

VEGETATION CHARACTERIZATION WITH OPTICAL, THERMAL AND HYPERSPECTRAL SENSORS



KASPER JOHANSEN, MATTHEW MCCABE and HALO Team

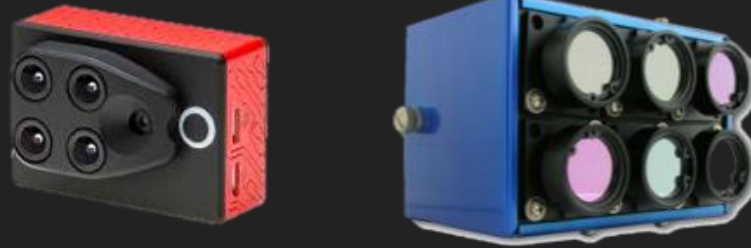
KING ABDULLAH UNIVERSITY OF SCIENCE AND TECHNOLOGY
HYDROLOGY, AGRICULTURE AND LAND OBSERVATION

Operate comprehensive and interchangeable payloads

Optical RGB



Multi-spectral



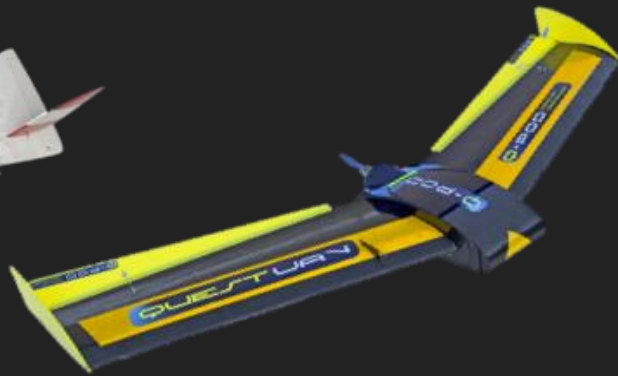
Hyperspectral



Thermal



Aeromao A300



Quest-UAV



DJI Matrice 100

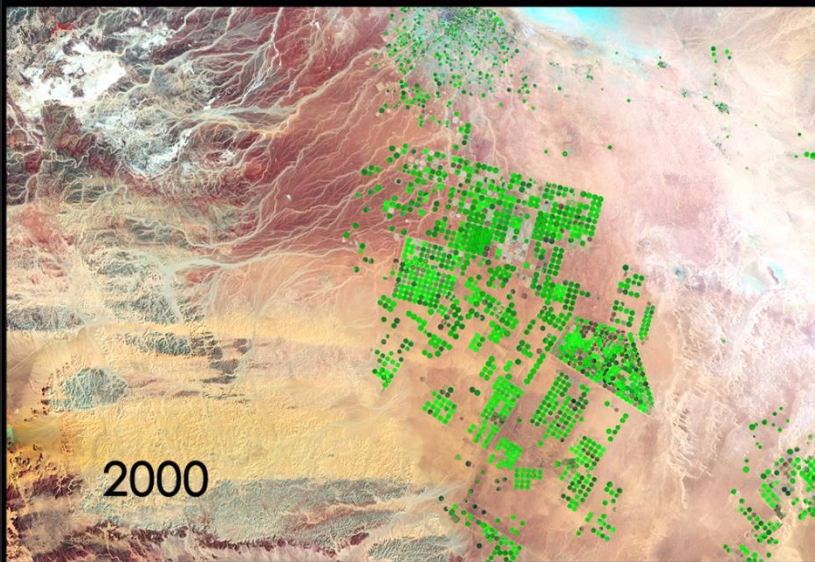
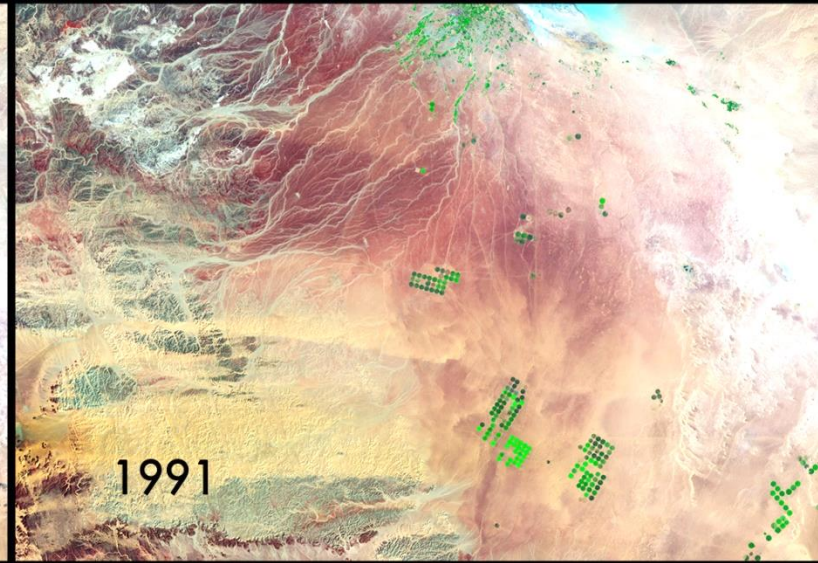
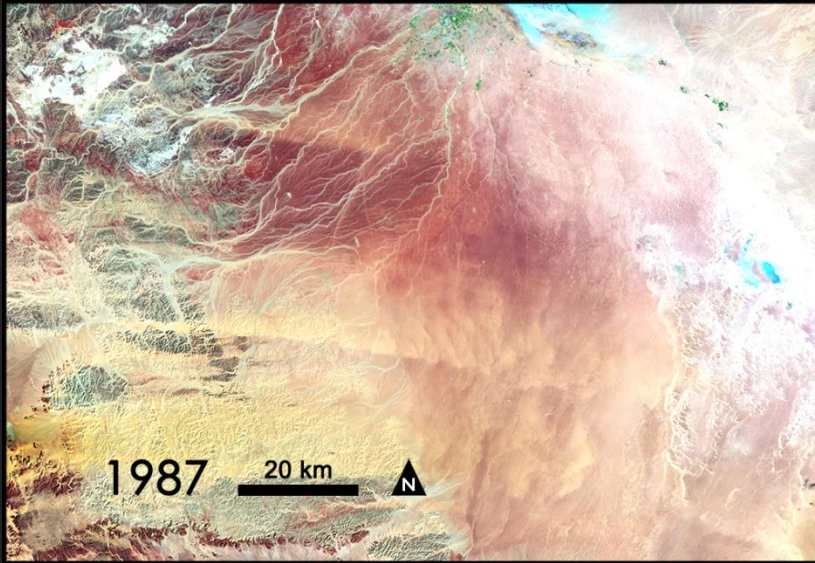


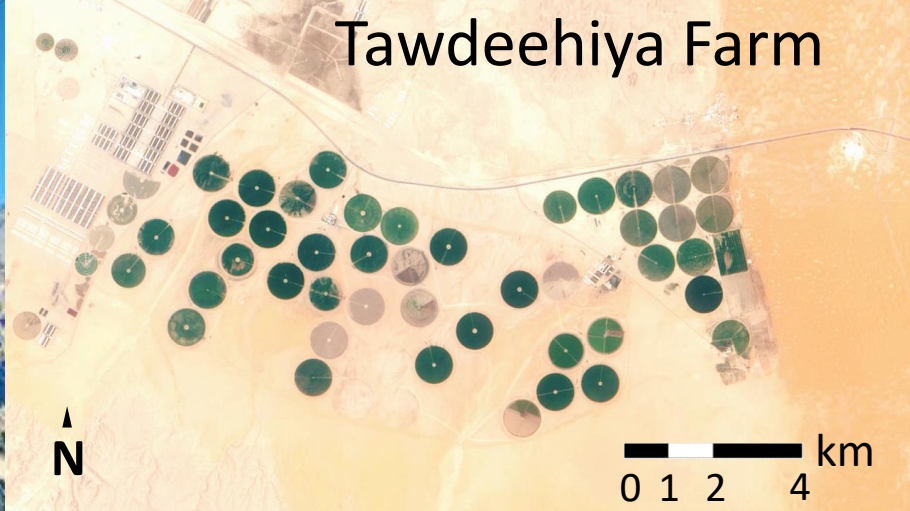
DJI Matrice 600

Agricultural Monitoring from UAVs at Field Scale

Agriculture in Al Jawf (North KSA)

Hot climate and low rainfall





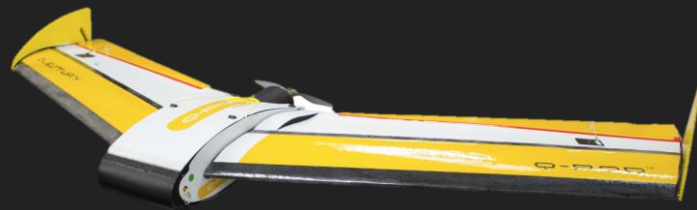
The Arabian Peninsula:

- Desert climate characterized by extreme heat
- 80% of water used in KSA is for agricultural application
- <100 mm of total annual precipitation



SONY NEX-7 Digital Camera

24MP CMOS sensor
Interchangeable lens (560 g body weight)



QUEST Fixed Wing Drone

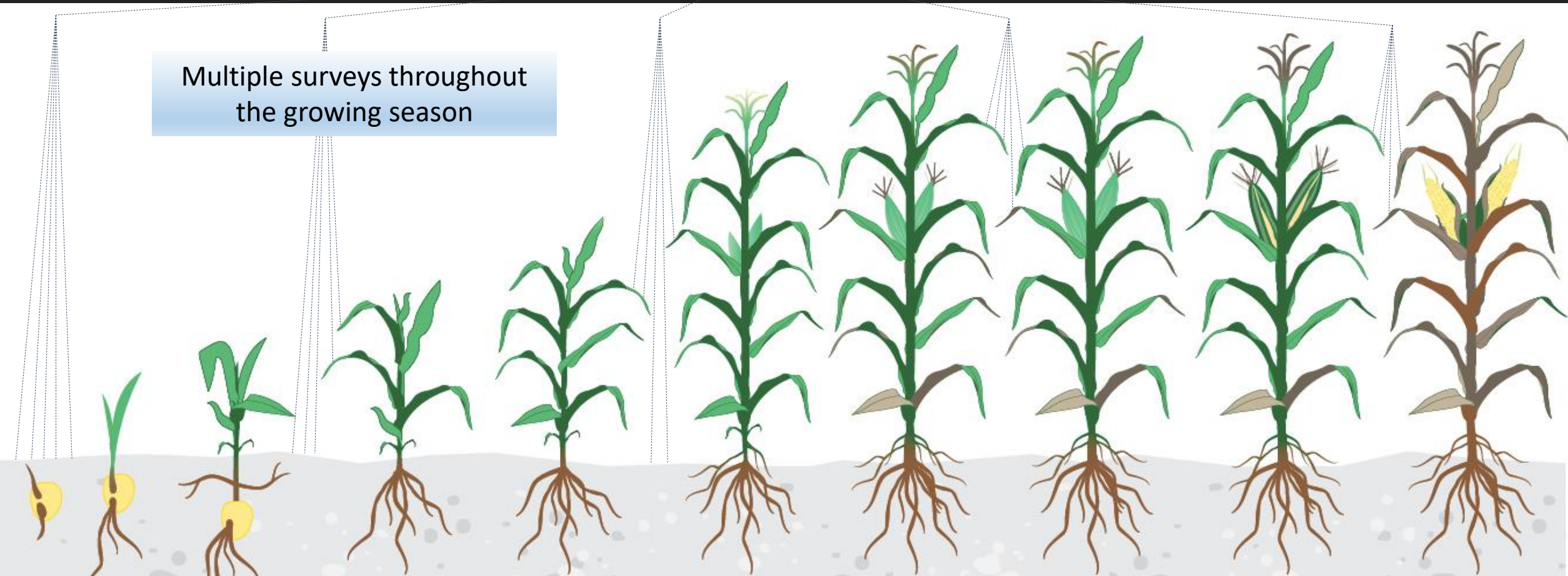
Approx. 40 minutes flight
Max GSD/Res 2.5 cm at 300 ft



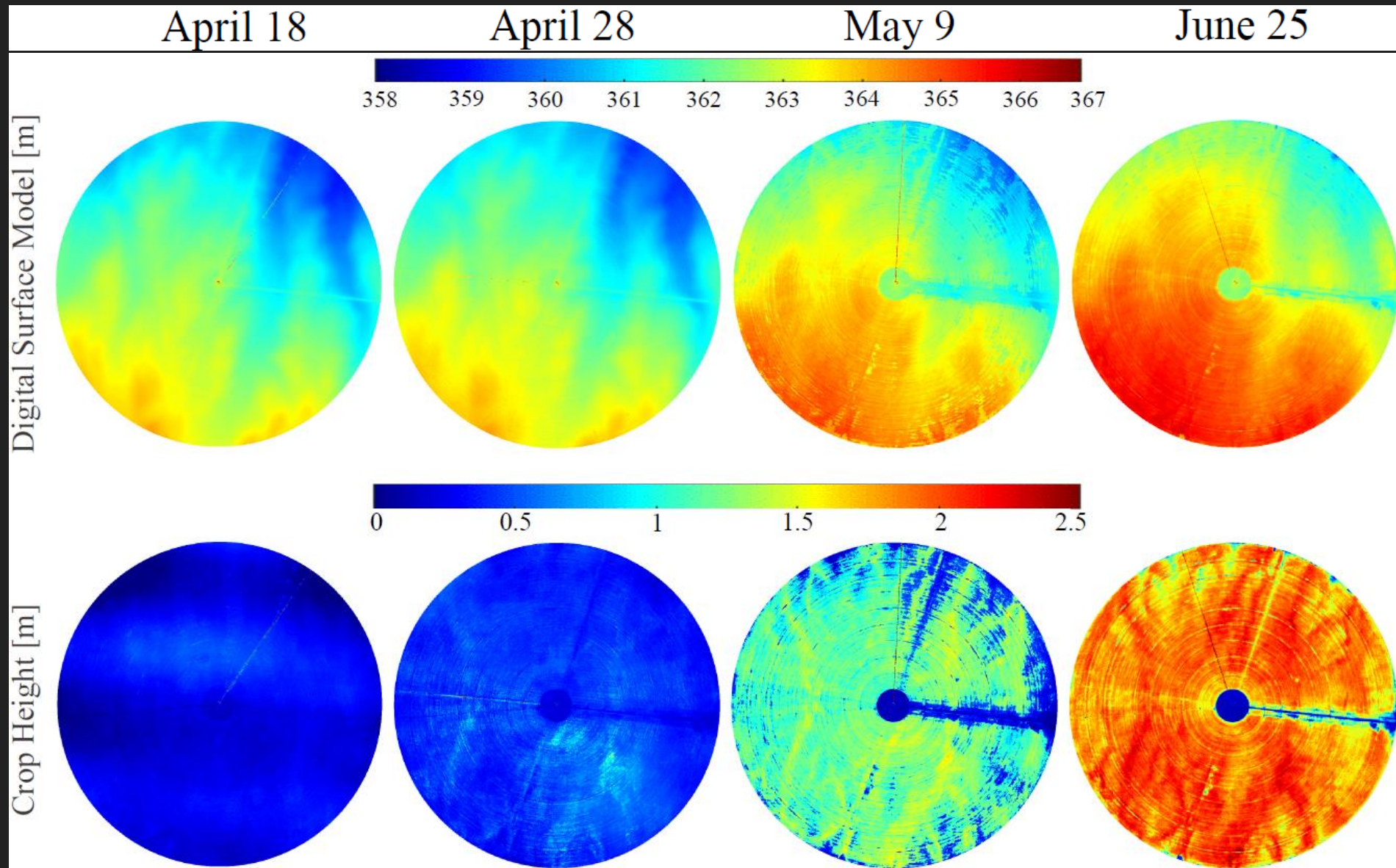
Agisoft PhotoScan

Photogrammetric processing of digital images
Automated 3D model reconstruction

Multiple surveys throughout
the growing season



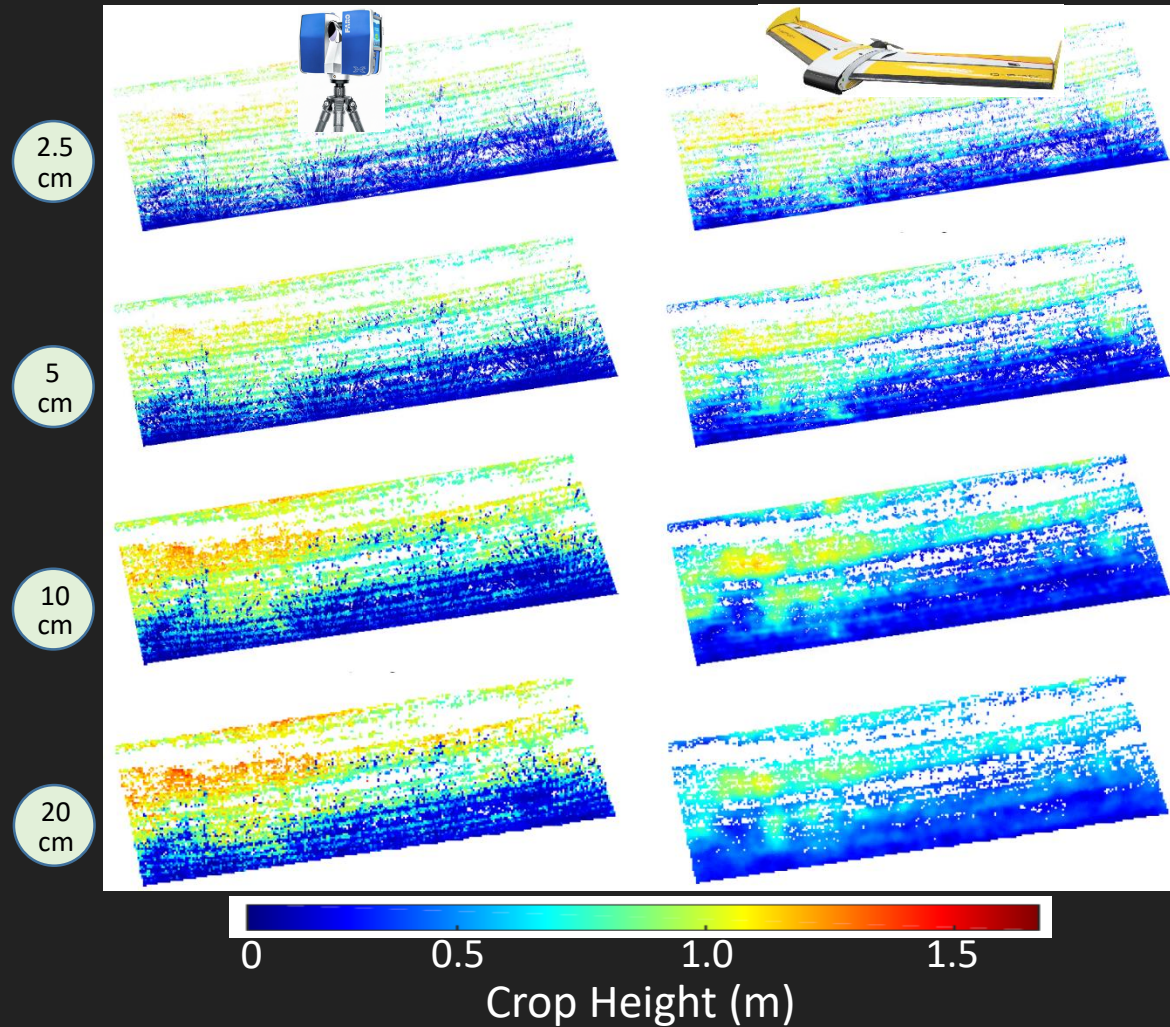
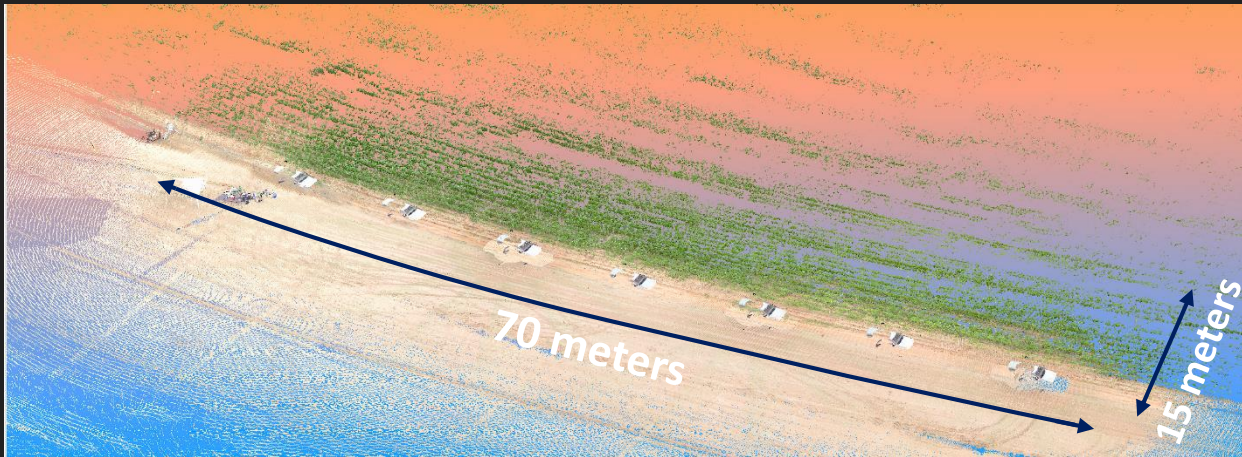
Crop Height During Growing Season



Digital Surface Model (DSM) – Digital Terrain Model (DTM) = Crop Surface Model (CSM)

Retrieval of Dynamic Crop Height from UAV

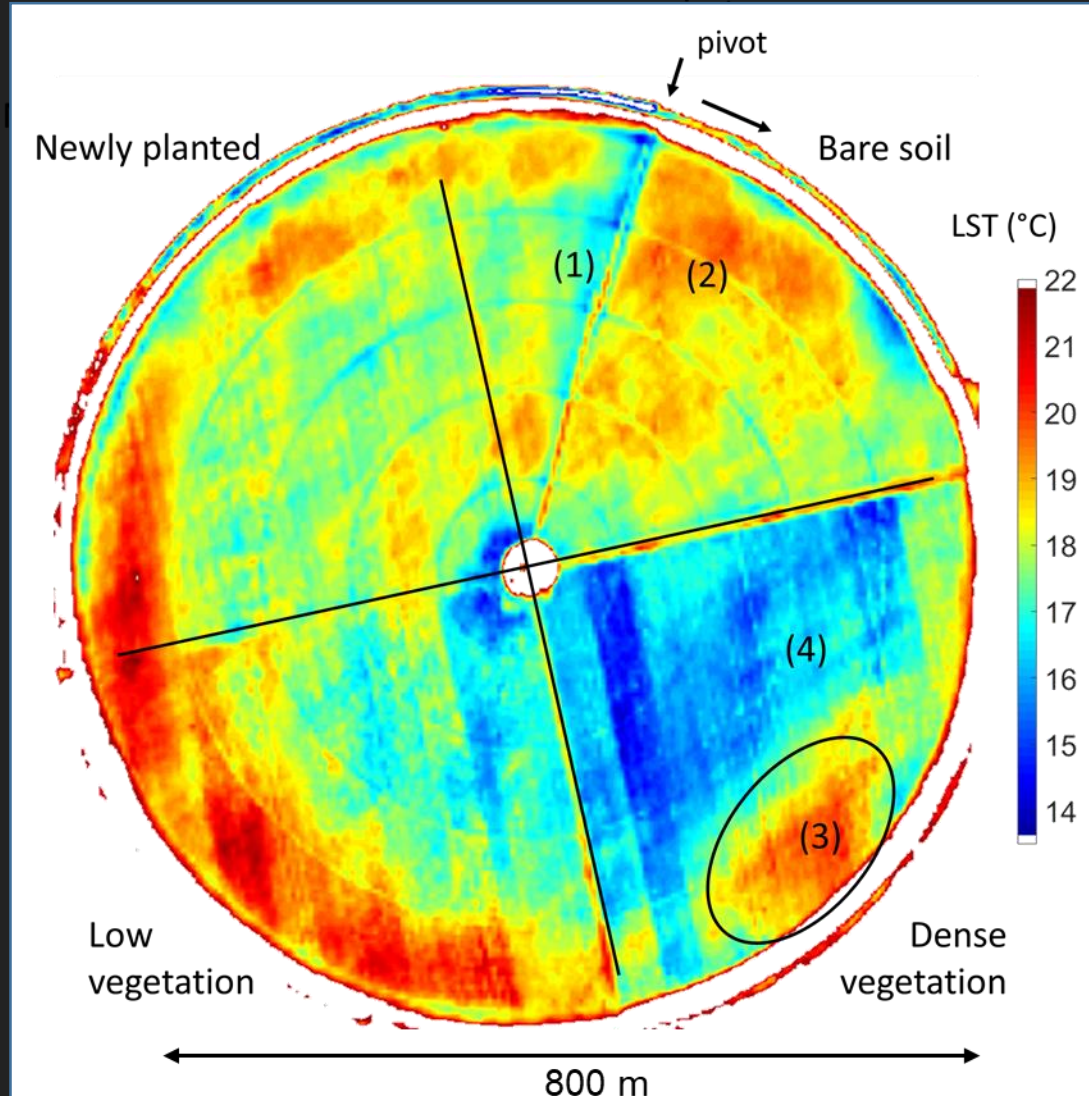
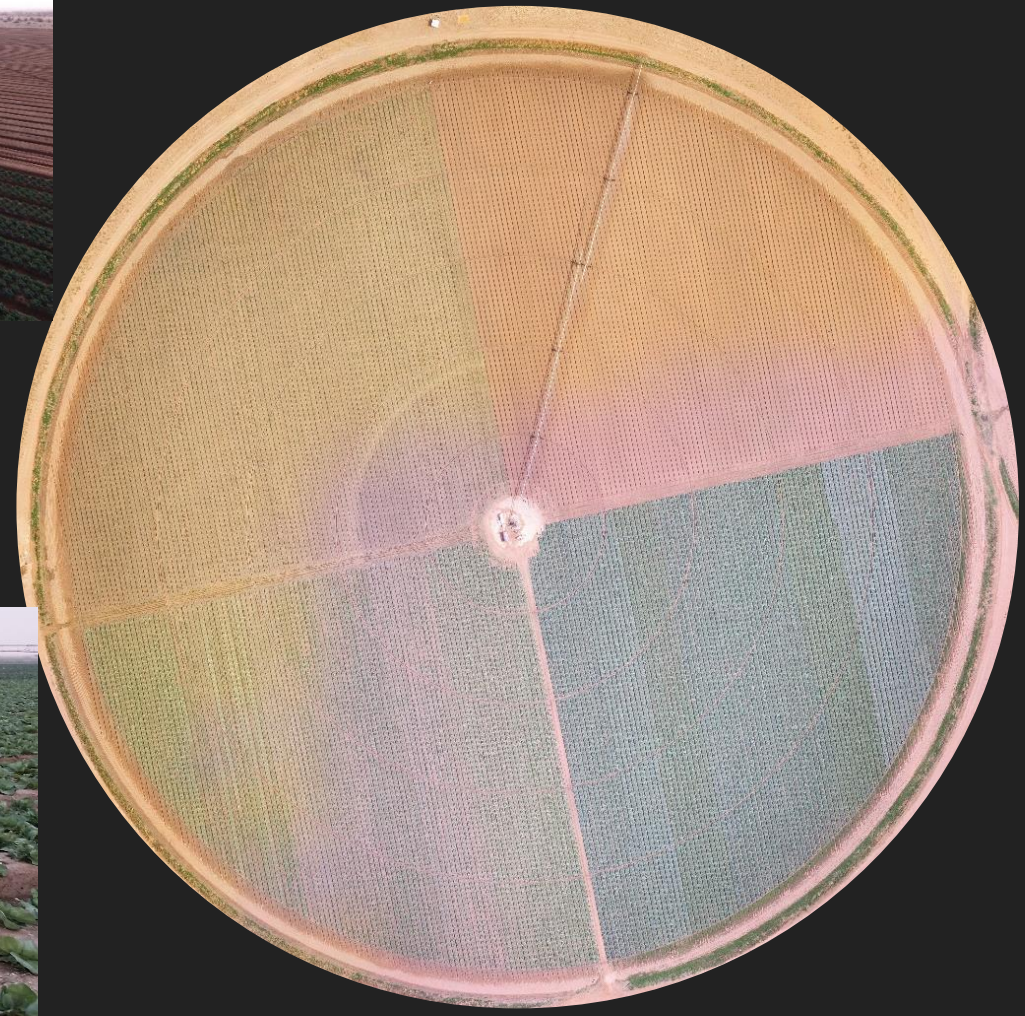
Validation with LiDAR system



Crop water stress at ultra high resolution and irrigation efficiency



Cabbage



Characterize plant traits and response under salt stress

Plant physiologists : Dissecting the genetic architecture of salinity tolerance in the wild tomato

Using **optical, thermal and hyperspectral sensing**



Field Design

- Four plots – 2 control and 2 salt-irrigated, each consisting of 300 plants
- 200 accessions (*S. pimpinellifolium*) x 6 replicates – 3 replicates in each treatment
- Plants positioned in randomized design
- Sown in greenhouse: 1 Oct 2017
- Transplanted: 1-2 Nov 2017
- Irrigation twice daily
- Saline irrigation from 14 Nov 2017
- Harvest: 18-25 Jan 2018



Field Measurements

Plant Dimensions – Manual and TLS Measurements



Measuring Biomass of Tomato Plants at Harvest



Meteological station



Chl & stomatal cond.



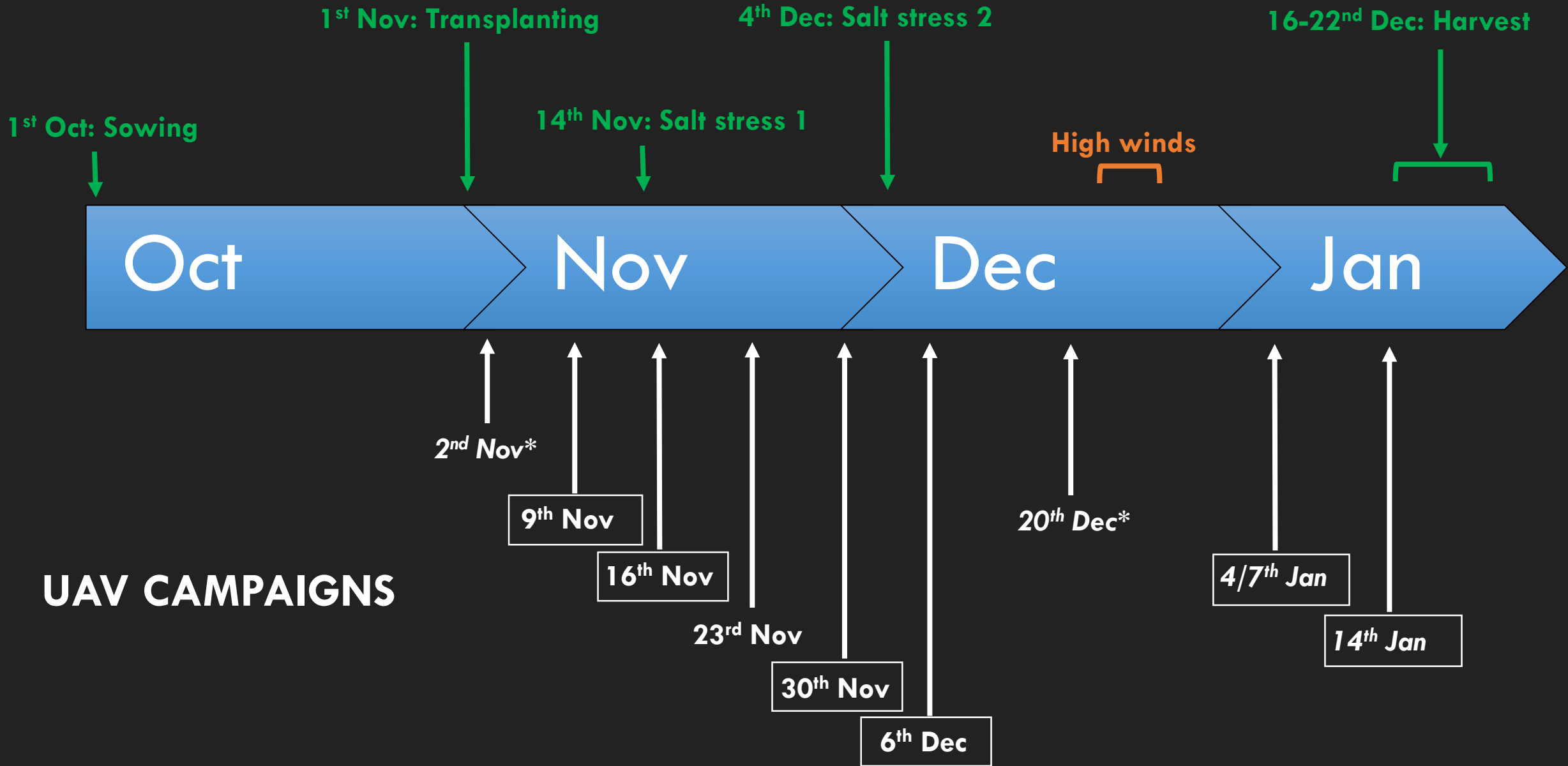
Plants and Soil Temperatures



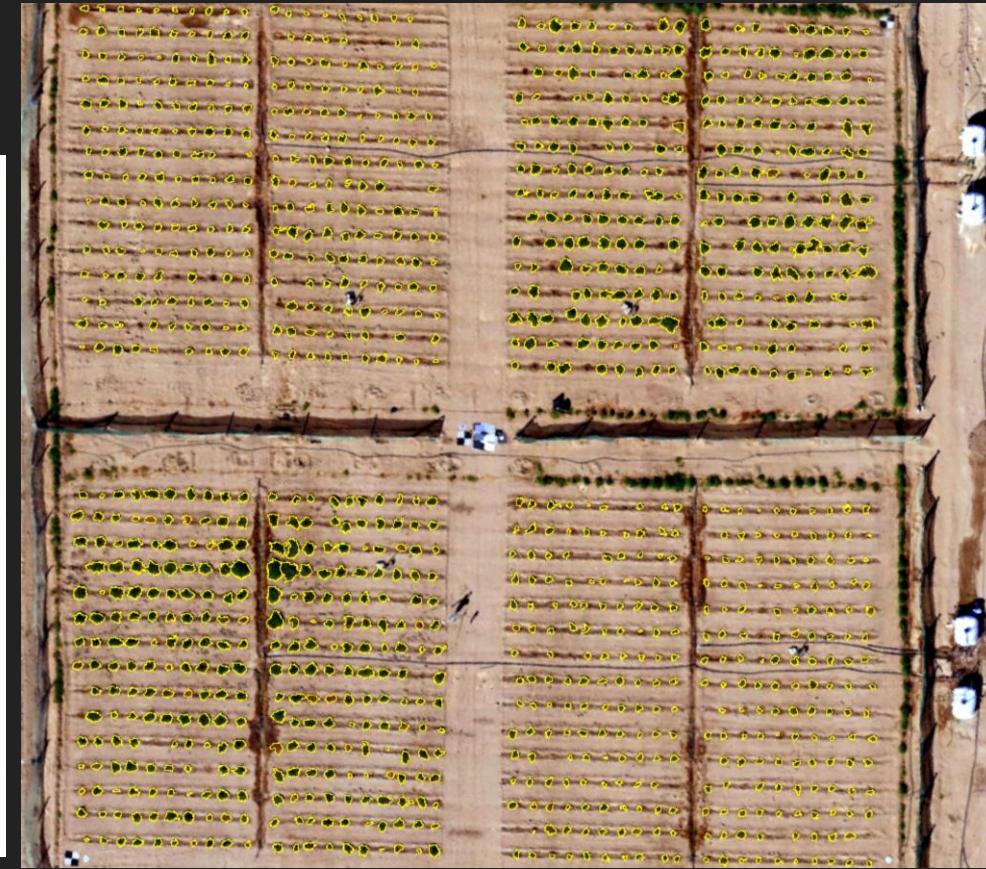
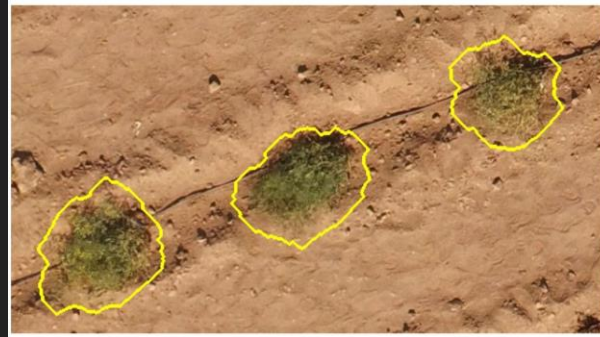
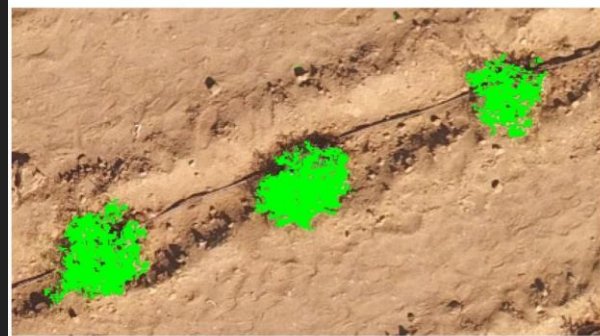
Counting and Weighing of Tomato Fruits at Harvest



UAV Data Acquisition – Timeline



Object-Based Image Analysis for Plant Delineation



Phenotyping Tomato Plants from Multi-Spectral Data

Plant Projective Cover



Plant Condition

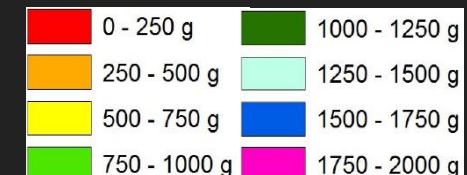
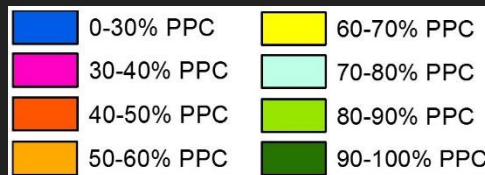


72 plants in poor condition (Yellow)

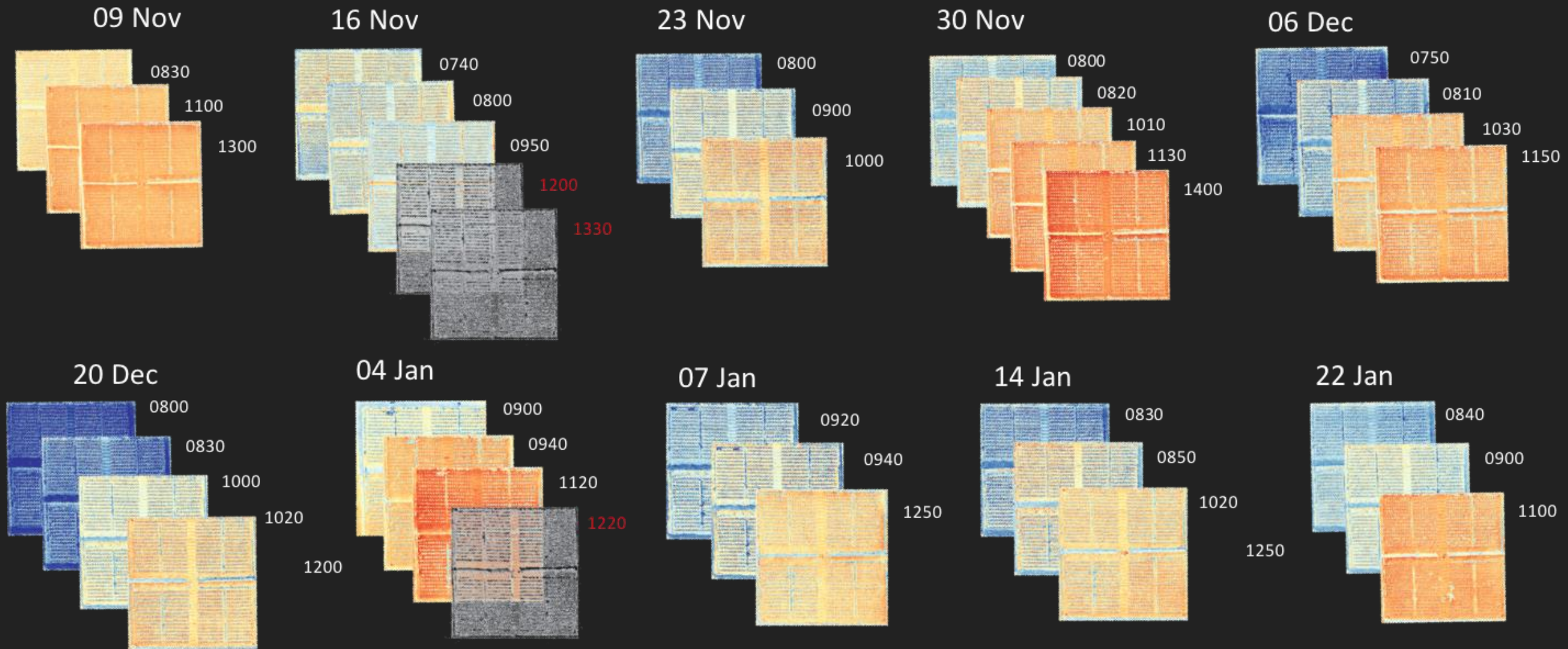
Yield Mass at Harvest



362 g/control plant
87 g/salt plant

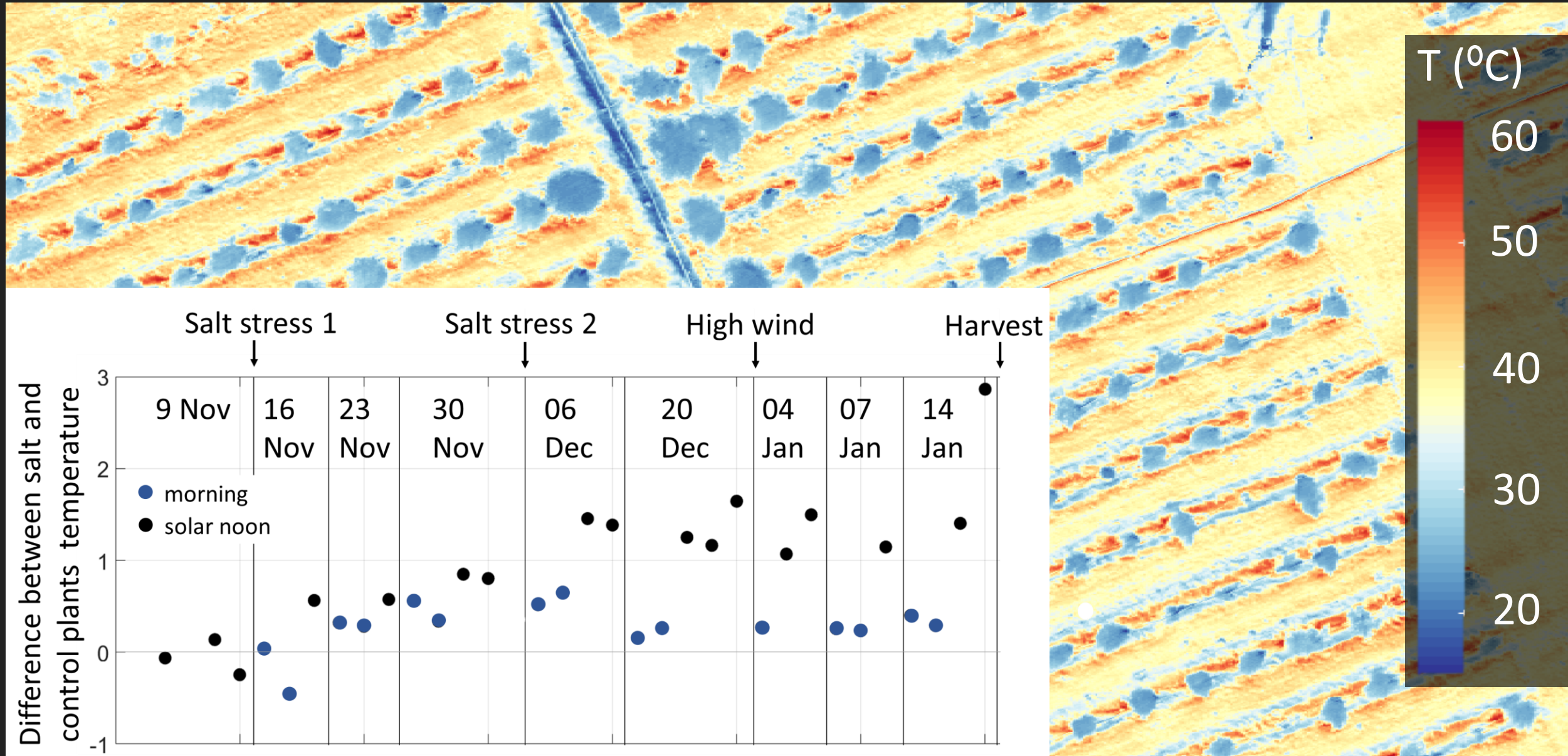


Dynamic LST: Hyper-Resolution Observations

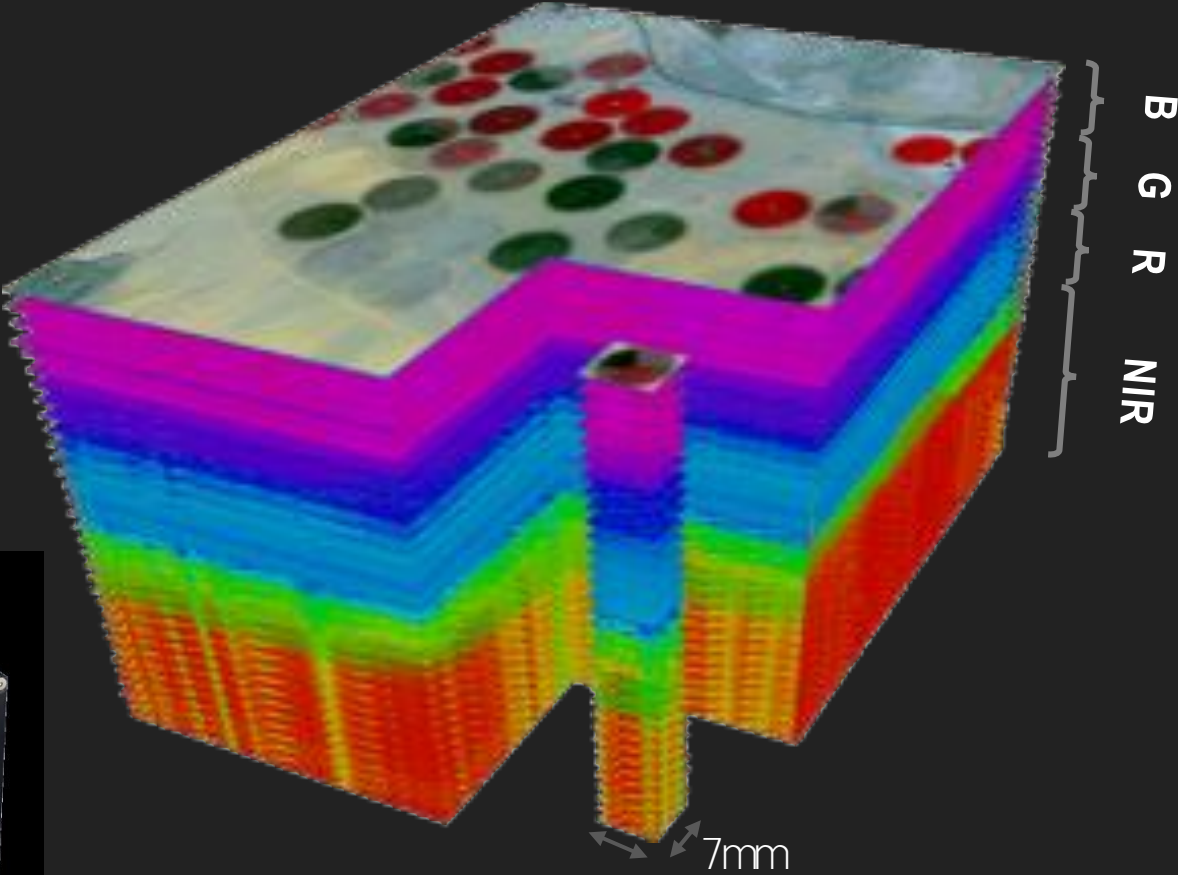
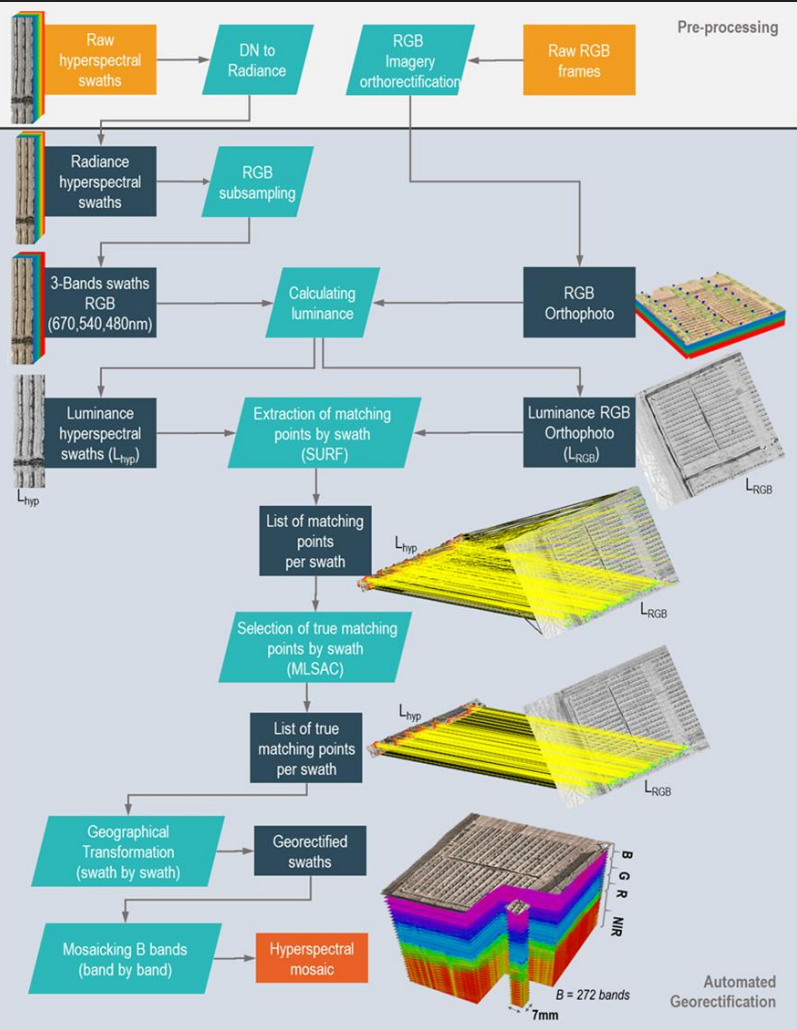


- Camera calibration, vignetting correction, effects of wind and flight direction, and impact of different orthomosaicing methods

Identifying Thermal Stress in Plants...at the cm Scale

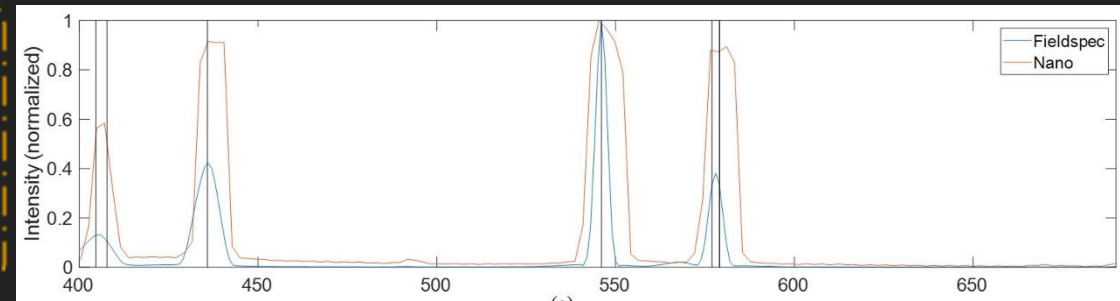
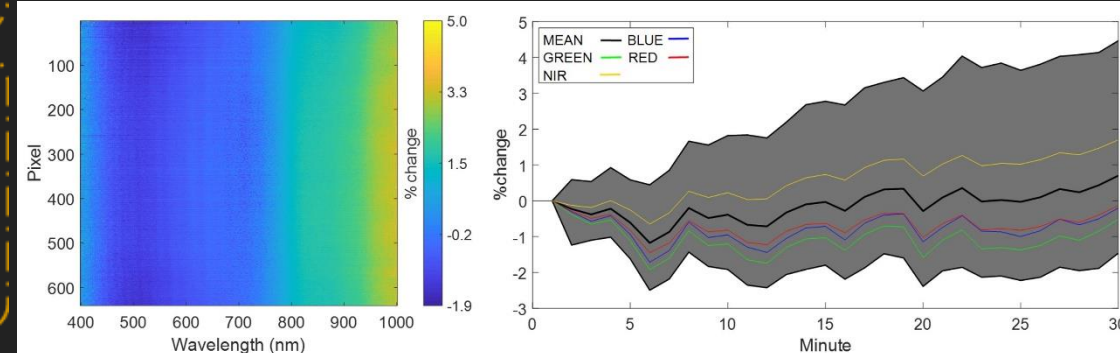
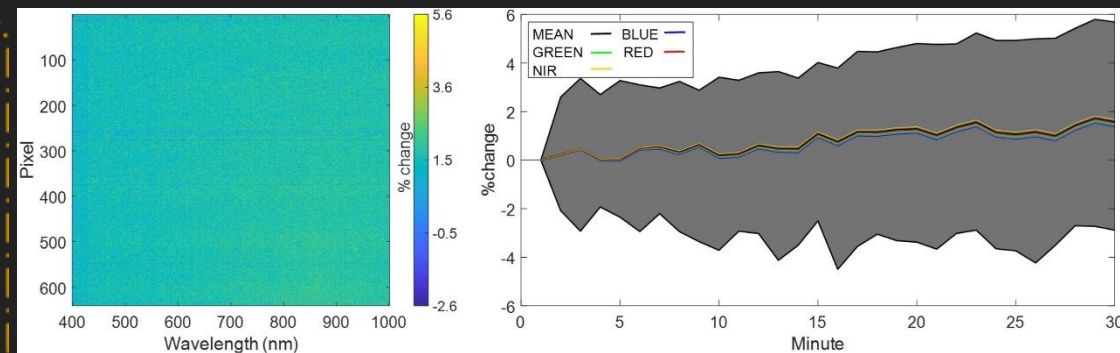
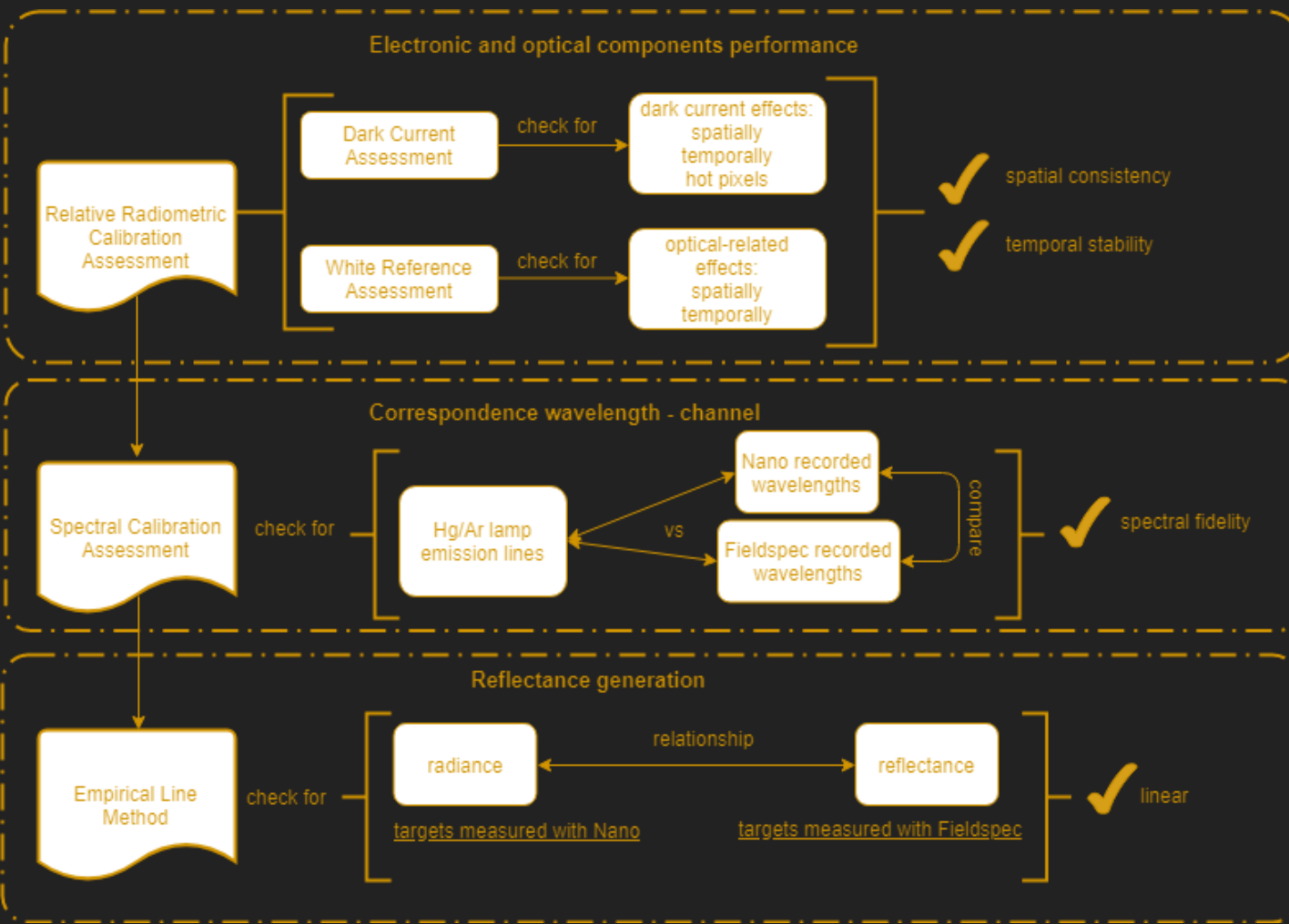


Geo-Referencing Hyper-Spectral Data



Hyperspectral Mosaic (200GB per flight)

Radiometric Assessment of Push-Broom Hyper-Spectral Data



Monitoring Crop Health from Hyper-Spectral Imagery

Vegetation Indices

Normalized Difference
Vegetation Index

$$NDVI = \frac{(NIR - Red)}{(NIR + Red)}$$

Modified Red Edge Normalized
Difference Vegetation Index

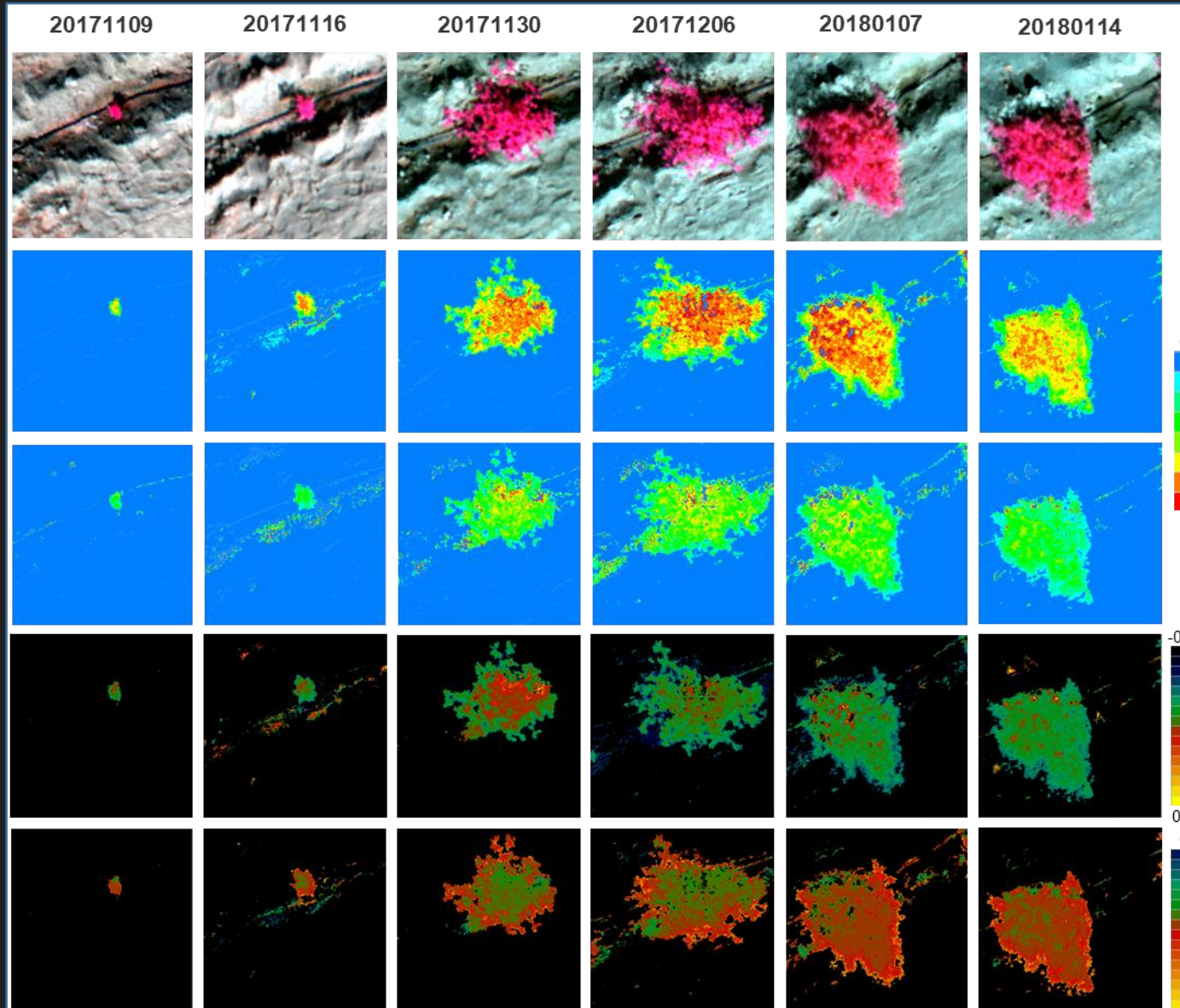
$$MRENDVI = \frac{\rho_{750} - \rho_{705}}{\rho_{750} + \rho_{705} - 2 * \rho_{445}}$$

Photochemical Reflectance Index

$$PRI = \frac{\rho_{531} - \rho_{570}}{\rho_{531} + \rho_{570}}$$

Structure Insensitive Pigment Index

$$SIPI = \frac{\rho_{800} - \rho_{445}}{\rho_{800} - \rho_{680}}$$

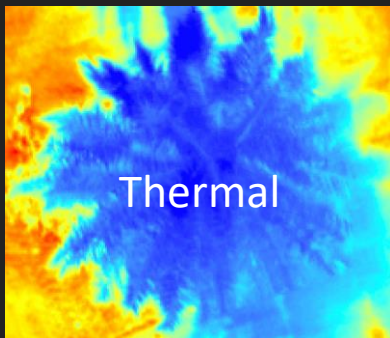


Red Edge NDVI:
Corrects for leaf specular reflection.
Changes in canopy foliage content,
gap fraction, and senescence.

Xanthophyll pigments:
Indicative of photosynthetic
light use efficiency.

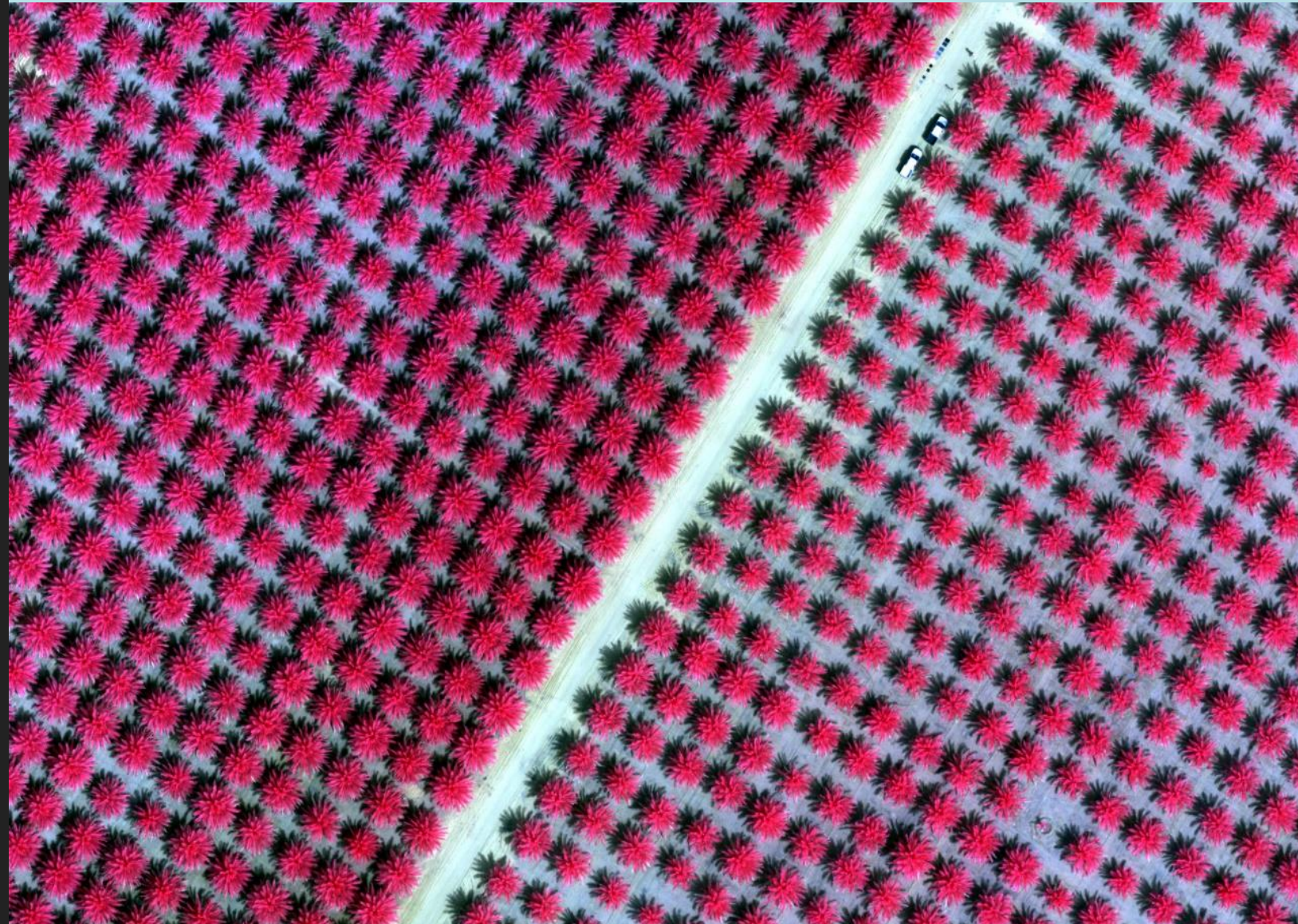
Ratio carotenoids to chlorophyll:
Less sensitivity to variation in
canopy structure. Increases in SIPI
indicate increased canopy stress.

Early Detection of RPW Infested Date Palms

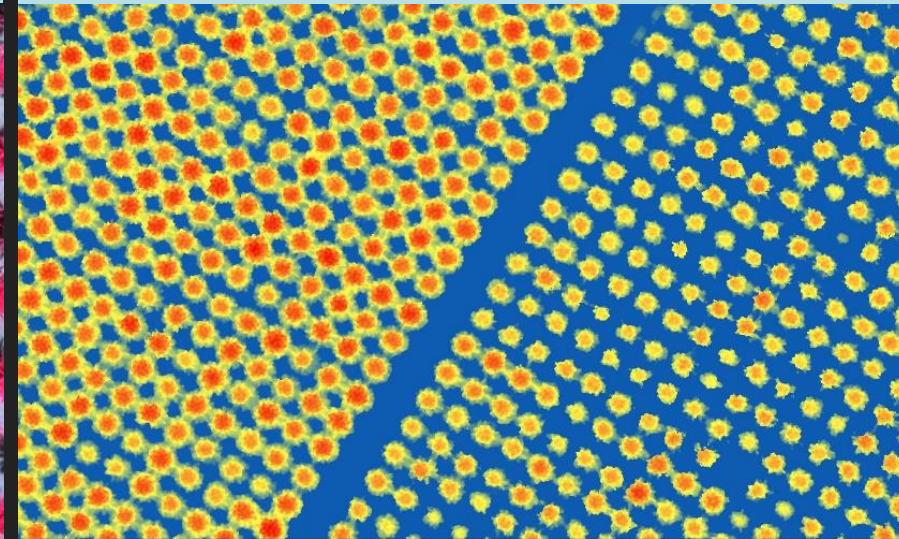


Multi-Spectral Date Palm Delineation

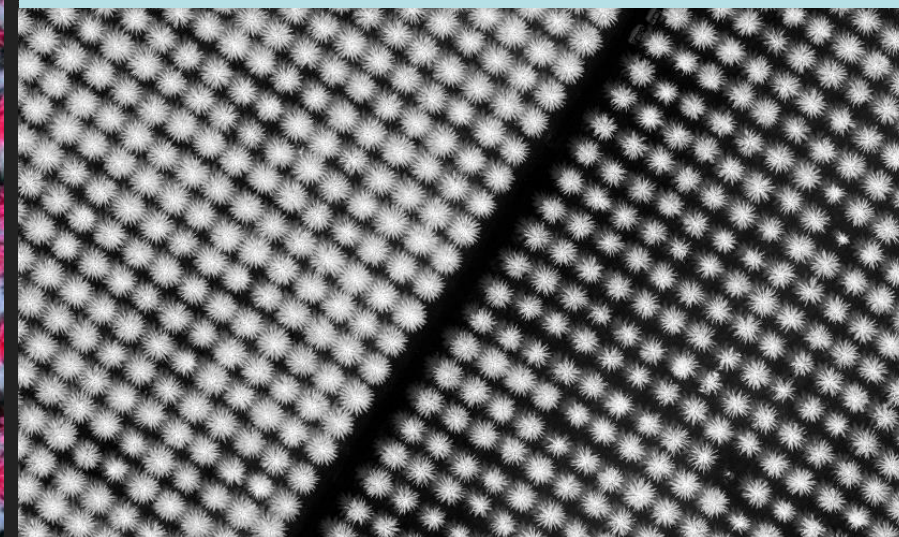
Orthomosaic of Multi-Spectral Imagery, Buraydah



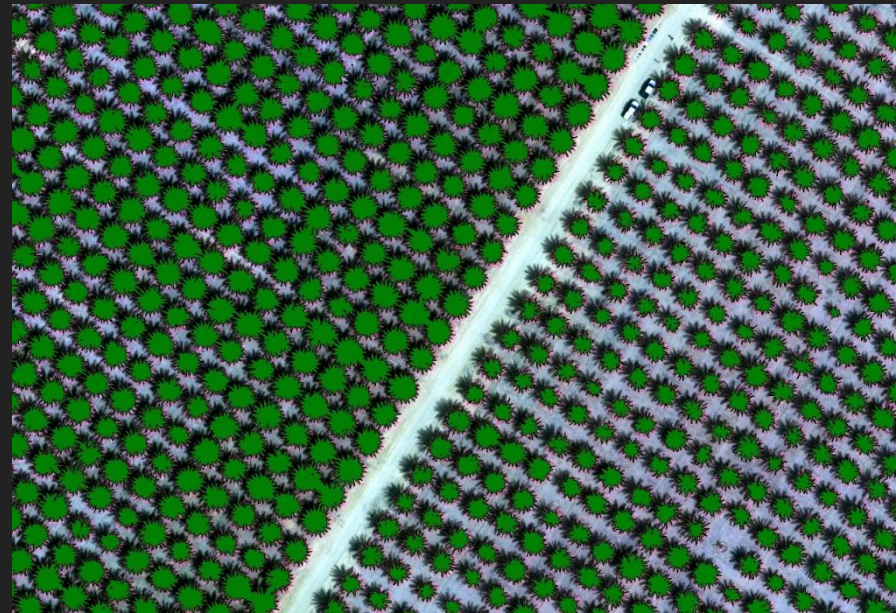
Canopy Height Model (DSM minus DTM)



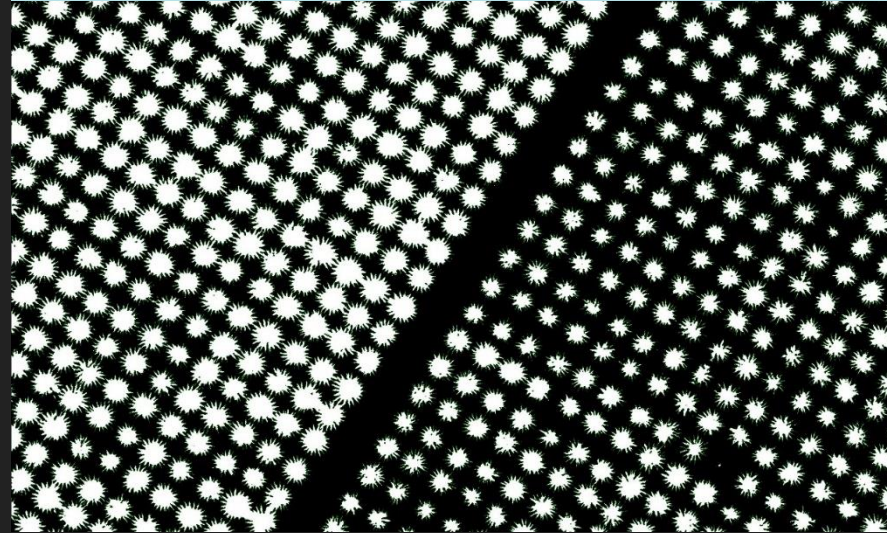
Normalized Difference Vegetation Index



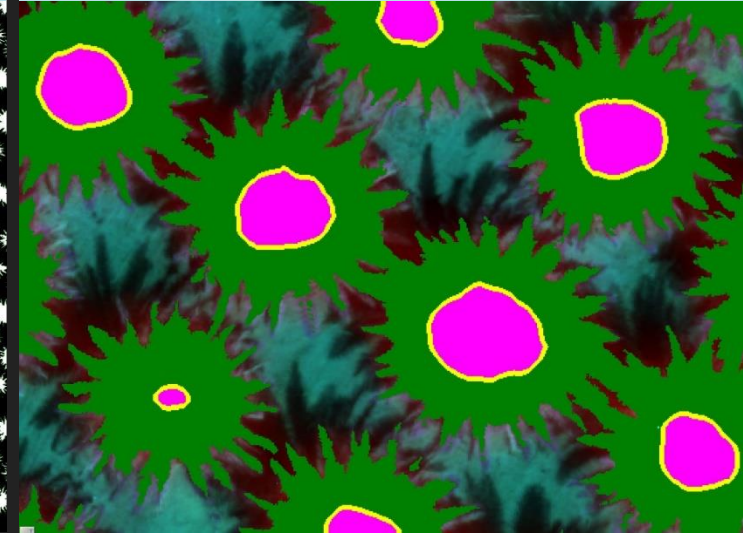
Multi-Spectral Date Palm Delineation



Mask of Date Palm Extent



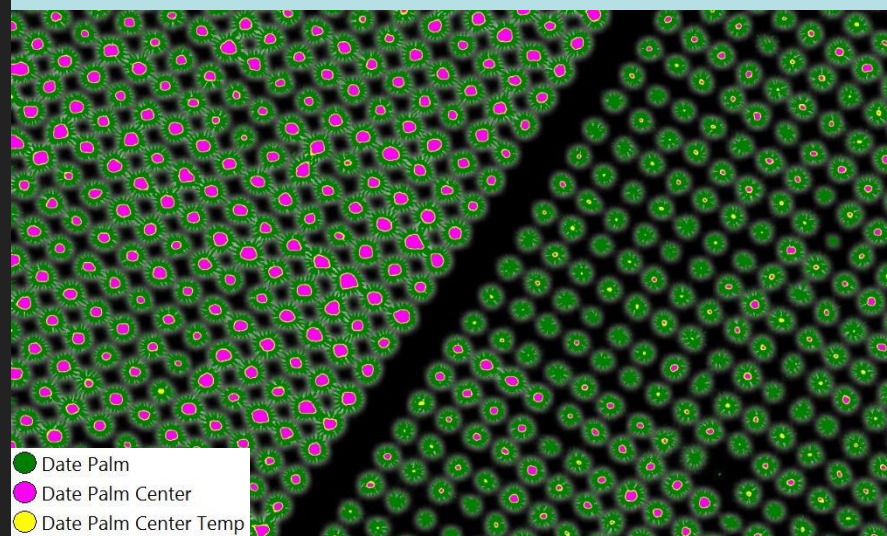
Growing palm centers outwards...



Averaging Filter of Extent



Center points of individual date palms



...if averaging filter values decrease

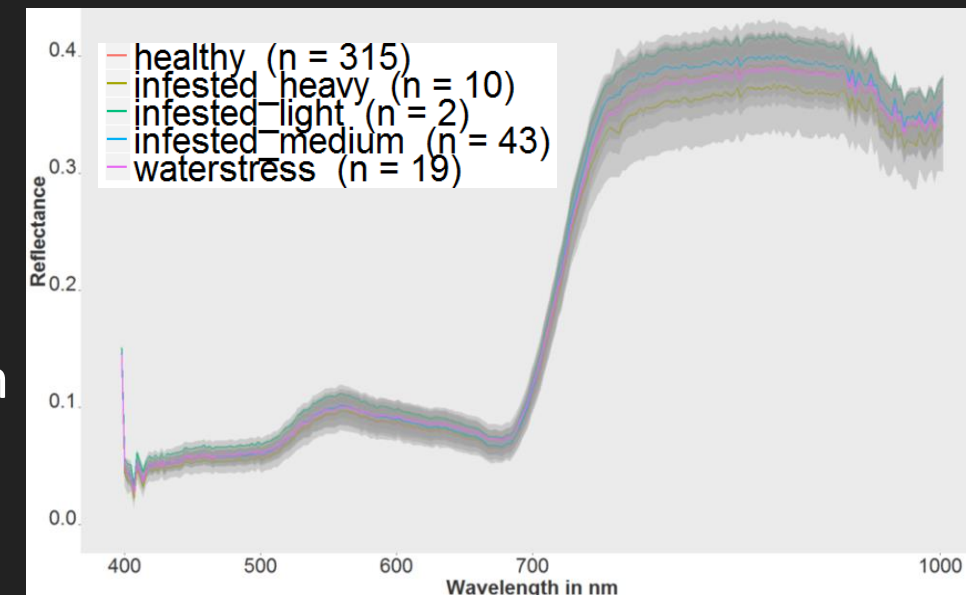
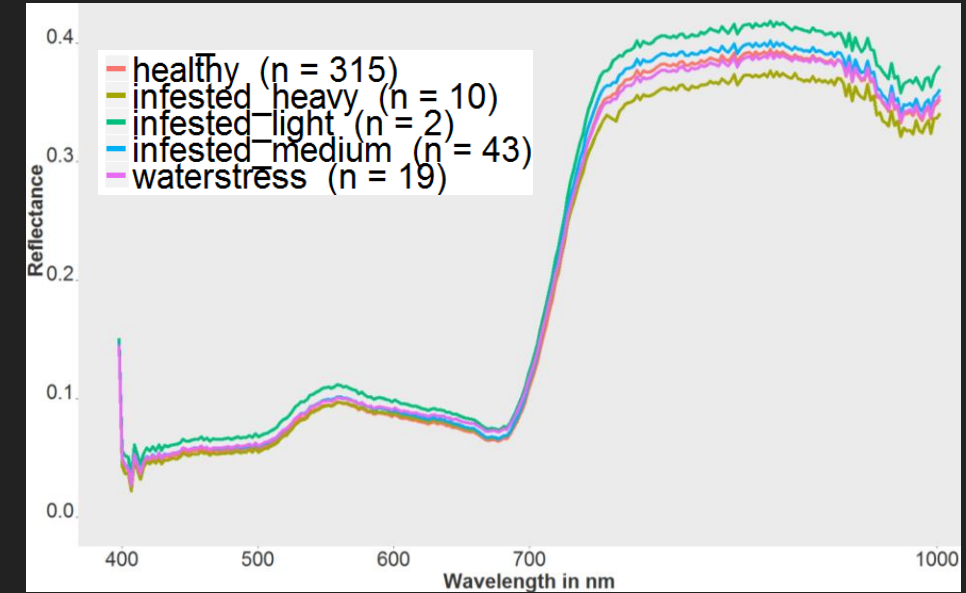
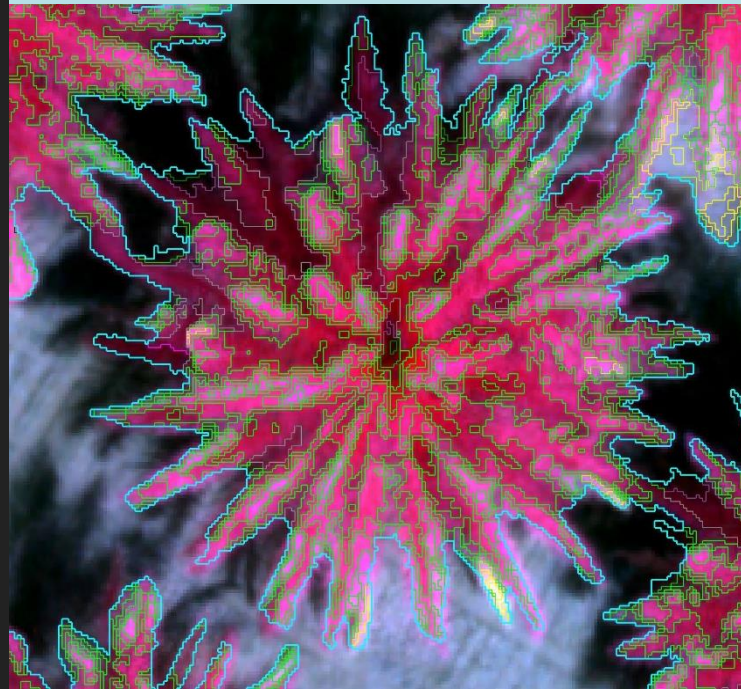


Initial Results – Hyper-Spectral Analysis

Delineating individual data palms

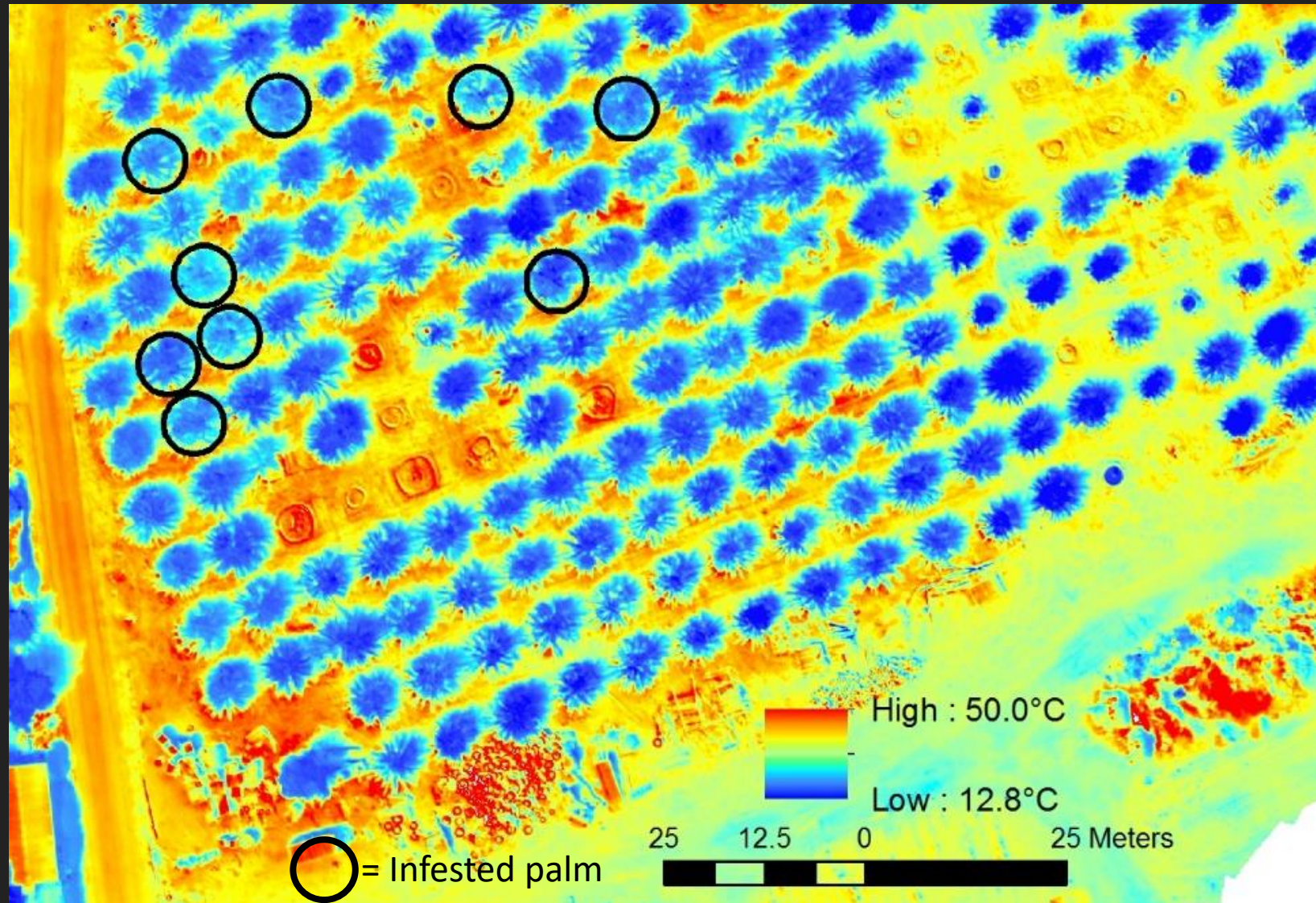
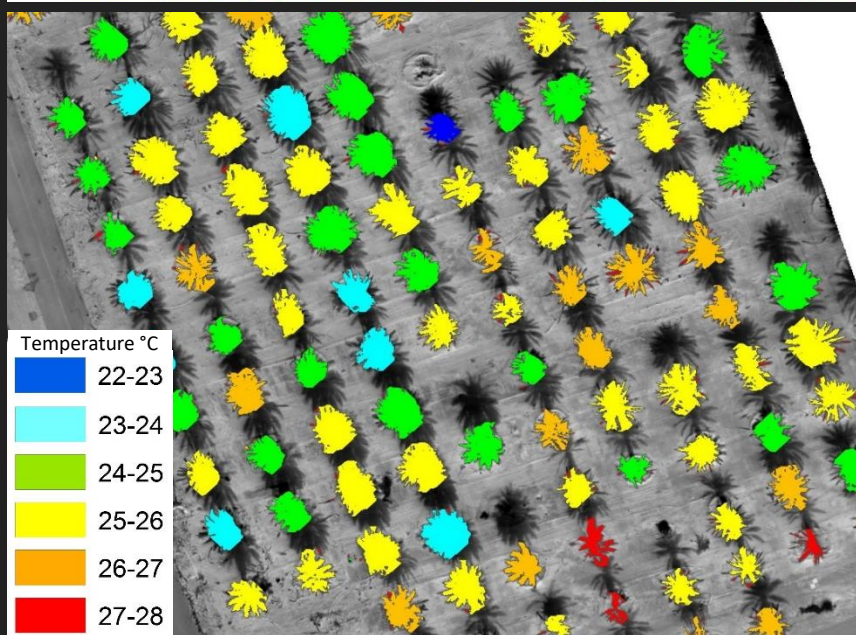
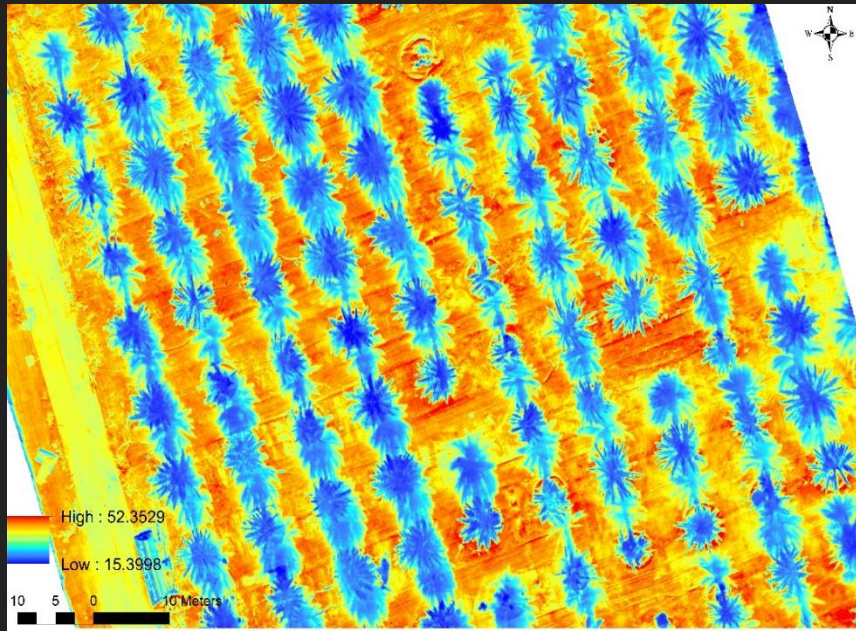


Individual properties of date palms



- Provision of highly detailed spectral reflectance associated with biophysical and chemical properties, including health
- HS data assessed for whole/individual components of palm
- Leaf structure, background effects and illumination differences cause variation in reflectance patterns

Initial Results – Thermal Data Analysis

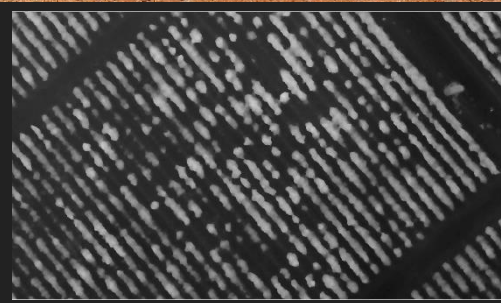
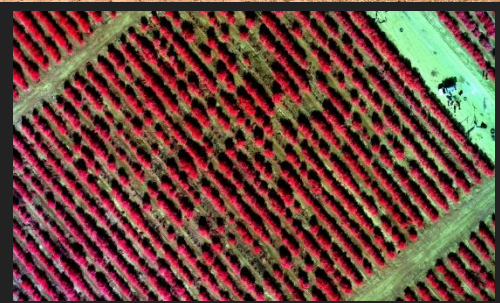


- Thermal data allows assessment of palm crown temperature, which relates to a palm's condition and ability to uptake water

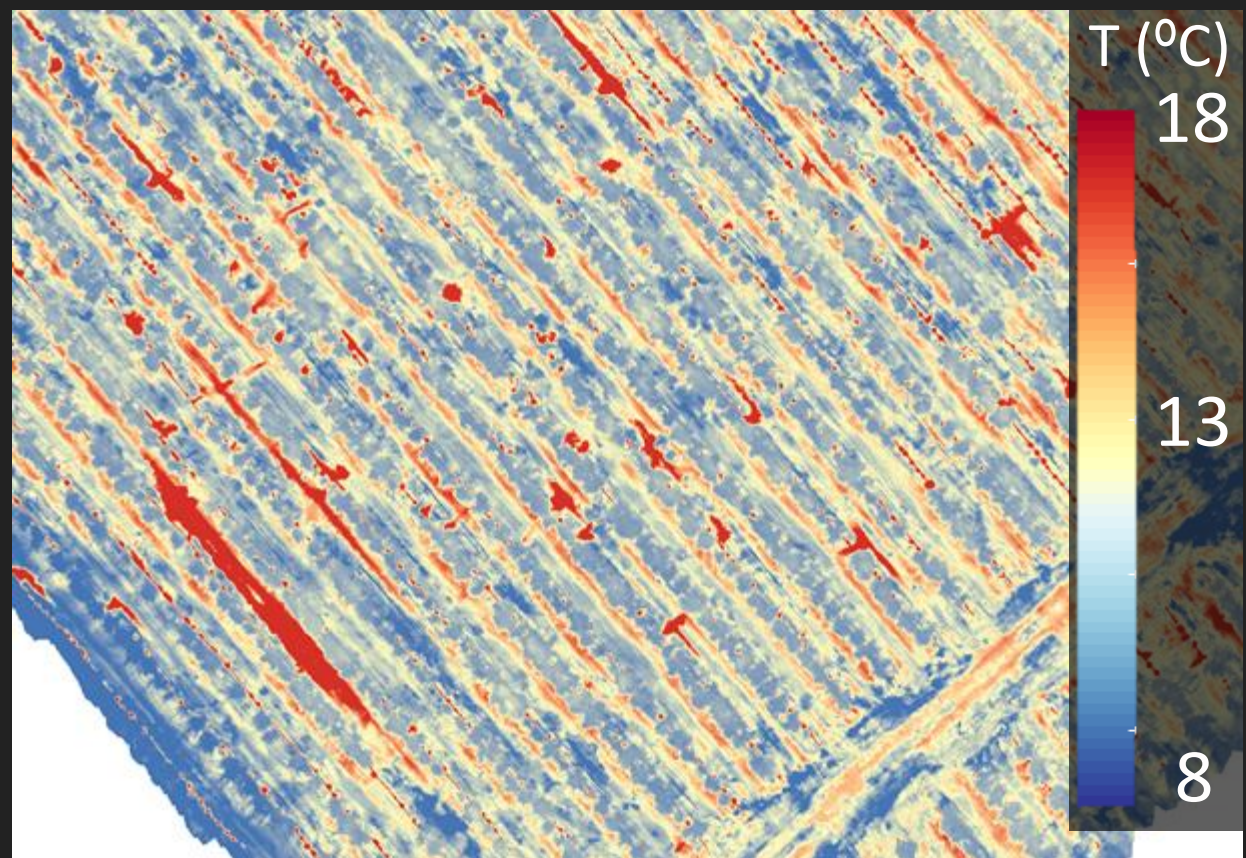
Initial Results – Thermal Data Analysis



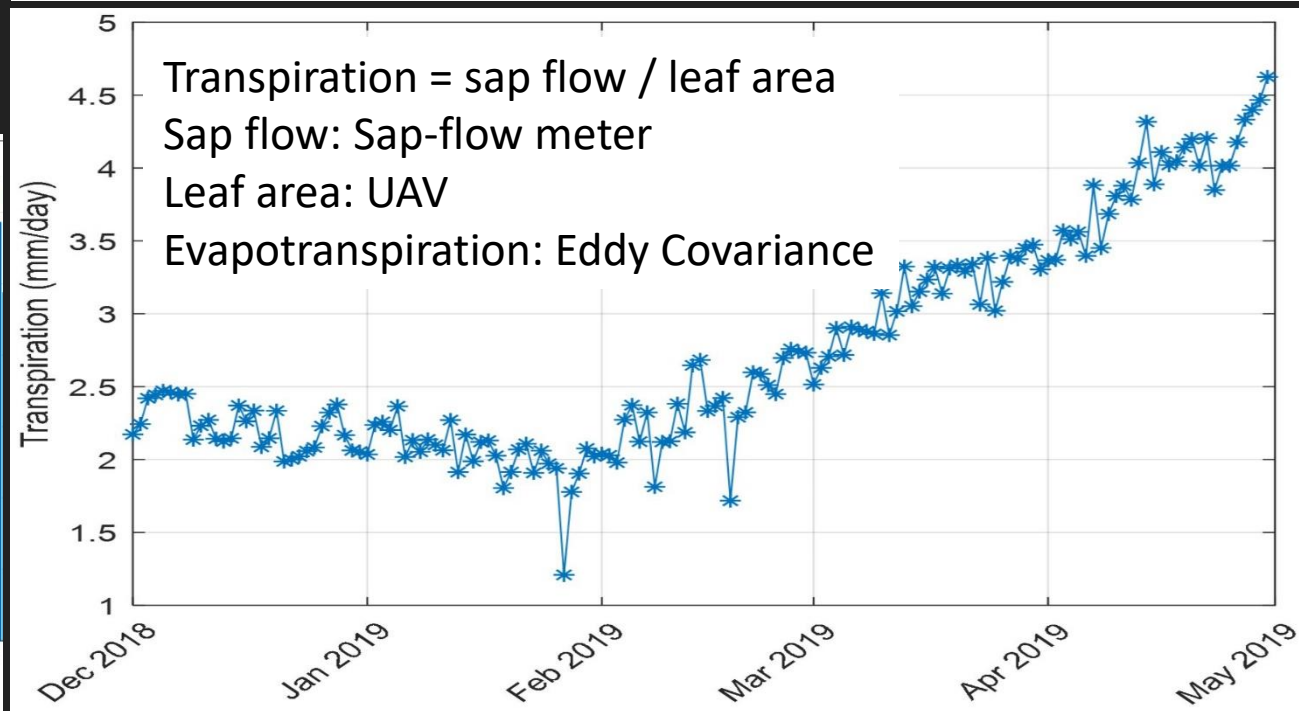
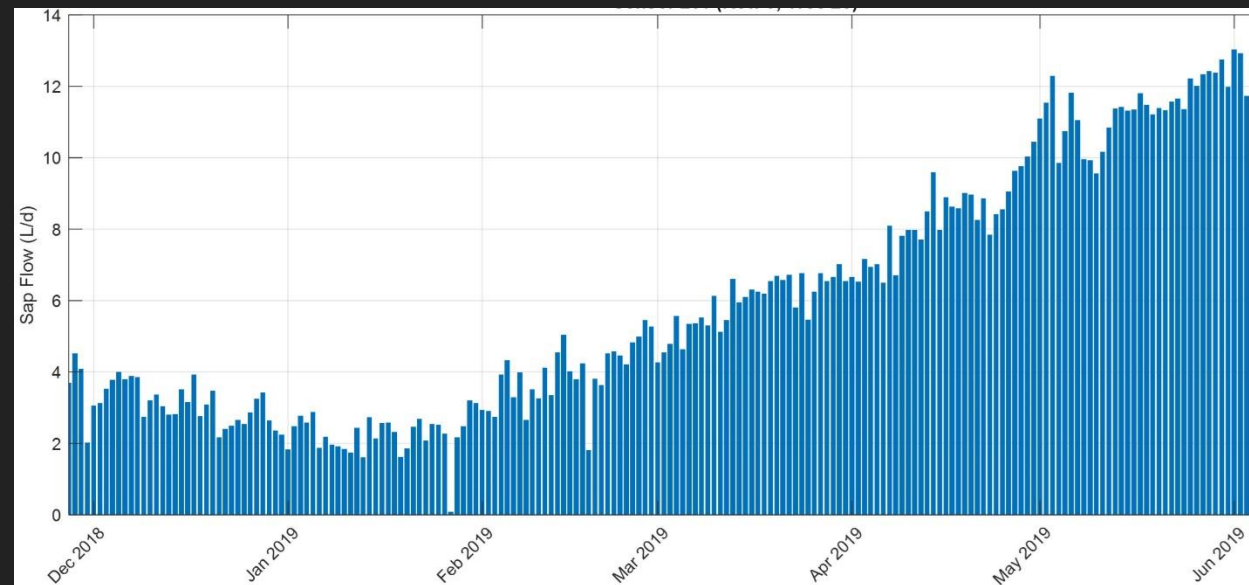
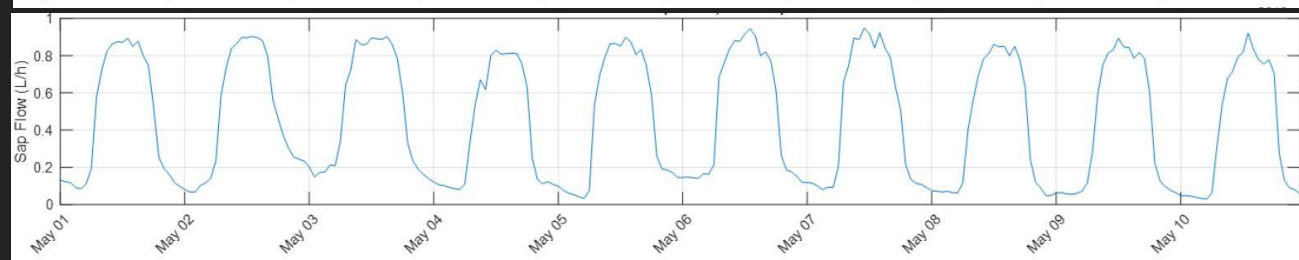
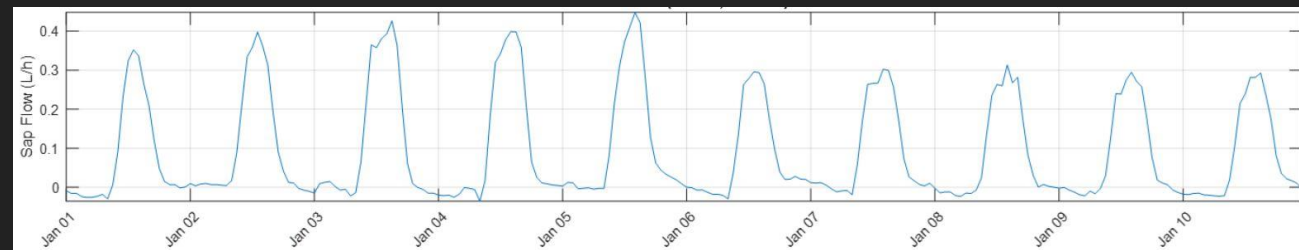
Monitoring Olive Trees in Al Jouf, Saudi Arabia



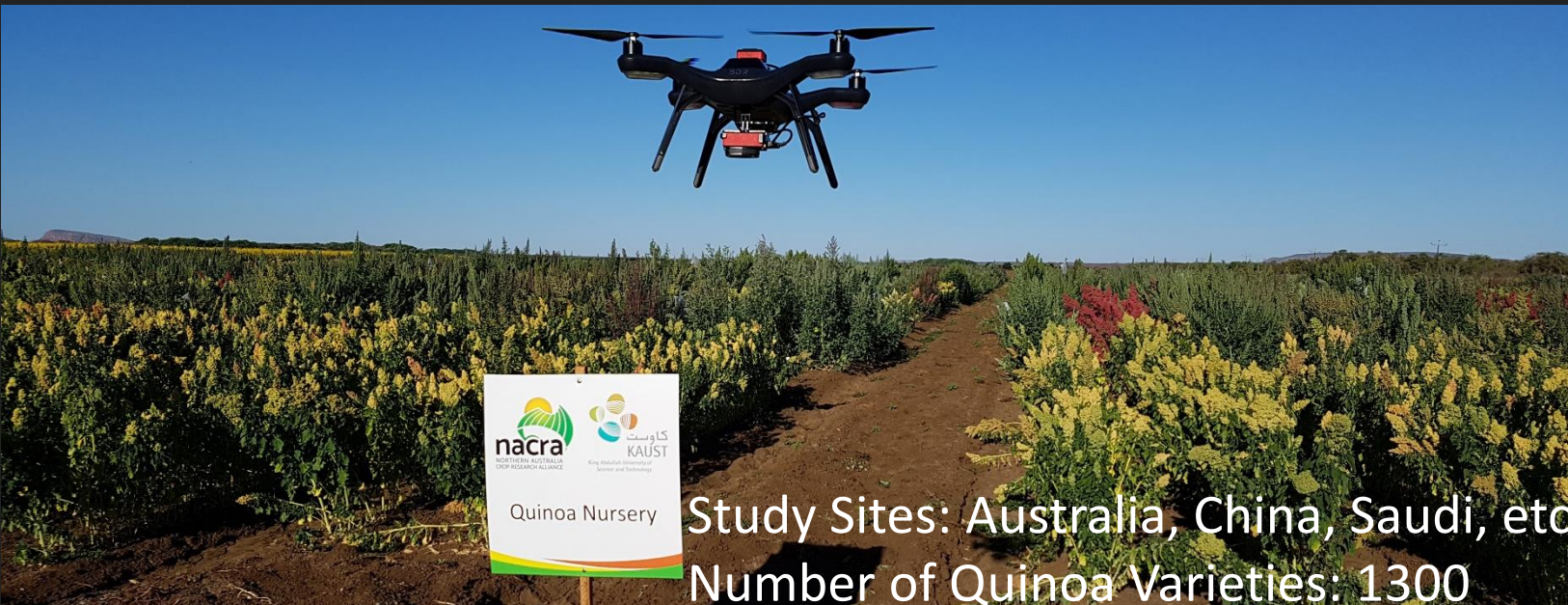
Detecting Irrigation Leaks from Night-time Thermal Data



Measuring Sap Flow of Olive Trees



Phenotyping Quinoa Varieties to Assess Performance



Mature Plant Traits

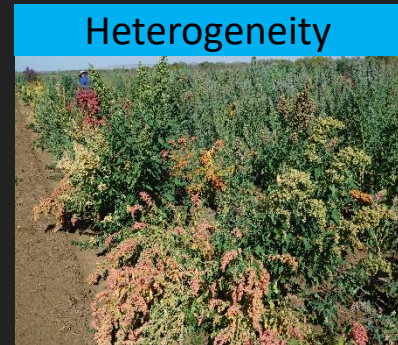
Panicle shape (at reproductive stage)

Panicle density (at reproductive stage)

Growth habit (at reproductive stage)

Panicle color or physiological maturity

- 1-White
- 2-Purple
- 3-Red
- 4-Pink
- 5-Yellow
- 6-Orange
- 7-Brown
- 8-Grey
- 9-Black
- 10-Red and white
- 11-Red and pink
- 12-Red and yellow
- 13-Green
- 14-Red and green



Hydrology, Agriculture and Land Observation



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