Title: High resolution geographical information system for assessing vineyard site suitability

Progress Report

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Objectives

To provide a high-resolution definition of Virginia's viticultural suitability based on climate, topography, land use, soil type, soil hydrology and the risks to grapes posed by certain pests and diseases. To provide the resulting imagery in an interactive, internet-based format accessible by individuals, agencies and service providers such as Cooperative Extension agents who can locally apply the results to vineyard site assessment. To provide logical definitions of future American Viticultural Areas (AVAs) that are recognizable by wine producers and consumers and that will provide additional, local branding of wines.

Justification & Methodologies

The Virginia wine industry adds 100 to 200 new acres of vineyard per year and much of that increase is due to new producers who are entering the industry. While much of the growth is centered in the northern Piedmont, interest in the Shenandoah Valley, southwest Virginia, the southern Piedmont and other less charted viticultural also exists. New vineyards must, however, be established in prudent sites to minimize the hazards of winter injury, spring frost, poor soil drainage, and biotic factors. While we have a description of what constitutes a good vineyard site from a physical and climatic standpoint, we do not have a current means of graphically representing such features to the interested vineyardist.

Researchers at Virginia Tech developed a Geographical Information System for assessment of vineyard site suitability in the late-nineties and distributed over 1400 county-specific maps through 2007. The maps showed areas of greater or lesser vineyard suitability on a 30- by 30-meter resolution, but were static tools which could not be accessed or manipulated by end-users. Further, the data used to develop the GIS maps in the nineties did not include soils or climate data, which are available today. Due to the outmoded nature of the first-generation GIS vineyard maps, their distribution was ceased in early 2008. The viticulture suitability GIS developed at Virginia Tech served as a model starting point for similar projects in North Carolina, Maryland and Pennsylvania. The PI of this proposal was instrumental in developing a first-generation GIS for North Carolina.

The proposed research will substantially build upon the earlier GIS maps, providing more information with a user-friendly, dynamic interface that allows the user to focus on the land parcels of interest to him or her. The proposed GIS vineyard site suitability program will include, but not be limited to, a variety of new data including:

- Geology and soils data now available in digital format
- Thermal satellite imagery showing specific weather events, such as day/night temperature differentials and frost events
- Agricultural census data on historical fruit production areas
- Contemporary climatic data collected by weather stations over the last decade, which can account for revisions needed for climate change (implications for emerging disease and pest issues)
- A more comprehensive mapping of vine pests and diseases (e.g., Pierce's Disease) based on research findings.

Providing a solid basis for established and defined viticulture zones also has short and long term benefits to the industry. The current legally defined wine regions (American Viticultural Areas, AVAs) in Virginia are not necessarily based on unique climate, soil, varietal selection or homogeneous cultural practices, and thus do little to inform the consumer about *terroir* or the unique attributes of the wine's place of origin. Successful product branding is increasingly going to rely on such unique attributes. Without discrediting current AVA's, this research project and the resulting tools will begin to form the foundations for logical 'viticulture zones' within Virginia by laying an objective groundwork of spatially homogenous growing regions of the state: creating a central tool of product development for growers, wine producers, marketers and tourism planners. As market competition continues to grow, branding of geographic areas will increasingly add additional value to wine.

Results

Status of Project Objective 1: GIS data development and analysis

A majority of the viticultural suitability parameters can be classified as either soil or climate. To date, most of the GIS development work has been focused on the soil-related parameters.

Soils

The SSURGO soil dataset maintained by the USDA's Natural Resources Conservation Service (NRCS) is the most comprehensive and complete soils GIS dataset available for Virginia. The SSURGO dataset consists of soil mapping units (polygons) containing one or more soil components, each of which may consist of one or more horizons. Data values describing these soil components and horizons are stored in a relational database. To develop thematic maps from this data, one must perform some data aggregation to ensure that the final map reflects all of the soil components (and horizons). The NRCS has developed a "Soil Data Viewer" extension for the ESRI ArcMap GIS software, which automates these aggregation processes for the most common use cases.

In addition to creating specific thematic GIS layers from the SSURGO data, this data also requires additional to create a single state-wide dataset, because the SSURGO data is maintained and distributed based on soil survey areas that correspond to county boundaries. While it is not necessary to merge the results from the different soil survey areas into one dataset in order to view the data, such aggregation is useful when determining the presence of gaps/overlaps between survey areas, and when developing analysis tools that operate on the soil data.

The SSURGO data is subject to irregular maintenance, and so it is important to keep track of the source date of the data used in any analysis. SSURGO data is not available for all of the counties in Virginia, although the state is mostly complete. For those areas where SSURGO data is not available, data from the less detailed “U.S. General Soil Map” (formerly referred to as STATSGO) is used.

Using these sources and methods, individual soil map layers have been created for the following parameters:

- Soil Depth
- Soil Drainage
- Soil Organic Matter Content
- Parent Material
- Saturated Hydraulic Conductivity
- Soil Bulk Density
- Available Water Capacity
- Soil Surface Texture
- Soil pH

Refer to Appendix A for examples of the soils layers. Based on meetings with Dr. Tony Wolf, approximate rankings of soil parameters values have been developed for use in the overall suitability analysis. Some of these soil layers are of critical importance, some are potentially limiting, and some are of minor significance. At this point, work on the soils data is largely complete, with remaining tasks including transferring the data to the server, optimizing the layers for web map display, and testing the data within the overall analysis algorithm (which is still being formalized).

Climate

Climatic map layers for use in the analysis will be developed using an interpolation method based on National Climatic Data Center (NCDC) records of weather station observations and other GIS datasets. First, reasonable estimates of climate parameters will be developed from analysis of the historical records of observations at each weather station. For example, the average annual rainfall (or seasonal rainfall) over the past 20 years may be calculated at each station. To create a statewide map of a climate parameter, interpolation between stations and/or regression modeling will be used, as appropriate.

For some climate parameters, correlation with other factors such as elevation and latitude can be exploited in the form of a multiple linear regression model. From this regression model, it is possible to generate a statewide map of the climate parameter that is more reasonable than simple distance-based interpolation between weather stations. It is important to note that such regressions are not physically-based models, but merely convenient statistical fitting procedures used to provide more reasonable climatic parameter mapping. The success of the regression modeling approach will vary with the climate parameter of interest, and depends on the selection of appropriate independent variables to use in the regression fit. It is expected that elevation, latitude, and aspect will be the most likely candidates for use as independent variables in such models. For example, on a previous project, the annual frequency of low temperature events was mapped as a function of elevation and latitude (refer to Appendix B).

Using this approach to climate data, it will be possible to develop climate data layers related to those parameters monitored at the majority of weather stations: temperature and precipitation. Although the final list of climate layers has not been established, possible layers include:

- Annual Frequency of -5° F events
- Average length of frost-free season
- Average maximum summer temperature
- Average growing season precipitation

Topography

In addition to the absolute elevation of a site, terrain data is also used in describing a site's relative elevation, slope, and aspect. To support these parameters, as well as the modeling and mapping of climatic parameters (described above), statewide terrain data from the National Elevation Dataset has been downloaded and merged. This terrain data is a raster dataset with a cell size of approximately 30m square. Although more detailed terrain data is available from the Virginia Base Mapping Program (VBMP), this data was originally developed for use in orthorectifying imagery, and has some flaws in consistency that affect its use as a terrain dataset. Furthermore, the VBMP terrain data often includes a higher level of detail than the other data being used in this statewide study, and the mix of resolution could lead to some confusion for the audience.

Refer to Appendix C for visualizations of the terrain data to be used in this project.

Other Factors

Aside from the soil, climate, and topographic parameters, other factors relating to viticultural suitability may also be included. Factors in this category, which have not yet been investigated, include:

- Disease and pest risk / prevalence
- Current land use
- Pollution
- Demographic / economic factors

Suitability Analysis and Ranking

The goal of the analysis and ranking system is to allow the audience to view an overall viticultural suitability layer, topic-specific suitability layers, or individual parameter layers.

The final system of equations to determine the overall suitability has not been finalized, however, a conceptual system has been proposed. The overall suitability map will be a function of a few topic-specific suitability map layers, such as soils, climate, and topography. Each of these map layers will actually be functions of a number of more specific parameters. For example, the soils suitability map will be a function of the various soil parameters described previously. To produce these suitability maps (either at a topic-specific level or at the overall level), a weighted average of the constituent layers will be computed, with weights are assigned based on expert judgment. Some of the parameter maps may act as hard limits which render certain geographic areas unsuitable, regardless of the values of other parameters.

Status of Project Objective 2: WebGIS site

Planning for the webGIS site has thus far been limited to discussion of the desired functionality and decisions regarding the software. The purpose of the overall website experience is twofold: to show the viticultural suitability map layers and analyses, and to provide a general reference regarding viticultural suitability. The website user should have the ability to view the overall suitability layers developed in this project, as well as to toggle on/off individual parameter layers from within a categorized list. Either on the same page, or as a hyperlink, additional descriptive information about each parameter (or analysis result) should be available.

Aside from the map viewing functionality, the GIS component of the website will also permit the development of task-based tools, such as report generation for a user-defined study area. Using ESRI's geoprocessing framework, such task-based tools may be built from a combination of standard geoprocessing tools and custom Python scripts.

At this point, ESRI's Javascript API appears to be the most appropriate software upon which to base the map viewer. The ESRI Javascript API offers some advantages over the more formal server-side web application frameworks; specifically, javascript applications are somewhat independent of the server environment, can begin loading more quickly, can be developed using standard web development software, and can still make calls to customized ArcGIS Server geoprocessing tasks.

A test website was created using the ESRI Javascript API, primarily as a proof of concept, with little attention to webpage design and layout. In this test, the map layers were served from ArcGIS Server as cached map services. For most of the layers in this project, cached services (that is, map services in which the content is stored as pre-rendered tiles) will be appropriate, as the content of the layers is not dependent upon real-time data. As work on the development and analysis of the viticultural suitability parameters continues, time will also be spent developing an attractive page layout for the map application.

Status of Project Objective 3: Logical basis for development of future AVAs

This objective will depend in part on the data and analyses developed under Objective 1.

Conclusions

Since this project is product oriented (GIS system) and in progress, there are no conclusions to report at this time.

Impact Statement

N/A, as is still in progress

Citation(s) for any publications arising from the project

None

Appendix A: Soils Data

The SSURGO soils data compiled for this project covers most of Virginia, and where it is incomplete, lower-resolution STATSGO data has been used. The following figures provide examples of some of the soil parameters available in SSURGO.

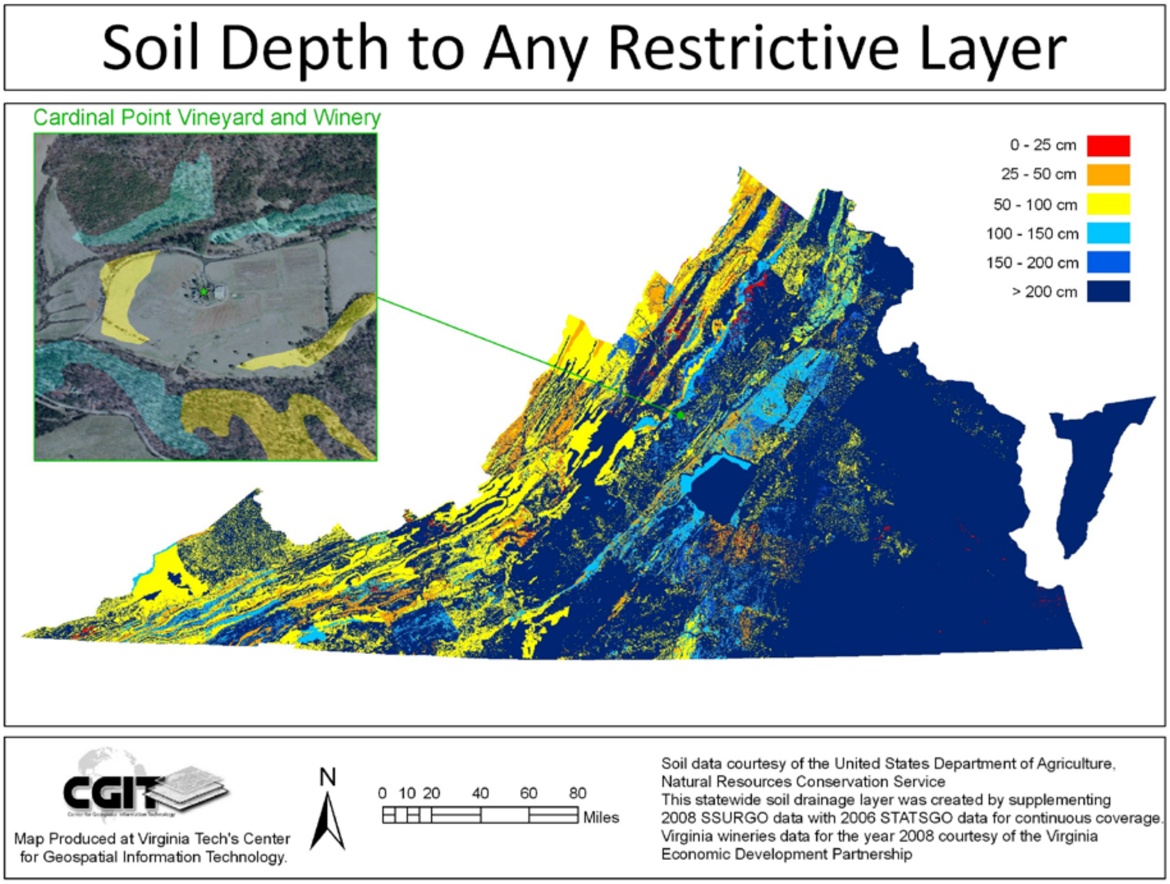

Figure A-1: Estimated soil depths. In the map inset, SSURGO estimates most of the soil is at least 200cm deep, with some areas of 50 – 100cm (yellow) and 100 – 150cm (light blue).

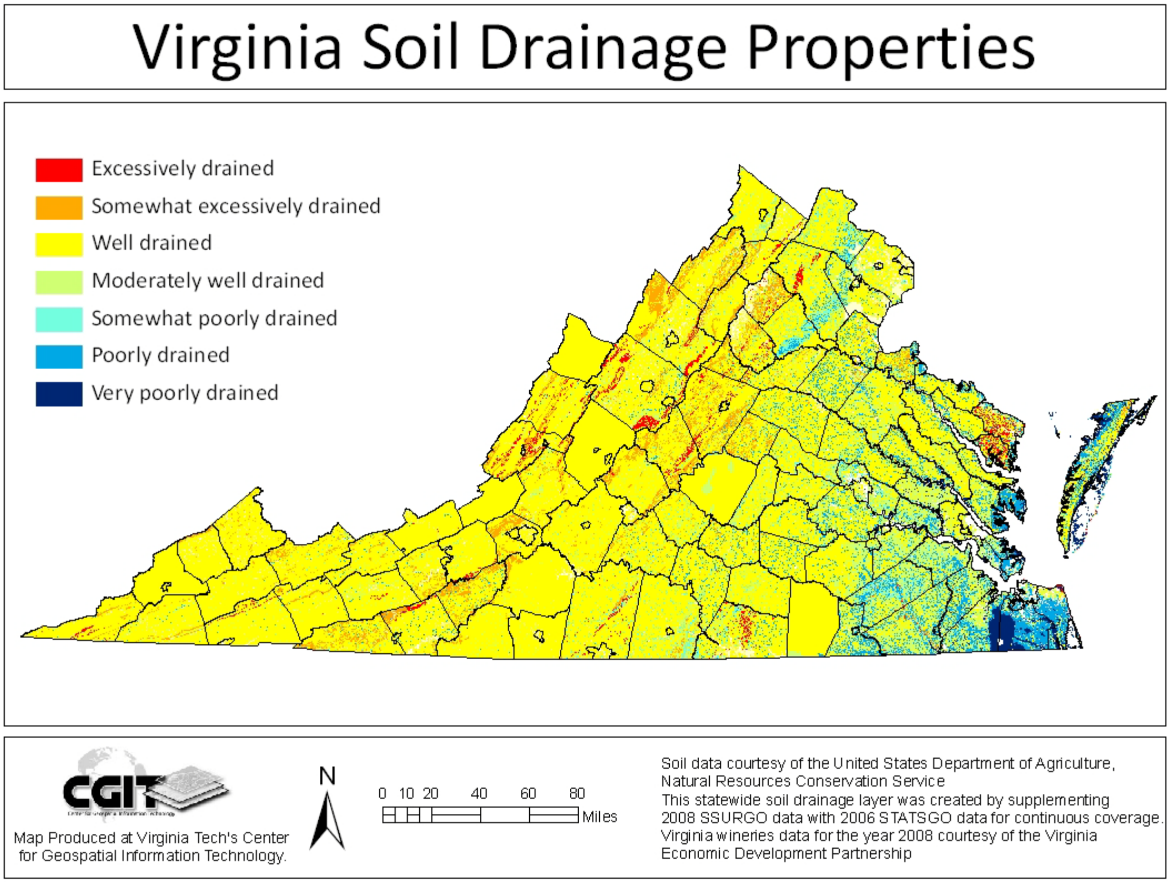

Figure A-2: SSURGO classifies most of Virginia as well-drained, with small regions of poor or excessive drainage generally corresponding to topographic features.

Appendix B: Climate Data Example

In a previous project for the Virginia Department of Emergency Management, CGIT developed climate maps using a regression fitting technique based on historical weather station data.

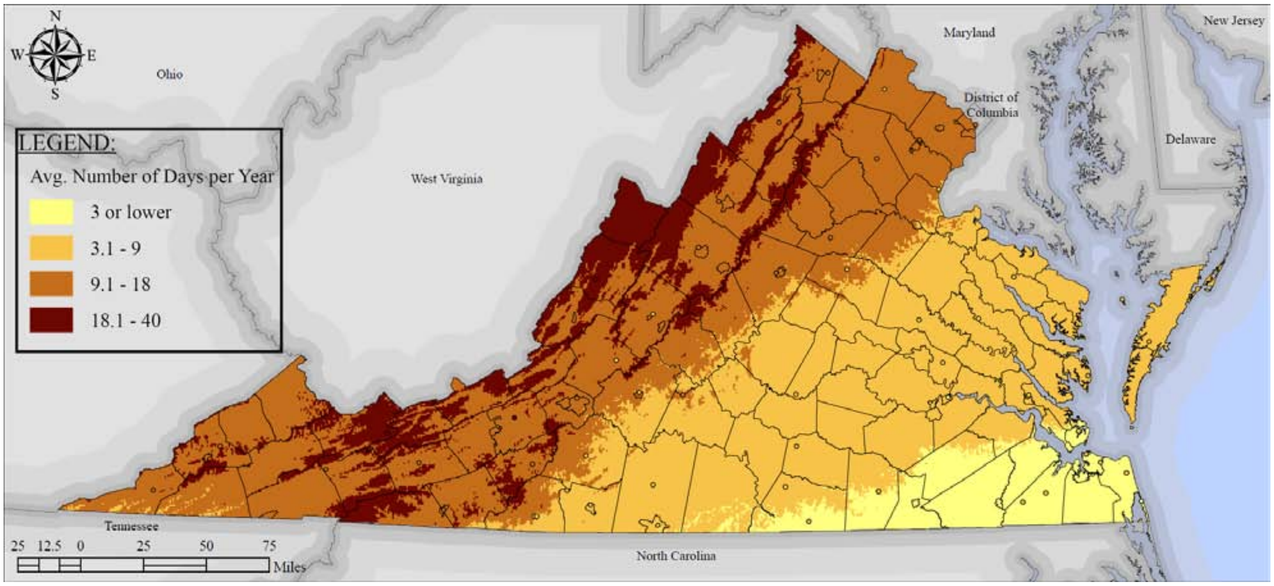

Figure B-1: Average annual number of days entirely at or below 32° F, based on regression fit developed using historical weather station records in combination with terrain and latitude data.

Appendix C: Terrain Data

The 30m NED terrain data provides raw elevation values for the state. This data can also be used to calculate slope, aspect (orientation), and other properties.

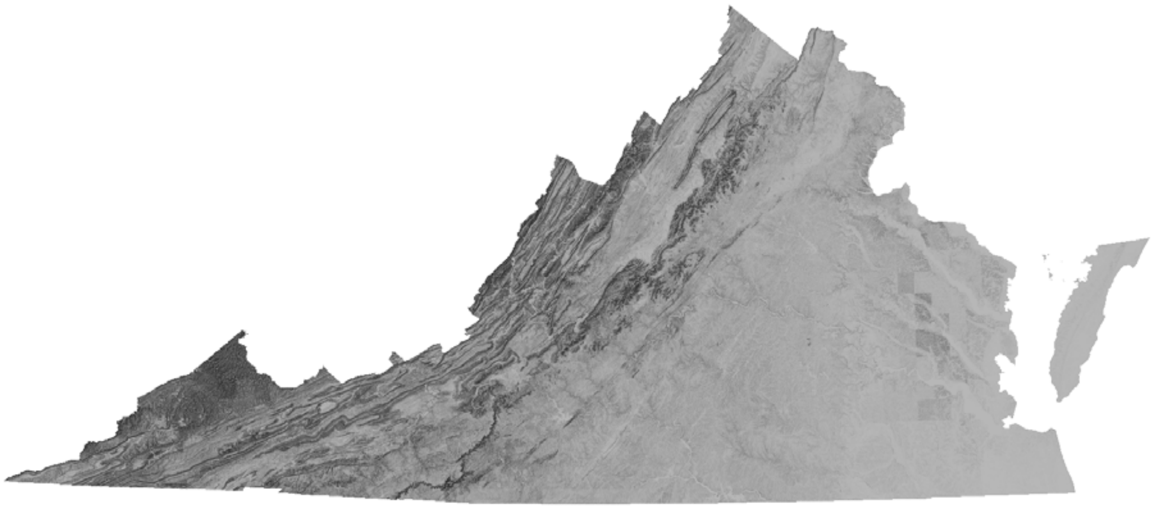

Figure C-1: Statewide shaded terrain visualization created from 30m NED data

Figure C-2: Enlarged section of shaded terrain visualization: Carvins Cove (north of Roanoke)