Sensor Technologies and Drones in Crop Production

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Sensor Technologies

- Acoustic
- Chemical
- Electrical
- Electromagnetic radiation
- Flow
- Force
- Ionizing radiation
- Magnetic
- Moisture
- Position, orientation, movement
- Pressure
- Proximity
- Thermal

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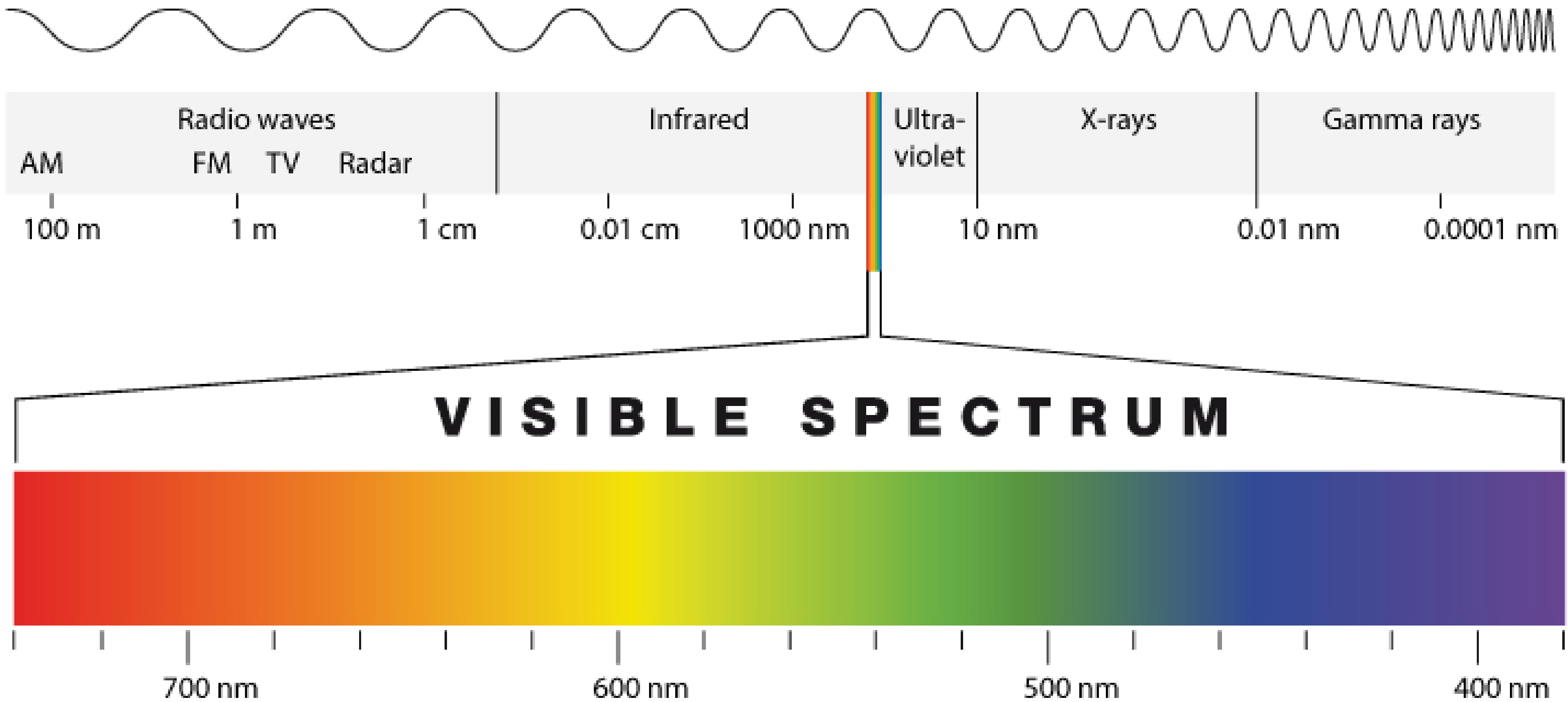
Electromagnetic Radiation



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Platform Trade-offs: Aerial vs Ground-based

- Aerial platforms can achieve a wide field of view
- Aerial platforms are free to navigate unconstrained by farm layout but potentially hindered by canopy
- Aerial platforms can travel faster
- Aerial platforms have limited flight time
- Fixed-wing platforms have more flight time than copters, but are less maneuverable

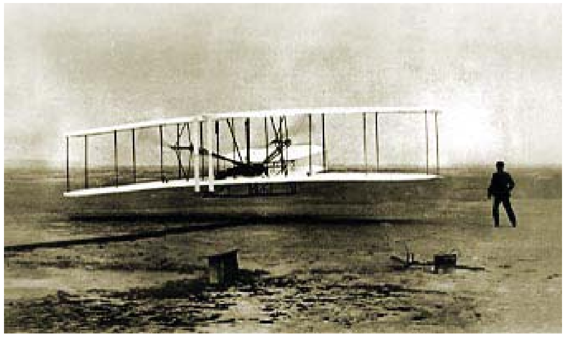
Historical Perspective

Imagery

- 1800: Discovery of Infrared
- 1830: Photography Invented
- 1858: Photography, photogrammetry from a balloon
- 1909: Photography from airplane

Platform

- 1800: Horses
- 1868: Steam tractors
- 1892: Gasoline tractors
- 1903: Fixed wing airplanes



http://www.brynmawr.edu/chemistry/Chem/mnerzsto/Marshall-Infrared.html | http://www.metmuseum.org/toah/hd/dagu/hd_dagu.htm | http://professionalaerialphotographers.com | http://www.lhf.org/en/teachers/learning_fields/history_of_tractors | http://www.farmcollector.com | http://www.sciencemuseum.org.uk | http://www.kittyhawknc.gov

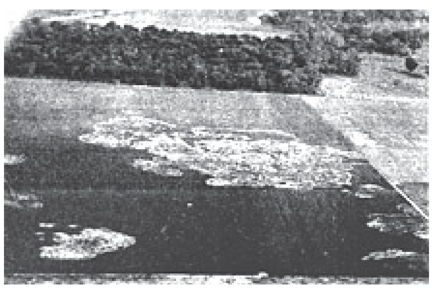
Historical Perspective

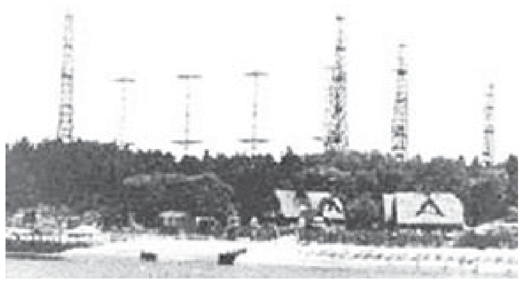
Imagery

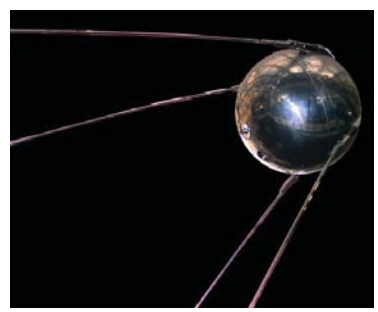
- 1927: Aerial imaging of crop disease
- 1930: US government soil studies
- 1935: Radar patented
- 1956: Colwell's paper on disease detection via infrared

Platform

- 1932: Rubber wheels
- 1939: Jet aircraft flies
- 1955: U-2 spy plane
- 1957: Sputnik 1
- 1961: Manned orbital flight







https://www.aps.org | http://www.apsnet.org | https://www.nasa.gov/ | http://www.esa.int

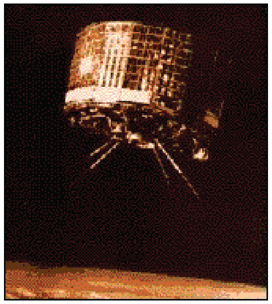
Historical Perspective

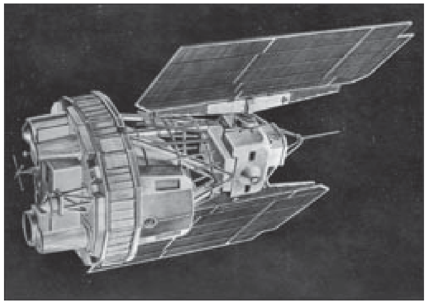
Imagery

- 1960: Skylab
- 1970: TIROS weather satellite
- 1972: Landsat 1
- 1980: Affordable digital image processing

Platform

- 1989: First commercial GPS receiver
- 1993: GPS fully operational
- 1994: GPS guided farming
- 2005: Personal drone aircraft





https://www.nasa.gov/ | http://retro-gps.info | https://www.virgin.com/ (Robert Blair) |

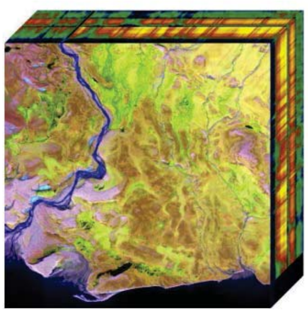
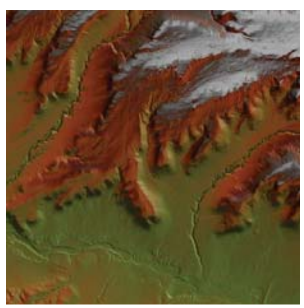
Historical Perspective

Imagery

- 1980: Hyperspectral sensors
- 1990: Airborne LiDAR
- 2000: Proliferation of hobby scale sensors
- 2013: Landsat 8

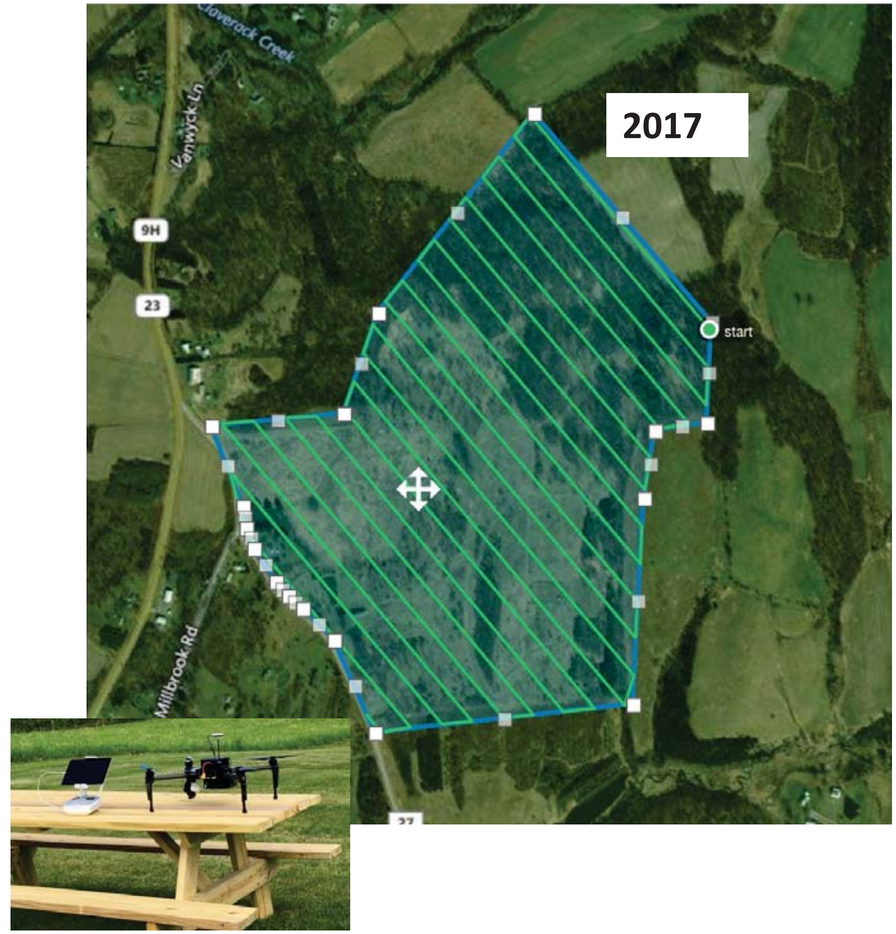
Platform

- 2010: Affordable personal quadcopters
- 2016: Specialized farming copters
- 2017: (Mostly) automated piloting

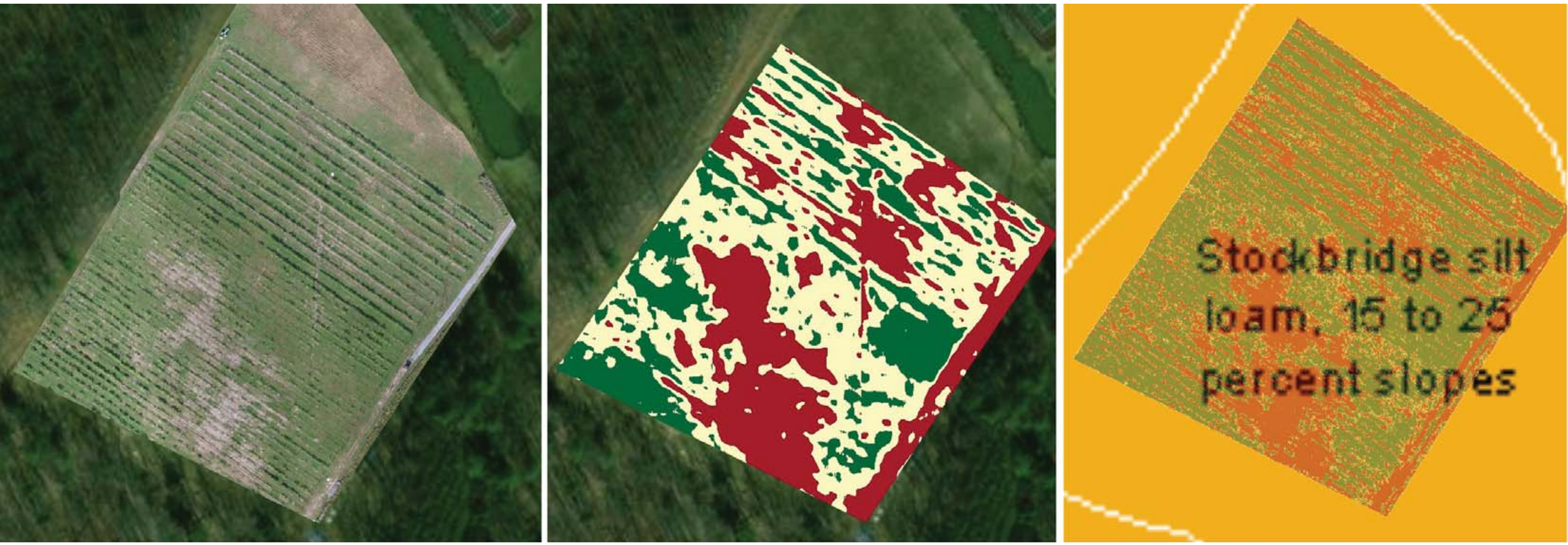

http://www.vespadrones.com | http://www.dji.com | http://landsat.gsfc.nasa.gov | http://www.robotshop.com

Technology Advancing Very Quickly

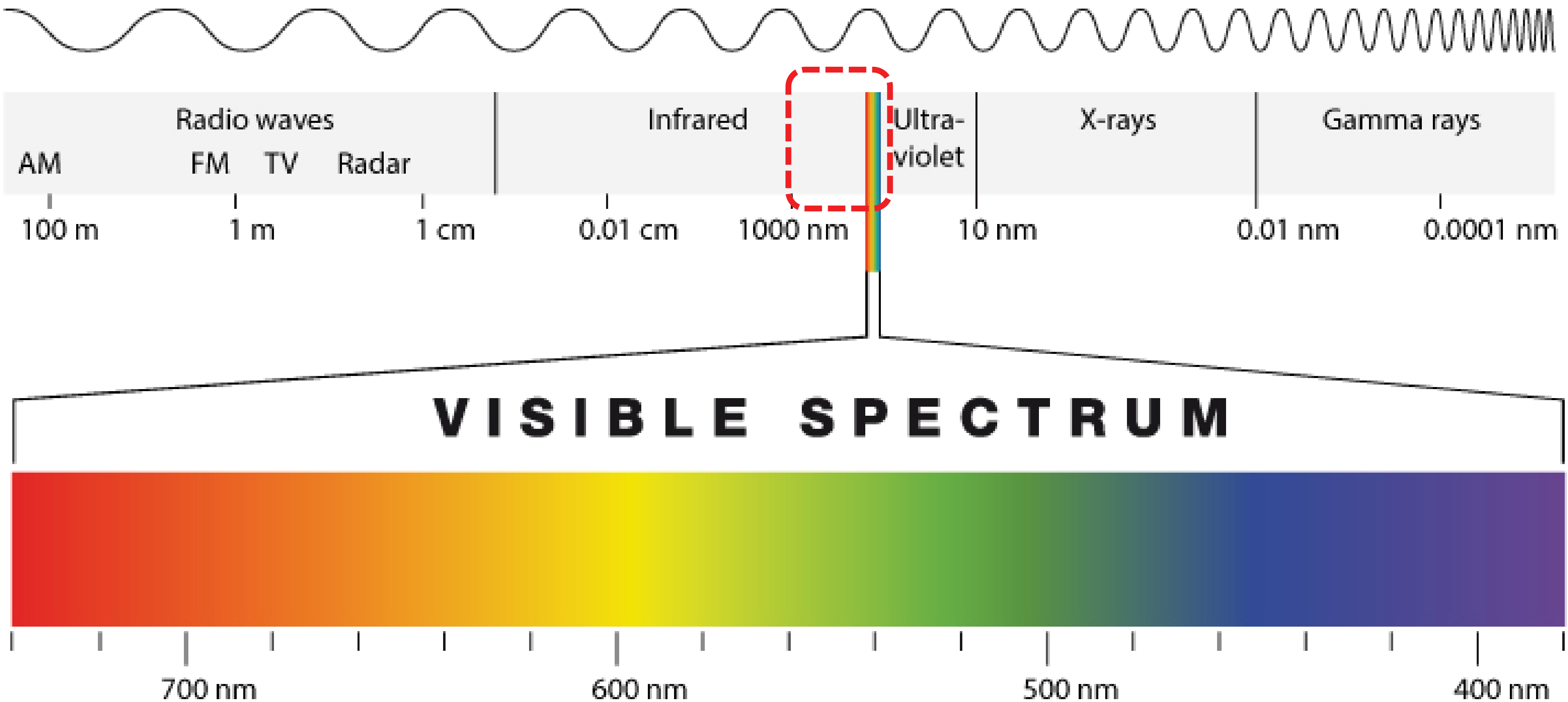


Visual Inspection with Aerial Drone

Visual/NDVI Inspection with Aerial Drone



Electromagnetic Radiation



http://www.chromacademy.com

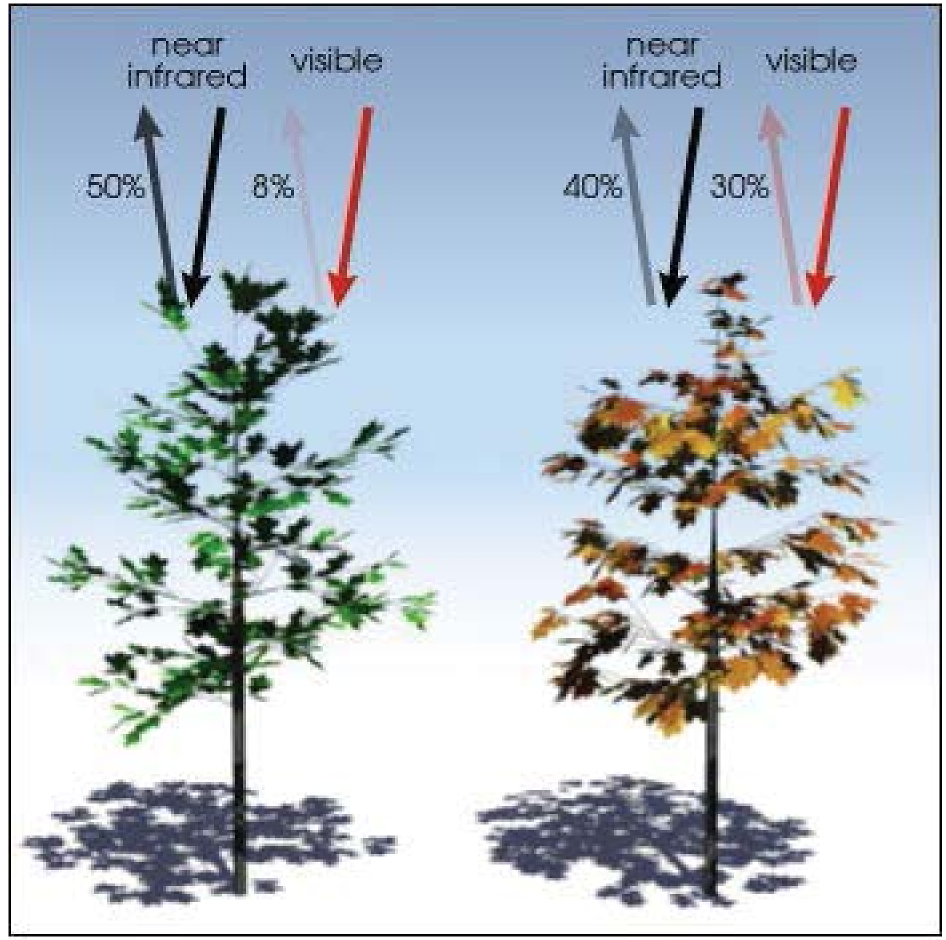
<u>N</u>ormalized <u>D</u>ifference <u>V</u>egetation <u>I</u>ndex

- NDVI = (NIR - VIS)/(NIR + VIS)
- Functional vegetation
  - Absorbs most VIS
  - Reflects much NIR

  (0.5–0.08)/(0.5+0.08) = **<u>0.72</u>**

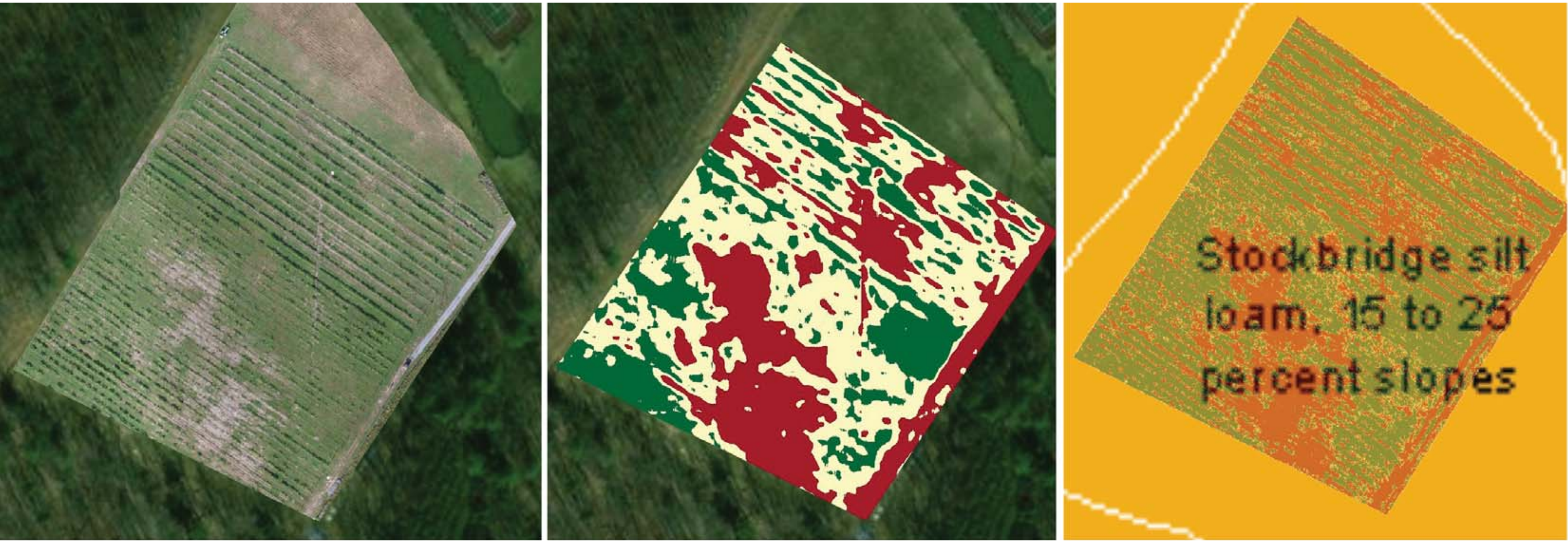
- Unhealthy vegetation (or non-vegetative surfaces)
  - Absorbs less VIS
  - Reflects less NIR

  (0.4–0.3)/(0.4+0.3) = **<u>0.14</u>**



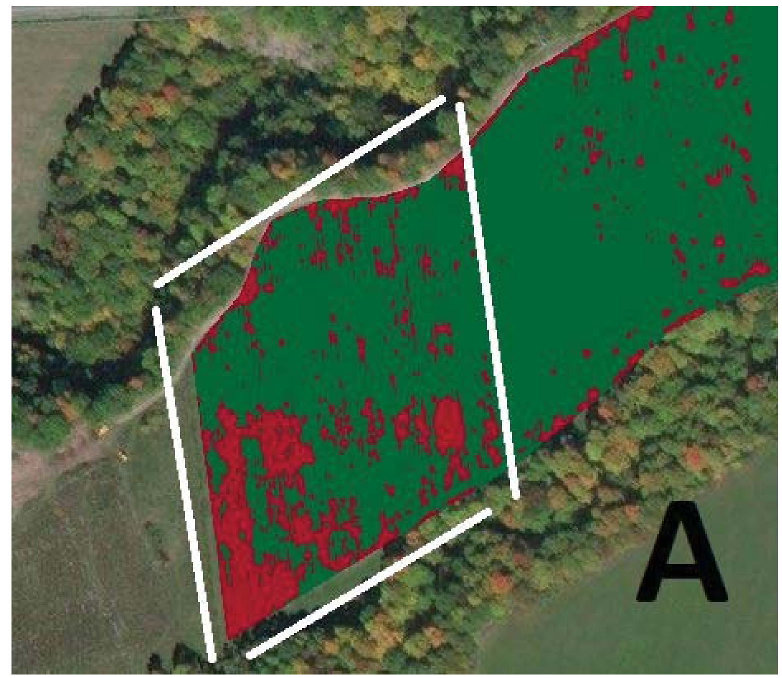
http://earthobservatory.nasa.gov/Features/MeasuringVegetation

Visual/NDVI Inspection with Aerial Drone

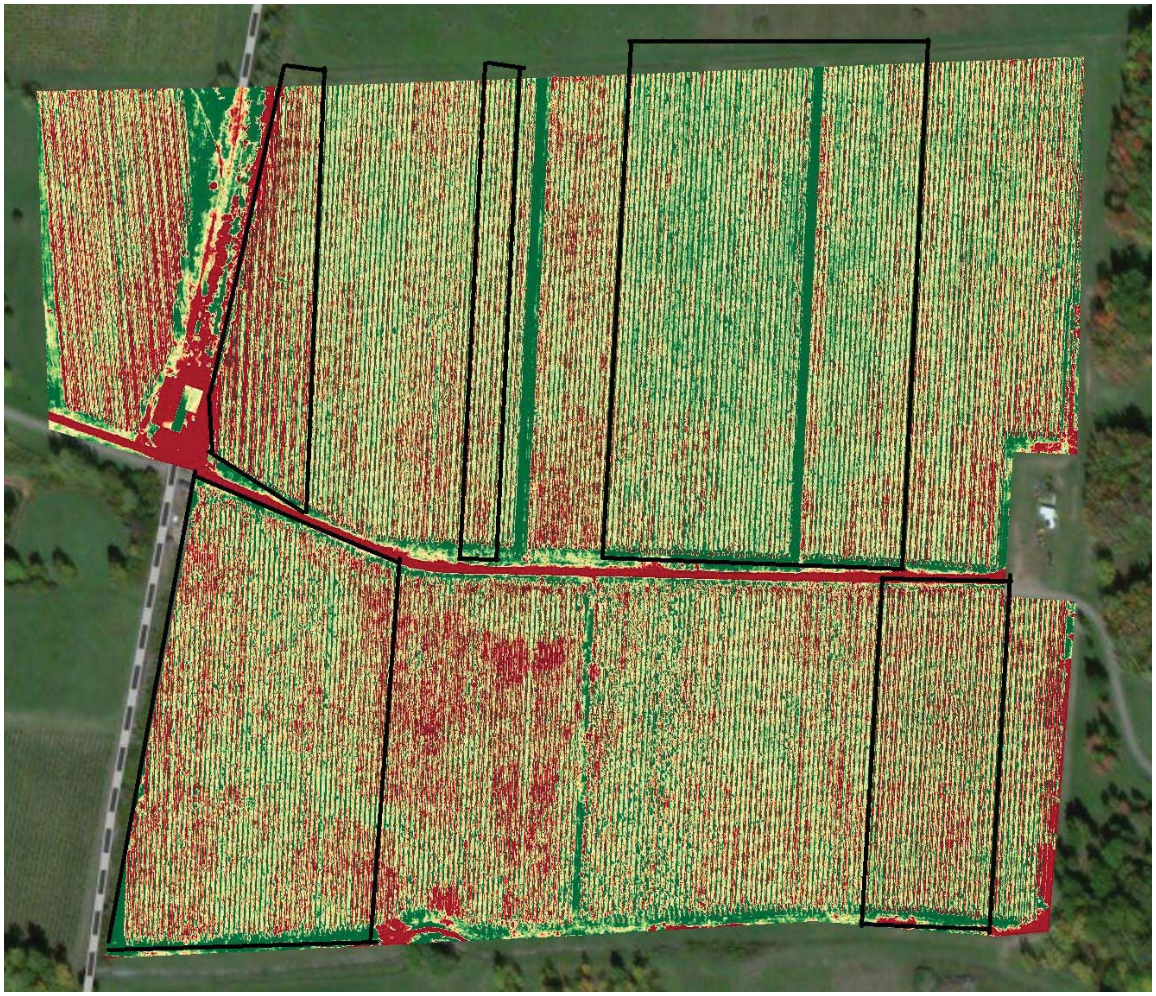


Imagery Guided Remediation Plan: Reduce Variability

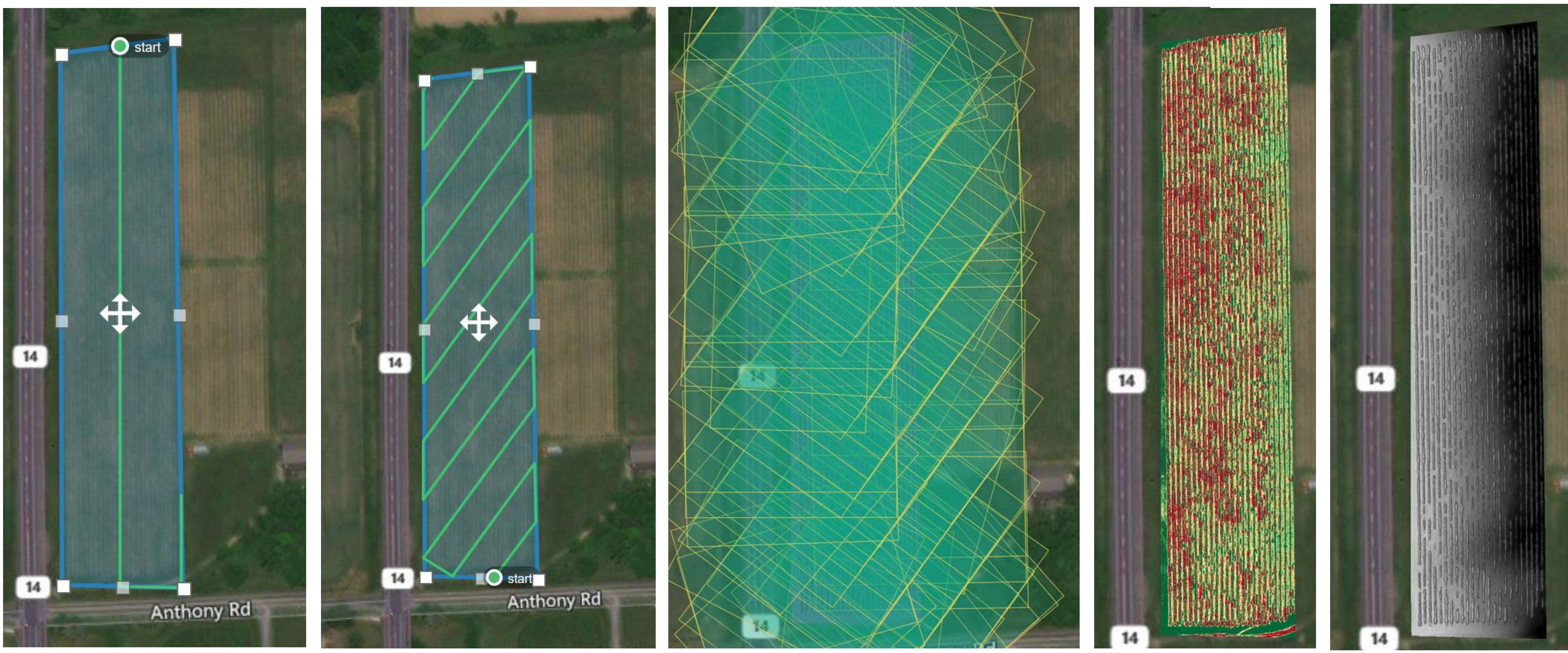
Drone NDVI Guided Differential Harvesting



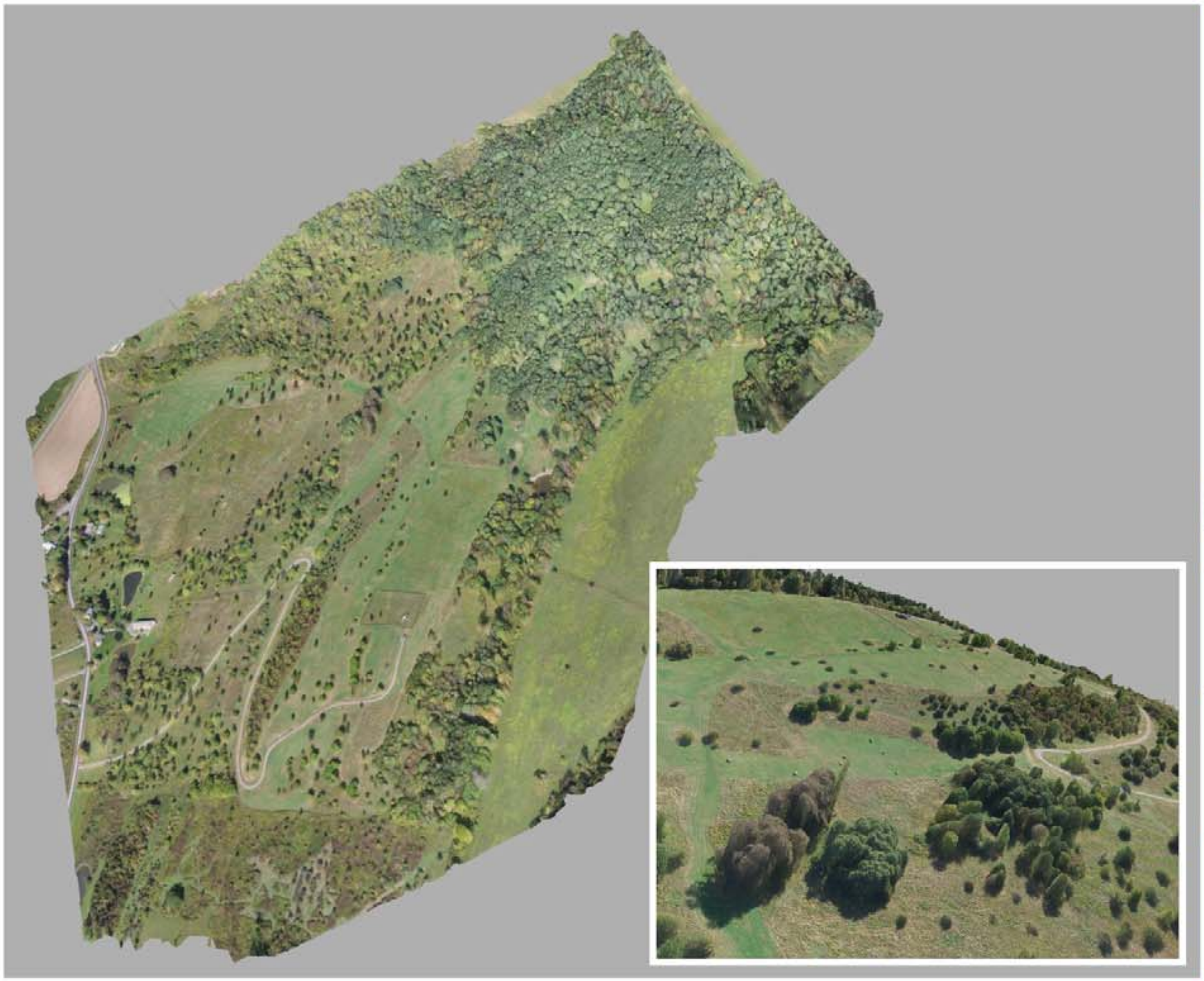
Drone NDVI Guided Differential Harvesting

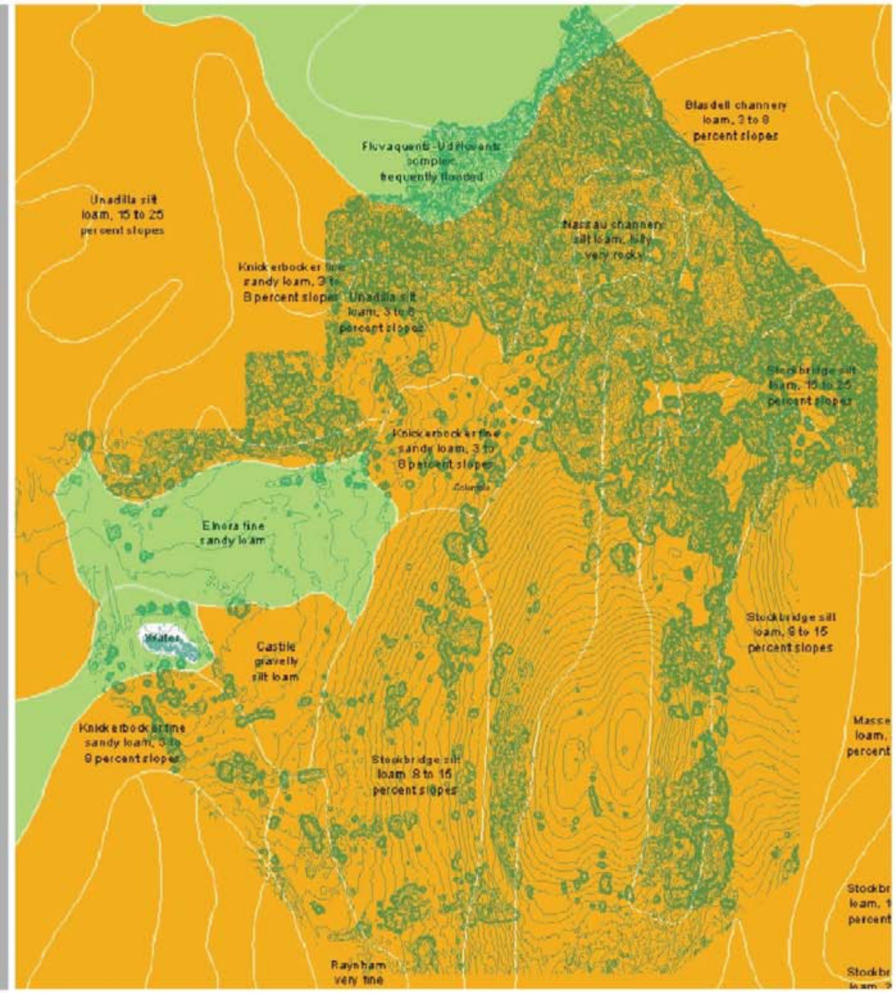


Drone Image Stitching and Elevation Mapping



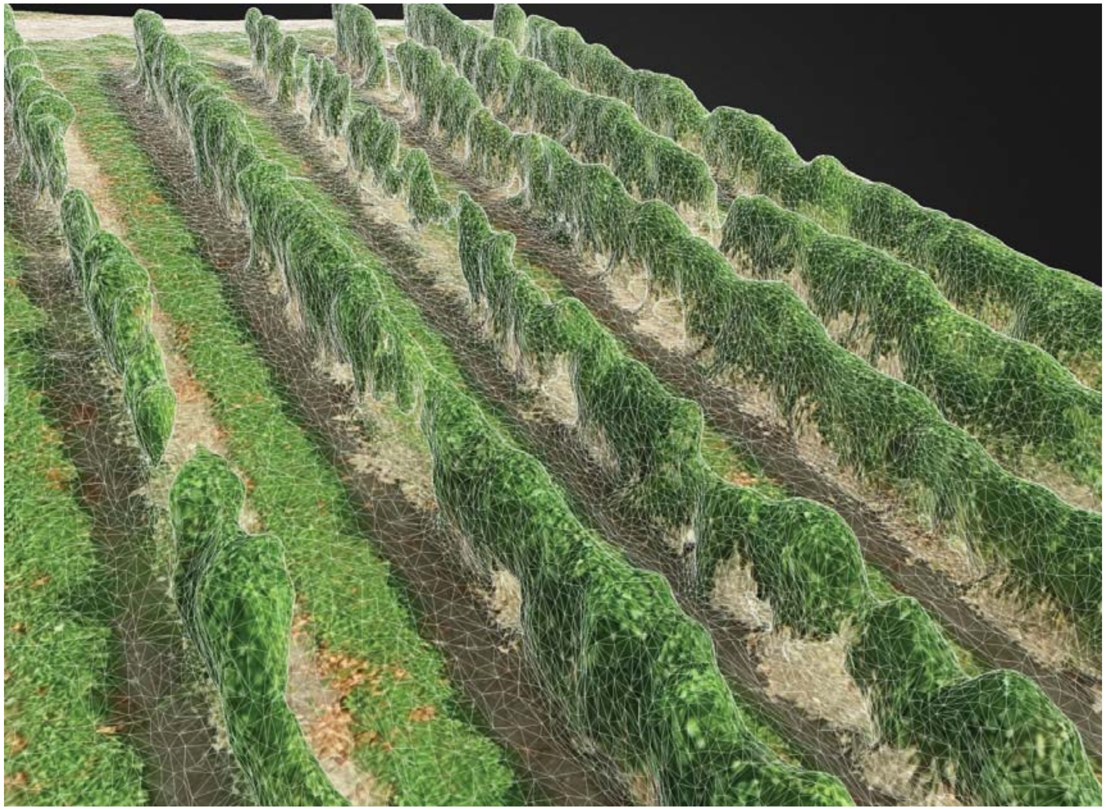
Interactive 3D Visual Inspection Models





Farm Visit – New Site Evaluation

Canopy Architecture – Fill and Volume

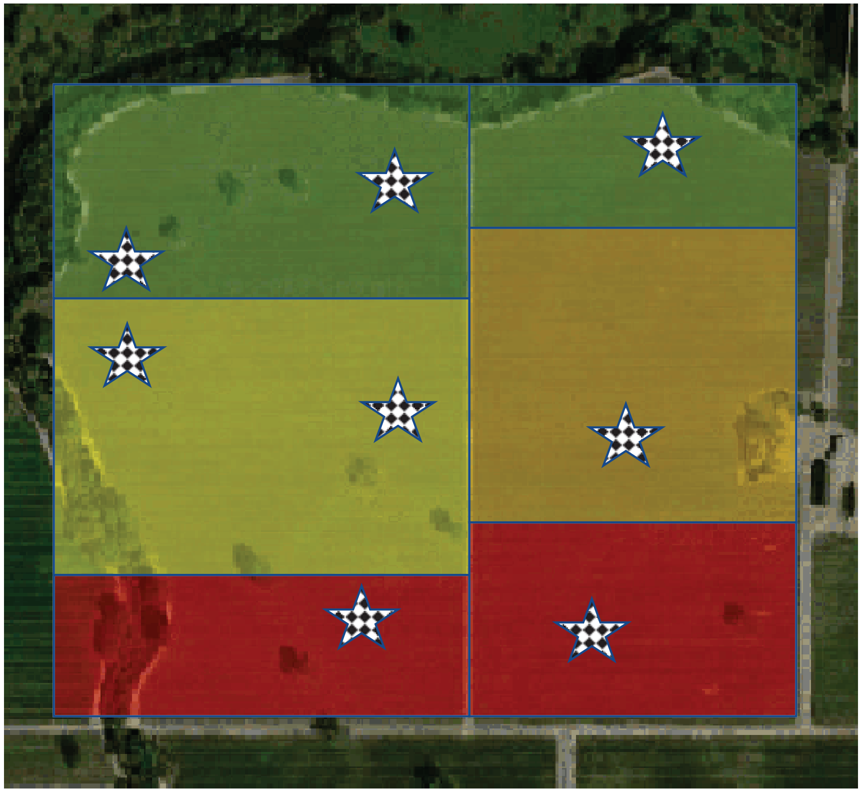


Using NDVI Imagery to Optimize Field Operations

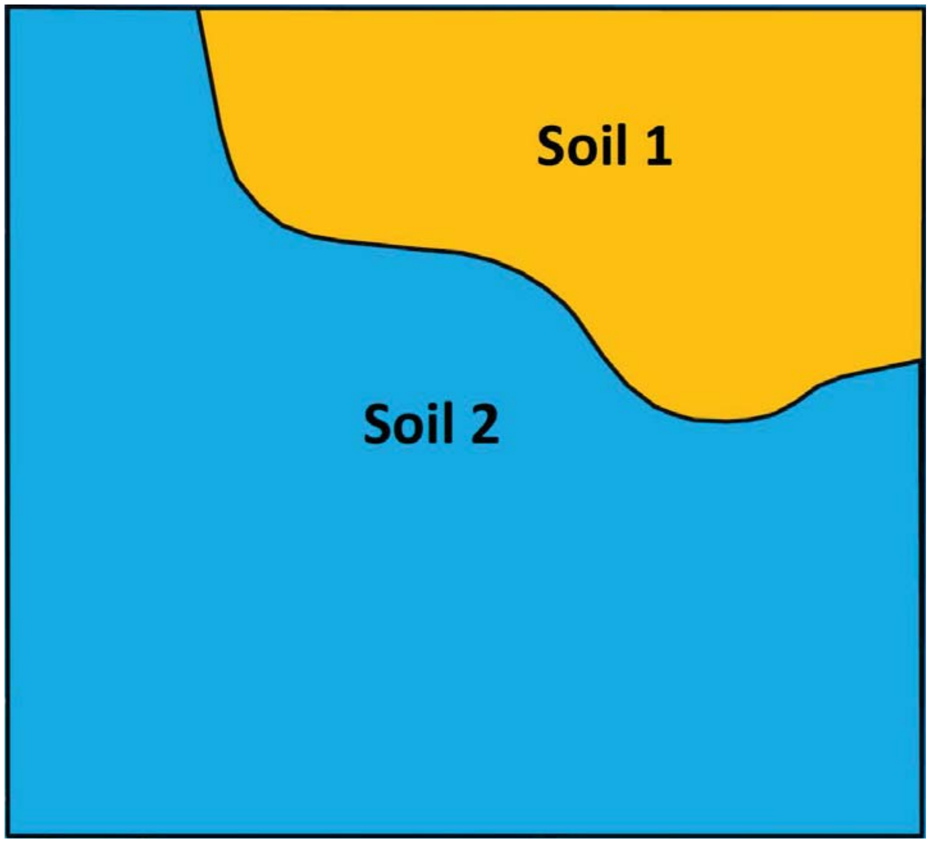
Block as Seen from Google Earth

Block NDVI Derived from Landsat 7 Data

Managing Variability Zones

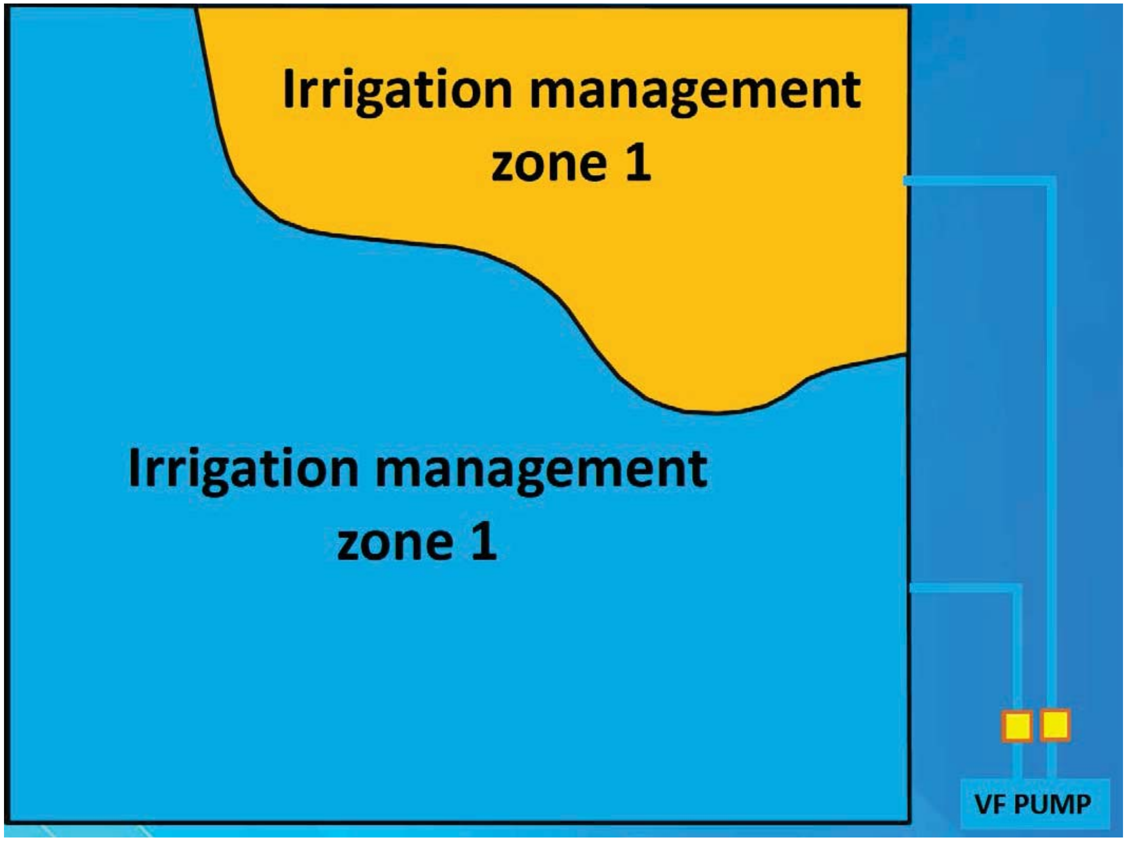


Zonal Management: Irrigation



Source: ESRI / E&J Gallo / IBM

Zonal Irrigation



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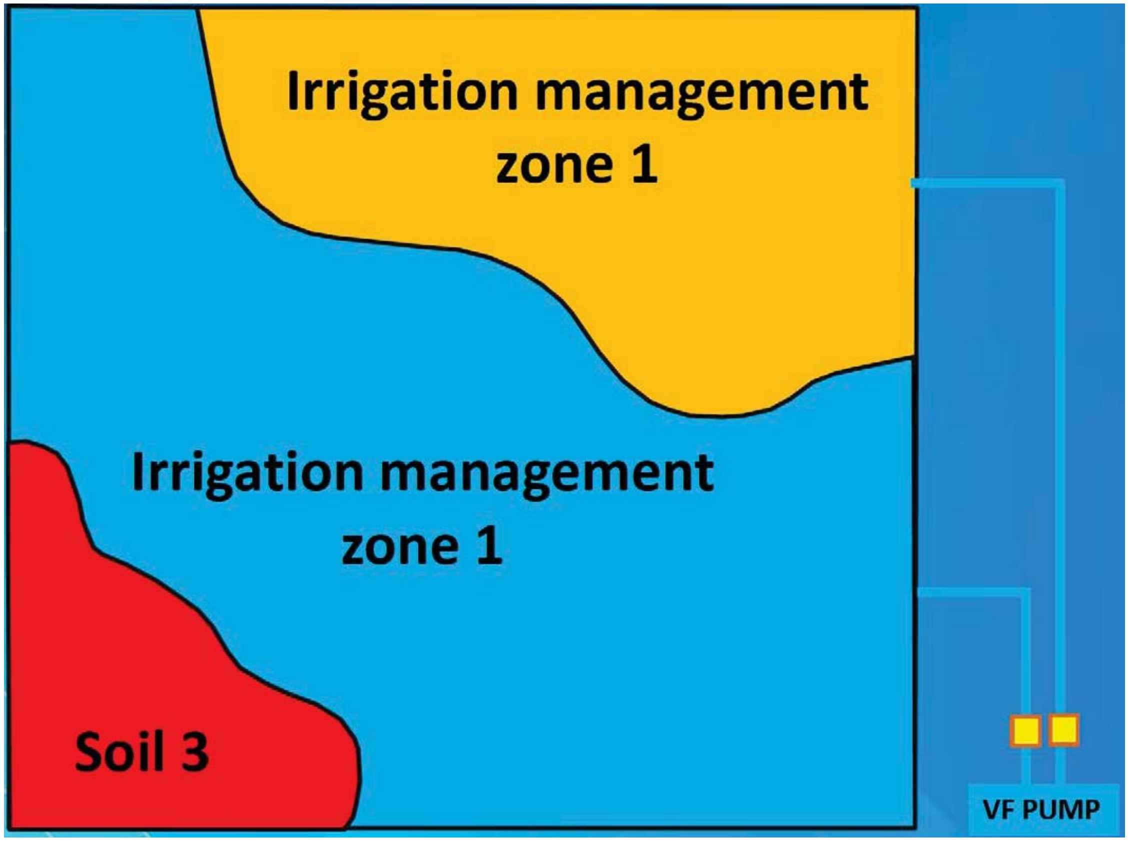

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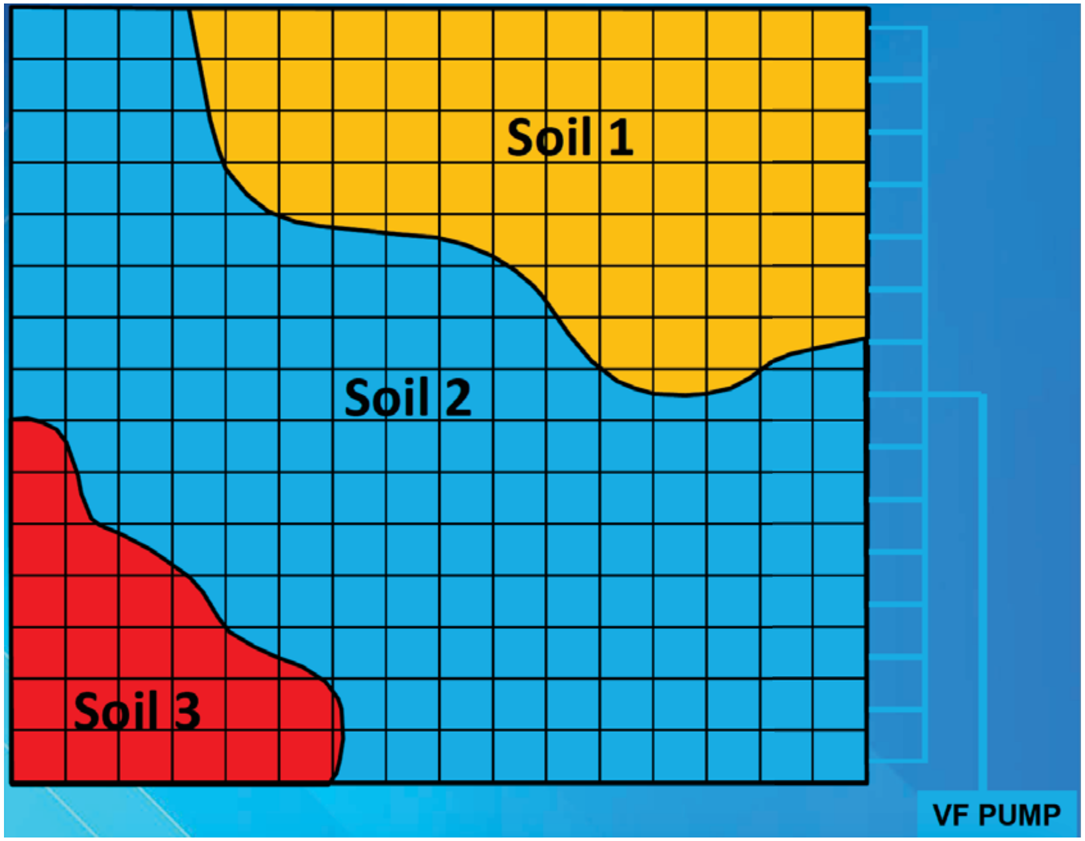
Modular Approach to Zonal Management



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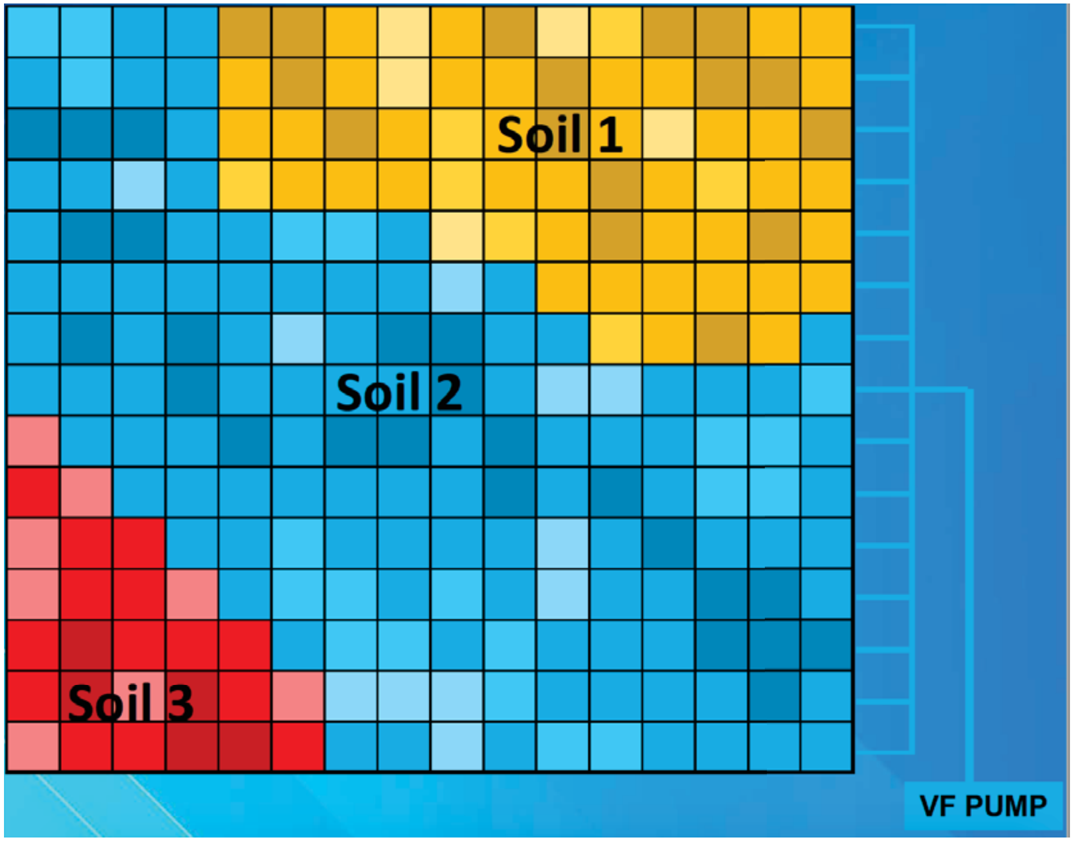
Modular = Small-Scale Zones

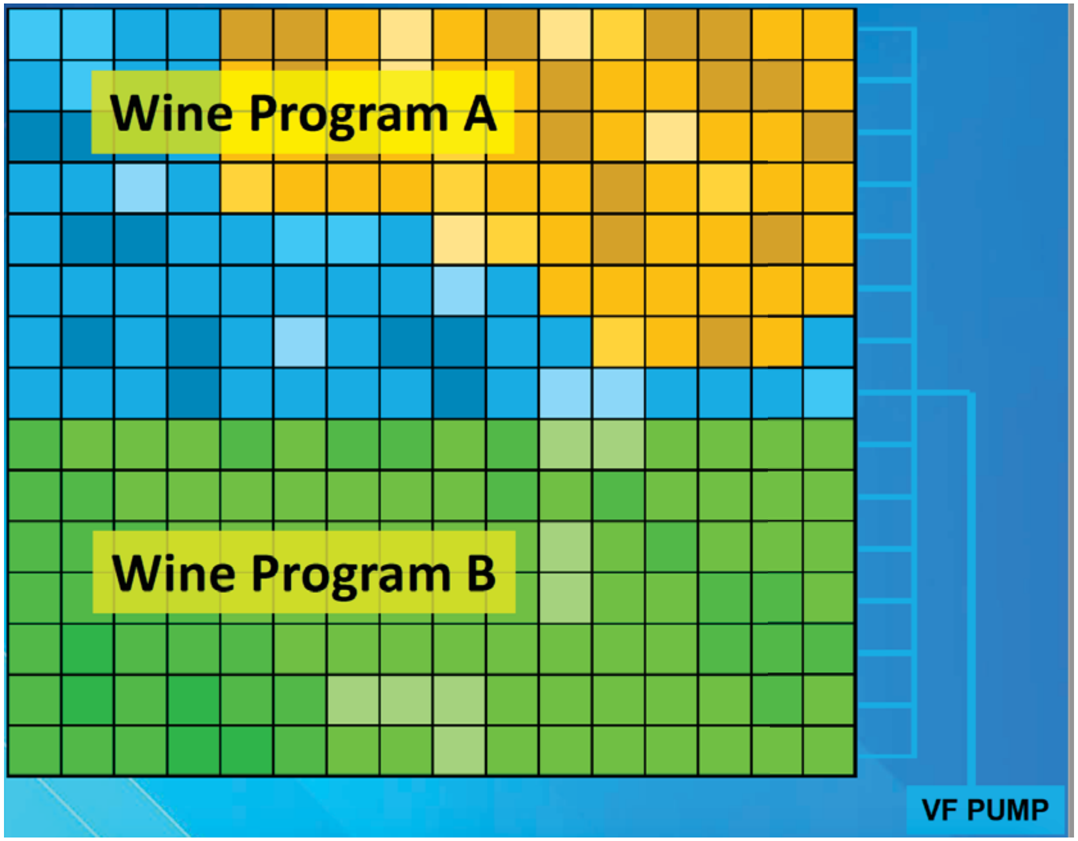


Source: ESRI / E&J Gallo / IBM

Modular Irrigation Control

Source: ESRI / E&J Gallo / IBM

Control of Variability



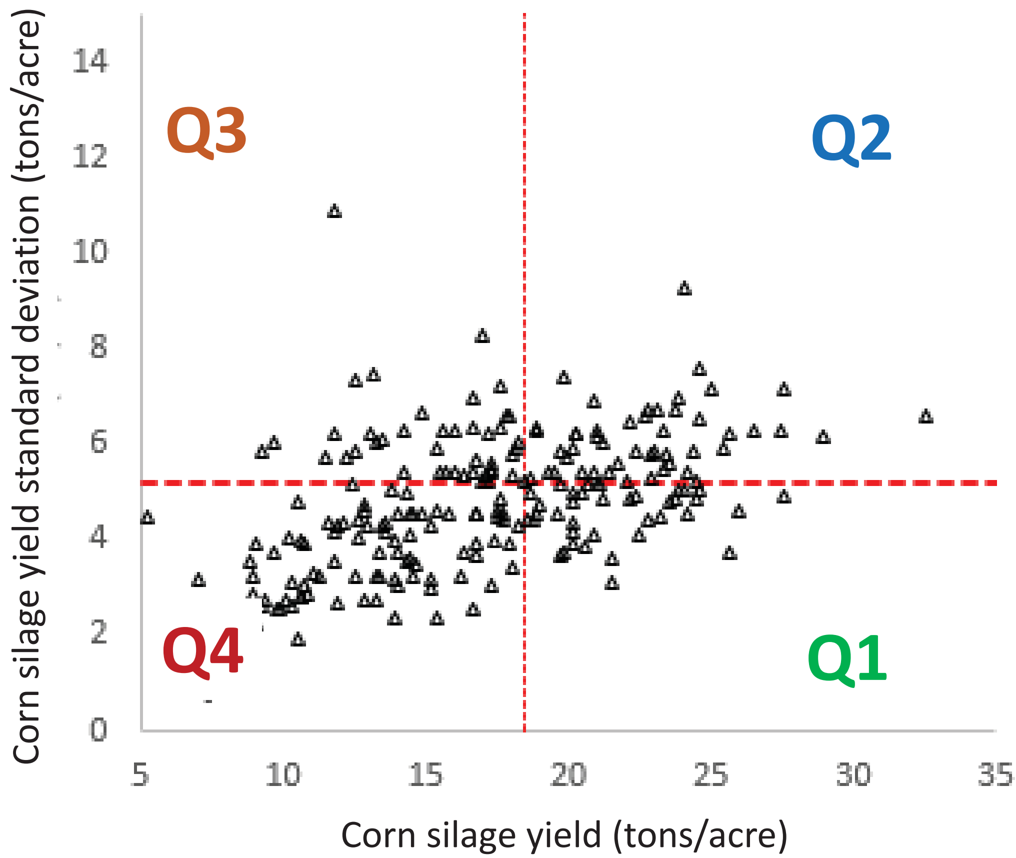
Source: ESRI / E&J Gallo / IBM

Corn Yield Stability Map

Corn silage example
Each triangle is one field with 3+ years of data

Corn yield data on farms can be used to develop field yield stability classifications:

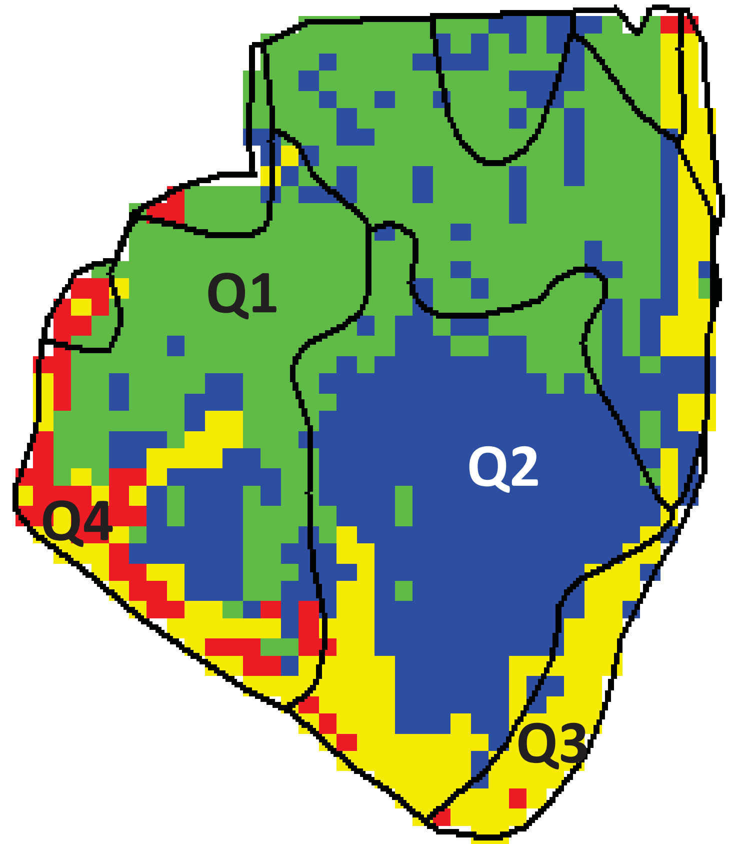
- Q1. High yield, low variability
- Q2. High yield, high variability
- Q3. Low yield, high variability
- Q4. Low yield, low variability



Source: Quirine Ketterings

Next Steps

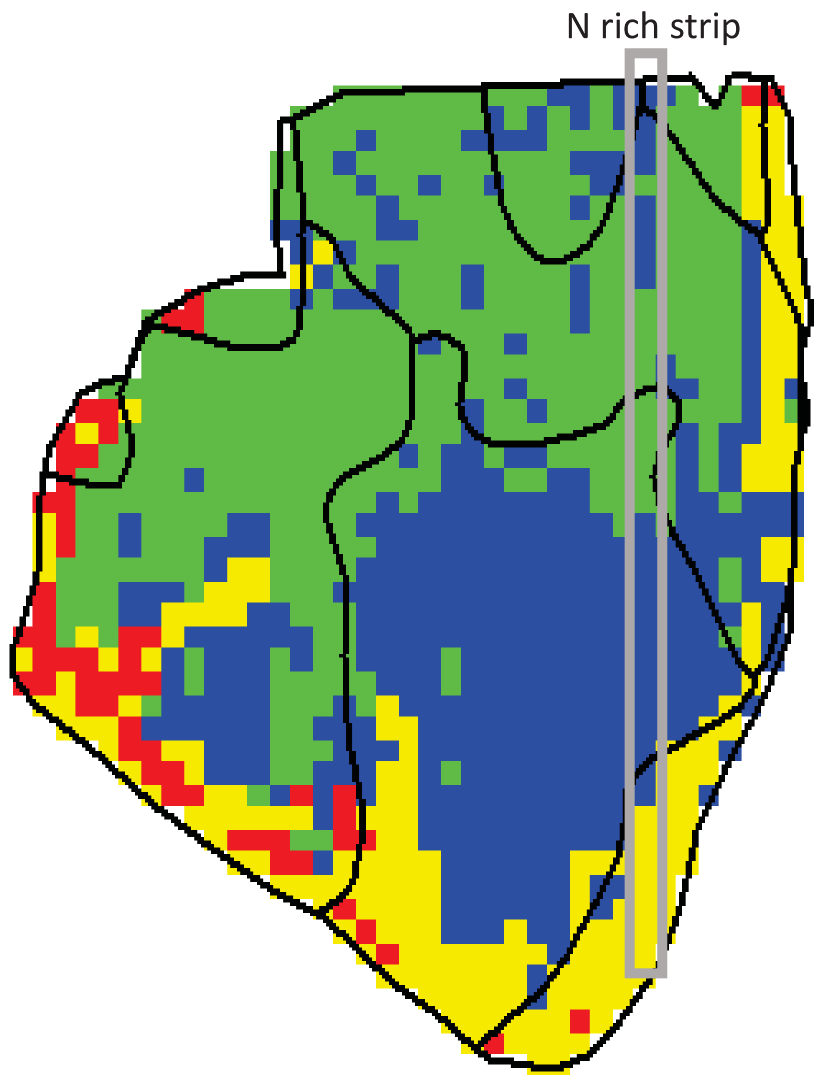
- Evaluate soil and field characteristics that separate Q1 versus Q2, Q3, and Q4 areas within a field (indicators/drivers for yield and yield stability).
- Project submitted for funding in 2018 and beyond.
- Collaboration with University of Buffalo (Dr. Erasmus Oware).



Source: Quirine Ketterings

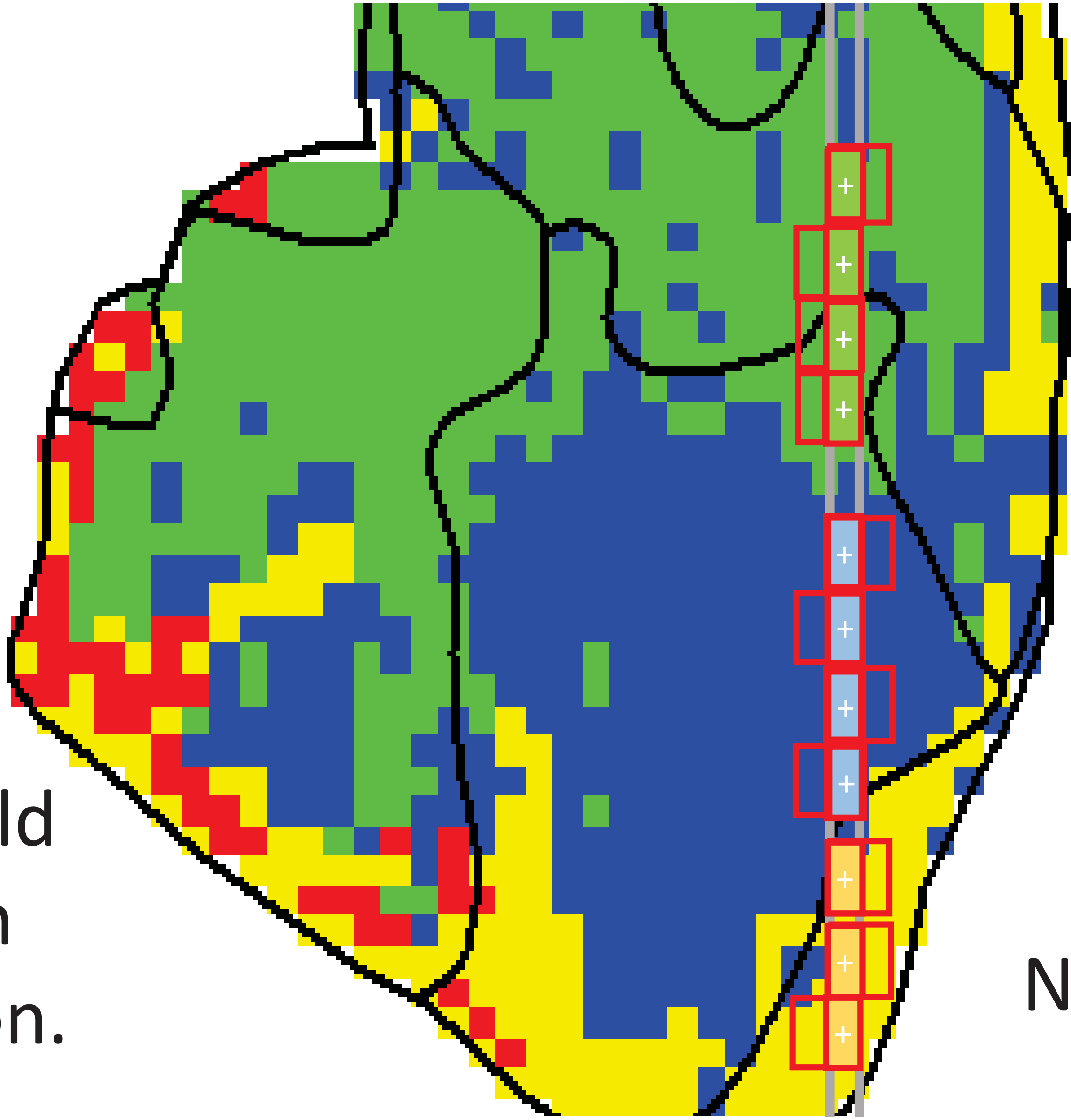
Next Steps

- Apply N rich strips across quadrants within a field to evaluate N response per zone:
  - Project submitted for funding; collaboration with Dupont/Pioneer, Growmark, Champlain Valley Ag, University of Buffalo, and counterparts in Missouri and Iowa and others.



Source: Quirine Ketterings

Next Steps

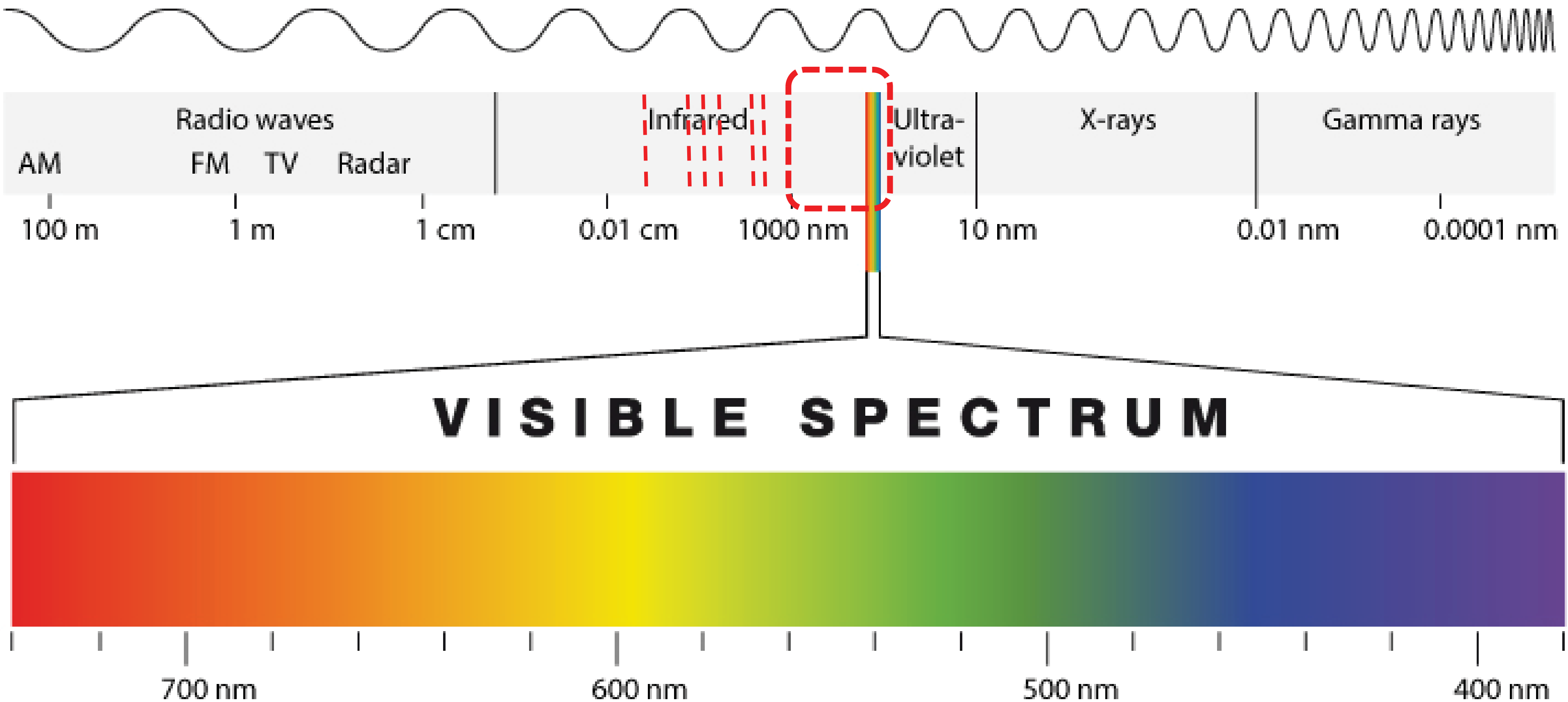


Document relative yield response in each section.

N-rich strip

Source: Quirine Ketterings

Electromagnetic Radiation



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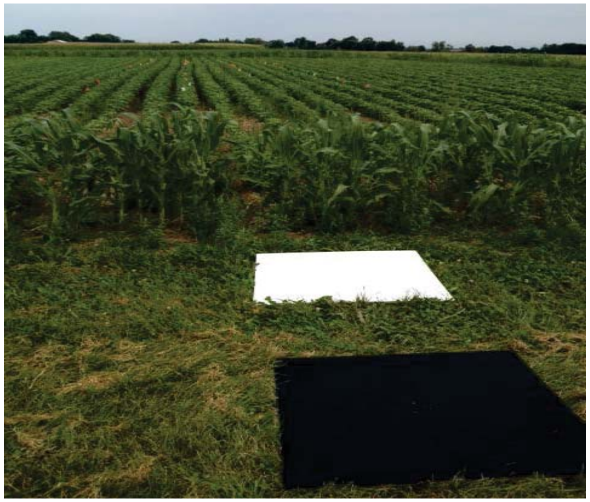
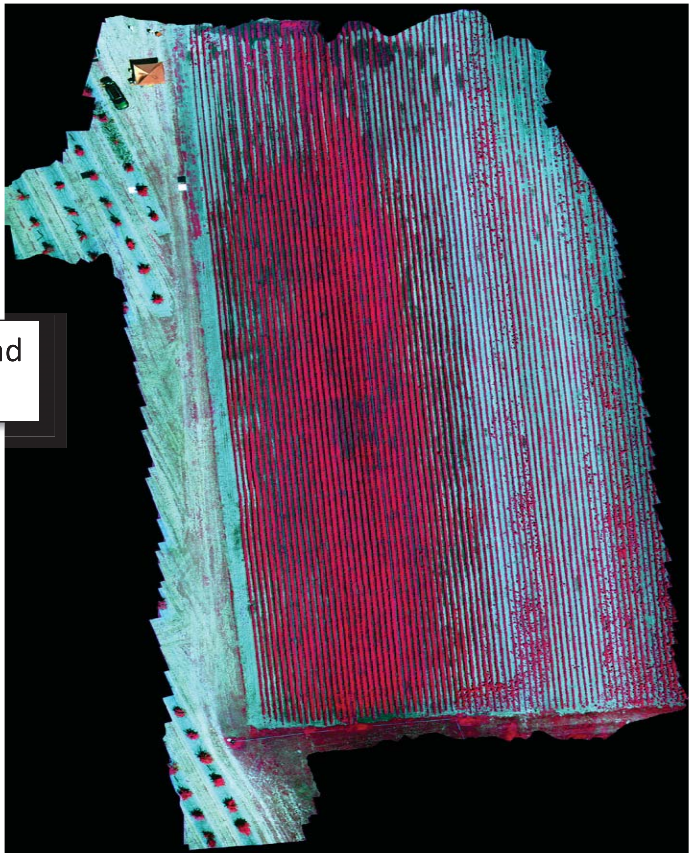
Current UAS Research Examples: **Snap beans**

- Cornell University (Drs. Sarah Pethybridge & Julie Kikkert)
- White mold risk modeling in snap bean crops
- Hyperspectral & lidar
  - Develop risk metrics
  - Enable judicious fungicide use

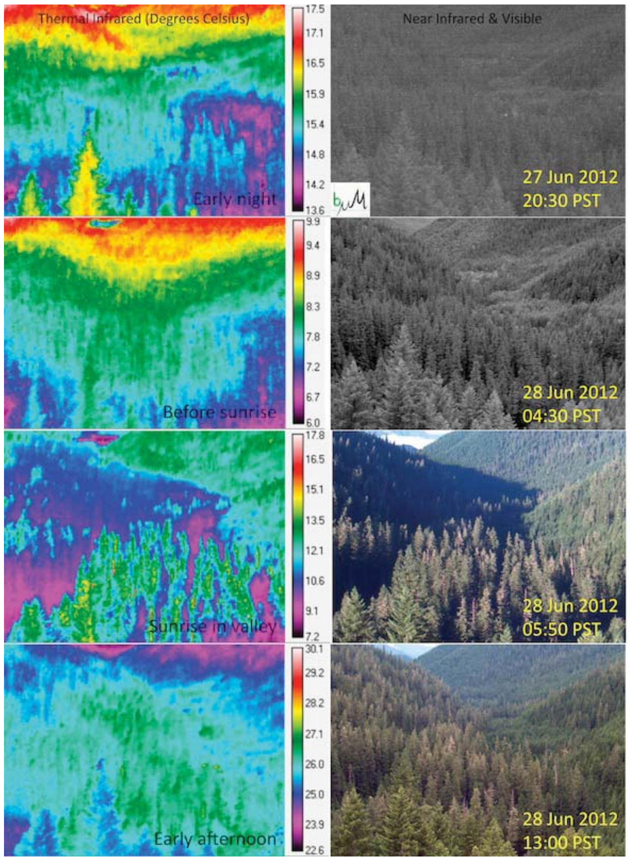
DJI M-600 (left); Calibration targets (below); and near-infrared image (right)





Source: Jan van Aardt, R.I.T

Thermal Imaging



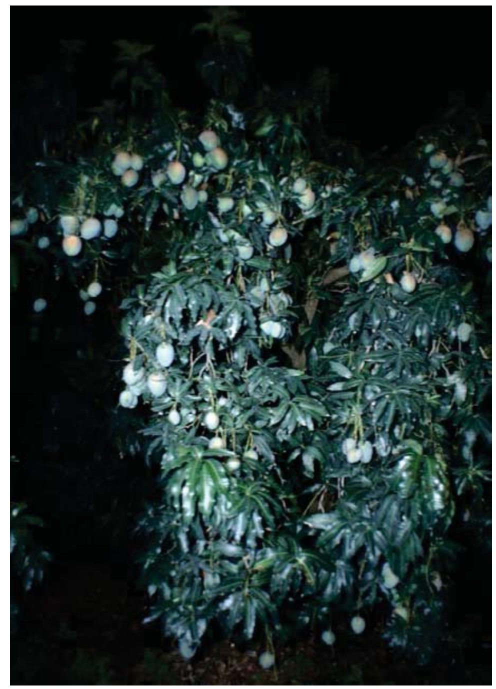
Crop Scanning using Aerial Robots

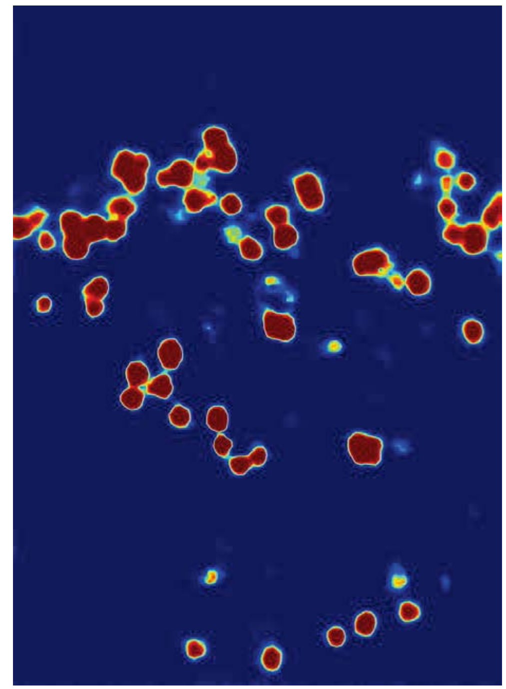
Source: University of Pennsylvania, GRASP Lab

Fruit Detection in a Mango Orchard

Orchard Rows

Video Frame & Detected Fruit





Source: University of Pennsylvania, GRASP Lab

Fruit Detection Applied to Mango Video Stream

- Computer vision system identifies fru quickly and accurate
- Identification necessary, but not sufficient to determine count
- Located fruit must b tracked to verify init identification and to avoid double counti

Source: University of Pennsylvania, GRASP Lab

Tracking and Counting Applied to Apple Video Stream

Source: University of Pennsylvania, GRASP Lab