Automated Estimation of Vineyard Water Status using LANDSAT and Water Balance Modeling.

Lars Pierce, California State University Monterey Bay
Andy Michaelis, NASA Ames Research Center
Daniel Bosch, Constellation Brands

**Motivation:** Grower irrigation goals in wine grapes

Achieving vine water stress targets by specific data:

- Wet yrs - Avoid too much water and vigorous canopy growth.
- Dry yrs - Provide enough water to support canopy growth and flowering.
- Estimating vine water stress in blocks without measurements.

**The Challenge:** Staying on course during wet vs. dry years

- Weather: rainfall, ET, GDD, AgriMet
- Topography: slope, aspect
- Satellite: Landsat NDVI, NASA
- Soils: USDA, NRCS

**VSIM algorithms relating vine growth to water stress**

- Estimating Kc from Leaf Area
  - William & Ayars, 2005
  - Agric For Meteor 132:201-211.

- Estimating LWP from Soil Moisture
  - Saxton, et al., 1986

- Estimating Stomatal Cond. from LWP
  - Williams & Araujo, 2002

**Inputs:** Driving Canopy Dynamics from Landsat NDVIs

- 7/10/13: Cover Crop Cultivation, Vine Growth
- 8/17/13: Calibrations
- 29-Oct: Vines Brush

**Inputs:**

- NDVI
- LAI
- Canopy ET model
- Drainage, irrigation

**Outputs:**

- Canopy growth, ET
- Soil moisture, LWP
- Drainage, irrigation

The VSIM Water Balance Model

Coupled to a simple Water Balance Model!

(based on FAO-56 Crop ET model, R. Allen et al., 1998)

**Daily Water Balance**

\[ \text{ET}_c = K_c \cdot K_n \cdot \text{ET}_o \]

\[ \text{LAI} = f(\text{NDVI}) \]

\[ \text{LWP} = f(SM) \]

\[ \text{SM}_y = \text{SM}_y + I + R - \text{ET}_c - D \]

**Web-based Geospatial Datasets**

<table>
<thead>
<tr>
<th>Dataset</th>
<th>Source</th>
<th>Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weather</td>
<td>CIMIS, Agrimet</td>
<td>Rainfall, ET, GDD</td>
</tr>
<tr>
<td>Topography</td>
<td>USGS</td>
<td>Slope, aspect</td>
</tr>
<tr>
<td>Satellite</td>
<td>USGS, NASA</td>
<td>Vine growth</td>
</tr>
<tr>
<td>Soils</td>
<td>USDA, NRCS</td>
<td>Water-holding capacity</td>
</tr>
</tbody>
</table>

**VSIM algorithms relating vine growth to water stress**

- Estimating Kc from Leaf Area
  - William & Ayars, 2005
  - Agric For Meteor 132:201-211.

- Estimating LWP from Soil Moisture
  - Saxton, et al., 1986

- Estimating Stomatal Cond. from LWP
  - Williams & Araujo, 2002
**VSIM Model:**
- For single blocks, Excel Spreadsheet
- For several blocks across vineyard, Amazon Cloud

**Testing VSIM: Soil Moisture Measurements vs. VSIM-based Estimates**
- Monterey, Pinot Noir Block, 2011 (VSP trellis, 5x8 spacing, alluvial fan soils)

**VSIM model inputs:**
- Landsat NDVIs (14 dates)
- CIMIS ETo, Rain, Tair (Arroyo Seco)
- Measured Irrigation
- USDA Soils
- Measured vs Simulated Soil Moisture
  - 0
  - 50
  - 100
  - 150
  - 200
  - 250
  - 300
  - 350
  - 400

**Date**
- 1/12
- 2/11
- 3/13
- 4/12
- 5/12
- 6/11
- 7/11
- 8/10
- 9/9
- 10/9
- 11/8

**Soil Moisture, mm**
- SimSM
- MeasSM

**Testing VSIM: Leaf Water Potential Measurements vs. VSIM-based Estimates**
- Napa (Oakville) 2011 Cabernet Sauvignon
- Across blocks, Various spacings & trellis-types

**Input**
- Landsat NDVI
- Oakville CIMIS
- Grower Irrigation
- USDA Soils
- Simulated LWP vs Measured LWP
  - LWP Measurements Courtesy of CWUS

**Combining Geo-spatial Datasets within Models to Estimate Crop Water Status by Block**
- Farm Input Database
- Crop Water Balance Calculations
- Farm-wide Water Status Report

**VSIM Report: Seasonal weather summary and comparison**
- Current yr weather metrics vs previous 2 yrs.

**VSIM Report: Block-by-block Summary**
- Block Summaries
  - Lower NDVI, brown = low NDVII
  - Higher NDVII, blue = high NDVI
- Blocks highlighted in red water stress > -14 bars
- Blocks highlighted in yellow, water stress = -10 to -14 bars

**TOPS**
- Terrestrial Observation and Prediction System
Benefits to the Grower:

1) Access and summarize important vineyard water balance variables:
- ET\textsubscript{o}, Tar, rainfall, GOIs by year for vineyard
- NDVI, Cover Crop, & Vine Kc by block and year
- USDA Sand, Clay, Gravel estimates by block
- Mean Slope and Aspect by block

2) Utilize these input datasets to calculate:
- Metrics that summarize vineyard water status:
  - Soil Moisture
  - Leaf Water Potential
  - Drainage or Runoff

Issues:

Input Data
- Satellite imagery – Clouds
- Weather – Extrapolation from station to block
- SOils – County wide surveys vs. Block scale
- Irrigation Data – Quality, Timeliness
- Rooting Depth – Time-consuming to measure
- Model
  - Simple, single canopy and soil layer
  - Estimating LWP from Soil Moisture

But... Still useful? Relative vs. Absolute Values?

VSIM/TOPS combines several different datasets that influence
vine water needs in order to assist growers in...
- Irrigating to vine water needs
- Responding to annual weather variations
- Comparing, Evaluating irrigation schedules

Input Datasets required to generate the Vineyard Water Stress Report

Web-based Geospatial Datasets accessed via TOPS:
- Landsat Imagery - NDVI (cover crop, vine Kc)
- CIMIS Weather - ET\textsubscript{o}, Rainfall, Air Temp
- NWS (7-day) & CPC (30-day) weather forecasts
- USDA Soils – Sand, Clay, Gravel
- USGS Topography – Slope, Aspect
  (averaged by block given a block boundary shapefile)

Data Required from Grower:
- Block Data – block name, variety, spacing, rootstock,
emiters/vine, emitter volume
- Grower Irrigation Logs – Gal/Vine by block and date
Reworking the VSIM/TOPS Vineyard Water Balance Report...

Grower Provides:
- Nothing

Block Boundaries

Block Boundaries & Irrigation Logs

Regional Summary & Forecast
- Sonoma, Napa, Monterey, Fresno, etc.
- Weather, forecast summaries
- NDVI imagery
- Simulated Soil Moisture, LWP
- Light, Moderate, Heavy Soils

Some Block-specific Analyses
- NDVI summary by block
- Simulated irrigation needs by block?
- Estimated & Forecast Soil Moisture, LWP

Farms Summaries by Block
- Irrigation Schedule Evaluation (LWP, Drainage)
- Current and Forecast Soil Moisture, LWP
- Sustainable Vineyard Water Use Report?

- Comparisons of current year to long-term averages
- Going beyond next week - Inclusion of CPC Forecasts (9-14 day, 30 day)

Ongoing studies

CA Dept of Water Resources - 2013-2015
Build out and automate VSIM/TOPS software
Beta-test software and automation in 2014 in winegrapes
Expand to other crops (almond, walnut) in 2015

Thank you.
For questions or more info please contact lpierce@csumb.edu

UCD RAVE 20Feb14