Impact of Climate Change on Wine Production in California:
A County Level Analysis

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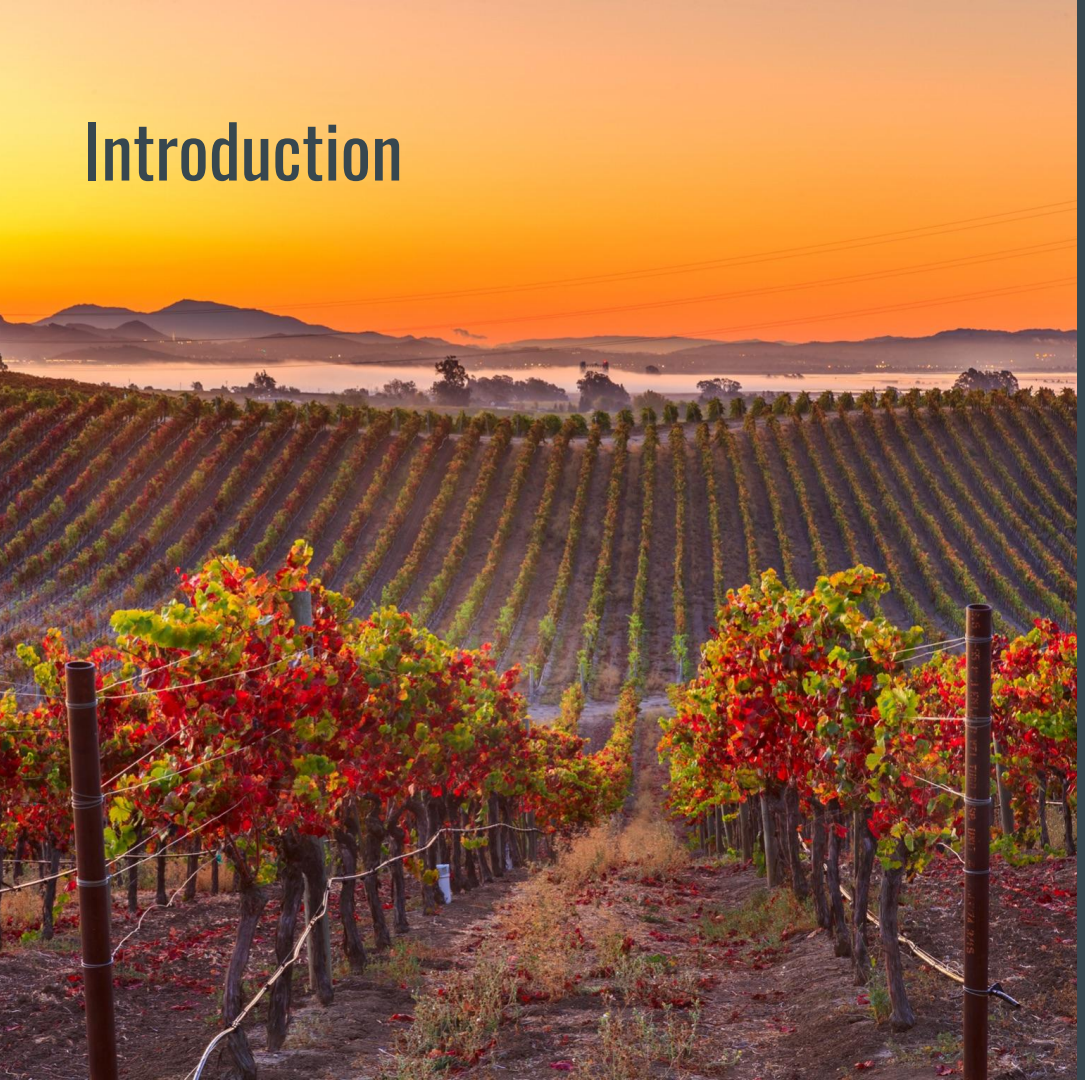
Introduction



- California is the largest agricultural producer and exporter in the United States, with roughly $49.1 billion of revenue being generated in 2020

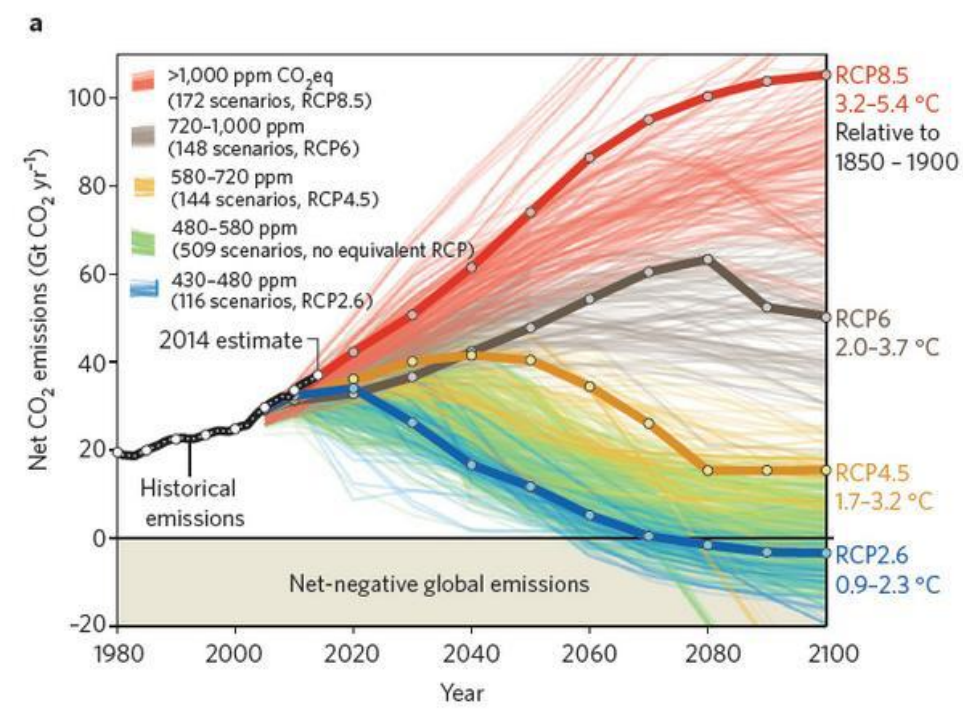
- California wineries 'experienced an increase in sales by volume in 2020, totaling an estimated retail value of 40$ billion’.

Introduction

- Climate Change is threatening wine quality and production.

- Temperature and Precipitation variability are the most important climate factors that will affect grapes quality and quantity in the future.

Problem Statement



- Can we detect a decrease in wine production, in a scenario with greater average temperatures and lower water availability?

- Serving as members of the Wine Institute Data Science Team, we develop a multiple linear regression model that could predict wine productions under two different forward-looking emissions scenarios: i) RCP 4.5; ii) RCP 8.5

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Methodology

- Necessary features
  - Temperature statistics
  - Change in temperature
  - Precipitation
  - Change in precipitation
  - County
  - Wine grape production
  - Value of grapes produced

Data Sources

Collected by domain experts

- NOAA
  - 1880-Present
  - By county
  - Minimum, maximum, and average temperature
  - Precipitation levels
- USDA Agricultural Statistics Service
  - 1980-Present
  - By county
  - Wine grape production by various metrics

Data Cleaning

- Climate data
  - Filtered to 2000-2020
  - Isolated top-producing wine counties
  - Renaming columns
  - Correcting datatypes
  - Merging to one dataframe
- Wine production data
  - Filtered to 2000-2020
  - Filtering to wine grapes
  - Dropping unit, crop name, and commodity code columns

EDA

Target variables:

- Harvested acres
- Total production
- Yield (production/acre)
- Price per unit (ton)
- Total price

Predictive Variables:

- Monthly precipitation
- Minimum temperature
- Maximum temperature
- Average temperature

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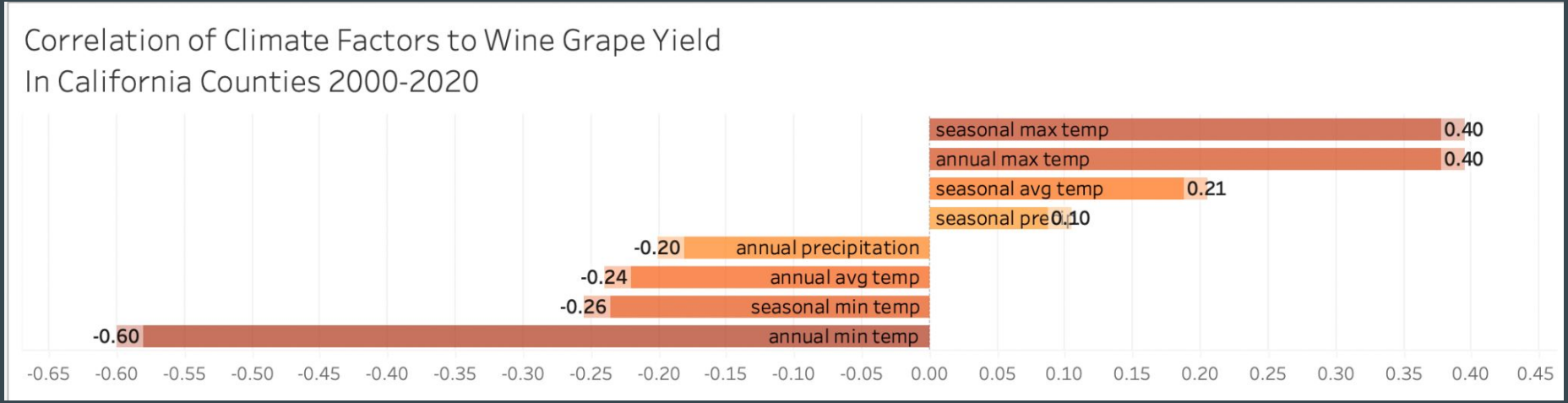
Correlation of Climate Factors to Wine Grape Yield
In California Counties 2000-2020
seasonal max temp
0.40
annual max temp
0.40
seasonal avg temp
0.21
seasonal pre
0.10
-0.20
annual precipitation
-0.24
annual avg temp
-0.26
seasonal min temp
-0.60
annual min temp
-0.65 -0.60 -0.55 -0.50 -0.45 -0.40 -0.35 -0.30 -0.25 -0.20 -0.15 -0.10 -0.05 0.00 0.05 0.10 0.15 0.20 0.25 0.30 0.35 0.40 0.45

EDA

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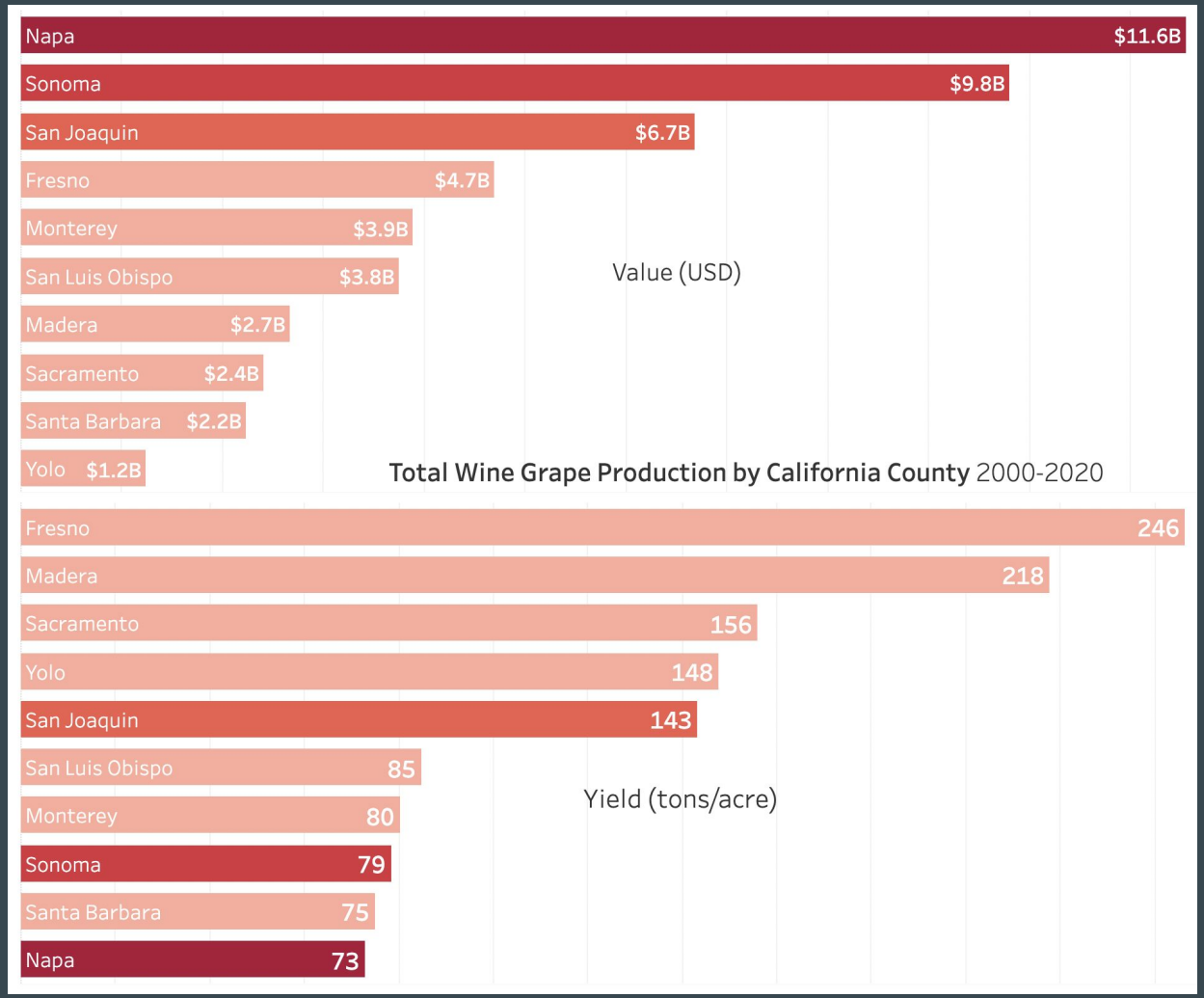
Napa $11.6B
Sonoma $9.8B
San Joaquin $6.7B
Fresno $4.7B
Monterey $3.9B
San Luis Obispo $3.8B
Madera $2.7B
Sacramento $2.4B
Santa Barbara $2.2B
Yolo $1.2B
Value (USD)
Total Wine Grape Production by California County 2000-2020
Fresno 246
Madera 218
Sacramento 156
Yolo 148
San Joaquin 143
San Luis Obispo 85
Monterey 80
Sonoma 79
Santa Barbara 75
Napa 73
Yield (tons/acre)

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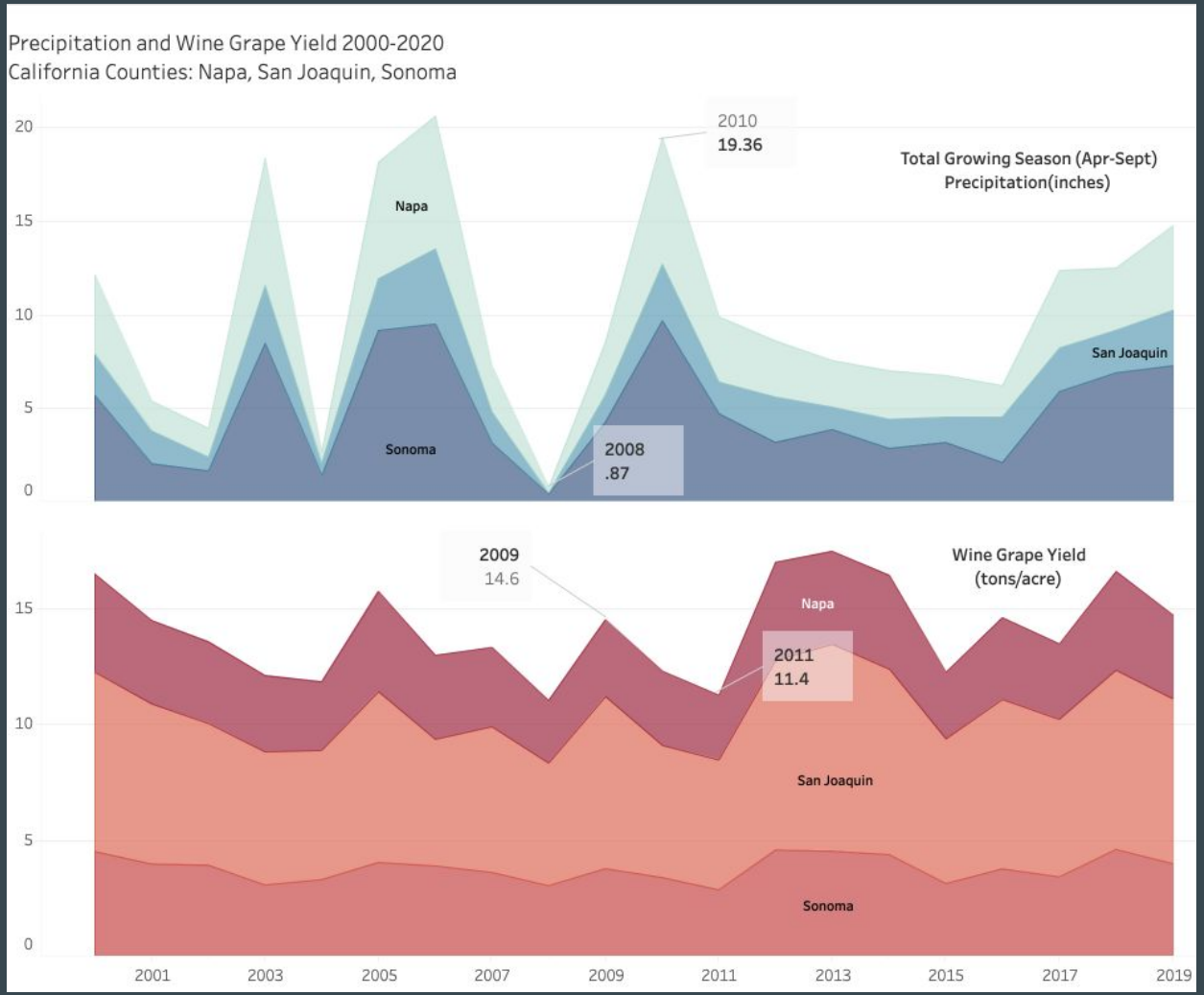
Precipitation and Wine Grape Yield 2000-2020
California Counties: Napa, San Joaquin, Sonoma
2010
19.36
Total Growing Season (Apr-Sept)
Precipitation(inches)
Napa
San Joaquin
Sonoma
2008
.87
2009
14.6
Wine Grape Yield
(tons/acre)
Napa
2011
11.4
San Joaquin
Sonoma
20
15
10
5
0
2001
2003
2005
2007
2009
2011
2013
2015
2017
2019

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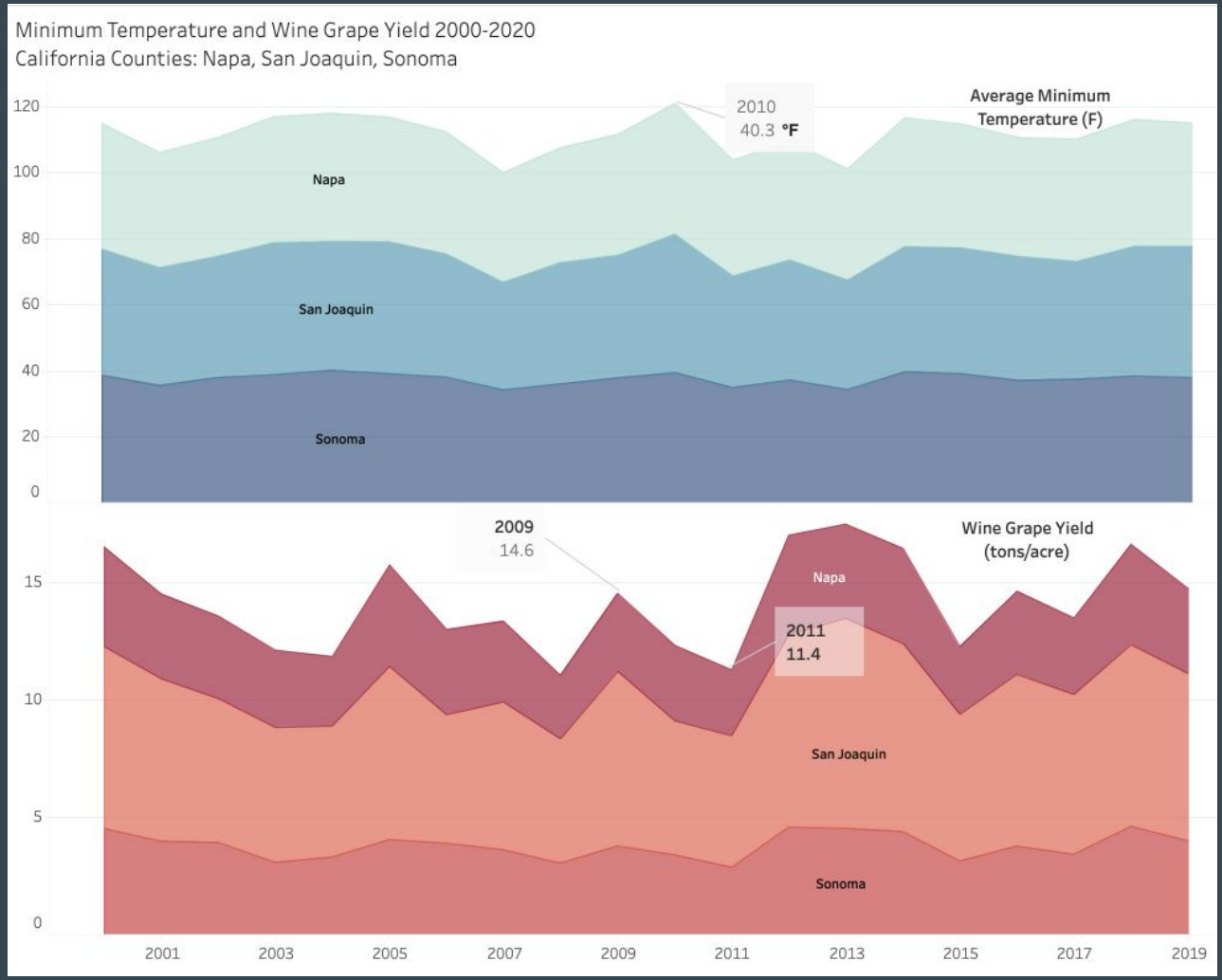
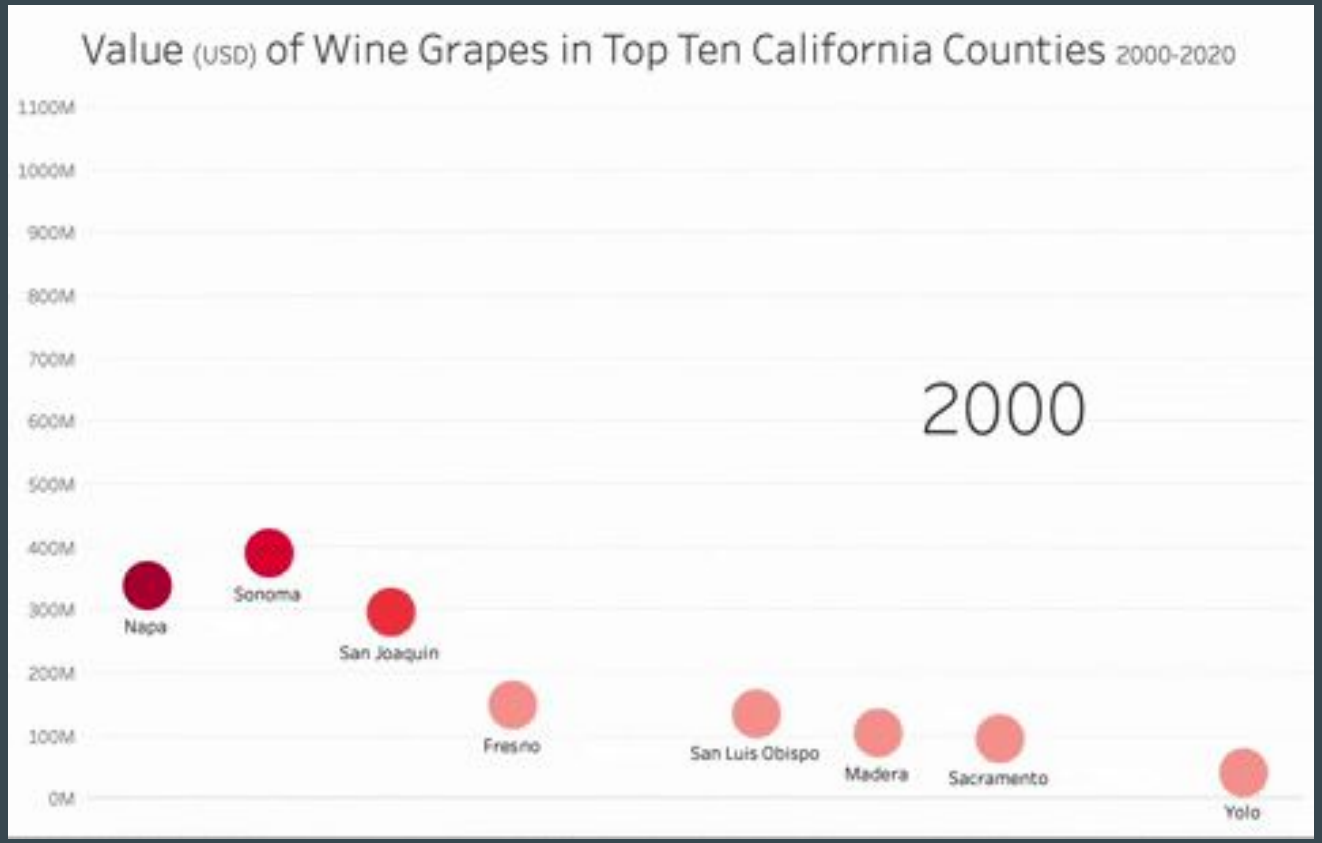

Minimum Temperature and Wine Grape Yield 2000-2020
California Counties: Napa, San Joaquin, Sonoma
Average Minimum Temperature (F)
2010
40.3 °F
Napa
San Joaquin
Sonoma
120
100
80
60
40
20
0
Wine Grape Yield (tons/acre)
2009
14.6
2011
11.4
Napa
San Joaquin
Sonoma
15
10
5
0
2001
2003
2005
2007
2009
2011
2013
2015
2017
2019

EDA


Value (USD) of Wine Grapes in Top Ten California Counties 2000-2020
1100M
1000M
900M
800M
700M
600M
500M
400M
300M
200M
100M
0M
2000
Napa
Sonoma
San Joaquin
Fresno
San Luis Obispo
Madera
Sacramento
Yolo

Feature Engineering

- Align monthly climate observations with annual yield
- Select features based on correlation with yield, while limiting collinearity
- Generate dummy variables for each county

Seasonal Maximum Temperature

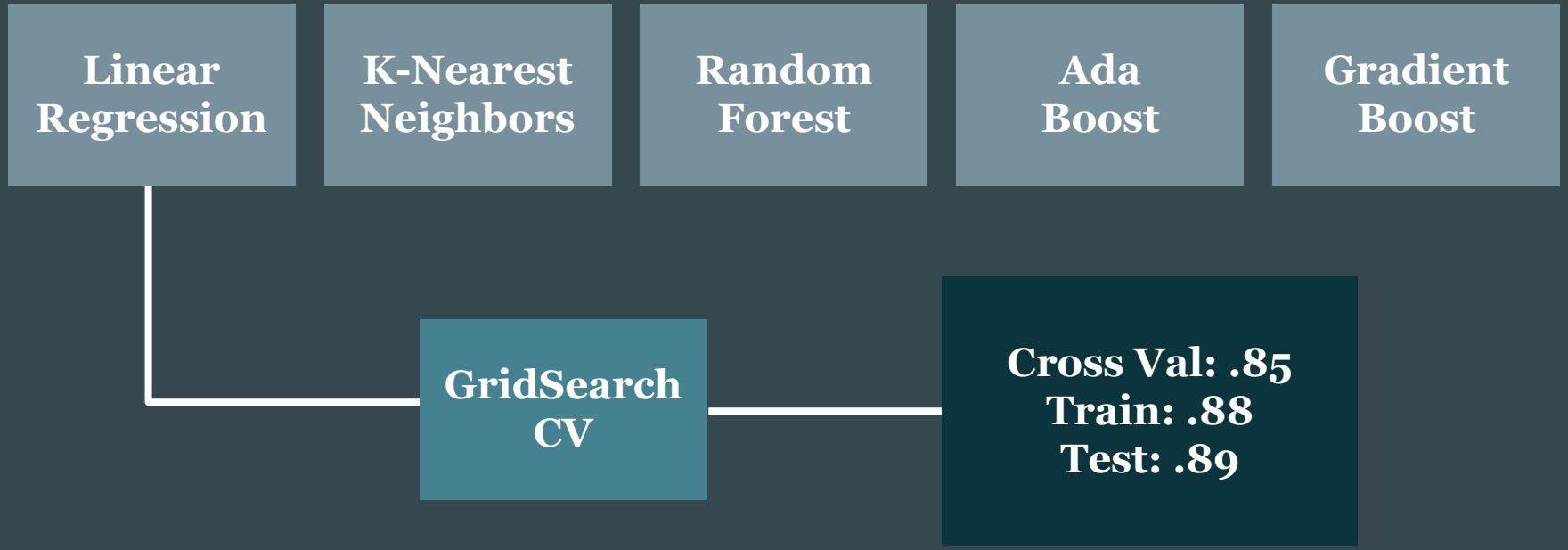
Seasonal and Annual Average Temperature

Annual Minimum Temperature

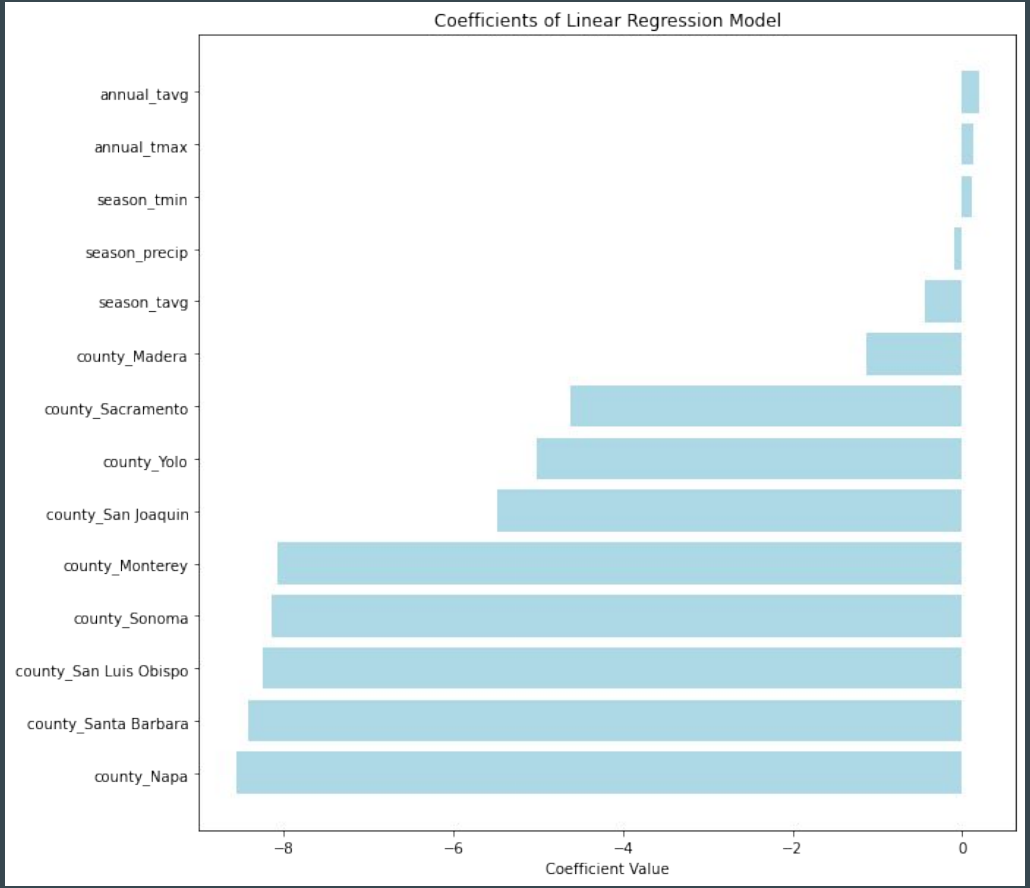
Seasonal Precipitation

County Dummies

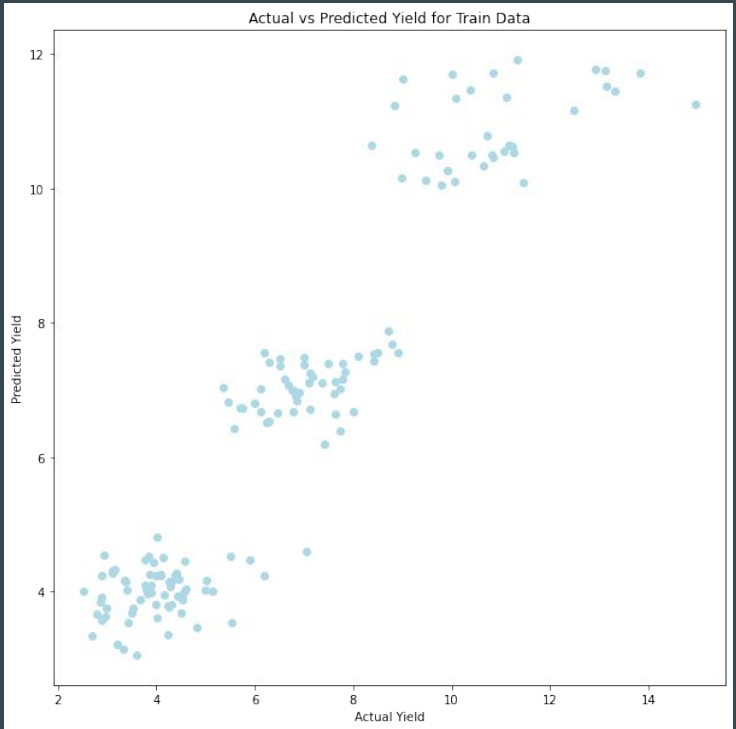
Model Selection

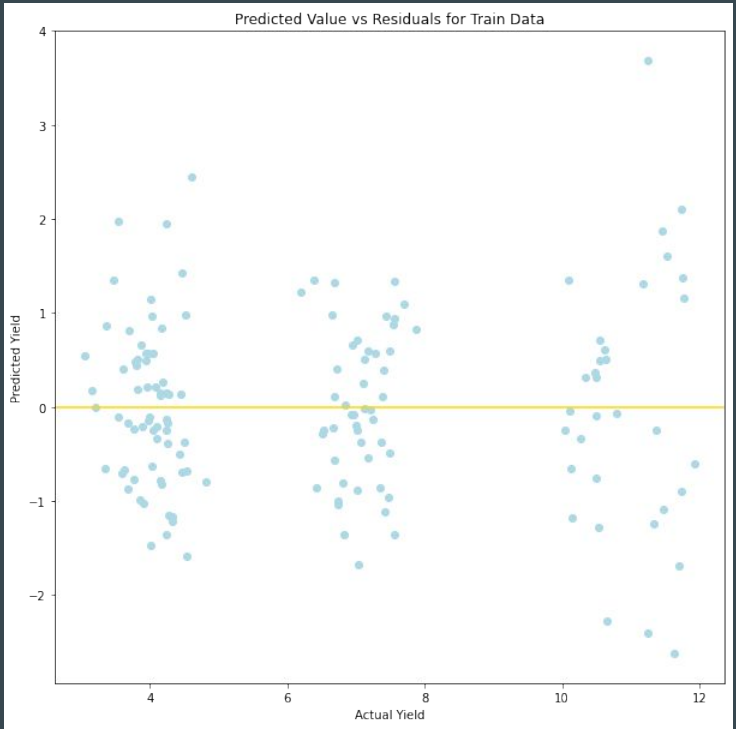


Production Model

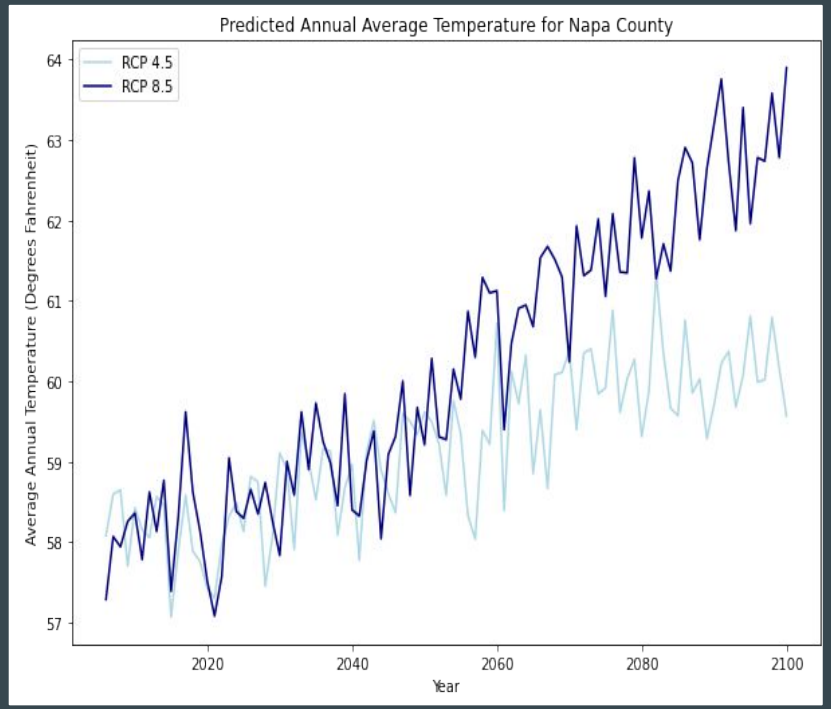


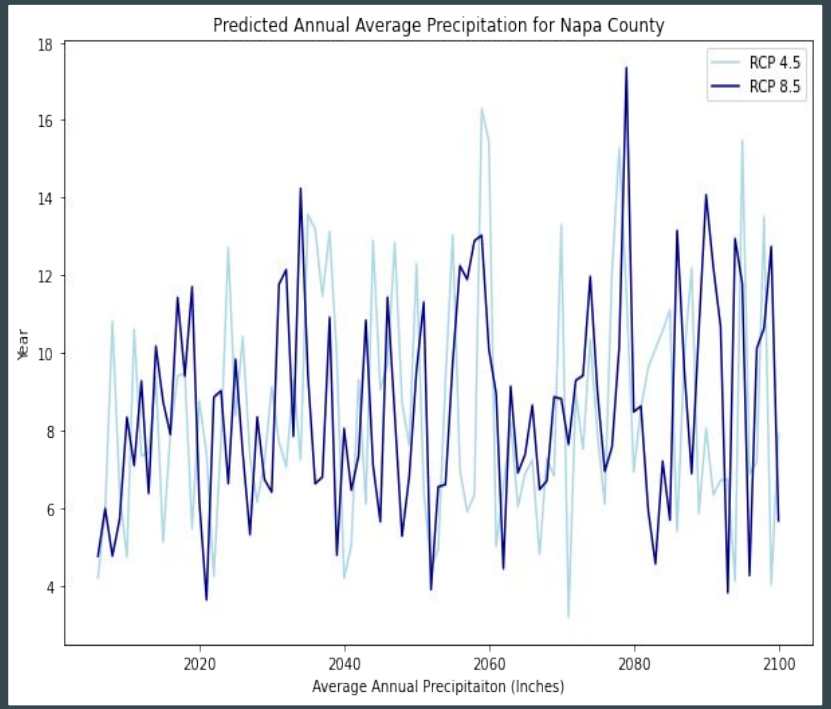
Production Model



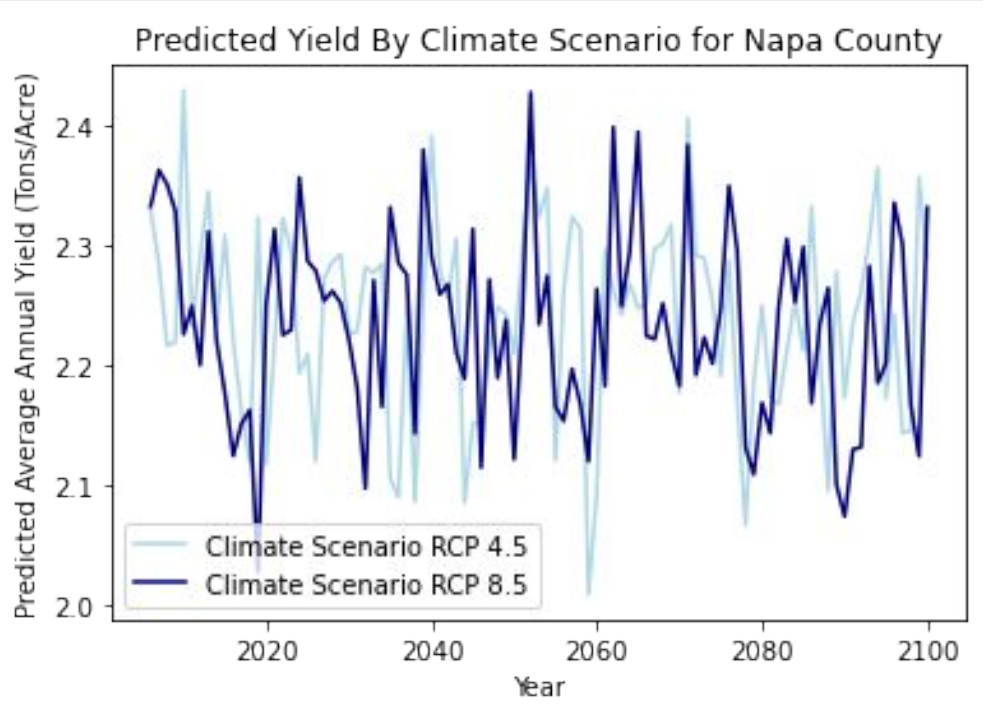


Future Projections





Future Projections



Over a 94 year period, one acre of productive land in Napa is predicted to produce 215.59 tons of wine grapes under Scenario 4.5 vs 219.61 tons under Scenario 8.5.

Conclusion

- Evaluated relationship between wine yield and climate metrics
- Predicted wine production with cross val score of nearly 90% on existing climate data
- Found model to be insufficient in predicting a substantial drop in wine production based on climate factors
- Determined the climate trend was not a significant enough over time to detect a clear difference in wine yield between the two RCP emissions scenarios

Next steps

- Consider adaptive behavior: resilient grape varietals (cool vs warm), shift in geographic location
- Collect more granular data on geographic and temporal scale
- Map against independent climate predictions
- Add additional climate variability indicators

Thanks!

Sources:

https://www.cdfa.ca.gov/Statistics/

https://wineinstitute.org/press-releases/california-wine-sales-hit-40-billion-in-2020-despite-pandemic/

https://www.ncdc.noaa.gov/cag/

https://www.nass.usda.gov/Statistics_by_State/California/Publications/AgComm/

https://www.ipcc-data.org/