their main goals” – Advisor 4

“Higher organic matter, and you've got better soil structure, more effective rainfall, hopefully a larger rooting area. I mean, if you've got more organic matter, you've got better structure infiltration. You've got more water-holding capacity. You've got more resiliency to these hot temperatures. You're covering the soil, so solar radiation. All those types of things, I would think...less erosion.” – Producer 5

“Well, it's to protect the soil from erosion with rainfall. And that's the key thing-- they want, they're aiming to add organic matter, and then they're also trying to make the vineyard more workable from the standpoint of access, to dry out the soils, create a firmer soil that they can drive their vehicles on early in the spring to put their sprays on” – Advisor 7
<table>
<thead>
<tr>
<th>Cover Crop Motivation/Benefits</th>
<th>Producers N (%)</th>
<th>Advisors N (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil Health</td>
<td>11 (100)</td>
<td>5 (55)</td>
</tr>
<tr>
<td>Erosion Prevention</td>
<td>10 (91)</td>
<td>7 (77)</td>
</tr>
<tr>
<td>Climate Resiliency</td>
<td>8 (73)</td>
<td>6 (66)</td>
</tr>
<tr>
<td>Water Conservation/Infiltration</td>
<td>5 (45)</td>
<td>5 (55)</td>
</tr>
<tr>
<td>Other</td>
<td>5 (45)</td>
<td>5 (55)</td>
</tr>
<tr>
<td>Carbon Sequestration</td>
<td>3 (27)</td>
<td>2 (22)</td>
</tr>
<tr>
<td>Grazing</td>
<td>3 (27)</td>
<td>1 (11)</td>
</tr>
<tr>
<td>Weed Management</td>
<td>2 (18)</td>
<td>1 (11)</td>
</tr>
<tr>
<td>Wine Quality</td>
<td>0</td>
<td>1 (11)</td>
</tr>
</tbody>
</table>

Table 5 Variables identified by participants as either being a benefit or motivation to implementing cover crops in the vineyard.

In discussing barriers to the adoption of CC, the top two struggles or difficulties mentioned by producers were timing of seeding (45%) and rodents or pest (45%), closely behind that was water (36%), cost or labor (36%), and invasive weeds (36%). In Other, producers mentioned CC as negatively affecting vineyard image as it might appear to people as less groomed (9%), and another barrier was the potential to lose tractor access to vines after rainfall due to the sogginess of the ground (36%). For advisors, the most common challenges identified were water use (55%) and cost or work (55%). In Other, advisors mentioned access to machinery (11%) and allowing habitats for snakes (11%) as difficulties to maintain CC. Interestingly, the availability of incentives was not explicitly mentioned as a deterrent to cover crop use and few producers mentioned cost and work to maintain CC as a barrier to implementing.
“I mean, as far as cover crop it's just timing and availability of the seeder is a little tricky, and the cost of the seed, but I think it's kind of a no-brainer.” – Producer 1

“But killing it at a certain time. That's why it's tough for me because I try to do my part with the environment, with the cover crops and everything but with water being such a big issue-- if water wasn’t an issue I'd just keep mowing it and not worry about it. But we have to kill it at a certain point. And so that's when we do use Roundup to try and kill it. So, the timing is really important. We want it to recede, but we want to kill it early enough to where it doesn't compete with the vines.” – Producer 5

“I would say that [cover crop] use and the variety mix and management of it is dominated by gopher and ground squirrel pressure. And then canopy health, their vine balance. So, between those two things, those usually determine if it's going to be a just a cheap barley. Get good cover on the winter then disc it under as soon as we can or if it's going to be more expensive brassica mix. Or a fescue mix if we're going to go more permanent. If ground squirrel and gopher issues are low and if the vines are in balance or we want to slow down the vigor. We'll go to more of the grasses, bunch grasses.” – Producer 6

“Most people claim that they use water and they use the nutrients, so they compete with the vines.” Advisor 2

“One more thing to have to do. Seed isn't that expensive, but it is an extra cost. So their calculation is in cost per acre. So for all the things to do, it's always per acre. "Pruning costs me this much per acre. Harvesting costs me this per acre. Fertilizer costs me this much per acre." And so, in terms of their total cost per acre, it's not that much, I don't think, extra. But it's just one more thing to have to do. And it has to be timed properly, so it has to come right after harvest then. And the equipment is different because now you're basically a green farmer, not a grape grower anymore, so different equipment. You've got a small window to put the seed in.” – Advisor 3

“I think mainly just the competition with their vines.” Advisor 5

<table>
<thead>
<tr>
<th><strong>Cover Crop Barriers</strong></th>
<th>Producers N (%)</th>
<th>Advisors N (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water Use</td>
<td>4 (36)</td>
<td>5 (55)</td>
</tr>
<tr>
<td>Cost or Labor</td>
<td>4 (36)</td>
<td>5 (55)</td>
</tr>
<tr>
<td>Seeding Timing</td>
<td>5 (45)</td>
<td>2 (22)</td>
</tr>
</tbody>
</table>
Table 6 Variables identified by participants as either being a barrier to implementing cover crops in the vineyard.

<table>
<thead>
<tr>
<th></th>
<th>4 (36)</th>
<th>2 (22)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Other</td>
<td>4 (36)</td>
<td>2 (22)</td>
</tr>
<tr>
<td>Rodents Pest</td>
<td>5 (45)</td>
<td>0</td>
</tr>
<tr>
<td>Information Need</td>
<td>2 (18)</td>
<td>3 (33)</td>
</tr>
<tr>
<td>Invasive Weeds</td>
<td>4 (36)</td>
<td>0</td>
</tr>
<tr>
<td>Tillage Need</td>
<td>0</td>
<td>2 (22)</td>
</tr>
<tr>
<td>Incentives/ Funding</td>
<td>1 (9)</td>
<td>1 (11)</td>
</tr>
</tbody>
</table>

4.2 Cover Crops and Climate

When asked if CC were a helpful adaptation to reduce climate impacts, 72% of producers responded yes and 27% responded no, despite this, all respondents actively use CC Table 7. Similarly, despite differences of opinion of CC utility for climate mitigation, producers experience the same barriers and benefits to using CC Table 7.

“If there's more harder rain it'll mitigate erosion. I don't see how it helps us with heat.” – Producer 4

“I mean, if anything you would want more protection for the soil if the climates-- if it's going to be hotter. So maybe I'll that the cover crop grow, mow it a little bit higher.” – Producer 5

“if we're going to get bigger-- more downpour rain on things, it seems like a huge negative would be if you were caught without any cover. The moment that rain came, you're going to lose a bunch of soil. So my take is stick with it, man. Yeah. Train your vines to go deeper.” – Producer 10

“You would have more rainfall and potentially hotter temperatures in the summertime. So actually, in that scenario, again, a cover crop is helpful to us because it would manage growth. If you wanted to have a competitive cover crop off of that rainfall, you would have it and then you would just have to decide at what point you don't want it there anymore competing with the vines.” – Producer 11
Will cover crops help mitigate climate impacts?  
N (%)  | Benefits of practice | Barriers to practice | Outcome
---|---|---|---
Yes 8 (72) | Climate resiliency (8)  
Soil Health (8)  
Erosion Prevention (7)  
Water Conservation or Infiltration (3)  
Carbon Sequestration (3)  
Weed Management (1)  
Other (4)  
Grazing (3) | Seeding Timing (4)  
Cost or Labor (3)  
Invasive Weeds (3)  
Rodents or Pest (3)  
Information Need (1)  
Water Use (2)  
Other (1)  
Incentives (1) | Actively Practicing (8)
No 3 (27) | Soil Health (3)  
Erosion Prevention (3)  
Water Conservation or Infiltration (2)  
Carbon Sequestration (1)  
Weed Management (1)  
Other (1) | Seeding Timing (1)  
Cost or Labor (1)  
Invasive Weeds (1)  
Rodents or Pest (2)  
Information Need (1)  
Water Use (2)  
Other (2) | Actively Practicing (3)

Table 7 Results showing the perception of cover crops as a climate adaptation amongst wine producers, associated benefits and barriers experienced by users of the practices, and the resulting outcome.

4.3 Conservation Tillage: Benefits and Barriers

Conservation tillage (CT) had few agreed upon benefits. Producers and advisors identified soil health (27%) and climate resiliency (27%) as benefits of CT. The benefits for using CT for managing weeds (0), sequestering carbon (9) or for wine quality (9) were largely insignificant to adoption of CT amongst our sample.
“Healthy soil, healthy vines, better wine. I mean, the end goal is to make the best wine we can and the most distinct wine we can from this site. And so through that, if the vines were getting their nutrients from the soil, there’s nutrients available in the soil and then the minerals because of the life in the soil, that makes better wine for us.” – Producer 1

“Keeping the soil structure in place so that the nitrogen has pathways to create life underground.” – Producer 2

“I think most people are concerned about that own their land. Some people have added that, "Well, a lot of growers don’t own their land, that they’re actually leasing the land." And maybe they aren’t planning to be there for that many years. In that case, they aren’t too concerned about long-term changes. They only do what works for now, and they are not even thinking about the future. So, it does depend what kind of grower you are, an older grower or a leasing grower.” – Advisor 1

“But, tilling reduces organic matter and then that will kind of trigger serious consequences and reduce water-holding capacity and reduce carbon sequestration. So, it will reduce adaptation and it will reduce mitigation.” – Advisor 2

“It ties into water conservation. And again, the only two ways for water to leave the vineyard is through the soil or through the leaves. So that if you’re doing that-- I mean, there are other ways, but they’re much more expensive, like you say, mulching. So, nobody does that.” – Advisor 3

<table>
<thead>
<tr>
<th>Conservation Tillage Benefits</th>
<th>Producers N (%)</th>
<th>Advisors N (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil Health</td>
<td>3 (27)</td>
<td>3 (33)</td>
</tr>
<tr>
<td>Climate Resiliency</td>
<td>3 (27)</td>
<td>5 (55)</td>
</tr>
<tr>
<td>Water Conservation</td>
<td>1 (9)</td>
<td>2 (22)</td>
</tr>
<tr>
<td>Erosion Prevention</td>
<td>3 (27)</td>
<td>0</td>
</tr>
<tr>
<td>Other</td>
<td>2 (18)</td>
<td>1 (1)</td>
</tr>
<tr>
<td>Weed Management</td>
<td>0</td>
<td>1 (1)</td>
</tr>
<tr>
<td>Carbon Sequestration</td>
<td>1 (9)</td>
<td>1 (1)</td>
</tr>
<tr>
<td>Wine Quality</td>
<td>1 (9)</td>
<td>0</td>
</tr>
</tbody>
</table>
These variables were identified by participants as the benefits to practicing conservation tillage.

According to producers, the most common barrier to implementing CT in vineyards was compaction (54%), second to that was informational needs (36%) and miscellaneous things (36%) such as vineyard aesthetics (18) and preventing frost build (18) up Table 9. No advisors identified compaction as being a barrier to adoption. Soil structure (18%) and water infiltration (18%) were the lease common to be identified as barriers to adopting CT by both producers and advisors Table 9.

“Most people will rip every few years and break up the compaction.” – Producer 2

“It's heavy clay. But combined with the magnesium, you'll have cracks that wide. And so, what those are freeways for the mealybug to move right over to the next line. And so, what we've done is we've done a practice of working, either disking or spading or chiseling every other row.” – Producer 7

“IT’s very heavy soils. And no till to me doesn't make sense here. I think it makes sense in other areas, but it does not make sense here. I've tried it trying to be a steward and carbon sequestering and we have to come back in and rip.” – Producer 8

“The biggest thing that eventually makes you do it is it just gets brushed it off and compacted. You see people doing ripping where there are things have gotten compacted from the tractor driving.” – Producer 11

<table>
<thead>
<tr>
<th>Conservation Tillage Barriers</th>
<th>Producers N (%)</th>
<th>Advisors N (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Other</td>
<td>4 (36)</td>
<td>3 (33)</td>
</tr>
<tr>
<td>Compaction</td>
<td>6 (54)</td>
<td>0</td>
</tr>
<tr>
<td>Rodents/Pest</td>
<td>3 (27)</td>
<td>2 (22)</td>
</tr>
<tr>
<td>Invasive Weeds</td>
<td>2 (18)</td>
<td>3 (33)</td>
</tr>
<tr>
<td>Information Need</td>
<td>4 (36)</td>
<td>3 (33)</td>
</tr>
</tbody>
</table>
Table 9 These variables were identified by participants as barriers to practicing conservation tillage.

4.4 Conservation Tillage and Climate

The utility of conservation tillage for climate mitigation amongst producers had more variation, the majority of producers found CT as helpful (93%) in mitigating climate impacts, and the rest did not see CT as a helpful adaptation (18%) or were unsure of its usefulness as a climate adaptation (18%) (Table 10). All producers who responded no to CT as a method for mitigating climate impacts did not adopt CT, despite identifying 3 of the same benefits and 2 of the same barriers to the practice as those who did utilize the practice (Table 10). Of the respondents who were not utilizing CT, they most common barriers identified was compaction (83%) (Table 10).

“I still don't know because the old school mentality of dry farming is to disc and create that dust crust to conserve water. So, I don't know if there's enough data yet in vineyard systems on long term no till in this area, to know how much water it's conserving I guess versus on till” – Producer 1

“I mean, tilling is going to have huge erosion problems as the rain keeps getting bigger, especially on slopes.” – Producer 4

“The best soil to protect during frost events is a wet, tilled soil. It's going to radiate the most heat back up at night. So, I think as people see things getting hotter and/or colder on the extremes, they're going to want fewer plants growing that compete and they're also going to want more tilled soil that can help them.” – Producer 6

<table>
<thead>
<tr>
<th>Using CT N (%)</th>
<th>Benefits N (%)</th>
<th>Barriers N (%)</th>
<th>Will practice help mitigate climate impacts? N (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes 5 (45)</td>
<td>Soil Health 2 (40)</td>
<td>Compaction 2 (40%)</td>
<td>Yes 5 (100)</td>
</tr>
<tr>
<td></td>
<td>Erosion 2 (40)</td>
<td>Rodents or Pest 1 (20%)</td>
<td></td>
</tr>
</tbody>
</table>
There were few identified benefits of maintaining set aside lands. The most commonly identified benefits were the benefits of ecology/biodiversity and the utility of these areas as physical barriers (44%) (Table 11). In Other, producers mention the benefit of using set asides for vine tours (22%), for redevelopment (11%) and for vineyard aesthetics (22%). More than half of advisors identified the Ecological/Biodiversity (55%) benefits of these areas, and a third of advisors identified set asides as improving climate resiliency, however zero producers made this acknowledgement (Table 11).

"Key motivation is I think that diversification is better for soil health and overall health of the vineyard." – Producer 2

"The main reason we did [buffer strips] was for the neighbors. So, we didn't want to get any drift onto their property or lights or dust. That was more of a neighborly thing." – Producer 3
“I don't need it, basically and plus, it would be a PR nightmare if I started chopping oak trees down. I'd like to sell wine right. Don't want to become on the most hated list.” – Producer 10

“They are reservoirs of diversity. There are studies that show the whole side of diversity, which it will be important in retaining nutrients in the vineyard and at the landscape level have a series of benefits. Sequestering carbon, returning nutrients, providing diversity.” – Advisor 2

<table>
<thead>
<tr>
<th>Set aside lands Benefits</th>
<th>Producers N (%)</th>
<th>Advisors N (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Other</td>
<td>5 (55)</td>
<td>1 (11)</td>
</tr>
<tr>
<td>Ecological/Biodiversity</td>
<td>4 (44)</td>
<td>5 (55)</td>
</tr>
<tr>
<td>Physical Barrier</td>
<td>4 (44)</td>
<td>1 (11)</td>
</tr>
<tr>
<td>Climate Resiliency</td>
<td>1 (11)</td>
<td>3 (33)</td>
</tr>
</tbody>
</table>

Table 11 These variables were identified by participants as benefits to maintaining set aside lands.

There were few agreed upon barriers to maintaining or implementing set aside lands. With only 22% of producers discussing funding or incentives and cost or work as barriers to having set asides. A third of advisors discussed information being a barrier to adoption of set asides. In other, one producer shared concerns about these areas, specifically the riparian buffers, as being potential vectors for the spread of pest and disease. In other, advisors shared that producers may not want to enroll areas of their land into conservation to avoid losing agriculturally productive, profitable lands (11%) and also shared that vineyards are already predeveloped, making it unlikely producers will or can change the layout of their land (11%).

“Farmers, they do things because either that's how they've always done them or it was suggested to them that they do. And they do it but they might not be thinking about these underlying things but they do it. And sometimes it's the right thing, and sometimes it's not. And I think education again is the missing part.” – Advisor 4
“I would have loved to have gotten funding just for plants and things through the Healthy Soils Program. But again, I didn't qualify.” – Producer 2

“But I would say going forward as a philosophy you're going to be hard pressed to find willingness for people to irrigate a unprofitable resource on an otherwise limited-resource project” – Producer 6

<table>
<thead>
<tr>
<th>Set aside lands Barriers</th>
<th>Producers N (%)</th>
<th>Advisors N (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Funding or incentives</td>
<td>2 (22)</td>
<td>0</td>
</tr>
<tr>
<td>Cost or Labor</td>
<td>2 (22)</td>
<td>2 (22)</td>
</tr>
<tr>
<td>Other</td>
<td>1 (11)</td>
<td>2 (22)</td>
</tr>
<tr>
<td>Information Need</td>
<td>0</td>
<td>3 (33)</td>
</tr>
</tbody>
</table>

Table 12 These variables were identified by participants as barriers to maintaining set aside lands.
Chapter 5

DISCUSSION

The objective of this research is to gain insight into the region-specific and practice-specific influences on adoption of cover crops (CC), conservation tillage (CT) and set aside lands as perceived by wine grape producers and viticulture advisors in the Paso Robles AVA.

All producers and advisors generally agreed upon the benefit of CC for Erosion Prevention, improving Soil Health, and building Climate Resiliency consistent with research on cover crop benefits (Roesch-McNally et al., 2018; Snapp et al., 2005). The barriers to CC identified by producers such as Rodent and Pest pressures or precision of Seeding Timing, were not a deterrent to CC use amongst our sample, and issues with Seeding Timing have previously been identified as barriers to CC (Roesch-McNally et al., 2018). There was less agreement on the benefits of CT amongst producers and advisors, and producers who did not adopt CT mentioned more barriers than those who did adopt CT. Producers who did not practice CT, identified issues of Compaction and Soil Structure at higher rates than producers who did practice CT, which are farm characteristics (Smit & Wandel, 2006) and practice-specific factors (Reimer et al., 2012) that may be potentially significant variables that may be inhibiting adoption and require more investigation. There were few recognized benefits of and barriers to maintaining natural set aside lands by both advisors and producers, indicating a potential lack of knowledge regarding set aside lands as conservation practices; information and awareness of practices has been shown to impact adoption (Baumgart-Getz et al., 2012; Knowler & Bradshaw, 2007; Prokopy et al., 2019)

Through this research, I was able to identify variables that may be motivating or inhibiting adoption of conservation practices, these variables were then used to develop influence diagrams that represent the prevalence of wine producer perceptions of conservation practices and likelihood landowners will adopt conservation practices. The variables in this influence diagram will be used to inform the content and design of a widely distributed survey that will sent out to
all agricultural producers in the Central Coast. This survey will gather data to quantify the prevalence of risks perceptions amongst central coast farmers and determine how risk perception affects likelihood of conservation practice adoption under external environmental risks.

5.1 Cover Crops

5.1.1 Producers vs. Advisor: Cover Crop Benefits

The most common benefit of CC identified by producers was the benefits to Soil Health, Erosion Prevention and Climate Resiliency, which are consistent with research on cover crop benefits (Roesch-Mcnally et al., 2018). Similarly, advisors most commonly identified the benefit of Erosion Prevention and Climate Resiliency, with about half identifying Soil Health. Soil Health benefits included any mention of organic soil matter, increased nitrogen, soil structure and protections from solar radiation, which is represented by some exemplar quotes in Section 4.1. Producer often associated benefits to Soil Health was the benefit of Erosion Prevention, both of which are widely studied benefits of cover crops (Roesch-Mcnally et al., 2018; Snapp et al., 2005). The prevalence of cover crop usage and the identification of Soil Health, Erosion Prevention and Climate Resiliency as benefits to cover crops amongst our sample or producers, shows these producers have a good understanding of the utility of this practice, which may be why all are choosing to adopt this practice.

Producers and advisors made similar connections between Erosion Prevention with the benefit of improved Water Conservation/Infiltration, or soil water storage capacity. Due to the topography in this area, this area is very susceptible to erosion, additionally, this area is projected to experience increased variability in precipitation, meaning rainfall averages are forecasted to widen in range (See Table 1) and growers could experience flood like down pours that could take away inches of top soil, requiring the use of cover crops to prevent soil loss. The impacts of CC on improving water infiltration, reducing erosion and increase water holding capacity is
extensive, the acknowledgement of these specific benefits amongst producer and the high adoption rate within this sample imply that these producers recognize the benefits to adoption.

5.1.2 Producers vs. Advisor: Cover Crop Barriers

Almost all producers applied CC to 100% of the land, and the barriers experience by producers did not appear to inhibit CC adoption but did largely affected management techniques and the scale of cover crop use. The most commonly identified barrier amongst producers was the Rodents and Pest and Seeding Timing. Seeding timing has been found to be a barrier or difficult in using cover crops (Roesch-McNally et al., 2018). Slightly less prevalent was the mention of Cost or Labor, which was recognized as a potentially significant barrier to CC adoption (Roesch-McNally et al., 2018). Advisors did not identify the same barriers as producers, the most commonly agreed upon barrier by advisors was Water Use and Cost or Labor, which may indicate a potential knowledge gap between advisor’s understanding and producer’s experiences and may be a potential area for focusing communication. However, roughly a third of producers mentioned water use as a barrier because cover crops have to be planted according to rainfall to avoid having to irrigate cover crops and increase water use, CC have been found to be more beneficial in area with abundant rainfall to avoid increases in irrigation and water competition between vine and cover crop (Snapp et al., 2005). Choosing the proper cover crop is very nuanced and requires different management techniques; elements like soil properties, soil needs, spatial and temporal characteristics are all elements that should be considered when selecting a cover cropping systems (Snapp et al., 2005).

5.1.3 Cover Crops and Influence Diagram

Since CC were used by every producer interviewed, the influence diagrams of variables motivating, or inhibiting adoption are not as informative. However, one objective of this research was to determine the influence, if any, future climate scenarios had on conservation practice utility. Our interviews were structured to discuss climate scenarios prior to discussing the topic of
conservation practices. When asked if CC can help mitigate impacts of climate change, roughly three quarters of producers responded yes, and a quarter responded no. All producers who considered CC as a means to help mitigate climate impacts also identified Climate Resiliency as a benefit, whereas the producers who did not consider CC to help mitigate climate impact did not identify Climate Resiliency, potentially representing an information need or area of focus for communication. Interestingly, producers who did not perceive CC to help with mitigating climate impacts did perceive the practice to have benefits on Soil Health, Erosion and Water Conservation/Infiltration. Having made, or not made the association of CC as a climate adaptation was not a deterrent to employing cover crops based on our sample.

**Figure 4** Influence diagram showing the perception of cover crops as a method for mitigation climate impacts, and differences in perceived benefits and barriers to cover crops.

5.2 Conservation Tillage

5.2.1 Producers vs. Advisors: Conservation Tillage Benefits

Slightly less than half of producer practiced CT, each practicing at varying degrees of magnitude and using different management techniques. In this analysis we define conservation
tillage as little to no soil disturbance which included no-till, spot-till or reduced tillage (Busari et al., 2015). There were fewer agreed upon benefits of CT with only about a quarter of producers agreeing on Soil Health, Climate Resiliency and Erosion Prevention, all of which are known benefits of CT (Busari et al., 2015). Advisors identified similar benefits to producers, such as Climate Resiliency and Soil Health. CT has been studied as a method for reducing soil degradation, increase carbon sequestration and preventing erosion (Hobbs, 2007). The association of CT with Soil Health, Erosion Prevention, and Carbon Sequestration was not strong, this may signify there is a lack of understanding of CT benefits which may be leading to the lower adoption rate in this sample.

An aspect that may be influencing conservation agriculture is the type of land ownership. One advisor brought up the potential impact that ownership may have on management decisions. The reasoning for this being that producers are more concerned with near term decisions, rather than long-term. The effect of land ownership on management decision making has been identified as a potentially significant variable for influencing adopting, which suggest that those that lease may be less likely to be stewards of the land then those who own it (Reimer et al., 2012). This was not a variable that was measured but is a recommend addition to the survey developed in the next phase of this research.

5.2.2 Producers vs. Advisors: Conservation Tillage Barriers

The barriers associated with CT appeared to impact the type of conservation tillage or management techniques used by producers. These barriers were often issues experienced by producers that made it difficult to be completely no till. A large number of producers expressed issues with Compaction of soil as the top reason for needing to till the soil, contrary to the studied benefits of CT which found CT to reduce soil compaction (Allmaras & Dowdy, 1985). However, these experiences with compaction reinforce the importance of examining farm-level
characteristics to understand the compatibility of a practice with individual farms (Knowler & Bradshaw, 2007; Prokopy et al., 2019).

Something that was not measurable in the data, but may be a significant indication of CT adoption is the soil type and its compatibility with CT. Topography, soil type and soil depth vary significantly within the AVA (Paso Robles AVA: 11 Viticultural Areas, 2018). The producers who were not practicing CT discussed the incompatibility of this method with their soil type or structure. Soil type was not elicited specifically because interview questions were structured to gather producer perceptions. However, it is recommended that the survey include questions that acquire soil type to better understand reasons for management decision.

5.2.3 Conservation Tillage and Influence Diagram

The identification of benefits and barriers experienced by producers actively or not actively practicing CT were used to construct an influence diagram. The influence diagram shows variables that may be motivating or inhibiting adoption of conservation practices. The producers who were not practicing CT, identified barriers of Compaction, Water Conservation/Infiltration, and Soil Structure at higher rates than those who did practice CT, signifying potentially significant variables that are inhibiting adoption of CT and are recommended to be addressed in the survey. This supports the literature that suggest farm characteristics (Knowler & Bradshaw, 2007; Smit & Wandel, 2006) and practices specific characteristics (Baumgart-Getz et al., 2012; Rogers, 2010) may be better indicators of adoption. All producers who practiced CT also perceive it to be a method for reducing climate impacts. There was more variance in the perception of CT for reducing climate impacts amongst producer who did not actively practice CT. Although limited, there are few responses from producers which indicate a need for more information regarding the effects of tillage and conservation tillage in regard to preventing frost damage, and for water conservation.
5.3 Natural Set Aside Lands

5.3.1 Producers vs. Advisors: Natural Set Aside Land Benefits

There was less agreement on the benefits of natural set aside lands amongst producers and advisors. The Conservation Stewardship Program incentivizes the conservation of natural lands for the benefit of “soil quality, soil erosion, water quality, air quality, plant resources and animal resources” (NRCS, 2011a). The perception of set aside lands having Ecological/Biodiversity benefits were not substantial. This may indicate a potential area requiring outreach and communication to inform on the ecological benefits of set aside lands.

There was a high percentage (90%) of producers who actively maintained set aside lands. Somewhat common was the utilization of these zones as physical buffers to environmental elements. Producers recognized that these buffers could act as wind breaks and as a wall to block...
biological agents from entering into the vineyard. Some producers recognized that set aside land had PR benefits, which suggested that the maintenance of these area was obligatory because removal could result in public backlash.

5.3.2 Producers vs Advisors: Natural Set Aside Land Barriers

Few barriers were associated with set aside lands. One advisor suggests that a barrier to implementing set aside lands is the lack of education and awareness, signifying that more outreach and communication is need on the ecological benefits of set aside lands. Set asides are area of land that do not generate revenue but do require resources to be maintained, however, the data did not show Funding or Incentives to be deterrent to maintaining set aside lands, however some producers suggest that funding may motivate or instigate conservation of these zones.

5.3.3 Natural Set Aside Lands and Influence Diagrams

The influence diagram of the benefits and barriers to set aside lands, and their influence on adoption was not as informative because the no one variable gathered significant agreement. Two producers in our sample were not asked about this practice, and of the nine that were asked, all maintained set aside lands, making it difficult to find variables that were negatively affecting adoption. Nevertheless, the diagram shown in Figure 6 is a visual representation of the benefits and barriers associated to this conservation practices.
5.4 Short Comings of Research Findings

One shortcoming of this research is that our small sample size limited the generalizability of our findings. Although our research sample included producers of large- and small-scale wine growing operations and advisors with academic backgrounds and from management agencies, it still is not a sufficient sample size to draw generalizations or conclusions. However, the information gathered from this analysis will inform a survey that will be sent to all growers in the San Luis Obispo County to obtain a more representative sample. Additionally, the intention of these interviews was to gather producer and advisor’s perception of environmental risk and of conservation practices as methods for addressing those risks, and the findings presented here do not differentiate between benefits or barriers that were perceptions or lived experiences.

Perceptions have been identified as significant for understanding adoption (Roussy et al., 2017), so qualifying the results by perceptions or experiences may have generate different results because perceptions.
Chapter 6

CONCLUSION

The implication of sustained conventional farming practices on environmental quality, soil productivity and climate resiliency demand that adoption of conservation agriculture practices be improved and facilitated. Current literature on the subject on conservation practice adoption suggest that practice-specific and region-specific factors may be more valuable in understanding the factors that facilitate or prevent adoption. The research presented here investigates farm-level characteristics and producer experiences with each conservation practice to identify factors that motivate or prevent adoption. This preliminary assessment of conservation practices finds that producers do recognize the benefits of CC and CT, such as improvements to soil health, reduction in erosion and reduce susceptibility to climate impacts, but may need more information regarding the benefits of set aside lands. Some farm-level characteristics like issues with rodents and pest, and practice-specific factors like seeding timing were commonly discussed as difficulties in using CC. This sample had low rates of CT adoption and the most commonly discussed difficulty with CT was issues of soil compaction and soil structure, indicating that farm-level characteristics may lessen CT compatibility in this area. There were few recognized benefits of and barriers to maintaining natural set aside lands by both advisors and producers, indicating a potential lack of knowledge regarding set aside lands as conservation practices.

The results of this research will be used to inform a survey that assess the prevalence of factors affecting conservation practice adoption amongst agriculture producers in the central coast of California. Based on these results, it is recommended that survey include questions on soil type and structure, and land ownership as they indicate potential variables that influence management decisions. Additionally, this analysis suggest that lack of information or information needs regarding the benefits to CT and set aside lands may be limiting their adoption, and recommend
that further outreach programs focus communication on informing producers on the on-site benefits and off-site benefits to these practices.
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APPENDICES

Appendix A: Interview Questionnaire

Interview Guide

This research was funded by the state of California’s Agricultural Research Institute as well as the USDA. It evaluates perception of future risks to viticulture amongst vineyard managers and advisors in the central coast. It also evaluates the perceived barriers and opportunities for the adoption of conservation practices. The knowledge we gain from interviews will help inform local RCDs, state and federal policymakers as well as agricultural advisors on vineyard manager perceptions and preferred strategies of managing future risks.

Your participation in this interview is completely voluntary. If you choose to participate in this interview, your responses will remain confidential and your name will never be used in any report or publication. You may skip any questions you do not want to answer and you can stop the interview at any time.

Are you willing to participate in the interview?

Do you mind if I record this interview for transcription purposes?

Opening questions

1. What is your current position/ title?
2. How long have you worked in your current position?
3. Can you describe the farmland you manage: eg what types of crops and livestock and range of farm size (in acres), variations in renting and owning?
4. What proportion of your operation is wine grapes?
5. What is the region, county or geographic area in which you farm?
6. What types of decisions are you responsible for making (agronomic, conservation, financial, all)?

Risk perceptions

7. What risks are you worried about in the short term (1-2 years)? Please rank them in order of importance. Which ones are most likely? Which ones are most impactful if they occur?
   1.
   2.
   3.
   4.
   5.

8. What risks are you worried about in the medium-term (3-20 years)? Please rank them in order of importance. Which ones are most likely? Which ones are most impactful if they occur?
9. Are there any other risks that you are concerned about but did not mention?
10. Can you tell me more...? Anything else? Don’t worry about whether it’s right, just tell me what comes to mind.

Reducing risk
11. Have you or any grape growers you know of taken any actions to reduce these risks (Go through each of the risks in list above)?
12. Is there anything you can do to reduce these risks that you haven’t attempted (Go through each of the risks in list above).

Climate risks facing viticulture/ growers they advise
13. What I’d like you to do now is talk to about climate change, that is tell me what you know about climate change and viticulture.
   - Anything else?
   - Can you tell me more...?
   - Anything else? Don’t worry about whether it’s right, just tell me what comes to mind.
   - Can you explain why?

Nature of effects
14. Can you tell me about the main harms/ risks to viticulture of climate change? Please rank them in order of importance.
   1.
   2.
   3.
   4.
   5.
   - How big are the potential impacts? What is their likelihood?
   - Will climate change impact certain growers/ regions more than others?
   - Do you have any reason to believe that your risk to climate change is low or high compared to others? (Can you tell me why?)
   - Do you have a sense of how certain scientists are on the impacts of climate change on agriculture?
   - Is climate change really a risk to viticulture? Or is it one of those risks that is not that important? How does it rank with the other risks you mentioned earlier?
   - Can you give me some idea of how climate change risk compares to that, say of labor shortages/ costs?
Effects processes (use only if brought up)

15. Can you tell me a little more about heat waves/ droughts/ disease outbreaks and their role in the risks that climate change poses for viticulture?
   • Expand with other common effect processes

Risk assessment and management

16. Where have you read or heard about climate change risks to viticulture?
17. Where have you heard about thing that can be done to manage climate risks to viticulture?
18. Have you heard about any government or private programs to deal with climate risks to viticulture?

Reducing climate change risk

19. Have you observed grape growers changing their farm-management practices to reduce or minimize impacts and risks associated with climate change?
   • If yes, what changes have you observed?
   • If no, why?
   • Go through each of the risks in list above. Can you tell me more...?
   • Anything else? Don’t worry about whether it’s right, just tell me what comes to mind.
   • Can you explain why?

20. What other practices not currently observed would you consider important to reduce or minimize impacts and risks associated with climate change (average temp and precip, droughts, floods, heatwaves)?
   • Go through each of the risks in list above.
   • Can you explain the main reason(s) (barriers) for not implementing such practices (e.g. uncertainty, long time horizon to make decisions)?
   • You talked about (cover crops) Can you tell me more about this?

21. How effective are the measures/ practices you have talked about in reducing climate risk (both observed and not)? Do they all work equally as well?

I. Projections

22. Here are some projections of future climatic conditions developed by the state of California to assist citizens in adaptation- change in average temps, heat waves, change in precip.
23. What is your response to these projections?
24. Taking into account these future climatic projections, does this change your perceptions of risks facing your operation, and adaptation measures, if any, you might consider?
   • How does it change?
   • Can you tell me about the main harm/ risks to lemon cultivation of these projections?
   • How big are the potential impacts?
   • Will these projections impact certain types of growers/ regions more than others?
25. **Taking into account these future climatic projections, are you more inclined to change your farm-management practices? Please briefly explain your answer.**

- If yes, what changes would you be most likely to implement? With respect to droughts, extreme precip, heatwaves, etc?
- If no, why?
- What more can you tell me about the impacts of these projections on lemon cultivation?

26. How might these projections be improved/ tailored to your needs?

### Thresholds

27. Next I would like to use these projections to inform the development of some thresholds, beyond which cultivation of wine grapes would cease to be financially/ agronomically viable

**TEMPERATURE**

- At what average annual maximum temperature? Are there particular times of year when lemons are especially sensitive to increases in average maximum (not heatwaves) temperatures?

- At what average annual minimum temperature? Are there particular times of year when lemons are especially sensitive to increases in average minimum (not heatwaves) temperatures?

- When do heatwaves become critical? At what level of daytime maximum temperatures? For how long? What time of year?

Describe the types of impacts from these heat waves, and explain adaptation tools that exist to help alleviate the impacts.

What if water availability was 25, 50 and 75% of current allocation? How would that effect the impacts and the ability to adapt?

- Are there other important temperature thresholds to consider in lemon cultivation?

**PRECIP/ DROUGHT**

- What level of water supply shortages and for how long (as percent allocation received) indicates a drought that would force you to change current planting regime (total area, varietals)

- 25%, 50%, 75% of current allocation? For how long?

- Describe the adaptation tools that exist to help alleviate the impacts.

- What is the predominate source of irrigation water? Does the form of water rights make the farmers you advise vulnerable during water supply shortages?

- On the whole, how much are you worried about the effects of SGMA?

- What changes in water management do you anticipate as a result of SGMA?
Has anticipation of SGMA led to changes in orchard management practices?
Do you anticipate future changes in management practices as a result of SGMA?

DECISION MAKING

What is the longest time ahead you look for making management decisions? 1-5, 5-10 years, or 20, or longer?

Conservation practices

28. Now I want to talk about the specific farm management practices. “If you knew with certainty that these conditions would occur, would the following practices on the cropland you own and rent increase, or stay the same?”

- Cover crops
  - Do you currently use cover crops? (If Yes, when? How much? Why?)
  - What are the main motivations and benefits (e.g., farm profit, erosion, fertilizer losses, and flooding)?
  - What are the main barriers and incompatibilities to use it?
  - Do you think using Cover Crops can reduce the impacts of climate change as conveyed in the earlier projections? Review/ walk through projections if necessary.
  - Do these projections make you more/ less likely to adopt this practice? (more likely, no change or less likely)?
  - If so, how? If not, why not?

- Conservation (reduced or no) tillage
  - Do you currently practice conservation tillage of some sort? (If Yes, when? How much? Why?)
  - What are the main motivations and benefits (e.g., farm profit, erosion, fertilizer losses, and flooding)?
  - What are the main barriers and incompatibilities?
  - Do you think using conservation tillage can reduce the impacts of climate change as conveyed in the earlier projections? Review/ walk through projections if necessary.
  - Do these projections make you more/ less likely to adopt this practice? (more likely, no change or less likely)?
  - If so, how? If not, why not?

- Hedge rows/ CRP/ Natural set asides
  - Do you currently manage natural land-set asides/ CRP/ hedge rows? (If Yes, when? How much? Why?)
  - What are the main motivations and benefits (e.g., farm profit, erosion, fertilizer losses, and flooding)?
  - What are the main barriers and incompatibilities?
  - Do you think using hedge rows and set asides can reduce the impacts of climate change as conveyed in the earlier projections? Review/ walk through projections if necessary.
  - Do these projections make you more/ less likely to adopt this practice? (more likely, no change or less likely)?
  - If so, how? If not, why not?
29. Can any other conservation practice help reduce the likelihood a risk (climate or otherwise) will occur or how large it might be? Which ones? How?

Closing questions

30. What additional weather/ climate/ practice information would be useful for you to have?
   - What are their informational needs regarding general risks, climate risks and motivations to adopt conservation practices?

31. What other central coast wine grape advisors/ experts/ growers should we talk to?

32. Just so I can get an overall picture of the demographics, could you tell me your:
   - Age (year born)
   - Highest grade in school you have completed? (If college, what coursework/degree?)
   - [Male___Female___]

Thank you for taking the time to talk with me today.

Other practices

If mentioned unprompted consider applying section J question format:

- Mulching with pomace and other green manure
- Contour planting and row direction
- Compost
- Water footprint analysis
- Drip irrigation
- Real-time evapotranspiration and soil moisture monitoring
- Set-aside lands- field margins, habitat patches
- Flower strips between rows
- IPM

- Other adaptation strategies
  - Pruning, canopy management, trellising
  - Evaporative cooling, wind machines, shade cloths
  - Irrigation
  - Grape variety/ rootstock
  - Diversification
  - Pesticides
  - Acid addition, dealcoholizing, blending
  - Research and marketing networks, other collective activities?
  - Groundwater recharge
    - Is strategically using groundwater to recharge aquifers a viable adaptation strategy during wet years?
    - Is groundwater recharge feasible during wet years?
    - Is it desirable?
Appendix B: Cal-Adapt Regional Climate Projection

Map of California quality wine regions

Map of Paso Robles AVA
Figure 1. Course resolution maps included in projections made using Cal-Adapt. (a) Shows the change in annual mean maximum temperature for best case (RCP 4.5) and worst case (RCP 8.5) future scenarios projected for beginning, mid and late century. (b) Shows the change in annual precipitation. (c) Shows the Change in wettest day of the year.