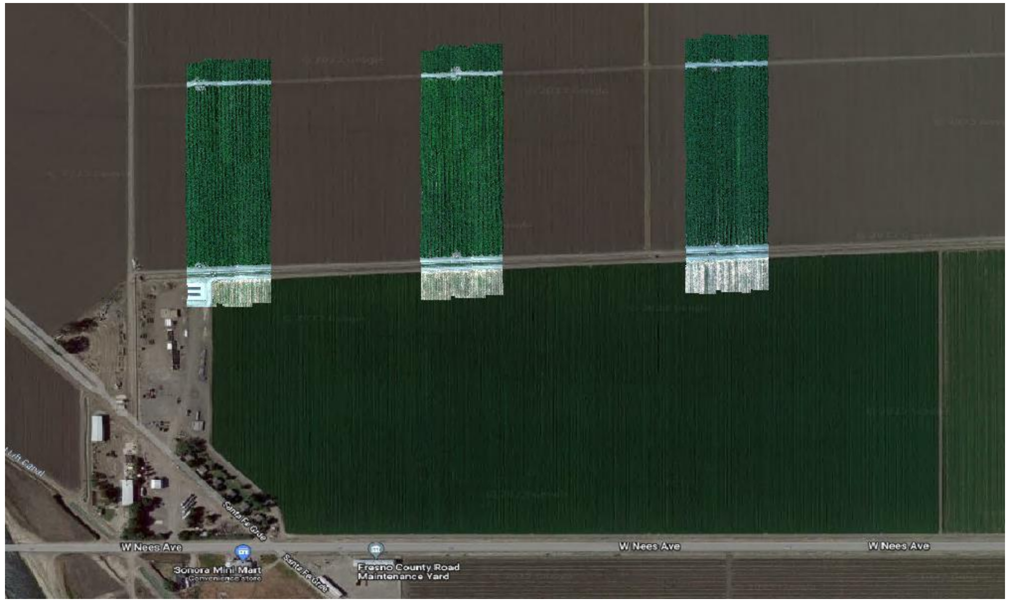
Central Valley CA – UAS Mission August 2023 – Data Processing – Victoria Scholl (USGS NUSO)

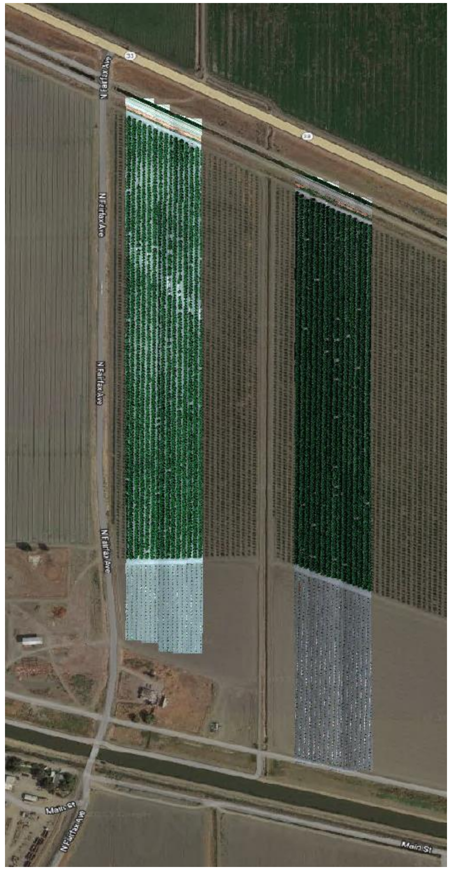
- Processed full scenes of **UAS Headwall Nano hyperspectral images** collected at a flight altitude of 90m (~300ft) August 15-17, 2023 over crop fields in CA.
- Radiometrically converted raw images to Radiance [mW/(cm^2*sr*um)] then **Reflectance** [scaled between 0-1] *calculated using the 2017 Headwall reference spectrum for our light tarp* and **Ortho-Rectified** each image using Shuttle Radar Topography Mission (SRTM) digital elevation models (DEMs).
- The ortho-rectified reflectance images are stored as 32-bit single precision floating point numbers in flat binary files with a band sequential (BSQ) interleave. Each image is accompanied by an ASCII text header file (.hdr) containing band center wavelengths and other parameters relevant to the images.
- In filenames, "_rd_rf_or" indicates an image that was corrected to radiance then to reflectance and finally orthorectified.
- Each image has **274 spectral bands** spanning visible and near infrared wavelengths, **398 to 1002 nm**.
  Images were georeferenced to a geographic coordinate system (latitude and longitude) and WGS84 datum with **5 cm spatial resolution**.
- Display true-color composite in GIS software using the following band combination: Band 124 as Red, Band 65 as Green, and Band 38 as Blue.
  Set the No Data value to 0,0,0 in these bands to make the black background appear transparent.
- Download images for each of the 12 flights by clicking each zip file on our outgoing server: https://gec.cr.usgs.gov/outgoing/UAS/CA_CentralValley_Aneece/
  - Aug 15
    - 20230815_T1_Cotton1_NS.zip
    - 20230815_T2_Almond1_NS.zip
    - 20230815_T4_Cotton2_NS.zip
    - 20230815_T5_Cotton3_NS.zip
    - 20230815_T10_Almond2_NS.zip
  - Aug 16
    - 20230816_T12_Grape_EW.zip
    - 20230816_T13_Grape_EW.zip
    - 20230816_T14_Grape_NS.zip
  - Aug 17
    - 20230817_T7_Rice_organic_EW.zip
    - 20230817_T16_T15_Rice_NS.zip
    - 20230817_T17_T18_T19_corn_NS_Exp8ms.zip
    - 20230817_T24_Rice_EW.zip

Overview of hyperspectral UAS flights

T1_Cotton1 T4_Cotton2 T5_Cotton3



T2_Almond1 T10_Almond2



T14_Grape

T12_Grape

T13_Grape

T17_T18_T19
Corn

T24

T16_T15

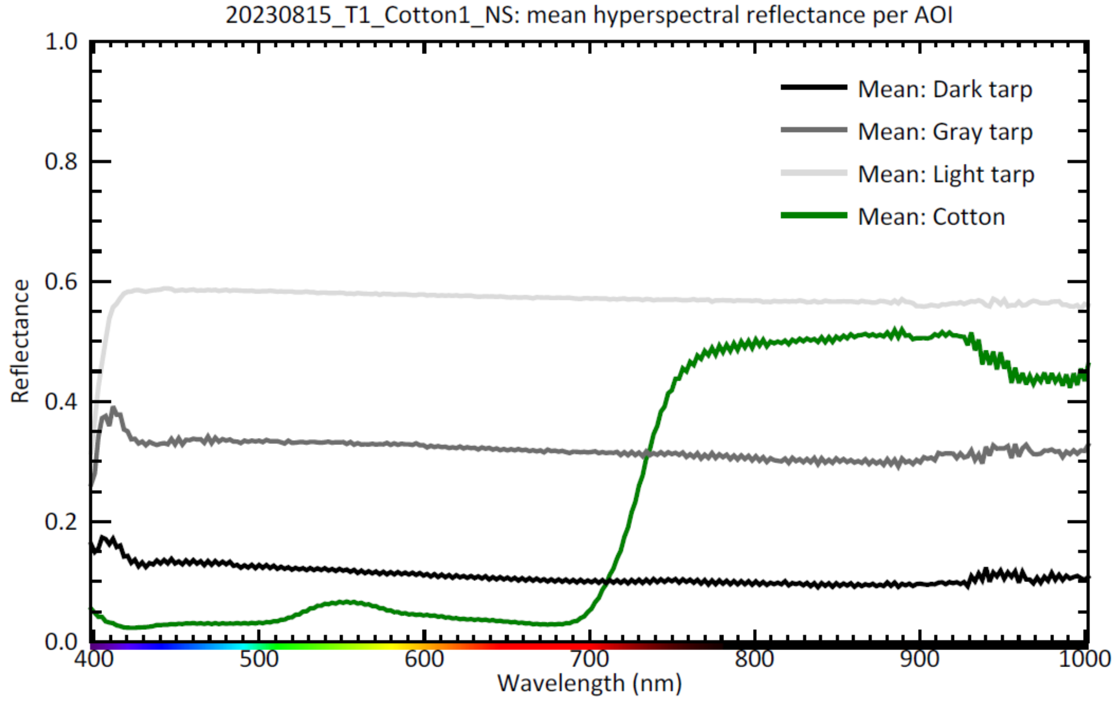
Conventional Rice

T7

Organic Rice

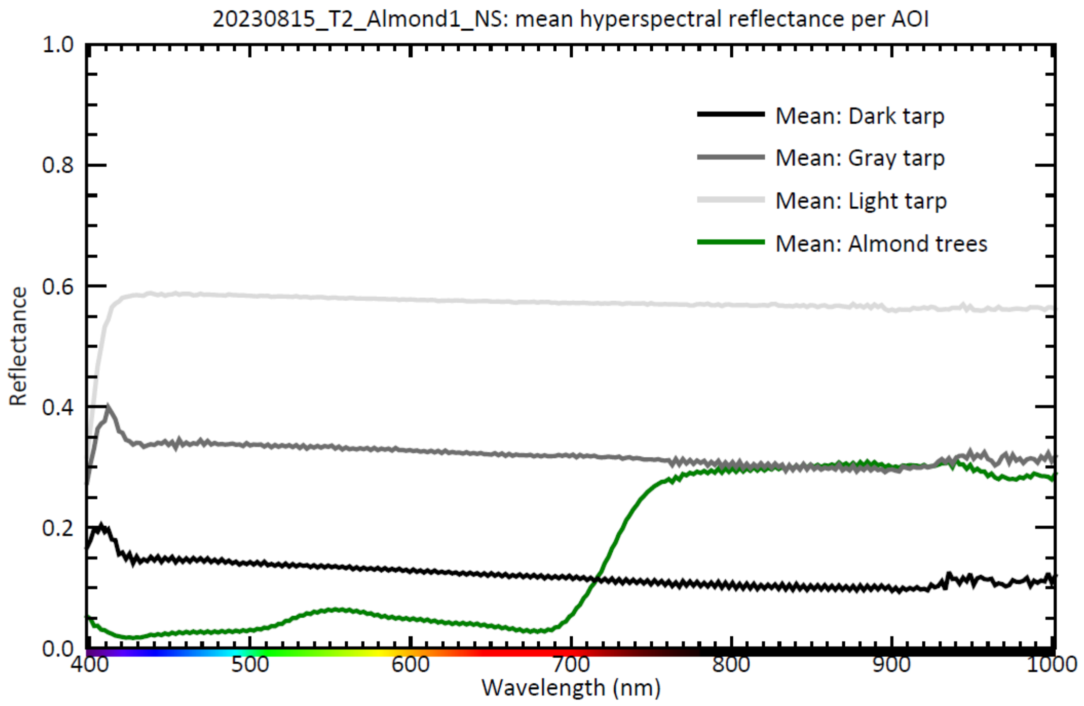
20230815_T1_**Cotton**1_NS

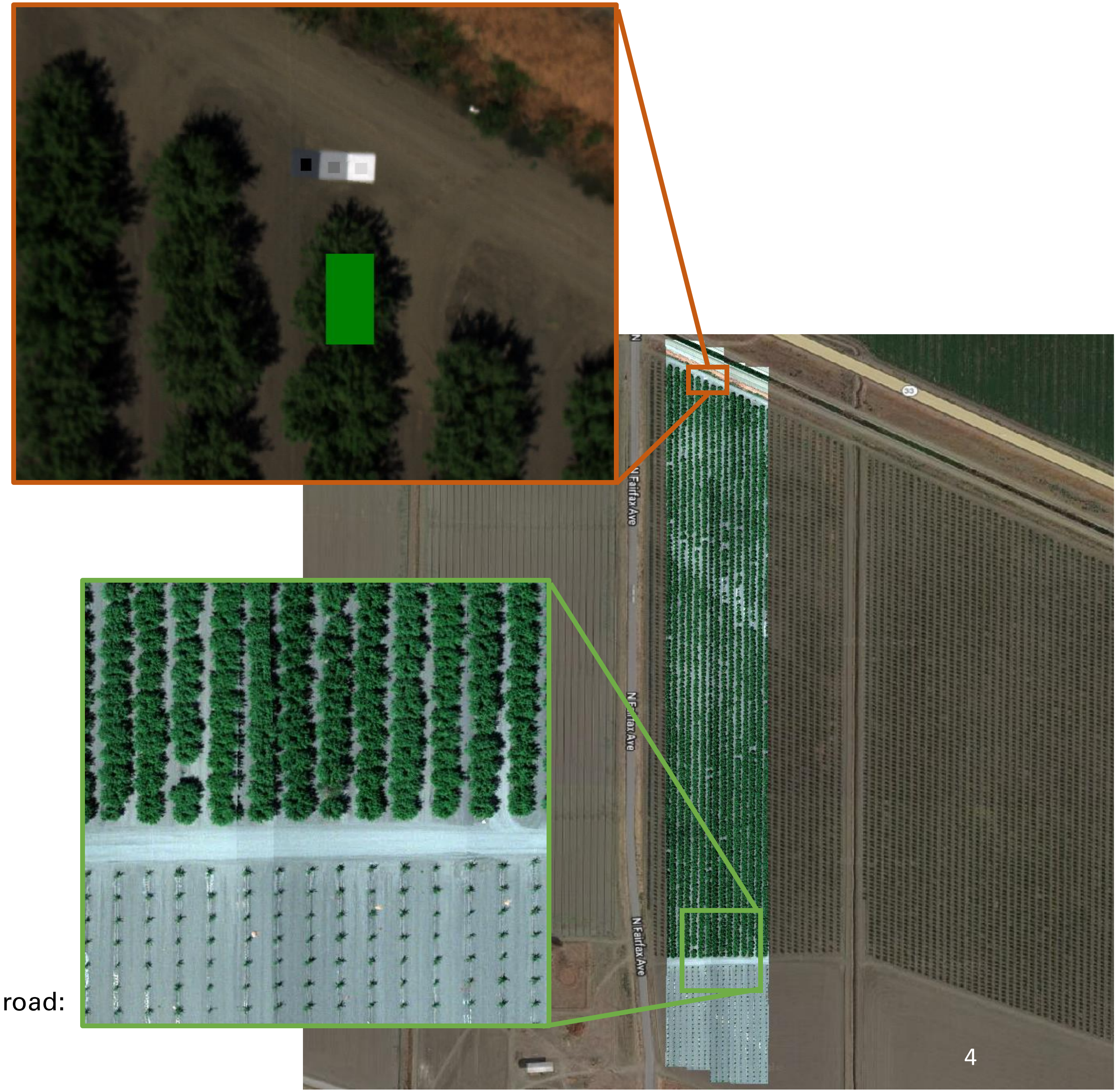
I drew areas of interest (AOIs) within each tarp and the vegetation at each site, then plotted the mean reflectance within each AOI to sanity check the reflectance values:



AOI polygons shown on a true-color composite of hyperspectral imagery:

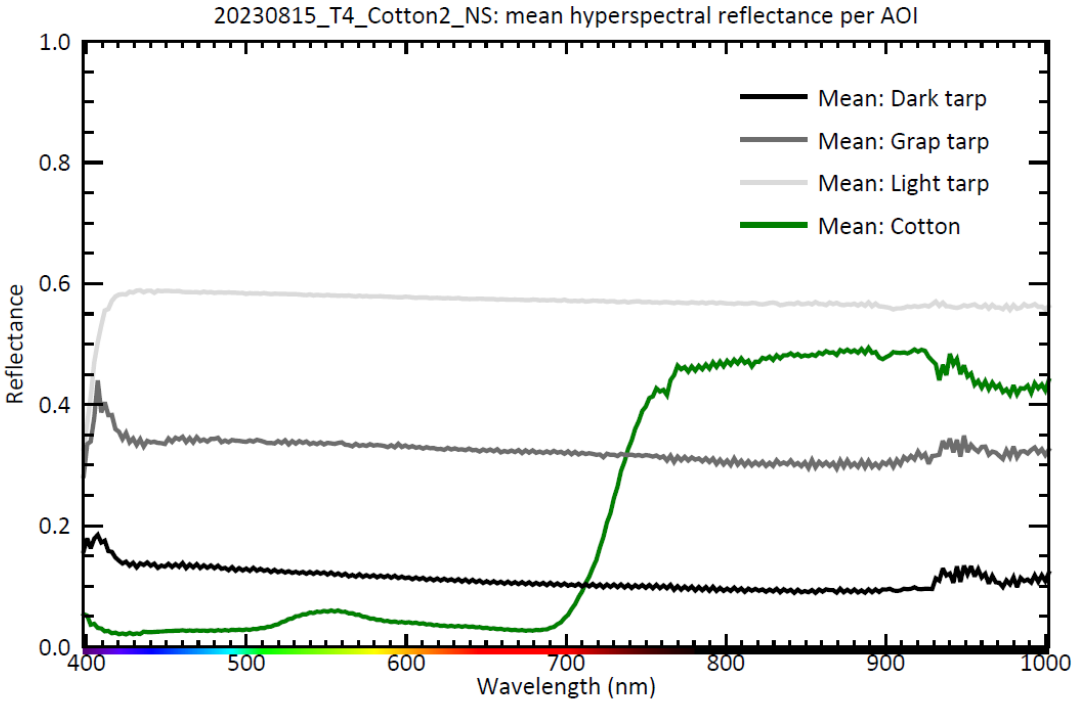
20230815_T2_**Almond**1_NS

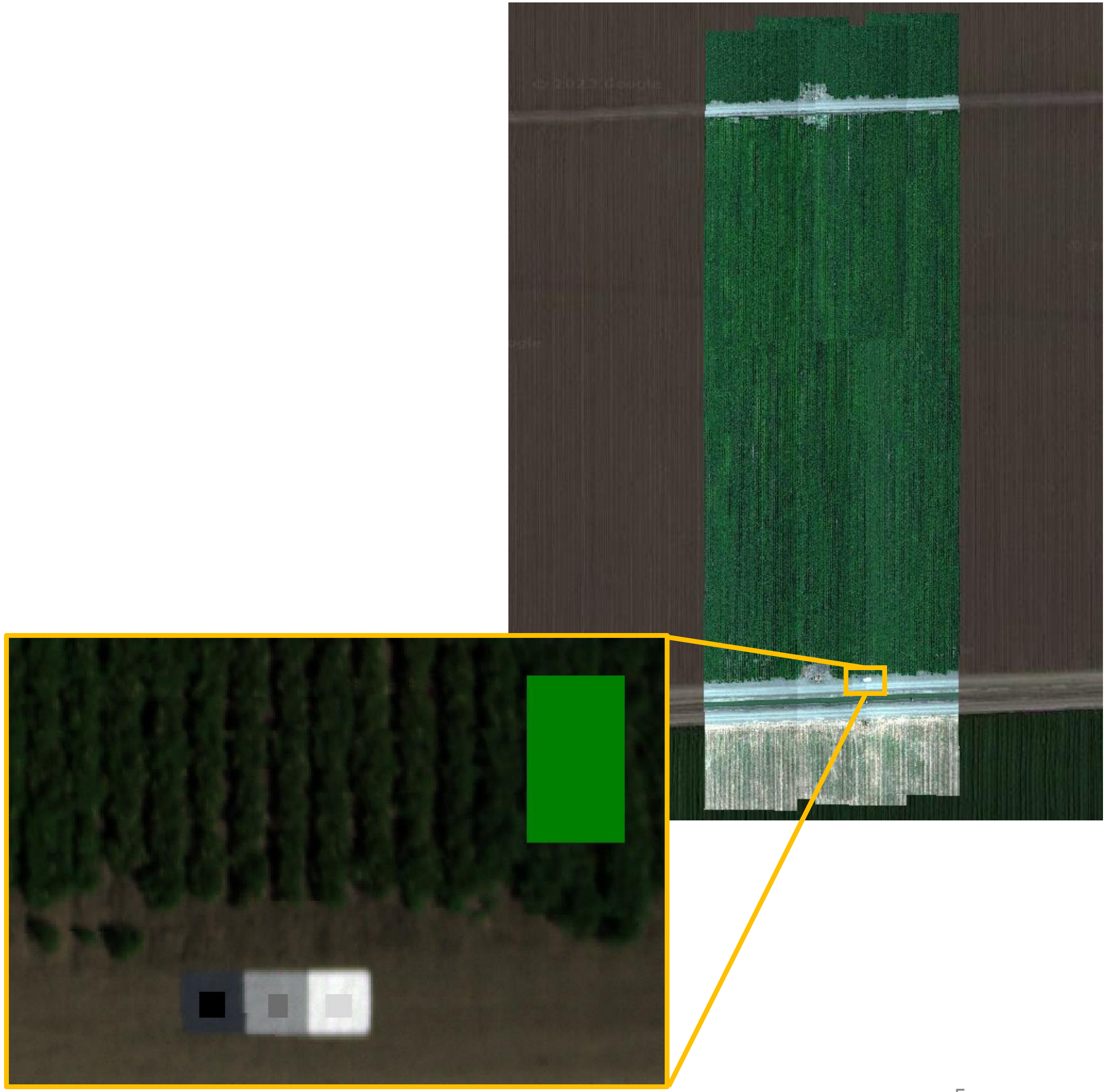




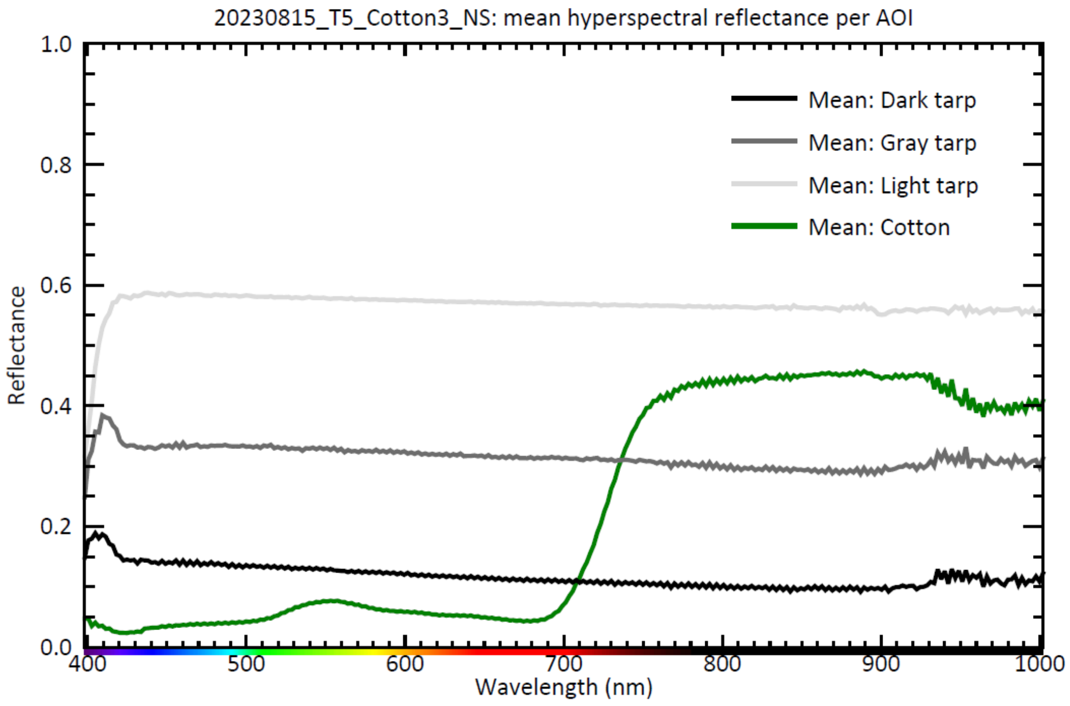
Pistachios south of the road:

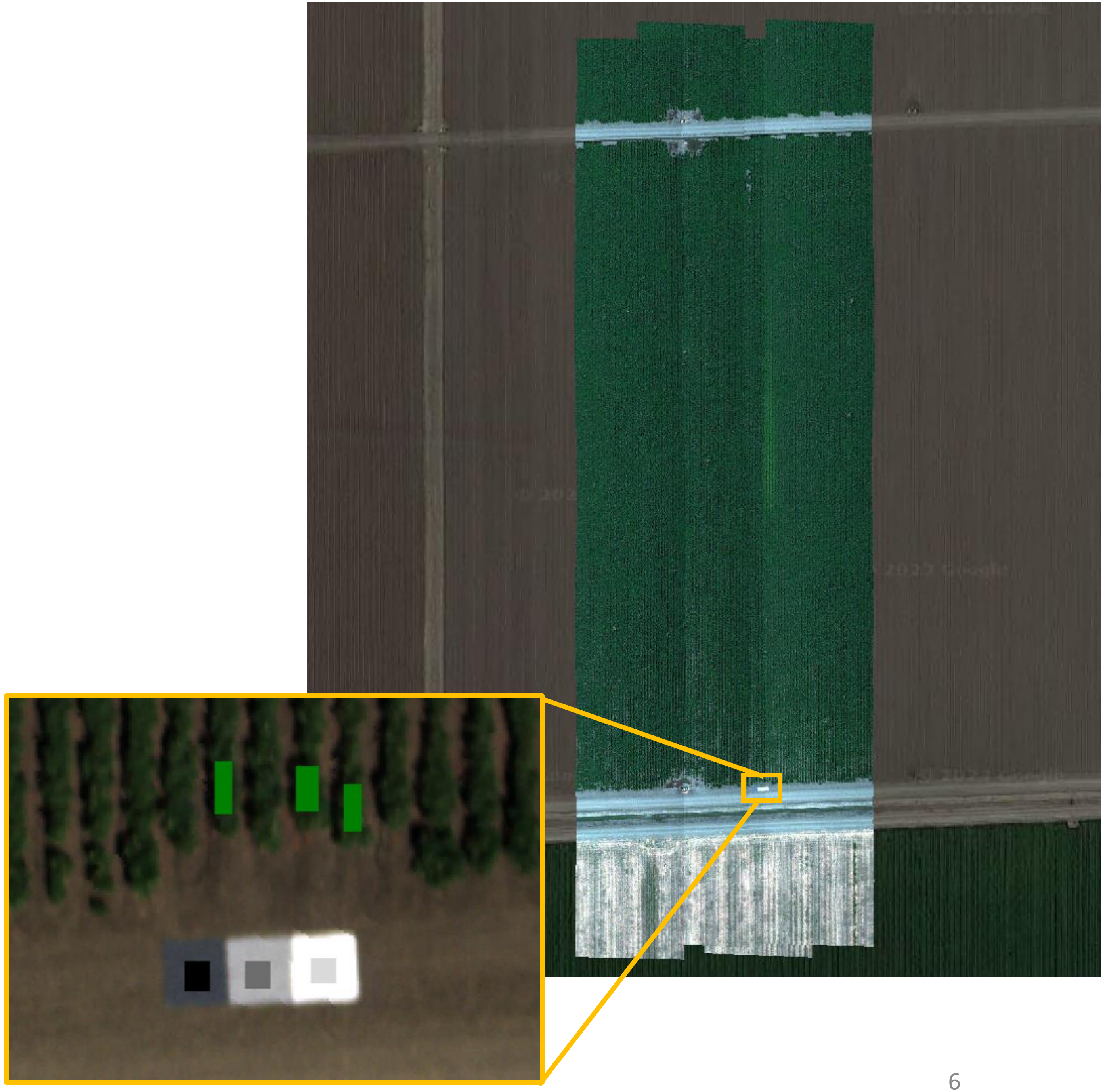
20230815_T4_**Cotton**2_NS





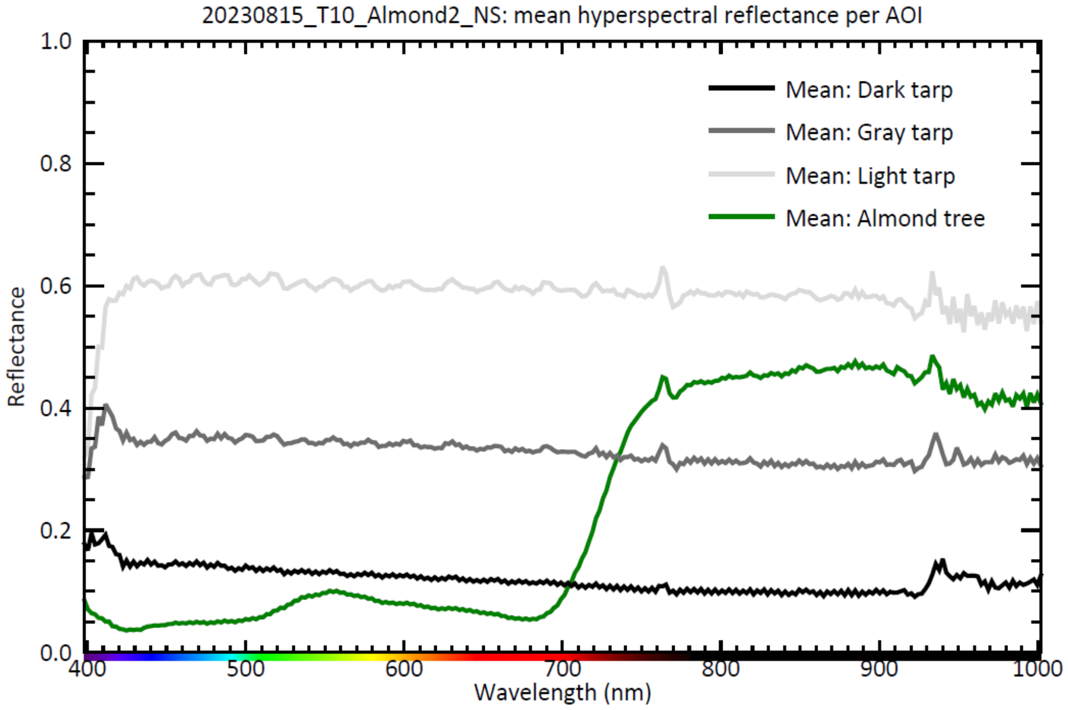
20230815_T5_**Cotton**3_NS

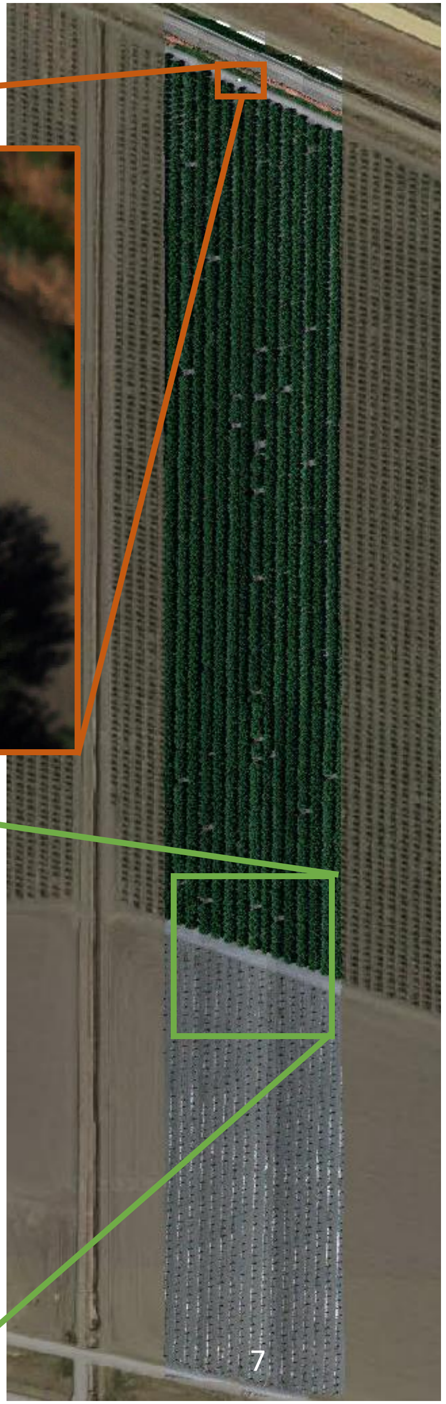


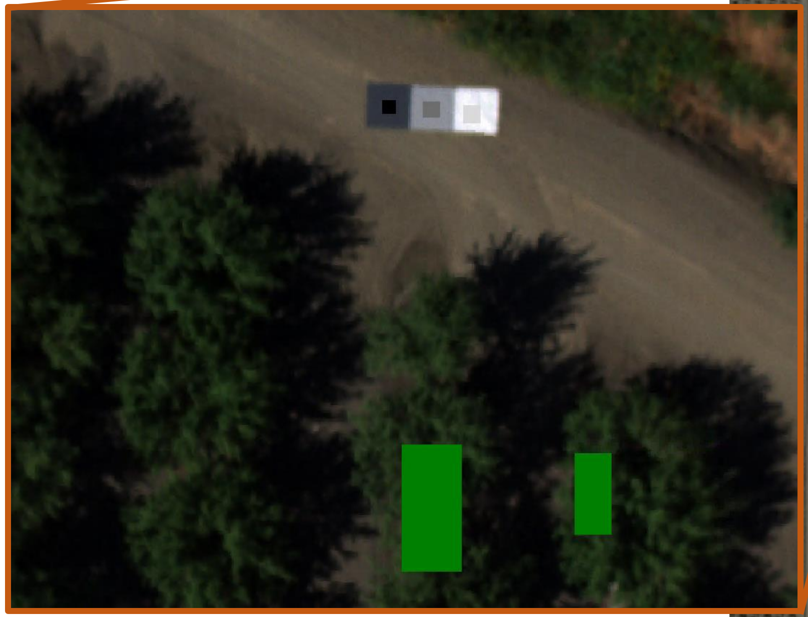


20230815_T10_**Almond2**_NS

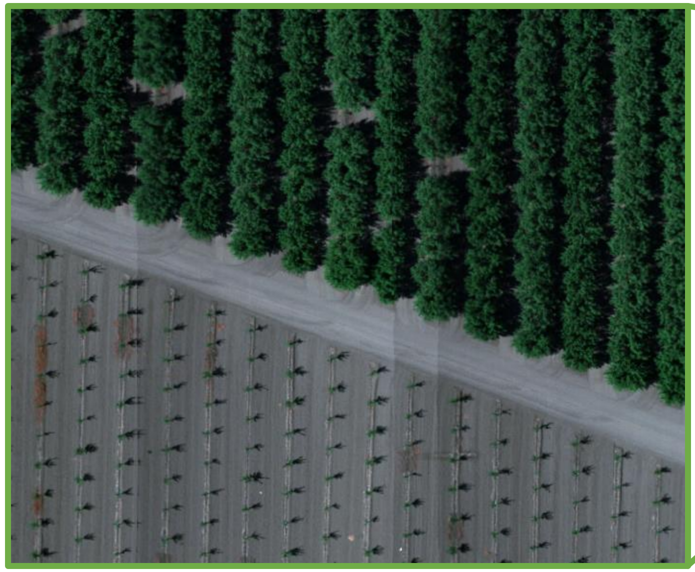
Noisier reflectance spectra compared to other flights?



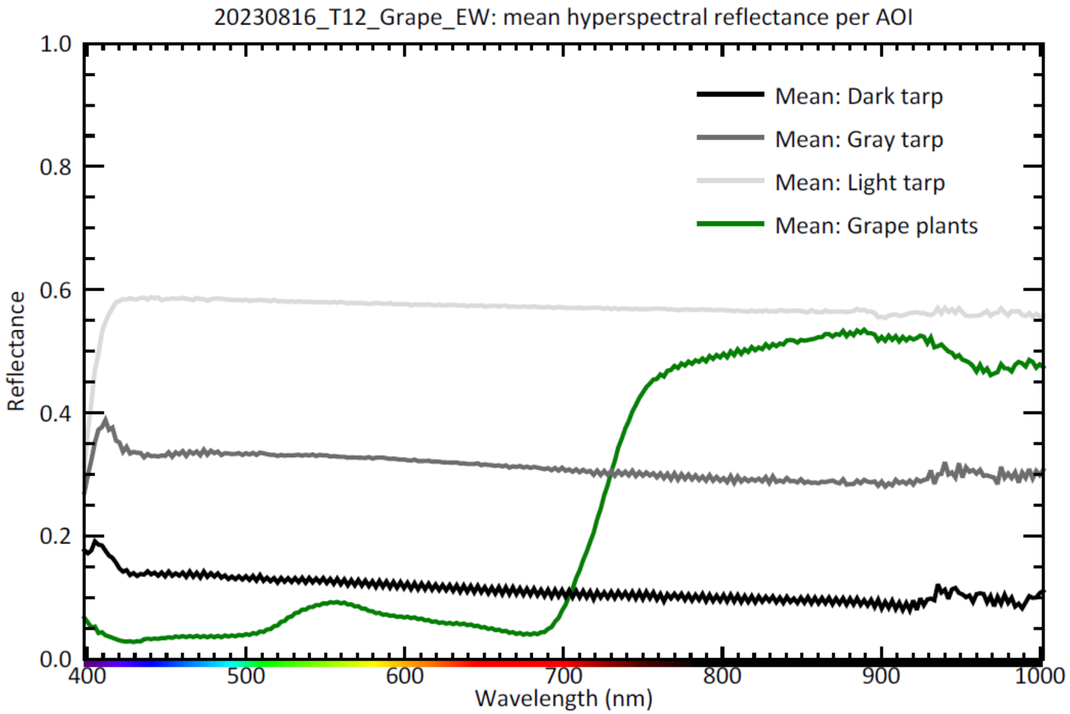


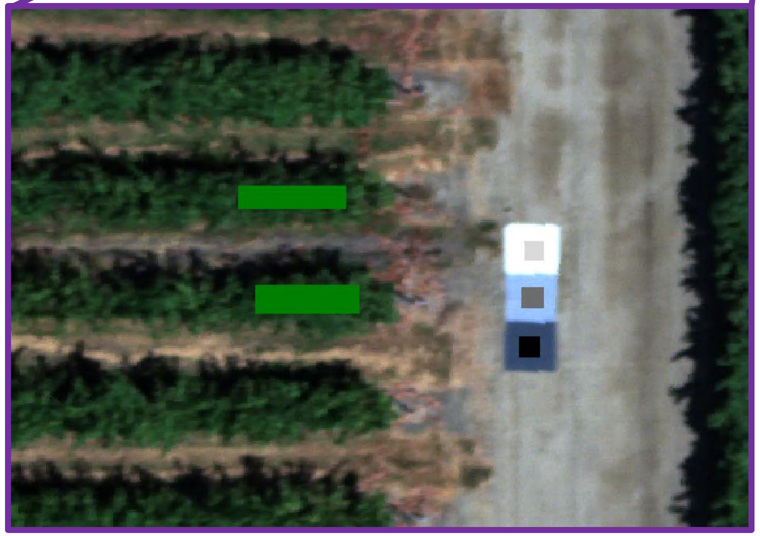


Pistachios south of the road:

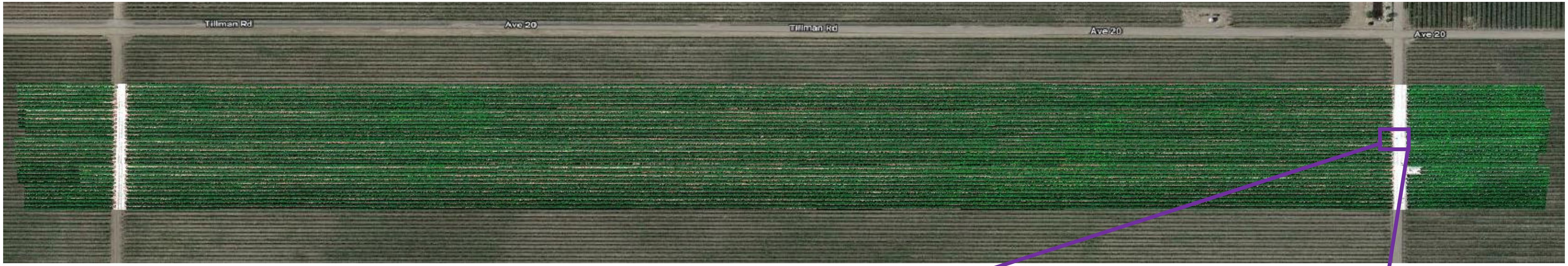


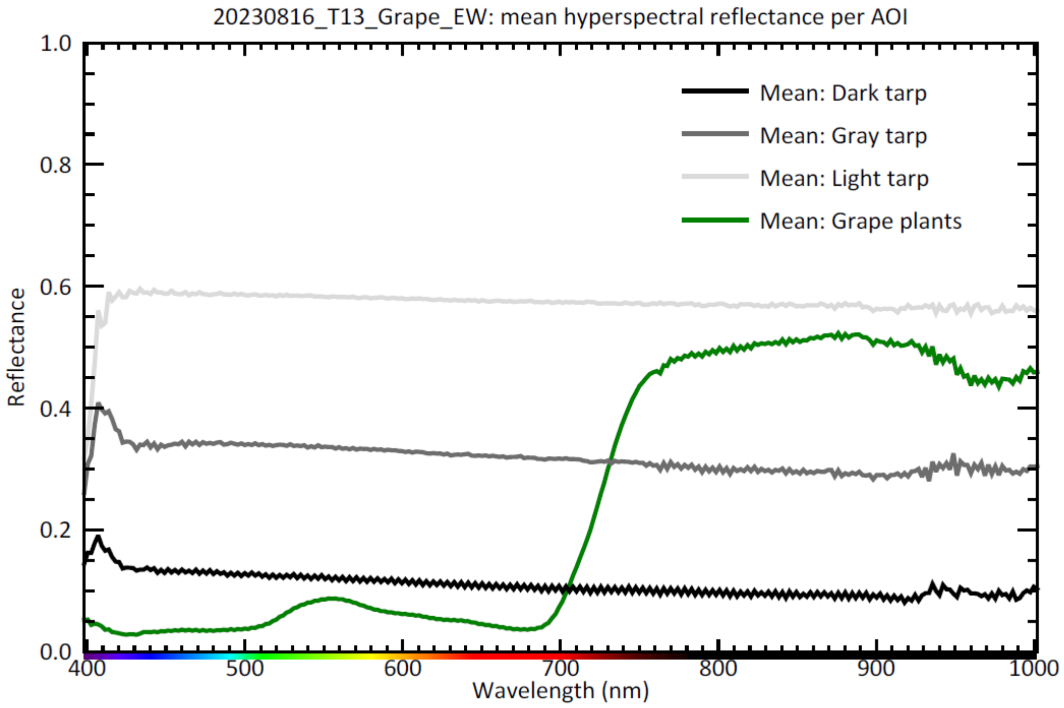
20230816_T12_**Grape**_EW

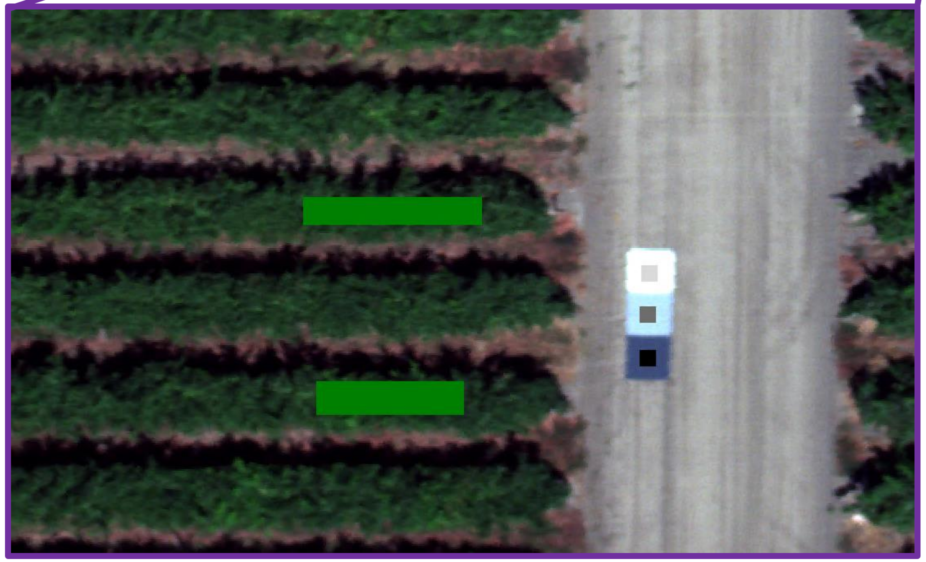




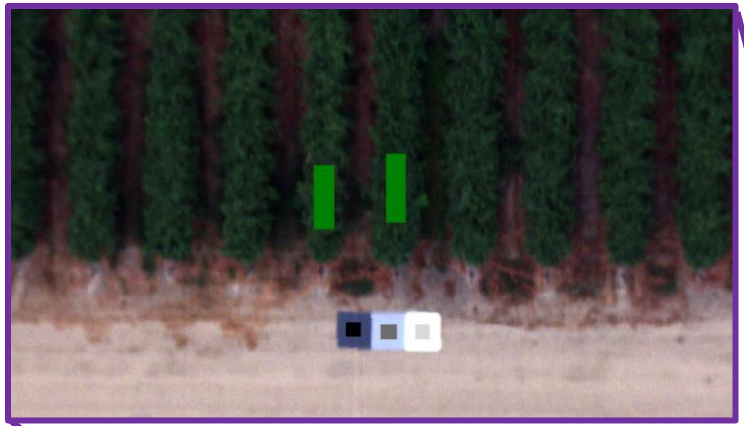
20230816_T13_**Grape**_EW

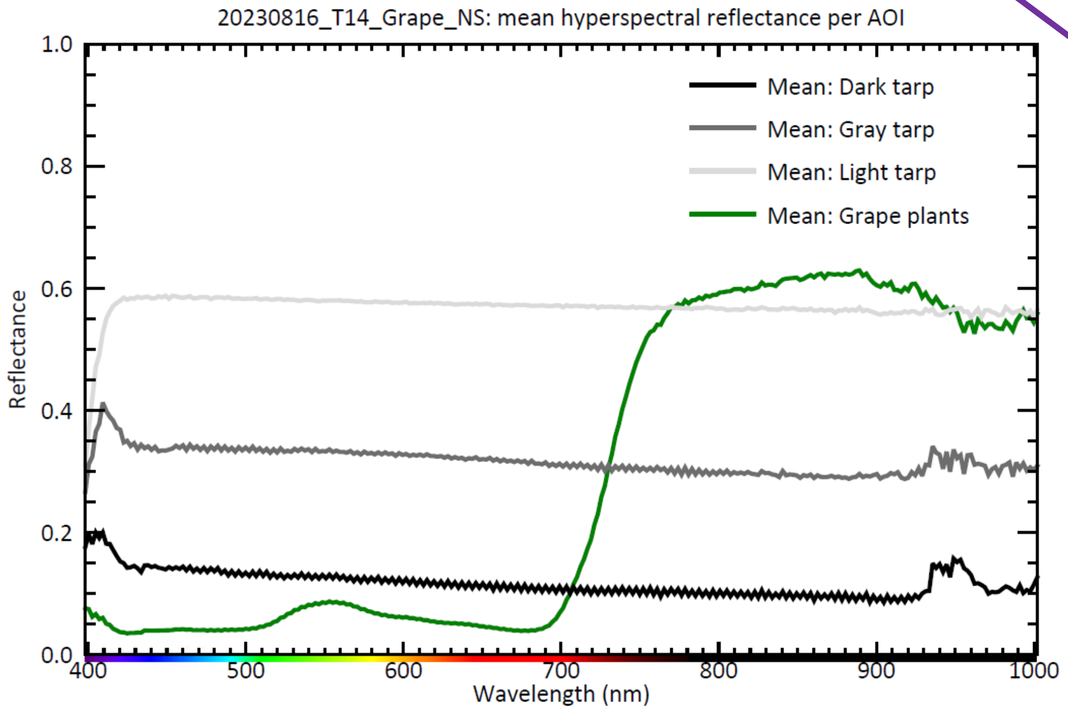






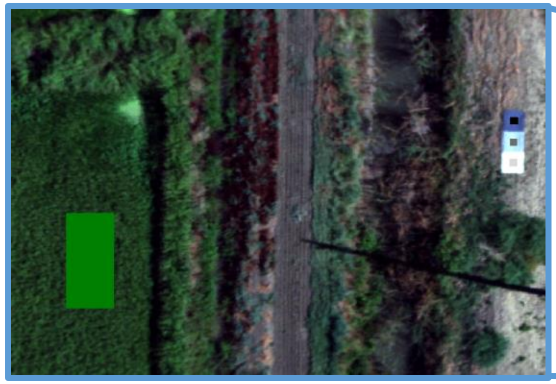
20230816_T14_**Grape**_NS



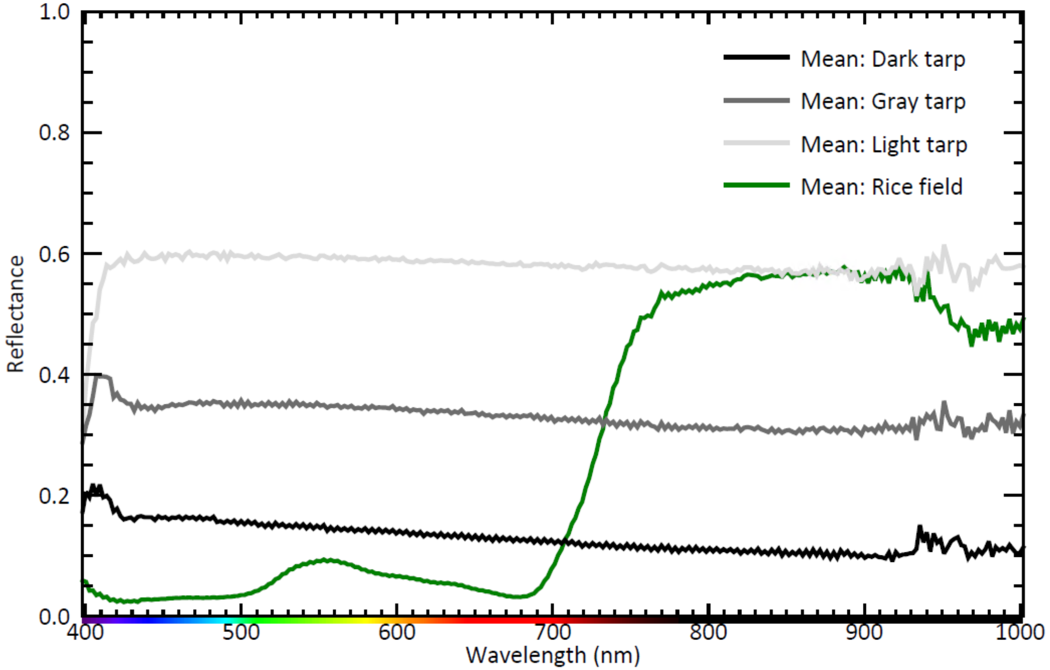


20230817_T7_**Rice_organic**_EW

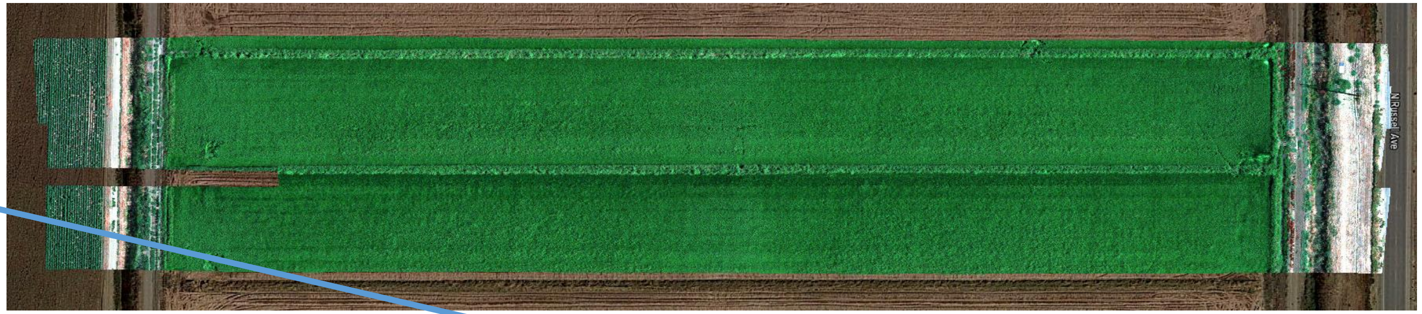
We repeated the same flight plan back-to-back for three iterations to enable comparisons.
Each flight of data is zipped separately on our outgoing server.



20230817_T7_Rice_organic_EW: mean hyperspectral reflectance per AOI

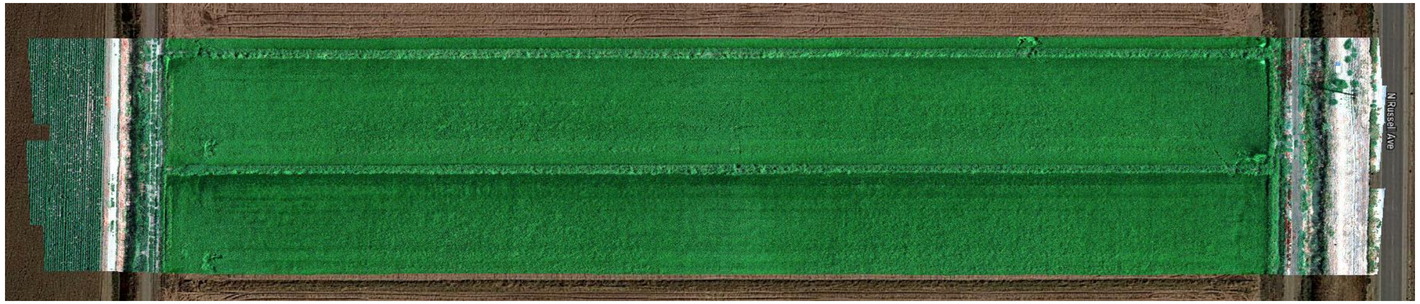


Flight 1: *missing image in third transect?*

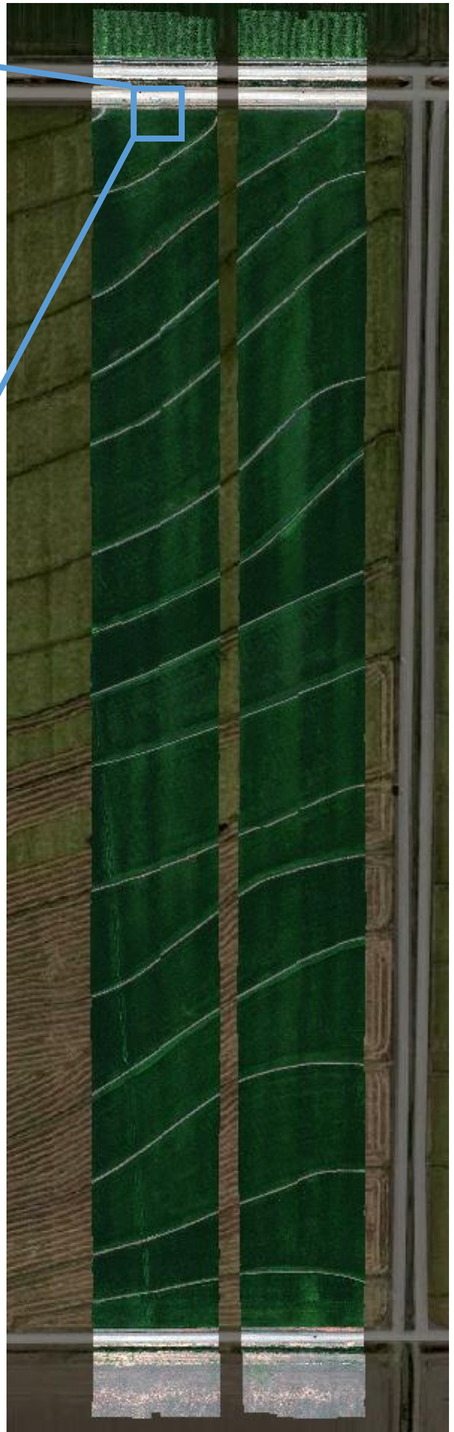


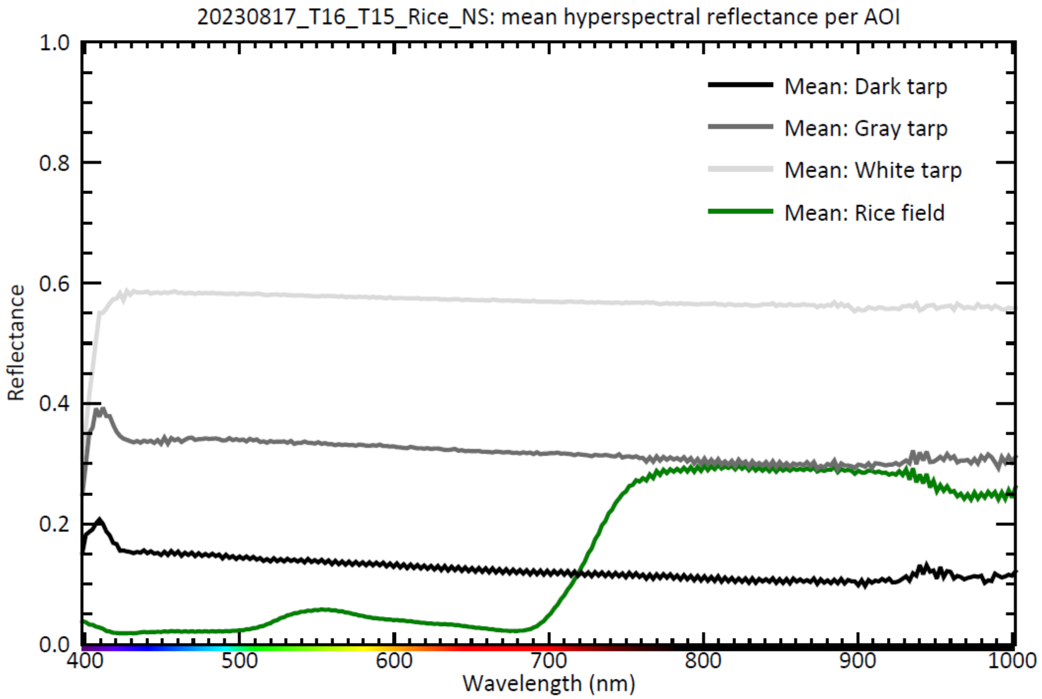
Flight 2:

Flight 3:



20230817_T16_T15_**Rice**_NS



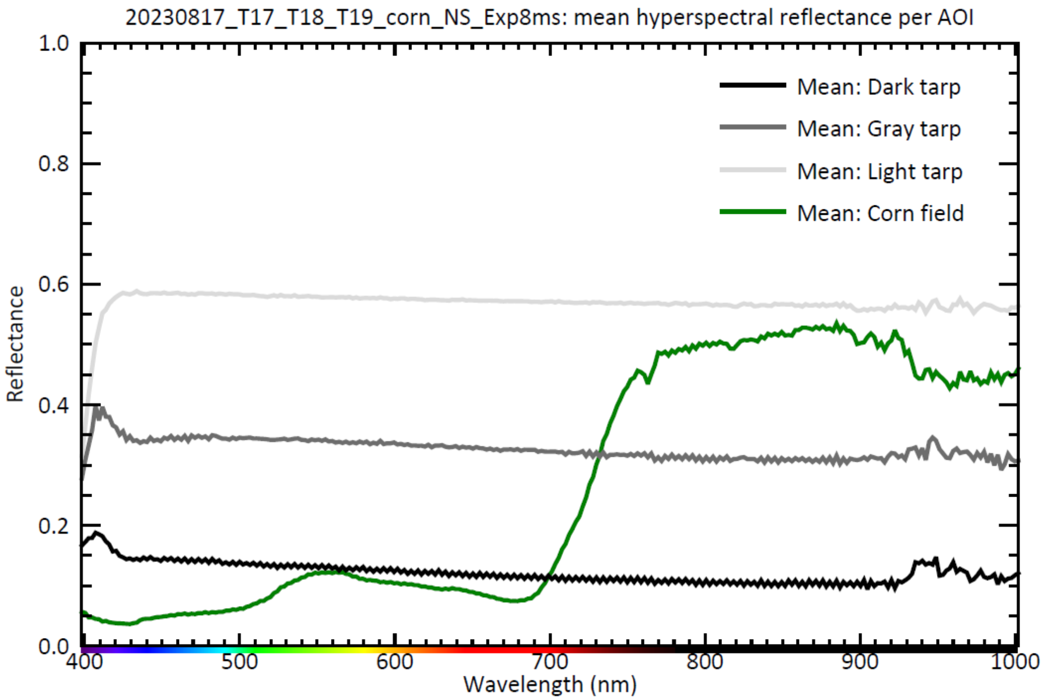


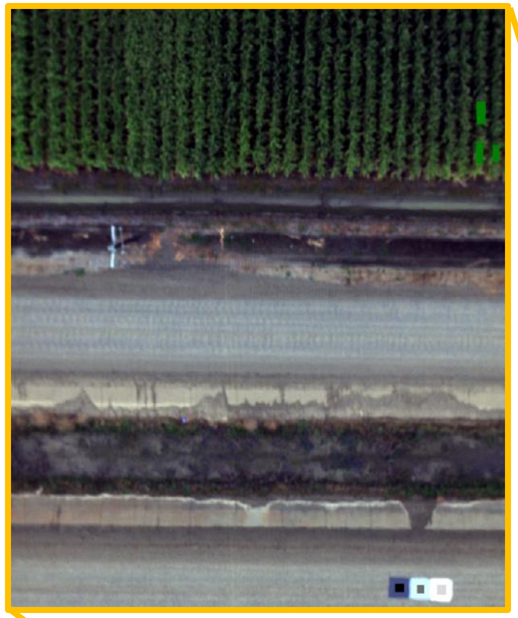
20230817_T17_T18_T19_**corn**_NS_Exp8ms

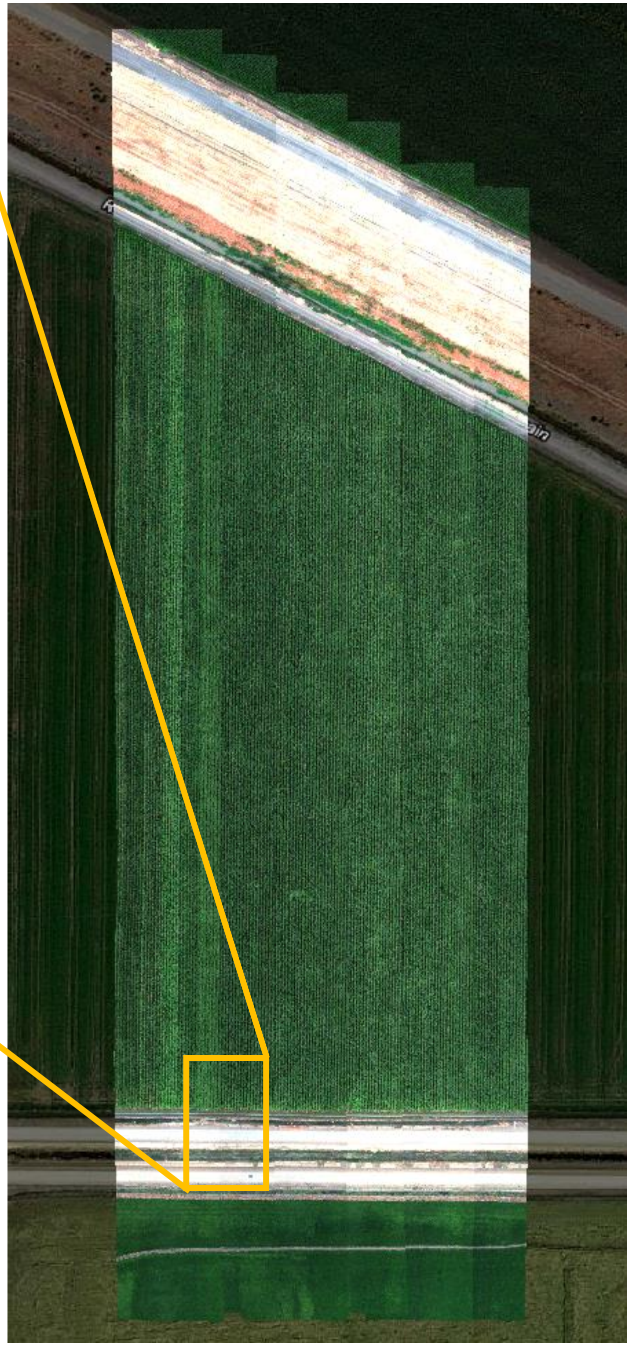
During this flight, the sky was overcast. To compensate for the darker illumination, we increased the sensor's exposure time and frame period to 8 ms for this flight over the corn field.

For all other flights with predominantly sunny skies, we utilized a sensor exposure time of 2.8 ms and a frame period of 5 ms.

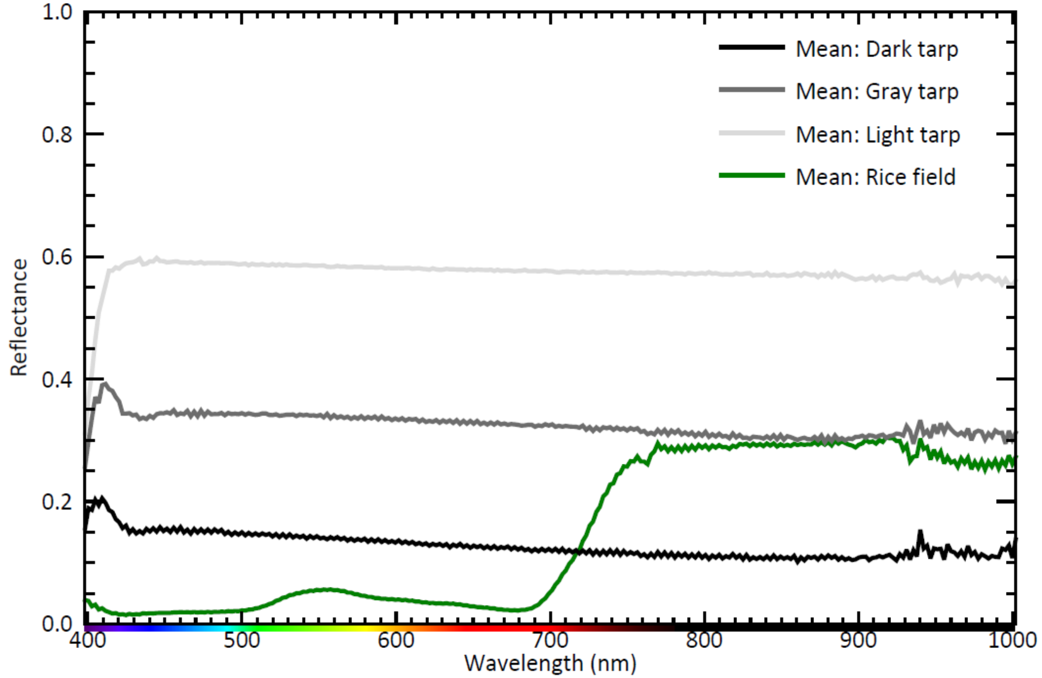
(Frame period cannot be less than 5 ms when we pair the Headwall Nano sensor with an Applanix APX-15 IMU.)

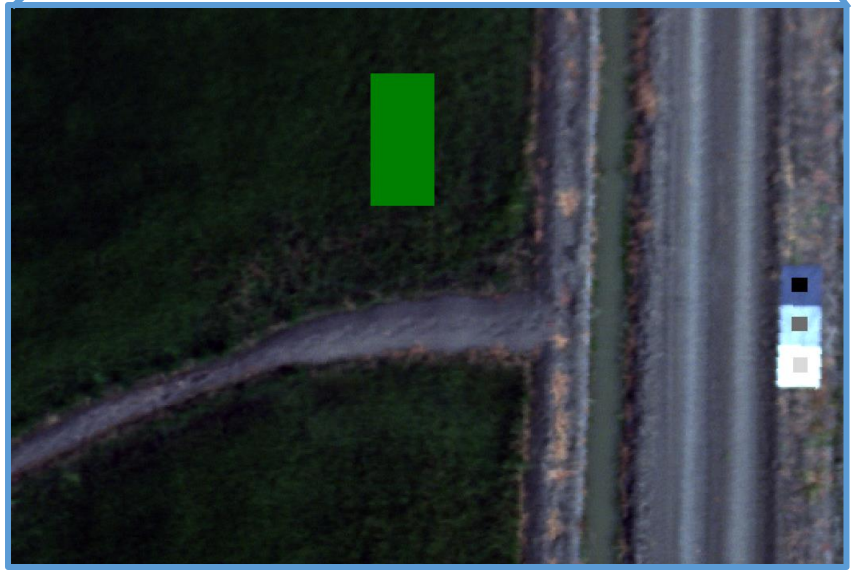






20230817_T24_**Rice**_EW





Content for metadata (part 1)

- **Originators:** Victoria M. Scholl, Matthew A. Burgess, Josip D. Adams
- **Title:** Hyperspectral orthorectified reflectance images from UAS surveys of agricultural crops in the Central Valley of California during August 2023
- **Abstract**
    - In support of U.S. Geological Survey (USGS) Western Geographic Science Center researchers, the USGS National Uncrewed Systems Office (NUSO) conducted 12 uncrewed aircraft systems (UAS) hyperspectral remote sensing flights in the Central Valley of California over a variety of crop fields: cotton, almond, pistachio, grape, rice, and corn. A Headwall Nano-Hyperspec line scanning sensor was flown at an altitude of 90 meters above ground level on a DJI Matrice 600 Pro UAS with approved government edition firmware during August 15-17, 2023.
    - The hyperspectral images were post-processed using the sensor manufacturer's proprietary software and following their recommended workflow. The orthorectified hyperspectral reflectance images are stored as 32-bit single precision floating point numbers in flat binary files with a band sequential (BSQ) interleave. Each image is accompanied by an ASCII text header file (.hdr) containing band center wavelengths and other parameters relevant to the images. Each image has 274 spectral bands spanning the visible and near infrared wavelengths, 398 to 1002 nm. The images were georeferenced to a geographic coordinate system (latitude and longitude) and WGS84 datum with an approximate spatial resolution of 5 cm.
- **Purpose**
    - Hyperspectral images capture detailed spectral information about the color of various agricultural crop fields. This hyperspectral sensor captured reflected light across the visible (VIS) wavelengths that our human visual system can detect, as well as into the near infrared (NIR) wavelengths that our human visual system cannot detect. VISNIR hyperspectral data can be used to classify land cover types and calculate spectral indices.
- **Supplemental information**
    - To display a natural color composite, Headwall recommends using the following band combination: assign band 124 as Red, band 65 as Green, and band 38 as Blue in GIS software. Set the No Data value to 0,0,0 in these bands to make the black background appear transparent.
- **Software versions**
    - Applanix POSPac UAV 8.8; Headwall SpectralView - Hyperspec v3.2.0 - Airborne

Content for metadata (part 2)

- **Lineage – Process Step Descriptions**

UAS hyperspectral images were collected using a Headwall Nano-Hyperspec line scanning sensor at a flight altitude of 90 meters above ground level. The hyperspectral images were post-processed using the sensor manufacturer's proprietary software and following their recommended workflow as summarized here. The data collected at each site were processed separately, but the same general processing steps steps were followed for each respective flight.

1. The Headwall Nano-Hyperspec was flown along with an Applanix APX-15 high-resolution GPS/IMU to capture information about the sensor's location and orientation during each UAS flight. We post-processed the APX trajectory using OPUS-corrected Trimble R8s Base Station data in Applanix POSPac UAV 8.8 software to yield a a smoothed best estimate of trajectory (SBET) file to be used later in the hyperspectral image orthorectification.
2. In Headwall SpectralView (Hyperspec v3.2.0 - Airborne) software, raw hyperspectral images were radiometrically converted to units of radiance (mW/(cm^2 * sr * um)) using a manufacturer-provided radiometric calibration file and dark reference data collected prior to each flight. Next, radiance hyperspectral images were radiometrically converted to units of reflectance using pixels within the white (~56% reflective) calibration tarp at each site. Specifically, Headwall's Spectral Angle Mapper classification tool was used to select many pixels within the tarp region and relate these pixels to a reference spectrum corresponding to the ~56% white tarp area. This reference spectrum is used to convert the rest of the pixels in each image to units of reflectance scaled between 0.0 to 1.0.
3. In Headwall SpectralView software, the reflectance hyperspectral images were orthorectified: this step removes image distortions introduced during UAS flight and corrects for terrain displacement to assign geospatial coordinates to each hyperspectral image based on an input elevation and sensor trajectory data. We utilized Shuttle Radar Topography Mission (SRTM) digital elevation models (DEMs) downloaded from USGS EarthExplorer and provided the SBET file created in Step 1. Using the Ortho-Rectification tool in SpectralView, parameters were tuned to obtain the best geometric corrections and alignment between multiple hyperspectral images.
4. These processing steps yielded a series of hyperspectral images per site, each with 274 spectral bands spanning the visible and near infrared wavelengths, 398 to 1002 nm. The orthorectified reflectance images are stored as 32-bit single precision floating point numbers in flat binary files with a band sequential (BSQ) interleave. Each image is accompanied by an ASCII text header file (.hdr) containing band center wavelengths and other parameters relevant to the images. The Headwall SpectralView software georeferences the hyperspectral images to a geographic coordinate system (latitude and longitude) and WGS84 datum with an approximate spatial resolution of 5 cm.

Content for metadata (part 3)

- **Attribute Accuracy**:
  - In the Headwall Nano-Hyperspec hyperspectral reflectance images, there are 274 reflectance values at each raster cell. To assess the accuracy of these reflectance values, we placed three radiometrically calibrated fabric tarps at each of the mapped sites with known reflectance values of approximately 0.56 (white), 0.30 (gray), and 0.11 (dark). We used the 56% tarp to calibrate the images to reflectance, which left the 30% and 11% tarps as independent validation for the reflectance values. The mean reflectance values in the hyperspectral images were calculated using Regions of Interest to select pixels within each tarp region in GIS software. The hyperspectral reflectance values were within 5% of the expected reflectance for the gray and dark tarps.
- **Logical Consistency:** The output hyperspectral reflectance values fall within expected ranges (between 0.0 and 1.0) and are generally within 5% of the expected calibrated tarp reflectance values used for validation.
- **Horizontal positional accuracy:** No formal positional accuracy tests were conducted.
- **Horizontal Coordinate System Definition**

Geographic:

Latitude_Resolution: 0.00000015

Longitude_Resolution: 0.00000019

Geographic_Coordinate_Units: Decimal degrees

Geodetic_Model:

Horizontal_Datum_Name: WGS_1984

Ellipsoid_Name: WGS_84

Semi-major_Axis: 6378137.0

Denominator_of_Flattening_Ratio: 298.257223563

To do in preparation for data release:

- Rename image files
- Zip image files for bulk download efficiency
- Create XML metadata file