# What instruments do we need on UAS to measure crop water status?

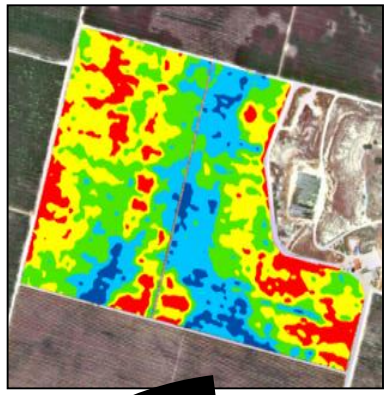
**Susan Ustin, UCD and Joaquim Bellvert, IMTA, Spain**

# Why is agriculture interested in Remote Sensing?

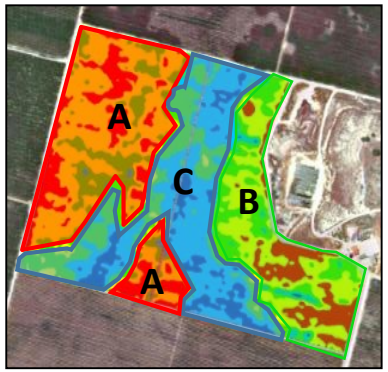
## Manage within-field Spatial Variability

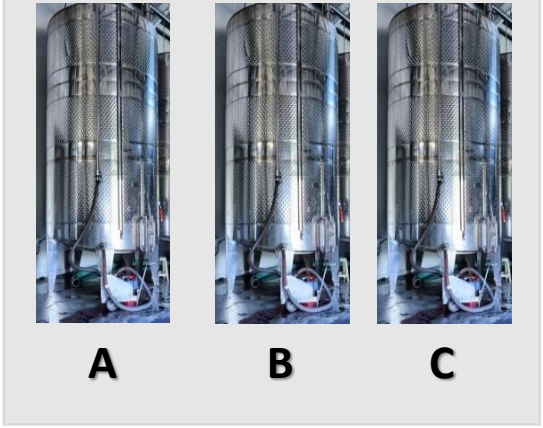
- Precision Irrigation
  - Improve irrigation efficiency
  - Determine crop water requirements
  - Identify crop water status
- Precise Fertilization
- Precise Pest Management
- Yield forecasting

Identify spatial variability

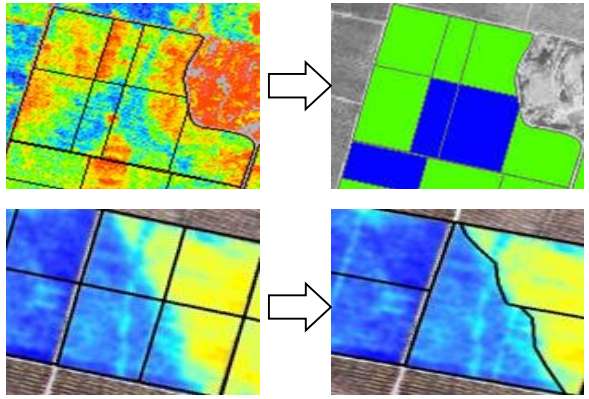


Selective Harvest

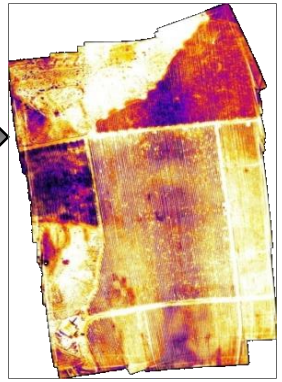


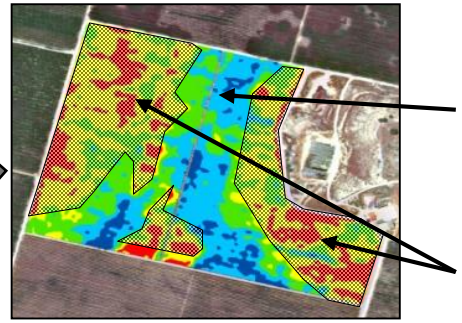

Re-design irrigation sectors



Detect plant water status with thermal imagery



Actions to reduce spatial variability

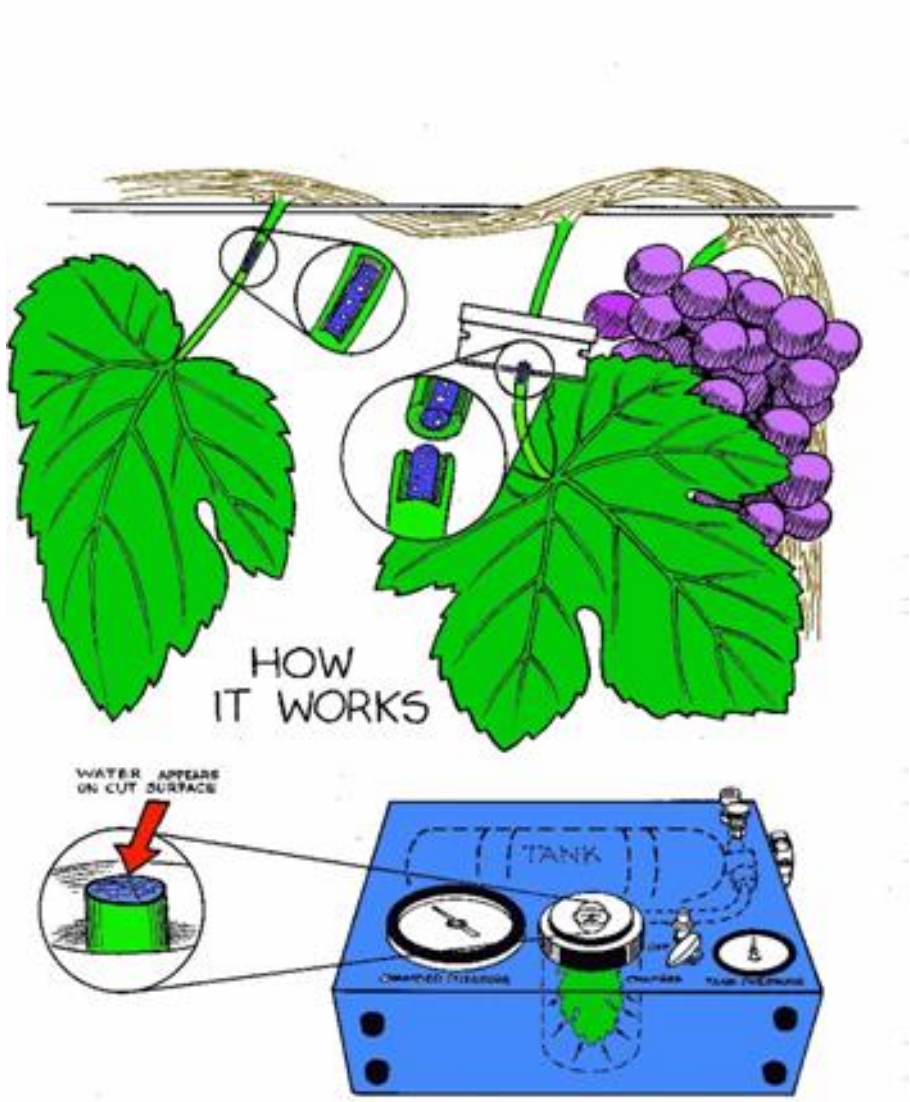


Summer pruning

Compost+deep plowing

# How do we measure usually crop water use and status?

# Traditional Approach:
# Pressure Chamber measures Leaf Water Potential



- Measures energy required to pull water from soil to leaves
- Widely used by growers to estimate water deficit

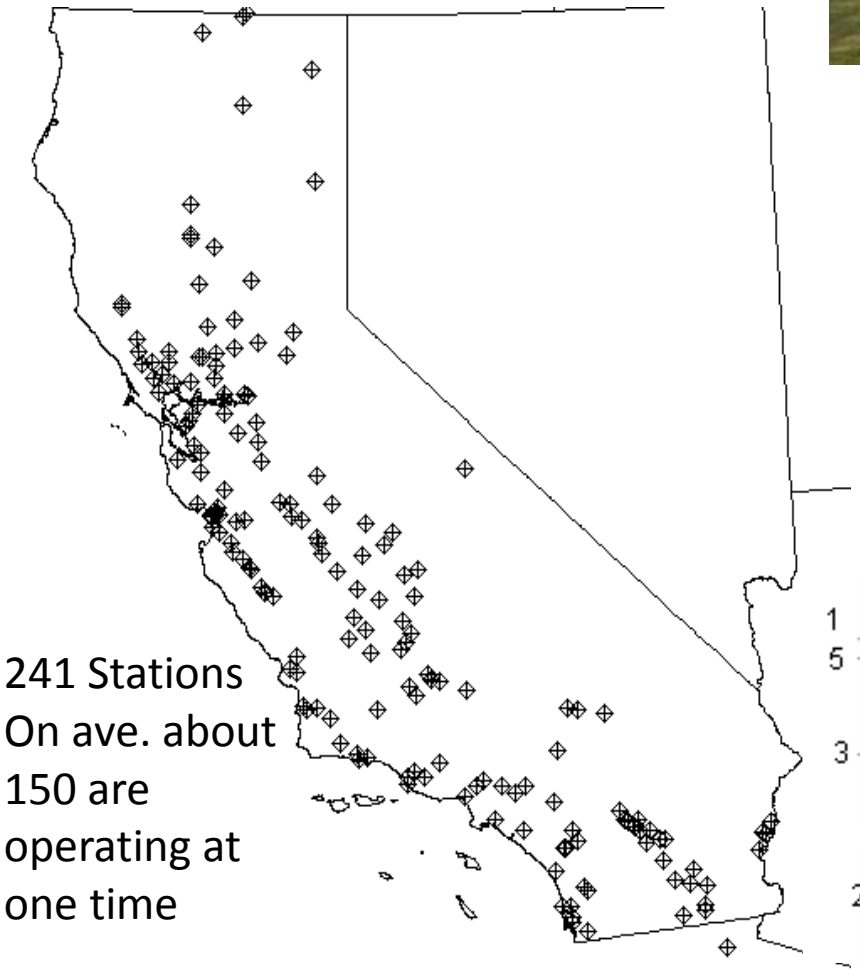
http://pmsinstrument.com/howitwks.jpg
http://pmsinstrument.com/pumpupsteminsert.jpg
http://pmsinstrument.com/tutorials/measuring%20winegrapes%2011.JPG

Station 182 Delano

Login | Register

CIMIS

CALIFORNIA IRRIGATION MANAGEMENT INFORMATION SYSTEM
CALIFORNIA DEPARTMENT OF WATER RESOURCES



241 Stations
On ave. about 150 are operating at one time

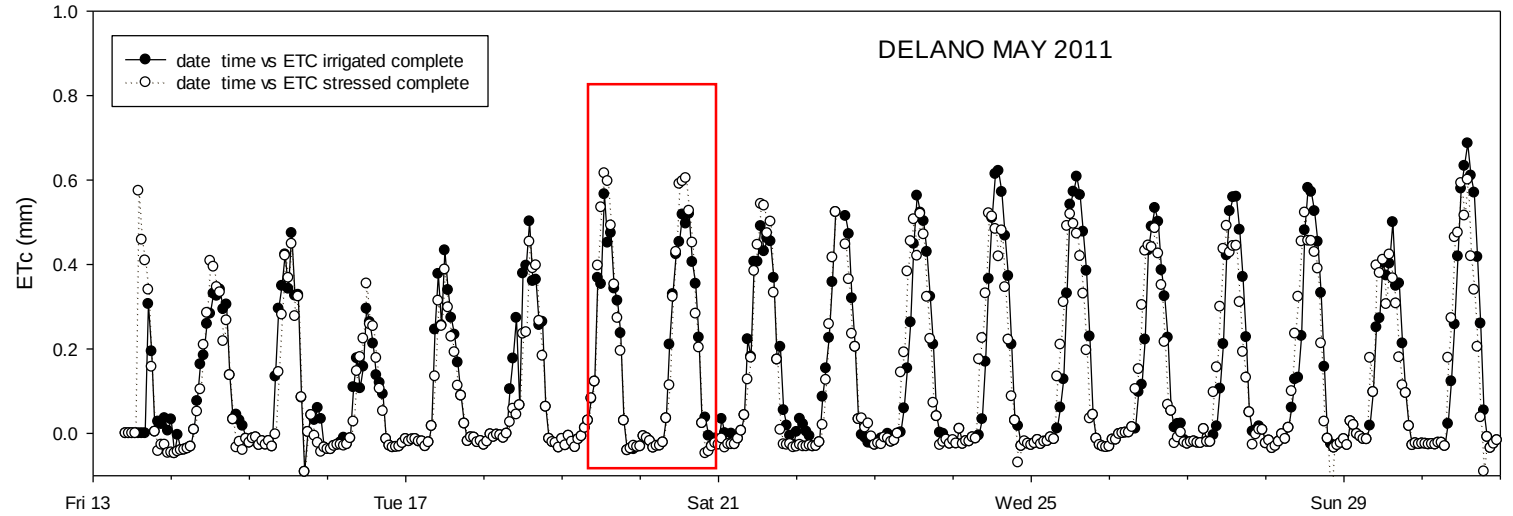
- Hourly and Daily Data for Potential (reference) Evapotranspiration ($ET_0$) based on weather conditions -- - not actual crop water use
- Long record of weather conditions at these sites
- Crop coefficients are used to adjust $ET_0$ to estimate of actual ET

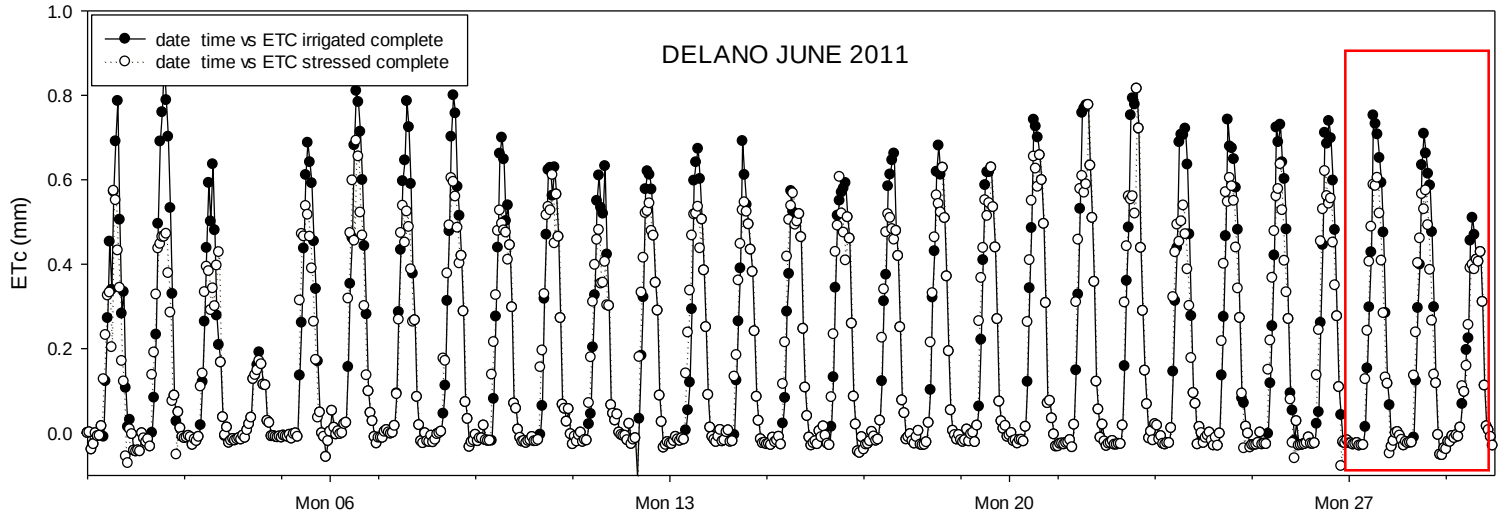
CIMIS weather stations are located throughout California, primarily in agricultural areas.
Established in 1982 to improve irrigation efficiency by establishing the maximum ET on a daily basis.

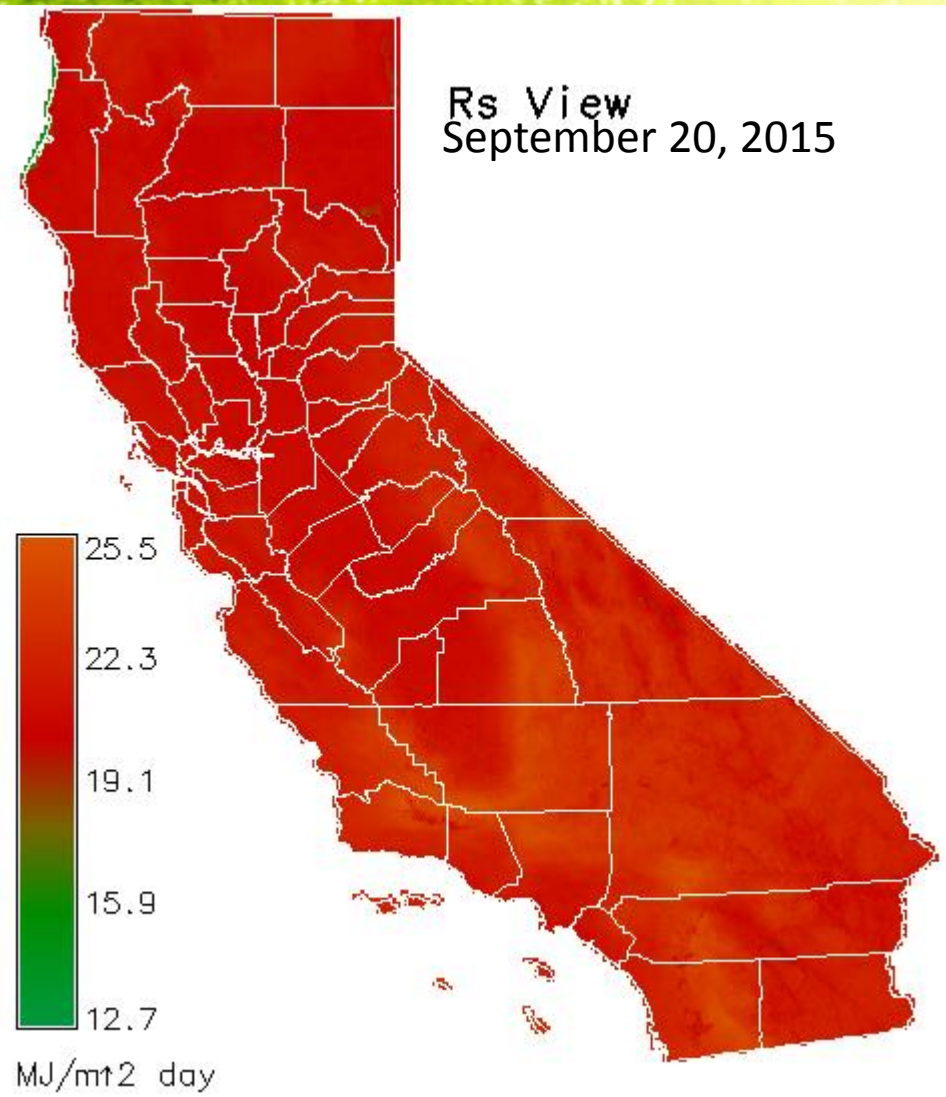
# Eddy Correlation Measurements of $CO_2$ and Water Fluxes

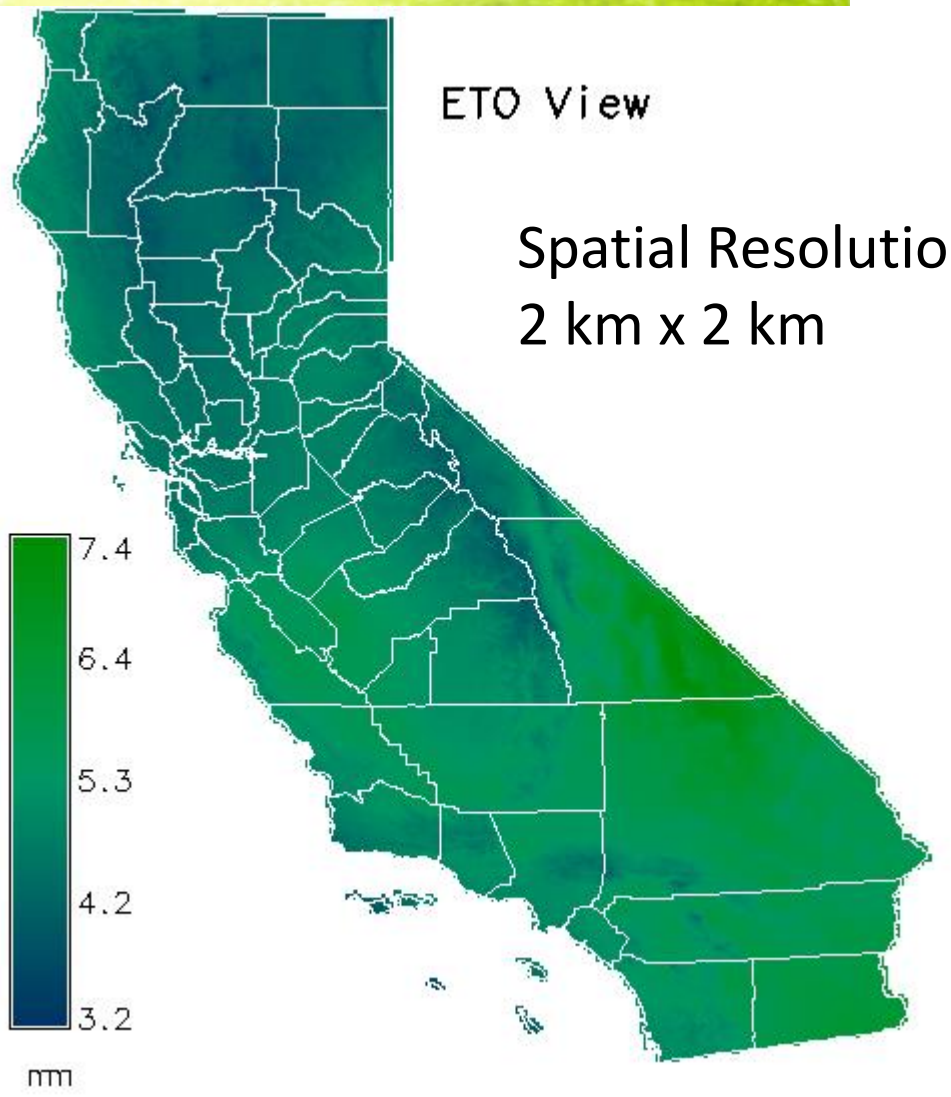
EC System measures gas concentrations, transport rates, and general weather station data

# Delano Vineyards 2011: ETc



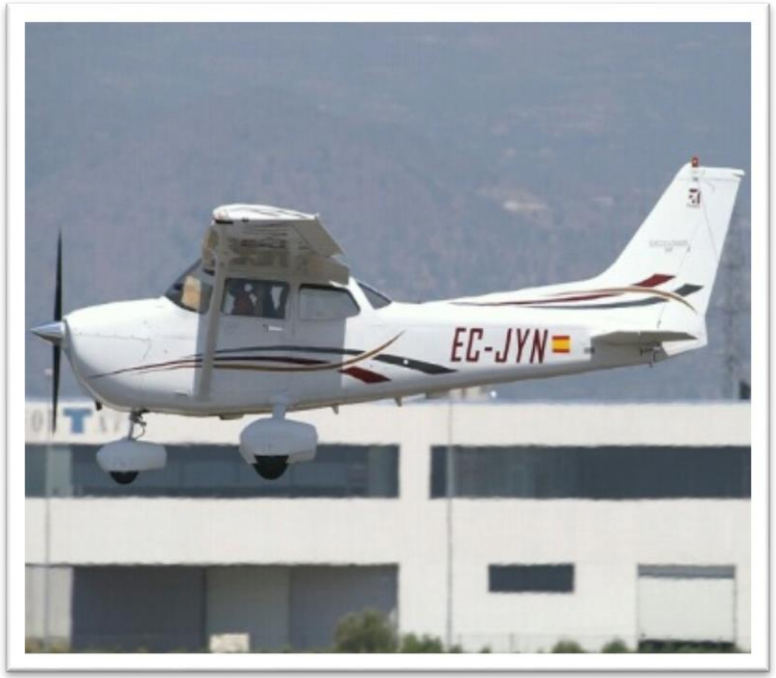


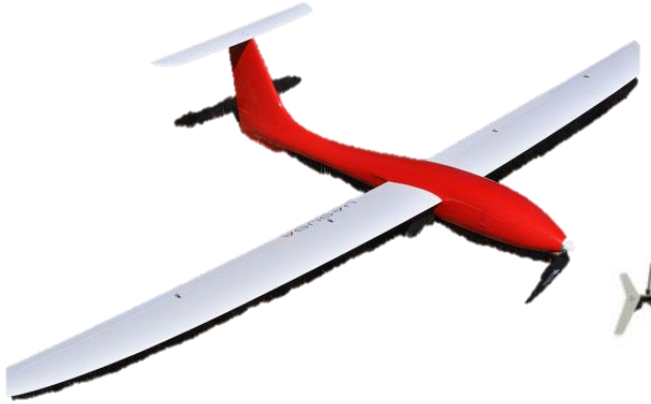

Spatial Resolution is
2 km x 2 km

# Spatial CIMIS: Statewide Daily Estimates of Potential $ET_0$

# What remote sensing platform is best for agriculture?

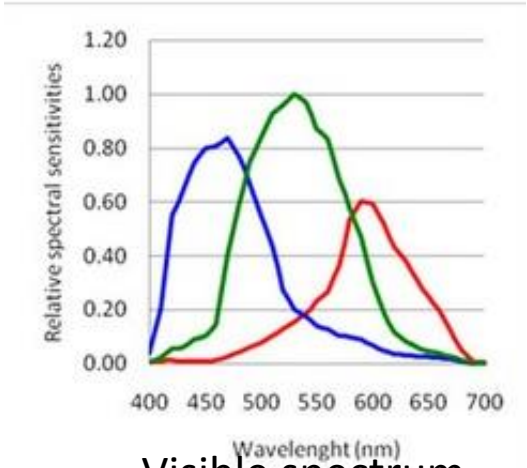
| | Satellites | Manned aircraft | UAS |
|---|---|---|---|
| | |  | |
| **Spatial** Resolution: | 1.5m to 30m | 1m to 5m typical | 10cm to 1m or more |
| **Spatial** Extent: | State-wide, regional | multiple farm to regional | subfarm to regional |
| **Spectral** Resolution: | Multispectral, Vis, NIR, TIR Lidar | Multispectral 3 or 4 band VNIR Hyperspectral, Thermal IR & Lidar | Multispectral 3 or 4 band VNIR Hyperspectral, Thermal IR & |
| **Temporal** Resolution: | On-schedule, Weekly | On-demand, generally irregular | On-demand, generally irregular |

# There are many UAS platforms from very small to suborbital, with a wide range of payload capacities and endurances

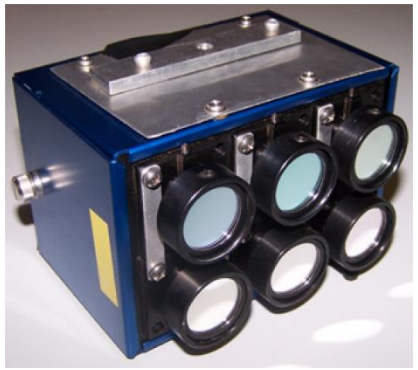


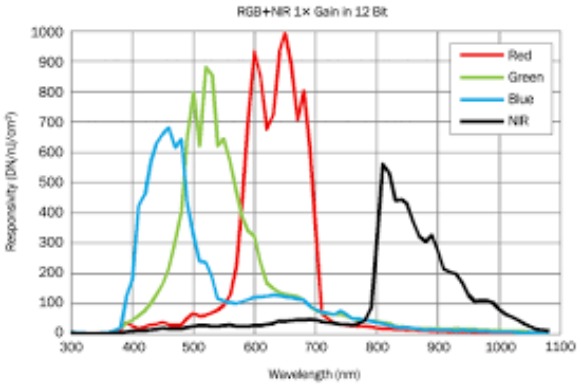
UAS FOR CALIFORNIA
WATER RESOURCES SUMMIT
What measurements are needed from UAS to manage water?

# What type of sensor do you need? Visible Bands and Color Infrared




Visible spectrum





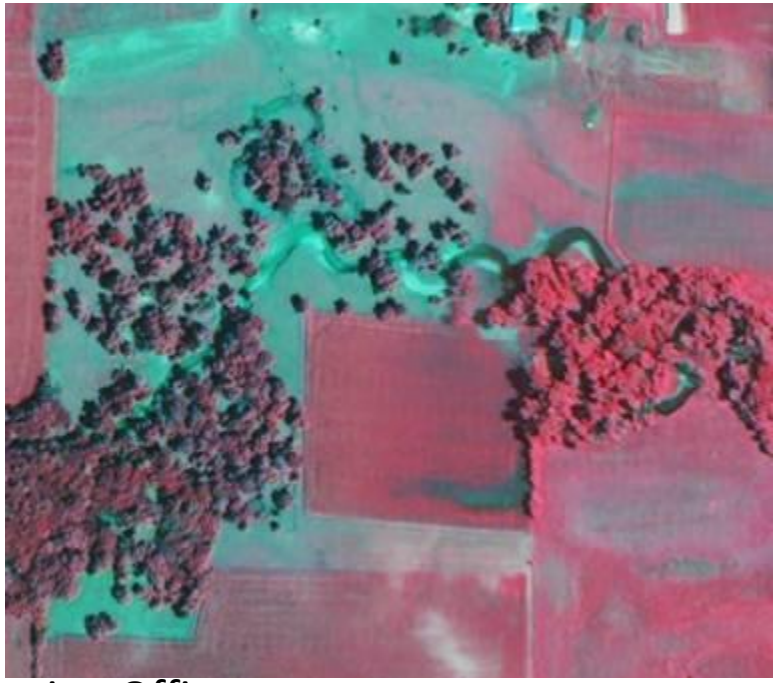

Visible and NIR spectrum

## Digital camera

Blue, green, red visible bands

## Multispectral imager

4-6 bands, visible and near-infrared (NIR)



Images from Minnesota Geospatial Information Office

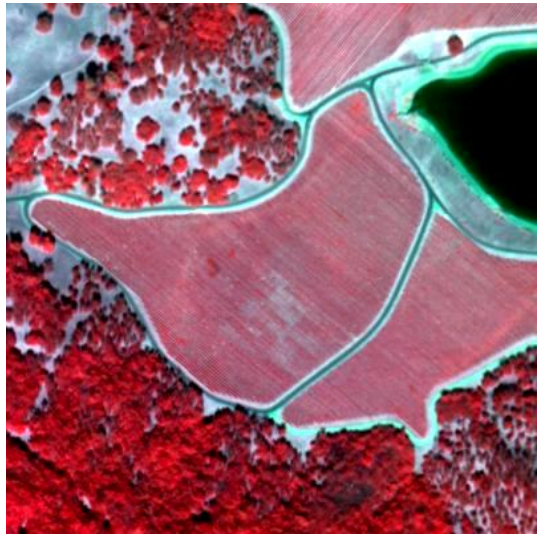
# Most UAS use simple visible or color infrared digital cameras

A DJI Phantom quadcopter with a GoPro Hero HD2 video camera

UC Davis Arboretum

RGB camera

Interpretations are based on spatial patterns



Color Infrared:
Green, Red, and Near-Infrared (NIR) bands

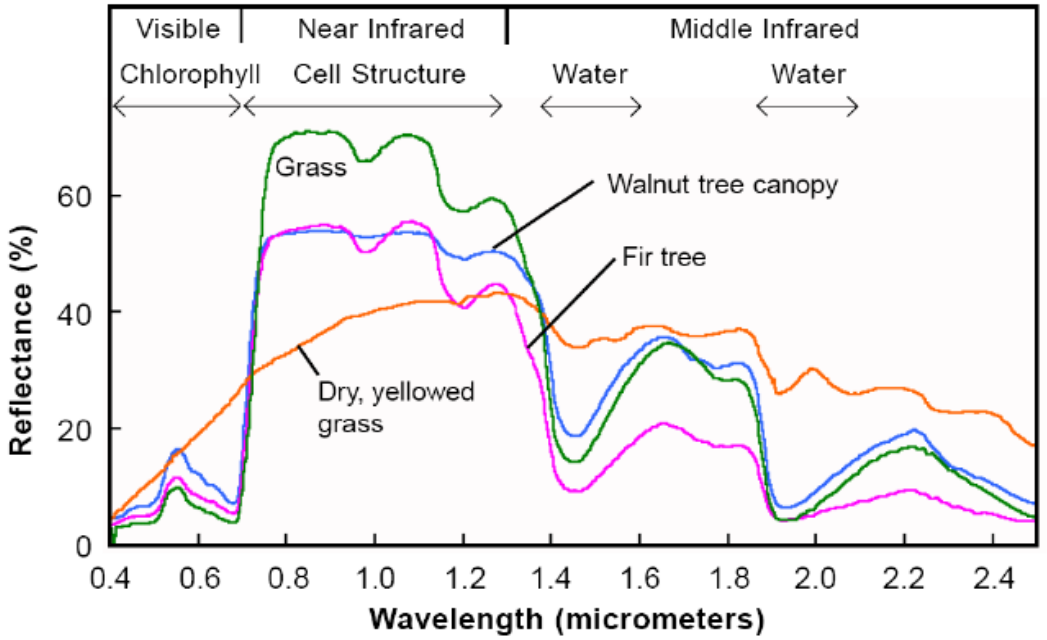
Gallo Vineyards
Sonoma County,
ADAR-5500

Plants have high reflectance in the NIR,
Which makes them red in Color Infrared imagery

# What type of sensor do you need?
# Hyperspectral Imager

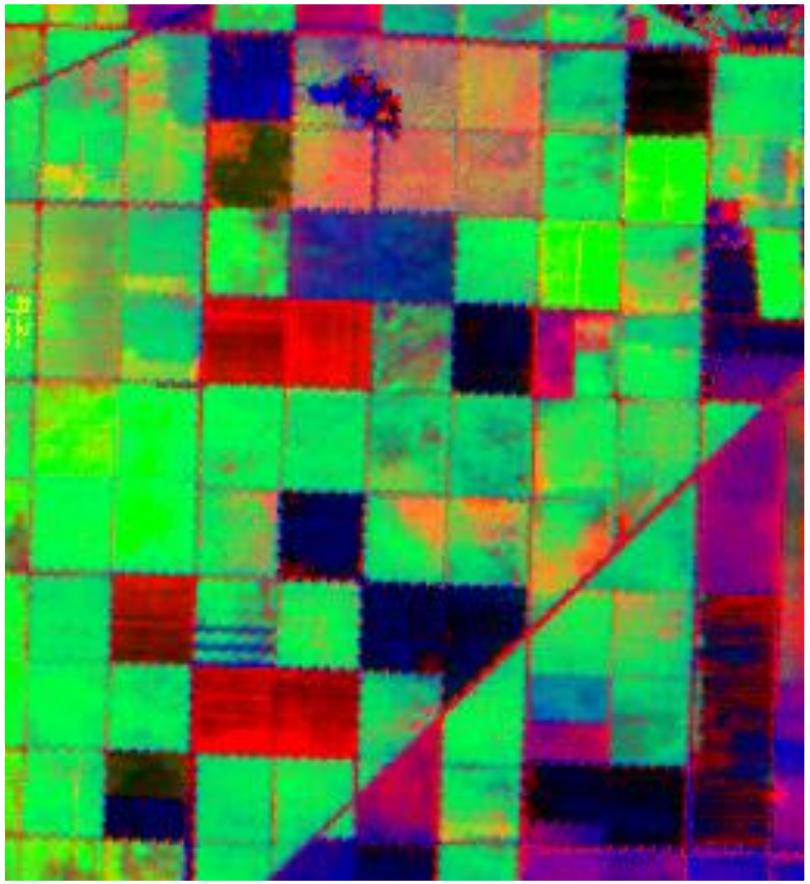
Hyperspectral imager

100s of bands, visible through reflected solar infrared (to 2500nm)

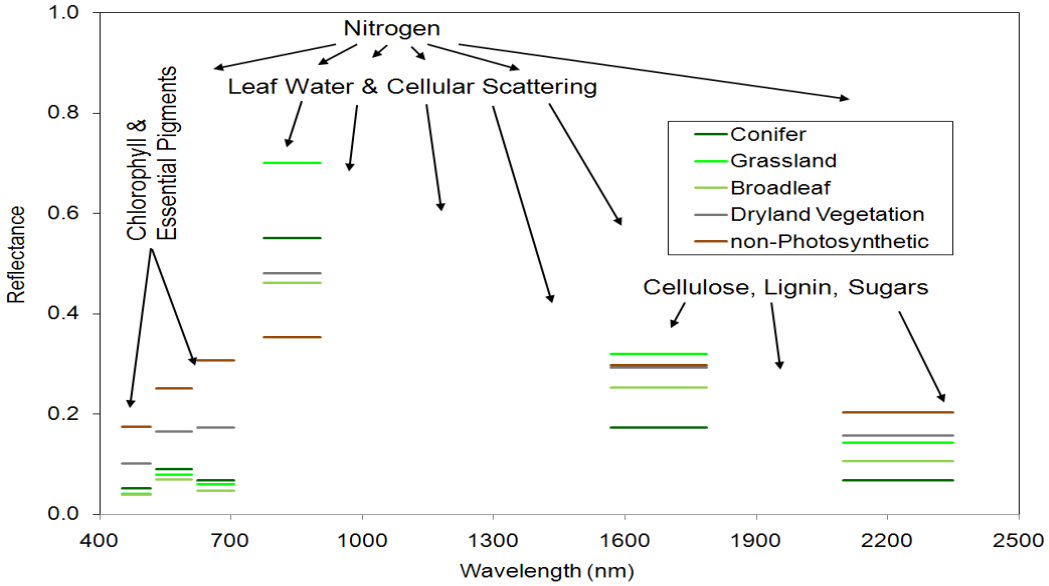



Fields are distinguished by different combinations of canopy chemistry and foliar density

Spatial patterns relate to crop types in different fields



Information content is less in multiband data



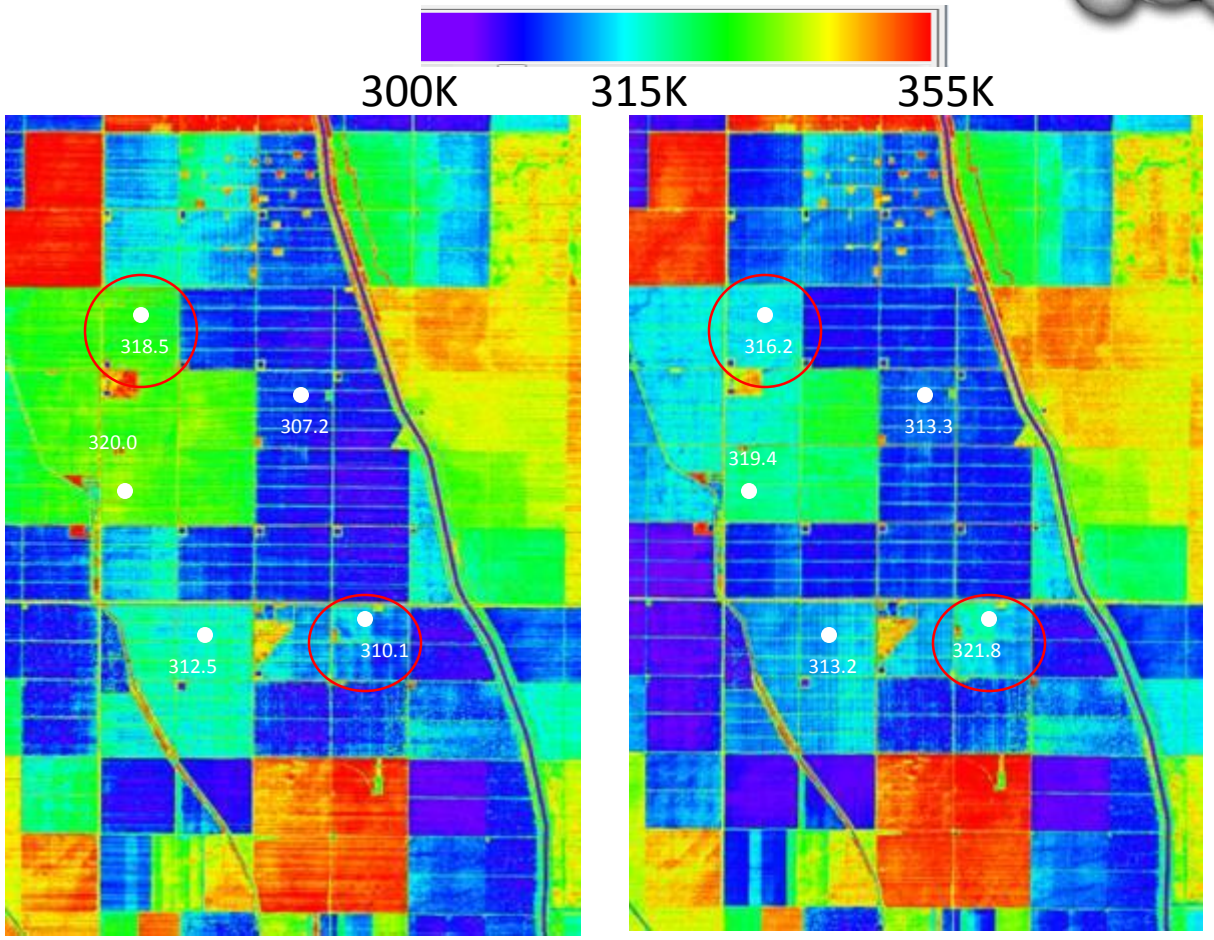
# Irrigation applications

## Plant water status

# What kind of data do you need? Thermal Imagery

Thermal cameras: Most are 1 band but multiband is available

True Color Visible Bands




Pass 1 (11:47) Air Temp: 306K
06/29/2011

Pass 2 (14:03) Air Temp:308.5K

# Identify the spatial variation in TIR

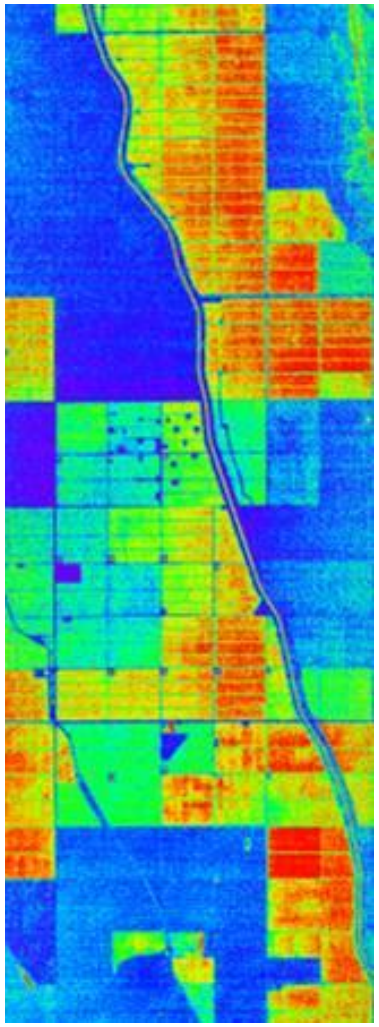
## What are the water requirements?

- How much?
- When?
- Where?

$ET_c$

$ET_c$

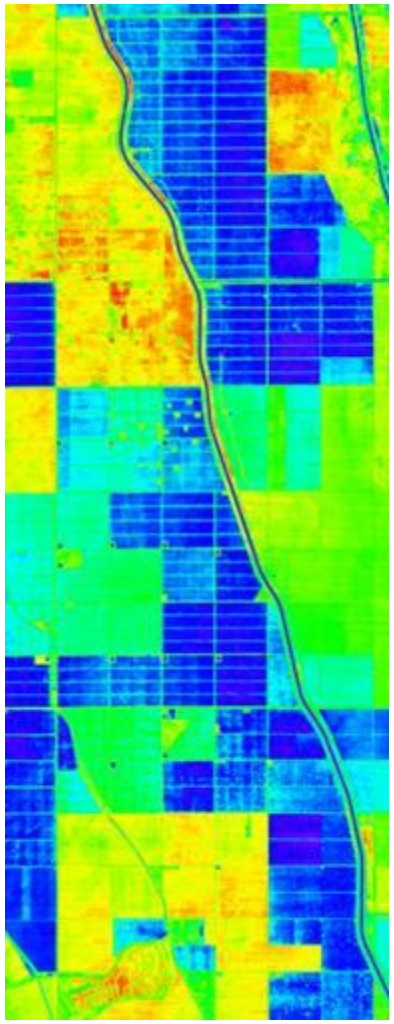
# Crop temperature is closely related to canopy temperature



Water Content

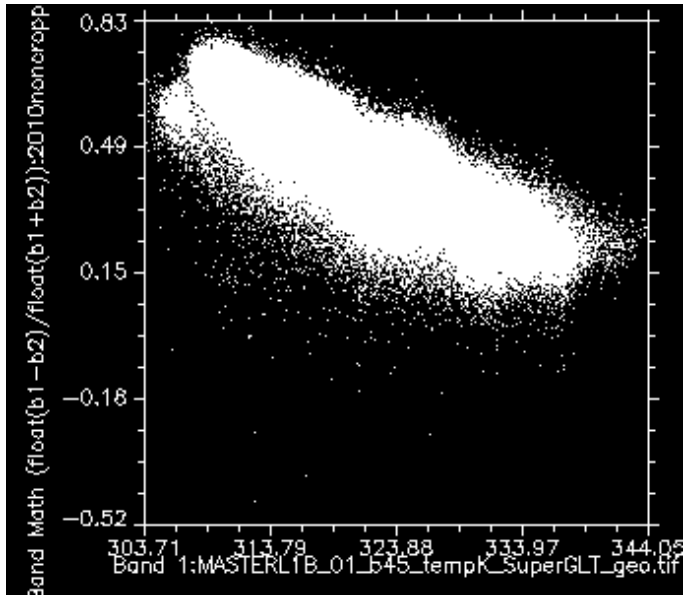
High

Low



Thermal Band temperature

Increasing Canopy/Surface Water Content

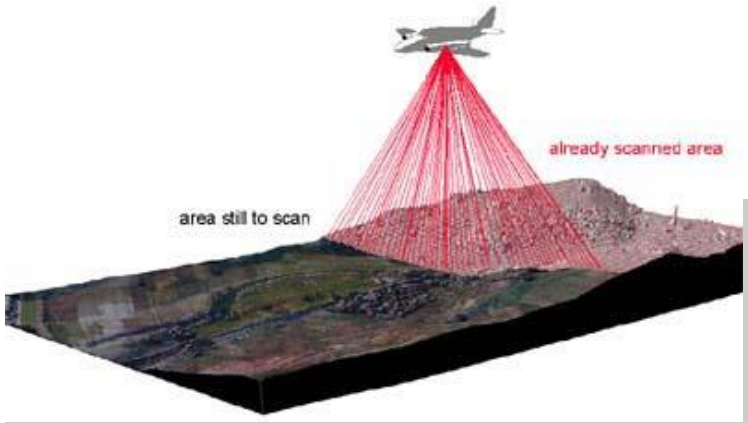


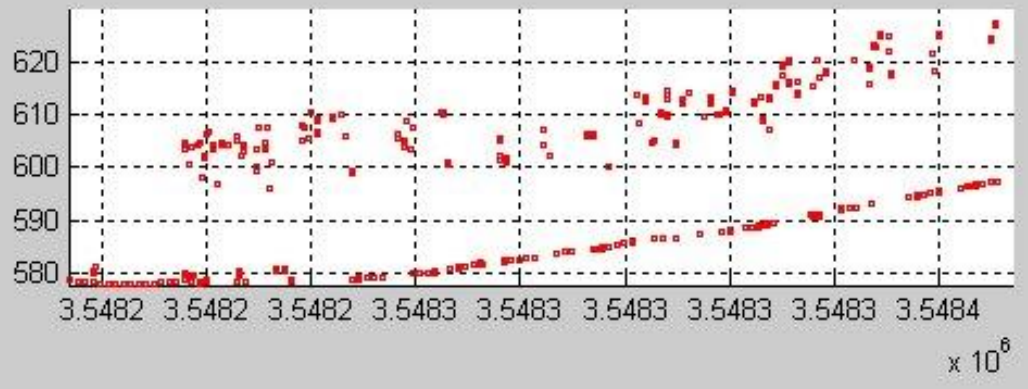

87°F

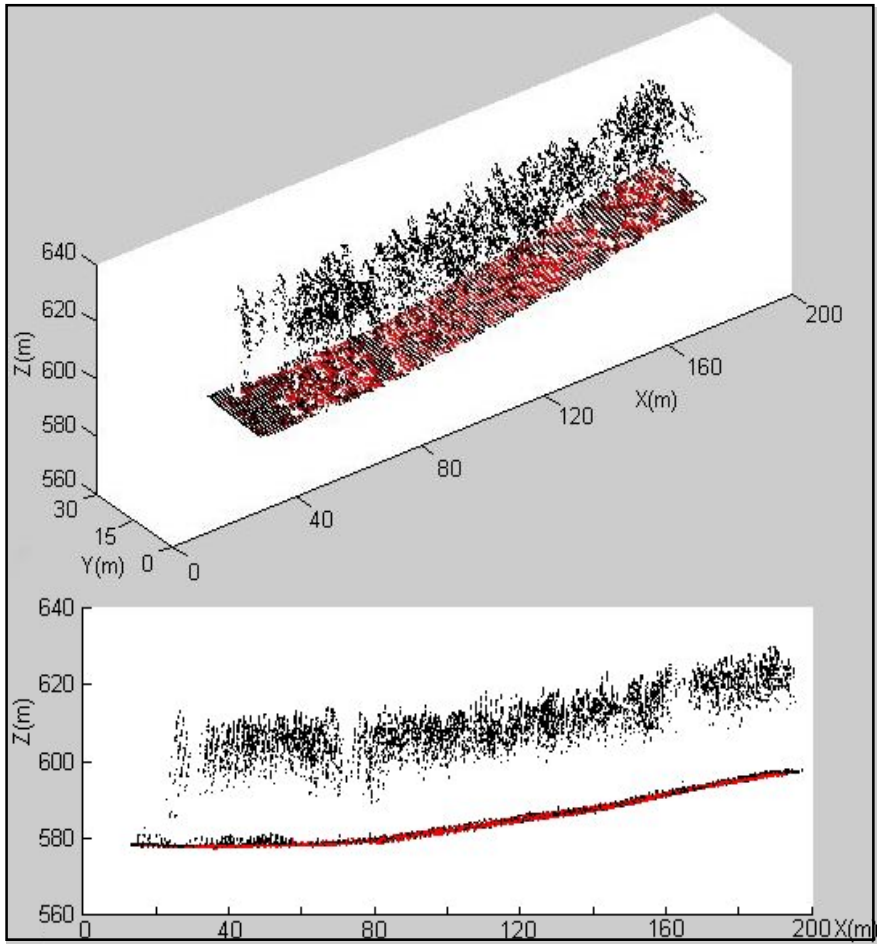
159°F

Increasing temperature

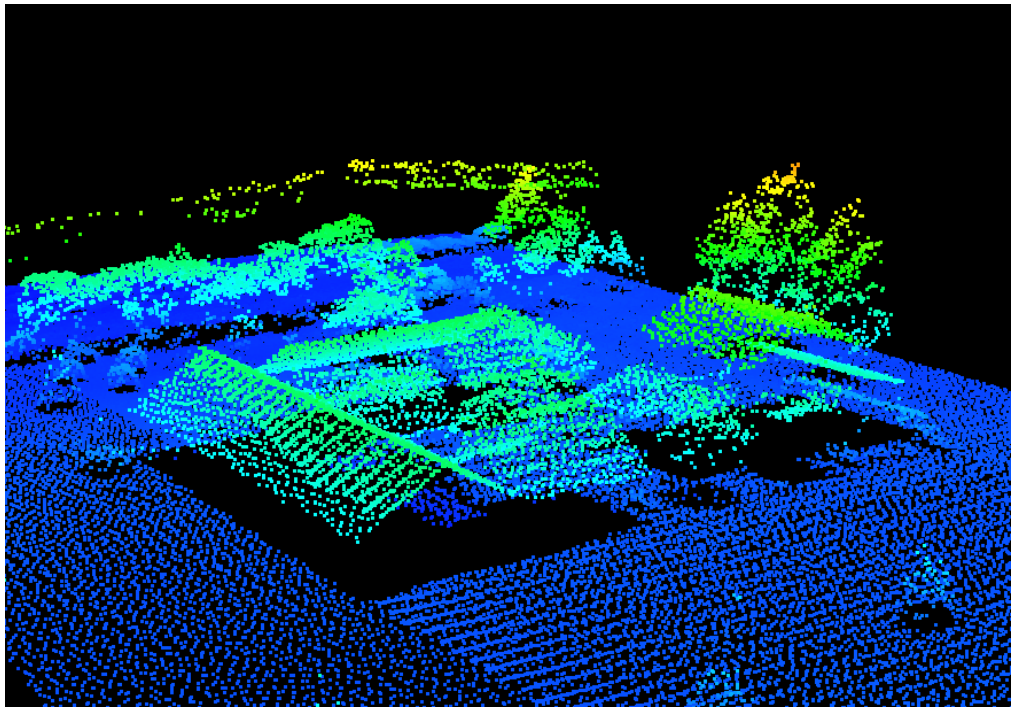
# Lidar Scanning provides topographic information and canopy structure




Riaño et al., 2004



Optech Orion H300 LiDAR system

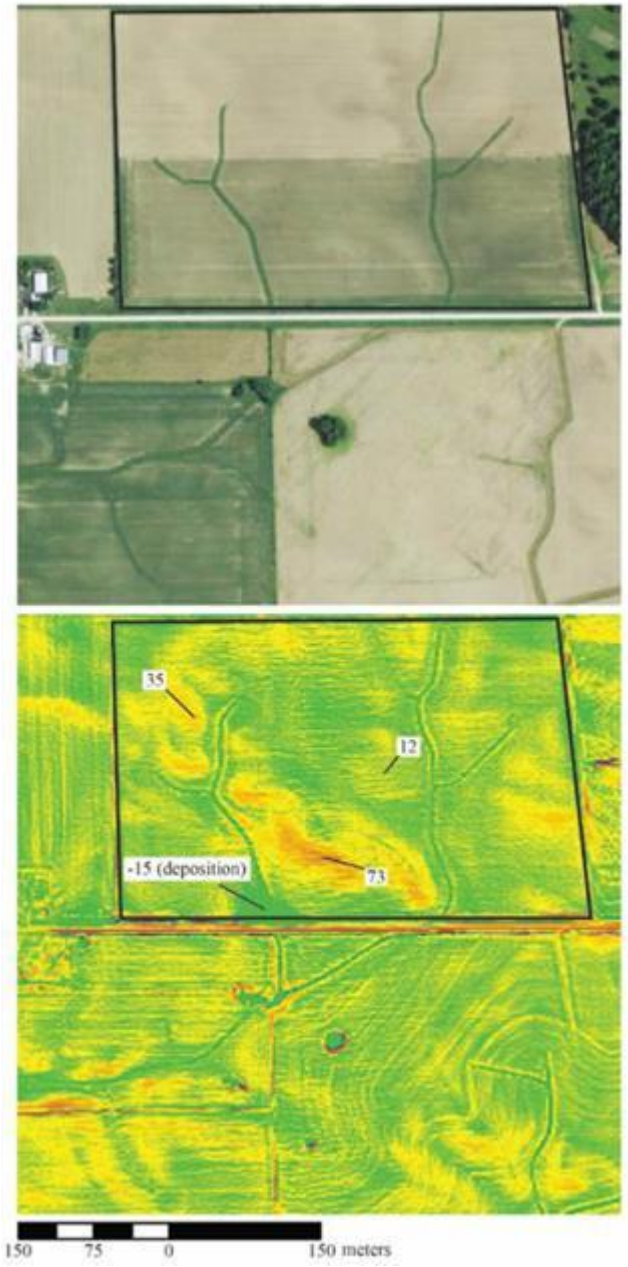
Lidar height image (by color) for a farm

Uniformity of crop growth

Soil drainage and erosion patterns

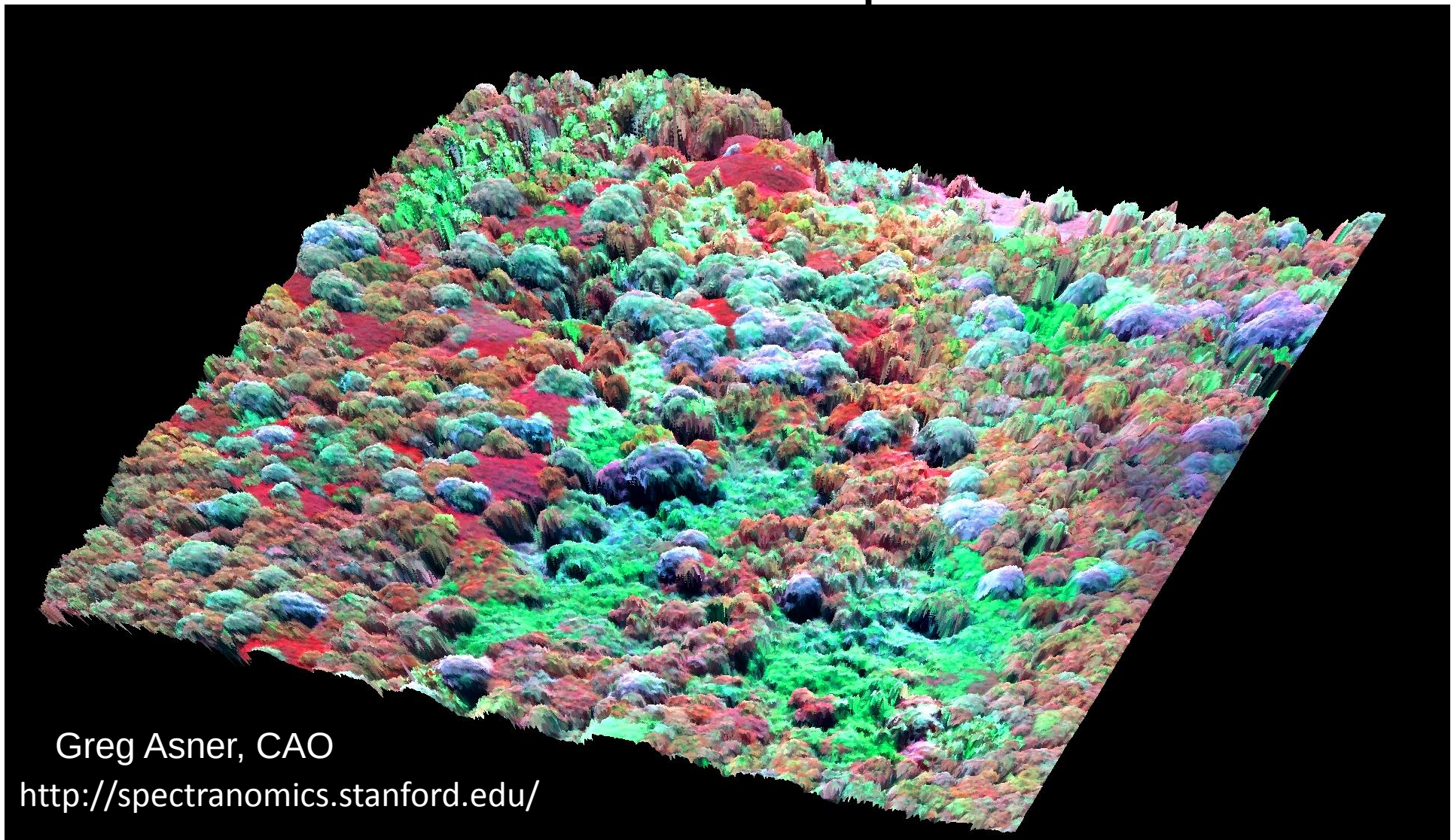
True Color

Lidar topography
Area average
Erosion rate is
3 tons /yr




Images from Minnesota Geospatial Information Office

# Mapping Biodiversity from Canopy Chemistry In Tropical Forest Canopies



Greg Asner, CAO
http://spectranomics.stanford.edu/

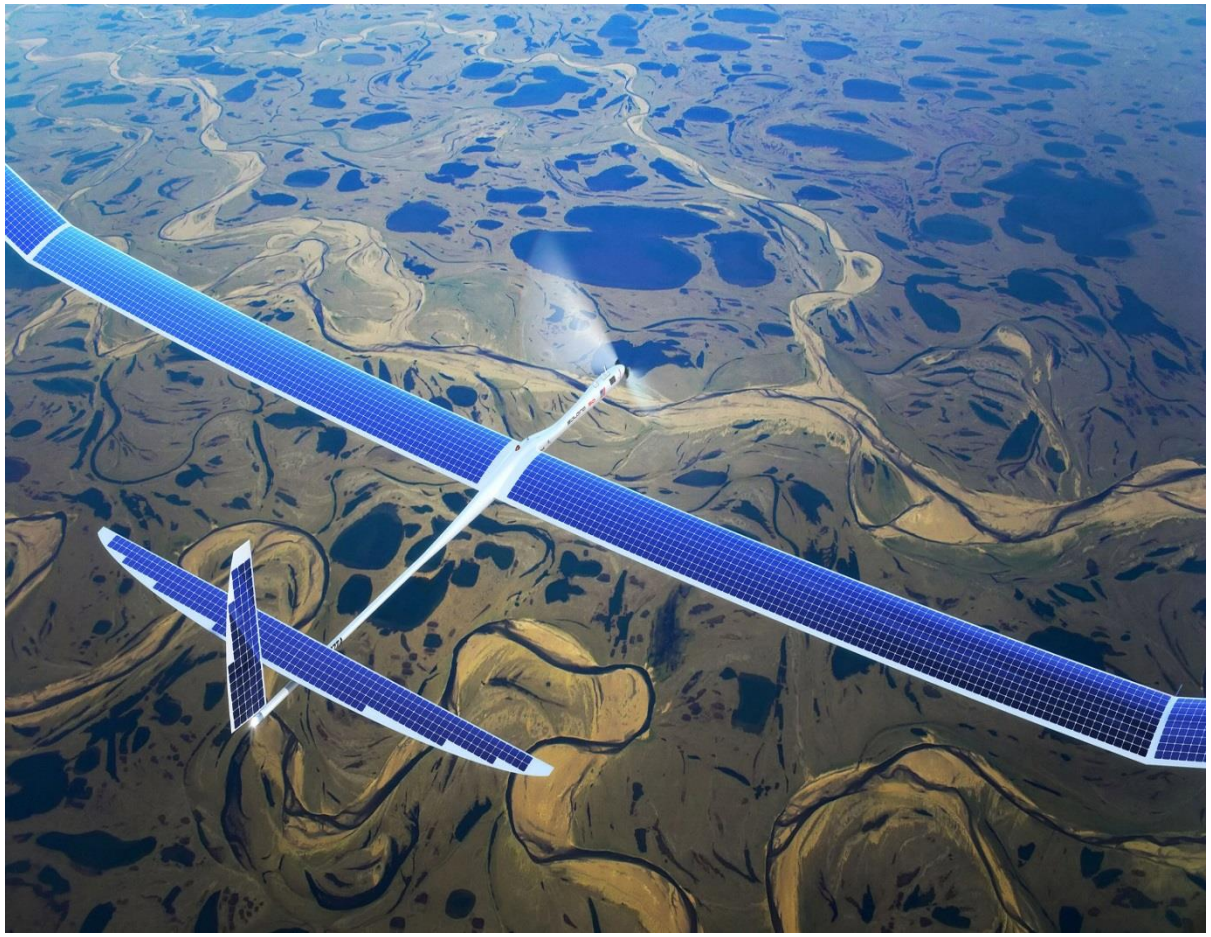
Fusion of LiDAR and Imaging Spectrometry

# Pesticide applications

Ken Giles, UC Davis

# The Future?

UAVs  solar powered



Fleets of personalized satellites