Applied Geomatics--connecting the dots between grapevine physiology, terroir, and remote sensing

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Geomatics-Oriented Projects

  – Assessing within site terroir by mapping soil texture and vine vigor, and their relationships to numerous other variables (five sites)

• Riesling terroir (1998-2003) [Reynolds et al. AJEV 2007]
  – Similar goals as Chardonnay

• Riesling terroir II (2005-). [Jim Willwerth, PhD 2010].
  – Assessing within site terroir by mapping soil and vine water status (10 sites)

• Cabernet Franc terroir (2005-). [Javad Hakimi, PhD 2009].
  – Similar goals as Riesling II (10 sites)
Projects contd.

• Thirty Bench Riesling (2006-). [Matthieu Marciniak MSc 2010].
  – Mapping six *sous-terroirs* in terms of water status; using low-elevation multispectral imaging to collect NDVI data (25 acres).

• Coyotes Run/ Lowrey (2008-). [David Ledderhof MSc 2010].
  – Similar to Thirty Bench, using four Pinot noir blocks (each about 2 acres)

• Stratus Vineyard (2008-). [Vickie Tasker MA 2010].
  – Using a combination of multispectral imaging, plus a network of soil Profile Probes and wireless temperature sensors
Ways of Extending Geomatics Research to Industry

• Introducing mapping tools for discriminating regions within vineyards with different yields, fruit composition, water status, disease or insect pressure

• Verifying sub-appellations

• Combining this with remote sensing to identify sub-blocks of superior quality

• Using identification of zonal differences to more precisely manage vineyards
Discriminating regions within vineyards with different yields, fruit composition, and water status. Understanding the basis for terroir.
Basic Procedures
Using GPS to delineate blocks and to geo-locate vines
Data Collection

• Leaf water potential
• Soil moisture
• Yield and yield components
• Basic fruit composition
• Specialized fruit composition—terpenes; phenolic analytes
• Weight of cane prunings
• And more......
Data Collection

- Soil texture (sand, silt, clay)
- Soil composition (P, K, Ca, Mg, B)
- Soil physical properties (pH, CEC, base saturation, organic matter)
- Tissue elemental composition
Manipulation of the data

- Using things such as leaf water potential, vine size, soil texture as “treatments” (actually categories) and performing standard ANOVA
- Correlations on all variables
- Spatial correlations on spatial variability between variables
- Temporal stability
Remote Sensing

- Aerial flyovers collect multispectral reflectance data
- Data are also collected on the ground to compare and verify
- Aerial data need to be manipulated using ENVI software to separate out canopy vs. soil/cover crop reflectance
Riesling II Project (2005-)
Jim Willwerth, PhD candidate 2010
Willwerth & Reynolds Progres Agricole et Viticole 2010 accepted

Project Objectives

• Use GPS & GIS to create spatial maps of variability within 10 Riesling vineyard blocks from each of the 10 VQA sub-appellations

• Identify zones within vineyard blocks based mainly on vine water status and assess these for fruit composition and wine sensory attributes

• Look for relationships between vine water status and other variables

• Attempt to validate the VQA sub-appellations based on sensory and chemical data
“High” water status zones

Spatial distribution of leaf water potential (-bars), Myers Vineyard, Vineland, ON; A: 2005; B: 2006; C: 2007. Consistent zones; temporally stable.

“Low” water status zones
Spatial distribution of berry weight (g), Myers Vineyard, Vineland, ON; A: 2005; B: 2006; C:2007. Higher LWP = higher berry weight.
Spatial distribution of berry Brix, Myers Vineyard, Vineland ON; A: 2005; B: 2006; C: 2007. Low LWP = highest Brix.
Spatial distribution of berry titratable acidity (g/L), Myers Vineyard, Vineland, ON; A: 2005; B: 2006; C: 2007. Low LWP = lowest TA.
Spatial distribution of leaf water potential (-bars), Chateau des Charmes (Paul Bosc Estate), Niagara-on-the-Lake, ON; A: 2005; B: 2006; C: 2007. Once again, temporally stable spatial patterns.
Spatial distribution of berry potentially volatile terpenes (mg/L), Chateau des Charmes (Paul Bosc Estate), Niagara-on-the-Lake, ON; A: 2005; B: 2006; C: 2007. Low LWP = highest PVT.
Sensory Map of Significant Sensory Attributes, Twenty Mile Bench; 2005
Factors contributing to sensory profile

Soil and vine water status responsible for 75% of the variability in the data set.
Verifying sub-appellations
Cabernet Franc Project
Javad Hakimi, PhD 2009
Hakimi and Reynolds AJEV 2010 in press

Project Objectives
• Use GPS & GIS to create spatial maps of variability within 10 Cabernet Franc vineyard blocks from each of the 10 VQA sub-appellations
• Identify zones within vineyard blocks based mainly on vine water status and assess these for fruit composition and wine sensory attributes
• Look for relationships between vine water status and other variables
• Attempt to validate the VQA sub-appellations based on sensory and chemical data
PCA of Sensory Data, Cabernet Franc 2005
Green bean associated with high water potential Lakeshore or riverfront sites

Variables (axes F1 and F2: 63.94 %)

Observations (axes F1 and F2: 63.94 %)

High water status

Low water status
Partial Least Squares (PLS)

Correlations with t on axes t1 and t2 (84.3%)
Using remote sensing to identify sub-blocks of superior quality
Thirty Bench Project
Matthieu Marciniak, MSc candidate 2010
Reynolds et al. Progres Agricole et Viticole 2010 accepted

Project Objectives

• Correlate remotely sensed spectral data to vineyard characteristics and fruit & wine composition of Riesling

• Use GPS & GIS to create spatial maps of variability within vineyard blocks

• Identify zones for premium wine production and/or precision management zones within vineyard blocks based mainly on vine water status
Thirty Bench- View of the Study Site

Courtesy Ralph Brown
Sentinel Vines
Spatial variation in soil moisture over four vintages

Temporal stability is apparent (orange areas = lowest soil moisture 2007-0; blue = lowest 2009)
Spatial variation in leaf $\psi$ over four vintages

Again temporal stability is apparent, as are spatial correlations between soil moisture and leaf $\psi$; yellow and orange areas are highest absolute values of leaf $\psi$ (i.e. most negative or lowest)
Yield

Once again, clear temporal stability is present (yellow/orange areas are highest yields)
Weight of cane prunings 2009
Some inverse spatial correlations with water potential and soil moisture
Brix and TA 2006

Brix. Has been temporally consistent over three vintages. Note the higher Brix (orange) in the low water status zones

Titratable acidity. Also has been temporally consistent over three vintages. Note the lower TA (blue) in the low water status zones
Potentially-volatile terpenes 2006

Highest in the low-vigor zones
Potentially-volatile terpenes 2009
Once again highest in the low-vigor zones, particularly Steel Post & Triangle
Spatial Correlations between variables within the same vintage

Low leaf water potential associated with higher Brix values

Note: Orange areas represent highest Brix and highest absolute values of water potential (i.e. most negative or lowest)
Yield and NDVI green 2006

A clear and temporally stable relationship between the two variables

Yield. “Y” zones (high vigor) = high-yielding too
Leaf water potential and NDVI 2006

Spatial patterns and relationships that are temporally stable

Mean leaf water potential (absolute value)

NDVI green
NDVI green 2008
Temporally stable compared to previous years
NDVI 2009

Once again, temporal stability was apparent relative to prior years
The Triangle Block has consistently won the most awards at Ontario wine competitions. Might we then use remote sensing to pick out blocks like Triangle in other cultivars?
Using remote sensing to identify sub-blocks of superior quality in red wine cultivars
Coyotes Run/ Lowrey Project
(Images and text courtesy David Ledderhof MSc candidate 2010)

Project Objectives

• Correlate remotely sensed spectral data to vineyard characteristics and fruit & wine composition of Pinot noir

• Use GPS & GIS to create spatial maps of variability within vineyard blocks

• Identify zones for premium wine production and/or precision management zones within vineyard blocks
Study Sites and Vineyard Data Collection

Study sites
- Coyote's Run: Red Paw & Black Paw Vineyards (three blocks)
- Lowrey's Farm (one block)
- Variety of soil types, age of vines, clones

Data collection
- Geolocating Sentinel Vines
- Soil Sample Collection & Analysis
- Aerial Image Capture (x4 in 2008 and 2009)
- TDR - Soil Moisture
- Pressure Bomb – Vine Water Status
- Ground-based Leaf Reflectance
Relative Location of Blocks: St. David's, Ontario

Image Source: Niagara Navigator {http://navigator.yourniagara.ca/navigator/#}
Coyote's Run Pinot noir

Images: July 29, 2008
Sample Results: Red Paw 2

Note: Different scale for each map
Red Paw 2 NDVI

The challenge - extracting NDVI data from cover-cropped vineyards without assessing the cover crop

Red Paw 2 NDVI

Red Paw 2 masked NDVI

Red Paw 2 NDVI map
Using identification of zonal differences to more precisely manage vineyards
Stratus Vineyards Project
(Vickie Tasker, MA 2010 pending)

Project Objectives

• Correlate remotely sensed spectral data to vineyard characteristics and fruit & wine composition of several *Vitis vinifera* cultivars (Chardonnay, Cabernet Franc, Semillon)

• Use GPS & GIS to create spatial maps of variability within vineyard blocks

• Set up a network of wireless temperature sensors and corresponding Profile Probe sites on a grid throughout the vineyard

• Attempt to see if localized soil moisture and/or canopy temperatures have major impacts upon fruit composition
Stratus Vineyards Project

Other Project Objectives

• Evaluate airborne digital imagery for the purpose of determining canopy variability and spatial patterns of interest in the vineyard.

• Develop a thermal environment map of the Stratus vineyard based upon in-situ temperature sensors at the canopy and soil level and aerial thermal infrared imagery.

• Develop a GIS database for Stratus that incorporates all currently available soils, drainage, and vine (clone, age and rootstock), in a format that is consistent with overlaying digital airborne remote sensing maps.
Stratus- General Soils and Varieties

Images courtesy Ralph Brown
Spatial variability of field and grape quality parameters and associated spatial pattern for sub-block CF1 at Stratus Wines in 2008.

Overview map not to scale.
Spatial variability of field and grape quality parameters and associated spatial pattern for sub-block CF2 at Stratus Wines in 2008.
Conclusions

- Geomatics has allowed us to conclude that the so-called terroir effect is based highly on vine water status.
- This technology has permitted verification of sub-appellations in the Niagara region.
- Coupling this with remote sensing might provide a method to identify premium sub-blocks based on e.g. water status using NDVI measurement.
- In every instance, any vineyard variable can be mapped and this spatial variability can be checked for temporal stability—permitting implementation of precision viticulture.