Visual and Thermal Imaging
An Imaging Component of the Precision Ag Toolkit

Jim Etro
jim@crop-vu.com
703-489-8507
Precision Agriculture is spatial and temporal

Precision Agriculture enables a detailed view and understanding of the crop as it is growing so that it can be managed affordably.

Tools of the Trade

High Fidelity Sensing and Analyses
Precise Positioning - GIS
Precise Machines

An Agronomist in the Field

Precision Leads to Increased Margins

http://www.crop-vu.com
High Fidelity Sensing

In Soil

In Plant & Near Plant

Aircraft & Satellite

at the temporal and spatial scale of the plant

http://www.crop-vu.com
Applying Imaging at the temporal and spatial scale of the plant

Provides the information needed for making agricultural decisions.

– Disease and Pest and Irrigation Scouting/Assessment

– Help Guide Management of Water & Amendments & Herbicides & Pesticides

– Canopy Management

– Life Cycle Mapping
  Follow Growth
  Mapping for Variable/Precision Harvest Operations

– Direct Resources (Labor/Water/Amendments/Herbicides/Pesticides)

To be at the temporal and spatial scale of the plant the imagery must be:

  High Resolution
  On-Demand

Affordability!!!

http://www.crop-vu.com
Remote Sensing & Analysis by Visual Imaging using NDVI
Hawk-Eye™ Remote Sensing System

Thermal and Visual Views of the Field
Oblique Steerable Views On-Demand
Remote Sensing & Analysis by Imaging

Visual – sensing reflected energy

Near-Infrared – sensing reflected energy

Far-Infrared – sensing emitted energy
The Imaging Spectrum

Daytime Visual

Nighttime Visual

Nighttime Thermal
Thermal Regulation in Isohydric Plants

- Scatter Visible and n-IR energy that isn’t used
- Transpiration
- Shade/Shape of the Canopy

Incoming Solar Radiation

Plant Using Incoming Solar Radiation

Plant Reflecting Incoming Solar Radiation

Plant Emitting Heat

http://www.crop-vu.com
Vineyard Thermal Observations

As the day progresses the canopy warms to a ‘comfortable’ range.

– Near sunrise, healthy grapevine canopy temperatures tend to be within a few degrees of the ambient air temperature.
– As the day progresses canopy temperatures warm so that during the middle of the day the healthy canopies reach a range of temperatures between 83°F and 91°F.
– Day-time temperature range is maintained even when the ambient air temperatures are as much as 10°F lower than the canopy temperature and when the ambient air temperatures are as much as 15°F higher than the canopy temperature.

As the canopy fills out canopy temperatures are inverse to the vigor (greenness).

– relatively cool temperatures inversely proportional to high vigor patterns.
– Relatively warmer temperatures are normally reflected in relatively lower vigor patterns.
– When high vigor – warmer temperatures is usually the signature of stress.
– the pattern over the extant of the field leads one to understand if it is water stress or a disease/insect stress.

As grapes approach ripeness this phase relationship may invert (become directly proportional)

– the canopy temperatures decrease and the vigor (leaf greenness) also decreases.
11 July 2008
Salinas Valley, WestSide

0930 Environment
airtemp - 64°
grndtemp - 73°
leafftemp - 64°
wind – calm
sky – 10/10
low stratus
vsby - 5mi

1230 Environment
airtemp - 74°
grndtemp - 96° sun / 79°shade
leafftemp – 83° - 90°sunside
wind – ~04/020
sky – 0/10
vsby - 9mi

Thermal (far-IR) Imaging
Daytime Warm-Up

Infrared (IR = 8-14μm)

Near Infrared (nIR = .780μm = 780nm)

http://www.crop-vu.com
Thermal (far-IR) Imaging

Temperature - Vigor Relationship

05 Jul 2007

In the IR band significant stress is evident.

06 Aug 2007

This area was hedged to facilitate a uniformity in the vigor. It was over cropped and is introducing stress.

05 Sept 2007

http://www.crop-vu.com
Quality
• 70°F to 80°F favor the accumulation of malic acid
• above 100°F accumulation of malic acid is degraded
• accumulation of anthocyanin is repressed when temperatures above 86°F

Disease
• The primary factor that controls the spread of Powdery Mildew is temperature.
• fungus can multiply rapidly when temperatures are in the mid-60s to mid-80s
• inactive while temperatures remain above 90°F and some spores and colonies are killed after relatively short exposures above 95°F

Pests
• As the canopy temperatures increase above 86°F Pacific Spider Mites tend to bloom and at 95°F the rate of development is at a maximum
Thermal (far-IR) Imaging
Heat/Water Stress

http://www.crop-vu.com
Stress Scouting

Salinas Valley

1130 PDT, 23 July 09

Air Temp - 71°

Sky – 0/8 cover

Vsby - unrestricted

http://www.crop-vu.com
Irrigation Scouting

Salinas Valley

1500 PDT, 23 July 09

Air Temp - 74°

Sky – 0/8 cover

Vsby - unrestricted

http://www.crop-vu.com
Assessing Surface Soil Moisture Using Thermal IR Imaging

Thermal Imaging for Soil Moisture/Drainage Pattern

- poorly drained field
- dry/drained field
- wetlands

Checking Drainage Planning Irrigation Strategies

http://www.crop-vu.com
Another Application for Thermal Imaging
Controlled Climate Building Audits

<table>
<thead>
<tr>
<th>Action</th>
<th>$$$ Impact Approximate</th>
<th>% Impact Approximate</th>
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<tbody>
<tr>
<td>.......... access doors ...........</td>
<td>$4,700/Yr</td>
<td>&gt; 1%</td>
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<tr>
<td>.......... Walls ...............</td>
<td>$24,000/Yr</td>
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<tr>
<td>....... on roof surface</td>
<td>$145,000/Yr</td>
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<tr>
<td>Increase ...... Insulation by factor of 3</td>
<td>$170,000/Yr</td>
<td>18%</td>
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