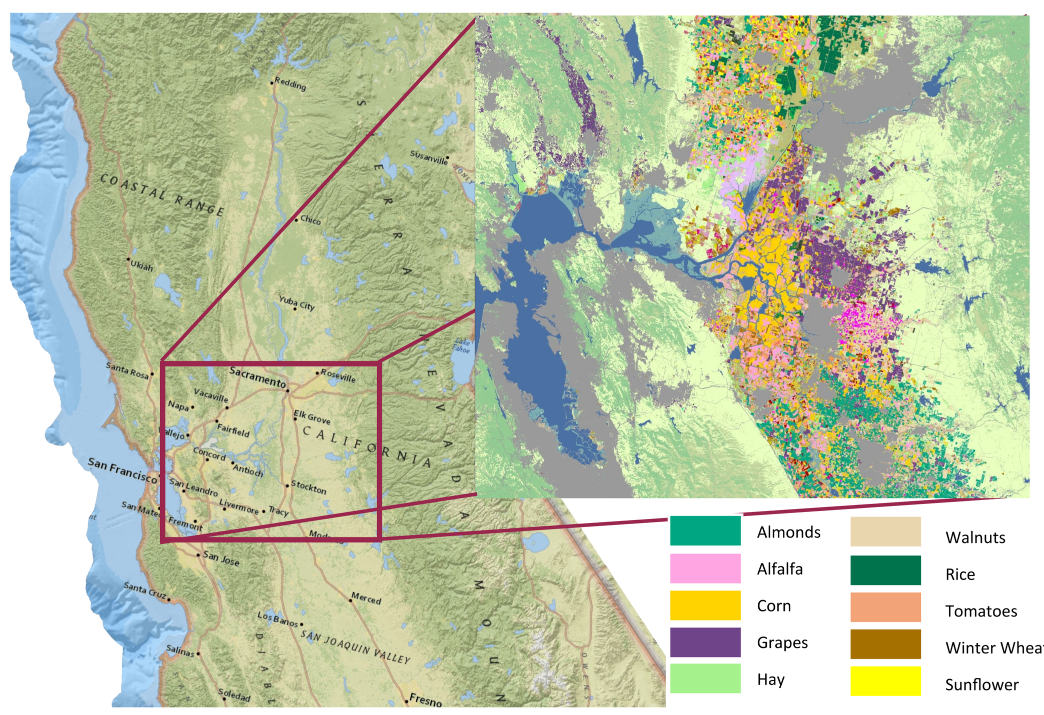
Chasing Terroir: Modeling Climate Change in Viticulture

INTRODUCTION

This study examines the future suitability of wine grape growing in California's most productive grape region using a variety of factors and climate change modeling. The region of interest is just east of the San Francisco Bay, extending towards the Sierra Nevada Mountains. While Napa and Sonoma (only partially visible and secondary to this analysis) are known as premier wine country in California, the Lodi region produces more than half of all wine grapes in California, and about 60% of Zinfandel wine grapes (Lodi Wine, 2019). As the workhorse of wine country, these larger viticulture operations may face huge losses with major shifts and variability in climate, and wine will be more expensive. At the same time, they are in a position to pioneer climate change mitigation and adaptation efforts, as well as sustainable practices to help fight climate change.



METHODS & DATA

Research Question

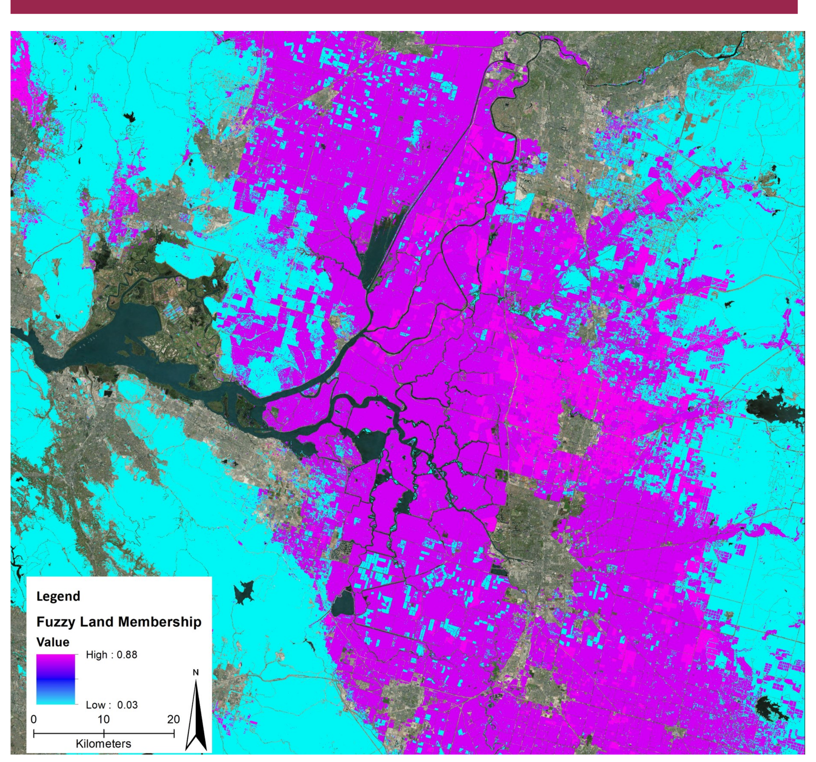
- How will climate change affect the spread of viticulture in the Lodi region of California's wine country?

This project is a combined effort of a fuzzy suitability with climate change considerations. Below is the general process used on the four data sets for producing the suitability analysis.

- Analysis of desired values for suitability ratings
- Polygon to Raster conversion and/ or unit conversion with Raster Calculator
- Project Raster was used to convert some files to Albers Equal Area as needed
- Some Items were Re-Classified to make values linear or Gaussian before fuzzification
- Fuzzification with Fuzzy Membership
- Intermediate maps for each dataset were created using Raster Calculator
- Weighted combination of individual fuzzified rasters using Raster Calculator. Weights were determined by using the Analytic Hierarchy Process, a pairwise comparison tool available online that provides consistency feedback (Goepel KD, 2017).

Data Series	File Used	Source, Availability	Specifications
Topography (Jarvis et al, 2008)	NASA Shuttle Radar Topography Mission (SRTM) .TIF raster tiles	Tufts GIS data M Drive	1 meter resolution GCS: WGS 84
Land Use (USDA NASS, 2007)	USDA Cropscape .TIF raster	National Agricultural Statistics Survey (NASS) Available online, public	30 meters resolution Projection: Albers Equal Area
Soil (NRCS, 2007)	USDA Soil Survey Geographic Database (SSURGO) .TIF raster	National Resources Conservation Service (NRCS) Available online, public	30 arc-seconds (~30m) resolution Projection: Albers Equal Area
Climate (Hijmans et al, 2005)	WorldClim bioclimatic variables, version 1.4 future and curent .TIF rasters	WorldClim Available online, public	30 arc-seconds (~30m) resolution GCS: WGS 84 Current: 1960-1990 averages Future: projected for 2050 (average of 2041-2060) using IPSL-CM5A-LR Representative Concentration Pathway (RCP)

LAND USE

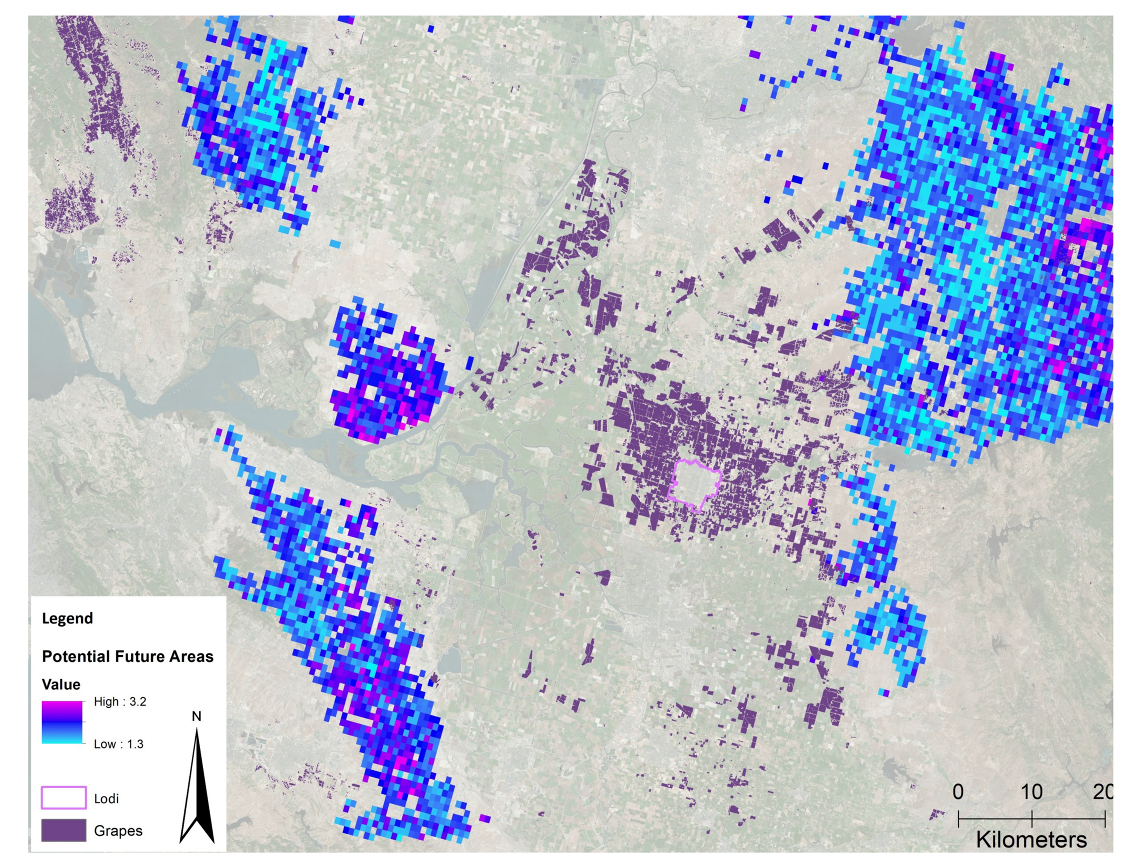


Considering existing land use is essential for this model since conservation land and land used for existing developments would not be considered for viticulture purposes. The National Agricultural Statistics Survey (NASS) of the USDA provides remotely sensed data on crop and land use that categorizes use by crop type or development type. The original version of the Cropscape layer is above, with the top 10 agricultural products in the area in the color legend of the inset map. This intermediate map at left is similar to a reclassification of current agricultural and general other uses, to show where viticulture expansion is more likely. This data was reclassified according the table at right, where current agricultural, fallow, and barren land were considered prime options; non-agricultural natural land without forest cover or wetlands had lower rankings. The reclassified land use raster was then added to the model with Fuzzy Membership.

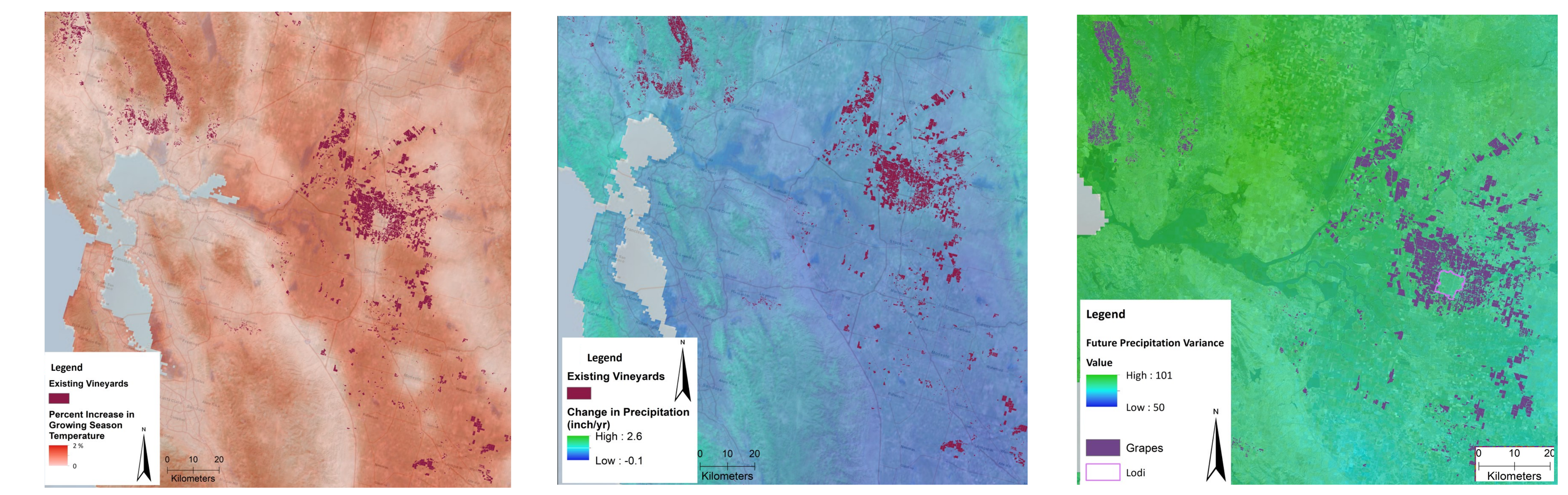
Category of Land	Rank
Grapes	3
Other crops/ag land	2
Non-ag, natural	1
Developed No data Water, wetland	0

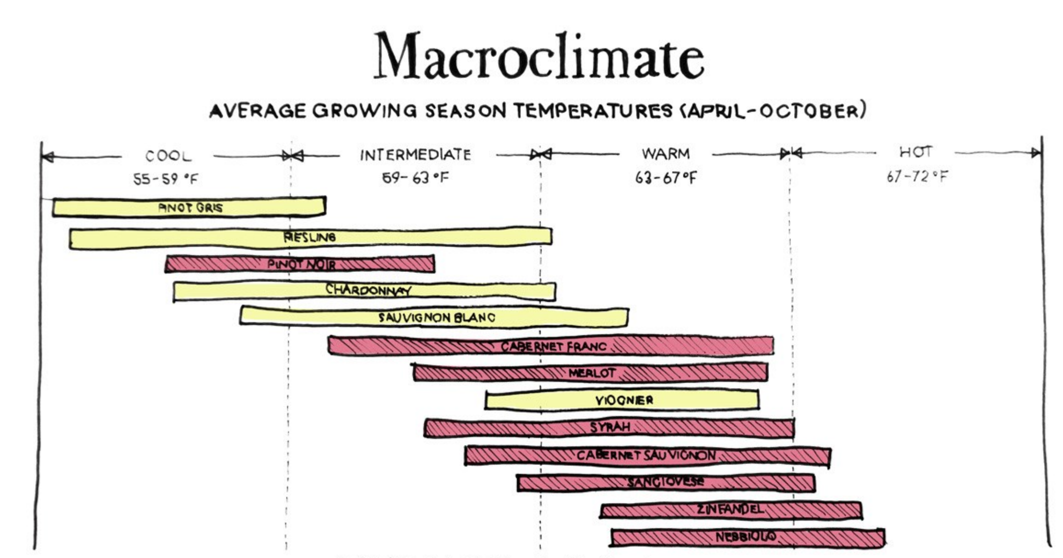
CLIMATE CHANGE MODELING

Climate change is already impacting agriculture in numerous ways and viticulture (wine grape growing) is particularly sensitive. Some regions in France have already faced decreasing yields and a loss of terroir (the local flavor of the land) due to altered growing conditions. Climate modeling has shown that increased growing season average temperatures (GST) increase wine quality, but beyond a certain point the vintage rating for hot seasons decreases (Jones et al, 2016). The increased 'hang time' (time on the vine post maturation) has led to phenological changes that increase production costs. Beyond changes to seasonality and temperature, variability in precipitation increases vulnerability to pests, and extreme climate events (particularly fire and flood for California) are also a major concern. From left, the three inset climate maps below depict the changing conditions The first map shows the percent change in the mean Growing Season Temperature (between April and November), projected to rise by up to 2% by 2050. Precipitation will increase in some areas, but drought is more of a concern for the Lodi (tip of the Central Valley), visualized here as the difference between the future and current projections. The third graph shows the coefficient of variation for future precipitation events, where the future variation ranges from 50 to 101, an increase over current variation of 25 to 74.



The final suitability raster above is the weighted combination of soil, land, topography, and future climate factors for viticulture. The growing region may be able to shift into the Sierra Nevada's more than it currently does, and there is also potential to grow in some regions north and east of Lodi.





This varietal chart from Dr. Jones, from a viticultural expert, helps to explain the difference in macroclimates for major wine varietals. In viticulture, macroclimate refers to the climate of the area directly surrounding the vineyard, rather than the typical definition of a large regional climate.

CONCLUSION

The results of this model imply that future temperature increases in climate have the potential to sustain and increase viticulture, but climate variability overall will likely undermine the spread of such a complex crop. Some areas that are currently vineyards will see changes to the growing season, and modeling the physiological impact to the vine is beyond this project. This simple model has many limitations, as there are a variety of other soil factors that can be included, and wind was not included as a climate factor here for the sake of simplicity. A lack of ground truthing is another limitation of this model. Modeling future climate changes and the resulting losses or additions to agricultural productivity uses numerous factors and a lack of precision is likely.

Furthermore, this model classifies all other agricultural land as a possibility, but that may not be an efficient or logical change. Wine consumption is a part of many cultures, but expanding food crop production should take priority in a world where climate change threatens agricultural productivity and population is still increasing.

CREDITS

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References:

Hijmans, R.J., S.E. Cameron, J.L. Parra, P.G. Jones and A. Jarvis, 2005. Very high resolution interpolated climate surfaces for global land areas. International Journal of Climatology 25: 1965-1978.

Jones GV, Snead N, Nelson P. Dec. 2004. Modeling Viticultural Landscapes: A GIS Analysis of the Terroir Potential in the Umpqua Valley of Oregon. Geoscience Canada. V 31; N4, 167-178.

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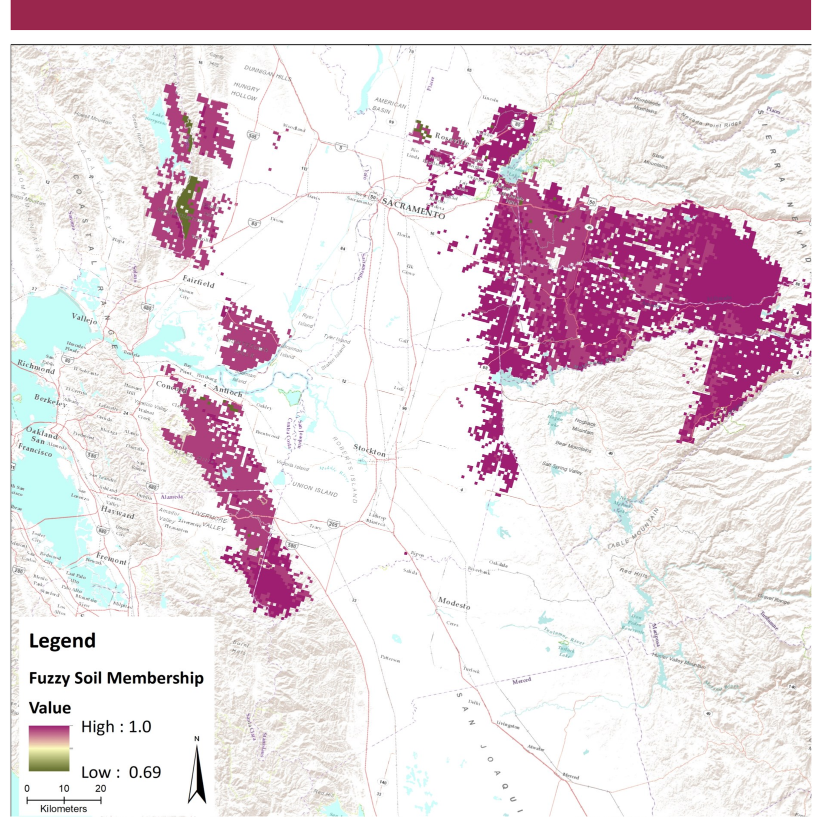
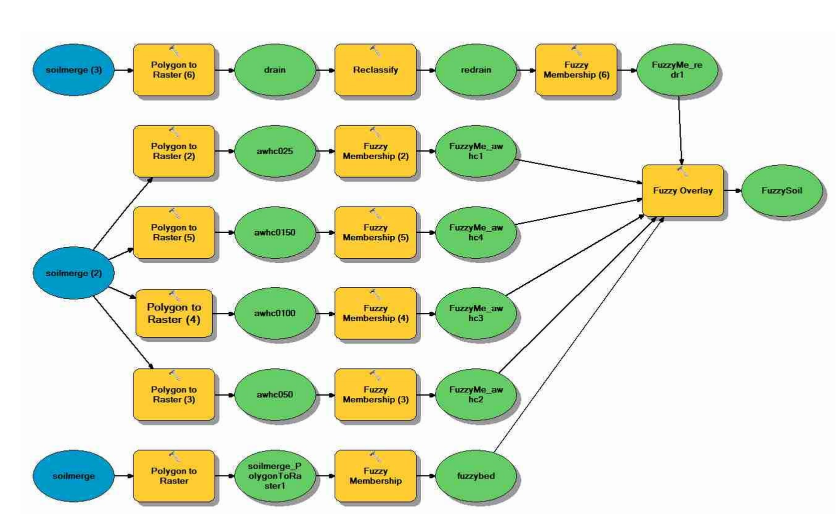
Maps are projected in Albers Equal Area. See data table for data sources

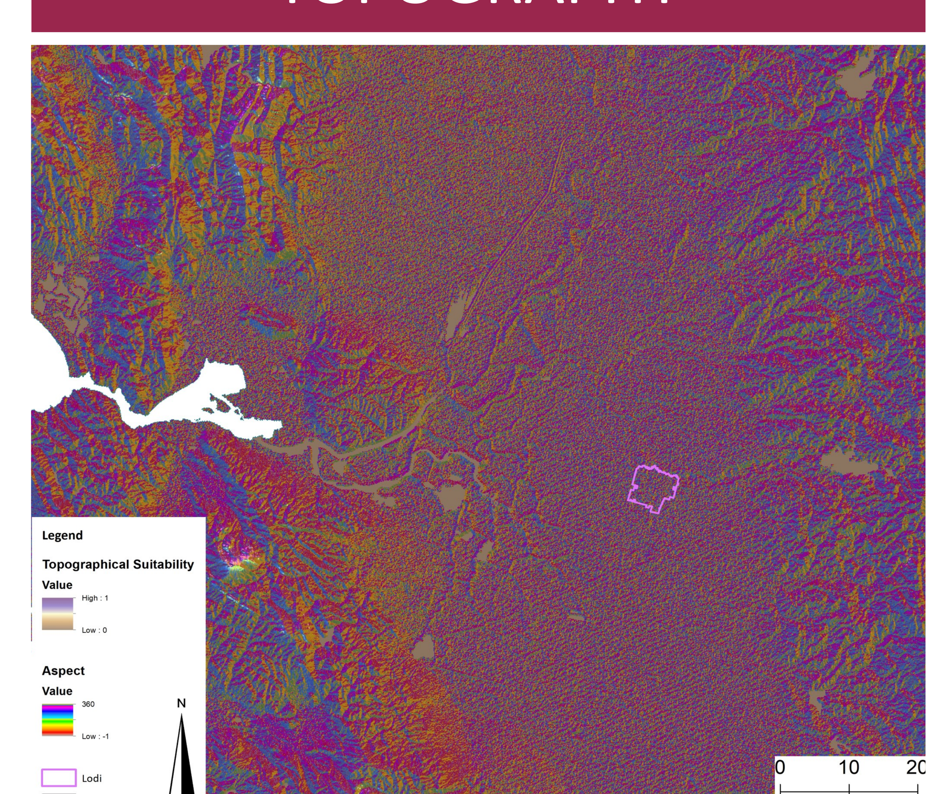
SOIL



Soil is a part of terroir and imbues different tastes into a wine – ash, mineral, acidity and clay content have all been said to come through the taste of the wine. In a more scientific sense soil is important for reasons other than taste as they regulate water and nutrient uptake and vine vigor. Depth to bedrock, Available Water Holding Capacity (AWHC), and drainage were considered in this analysis. The roots of a grapevine range from 24" into the soil up to 15' for very old vines with accommodating soil subtypes. SSURGO soil data was filtered to only show cells with a minimum depth to bedrock of 24" and then data was converted with Fuzzy Membership to rate deeper zones as more desirable. Available Water Holding Capacity (AWHC) is a function of soil type and texture and represents the amount of water in a particular depth of soil that is available to a plants roots for uptake. SSURGO soil data contained 4 depth level ratings of AWHC and these were added to the model with Fuzzy Membership separately, (see model at right) with the most shallow layer being weighted more than the deeper three. Finally, drainage properties of the soil are important for allowing roots to penetrate the soil and excess water to drain. SSURGO soil data contains categorical ordinal ratings which were reclassified for the purposes of this project and added to the model with Fuzzy Membership. The intermediate map shown here (at left) represents equal weighting for the three soil variables.



TOPOGRAPHY



Elevation, Slope and Aspect contribute topographical variables to viticulture. Higher elevations are often excluded due to soil and bedrock type, as well as cooler temperatures at night, but elevation in itself does not disqualify land for viticulture. As with all agriculture, level land is generally preferred, though wine grapes in rich valley slopes command a certain terroir and volcanic soils are often desirable. Aspect, or the direction that the land faces, determines how much sunlight the vines can receive and therefore impacts the amount of photosynthesis. All three variables can be processed through the NASA SRTM elevation files. Elevation and slope were processed directly into Fuzzy Membership using a Gaussian distribution, while aspect required reclassification according to the table below before Fuzzy Membership for the model. This intermediate map shows topographical suitability after Fuzzy Membership overlaid with Aspect. As the most impactful of the three topographical variables, aspect is easily visualized and dominates the intermediate results.

Aspect	Direction	Ranking
1-0	Flat	0
0 – 22.5	North	1
^ – 67.5	NE	1
^ – 112.5	E	0
^ – 157.5	SE	2
^ – 202.5	S	2
^ – 247.5	SW	1
^ – 292.5	W	1
^ – 337.5	NW	2
^ – 360	N	1

Elevation	Ranking
0-199	0
200-399	1
400-799	2
800-999	1
1000-1199	0
>1200	0 (-1)

Slope	Ranking
<1 to 0	0
1-5	1
5-15	2
15-19	1
20-29	0
30+	0 (-1)