Abstract

In 2020, the global wine market was valued at 339.53 billion USD and is projected to keep growing (https://www.fortunebusinessinsights.com/wine-market-102836). Climate change is also unquestionably causing more chaotic storm and precipitation events, as well as causing increases in the range of temperatures around the world. This study seeks to understand the effects of temperature ranges and precipitation events on wine grape yields in Sonoma Valley. An LSTM (Long Short-Term Memory) model is used to see if fluctuations in precipitation and temperature can be used to predict the grape yield per acre of vineyards, with Sonoma Valley as an example study.

Data Wrangling and Exploration

Two key sources of data were used in this study: a table of wine production from Kaggle (https://www.kaggle.com/datasets/jarredpriester/california-wine-production-19802020), and weather data from the National Oceanic and Atmospheric Administration (NOAA, https://www.ncei.noaa.gov/metadata/geoportal/rest/metadata/item/gov.noaa.ncdc:C00861/html).

Sonoma Valley wine production has grown considerably since 1980 (Fig. 1), with wine grape acres harvested nearly tripling in the last 40 years, making it a good sample location for this study.

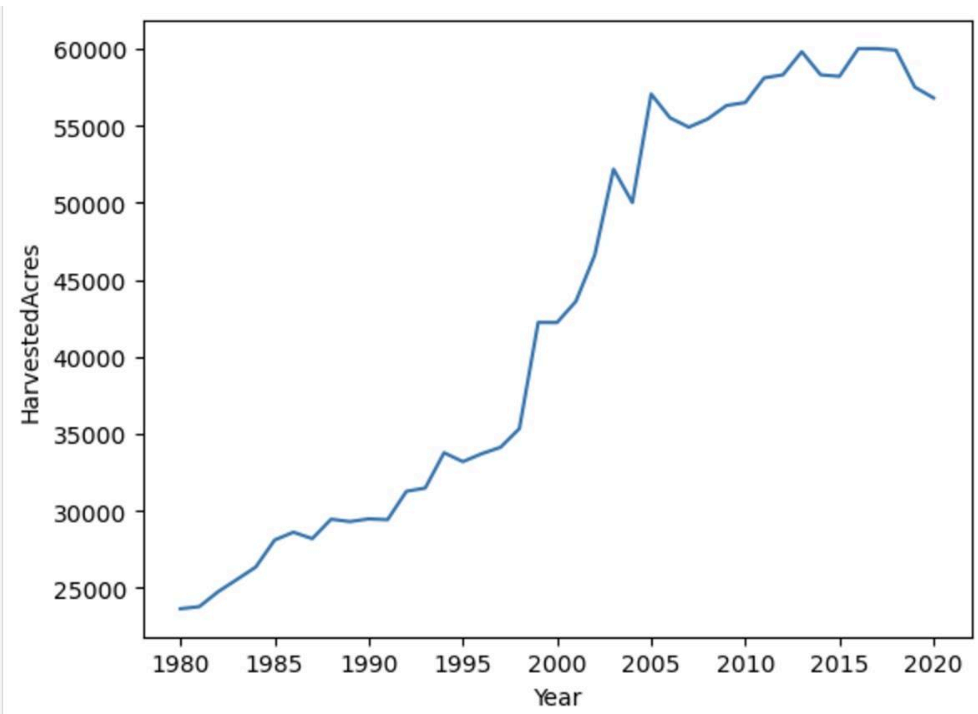

Figure 1: Harvested acres of wine grapes in Sonoma Valley between the years 1980-2020.

NOAA provides weather data for several weather stations around the county. Many of these stations were more than fifty percent empty, so only weather stations with at least 80% of daily data were aggregated into a single annual average value for precipitation, maximum temperature, and minimum temperature. Because a few of these stations contained multiple values of precipitation and temperature, there is a slight range for many years, as evident in Figures 2, 3, and 4 by the faded blue band about the blue line. The weather data collected was daily, but due to the nature of the yield data (i.e., one value per year), the precipitation and temperature data were averaged to a single value for each year.

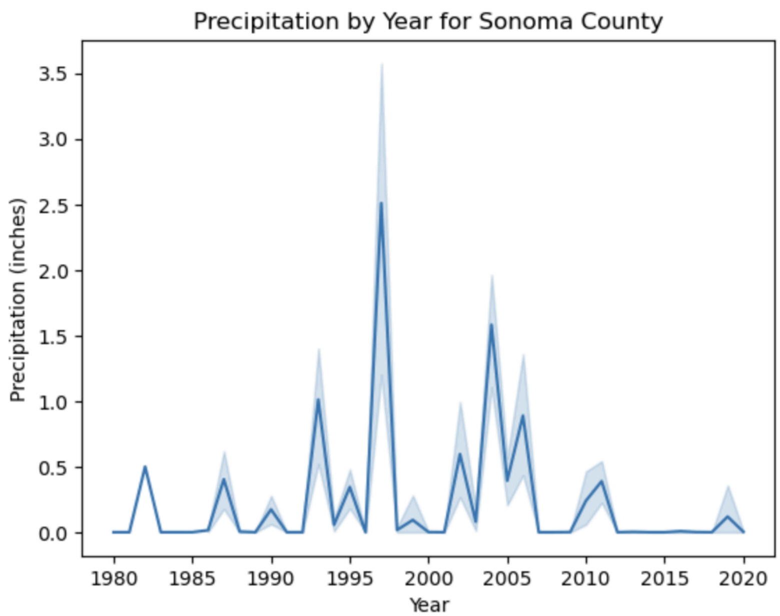

Figure 2: Precipitation average in inches per year, for 9 weather stations.

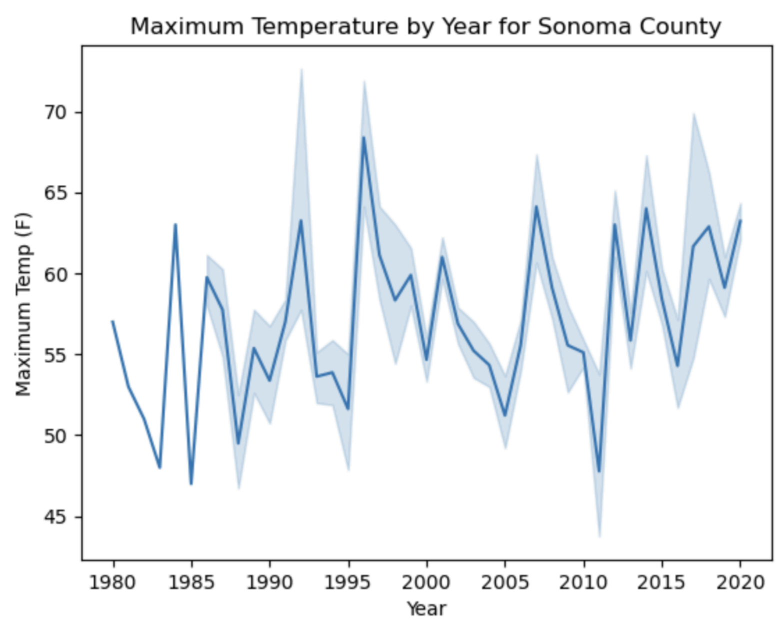

Figure 3: Maximum temperatures in Fahrenheit per year, for 9 weather stations.

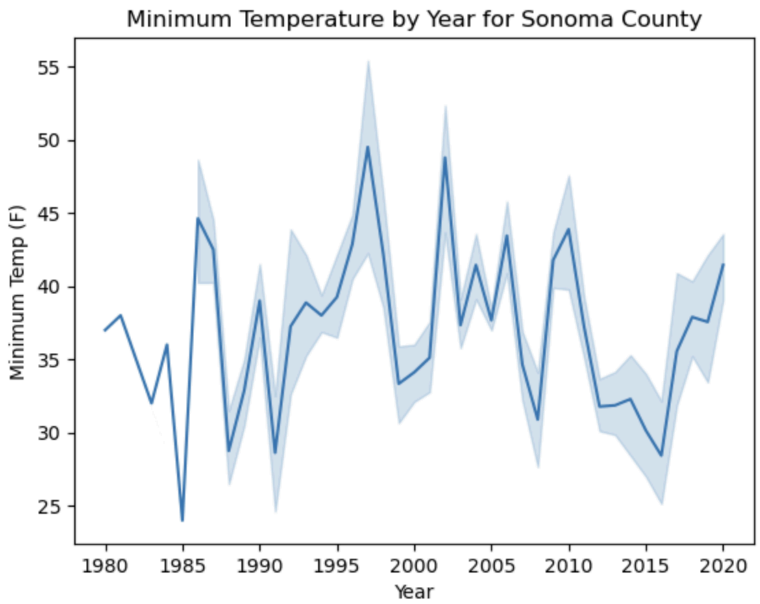

Figure 4: Minimum temperatures in Fahrenheit per year, for 9 weather stations.

Model and Results

An LSTM model was selected to see how well fluctuations in precipitation and temperature could predict wine grape yield per acre. Refer to Appendix 1 for model metrics and Appendix 2 for model hyperparameters. The model with the closest fit (Figure 5) was the fourth model: a single layer with a tan-h activation and a learning rate of 0.001. Figure 6 summarizes graphically the four models against the true wine grape yield.

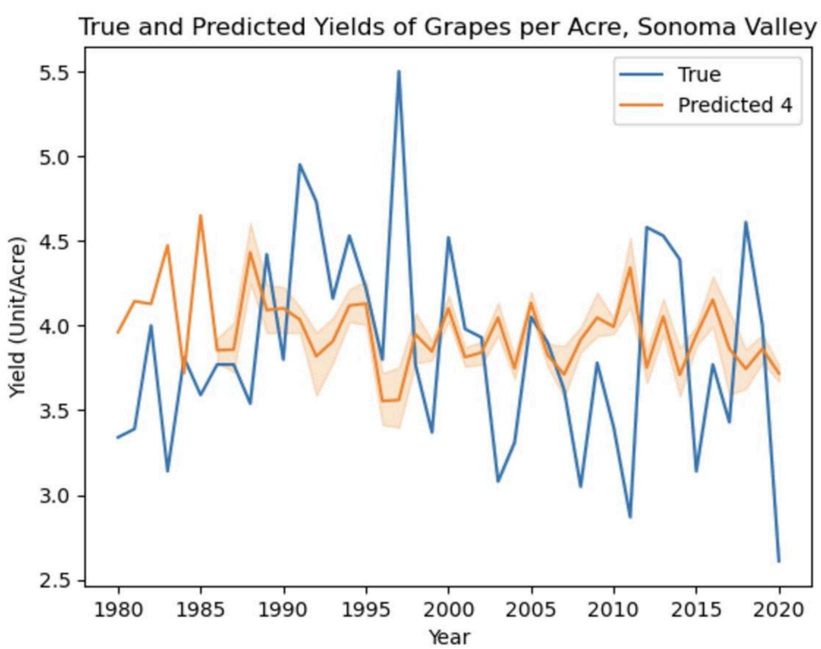

Figure 5: The closest fit LSTM model with a learning rate of 0.001 and tanh activation.

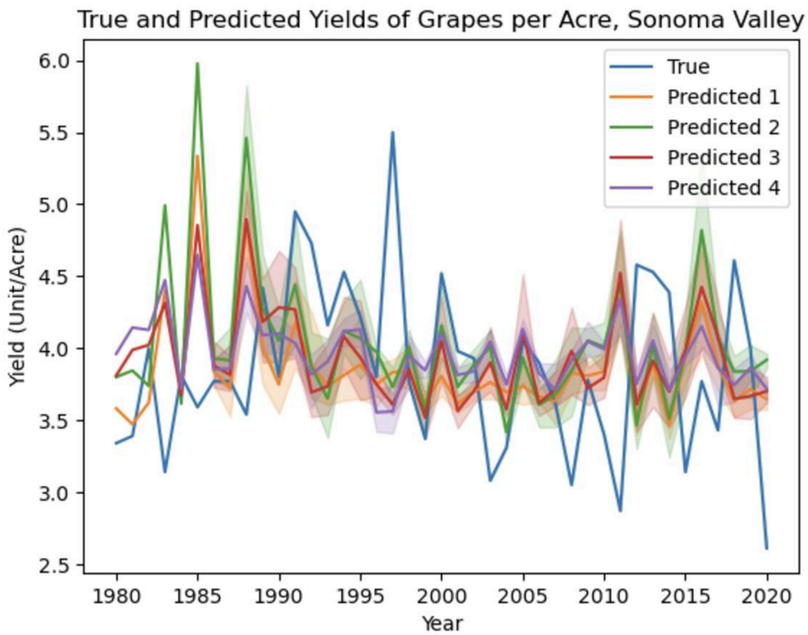

Figure 6: A graphical summary of the four different models against the true wine grape yield.

Conclusion

From Figures 5 and 6 we can see that the models can make reasonable estimates for wine grape yield for years without extremely high or low yields. This model helps illustrate that temperature and precipitation fluctuations do influence grape yield, but clearly there are other factors that need to be taken into consideration such as the hydraulic conductivity of the soils of the various vineyards, fertilizer usage, grape varietal (this may affect planting density and harvest time) for example. Perhaps the first factor to change is to take advantage of the daily temperature and precipitation data. The annual average is not nearly as informative as highlighting any temperature or precipitation extremes that happen on a daily basis.

Three possible recommendations following the results of this project:

1. Consider drip irrigation as a means to mitigate lower rainfall years
2. Track the soil moisture content of the soil to see how changes in precipitation may be affecting the wine grape yield
3. Support climate change legislation

Appendix 1: Model Metrics

STATION	NOAA weather station, string encoded to an int
PRCP	Float, annual precipitation in inches
TMAX	Float, maximum annual temperature in degrees F
TMIN	Float, minimum annual temperature in degrees F
Year	Int, Year
Yield	Float, Yield of wine grapes, per acre

Appendix 2: Model Hyperparameters

Model	Learning Rate	Activation	Num. of LSTM Layers	Num. of Units	Optimizer	Loss Function
1	0.01	relu	1	50	Adam	mse
2	0.01	tanh	1	50	Adam	mse
3	0.01	tanh	3	50	Adam	mse
4	0.001	tanh	1	50	Adam	mse