

Modeling viticultural landscapes: a GIS analysis of the viticultural potential in the Rogue Valley of Oregon

Modélisation des paysages viticoles : une analyse SIG du potentiel de la viticulture dans la Rogue Valley de l'Oregon

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Abstract: Terroir is a holistic concept that relates to both environmental and cultural factors that together influence the grape growing to wine production continuum. The physical factors that influence the process include matching a given grape variety to its ideal climate along with optimum site characteristics of elevation, slope, aspect, and soil. While some regions have had 100s and even 1000s of years to define, develop, and understand their best terroir, newer regions typically face a trial and error stage of finding the best variety and terroir match. This research facilitates the process by modeling the climate and landscape in a relatively young grape growing region in Oregon, the Rogue Valley. The result is an inventory of land suitability that provides both existing and new growers greater insight into the best terroirs of the region.

Key words: grapes, wine, viticulture, terroir, Oregon

Introduction

Assessing a site's physical characteristics is arguably the single most important process that any potential grape grower will encounter when starting out (Jones and Hellman, 2003). Combined with matching the site to a grape variety, this decision will ultimately affect the vineyard's yield, the quality of the wine produced, and the vineyard's long-term profitability (Wolf, 1997). In addition, site selection normally involves compromises, in that few sites will possess ideal landscape and climate characteristics in every respect. Site assessment represents a complex suite of issues that must be factored into any plan to establish a successful vineyard operation. The French have named this interaction between cultural practices, the local environment, and the vines, the « terroir »” While there will always be some disagreement over which aspects of the terroir are most influential, it is clear that the prudent grape grower must understand their interactions and controls on grape growth and quality (for a good review of the concept of terroir see Vaudour, 2002). Numerous overviews exist that detail site selection in general (e.g., Dry and Smart, 1988) or for specific regions (e.g., Wolf, 1997; Jones and Hellman, 2003) and focus mostly on climate, topography, and soil factors. Furthermore, applied terroir-related research has resulted in examinations of individual elements such as soil (Becker, 1988), plant growth (Tesic *et al.*, 2002), viability of specific varieties (De Villiers, 1997), cultural practices (Jordan *et al.*, 1980), climate (Jackson and Cherry, 1988), and the zoning of viticultural environments (Carey, 2001). Others have addressed site suitability issues as a collection of factors that allow insights into a region's unknown potential (e.g., Boyer and Wolf, 2000) or as a measure of prediction for new areas to plant in existing regions (e.g., Margary *et al.*, 1998; Jones *et al.*, 2004).

Oregon currently ranks as the fourth largest wine producer in the United States, growing grapes in eleven American Viticultural Areas (AVAs) recognized and defined by the Bureau of Alcohol, Tobacco Tax, and Trade Bureau (TTB), which are based on geographic, historical, and cultural identity along with climate, soil, geology, and terrain uniqueness compared to surrounding areas. In 2005 there were 734 vineyards and 303 wineries growing over 25 different varieties on over 6,000 harvestable hectares with an economic benefit of over 420 million US\$ to the state (sourced from the Oregon Vineyard and Winery Reports). The Rogue Valley AVA is the southern-most winegrape growing region of Oregon is located entirely within Jackson and Josephine counties (figure 1). Established in 1991, the Rogue Valley AVA consists of four main areas: the Upper and Lower Rogue Valley, the Applegate Valley, and the Illinois Valley, which together have over many potential acres for grape growing. Drained by the Rogue River and its tributaries, the region presents a diverse array of landscapes and climates for grape growing. Currently, the Rogue Valley AVA has over

130 vineyards growing on nearly 900 ha (Oregon Vineyard and Winery Reports, 1987-2005). The number of wineries has grown from five in 1987 to 16 in 2005, with the total amount of grapes crushed increasing from 514 to over 3500 tons. Because of a diverse climate, the region offers the various conditions needed to produce both cool and warm-climate grape varieties. Grape varieties commonly grown in the Rogue Valley AVA today include Merlot, Pinot Noir, Cabernet Sauvignon, Chardonnay, Pinot, Gris, Riesling, and Gewurztraminer.

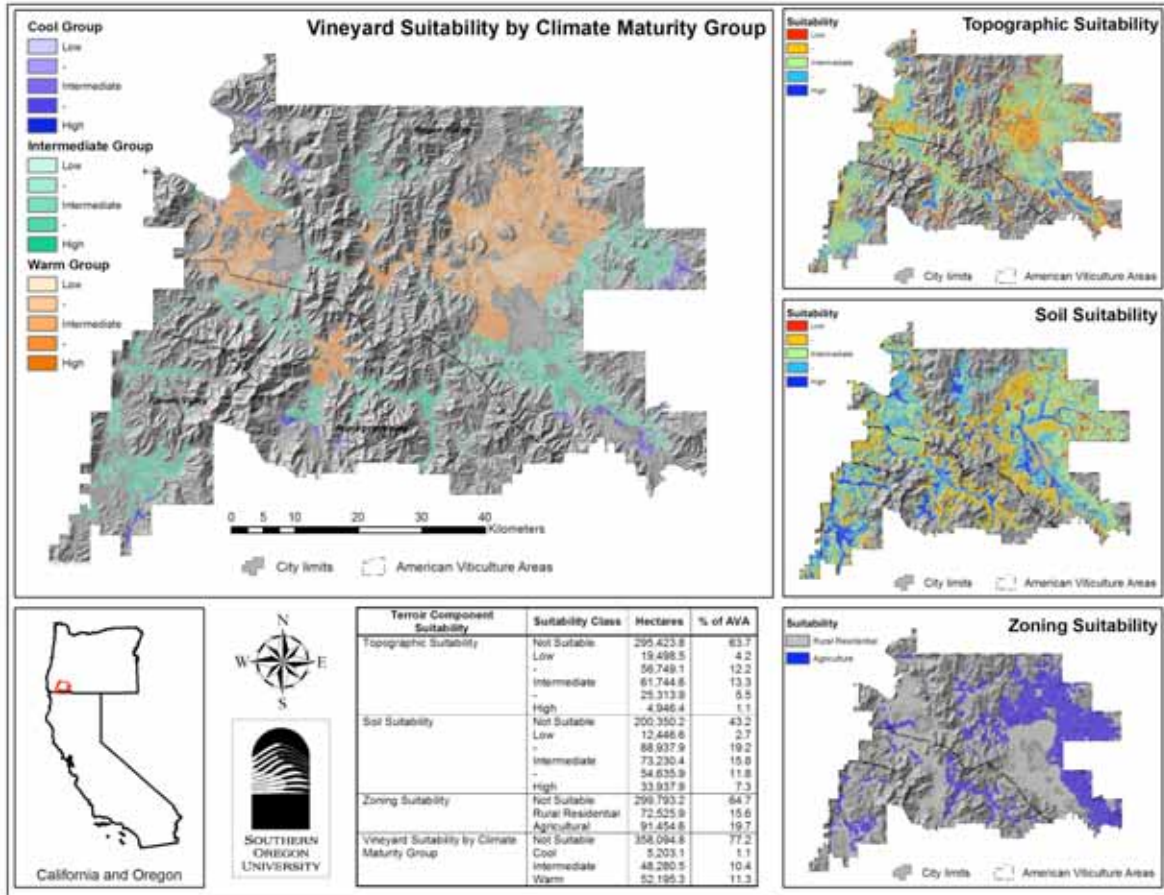


Figure 1 - Map frames of the various terroir components analyzed. Clockwise from upper right; topographical suitability, soil suitability, zoning suitability, climate suitability, and combined vineyard suitability using each of the four components and shown by climate maturity groups. See text for details.

In addition, plantings of Cabernet Franc, Pinot Blanc, Tempranillo, Viognier, Zinfandel, Malbec, and Syrah are increasing. The region has the highest elevations, but is overall the warmest and driest, of the Oregon AVAs (Jones and Hellman, 2003). The general north-south tending valleys, with their proximity to the Pacific Ocean and intervening topographical barriers, create a climate transect of wetter and cooler conditions in the western parts of the region to the warmer and drier eastern areas. Precipitation varies from 300-1,500 mm across the region, declining in amount from west to east with less than 15 percent of the total precipitation occurring during the growing season of April through October. The frost-free period averages 155-185 days, with the average last and first frosts occurring on May 10 and October 10, respectively (median frost dates defined for 0°C). The growing season is shorter in the Rogue Valley AVA than in the other AVAs due to higher elevations that bring later and earlier frost potential in the spring and fall, respectively. Growing degree-days exhibit a similar spatial trend, with values ranging from 1,300 to nearly 1,700 from west to east (Jones and Hellman, 2003).

The landscape of the Rogue Valley AVA is extremely diverse, being derived from the joining of three mountain ranges of varying ages and structure: the Klamath Mountains, the Coastal Range, and the Cascades (Jones and Hellman, 2003). The region is drained mainly by the Rogue River and its major tributaries; the Applegate River, the Illinois River, and Bear Creek. The agricultural landscape of the Rogue Valley AVA is mostly comprised of valley lowlands with some isolated hills, stream terraces or benches, and footslopes of alluvial fans scattered by hilltops and ridges. From this diverse geology comes a widely varying mix of metamorphic, sedimentary, and volcanic derived soils (Jones and Light, 2001). The broad valleys of the Rogue Valley AVA contain thick beds of rock and gravel derived from a mix of alluvial and glacial origins.

Furthermore, while most soils in the region have the moisture-holding capacity needed for winegrape production, water availability is a principal consideration for any site in the region. Vineyards in the region are found on flat to very steep slopes (up to 30%) that are distributed along isolated hills, stream terraces or benches, and at the foot of alluvial fans (Jones and Light, 2001). Elevations of potential and existing vineyard sites range from near 275 m to over 700 m.

Even with over 40 years of post-prohibition grape growing experience, deciding to grow grapes in the Rogue Valley can be a complex issue owing to the diverse geography and climate. For any existing and potential grape grower, vineyard site selection, or choosing the best terroir, is the single most important decision to be made. Therefore, the research described herein attempts to understand the locational factors important to grape growing in the Rogue Valley AVA through a multi-factor terroir-related analysis. The goal of the research is to model the best grape growing landscapes in the Rogue Valley AVA, and to provide an inventory of sites to facilitate greater success in the grape growing to wine quality continuum.

Data and Methods

To analyze the terroir of the Rogue Valley, a multi-stage Geographic Information System (GIS) analysis was set up to incorporate factors related to the topography, soils, land use zoning, and climate. The topographical landscape was analyzed through the use of 110 United States Geological Survey 10 meter digital elevation models (DEM). Each 1:24,000 scale quadrangle for the region was mosaicked into a single DEM grid (raster data). The entire landscape in the Rogue Valley AVA was then categorized for the most advantageous elevations, slopes, and aspects for growing grapes following the methodology of Jones *et al.* (2004) for the Umpqua Valley, a growing region to the north of the Rogue Valley. The categorization was constructed as a multi-layer, landscape-driven potential site analysis using ArcGIS (©Environmental Systems Research Institute) with class rankings given each grid based on its potential. Due to variations in local relief, elevations were categorized for the four sub-regions; the Illinois Valley (400-600 m), the Applegate Valley (350-650 m), the Lower Rogue Valley (300-500 m) and the Upper Rogue Valley (400-800 m). The entire region was masked by the sub-region, reclassified into suitability classes, and then combined back to create a single elevation suitability grid. The most advantageous elevations in each region were given the highest value and those greater than a given region limit were considered not viable (classed -1). Slopes were categorized into suitability classes from less than 1% (or basically flat with poor cold air drainage) to those over 30% being classed -1 or not viable (increasing slopes cause problems using vineyard equipment). The best slopes are considered to be those in the 5-15% range. While the aspect of the landscape is typically used to define solar exposure, aspect alone does not account for obstructions such as other hills or swales in the landscape and does not factor in the sum total of the seasonal variation in solar declination and azimuth. To account for these variations, hillshade grids with the appropriate declination and azimuth were calculated for the first day of each of the seven months of the growing season (April-October) and for six daily time steps (1,000, 1,200, 1,400, 1,600, and 1,800 hours). The grids were then added together to obtain a cumulative solar illumination grid that was categorized into suitability classes with those with the greatest solar illumination (a proxy of solar radiation receipt), and therefore ripening potential, given the highest ranking. The three separate grids were then added together to produce a single topographic suitability grid with values ranging from not viable (anything with a negative score, coming from either being too high in elevation or on extremely steep slopes) and least suitable through most suitable landscapes.

To analyze the Rogue Valley AVA's soils, data were obtained from the Soil Survey Geographic (SSURGO) Database for the Josephine and Jackson County Area, Oregon (National Resource Conservation Service, 1983 and 1993, respectively). Site suitability relative to soils is analyzed in a similar manner to Margary *et al.* (1998) for New York using the Soils Suitability Extension (SSE) with adjustments made for soils found in Oregon (Stulz, 2001). Four soil properties were used in the categorization of suitability: drainage, depth to bedrock, available water holding capacity, and pH. Drainage is thought to be the most important soil factor in establishing and maintaining a vineyard and is influenced by many structural issues such as texture, depth, slope, and aspect. To assess soil drainage, the SSURGO database was analyzed by individual Hydrologic Soil Groups by map unit in the database. The four groups represent variations in drainage from good to poor (groups A to D). In dry growing regions like Oregon, depth to bedrock gives an indication of how well vines can cope with dry periods, with a minimum of 75-100 cm generally needed (Jordan *et al.*, 1980; Dry and Smart, 1988). Mean depth to bedrock was calculated using the SSURGO database from the low to high bedrock depths for each component, and a weighted average was obtained for each map unit. While drainage is extremely important in vineyards, a soil's available water holding capacity (AWC) is important as those

soils with adequate water holding capacity are at an advantage, giving vines the greatest ability to tolerate periods of moderate drought. AWC was calculated from the SSURGO database by computing the mean value for each soil layer, summed over the layers for each component, and then weighted by the percentage of each component per map unit (Margary *et al.*, 1998). Soil pH gives an indication of fertility and nutrient balance with most ideal vineyard soils being found between 5.5 and 8.0. Outside this range, nutrients may become out of balance, with deficiencies or toxic levels effecting vine uptake or beneficial relationships with microorganisms. Soil pH was computed from the SSURGO database by computing the mean value for each soil component and then weighting by the percentage of each component per map unit.

The spatial polygon soils data was then converted to grids at the same 10 meter resolution to match the landscape suitability grid. Each soil factor was then grouped into classes based upon their individual values; drainage from poor to excessive, available water holding capacity from 0.0-0.25 cm of water per cm of soil; depth to bedrock from 0-150 cm; and pH from values from 5.0-8.0. All classes in each grid were then scaled and weighted with drainage given the greatest weight (40%) and each of the other factors weighted 20%. A final grid of soil suitability was then constructed from the weighting of the four soil factors.

To incorporate land use issues relative to agricultural development, a statewide generalized zoning coverage was used in the analysis (sourced from the Oregon Geospatial Data Clearinghouse). The zoning data used was initially digitized from data collected from 1983 through 1986 by the Oregon Department of Land Conservation and Development. Since its production, limited zoning changes have occurred and the dataset represents the best statewide zoning coverage available for the state of Oregon. For this analysis only lands zoned agriculture, mixed agriculture, and rural residential are considered as viable parcels on which to develop a vineyard. The rural residential zoning allows for small vineyard development and is included because many existing vineyards in southern Oregon can be found on sites with this zoning.

To assess the climate suitability of the Rogue Valley AVA, a climate model was developed using the PRISM (Parameter-elevation Regressions on Independent Slopes Model) model which is derived from a combination of point data, a digital elevation model, and other spatial data sets to create estimates of monthly and annual climate variables that are gridded at roughly 1.45 miles resolution (Daly *et al.*, 2001). The model builds climate maturity groupings for cool (1050-1250), intermediate (1250-1450), warm (1450-1650), and hot (>1650) climates based on growing degree days (GrDDs; from April to October using a base of 10°C) using practical experience in Oregon (Jones and Hellman, 2003).

The three site factors – topography, soil, and zoning grids – after being internally scaled relative to their individual grape growing influences (as defined above), were then combined to produce a composite suitability grid taking into account the combined landscape/land use effect. The composite grid was then used to mask the climate maturity group grid to produce a spatial depiction of the best vineyard sites in each climate maturity group in the Rogue Valley AVA.

Results and Discussion

The first stage of the suitability analysis for the Rogue Valley AVA resulted in a grid depicting those landscapes most topographically appropriate for grape growing in the region. Over 63% of the AVA is considered not suitable due elevations above the maximum thresholds in the four regions (table 1 and figure 1). The most topographically suitable landscapes (as scoring the highest on elevation, slope, and solar illumination combined) make up over nearly 5 000 ha and are scattered over the AVA but are typically found on footslopes of the surrounding mountains, stream terraces, benches, or isolated hills.

The soil analysis resulted in four individual grids that depict drainage, depth to bedrock, available water holding capacity, and pH variations for individual map units for the AVA (not shown individually). Spatial variations in hydrologic groups indicate that the best drained soils are found in sandy soils and along the alluvium filled valleys and terraces of the main rivers. Similar patterns are found with depth to bedrock, with the deepest soils found in broad areas surrounding the main river drainages, in upland regions in the volcanic soils of the Cascades, and in isolated areas throughout the AVA. Available water holding capacity (AWC) varies from the higher values in the more silty to clayey soils, to lower values in the soils of the Klamath Mountains and some of the more excessively drained soils in the area. Soil pH in the AVA ranges from 4.6 to 6.7 with a mean of 5.6. The combined weighted soils suitability categorization results in a single grid that depicts the best soils for grape growing with moderate to well drained soils, adequate depths to bedrock, moderate to good water holding capacity, and more neutral soil pH. The most suitable soils, those scoring highest across all four properties, represent over 30,000 ha and are found along the main reaches of the main rivers, but typically above the valley floor across each of the four regions (figure 1).

General agricultural zoning in the AVA represents 35.5% of the region (table 1 and figure 1). For land zoned agriculture, the designations are further divided into two broad categories: exclusive farm use (19.7%) and agriculture-rural residential (15.6%). This results in over 160,000 ha of land that is zoned appropriately for vineyard development (figure 1); however this does not mean that this land is available.

Table 1 - Suitability of the various terroir components analyzed.
See the text for detailed descriptions of the suitability classes given in the table.

Terroir Component Suitability	Suitability Class	Hectares	% of AVA
Topographic Suitability	Not Suitable	295,423.8	63.7
	Low	19,498.5	4.2
	-	56,749.1	12.2
	Intermediate	61,744.6	13.3
	-	25,313.9	5.5
	High	4,946.4	1.1
Soil Suitability	Not Suitable	200,350.2	43.2
	Low	12,446.6	2.7
	-	88,937.9	19.2
	Intermediate	73,230.4	15.8
	-	54,635.9	11.8
	High	33,937.9	7.3
Zoning Suitability	Not Suitable	299,793.2	64.7
	Rural Residential	72,525.9	15.6
	Agricultural	91,454.6	19.7
Vineyard Suitability by Climate Maturity Group	Not Suitable	358,094.8	77.2
	Cool	5,203.1	1.1
	Intermediate	48,280.5	10.4
	Warm	52,195.3	11.3

The climate maturity analysis produced a grid that spatially represents the potential for the region to ripen given varieties based upon heat accumulation. The resulting grid depicts 43.2% of the region not being climatically suitable while 4.5% is classified as being cool, 31.2% intermediate, and 21.1% warm climate maturity groups (not shown). There are no areas deemed suitable to the hot climate maturity grouping in the AVA.

The climate maturity group suitable areas were then masked with the combined topographical, soil, and land use suitability grid to further reduce the landscape suitability to only those that can adequately ripen fruit across any of the climate maturity groups. The composite suitability grid is then depicted using the individual climate maturity groupings to show the spatial variation of terroir potential in the AVA (figure 1). Areas of non-suitable land are generally being limited through one of four main factors: elevation, slope, urban or forest zoned lands, or climate (shown in gray in figure 1). The cool climate group, representing 1.1% of the AVA, is found in isolated areas in the higher elevations near the periphery of the AVA. The intermediate climate group areas (10.4% of the AVA) are found throughout the region with much of upper Bear Creek, the Applegate and the Illinois Valleys in this class. The warm climate group (11.3% of the AVA) is found in the area around Grants Pass, north of Medford, along the Rogue River and into the Evans Creek Valley, and in the Missouri Flats area of the Applegate Valley. Examining only those landscapes that scored in the two highest landscape suitability zones results in 617, 5345, and 2035 ha of the most suitable lands found in the cool, intermediate, and warm climate maturity groups, respectively (table 1).

Conclusion

This research represents an attempt to define and map terroir potential by examining the grape growing landscape in the Rogue Valley AVA of Oregon through the spatial analysis of topography, soil, land use, and climate. The combined topographical suitability analysis shows that nearly 5,000 ha in the AVA could potentially provide high quality landscapes for grape growing. An assessment of soil suitability finds spatial variations in drainage, depth to bedrock, available water holding capacity, and pH that are related to the underlying geology. The most advantageous soils with moderate to good drainage, adequate soil depths, fair to good water holding capacity, and near neutral pH are located on alluvial terraces above the main rivers and in many isolated areas throughout the county. The region has over 35% of its land zoned for agriculture or rural residential, which is more easily developed into vineyard sites. Overlaying climate and landscape

factors results in a collection of suitable sites depicted by each of the cool, intermediate, and warm climate maturity groupings. The results indicate that very good landscapes exist across each of the climate maturity types with strong potential for future development and production of quality fruit and wines.

The Rogue Valley AVA is a promising region for winegrape production with a short history of viticultural practices revealing the potential to ripen cool to warm climate grape varieties. Rapid growth of the industry is likely to continue due to current successes and the availability of land. Through the use of spatial analysis this research has helped to further define the terroir potential of grape growing in the Rogue Valley AVA. The results provide existing and future growers with baseline knowledge of the region's grape growing potential relative to its topography, soil, land use, and climate. While not specifically addressing the cultural aspects of terroir (e.g., style-directed viticultural and enological practices), which typically take many years to become dominant, the results presented here should serve to initiate better decisions in the site selection process, thus leading to fewer and/or more efficient trial and error procedures. In addition, for most potential growers, site selection will involve compromises, in that few sites will possess ideal characteristics in every respect. While compromise in many cases has been the rule, this body of research presents one of the best tools yet to enhance the site selection process for future growers in the Rogue Valley AVA. Finally, the process developed here theoretically can be applied to any area where adequate spatial data resources are available.

Acknowledgements: This research is a compilation of various ongoing research projects that were funded by numerous sources: The Oregon Wine Board, the Rogue Valley Winegrowers' Association, and the Carpenter Foundation at Southern Oregon University. The authors would like to extend their appreciation to all of the grape growers in the Rogue Valley AVA.

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