Airborne Remote Sensing for Precision Viticulture in Niagara

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Why the interest in precision viticulture?

• Highly variable regions in Niagara due to unique geological history and location—topography, soil type, micro-climate (*terroir*)
• Different areas in same block may differ in vigour, nutrient availability, water status, fruit quality, etc.
• Can apply spatially-variable management to try to even out production (e.g., fertilizing, irrigation, thinning) or...
• Adapt to variability by managing zones differently and segregating fruit at harvest for unique character ‘reserve’ wines
Napa, Australia and New Zealand – the beginning of remote sensing for viticulture

- Started with the development of a tool to monitor phylloxera spread ~ 20 years ago
- Napa work started with NASA (Lee Johnson) - Developed tool to monitor phylloxera spread and found that RS data had other uses:
  - Crop scouting
  - Vineyard management
  - Harvest planning to maximize reserve wine production
- Commercial RS services began 1999
Spectral differences in grape canopy

- Typical green vegetation reflectance
  - chlorophyll absorbs at 420, 490 nm, green peak ~ 540-560 nm
  - second chlorophyll trough at 660-680 nm
  - red edge to NIR plateau 700-740 nm
  - water overtone troughs at 1450 and 1940 nm

- Stressed leaves reflect more strongly than healthy leaves in green-yellow-orange (540-640 nm) and in the red (660-700 nm), lower in NIR

- Reflectance in spectral bands combined as indices to emphasize soil or vegetation, e.g. NIR+red or NIR+green for Normalized Difference Vegetation Index (NDVI)
Leaf Reflectance – spectral differences between phylloxera-infested and healthy vines (CSU 2002)

differences
NDVI Green Ratio \( \frac{R_{740} - R_{550}}{R_{740} + R_{550}} \) used to separate healthy from infested vines.
RS images contain other information too!

- Spatial patterns reveal underlying variability in soil type, moisture, fertility, disease, etc.
- Time series of images show temporal effects – e.g., weather effects (drought), disease spread, insect infestation
- Spatial information in a geo-referenced image (i.e., image elements tagged with geographic position) useful for determining areas, GPS location in vineyard, etc.
RS images from 4-band CMOS cameras in small aircraft at 3500 ft AGL
Multi-band images co-registered – e.g., RGB colour

Red band

Green band

Blue band
NIR, red and green gives colour-infrared composite (CIR)
CIR highlights vegetative canopy (red)
Many vineyard blocks show canopy variation, reveal underlying variability of site.

June 29, 2007

August 28, 2007
Band reflectance in multi-spectral image used to classify and interpret image

Red is grape canopy (and trees in bush)

Black is soil

Green is other vegetation (floor)
NDVI highlights canopy vigour – yellow (low) to bright green (high) for one date - August 28, 2007
Change in NDVI shows canopy development from July 20 to August 14, 2007.
green = +ve change, blue = -ve change
30-Bench Winemakers Project

• Large Riesling block
• Divide into zones based on vigour
• Harvest fruit and vinify separately
• Determine variability of fruit, wine
• Stability of zones across years
30-Bench vineyard management zones from 2005 RS images - canopy vigour from NDVI (red)
Geo-referenced image also contains spatial information e.g., Area of zones? GPS for vines?

Length of 1st row = 233.9 m

+ = GPS coordinates of sentinel vines
Sentinel vines are used to make ground measurements, chart stability of zones

- Vines are flagged and geo-referenced (GPS)
- Same vines are revisited year after year
- Collect canopy, soil, fruit characteristic data
- Fruit from sentinel vines grouped by water stress for small wine batches
- Fruit from each management zone harvested separately
- Winery keeps zone batches separate through process
Ground data collected from sentinel vines

- Soil moisture from portable TDR
- Vine water status from pressure bomb
- Leaf reflectance spectrum
- Harvest data – yield, berry weight, Brix, pH, etc.
- Sensory and chemical wine data
Measuring leaf reflectance in management zones
2006 – cool and wet! Average soil moisture
Yield per vine (kg) in 2006 season

The map illustrates the yield per vine in kg for the 2006 season, with the color scale indicating different yield ranges. The map is overlaid with a satellite image for reference.
Total monoterpenes in fruit (2006 season)
Soil Moisture

Brix

Yield per vine

Total monoterpenes
2007 – hot and dry! Average soil moisture
Yield per vine (kg) in 2007 season
2007 hot and dry – pattern of variability

Soil Moisture

Yield per vine
Are the zones stable?

- Well, yes they seem to be – in this vineyard diagonal zones appear in all 3 years
- Zones are evident in aerial images
- Due to soil type and topography variation
- Effects of zones change from wet year to dry year – are these predictable in advance?
- How can we manage this?
- What next?
Re-draw Zones – based on 2 year dataset
Thermal (long-wave) infrared imaging

- Lakeshore Rd NOTL
- Evenly spaced flights dawn to dusk
- Changes in surface temperature due to canopy, soil, moisture
- Heating and cooling
Thermal image shows surface temperature differences – canopy is cool (blue) soil surface is warmer (orange)
Thermal sequence heating pattern shows problem areas (warmer), active canopy (cooler) – useful for irrigation scheduling?
Remote Sensing and Weather Data Integrated On-line System for Vineyard Management

Partnership formed to develop and commercialize remote sensing services for viticulture in Ontario.

System is needed to acquire, process and deliver imagery to users in a useful form.

Geo-spatial information is extracted, combined with weather data as input to models for prediction of vine stress.

Integrated as an on-line system, outputs are useful for decision making – spraying, irrigation, harvesting.
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