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

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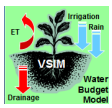

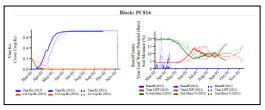

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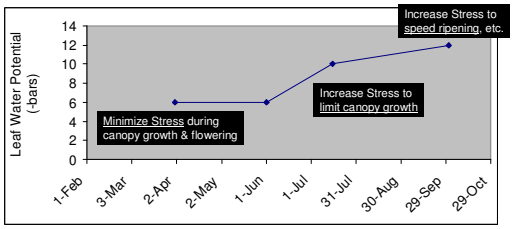
Motivation: Grower irrigation goals in wine grapes

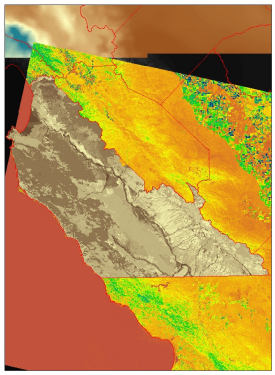
Achieving vine water stress targets by specific dates.



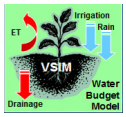
The Challenge - Staying on course during wet vs. dry years
- Wet Yrs - Avoid too much water and vigorous canopy growth.
- Dry Yrs - Provide enough water to support canopy growth and flowering.
- Estimating vine water status in blocks without measurements.

Motivation: Web-based Geospatial Datasets

Dataset	Source	Information
Weather	CIMIS, AgriMet	Rainfall, ET, GDD
Topography	USGS	Slope, Aspect
Satellite NDVI	USGS, NASA	Vine growth
Soils	USDA NRCS	Water-holding Capacity



The VSIM Water Balance Model

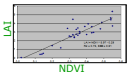


Daily Water Balance

Inputs:
NDVI (Landsat)
Tair, Rain, ETo (CIMIS)
Soils (USDA)
Irrigation (Grower)
7-day Forecast (NWS)
Slope, Aspect (DEMs)
Block Data (Grower)

Outputs:
Canopy Growth, ET, Soil Moisture, LWP, Drainage, Irrigation

LAI = f(NDVI)



K_c = f(LAI)

Crop Coefficient Canopy ET Model

$$ET_c = K_s * K_c * ET_o$$

LWP = f(SM_d)

$$SM_d = SM_y + I + R - ET_c - D$$

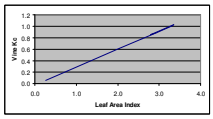
Coupled to a simple Water Balance Model

$D = SM_y - FC$

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

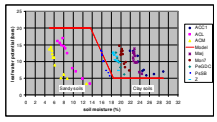
VSIM algorithms relating vine growth to water stress

Estimating Vine Kc from Leaf Area
Williams & Ayars, 2005.
Agric For Meteor 132:201–211.

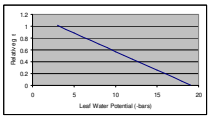


Estimating LWP from Soil Moisture
Saxton, et. al, 1986.
Soil Sci. Soc. Amer. J. 50(4):1031-1036.

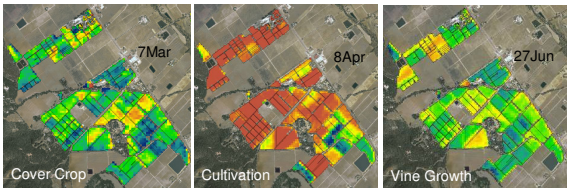
Williams, Baeza, & Vaughn, 2011.
Irrigation Science 16 March 2011.

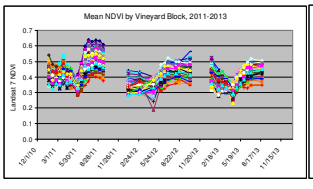


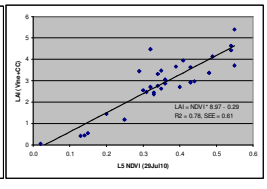
Estimating Stomatal Cond. from LWP
Williams & Araujo, 2002.
J. Amer. Soc. Hort. Sci. 127(3):448-454.



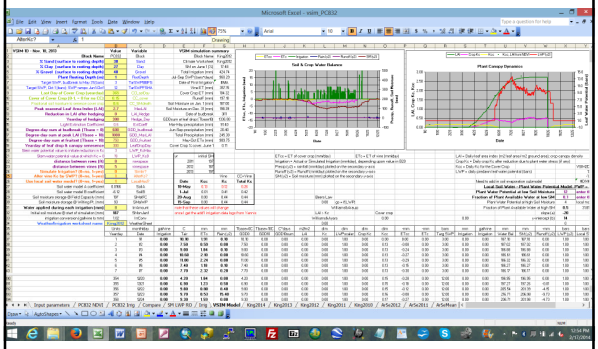
Inputs: Driving Canopy Dynamics from Landsat NDVIs







VSIM Model:
•For single blocks, Excel Spreadsheet
•For several blocks across vineyard, Amazon Cloud



Testing VSIM: Soil Moisture Measurements vs. VSIM-based Estimates

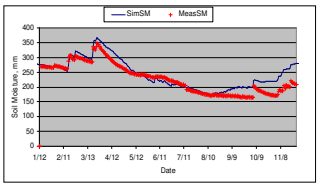
Monterey, Pinot Noir Block, 2011 (VSP trellis, 5x8 spacing, alluvial fan soils)

VSIM model inputs :
•Landsat NDVIs (14 dates)
•CIMIS ETo, Rain, Tair (Arroyo Seco)
•Measured Irrigation
•USDA Soils

Daily estimates of soil moisture generated using VSIM Jan-Nov 2011

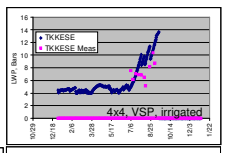
Measurements
•C-probes at 1', 2', 3', 4' depth
•8 locations within block
•Averaged across block

Comparison
Measured vs Estimated Soil Moisture



Testing VSIM:
Leaf Water Potential Measurements vs. VSIM-based Estimates

Napa (Oakville) 2011
Cabernet Sauvignon



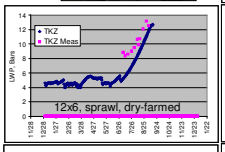
Across blocks, Various spacings & trellis-types

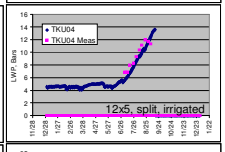
Inputs
Landsat NDVI
Oakville CIMIS
Grower Irrigation
USDA Soils

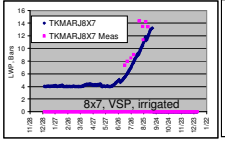
Measured LWP (red points)

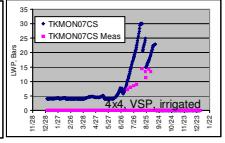
Simulated LWP (blue points)

LWP Measurements Courtesy of CWUS





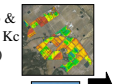




Combining Geo-spatial Datasets within Models to Estimate Crop Water Status by Block

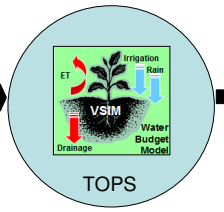
Sand, Clay (USDA) Slope, Aspect (DEMs)

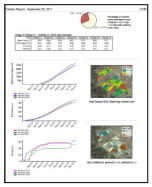
Cover Crop & Vine Vigor, Kc (Landsat)



Daily, Forecast Tair, Rain, ETo (CIMIS, NWS)

Grower Data (Irrigation, Block Mgmt)



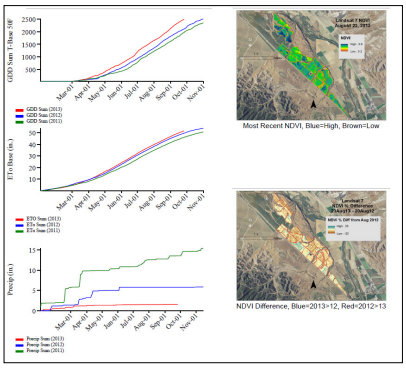


Farm Input Database → Crop Water Balance Calculations → Farm-wide Water Status Report

VSIM = Vineyard Soil Irrigation Model; TOPS = Terrestrial Observation and Prediction System

VSIM Report: Seasonal weather summary and comparison

Current yr weather metrics vs. previous 2 yrs.



The most recent Landsat satellite NDVI image (blue = high NDVI, brown = low NDVI)

Difference in NDVI image between current yr and last yr (brown = lower NDVI, blue = higher NDVI)

VSIM Report: Block-by-block Summary

Block Summaries

SM = Estimated Soil Moisture %
LWP = Estimated Leaf Water Potential (bars)
SW Def = Estimated Soil Water Deficit (inches)
Vine Kc, Kcc = Vine, Cover Crop crop coefficient
LWP Warning Colors: > 14 red, 10 - 14 yellow
Last Irrg = Date of Last Irrigation

	September 13, 2013 - September 19, 2013					September 20, 2013 - September 26, 2013 - forecast				
Pine Ck	Mean	Sum	Date	Mean	Mean	Mean	Mean	Mean	Mean	Mean
Block	SM %	gal/vine	Lst Irrig	LWP, bars	SW Def	SM %	SW Def	LWP, bars	Vine Kc	Kcc
PC830	5.96	0.00	08-23	15.41	1.30	5.59	1.46	16.72	0.64	0.00
PC831A	7.28	7.20	08-23	11.93	0.75	6.52	1.08	13.79	0.71	0.00
PC831B	7.58	11.38	08-23	11.78	0.75	6.85	1.07	13.42	0.66	0.00
PC832	6.63	14.50	08-23	13.42	1.02	6.05	1.27	15.16	0.71	0.00
PC833	8.80	0.00	08-23	9.48	0.15	7.93	0.51	10.84	0.57	0.00
PC834	10.80	0.00	08-23	9.49	0.21	9.88	0.59	10.53	0.63	0.00
PC835	12.14	0.00	08-23	9.04	0.02	11.15	0.43	9.95	0.63	0.00
PC836	5.89	11.00	08-23	16.13	1.45	5.49	1.62	17.61	0.73	0.00
PC837	7.19	22.29	08-23	13.31	1.13	6.60	1.38	14.85	0.71	0.00
PC838	6.92	21.54	08-23	13.35	1.07	6.34	1.32	14.94	0.68	0.00

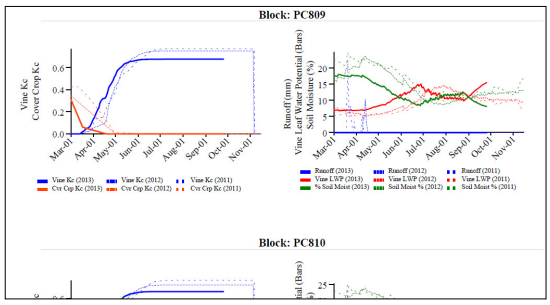
Blocks highlighted in red water stress > -14 bars
Blocks highlighted in yellow, water stress = -10 to -14 bars

VSIM Report: Canopy and Water Balance Dynamics By Block

Cover crop cover (orange)
Vine growth (Kc, blue)

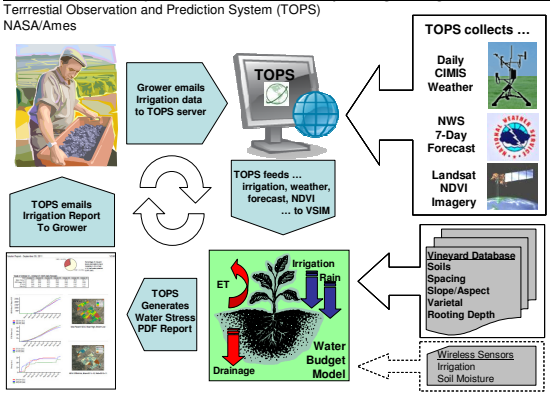
Soil Moisture (green)
Leaf Water Potential (red)
Drainage (blue)

Current year (solid), previous years (dashed)



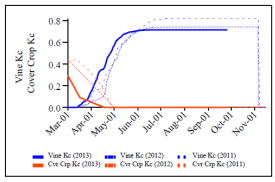
Automated Vineyard Water Stress Reporting using TOPS/VSIM

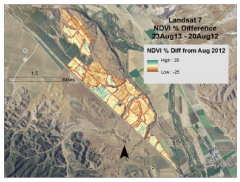
Terrrestial Observation and Prediction System (TOPS)
NASA/Ames



Benefits to the Grower:

1) Access and summarize important vineyard water balance variables:
- ETo, Tair, rainfall, GDDs 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



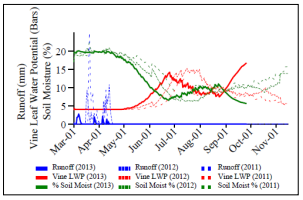


Benefits to the Grower (cont.):

2) Utilize these input datasets to calculate:

- Metrics that summarize vineyard water status:

Soil Moisture
Leaf Water Potential
Drainage or Runoff



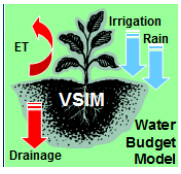
- Forecasts of vineyard water status by block for the current year

High Soil Moisture in Wet Years (delayed irrigation)
Low Soil Moisture in Dry Years (early irrigation)
Maintaining a vine water stress goal throughout season

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?

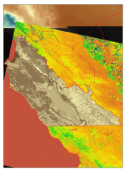
VSIM/TOPS combines several different datasets that influence vine water needs in order to assist growers in …

- 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 - ETo, 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, emitters/vine, emitter volume
- Grower Irrigation Logs – Gal/vine by block and date

Reworking the VSIM/TOPS Vineyard Water Balance Report….

Grower Provides….

Nothing → Regional Summary & Forecast
- Sonoma, Napa, Monterey, Fresno, etc.
- Weather, forecast summaries
- NDVI imagery
- Simulated Soil Moisture, LWP
- Light, Moderate, Heavy Soils

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

Block Boundaries & Irrigation Logs → 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 (8-14 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