Impacts of Global Warming on Southern California's Winegrape Climate Suitability

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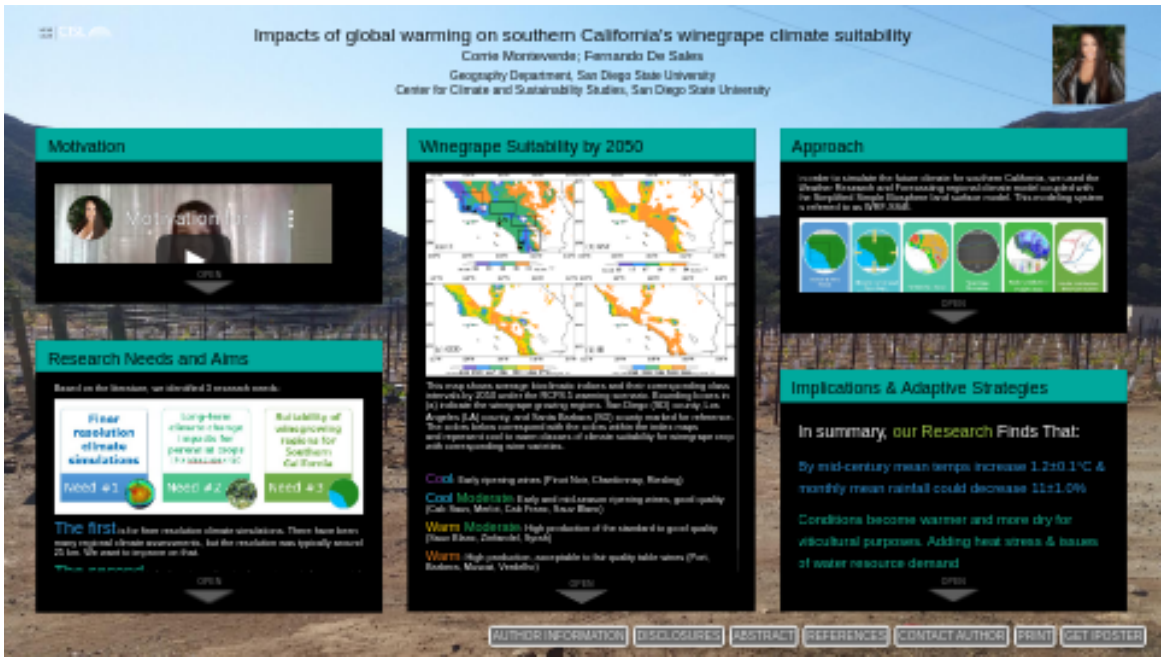
Abstract

Southern California has seen a resurgence of winegrowing regions in the past few decades, however the future of winegrape climatic suitability in the area has not been exhaustively explored. This study evaluated the future climate suitability for the cultivation of winegrape and potential global warming impacts on southern California's winegrowing regions through a series of high-resolution surface air temperature and precipitation projections obtained with the WRF-SSIB regional climate model. Results reveal that by mid-21st-century the surface air temperature will increase by approximately 1.2 °C, while average precipitation will decrease by as much as 11% in the southern winegrowing areas under the Intergovernmental Panel on Climate Change high greenhouse-gas emissions scenario. Evaluation of bioclimatic suitability indices indicate increases in heat accumulation for all major winegrowing areas; including an increase of about 10% in growing-degree day, while morning low temperatures in September may experience increases of approximately 11% in the future, thus impacting negatively the ripening stage of grapevines and leading to changes in wine composition and quality. Additionally, the extent of areas classified under the cool to warm climate suitability categories could decrease by nearly 42% in the study area by 2050. Conditions in southern California are already warm and dry for viticulture and continuing heat accumulation increase, along with rainfall reduction, could potentially place additional stress to winegrape crop in the area, including advanced phenological timing and moisture deficit stress that could lead to decreases in yield. The projected decline in viticulture suitability highlights the need for adaptive capacity within this sector to mitigate the impacts of global warming. Possible mitigating strategies include planting hotter climate grape varieties, moving vineyards to regions that are more suitable in the future, and adopting dry-farming techniques.

Impacts of global warming on southern California's winegrape climate suitability



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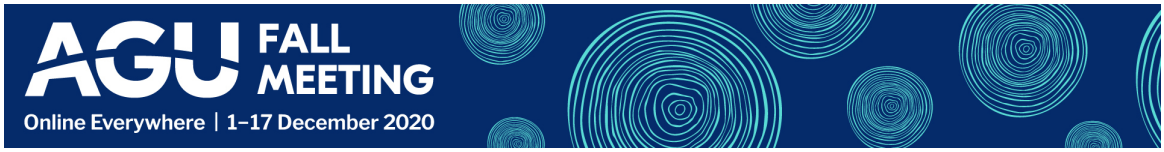


MOTIVATION

[VIDEO] https://www.youtube.com/embed/H2ozfKpqvn4?rel=0&fs=1&modestbranding=1&rel=0&showinfo=0

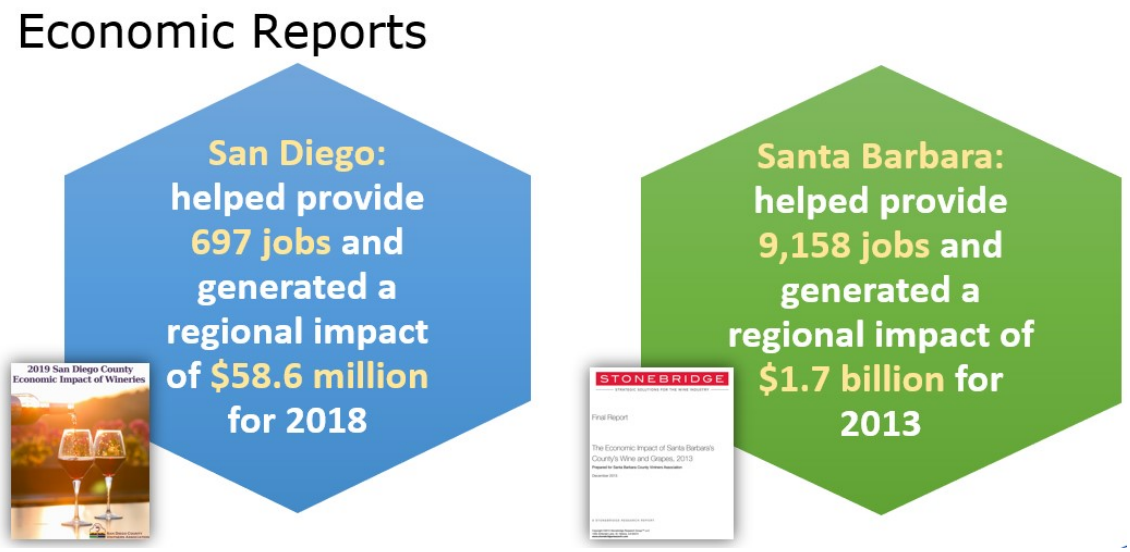
Winegrape:

Type of grapes grown on grapevines

Used specifically for wine production

Economically important perennial crop

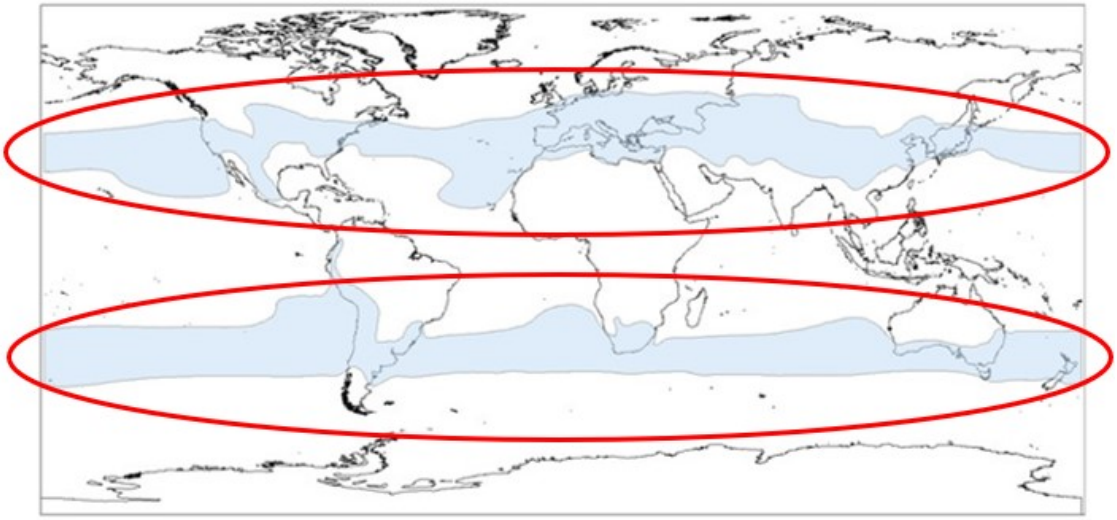
We know that this is an important crop because of the regional economic impact. Check out these two economic reports! One from San Diego for 2018 and one for Santa Barbara for 2013.



Clearly a very important crop for southern California.

BUT!

Winegrape crop is located in narrow climatic zones (see below).

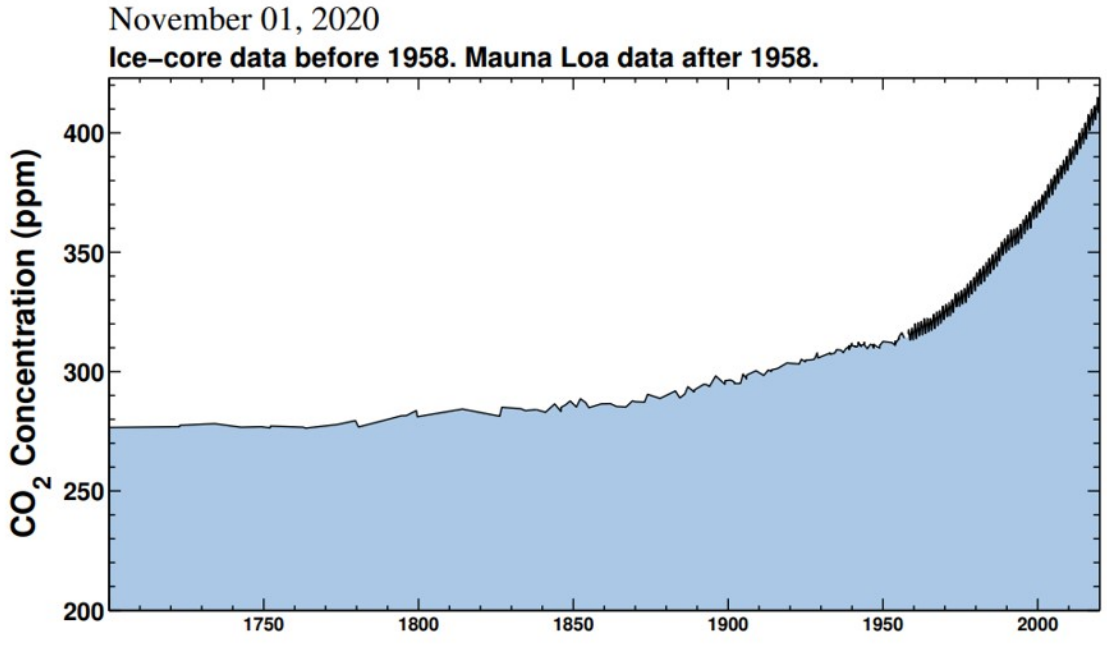


Geographic Extent* of Winegrowing Regions (30-50° N/S)
*based on 10-12° and 20-22° isotherms

Winegrape is sensitive to short-term variability & long-term change in climate, more than other crops (Jones & Webb, 2010)

Therefore, it is at risk due to future changes in climate

Recent trends in climate indicate global warming mainly due to the increase in greenhouse gases (GHGs) from antrhopogenic activities, like fossil fuel burning. The graph below shows CO2 concentration from 1700 to 2020, as CO2 is the most common and worrisome GHG.



CO2 concentration from 1700 - 2020

You can see very clearly that CO2 is increasing, and this has many implications for rising global temperatures. Issues of global warming's impact are not just an issue to scientists.

The wine community recognizes the climate's impact on winegrape crop. There was a working group called the International Wineries for Climate Action established in 2019 specifically formed to address impacts on their business. They said that "membership will focus on wineries who recognize that climate change is the most significant threat facing the wine industry". -Torres and Jackson family Wineries

It is apparent that this crop is at risk due to future changes in climate, and this is coming from scientists and the wine community itslef.

RESEARCH NEEDS AND AIMS

Based on the literature, we identified 3 research needs:

The first is for finer resolution climate simulations. There have been many regional climate assessments, but the resolution was typically around 25 km. We want to improve on that.

The second is for long-term climate change impacts for perennial crops (meaning lasting longer than one year). These crops can act as a climate change indicator for other valuable crops in this region.

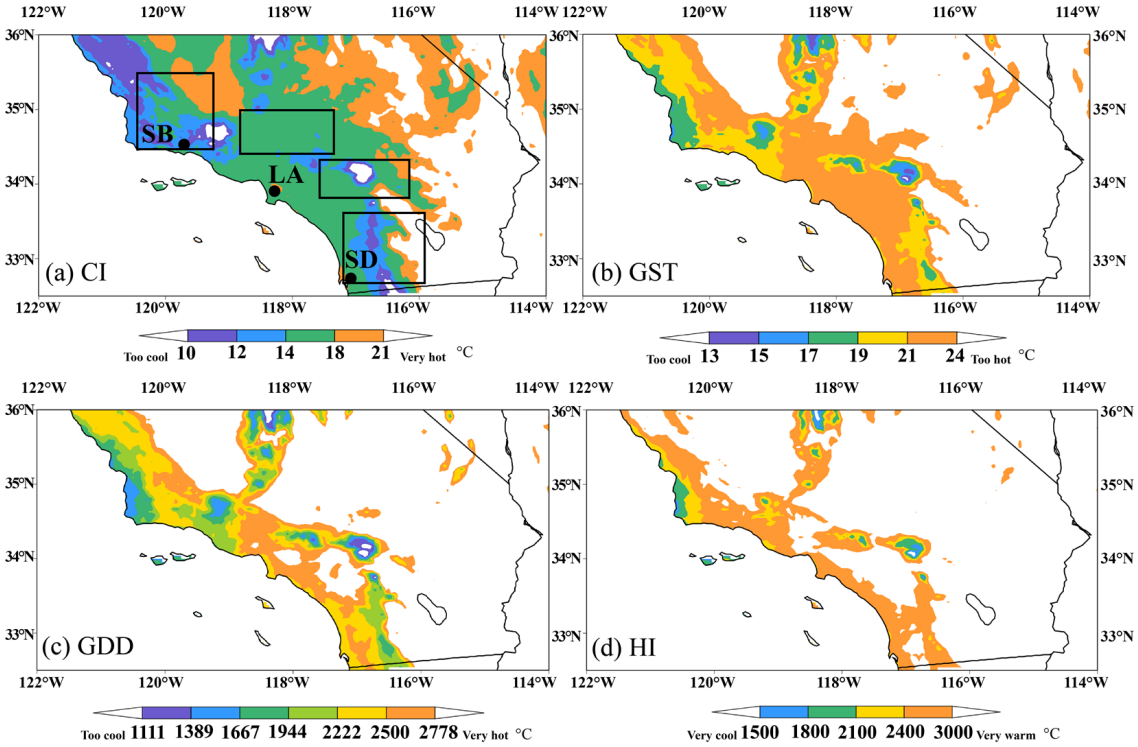
The third was for the suitability of winegrowing regions for southern California. With the increased interest in winegrape crop and its economic importance, this type of study is necessary.

Based on needs...

This study aims to:

- Improve the current understanding of the effects of global warming on the region's viticulture
- By generating accurate regional-scale information about the crop's climatic suitability
- That can assist local growers in the development of strategies to alleviate the negative impacts of a warmer climate

WINEGRAPE SUITABILITY BY 2050



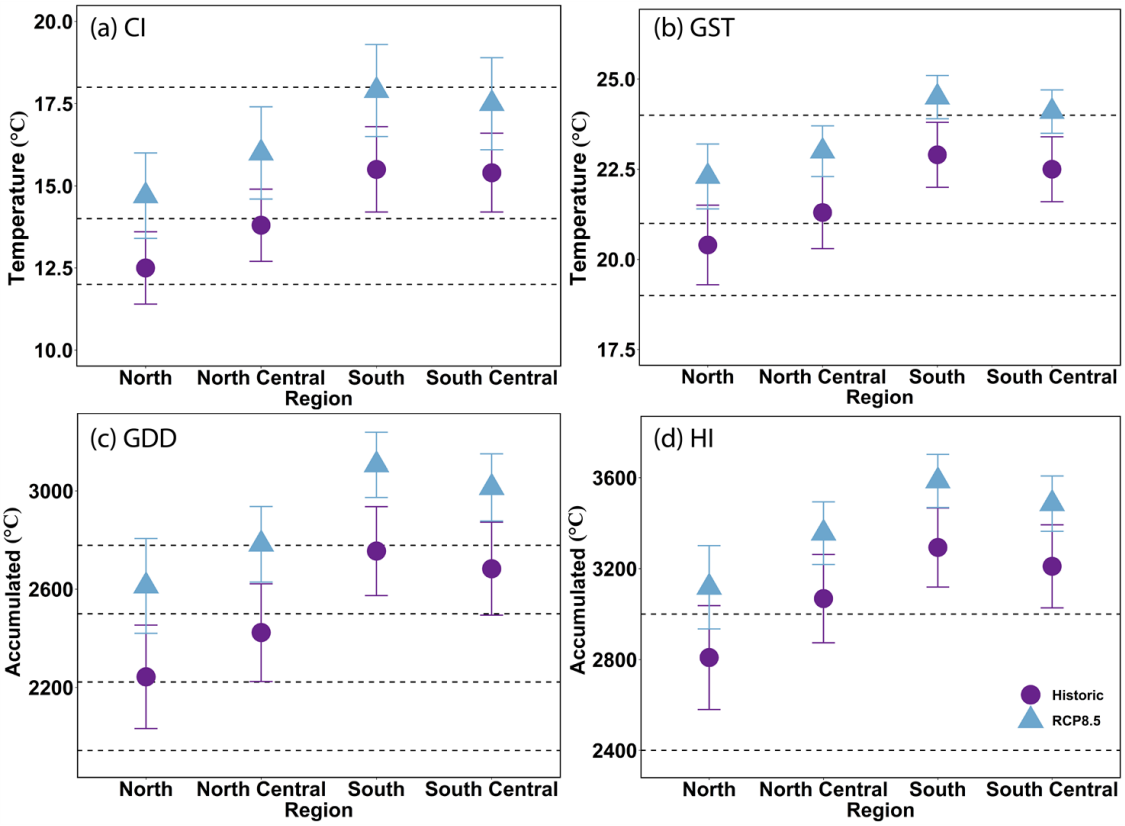
This map shows average bioclimatic indices and their corresponding class intervals by 2050 under the RCP8.5 warming scenario. Bounding boxes in (a) indicate the winegrape growing regions. San Diego (SD) county, Los Angeles (LA) county, and Santa Barbara (SD) county marked for reference. The colors below correspond with the colors within the index maps and represent cool to warm classes of climate suitability for winegrape crop with corresponding wine varieties.

Cool: Early ripening wines (Pinot Noir, Chardonnay, Riesling)

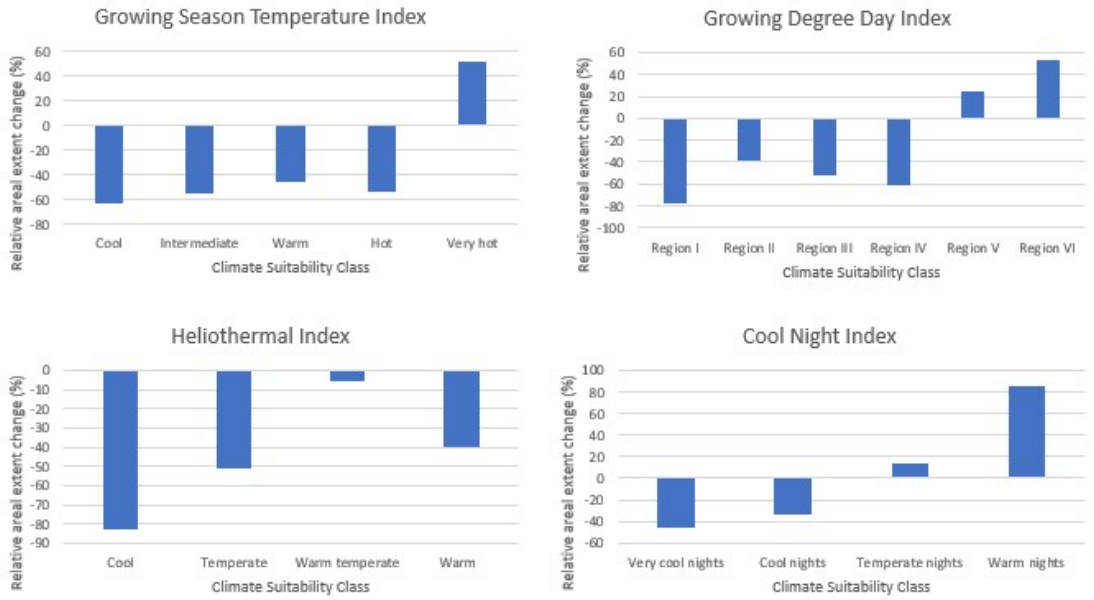
Cool Moderate: Early and mid-season ripening wines, good quality (Cab Sauv, Merlot, Cab Franc, Sauv Blanc)

Warm Moderate: High production of the standard to good quality (Sauv Blanc, Zinfandel, Syrah)

Warm: High production, acceptable to fair quality table wines (Port, Barbera, Muscat, Verdelho)



Regions transition into some of the warmest climate suitability classes based on index calculations (see figure above). This shows the change in average indices from historical to future period based on the RCP8.5 warming scenario for 2041-2050 with index class breaks represented by dashed lines. Grapevines and winegrowers need consistency, so shifts in climate structures can produce unreliable yields and ultimately change the quality of the grape.



These graphs show changes in areal extent between the historical and future time period for each index categorized by classes. The main conclusions from these graphs are:

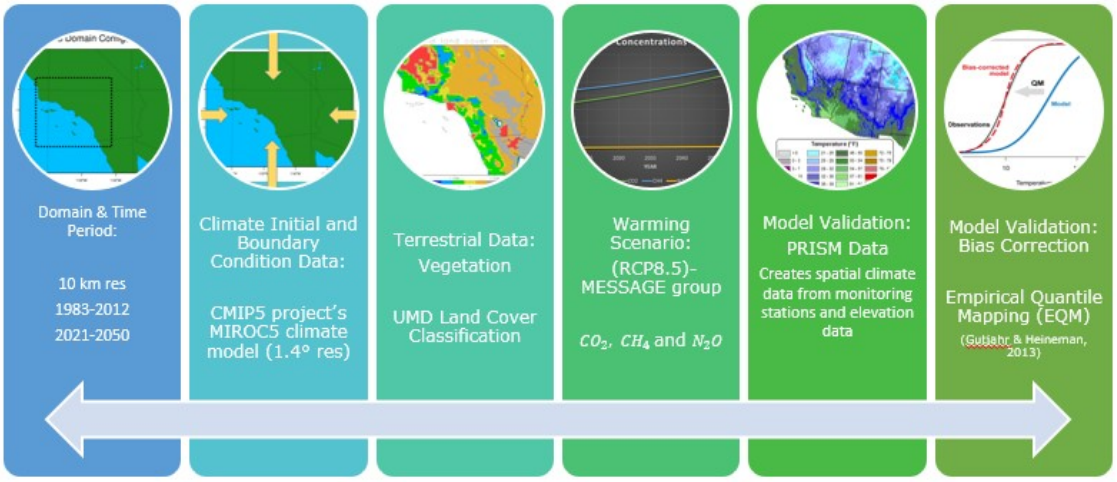
•By 2050, areal extent of regions across all indices reduce an average 42% for cool to warm categories

•Increase 59% for the warmest category of GST, GDD, CI

•Reduction of 8600 and 8700 km2 for GDD and HI, respectively

APPROACH

In order to simulate the future climate for southern California, we used the Weather Research and Forecasting regional climate model coupled with the Simplified Simple Biosphere land surface model. This modeling system is referred to as WRF-SSiB.



Important Model Information:

Resolution of WRF-SSiB modeling system: 10 km

Time period: 1983-2012 (historical or baseline simulation); 2021-2050 (future climate simulation)

Climate Initial and Boundary Condition data: MIROC5

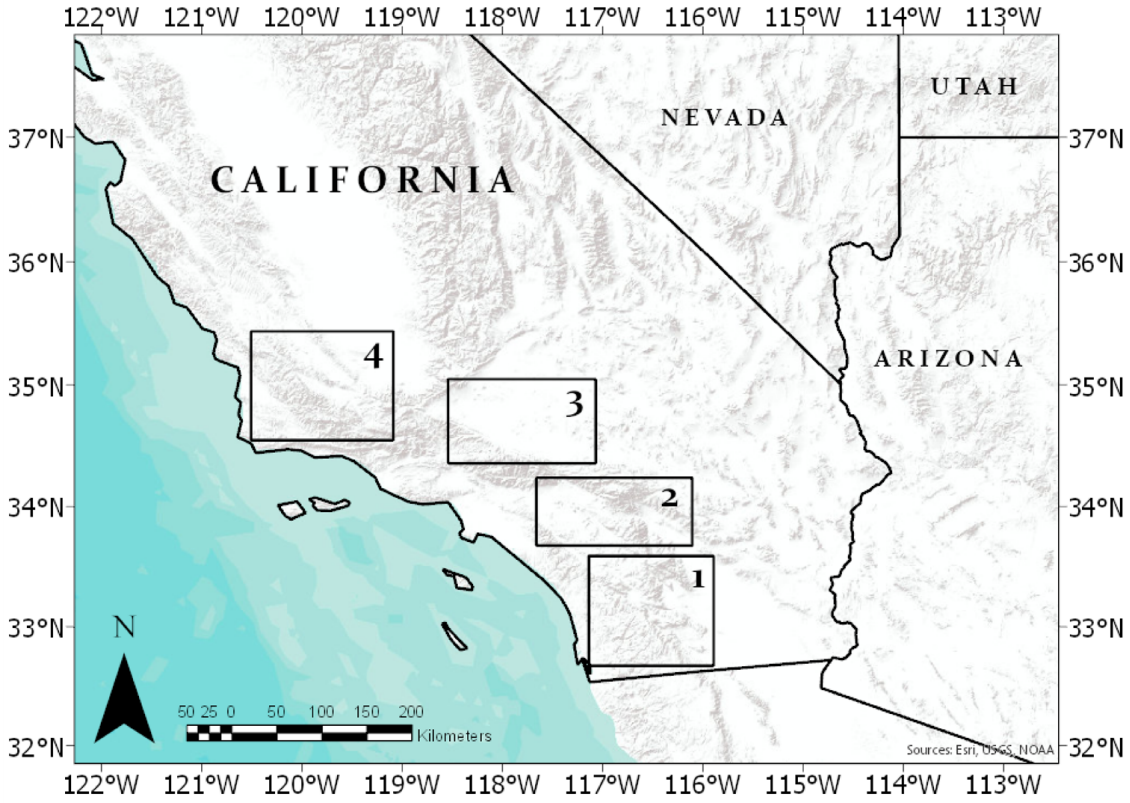
Terrestrial data: UMD Land Cover Classification

Warming Scenario: RCP8.5 created by MESSAGE group (including CO2, CH4, and N2O)

Model validation data: PRISM data

Model validation bias correction: Empirical Quantile Method

Study Area:



This study focused on four regions in southern California based on 14 American Viticultural Areas (AVAs) in the counties of Los Angeles (Region 3), Santa Barbara (Region 4), San Luis Obispo (Region 4), San Bernardino (Region 2), San Diego (Region 1), and Riverside (Region 1).

Bioclimatic Indices:

$$HI = \sum_{April\ 1}^{Sept\ 30} \left(\frac{(T - T_b) + (T_x - T_b)}{2} \right) * d$$

$$GDD = \sum_{April\ 1}^{Oct\ 31} ([T_{max} + T_{min}]/2) - 10°C$$

$$CI = (\frac{1}{N}) \sum_{Sept\ 1}^{Sept\ 30} T_n$$

$$GST = 1/n \sum_{April\ 1}^{Oct\ 31} (T_{max} + T_{min})/2$$

To help classify winegrowing regions and corresponding climate suitability, we use bioclimatic indices (see above).

Heliothermal Index (HI): Describes the level of heliothermal potential and provides a better idea of the sugar potential according to varieties than the classic temperature sums

Growing Degree Days (GDD): This is very similar to HI and calculates the heliothermal potential during the growing season but does not take into account maximum temperature, like HI

Cool Night Index (CI): This is the night coolness variable when ripening usually occurs beyond the ripening period. It helps give a better idea of the secondary metabolites (aromas, polyphenols) in grapes. It describes grape and wine color and aromas

Growing Season Average Temperature (GST): This calculates the average growing season temperature and correlates broadly to the maturity potential for winegrape varieties

(Explanation of variables: T= average temperature; Tmax= maximum temperature; Tmin= minimum temperature; Tn= minimum temperature for individual day; N= number of days in month; d= length of day coefficient)

Class Intervals:

Index	Class Interval	
HI	Very Cool	<1500
	Cool	1500-1800
	Temperate	1800-2100
	Warm Temperate	2100-2400
	Warm	2400-3000
	Very Warm	>3000
CI	Very cool nights	<12°C
	Cool nights	12°C-14°C
	Temperate nights	14°C-18°C
	Warm nights	>18°C

Index	Class Interval	
GDD	Too cool	<1111
	Region I	1111-1389
	Region II	1389-1667
	Region III	1667-1944
	Region IV	1944-2222
	Region V	2222-2500
	Region VI	2500-2778
	Too hot	>2778
GST	Too cool	<13°C
	Cool	13-15°C
	Intermediate	15-17°C
	Warm	17-19°C
	Hot	19-21°C
	Very hot	21-24°C
	Too hot	>24°C

These are the indices and their corresponding class intervals. They range from cool to hot classes.

IMPLICATIONS & ADAPTIVE STRATEGIES

In summary, our Research Finds That:

By mid-century mean temps increase 1.2±0.1°C & monthly mean rainfall could decrease 11±1.0%

Conditions become warmer and more dry for viticultural purposes. Adding heat stress & issues of water resource demand

Regions transition into some of the warmest climate structures which might change the overall wine style framework that can be produced

Impact on Winegrape Crop:

1. Increased temperatures and decreased precipitation indicate growing regions could become more prone to experience moisture deficit stress, resulting in changes to quality, appearance, flavor, taste and aroma
2. Changes in CI are associated with grape color and wine aroma and could be impacted greatly
3. Higher temperatures and increased GST can negatively impact yield in the future
4. As heat accumulation changes, associated with increases in GDD, the ability to ripen certain varieties may change
5. Very warm temperatures can destroy entire crops, which these regions might experience more frequently in the future

Although regions are in very warm climate classes, this is not the final say for viticulture. There are adaptation strategies!

Strategies include:

- Planting hotter climate varieties
- Using subsurface drip and night irrigation
- Installing cooling equipment
- Purchasing land in cooler climates
- Using different plant material rootstock
- Implementing dry farming

What is dry farming?

Dry farming works to conserve soil moisture during long dry periods primarily through a system of tillage, surface protection, and the use of drought-resistant varieties. Find out more about dry farming here (http://agwaterstewards.org/practices/dry_farming/).

Future Research Should Focus On: