The Effect of Climate Change on Viticulture in Virginia

A Spatial Analysis on How Climate Change will Effect Wine Production in Virginia

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Abstract

In this study I wanted to determine what the effects of climate change would be on viticulture in Virginia. I combined future projections, up until year 2099, of both the average temperature and the average precipitation data with the historic averages, going back to year 1961, of the temperature and precipitation in Virginia. This VEMAP climate model is based on two future climate change scenarios at a resolution of 0.5 degree latitude/longitude for the conterminous United States. The scenarios used in the Vegetation Ecosystems Modeling Analysis Project (VEMAP) are: a moderately warm scenario produced by the general circulation model from the Hadley Climate Center with an up to a 2.8 degrees C increase in average annual U.S. temperature in 2100, and a warmer scenario with an up to a 5.8 degrees C increase in average annual U.S. temperature in 2100, from the Canadian Climate Center. Changes in monthly mean temperature were calculated as differences and the changes for monthly precipitation were calculated as change ratios. I also used the different locations of vineyards and wine regions in Virginia, the soil types for growing grapes in Virginia, and the geologic regions and fault lines in Virginia. Using ArcGIS, I looked for patterns between these factors. I found that there is an increase in the projected temperature from the historic temperature. There is also an increase between the projected average precipitation from the historic average precipitation in Virginia.

Climate is one of the key controlling factors in grape and wine production, affecting the suitability of certain grape varieties to a particular region as well as the type and quality of the wine produced. Wine composition is largely dependent on the mesoclimate and mircoclimate. this means that for high quality wines to be produced, a climate-soil-variety equilibrium has to be maintained. The interaction between climate-soil-variety will in some cases come under threat from the effects of climate change. Gradual temperature rise and gradual increases in precipitation is projected to continue in the future. This means that growers will have to adapt to climate change using various strategies. Virginia's climate is diverse and much of the agriculture in Virginia is resistant to changing climate, but the potential impact of rising temperatures, precipitation, and change of soil type, could effect the quality of grapes being produced.

Introduction / Lit Review

Wine has been produced in Virginia since the early days of European colonization in the 17th century; however, the industry did not start developing until twenty years ago. As of 2012, the top 5 varieties produced are: Chardonnay, Cabernet Franc, Merlot, Vidal Blanc and Viognier. Chardonnay is one of the most widely-planted grape varieties. It has a reputation for relative ease of cultivation and the ability to adapt to a variety of different conditions. Cabernet Franc can adapt to a wide variety of vineyard soil types, but seems to thrive in sandy, chalk soils. Merlot thrives in clay soils and tends to bud early. Vidal Blanc is very adaptable and cultivated mainly in the US and Canada. It is difficult to balance Viognier growing conditions. It typically requires warmer climate, sun, and granite soils (Kenny, 1993). Virginia ranks fifth in the nation for both bearing acreage and grape production. The central and northern Virginia counties, in particular those located just east of the Blue Ridge Mountains, account for the significant majority of the state's production. (Hannah, 2013).

Granite-based soils in western areas of the state and sandy soil in the eastern both offer prime grape-growing ground (Brady, 2008). Good drainage can be found on most landscapes at most elevations. However, increases in the amount of rainfall have will likely cause an increase in soil erosion and land loss. Soils are intricately linked to the atmospheric–climate system through the carbon, nitrogen, and hydrologic cycles (Blum, 2004). Therefore, altered climate will have some effect on soil processes and properties.

The diversity of wine production depends on subtle differences in microclimate; therefore, it is especially sensitive to climate change. Several studies on climate change and viticulture around the world have suggested that a warmer climate will impact wine-grapes through over-ripening, drying out, rising acidity levels, and greater vulnerability to pests and disease, resulting in changes in wine quality (e.g. complexity, balance and structure) or potentially the style of wine that can be produced (Mozell, 2014). Prolonged high temperatures can have a negative impact on the quality of the grapes as well as the wine as it affects the development of grape components that give color, aroma, accumulation of sugar, the loss of acids through respiration as well as the presence of other flavor compounds that give grapes their distinctive traits. Sustained intermediate temperatures and minimal day-to-day variability during the growth and ripening periods are favorable (Kang, 2009).

The Earth's climate system is definitely changing. There is not a lot of data on Virginia's wine industry because it is so new, and typically climate impact studies take data from decades on end. Using GIS I hoped to find patterns between future climate change in Virginia and the production of wine grapes.

Methodology

- Used Virginia vineyard data provided by virginiawine.org to map the vineyards and wine regions in Virginia.
- Used the Projected Annual Average Maximum Temperature (degrees C) data from the HAD future climate scenario 2070-2099 for the United States.
  - This projection is at a resolution of 0.5 degree latitude/longitude. This is produced by the Vegetation Ecosystems Modelling Analysis Project (VEMAP).
- Used the Projected Annual Average Precipitation (mm) data from the HAD future climate scenario 207-2099 for the United States.
  - This projection is at a resolution of 0.5 degree latitude/longitude. This is produced by the Vegetation Ecosystems Modelling analysis Project (VEMAP).
- Used the Historic Annual Average Maximum Temperature (degrees C) data from the HAD future climate scenario 1961-1990 for the United States.
  - This projection is at a resolution of 0.5 degree latitude/longitude. This is produced by the Vegetation Ecosystems Modelling analysis Project (VEMAP).
- Used the Historic Annual Average Precipitation (mm) data from the HAD future climate scenario 1961-1990 for the United States.
  - This projection is at a resolution of 0.5 degree latitude/longitude. This is produced by the Vegetation Ecosystems Modelling analysis Project (VEMAP).
- Used data from the USA Soil Survey Geographic (SSURGO) to show the most populous soils in Virginia and how they correlate to the winery locations.
- Used data from The USGS National Map to identify the geology of Virginia

Conclusion

Virginia is comprised of five distinct climate regions: the Appalachian Plateau, the Valley and Ridge Region, the Blue Ridge, the Piedmont, and the Atlantic Coastal Plain. The western area of Virginia has a granite-based soil while the eastern region is very sandy. The western area of Virginia also has a higher elevation and different drainage patterns that the eastern coast of Virginia (Bloomer, 1955). Given Virginia's diverse terrain, climate, and landscape, there are a great variety of wines produced with a variety of tastes, varietals, and subtlety in flavor. However, it is predicted that the shift in climate change patterns may move premium grape growing regions out of areas currently devoted viticulture and simultaneously cause a shift in current grape variety cultivation. The shift in climate may cause shifts to grape chemistry and the resulting quality of wine. The wine industry is sensitive to climate change. In order to produce quality wine, grapes have very specific requirements in terms of temperature, soil characteristics, and rainfall.

Climate change could move up the timeframe of the growing season. It could also force wine makers to look for vineyard locations further north to avoid the warmer temperatures. Planting grapes in the north or on north facing land would force the grapes to ripen slower. Soil erosion, land loss, and drainage problems due to climate change along the different geologic regions could also effect vineyards. Building a vineyard on a fault line may be a mistake because of the increased risk of these problems.

Data Sources

Figure 1-6 data sources include: 1) Virginia State Outline from VHDA_GIS and ESRI, 2) List of 237 Virginia vineyards provided by virginiawine.org, 3) Historic Average Annual Temperatures and Projected Average Annual Temperatures provided by VEMAP Data Basin Dataset from the Hadley Climate Centre, 4) Historic Average Annual Precipitation and Projected Average Annual Precipitation provided by VEMAP Data Basin Dataset from the Hadley Climate Centre, 5) USA Soil Survey Map provided by ESRI and the United States Department of Agriculture's Natural Resources Conservation Service. 6) Geologic Regions provided by VBGIS and The USGS National Map

Results and Discussion

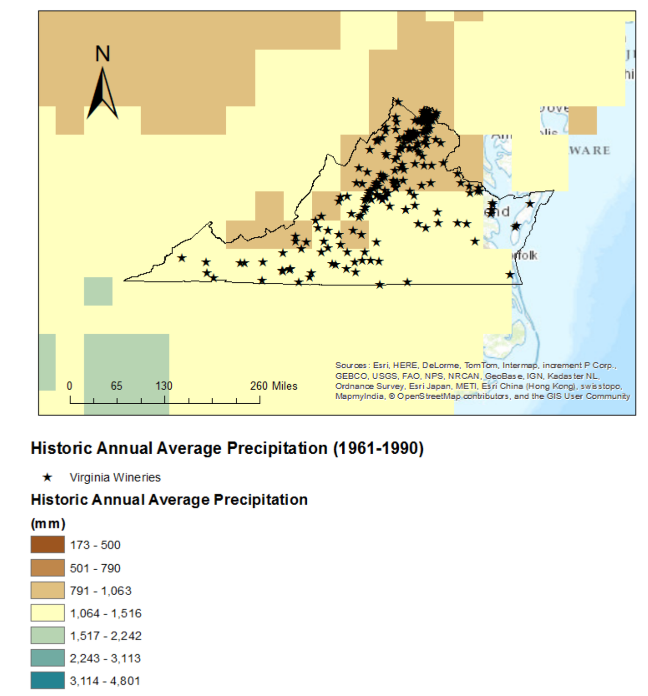

Figure 1: This shows the historic average annual Precipitation data for Virginia. I used natural breaks Classification. The yearly average precipitation is between 791mm and 1516mm. A typical grape vine needs 635-890mm of water a year (Mozell, 2014).

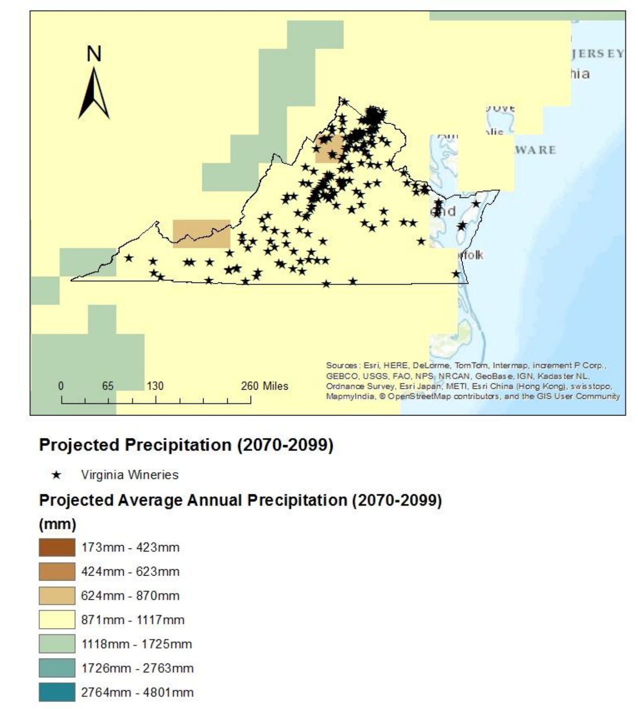

Figure 2: This shows the projected average annual precipitation data for Virginia. I used natural breaks classification. The yearly average predicted precipitation is between 624mm and 1725mm. This is an increase from the historic precipitation.

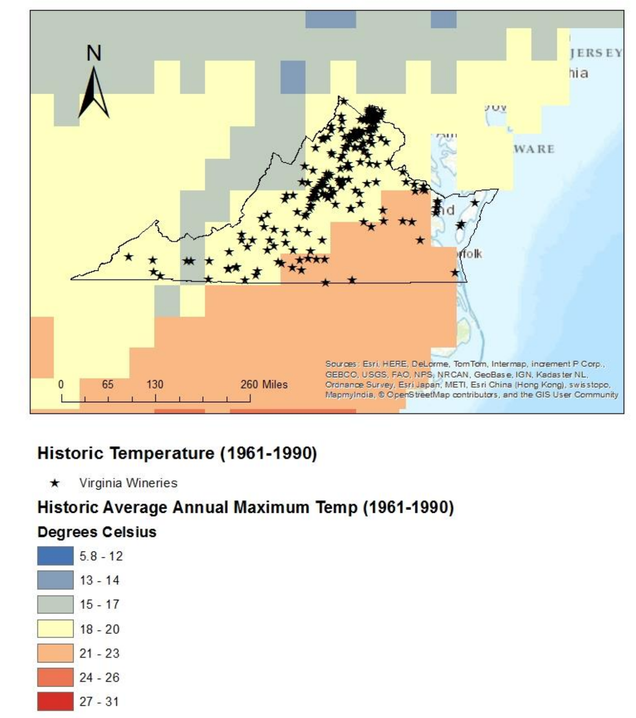

Figure 3: This shows the historic average annual Temperature data for Virginia. I used natural breaks Classification. The yearly average temperature in degrees Celsius is between 15°C and 23°C.

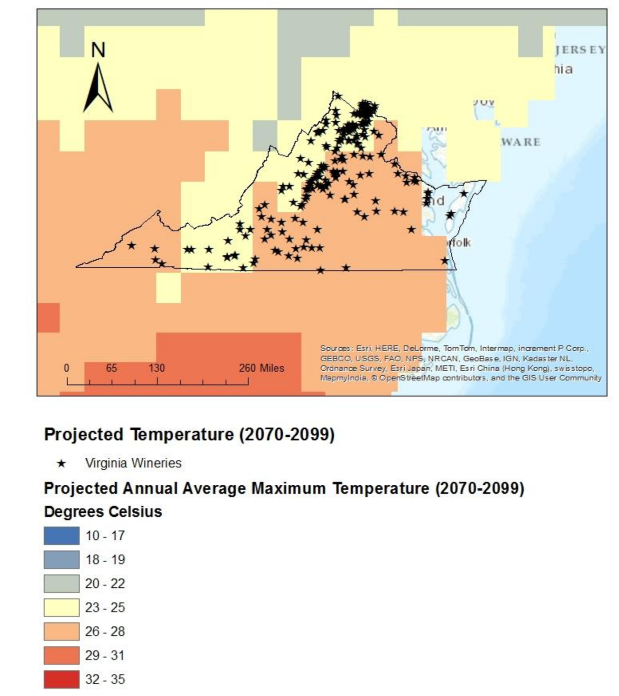

Figure 4: This shows the projected average annual Temperature data for Virginia. I used natural breaks classification. The projected yearly average temperature In degrees Celsius is between 23°C and 28°C. Grapes in warm climates lose their acid through respiration, while grapes in cooler climates will retain their acid (Mozell, 2014.)

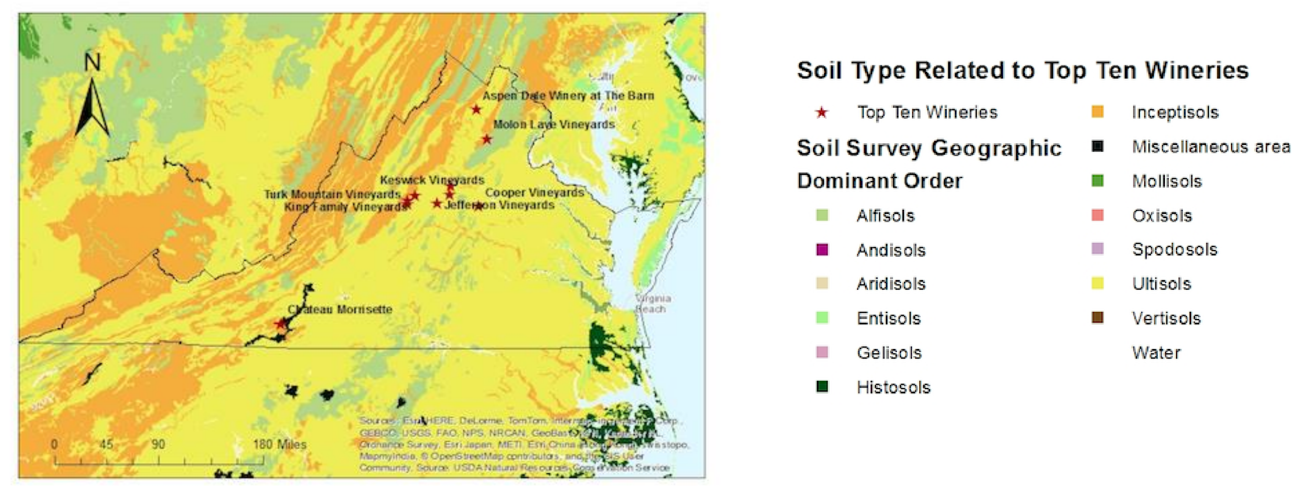

Figure 5: This shows Virginia's top ten wineries related to the soil types in Virginia. The most common Soil types include: Alfisols, Inceptisols, and Ultisols. Alfisols are arable soils with water content adequate for at least three consecutive months of the growing season. Inceptisols are often found on fairly steep slopes and on resistant parent materials. Land use varies considerably with Inceptisols. A sizable percentage of Inceptisols are found in mountainous areas and are used for forestry and agriculture. Ultisols are reddish, clay-rich, acidic soils that support a mixed forest vegetation prior to cultivation. They are naturally suitable for forestry and can be made agriculturally productive with the application of lime and fertilizers. Increases in temperature and changing precipitation patterns will affect the provision of water and nutrients for plant growth, the regulation of the water cycle, and the storage of carbon. (Brady, 2008)

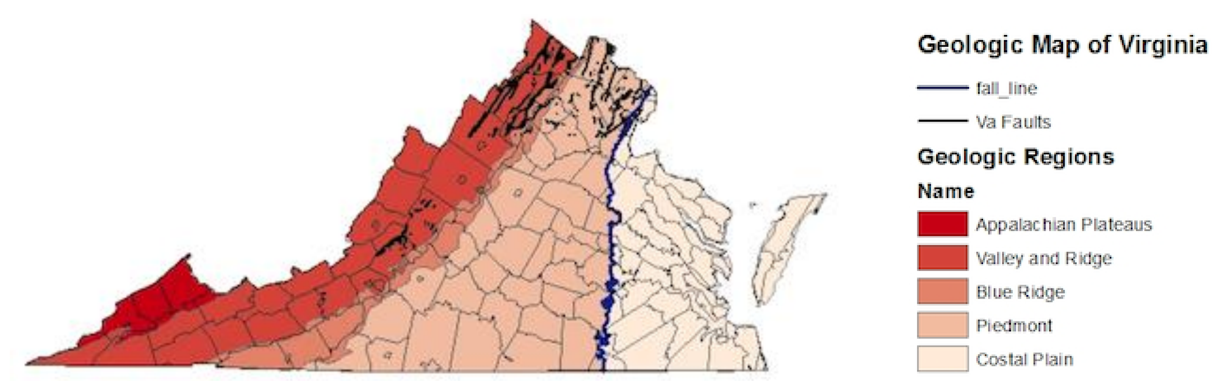

Figure 6: The Appalachian Plateau region is rugged. It has a dendritic drainage pattern with an Elevation between 1000'-3000.' The valley and Ridge region is composed of long linear ridges Separated by linear valleys with trellis drainage. Its elevation is between 1000'-4500.' The Blue ridge region is rugged with steep slopes, narrow ridges, and broad mountains. Its elevation is between 1500'-4200.' The Piedmont region is composed of a broad upland with low to moderate slopes. Its elevation is between 600'-1000' in the west, but it gradually diminished to 250'-300' in the east. The Coastal Plain region is flatter, with low slopes, and gentle drainage divides. Its Elevation is between 60'-250' (Bloomer, 1955). The Fall Line separates the Coastal Plain from the hard bedrock of the Piedmont. With the presence of faults and increased precipitation comes the Potential for landslides and soil erosion (Highland, 2008). The vineyards built along these areas could suffer from soil loss, land loss, and drainage problems from the effects of climate change.

Future Research

Future research could include the effects of viticulture globally. One could research potential shifts in locations of successful wine regions due to global climate change by comparing current region's climate to future changes in climate. One could also research a shift in soil due to climate change and its effect on wineries production.

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