Remote sensing of plant water status using satellite, airborne and UAV imagery: What does it mean for you?

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Remote Sensing Instruments

Satellite

Manned aircrafts

Unmanned Aerial Vehicles (UAV)

Multispectral, Thermal
Landsat, Sentinel 2

Worldview 3
Planet Labs

Spatial resolution
Spectral resolution
Temporal resolution

Sensor Types

Multispectral, Hyperspectral
Thermal, LiDAR

Slide from Joaquim Bellvert-Rios

Plant based-sensors

Shortcomings of the Pressure Chamber

1) Manual method; can't be automated
2) Requires field visit with operator
3) Limited time period to take measurements; ~11am - 2 pm

How to adequately characterize variability in a field?

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Meteorological sensors

Weather station

Eddy flux measurement station

Shortcomings of weather stations and Eddy correlation flux stations

1) Measurements at only one location (or few)
2) Instruments need frequent calibration and attention; data complex to analyze
3) Measures continuously but much data is discarded due to wind direction and low wind speed

How to adequately characterize variability in a field?

Carneros Vineyard, Napa Valley

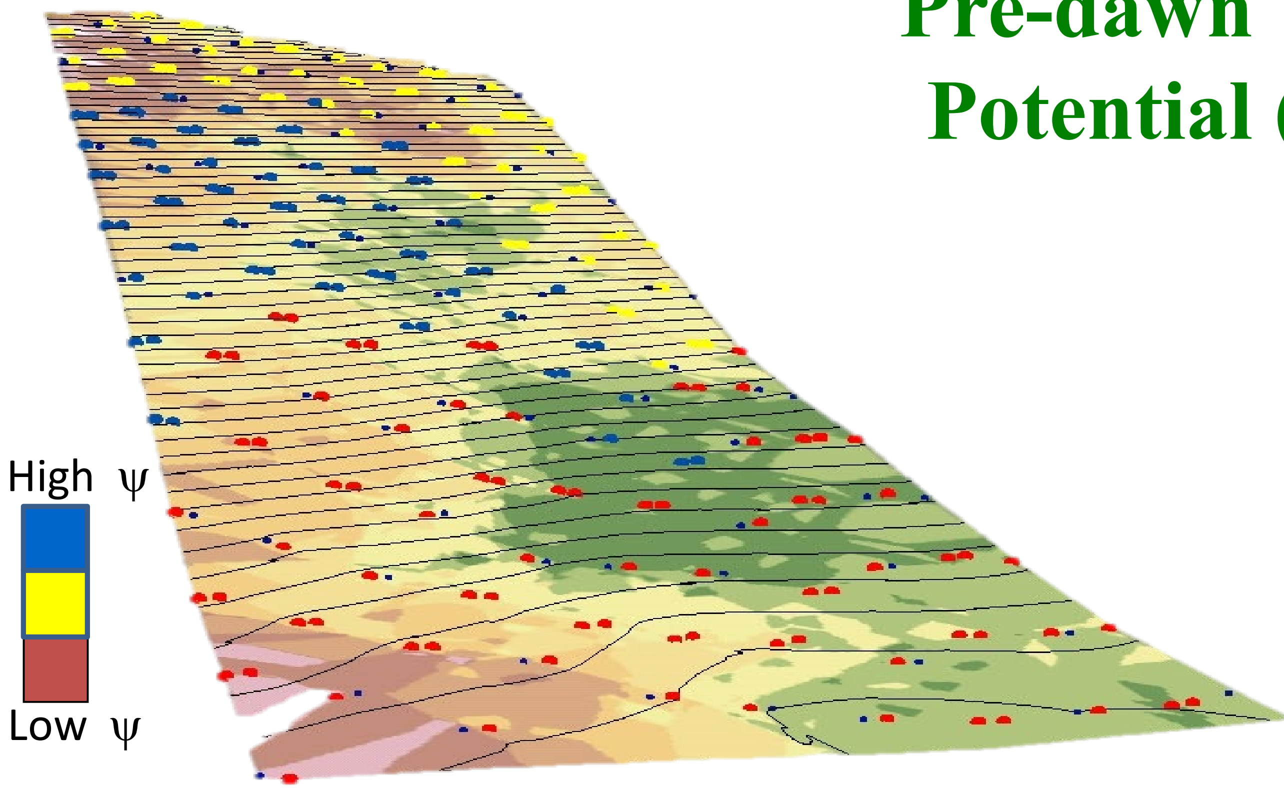
Slide from David Smart, UCD

16 Ac (6.5 Ha) Pinot noir Vineyard in the Carneros Region of Napa Valley

Slide from David Smart, UCD

Hyperspectral Aerial Imagery: a Precision Farming Tool to Support Zonal Management

Spatial Heterogeneity in Pre-dawn Water Potential (ψ_{PD})

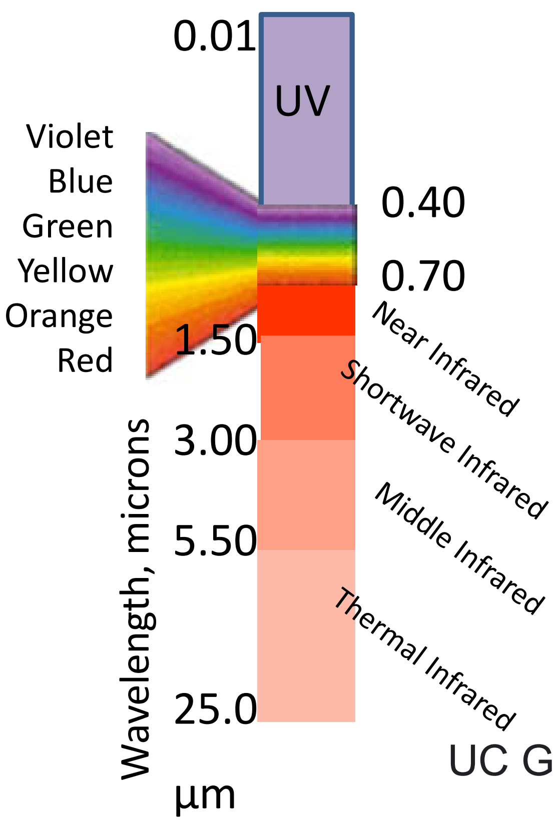


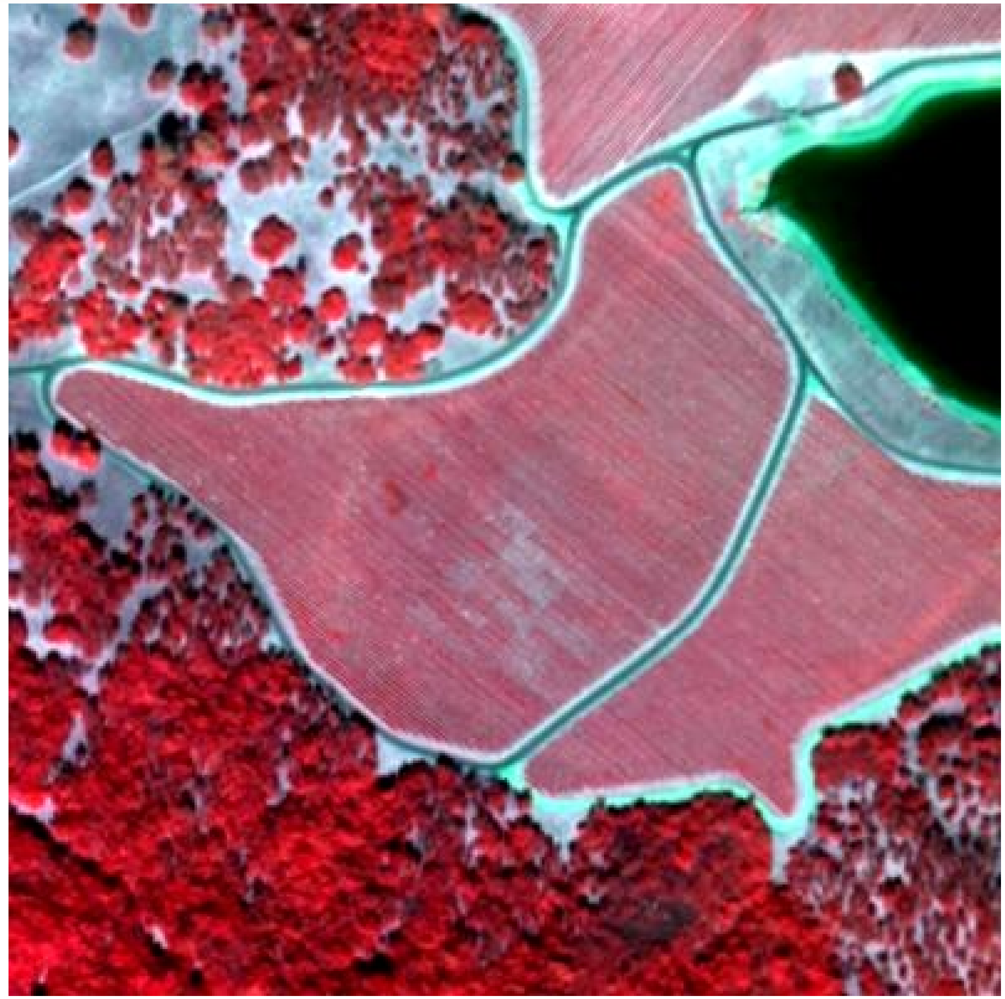
Slide from David Smart, UCD

Remote Sensing Spectral Measurements

Color Infrared Image

Spectral bands	Display color
Green	Blue
Red	Green
Near-infrared	Red

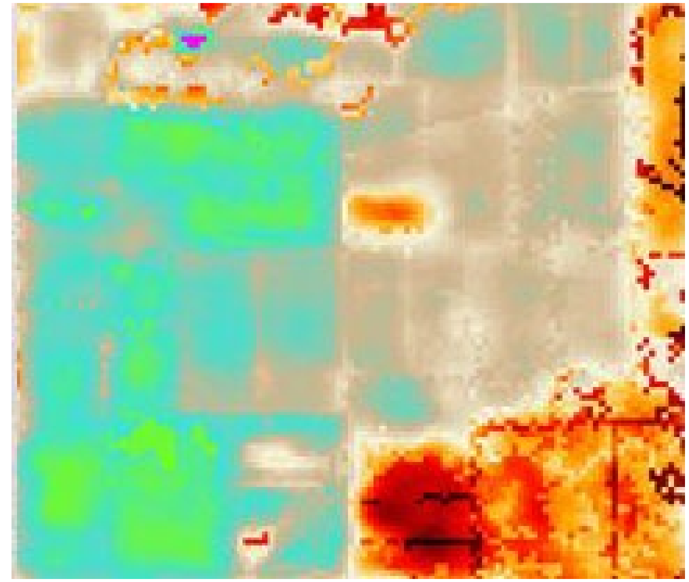




Gallo Vineyards, Sonoma County, ADAR-5500

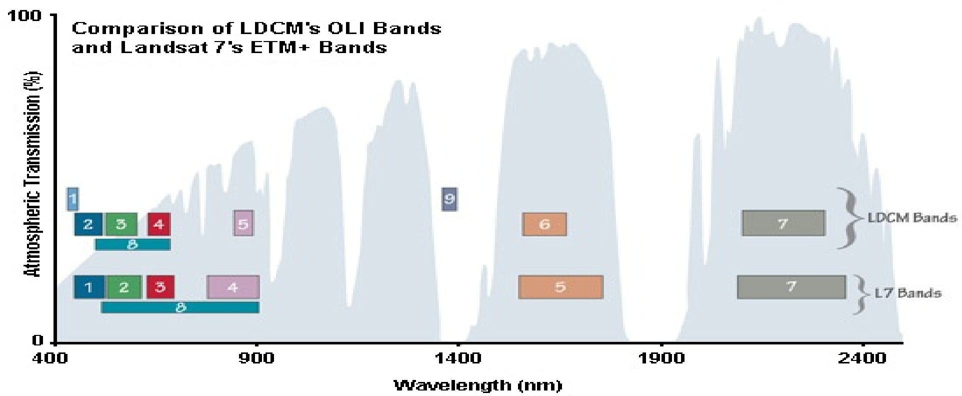
Landsat Multispectral Satellites, public domain 30m pixels

Available since early 1970s, Landsat 5 launched in 1984, Landsat 7 in 1999 and Landsat 8 in 2013, Landsat 9 expected end 2019.
All have 30m pixel resolution.



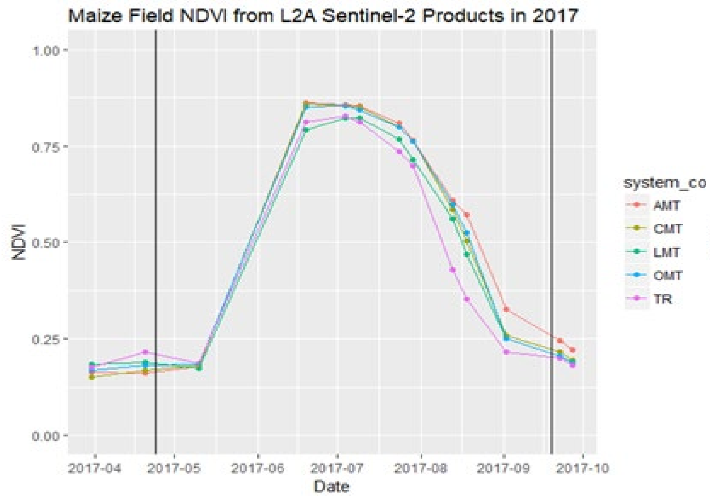
Landsat image used to identify location of vegetation and scale Evapotranspiration using the METRIC model

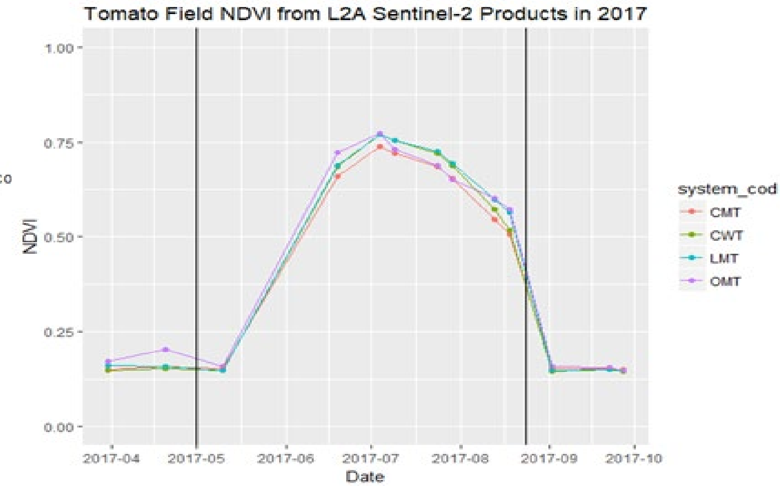
Evapotranspiration from Gallo vineyards in Lodi, California, measured using an adjusted form of METRIC. Lower evapotranspiration is shown in red and higher is in blue. Courtesy of E. and J. Gallo. From https://www.usgs.gov/centers/fort/science/agriculture-landsat-imagery-a-unique-resource?qt-science_center_objects=0#qt-science_center_objects

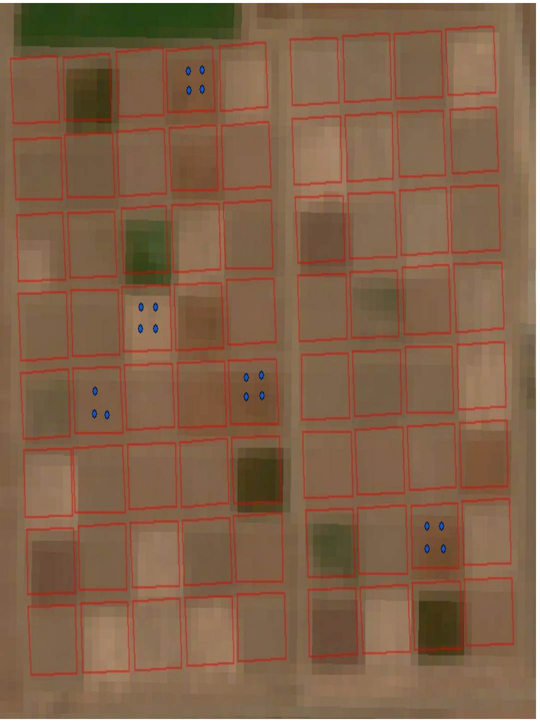


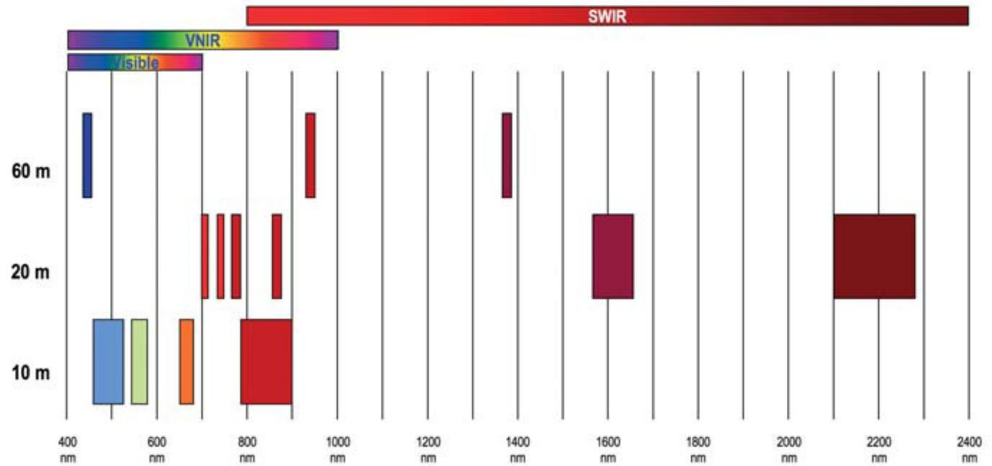
Sentinel 2 data from the European Space Agency, Public domain; data every 5 days

	tomato_mac	tomato_gre	tomato_vin
2016-05-15	0.38		0.35
2016-06-24	0.9	0.57	0.91
2016-07-14	0.91	0.7	0.92
2016-08-03	0.91	0.84	0.88
2016-08-23	0.48	0.62	0.33
NDVI_mean	0.96	0.81	0.9
NDVI_max	0.91	0.57	0.91

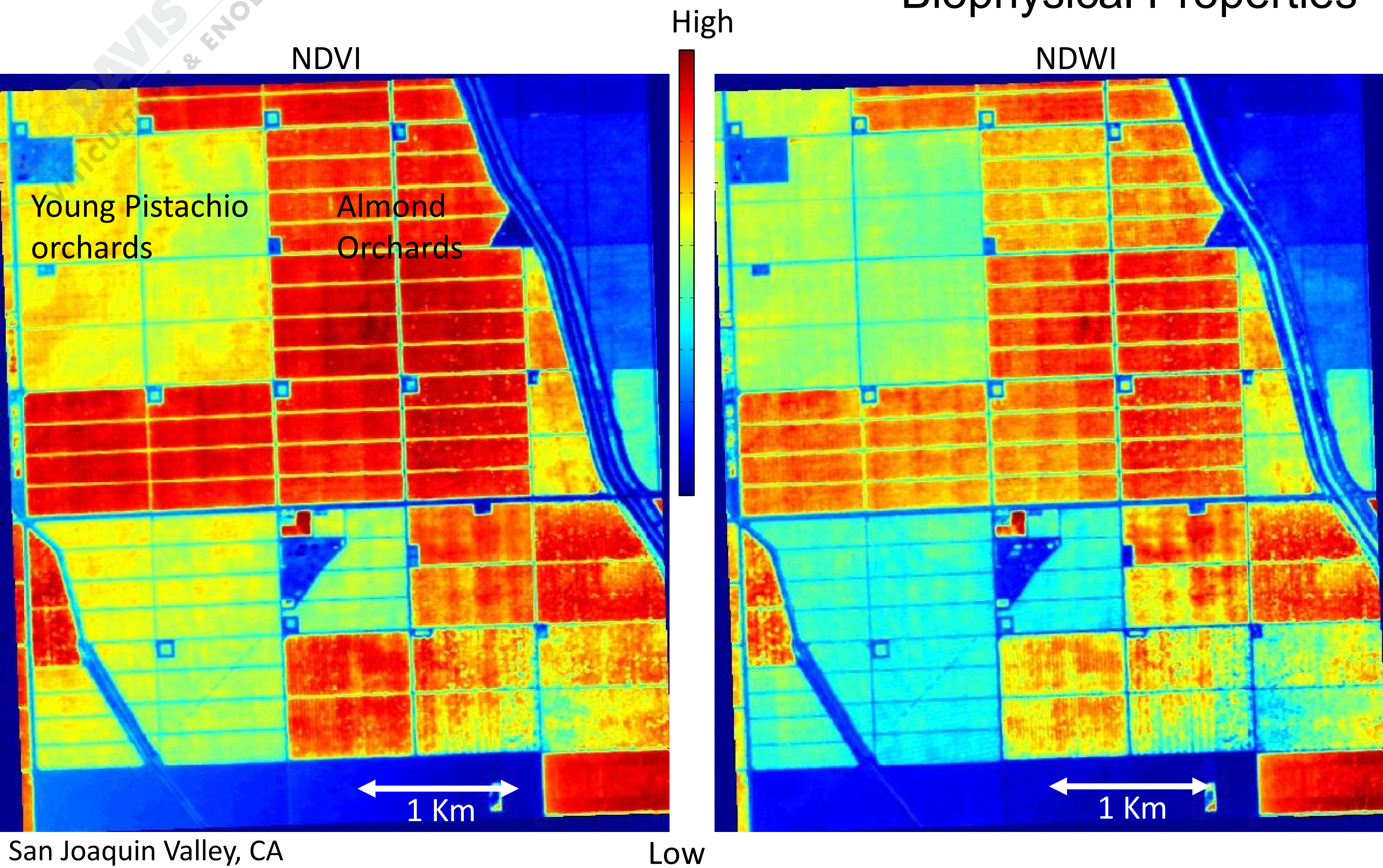






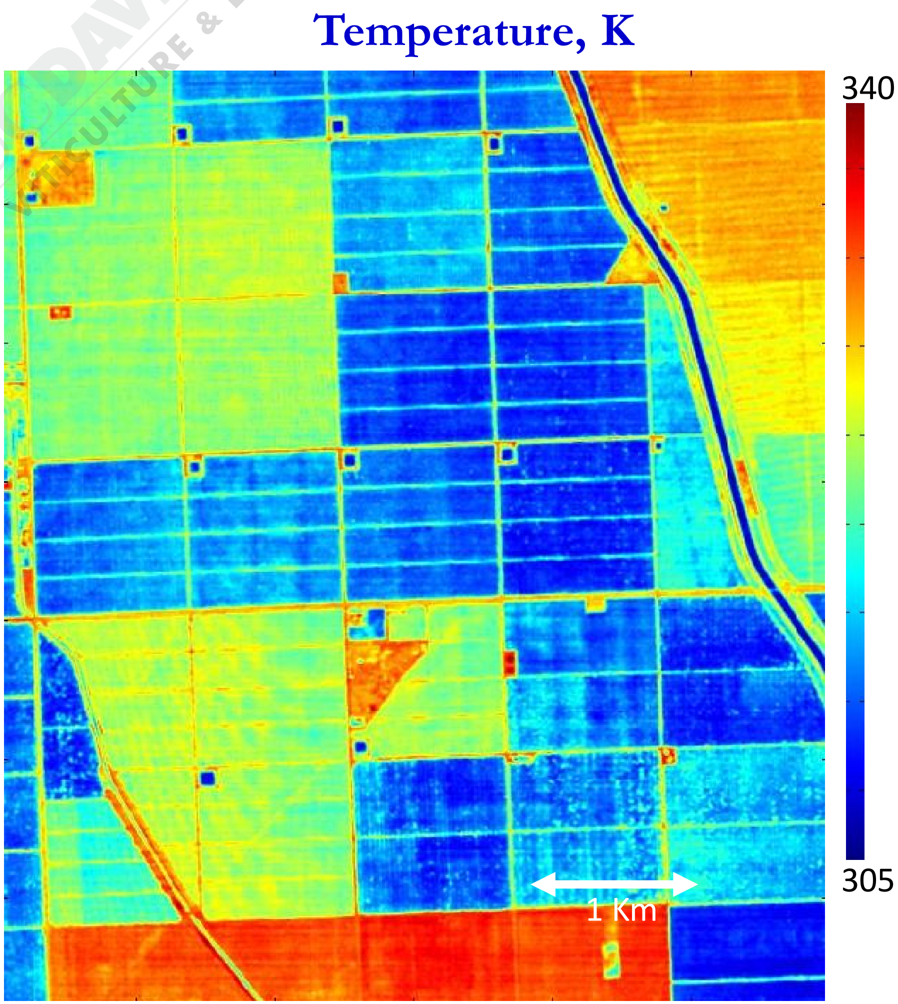


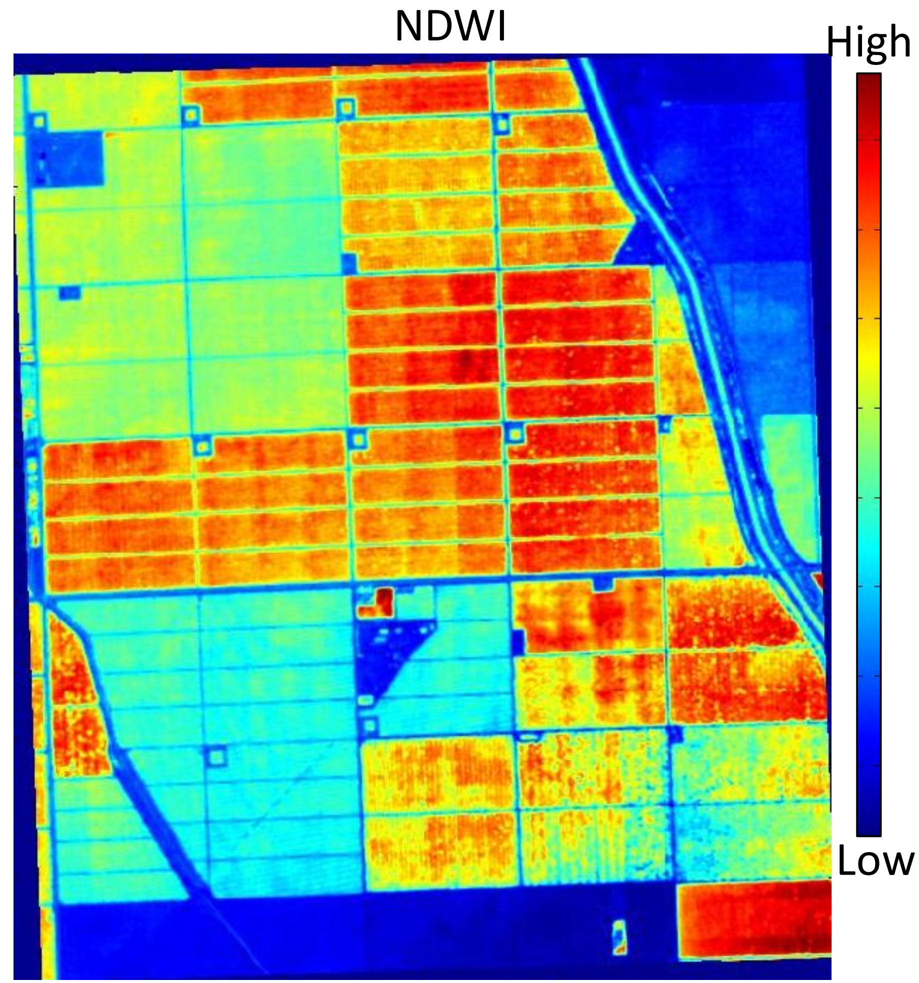
NDVI Patterns Are Only Partially Correlated with Other Leaf Biophysical Properties



San Joaquin Valley, CA
July, 2009, NASA Airborne
MASTER sensor

B. Remote Sensing and Relevant GIS Data: b. Emitted thermal infrared

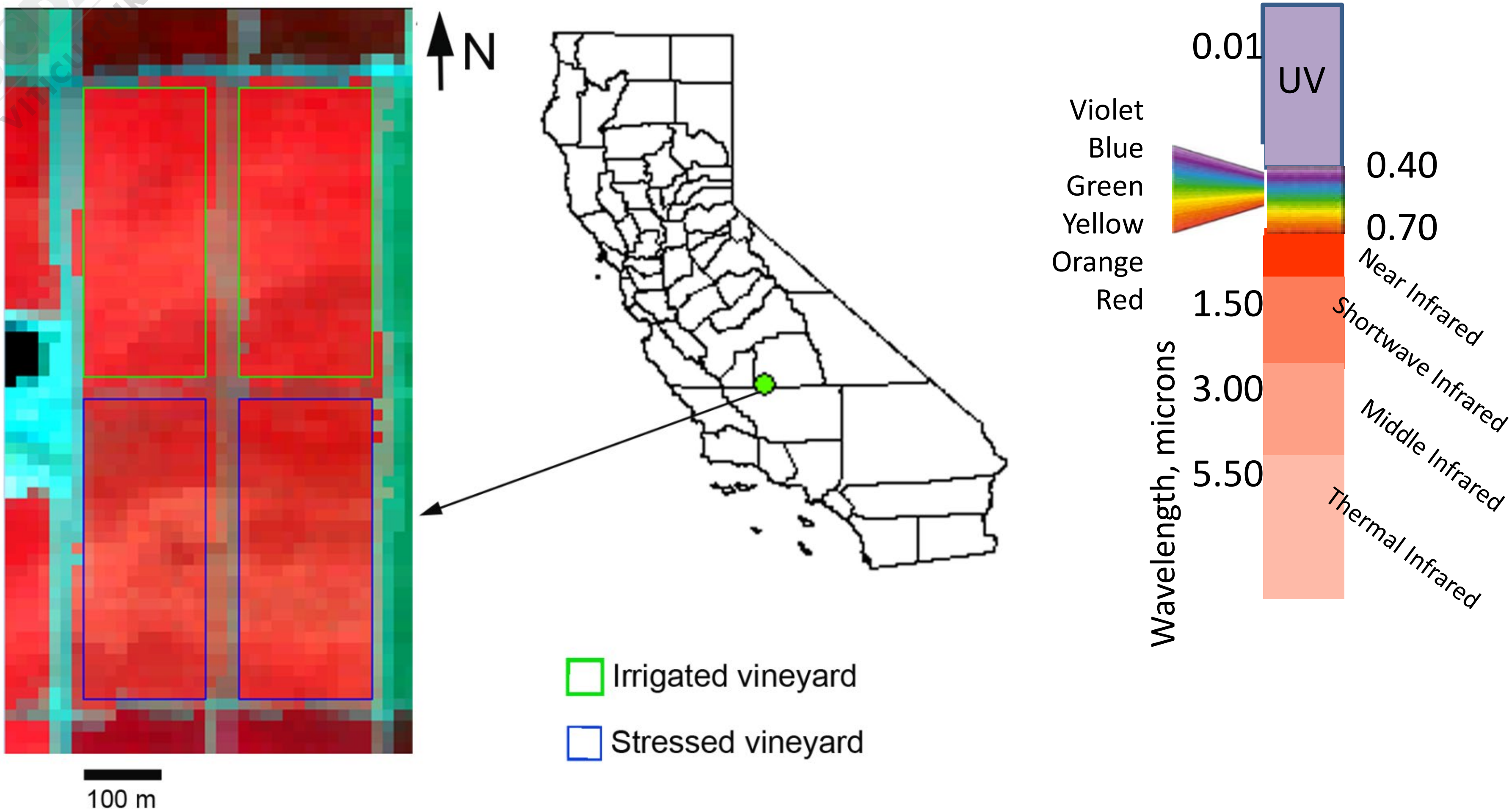




Normalized by density of green foliage , blocks can have different temperatures but nearly the same water stress, or the same temperature and different water stress.

Airborne MASTER, July 2009

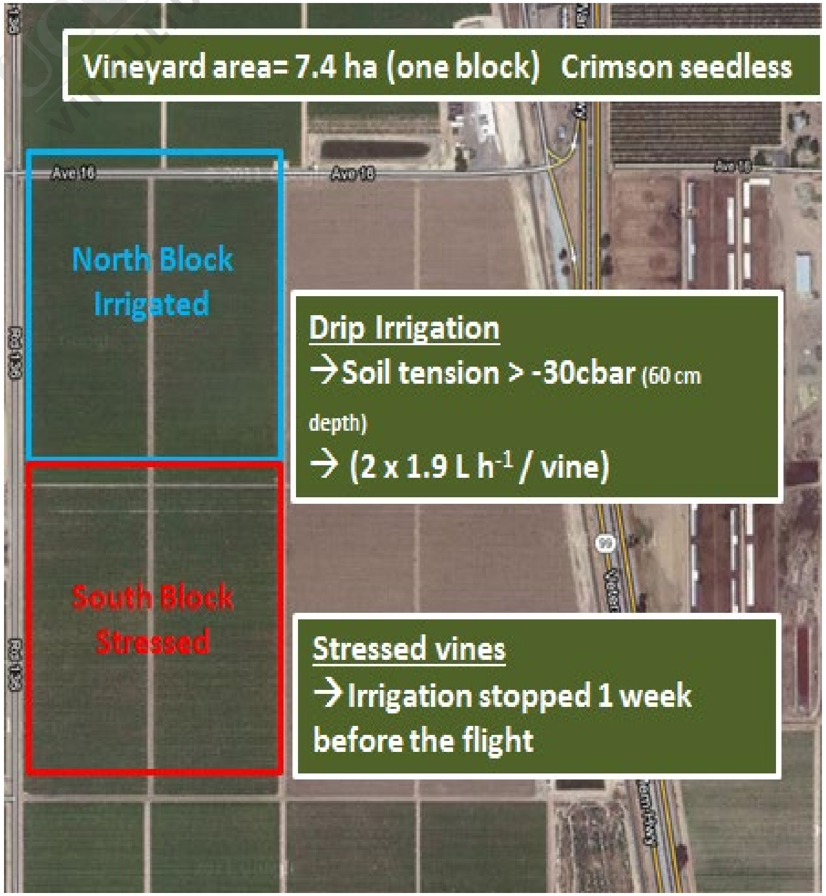
Table Grape Vineyards in the San Joaquin Valley



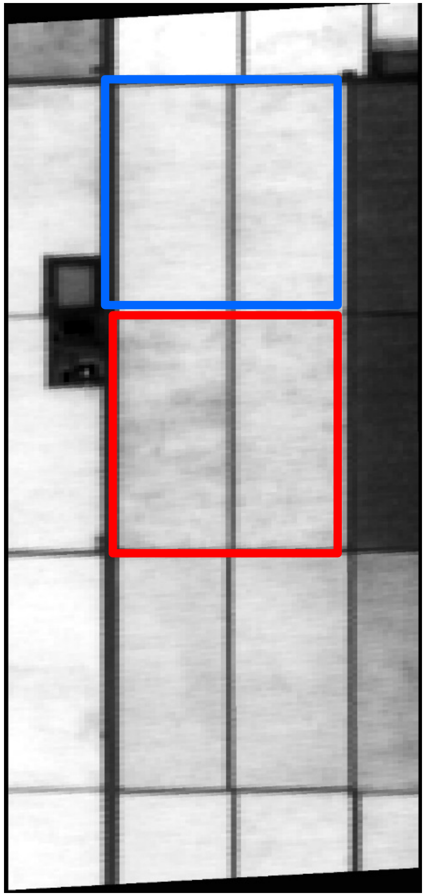
MASTER bands R: 860 nm, G: 650 nm, B: 550 nm

Collaborative project with David Smart, UCD

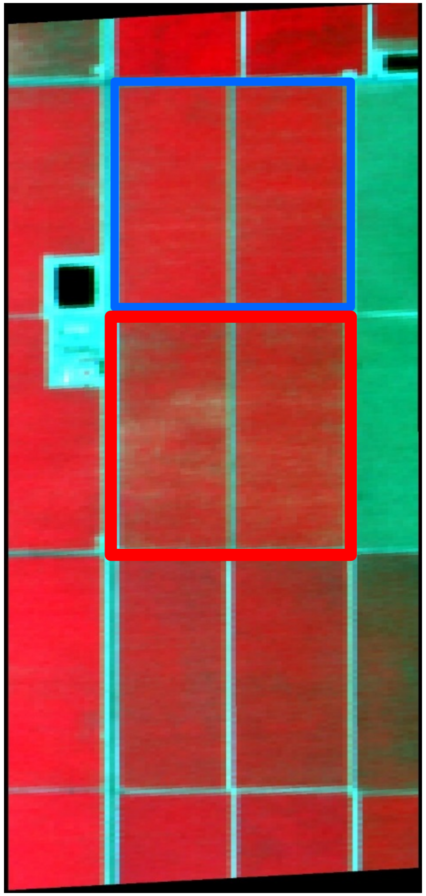
Detecting Water Limitation Stress in Vines using Simple band ratios and Color Infrared



NDVI



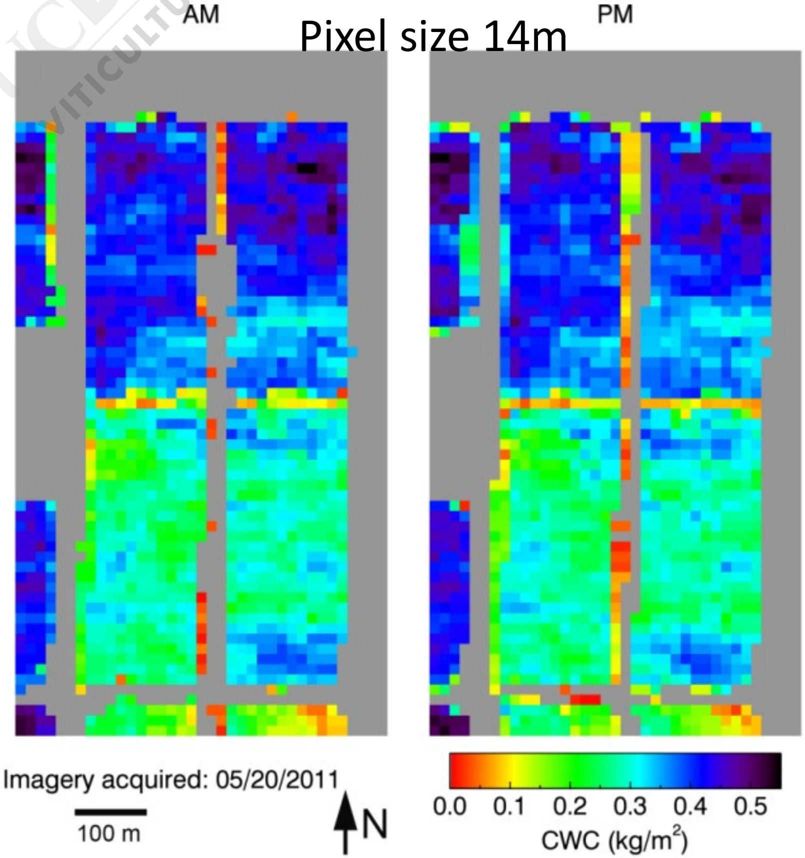
Color IR

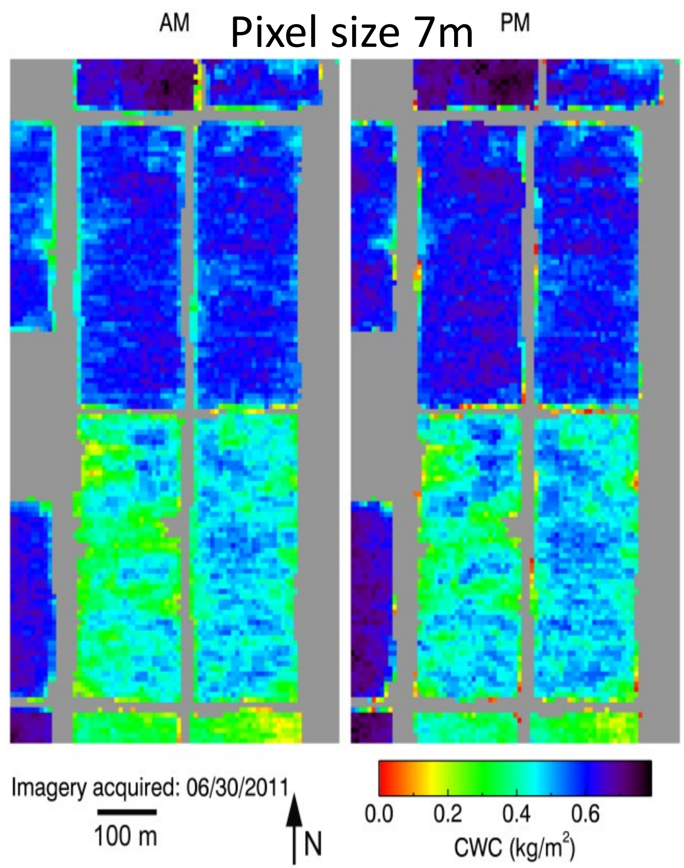


Collaborative project with David Smart, UCD

Canopy Water Content (CWC) Maps:

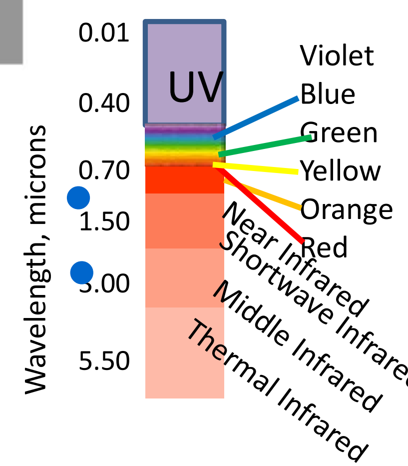
Vineyard Differences (05/20/11) after 5 days of withholding water and 1 month later (06/30/11)





The effect of mild water stress for 5 days, led to large differences in canopy water content.

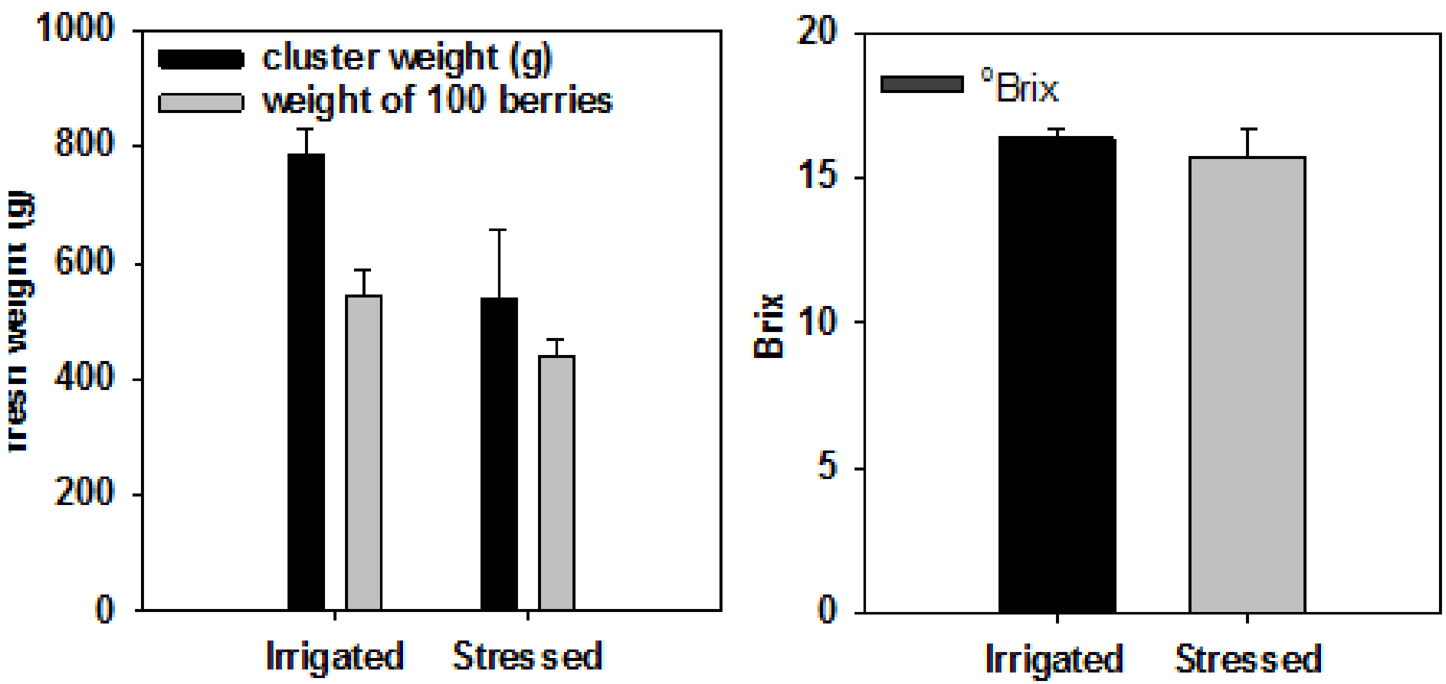
At harvest, grape clusters were smaller and grapes weighed less than the control vineyard.



*CWC calculated by regression between DNII and field measured Leaf Water Content (R^2=0.70) x Leaf Area Index (R^2=0.70)

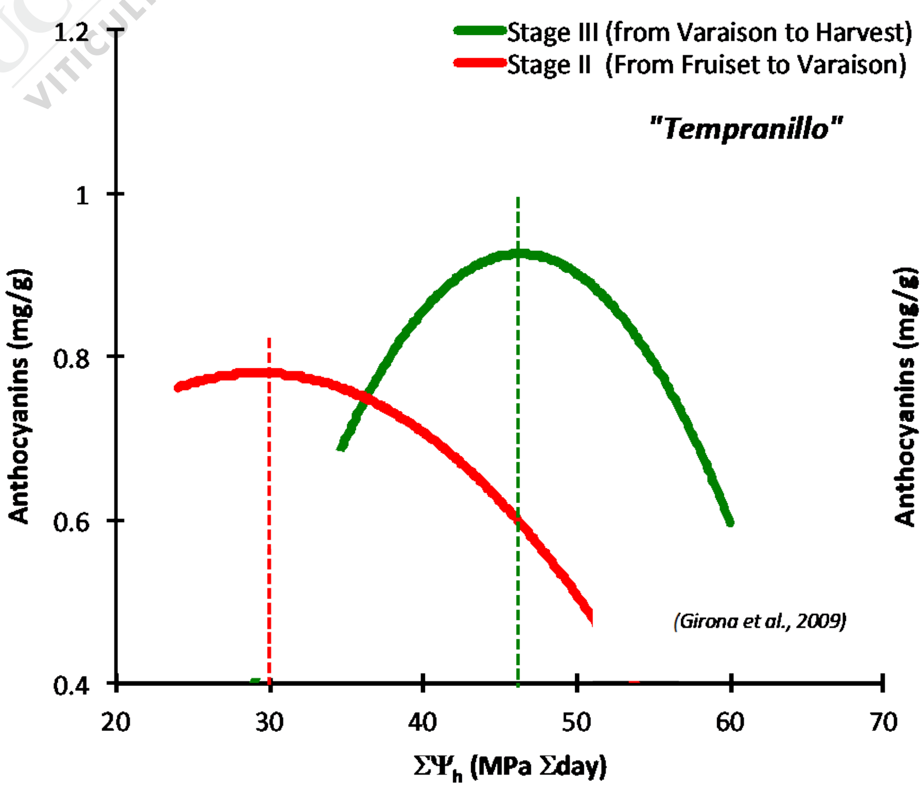
M.M. Alsina et. Al. 2012. ECPA Llieda-def

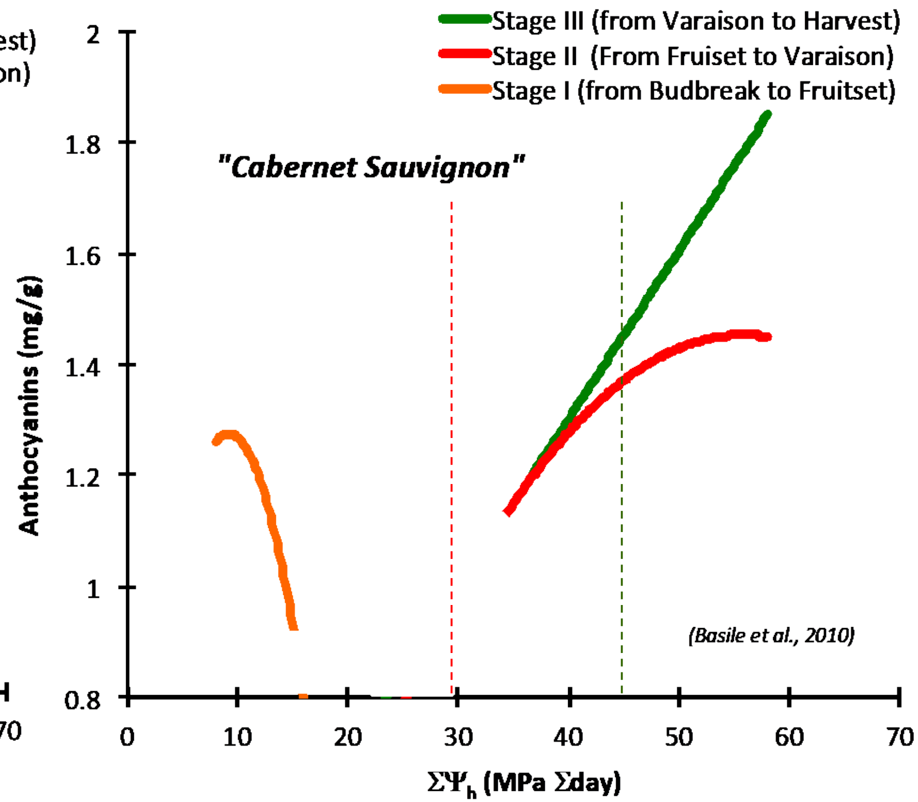
Effect of 5 day Irrigation Deficit in May on Grape Yield



Collaborative project with David Smart, UCD

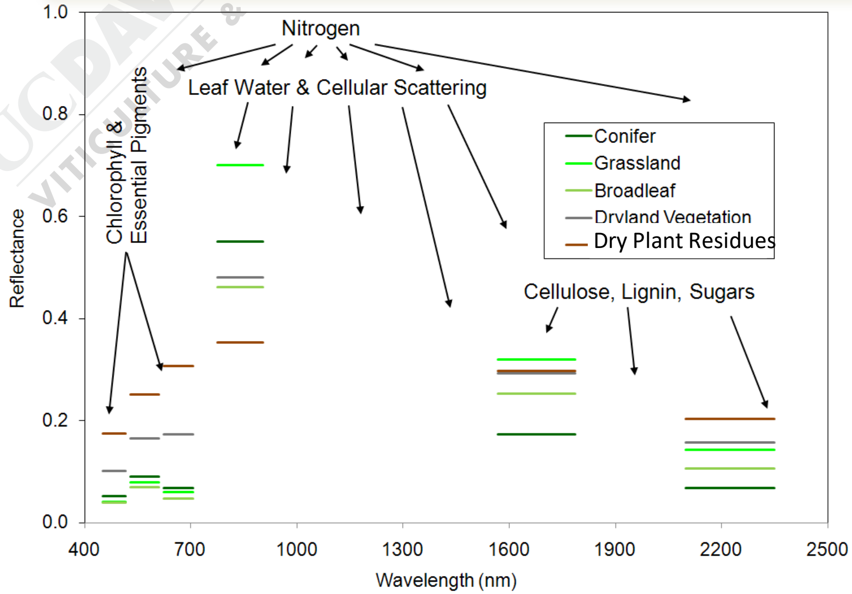
Seasonal Sensitivity to Water Stress in Wine Grapes





Variable Response with Stage and Varietal

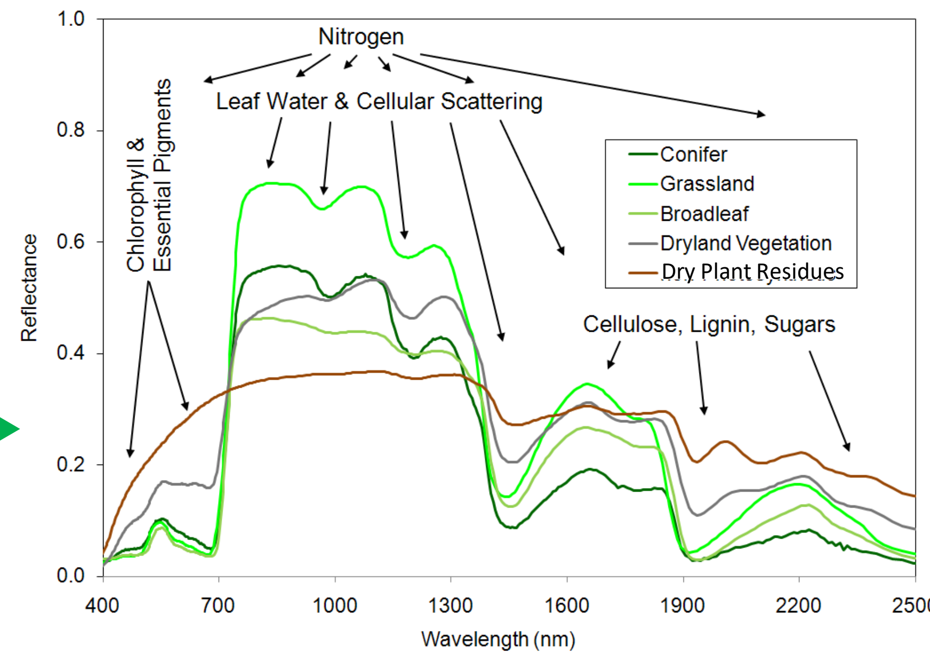
Imaging Spectroscopy vs. Multispectral Instruments



Multi-spectral imaging usually measures 3-6 bands, some information useful for management is missed

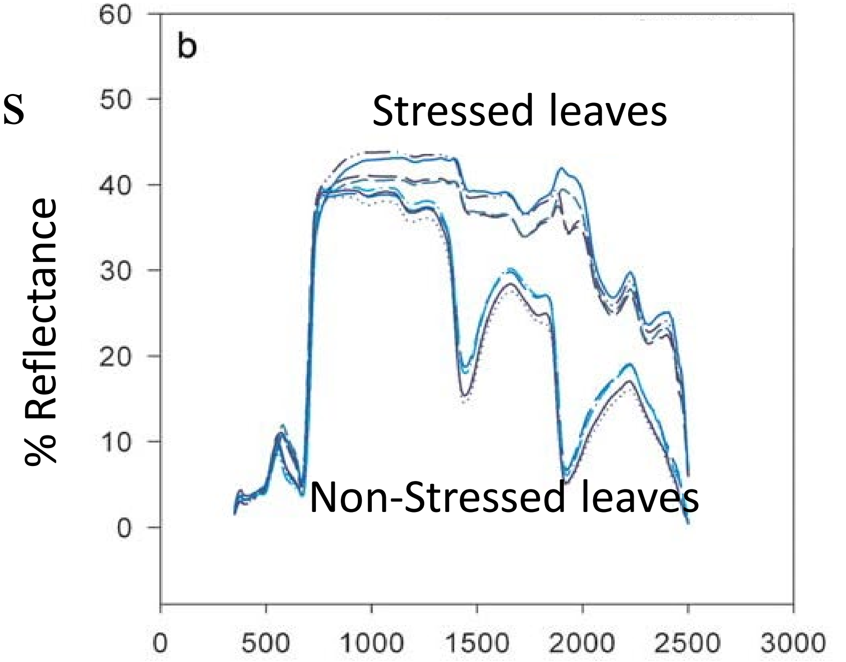
Imaging Spectroscopy measures the full spectrum

measurement contains more information for management

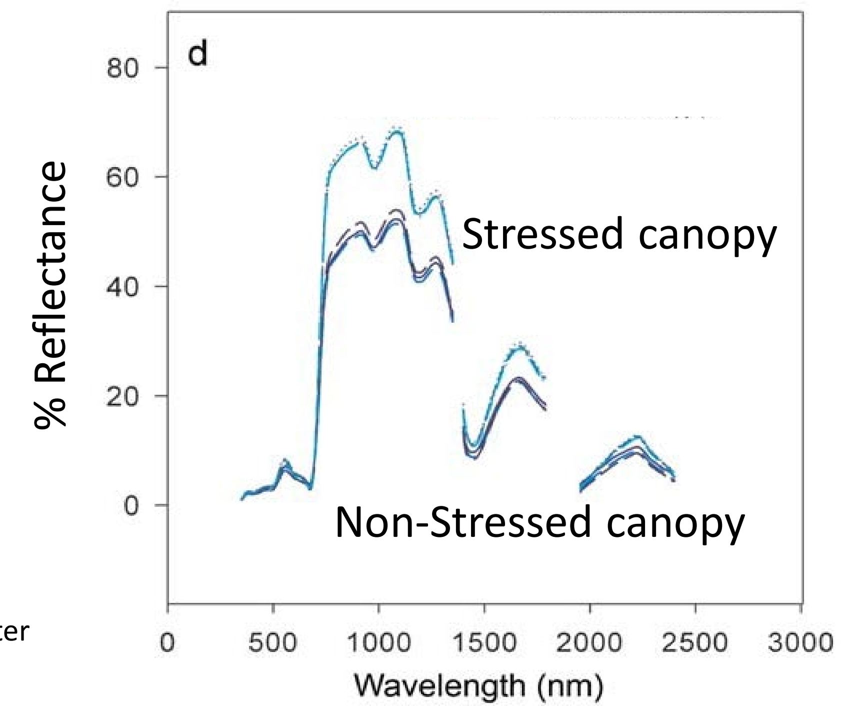


Detection of water stress at leaf and canopy scales measured on 125 leaves and canopies in a vineyard of *Vitis vinifera* cv. Pinot noir.

(**b**) Average reflectance of leaves from 4 stressed vines (Ψstem - Ψ PD <-0.85 MPa) and 4 non-stressed vines (Ψ stem - Ψ PD >-0.45 MPa).



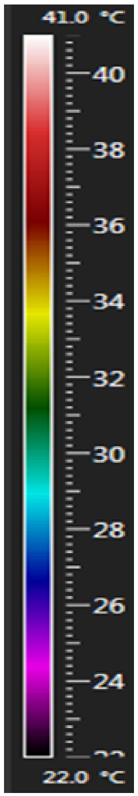
Average reflectance of 4 stressed vines (Ψstem - Ψ PD <-0.85 MPa) and four nonstressed vines (Ψ stem - Ψ PD >-0.47 MPa), measured at heights of 0.3, 0.5, and 0.7 m.

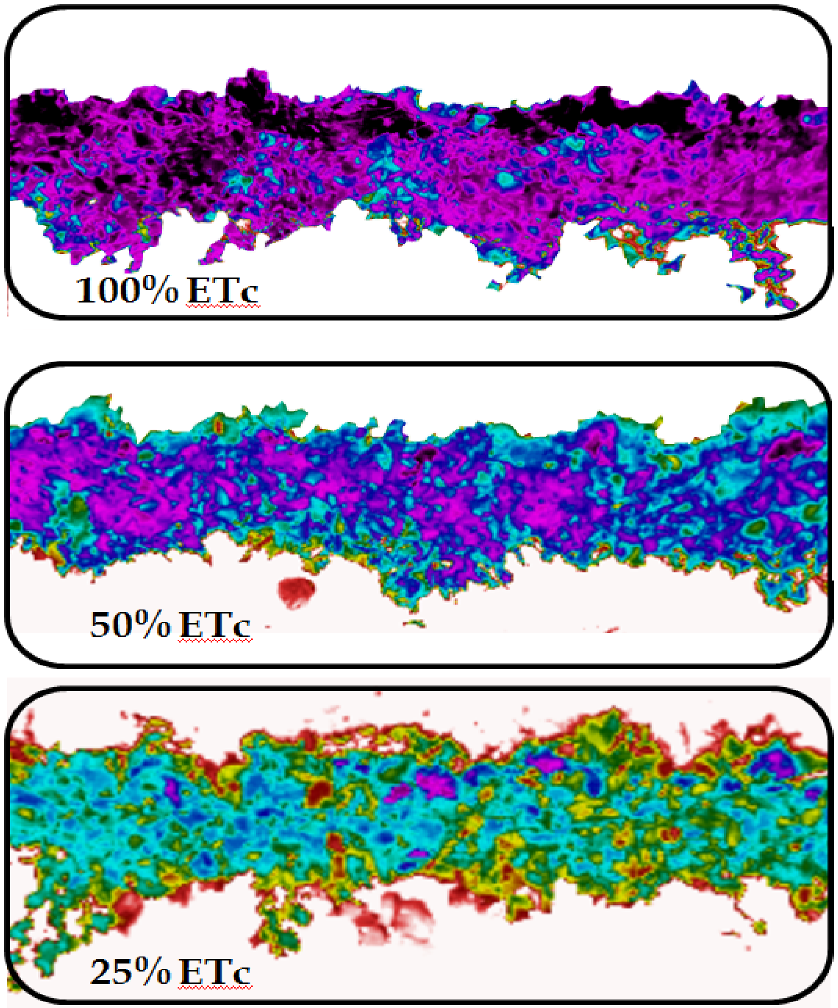


JR Rodríguez-Pérez, D Riaño, E Carlisle, S Ustin, and DR. Smart 2007. Evaluation of Hyperspectral Reflectance Indexes to Detect Grapevine Water Status in Vineyards. Am. J. Enol. Vitic. 58:302-317 (2007)

Aerial Thermal Imagery: a Precision Farming Tool to Support Zonal Management

Air Temperature 77°F (25.0°C)





Canopy Temp: 75.7°F (24.3°C)

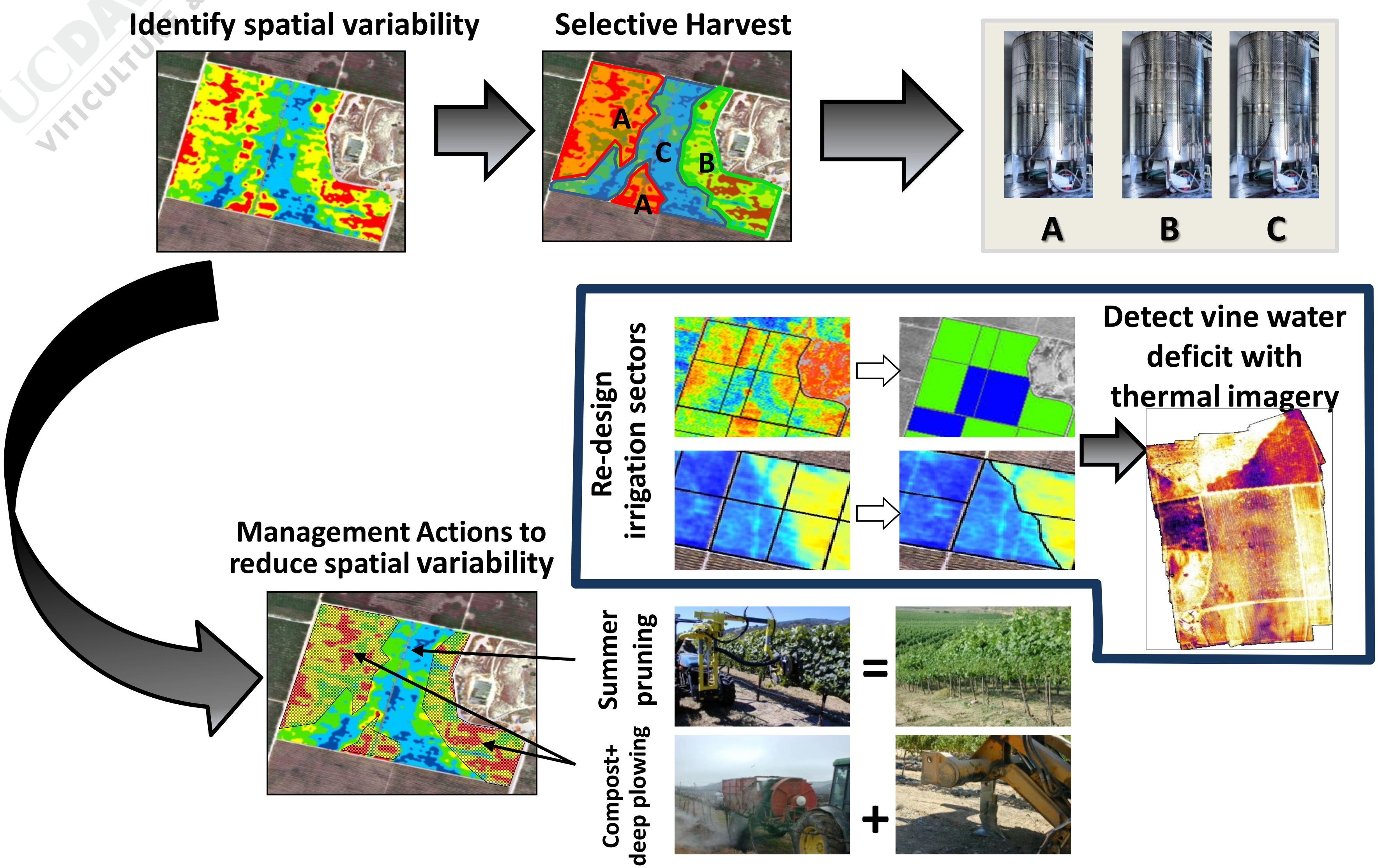
Canopy Temp: 81°F (27.2°C)

Canopy Temp: 87.4°F (30.8C)

IRTA RECERCA I TECNOLOGIA AGROALIMENTÀRIES

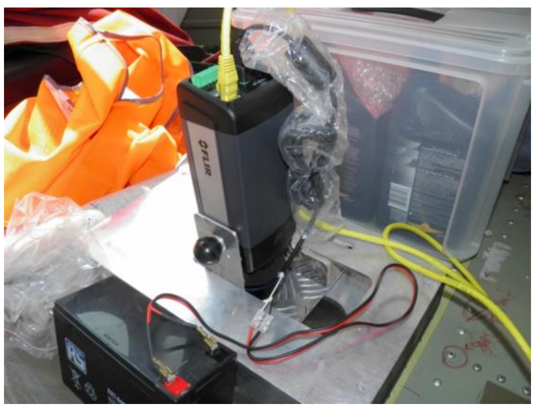
Slide from Joaquim Bellvert-Rios

Connecting Management Actions with Remote Sensing Imagery



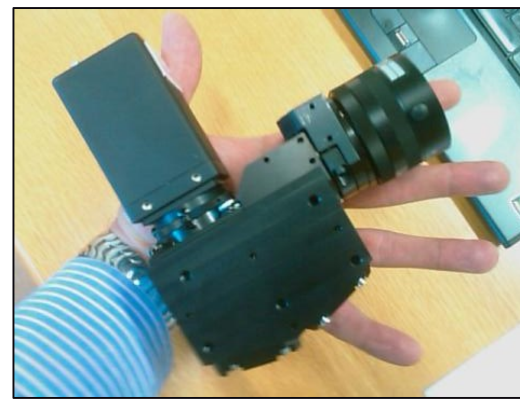
Slide from Joaquim Bellvert-Rios

Manned aircraft



FLIR SC-655

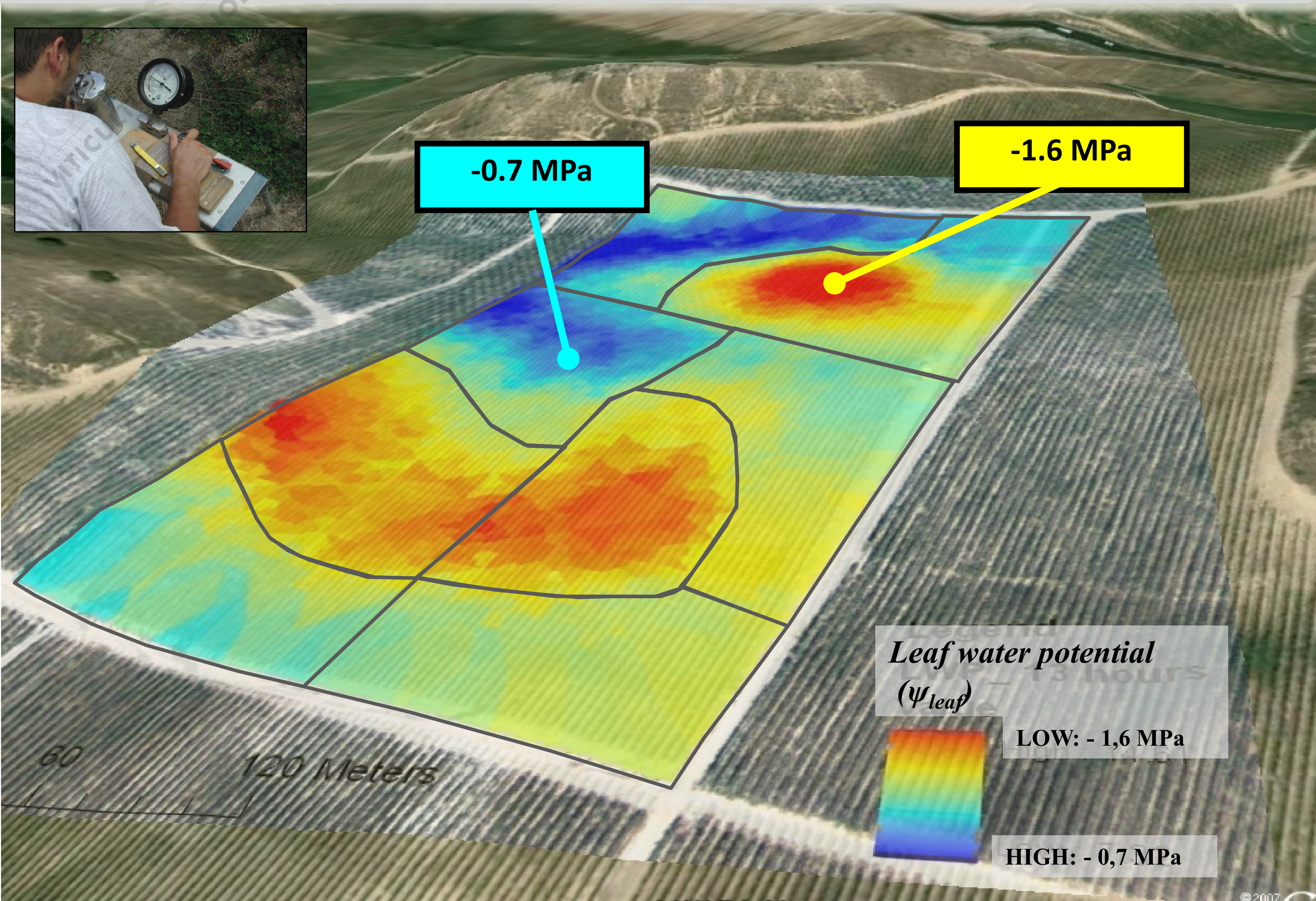
Field of view (FOV)	45º
Spectral range	7.5-13 µm
IR resolution	640 x 480 pixels
Detector pitch	17 µm



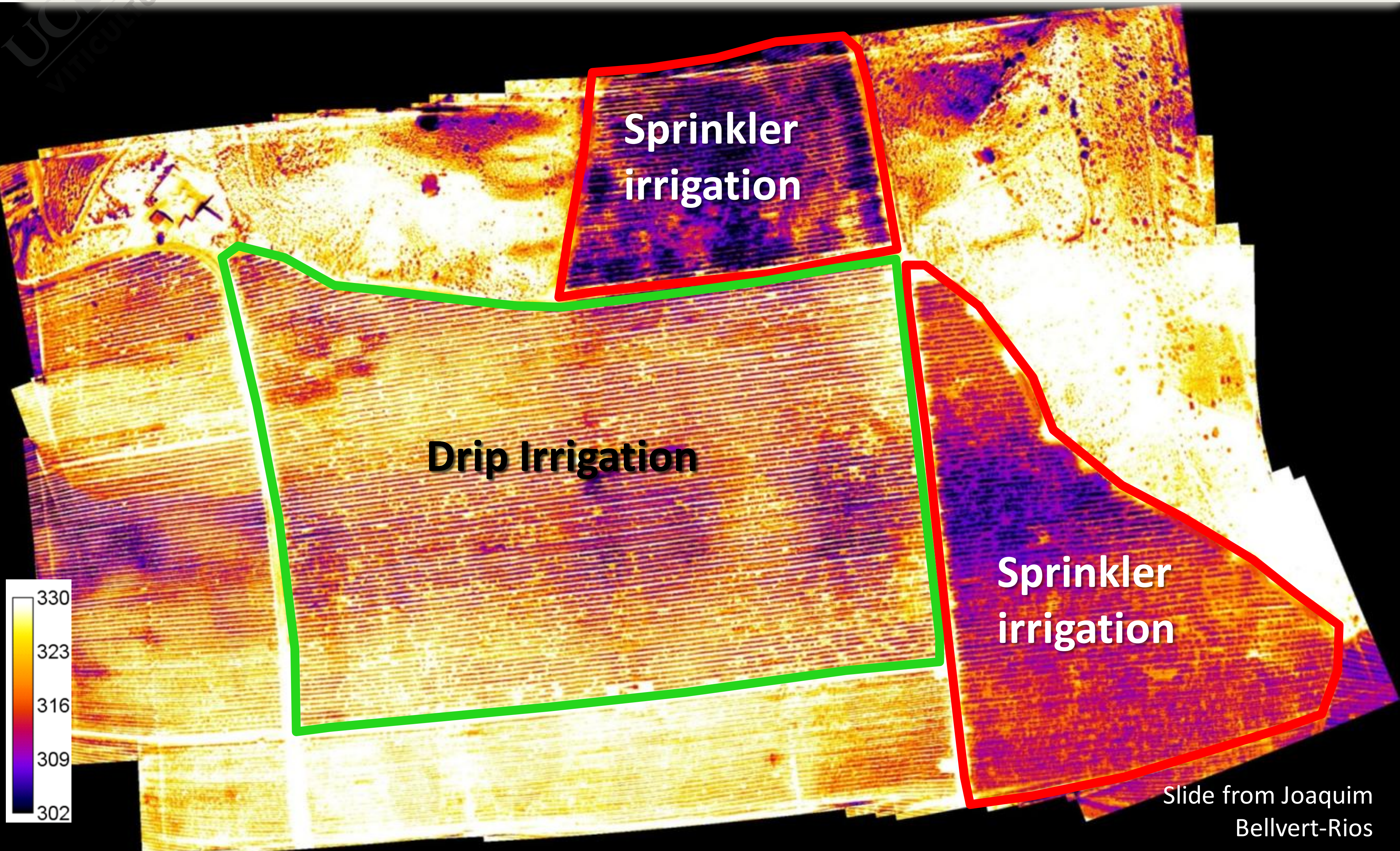
Microhyperspectral Camera
Headwall Photonics

Spectral range:	350-1000nm or 900-1700nm
Resolution	1004 x 1004 pixels
Radiometric resolution:	12 bit
Weight:	1 lb.

Spatial variability of vine water status in a 15-ha vineyard



Thermal Image Mosaic of 62 ac. (25 ha) vineyard, measured from a UAV in July 2009 at Raimat, Lleida (Spain)
3 hrs., 3700 ac., 8-12 in. pixels



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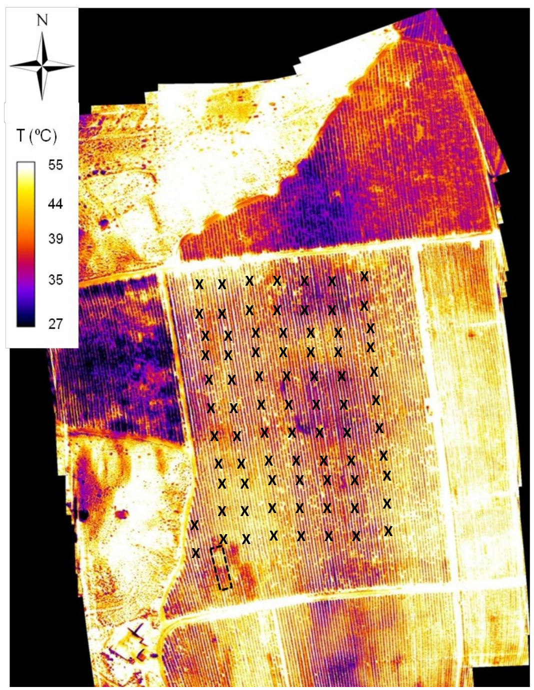
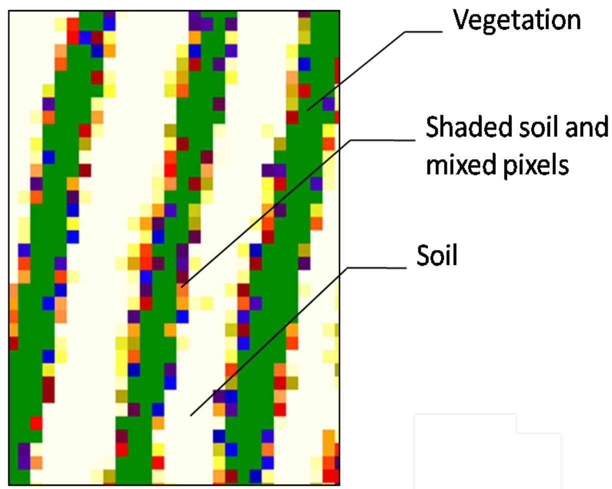
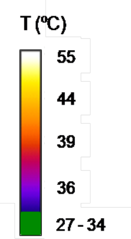
Relationship between Spatial Resolution and Temperature Estimates, Difference Leaf - Air

'Pinot-noir' grapevines

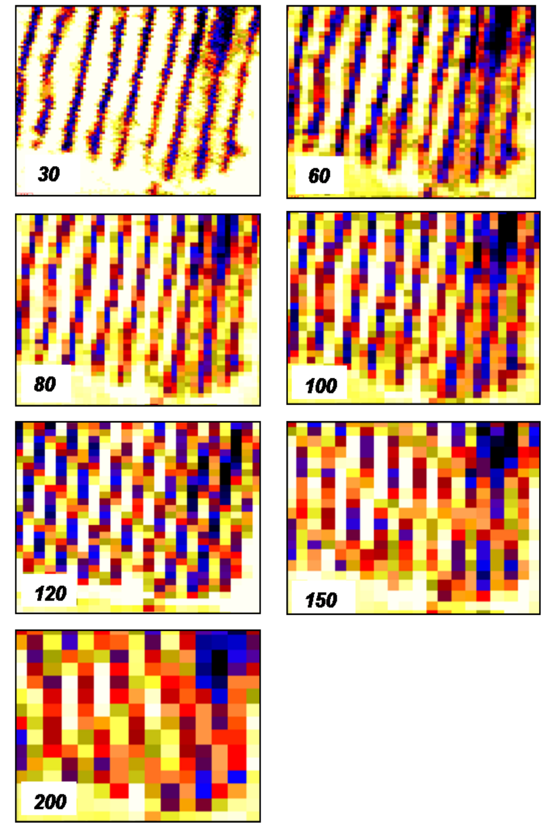




30 cm (R^2= 0.71)



Spatial Resolution



Other scales, R^2 =0.05-0.38

Slide from Joaquim Bellvert-Rios

Relationship between T_{leaf}-T_a at vineyard level

'Pinot-noir' grapevines

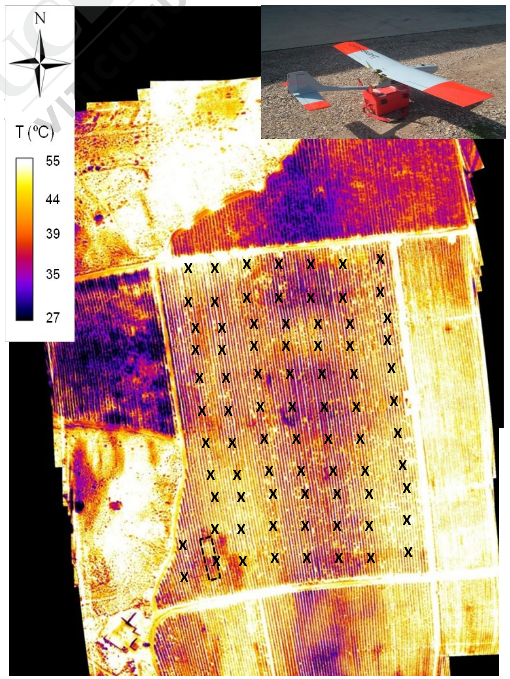
07:30 h (solar time)

It was not possible to distinguish between soil/vegetation pixels

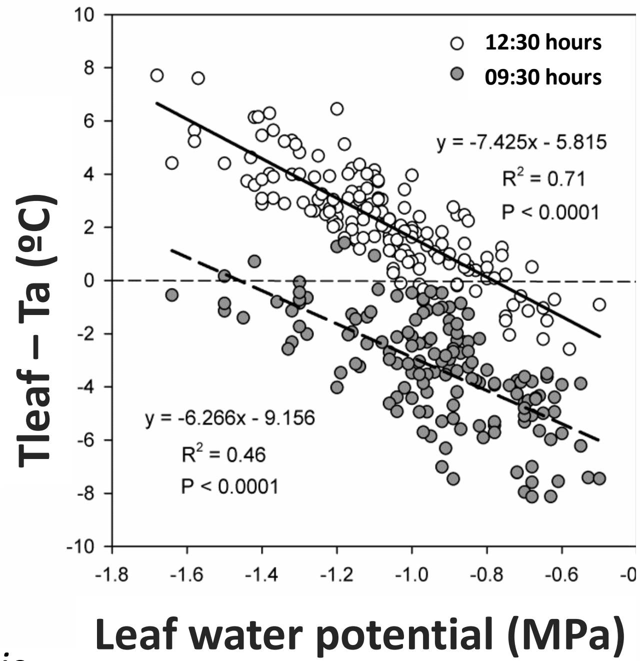
Flight time: 12:30 h

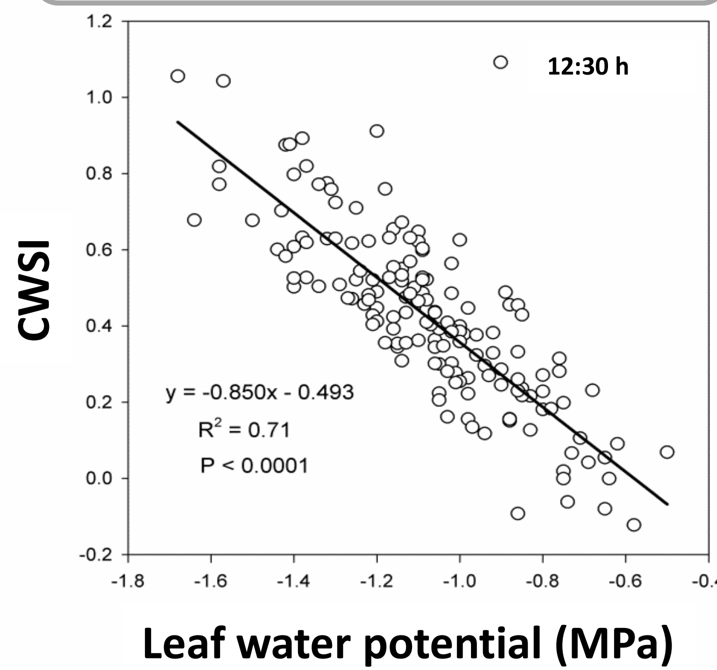
Tair: 32.27 ºC

VPD: 2.37 kPa



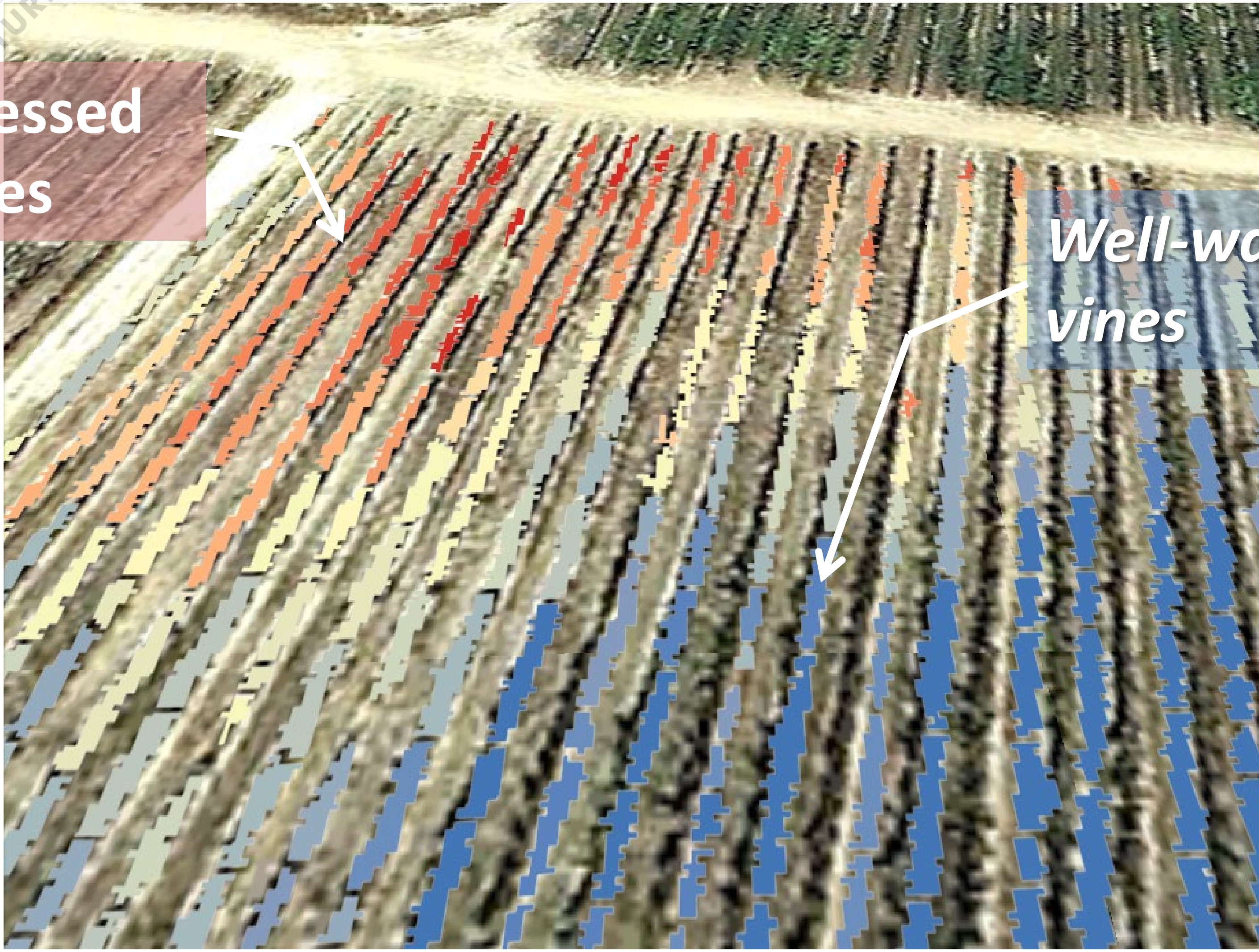
$$\mathrm{CWSI} = \frac{(T_c - T_a) - (-1.709 \cdot \mathrm{DPV} + 2.534)}{(0.465 \cdot \mathrm{DPV} + 6.125) - (-1.709 \cdot \mathrm{DPV} + 2.534)}$$





Bellvert et al. (2014) PrecAgric

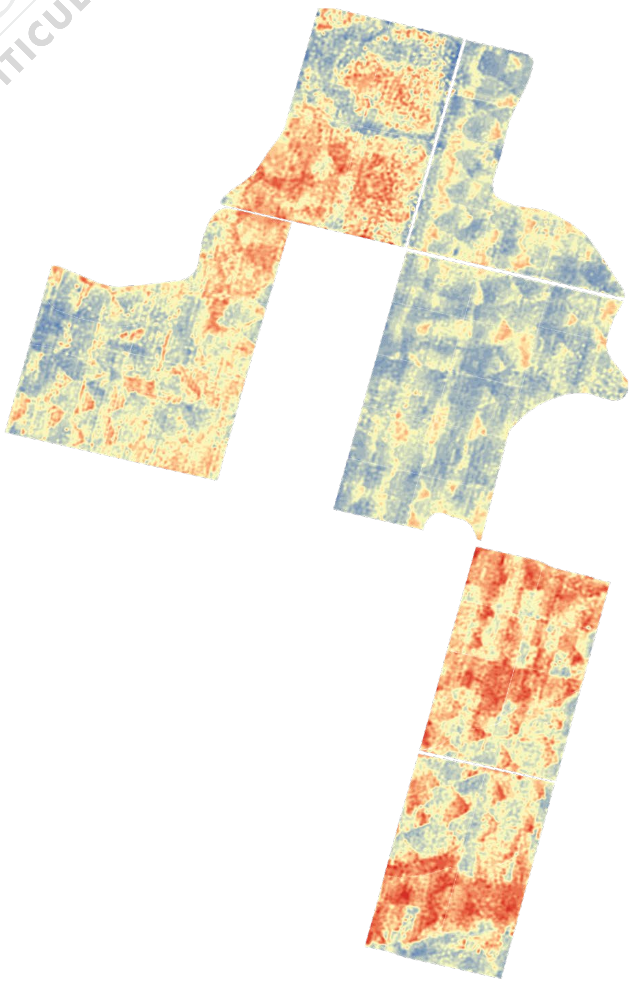
Spectral Aerial Imagery: a Precision Farming Tool to Support Zonal Management



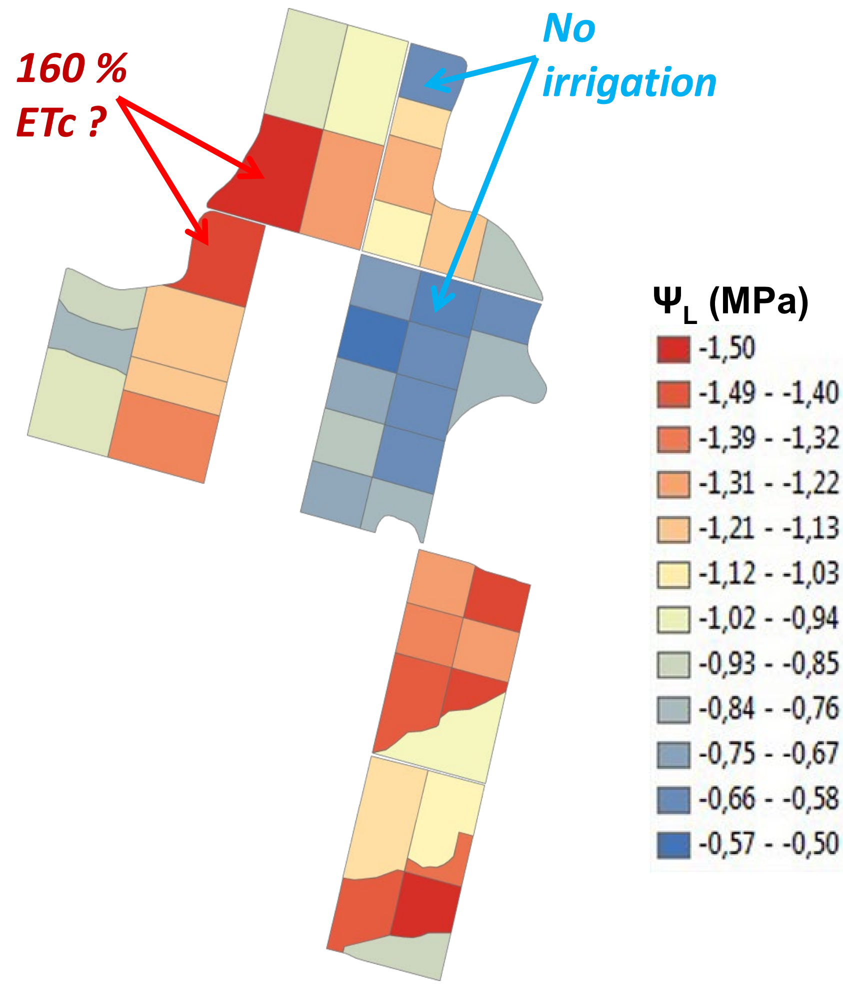
Slide from Joaquim Bellvert-Rios

Conversion of Thermal Values to ψ_{leaf} maps

ψ_{leaf} maps at vine level



ψ_{leaf} maps at irrigation sector level



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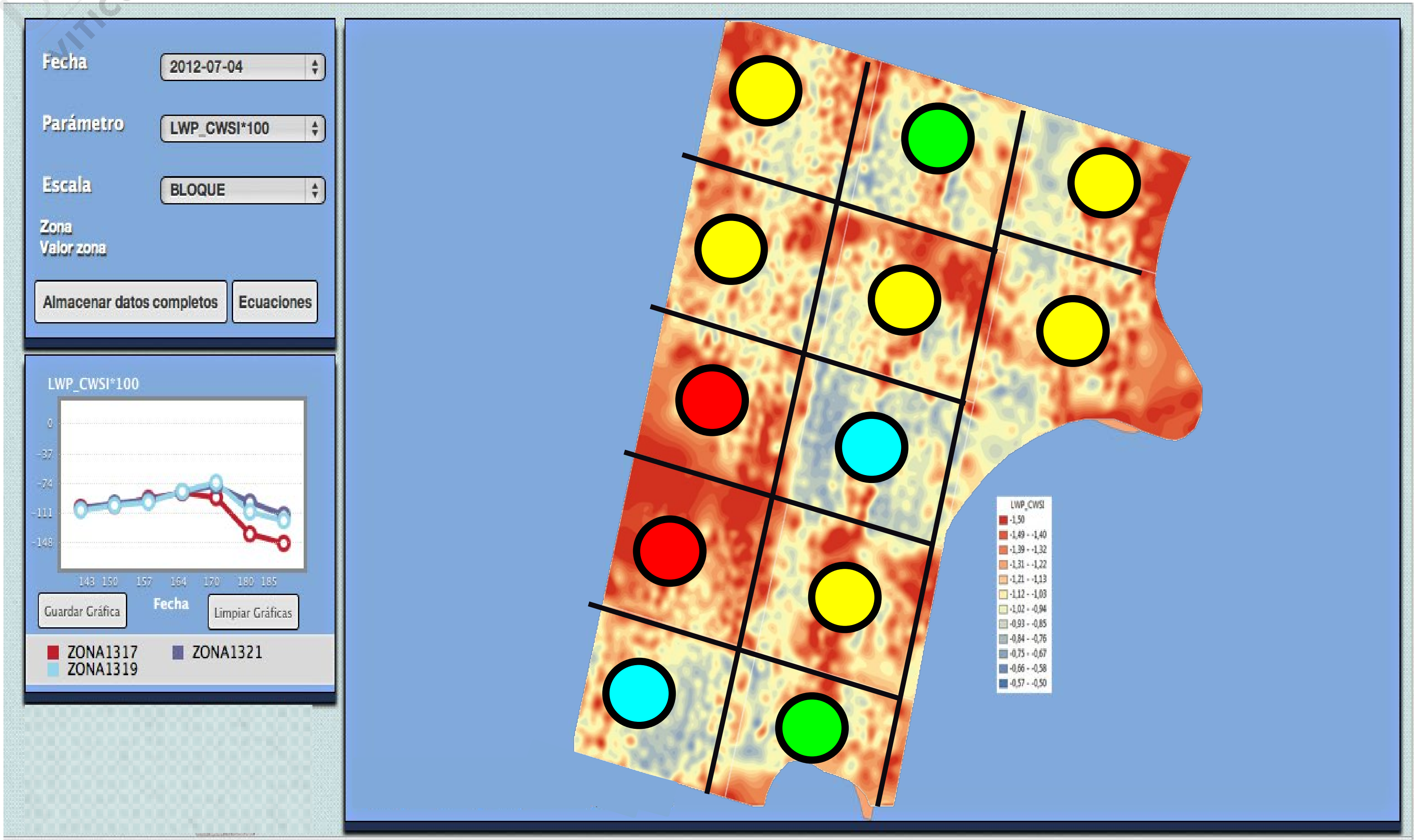
Conversion to Crop Irrigation Prescription Map

$\Psi_{optimal}$= -1.0 MPa



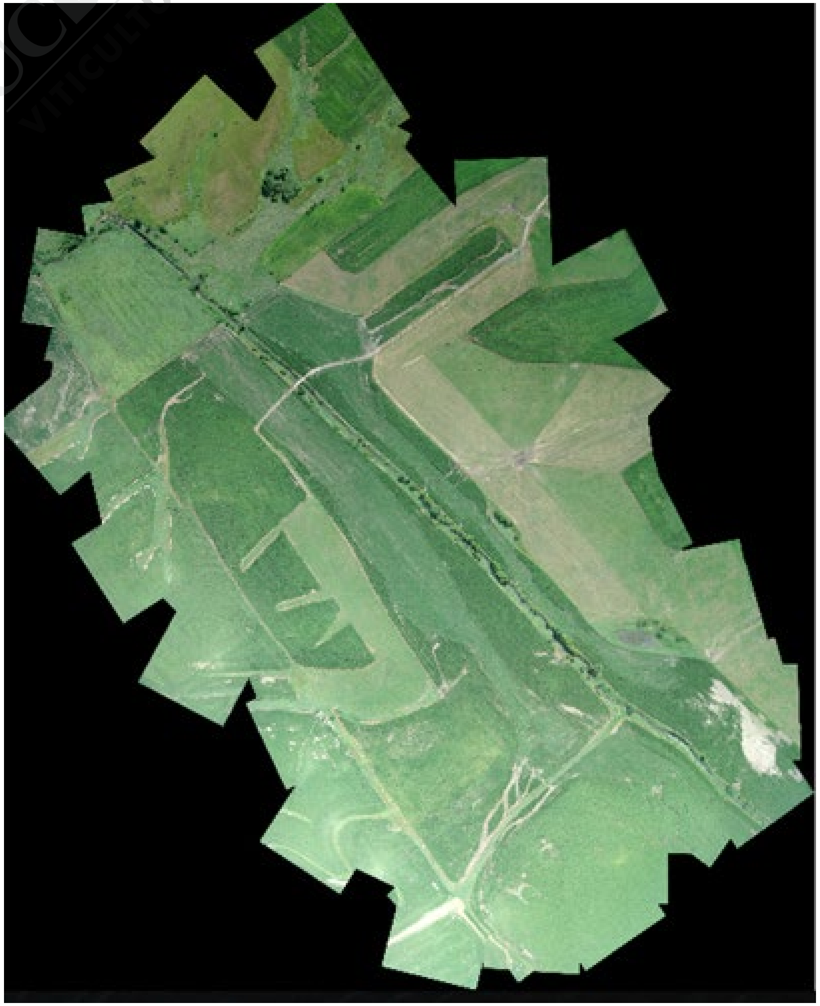
Slide from Joaquim Bellvert-Rios

Unmanned Aerial Vehicles (UAV)

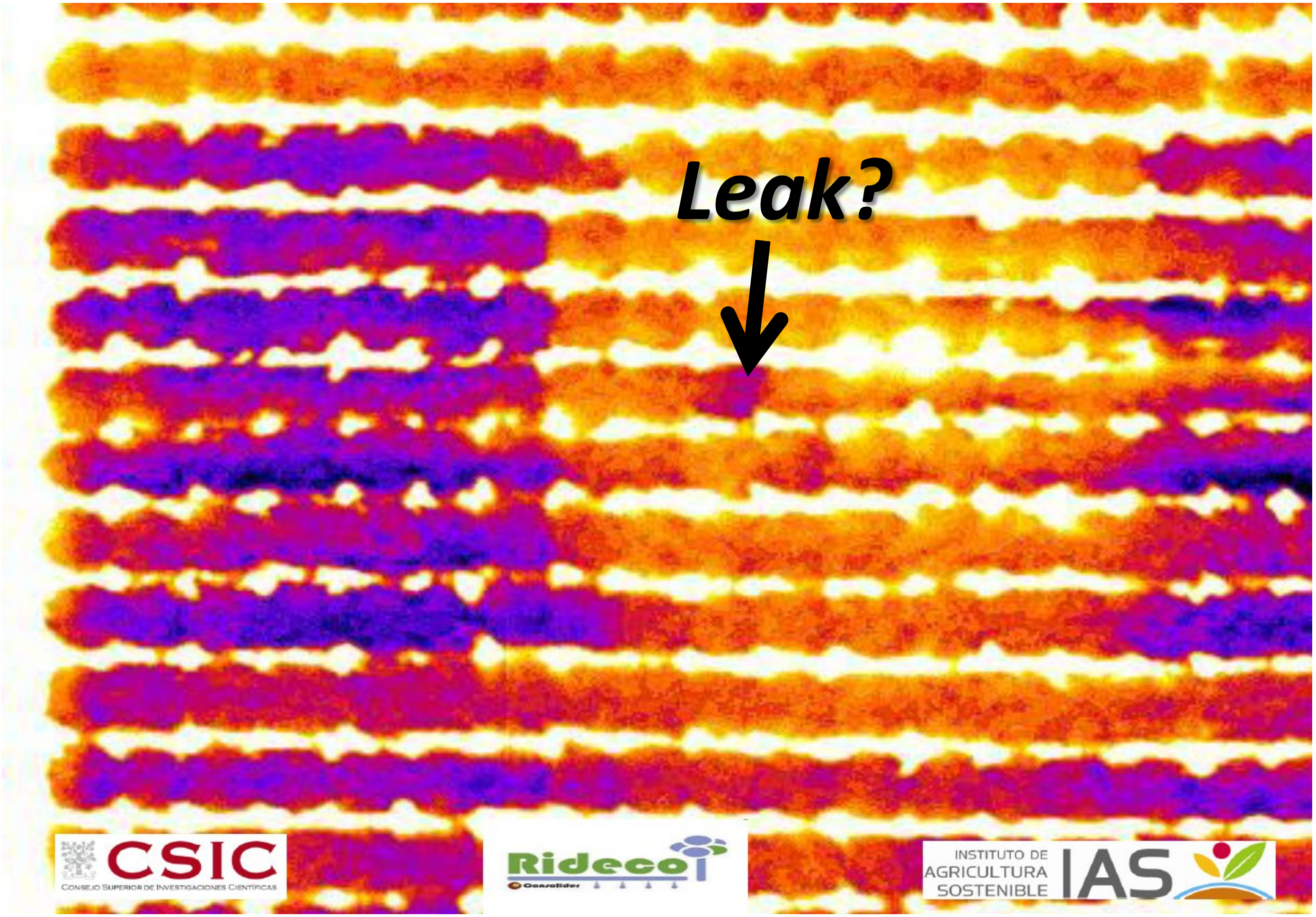
INSTITUTO DE AGRICULTURA SOSTENIBLE IAS

CSIC

sUAS Measure at scales of cm. However the resampling to create mosaics limits the value of spectral information



Spectral Aerial Imagery: A Precision Farming Tool for Problem Detection



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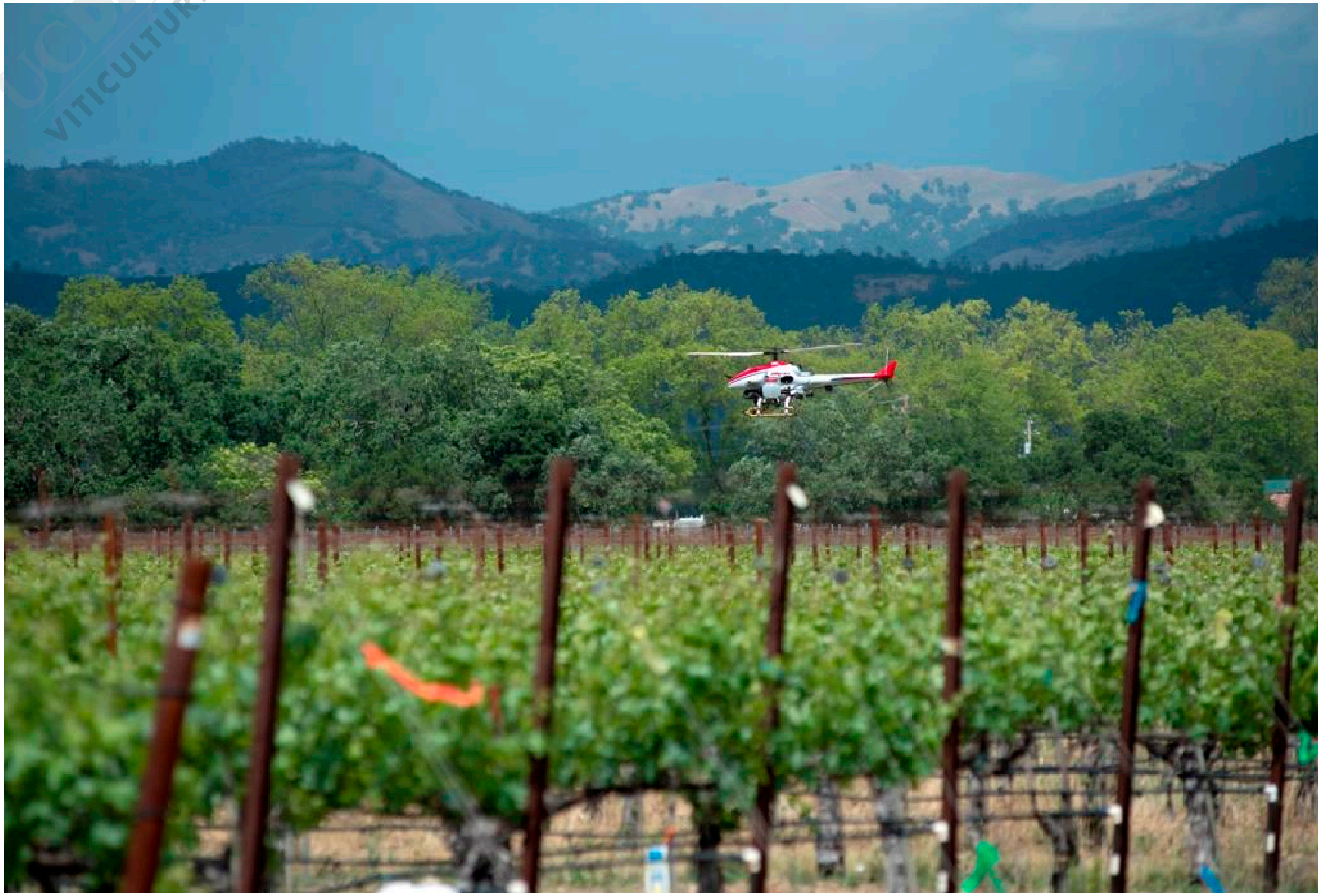
Precision Spray Application with UAV



Prof. Ken Giles, UC Davis "Anything that's boring, repetitive and dangerous: Get a drone,"

Thank you for Your Attention!