Drones in the Coastal Zone – Community of Practice Meeting - Thursday, May 4 - 1:30-3:00pm

Number of folks in attendance: 37

Welcome & Introductions

- Updates Steering Committee
    - SECOORA will be seeking applications to sponsor candidates from the US Southeast region to attend three Uncrewed Aircraft Systems (UAS) executive education courses offered by the Nicholas School of the Environment at Duke University. The RFP will be released in early June 2023, with submissions due at the end of June 2023. See course info: https://marineuas.net/UAS/uas-applications-and-operations-in-environmental-science/
- CERF 2023 Special Session: Using Drones to Assess Coastal Resilience and Recovery
    - Invitation to submit abstracts. Abstracts due May 10. https://conference.cerf.science/call-for-abstracts-2023

Presentation: The Case for Low Altitude LiDAR in Tidal Environments – Eric Harkins, founder and CEO of Back Forty Aerial Solutions, LLC – See Slides

- Back Forty Aerial Solutions, LLC - Collaborating on North Inlet-Winyah Bay – National Estuarine Research Reserve.
- Light Detection and Ranging (LiDAR) - active sensor (send out pulse and get return), extremely precise measurements. LiDAR sensors are reducing in size and can be integrated on drones. LiDAR needs ground control points. LiDAR overlap requirements are lower and can cover larger areas vs photogrammetry.
- Case Study: Ghost Island and Crab Haul Creek
    - Goal was to figure out how to cover the most acreage, sustain high data quality, which led to testing scanners, and documenting insights.
    - Eric reviewed the XT32 data with the COP. Higher density of data in an area but produces more noise. Sensor depends on research purpose.
    - Recommended Rock Cloud for sharing multiple points of data. Erik Smith will be publishing the data.
- Q&A
    - How do RTK elevations vs lidar derived elevations compare to each other?
        - RTK elevations were used for a trajectory process to bring down error. Had 5cm in vertical error and brought down to 2 cm vertical error. LiDAR is inverse of photogrammetry (tighter vertical and sway in horizontal).
        - Clarification: Assuming LiDAR is giving ground level. Do you find checkpoints with the same elevation in using LiDAR if compared?

        - Checkpoints in Creek bank and through marsh vegetation. Yes, there is an offset of 3cm. But it was uniform across all vegetation and site selections.
            - Was uniform offset a function of multiple laser beams of XT32? Up for debate
    - Flight speed - slower over area = more hits, would that have boosted groundhits?
        - Yes, but there is a point of diminishing returns and efficiency.
    - Fly over the ocean and get a 3d wave file over the ocean?
        - If you fly over water, yes you get return if water is moving). Have a 10% return at 400 feet.

Presentation: Using Drone Data and Machine Learning to Map Invasive Species and Monitor Coastal Restoration – Brendan Brown & Drew Reicks, CDM Smith – See Slides

- Developing capabilities for data and having good ground truth data to serve machine learning models. Using a combination of multi spectral camera data. Large drone datasets need to be easily sorted through. Utilize automation and machine learning to manage drone derived datasets.
- Case Study: comparing trajectory of restoration with the reference wetland areas. Performed 80 plots and created an estimate of biomass for each pot. Using drones for coverage percentages (comparing NAVDI signature and infrared band compared to red band). Fractional Vegetation Coverage - measured over 5 years and saw an increase in coverage and mitigation area. Tough to get an accurate representation of the height of the grass. Combined models to create algorithms for a Biomass model in open-source python.
- Invasives species and identification and mapping. Collected data to train the model. Species accuracy is 80% and grouped together.
    - What drone were you flying for that Hillsborough project? And what property was it, if you don't mind answering.
        - Inspire (?) Drone. Balm Boyette Scrub Nature Preserve and little manatee river preserve.
    - Each line represents a ground truth polygon in the field. Multispectral use for water is a challenge (too many different factors, turbidity, etc.). Cannot make MDI effective (???).
    - Ground truth biomass - allometric equation from 190 individual stems (dried and weighed). With drone data, each quarter went and measured the stem heights and converted data to biomass for that plot.

Discussion items:

- FAA's final rule requiring all UAVs flying outside a FAA-recognized Identification Area (FRIA) be equipped with Remote ID either as part of the aircraft or using an add on module, effective

September 16, 2023. How are organizations planning to meet the requirement?
https://www.faa.gov/uas/getting_started/remote_id

- Troy - not seeing many on the market. 1072 alpha amendment - it does say take a remote ID device and move from drone to drone (must have the same serial number applied as transferred drone to drone).
- Douglas Cahl - do we just expect cheap remote id modules to become available soon?
- Erik Smith - I have been assuming DJI would be coming out with an add on (given how many drones they have out there...)
- Back Forty Aerial Solutions - I'm not sure of cost, but I know Kenji Sugahara of this company got a patent for a remote id item. Haven't seen it hit the market yet though https://www.airsentinel.ai/
- Marianna Coppola - I think Parrot is developing firmware for that. Unknown if happening.
- Scott Reynolds - South Carolina cannot purchase outside of the US and cannot use PIX4D due it being France. Vertigo Drones resells.

The Case for Low Altitude LiDAR in Tidal Environments

A brief overview of LiDAR and data summary from flights at

North Inlet-Winyah Bay NERR, Georgetown, SC

Eric Harkins

CEO, Back Forty Aerial Solutions

BACK FORTY
AERIAL SOLUTIONS

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Who are we?

BACK FORTY
DRONE SERVICE PROVIDERS
BACKFORTYDRONES.COM

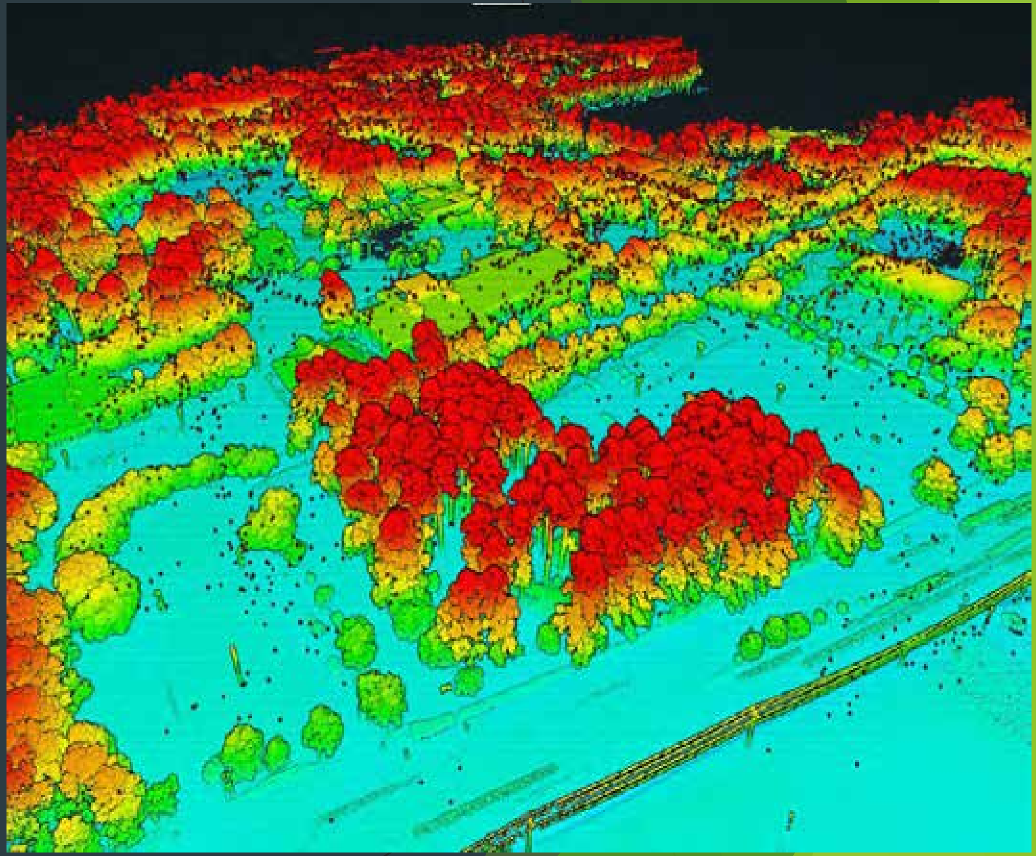
- One of SC’s longest continuously operating drone services businesses (2015)
- Certified FAA 107 RPICs, with >4000 logged flights
- Approaching $1million in annual revenue, 9 drones currently in inventory
- We specialize by learning the payloads and science, then confidently apply it to solve and research customer applications
  - 2D & 3D Aerial, Mobile, and SLAM Digital Twin Applications
  - Civil Construction & Environmental Documentation/ Marketing
  - Asset Inspections

Who am I?

- SC Native - Spring Valley HS, USC & Clemson
- Before drones I worked Forestry, GIS, and IT
- Feathers in The Cap: >370 hours logged sUAS flight
  - Wrote the manual for large acreage mapping with sUAS for Dronedeploy (2016)
  - First Commercial Flight inside Williams Brice Stadium (2016)
  - First sUAS Map of Entire USC Campus (1100 acres, 2017)
  - Pilot in First-ever Coordinated sUAS deployment for Natural Disaster Response (Hurricane Irma, Florida Power & Light, 2017)
  - Worked as Customer Success Manager at Kittyhawk.io, now Aloft, and onboarded entire National Civil Air Patrol to the platform (2018-2019)
  - Trained US Navy EOD Operators on sUAS platforms for use in active war zones (2018)

So what is LiDAR and why is it so special?

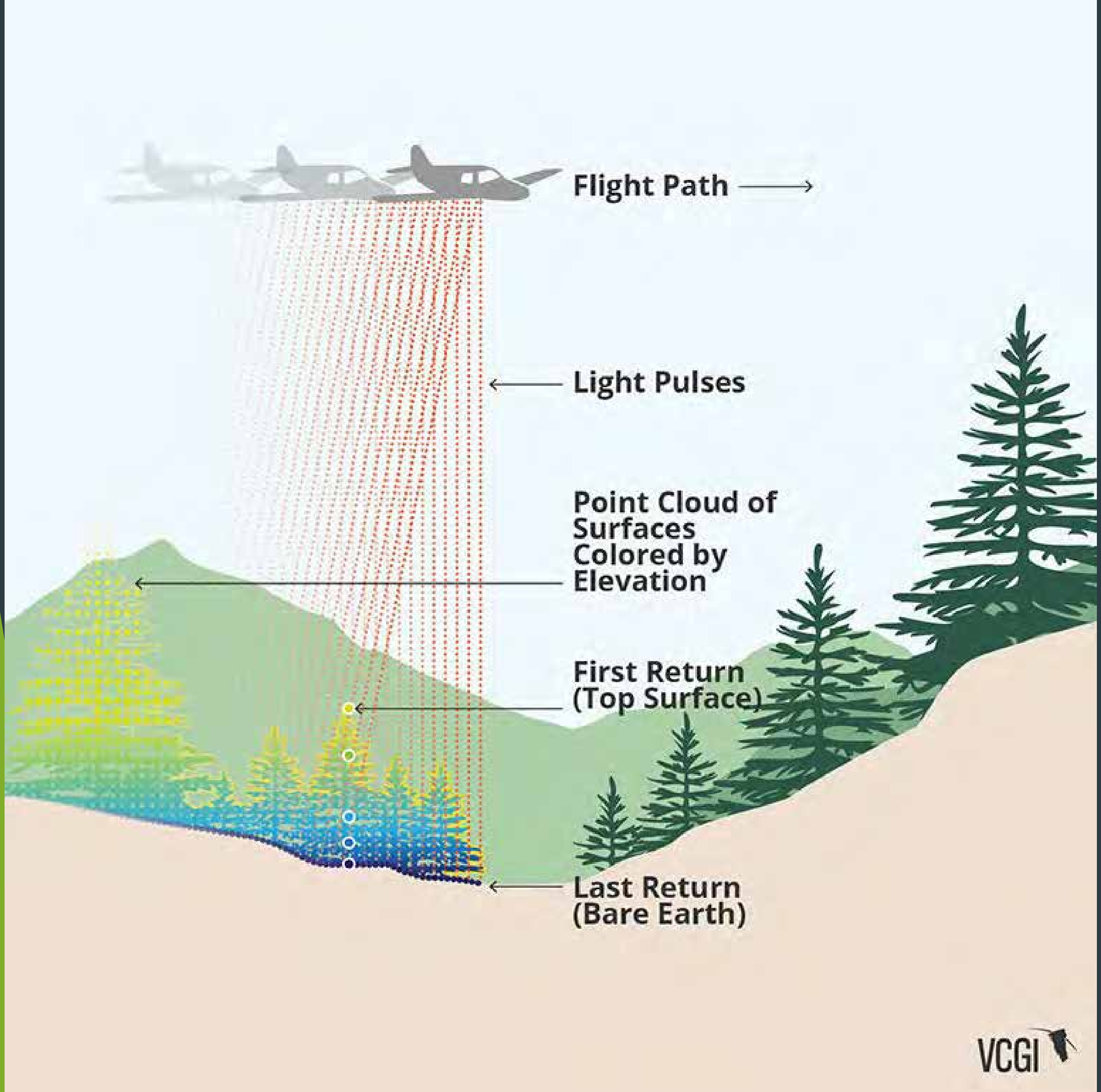
Light Detection and Ranging

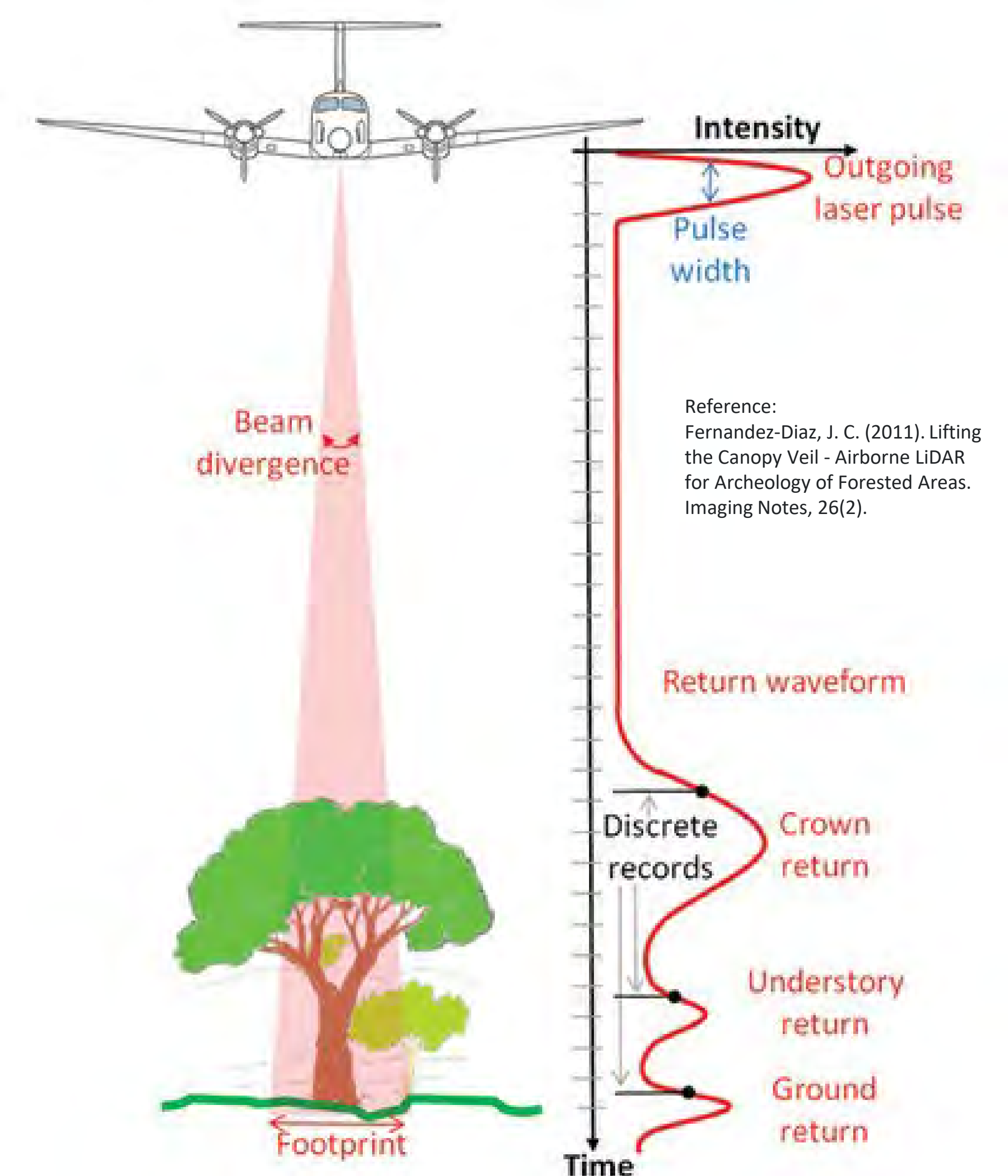


- Drones can now measure objects extremely accurately thanks to Lidar technology.
- Extremely precise X-Y-Z measurements are made by firing hundreds of thousands of laser pulses per second at a target object and timing the time it takes for each pulse to bounce back.
- With the aid of this cutting-edge remote sensing system surveying, digital twining, and GIS applications may now be carried out with unprecedented precision.

So what is LiDAR and why is it so special?

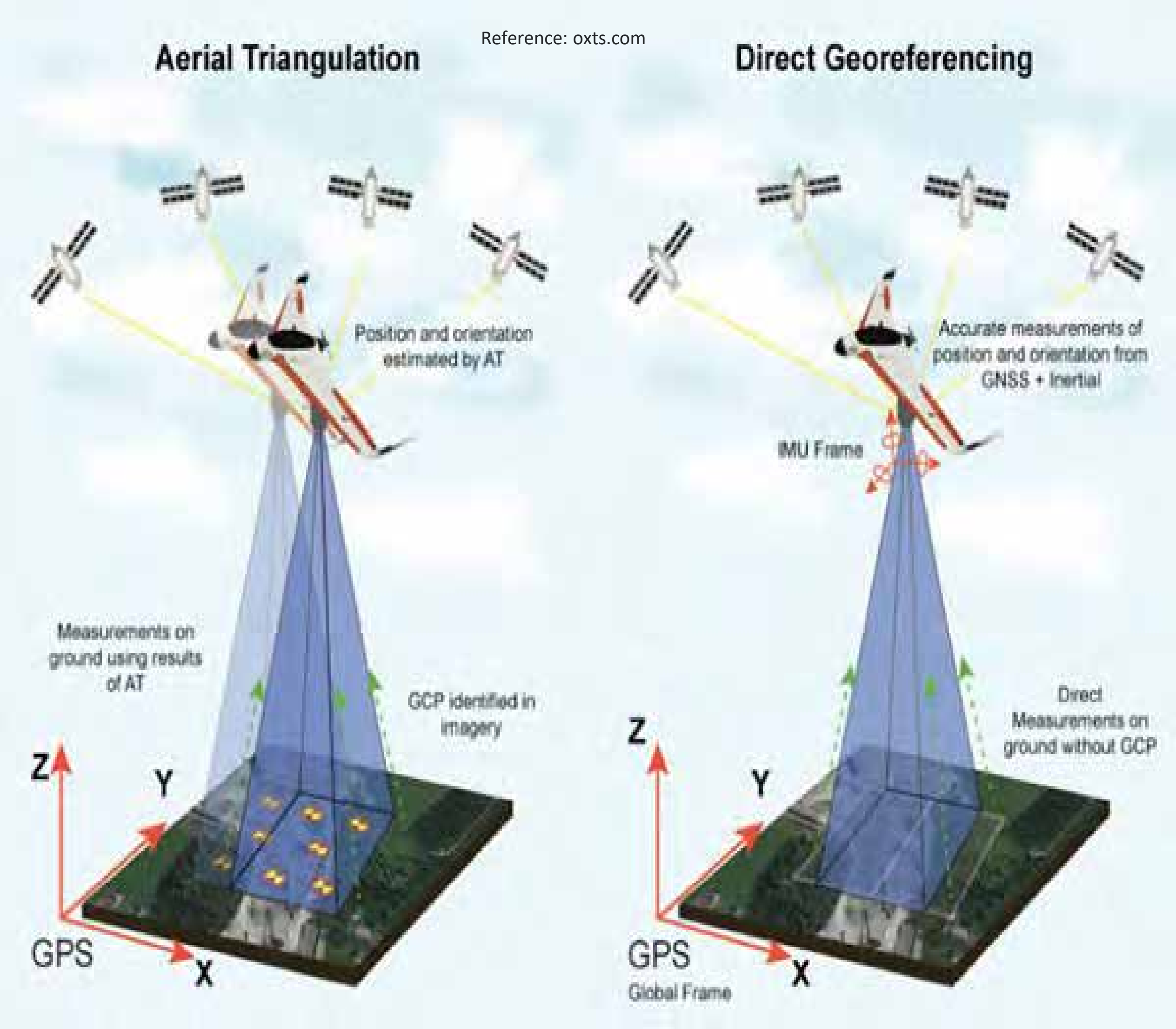
Light Detection and Ranging

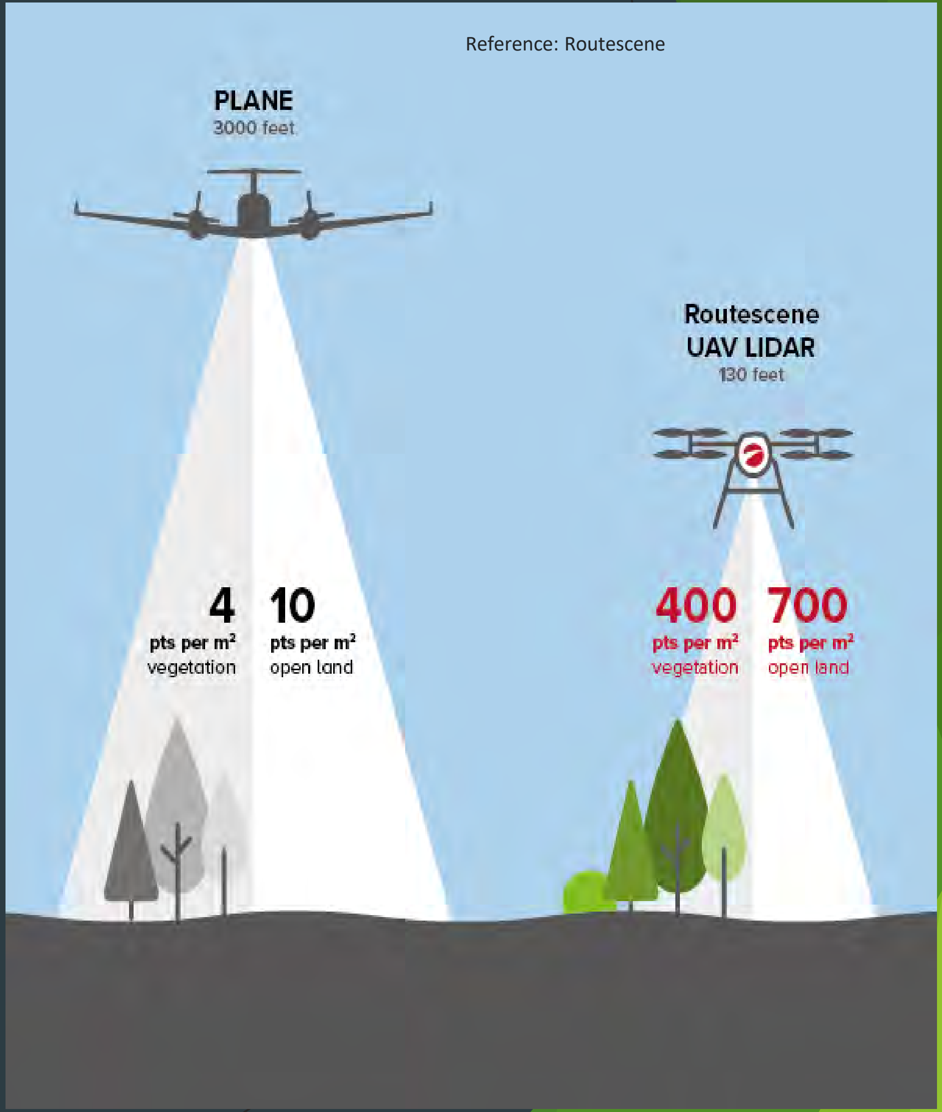




So what is LiDAR and why is it so special?

Active Sensors > Passive Sensors, for certain applications



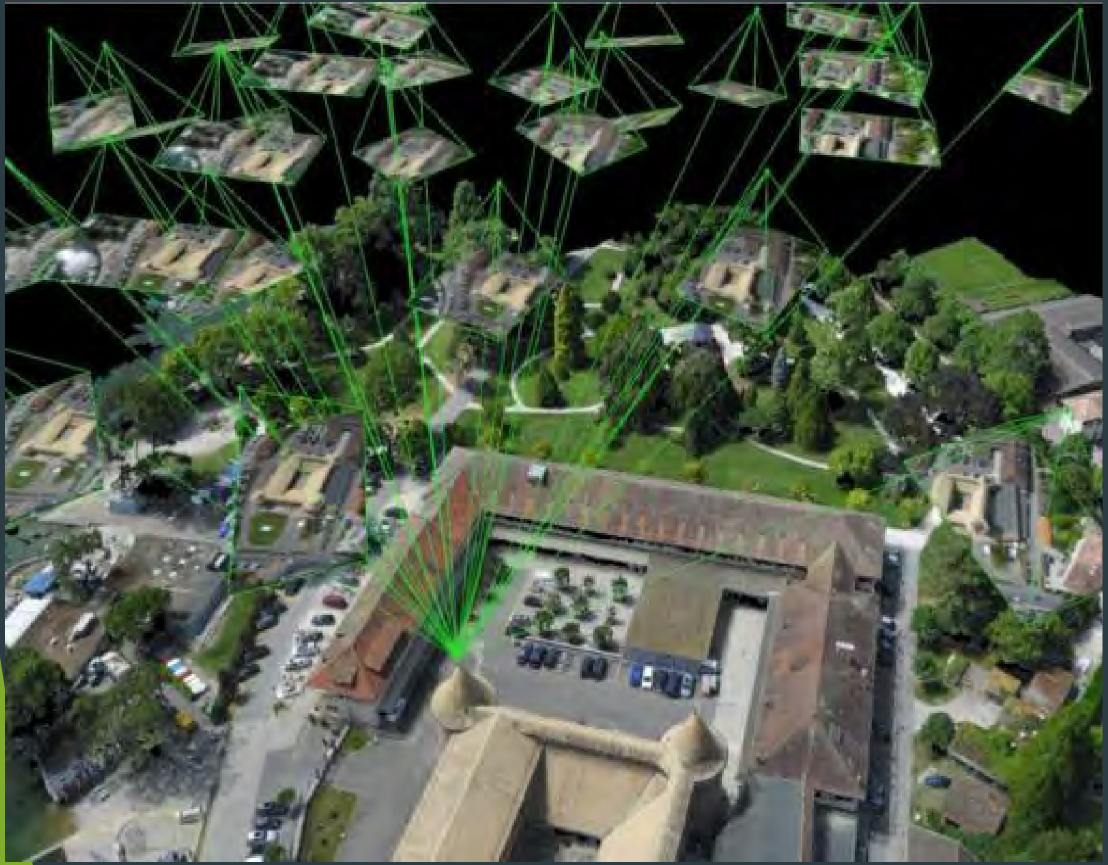


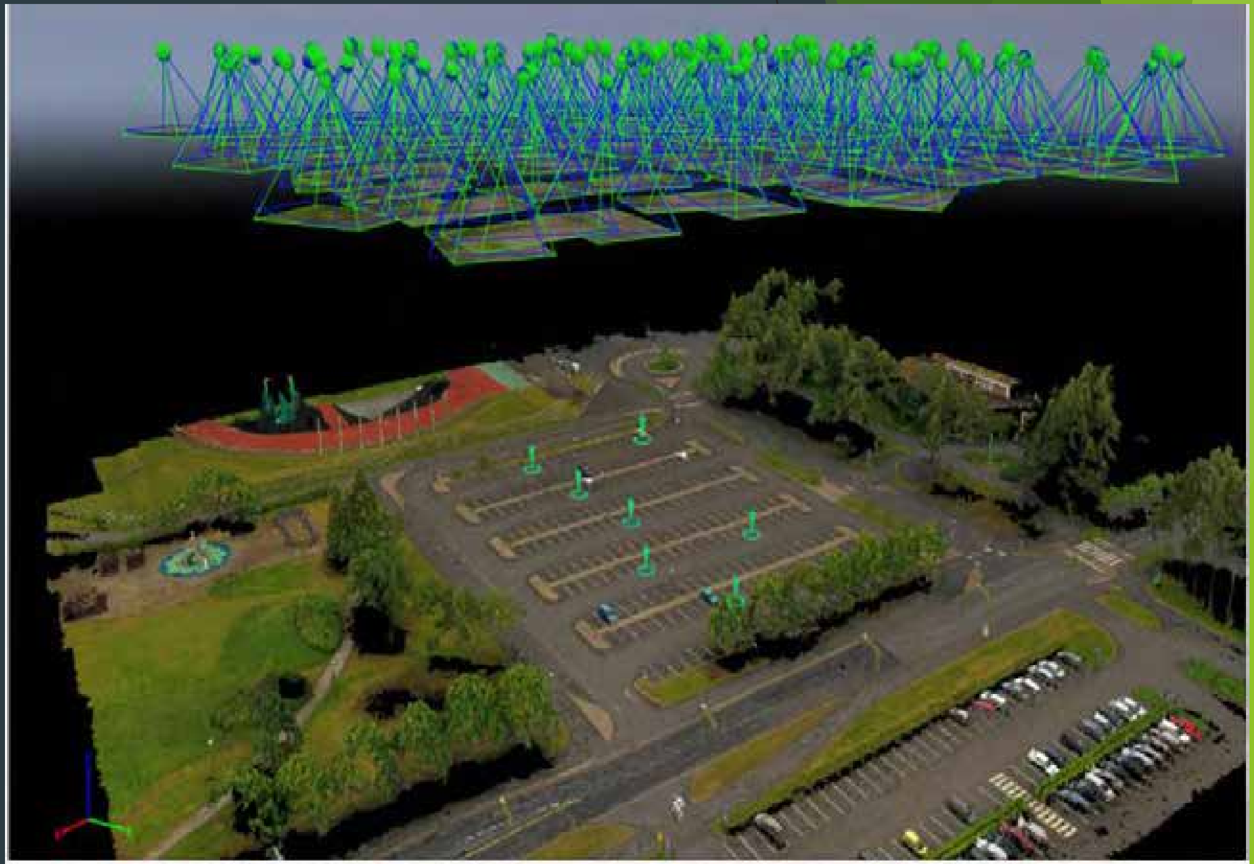
So what is LiDAR and why is it so special?

Lidar vs. Photogrammetry- Ground Control Points

So what is LiDAR and why is it so special?

Lidar vs. Photogrammetry- Direct Referencing vs Aerial Triangulation

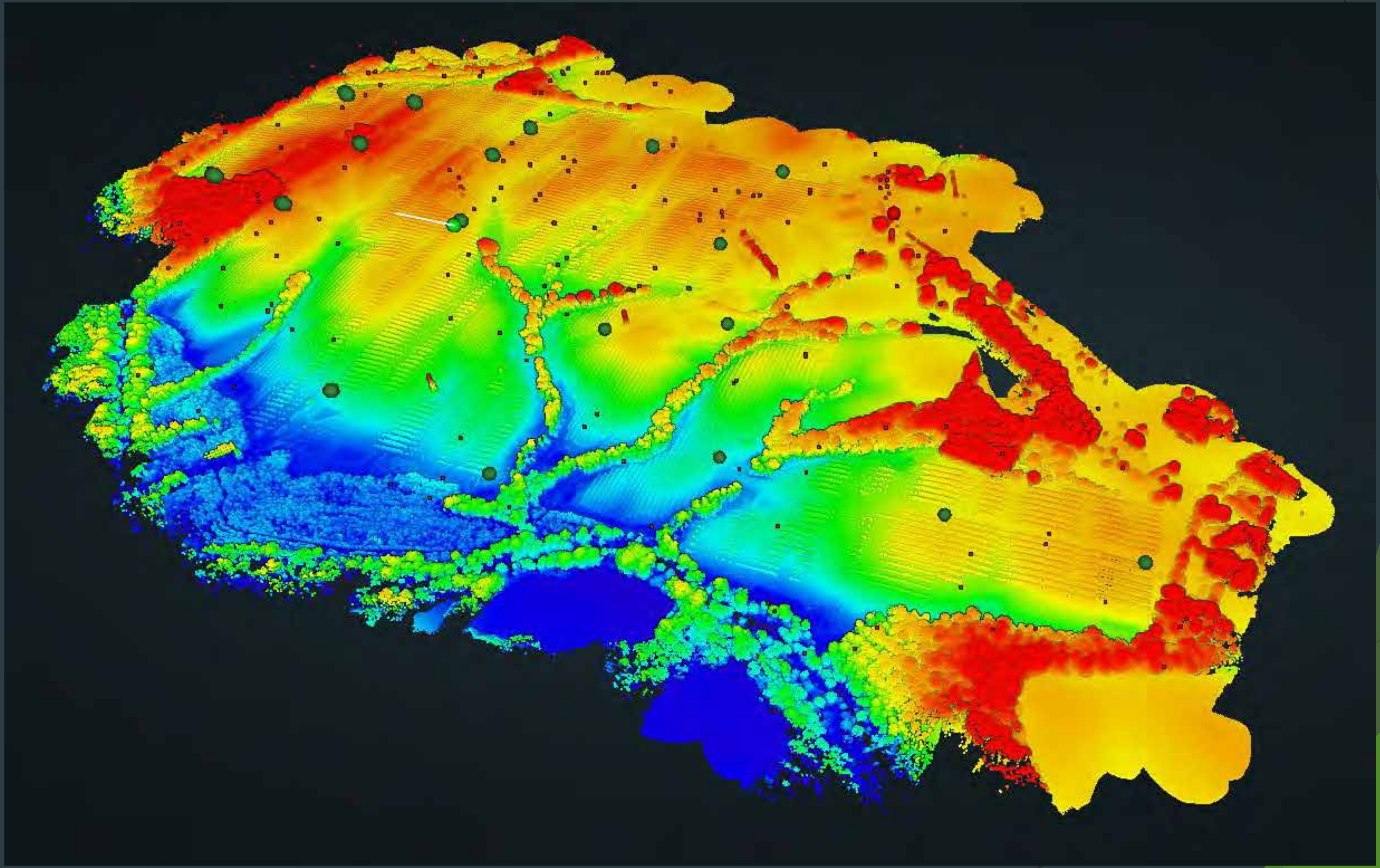




Reference: PIX4D

So what is LiDAR and why is it so special?

Operational Efficiency: 430 acre solar farm collected in 1 afternoon, 0.09’ vertical accuracy



So what is Back Forty doing with LiDAR?

Dense data of large or small areas, through vegetation and complex environments, collected day or night, with shorter processing/ delivery times

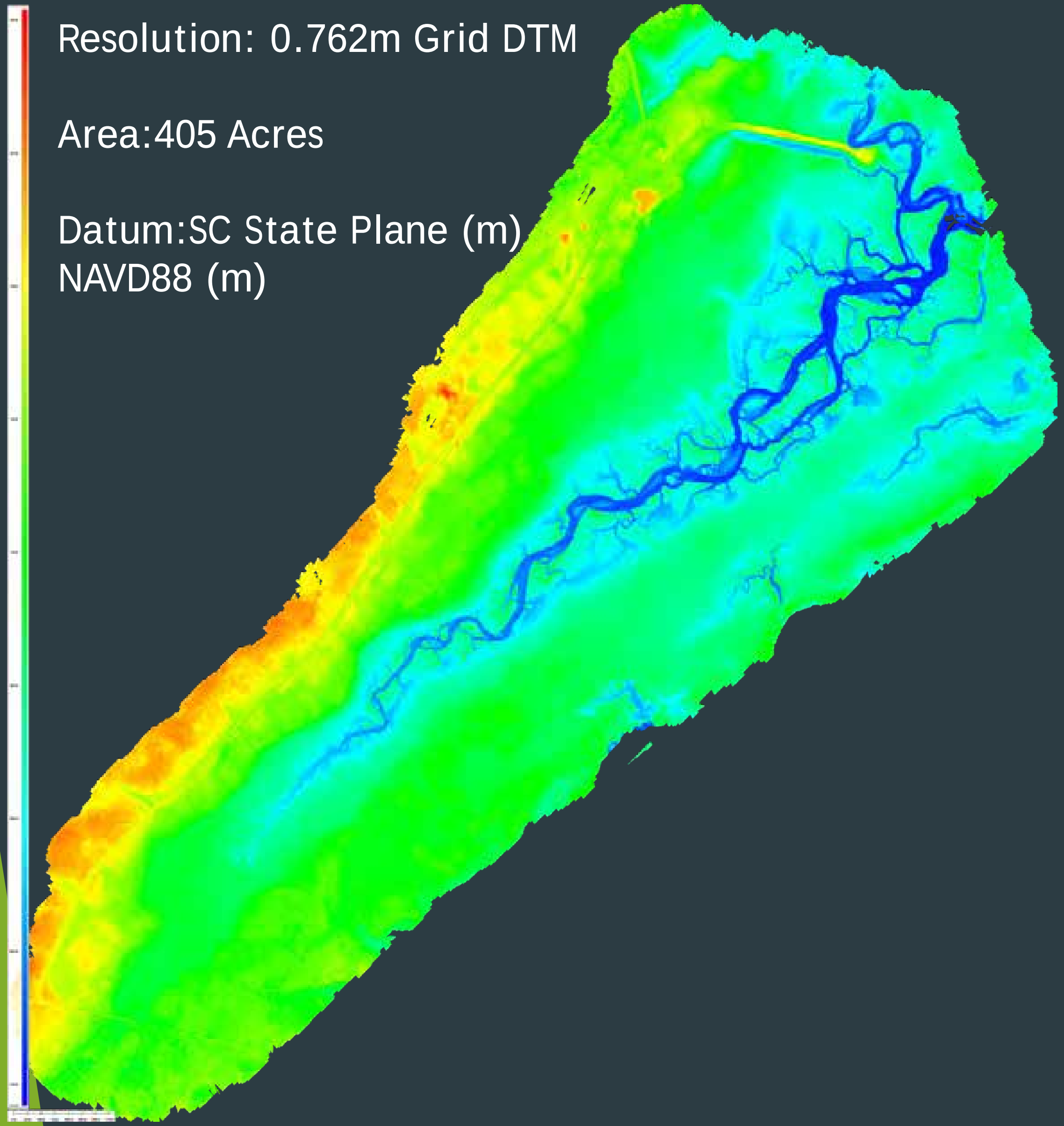
Aerial, Terrestrial, Mobile, Handheld SLAM

Case Study – Goat Island & Crab Haul Creek

Resolution: 0.762m Grid DTM

Area:405 Acres

Datum:SC State Plane (m)
NAVD88 (m)



Equipment

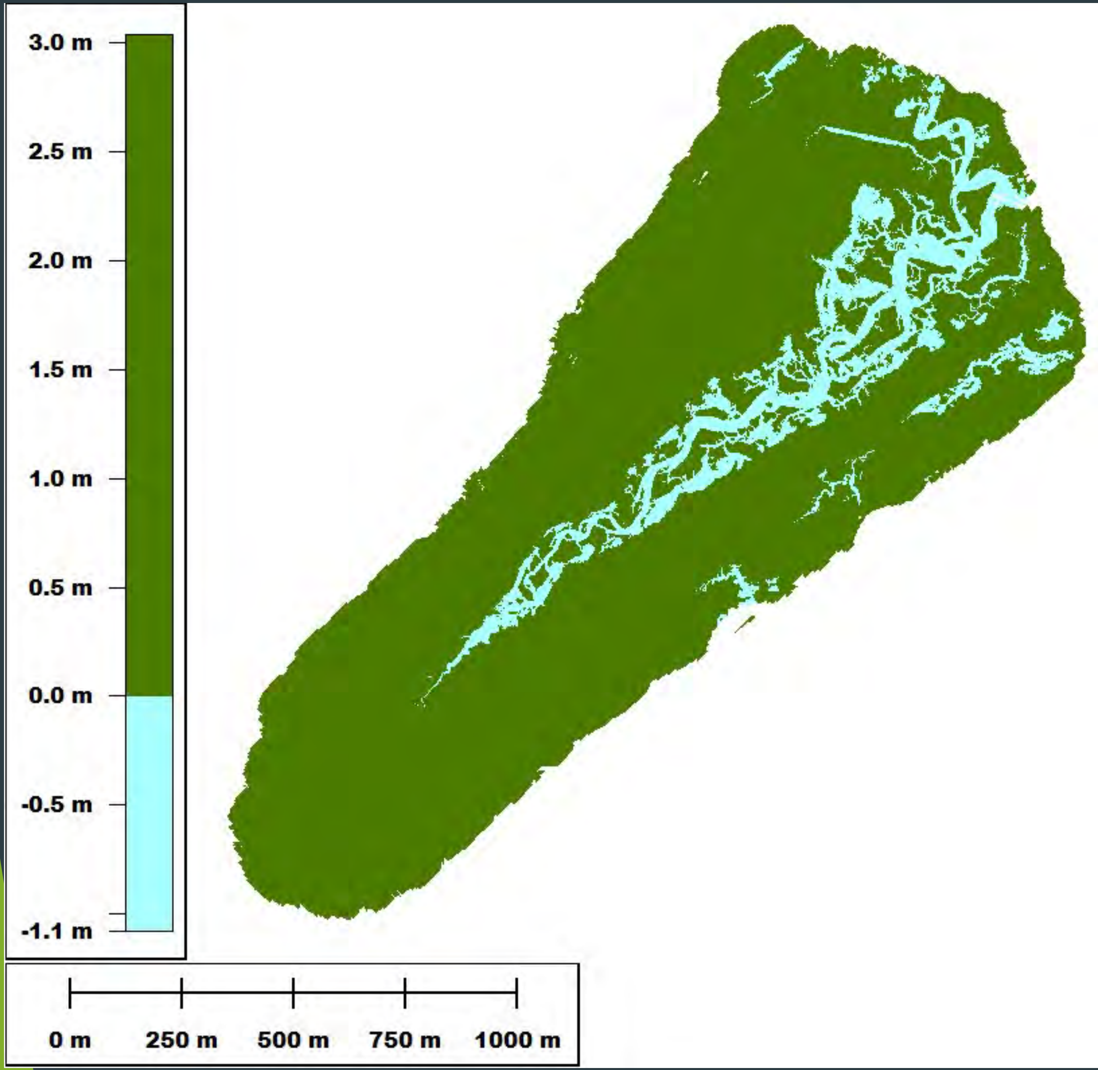
- DJI Matrice 300 RTK Drone
- Emlid RS2 GPS – Base Station, GCPs, and Checkshots
- Inertial Labs Livox Avia Payload (Single Laser, 3-return)
- Inertial Labs Hesai Pandar XT 32 Payload (32 Laser, 2-return)

Tested Variables

- We benchmarked different scan patterns on the Avia (linear and spirograph) and the XT-32's linear scan pattern.
- We tested different altitudes, and drone speeds to determine operational efficiency vs data quality. Low and slow vs high and fast.
- We tested sensors for quality of vegetation canopy penetration for DTM creation in the spartina and forest-tidal zones.
- We tested for vegetation density using different scan patterns.

Case Study – Goat Island & Crab Haul Creek

Area Below MSL in 0.762m grid DTM



LP360 Vertical Control Report for XT32 Dataset (m)

- ---- Statistical Point Counts ----
  - Horizontal Measured: 0
  - **Vertical Ground Shots Measured: 315**
  - Withheld: 36 of 351 | Reason: Elevated Target, outside of surface
  - Vertical Error Mean: -0.040
  - Vertical SDOM: 0.002
  - Vertical Sz: 0.035
  - Vertical Error Min, Max: [-0.162,0.086]
  - Vertical Error Range: 0.248
  - Vertical RMSE: 0.053
  - Vertical NMAS/VMAS Accuracy (90% CI): ±0.087
  - Vertical NSSDA Accuracy (95% CI): ±0.104
  - ASPRS Vertical Accuracy Class: 0.053
  - Vertical Min Contour Interval: 0.159
- --------- Surface Definition ---------
  - Surface Method: Inverse Distance Weighted (IDW)
  - Power: 2
  - Radius: 10

What sets BFAS apart as a service provider? Experience & Flexibility

R&D Partners with Proven Results

- We continue to reinvest profits into extensively field testing a range of lidar and photogrammetry payloads, as well as workflows, to filter through the marketing fluff and get solid data at the best price
- We have refined processes around equipment, software, and post-processing with ability to scale up to massive projects while maintaining quality
- We have equipment available for use to qualified users, but can also provide turn-key data collection, or even pilots to increase existing bandwidth for larger projects like disaster response

Versatility and Ambition

- While compliant with the same FAA regulations as state and local agencies under Part 107, we are agile in our procurement and mobilization capabilities, with specialized field vehicles, and an array of drones, payloads, software, and personnel
- We're nerds at heart, and always curious to solve a problem and discover a new use case!
- We see BVLOS and long endurance mapping (4+ Hour Flight Times), >400ft flights as the natural evolution of our mapping service offerings with the implementation of Remote ID Compliance.

Next Steps:

- Select a project
- Trial period against traditional methods
- Let’s break some eggs (but not drones)

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Using Drone Data and Machine Learning to Map Invasive Species and Monitor Coastal Restoration

Drones in the Coastal Zone

Brendan Brown, PWS; Drew Reicks, CFP, GISP

May 2023

sky wave™ at CDM Smith

Sky Wave at CDM Smith is leveraging remote sensing and machine learning to analyze sites and develop solutions.

sky wave™

Sky Wave is led by multi-disciplinary experts who create integrated solutions to your challenges.

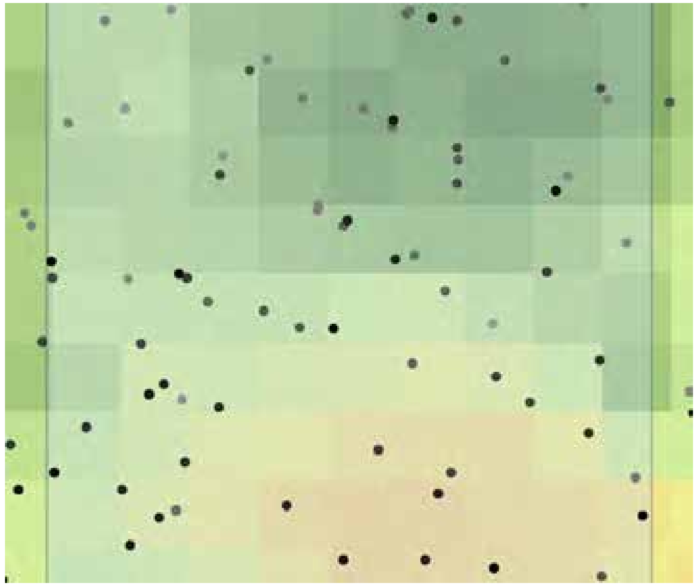
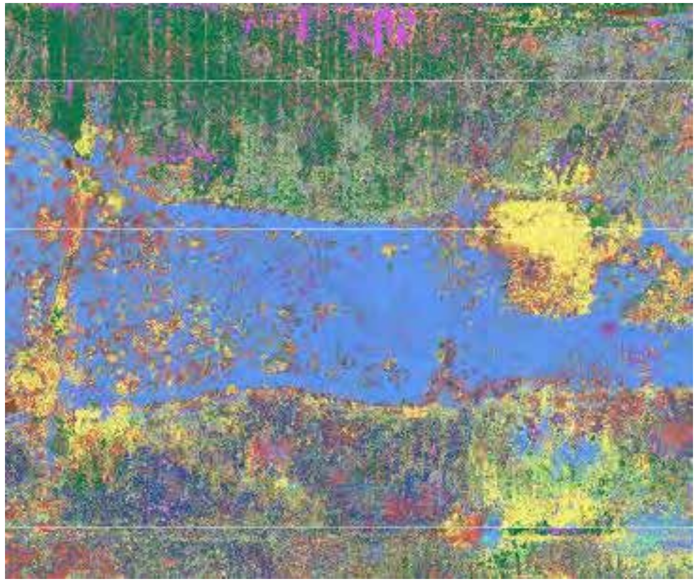
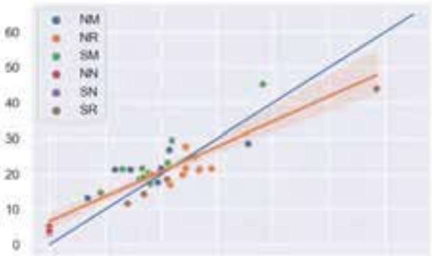
- Surveyors
- Engineers
- Geologists
- Scientists
- FAA-certified drone pilots
- Remote sensing scientists
- Artificial intelligence engineers







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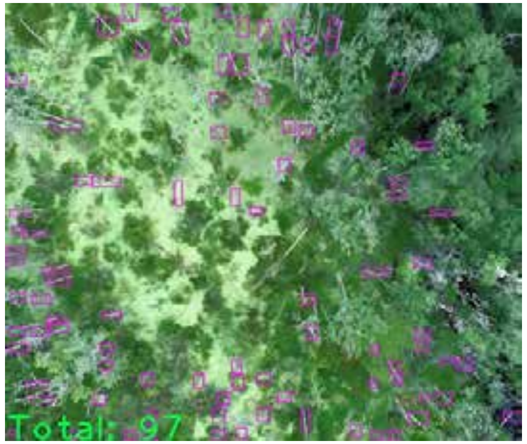
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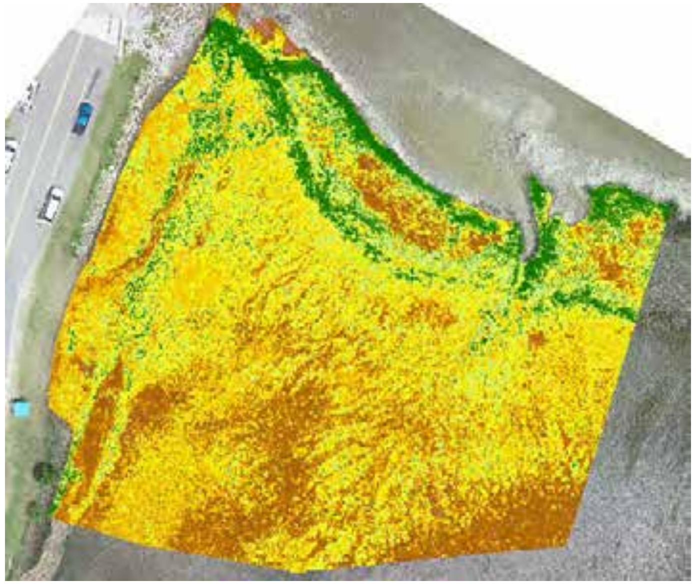
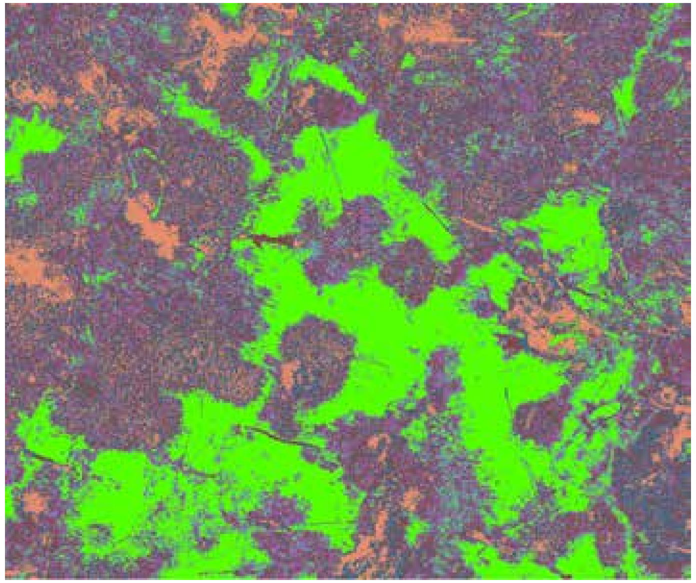
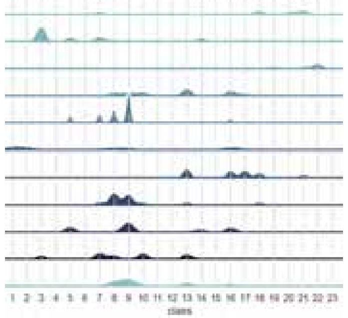
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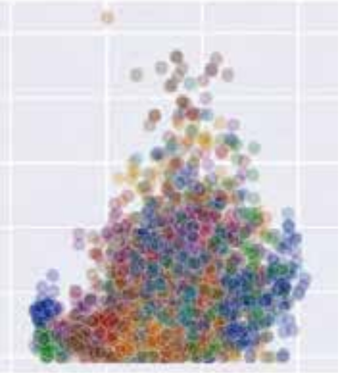
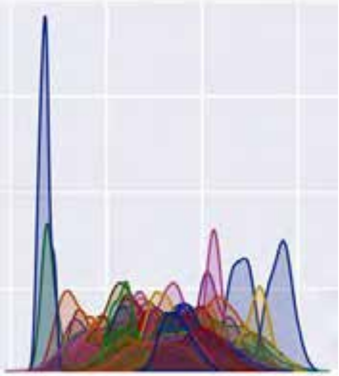
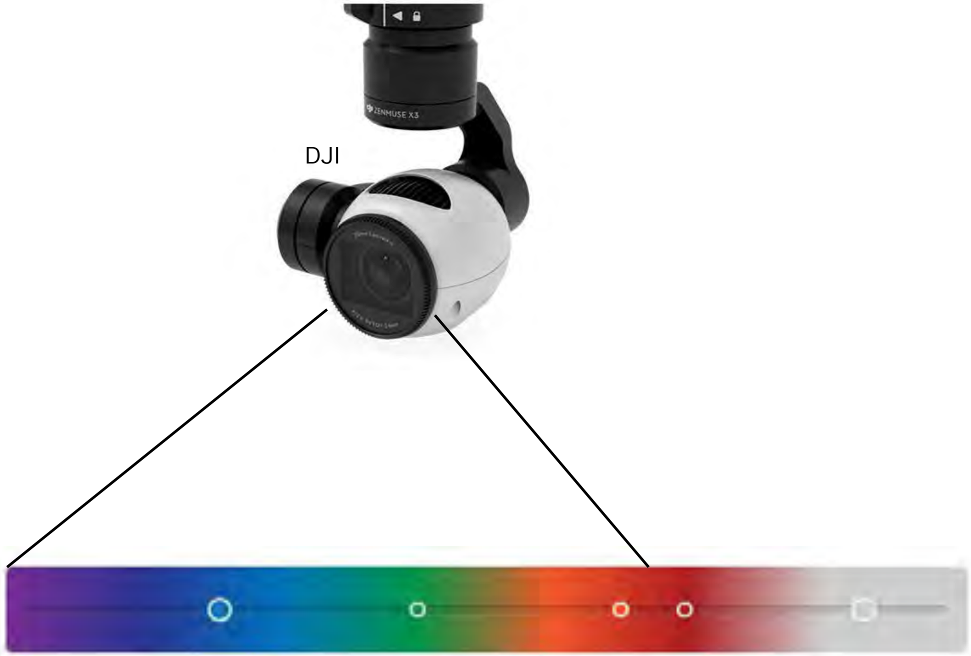
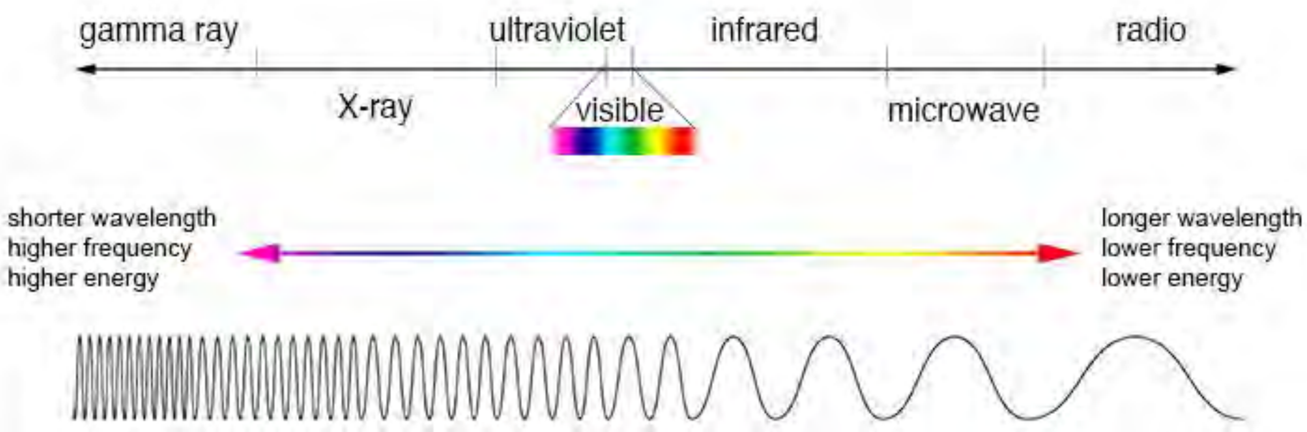
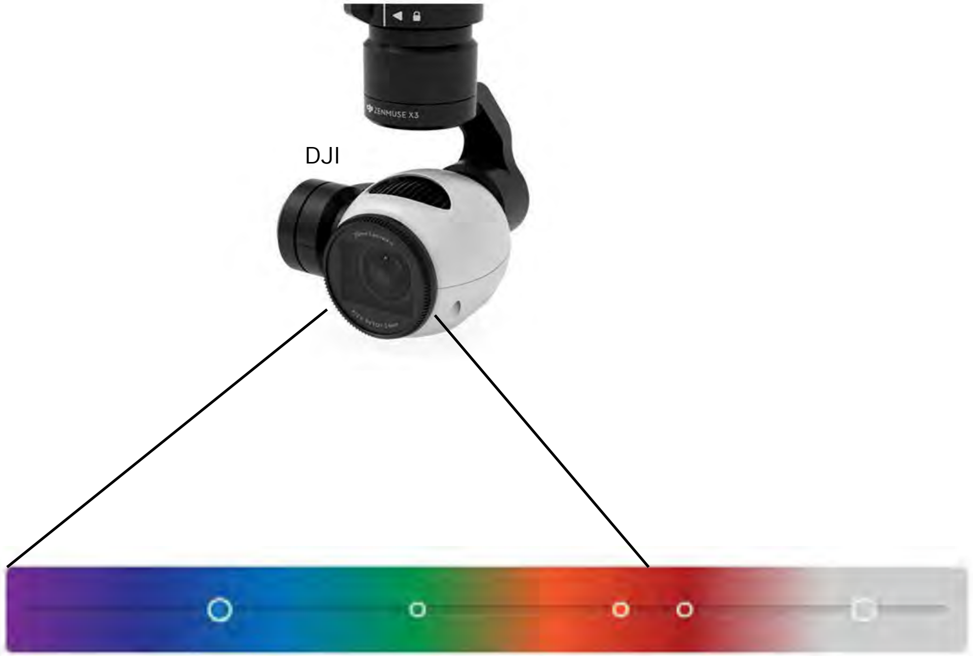



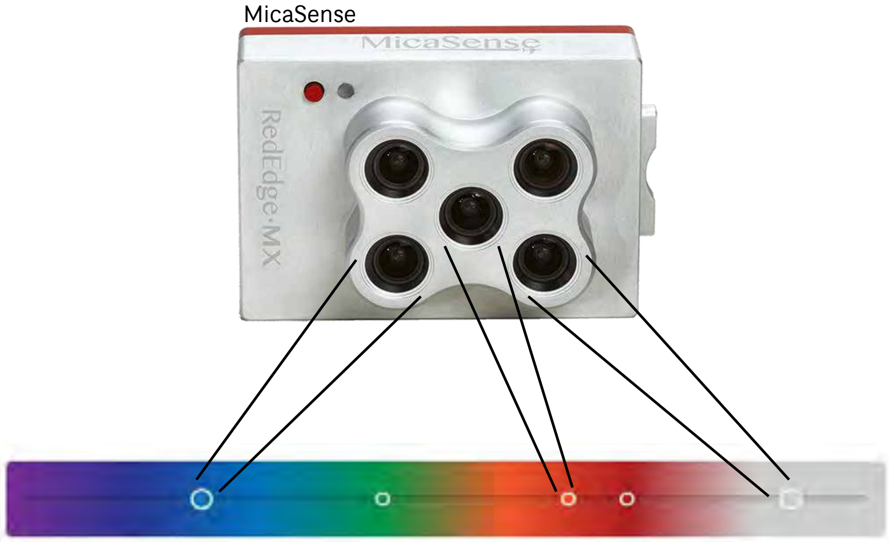
Digital cameras on drones provide high resolution imagery

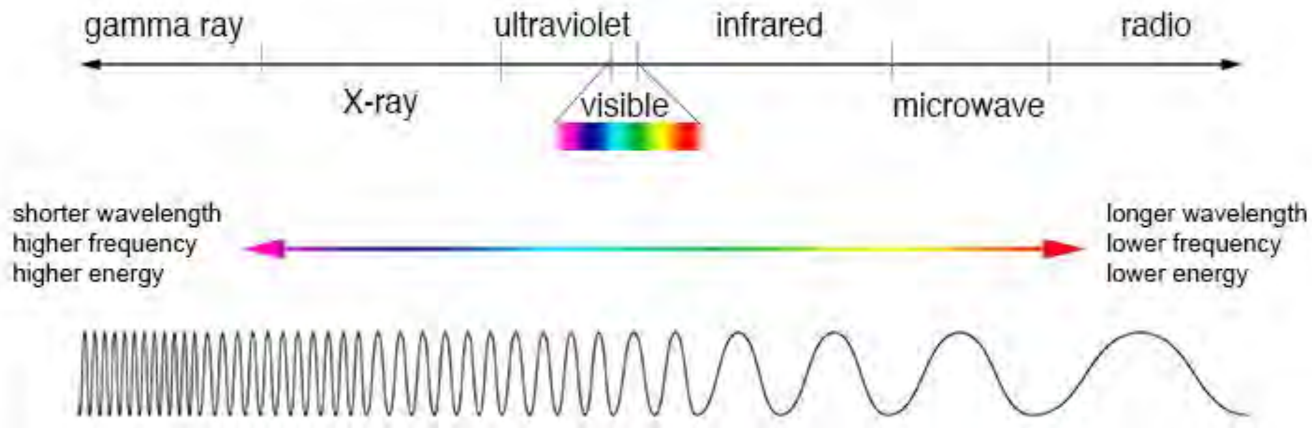




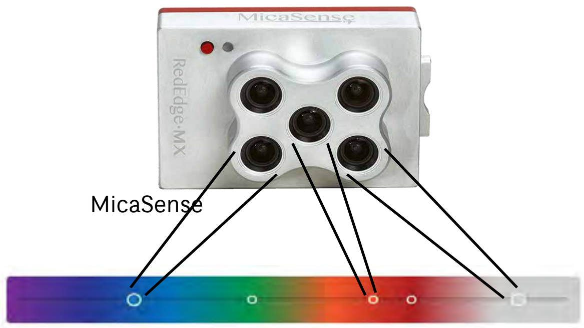
Multispectral sensors collect visible and non-visible portions of the electromagnetic spectrum.



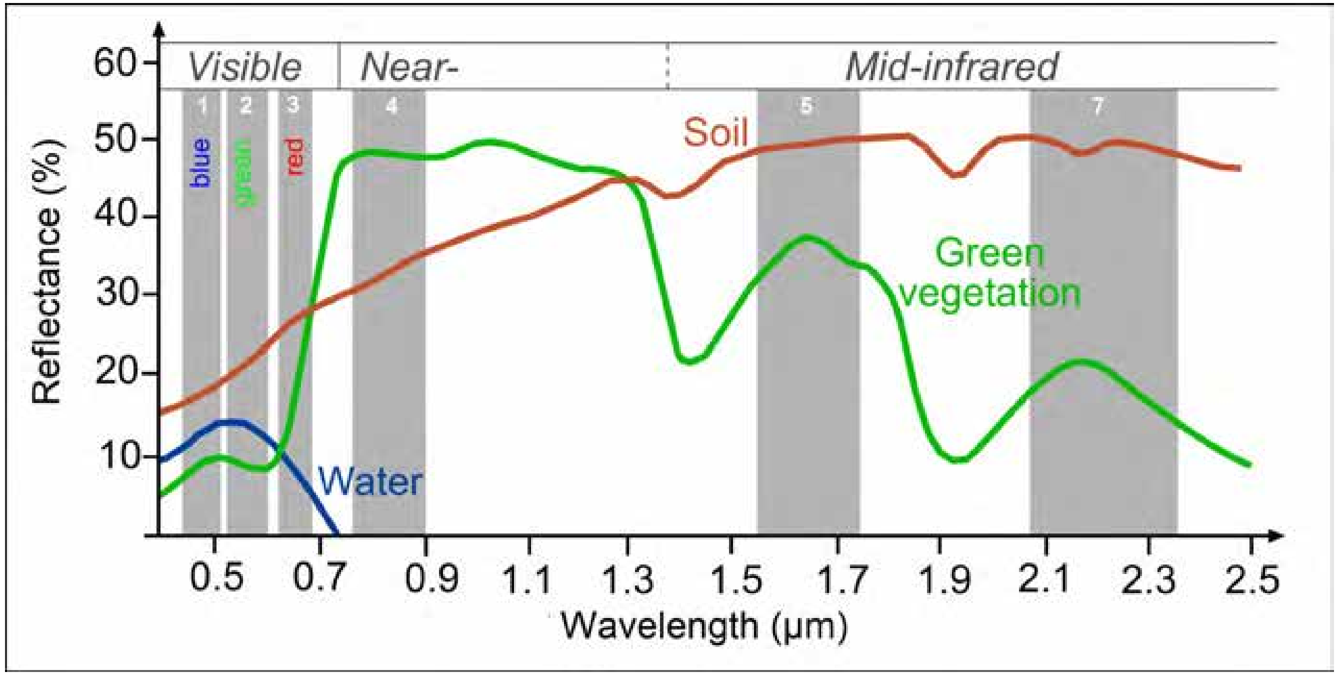




Multispectral data provides information on spectral signatures of land cover

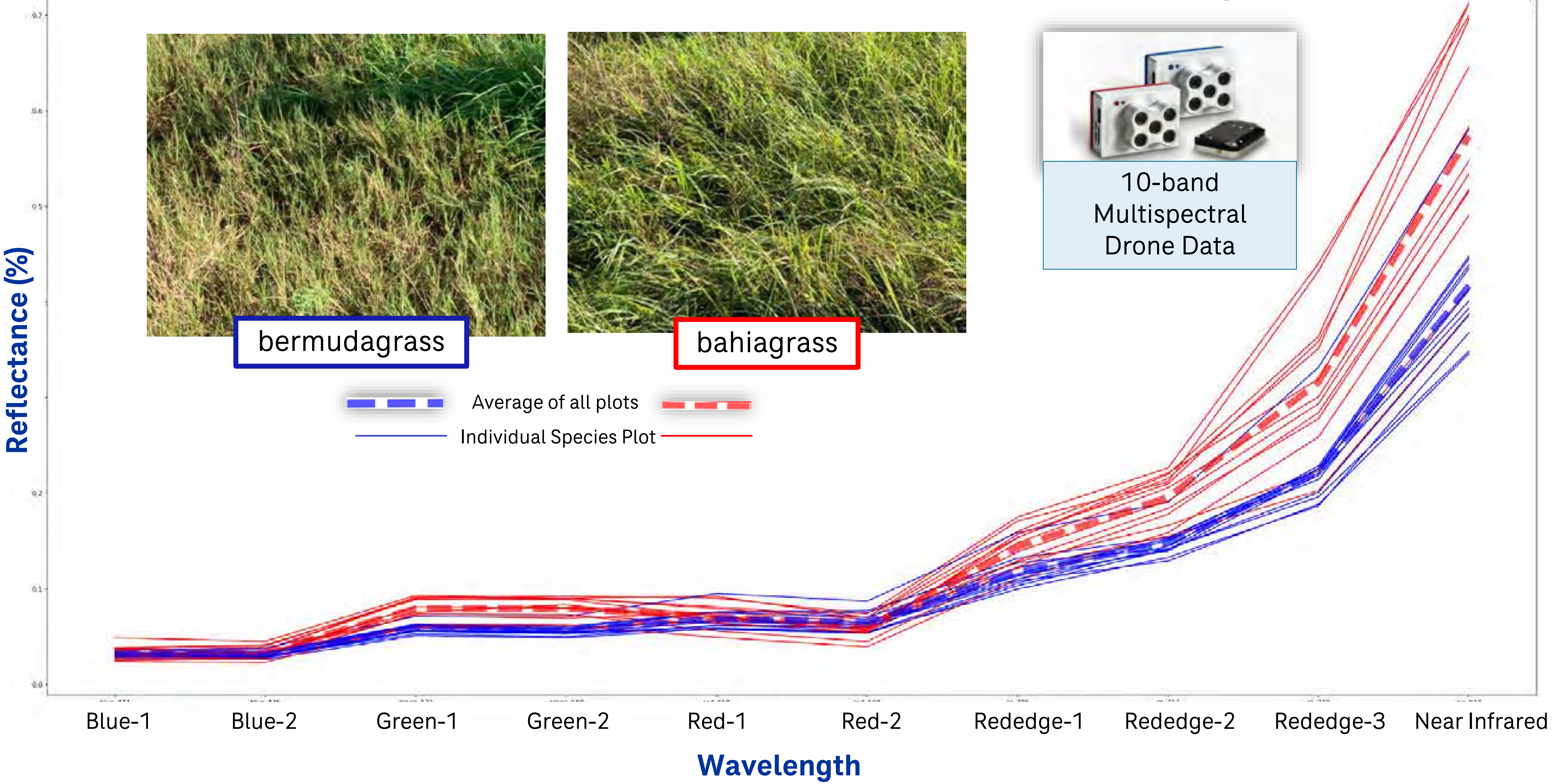


Spectral signatures

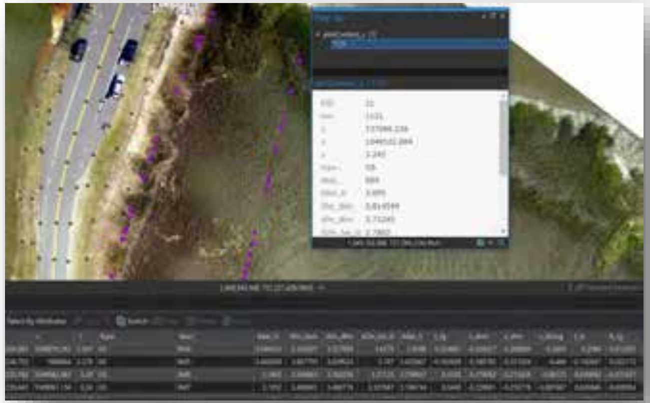


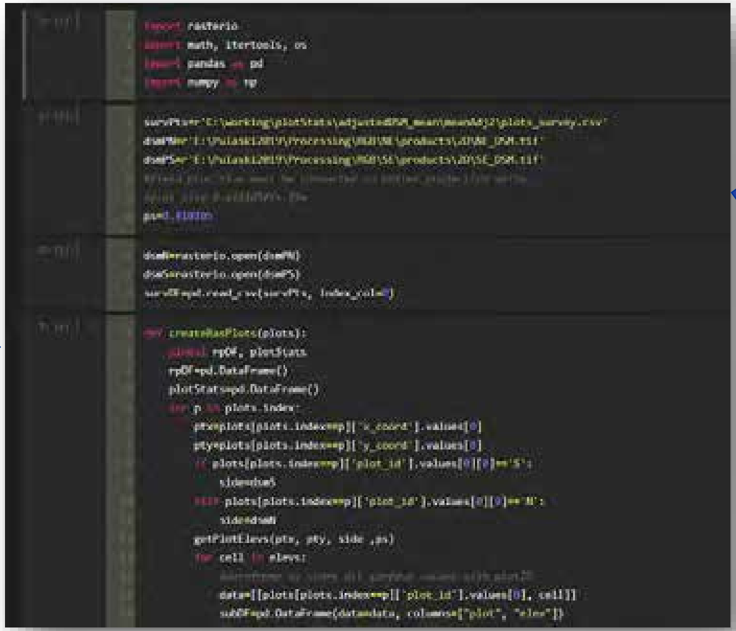
Source: NASA

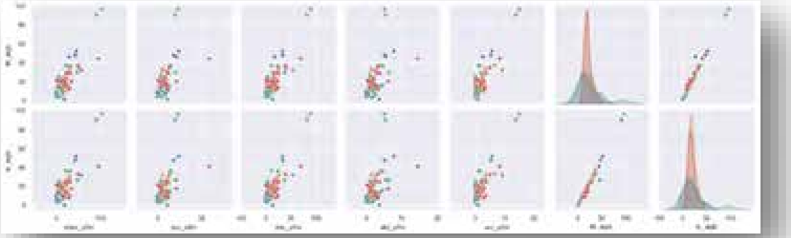
Different plant species can have different spectral signatures

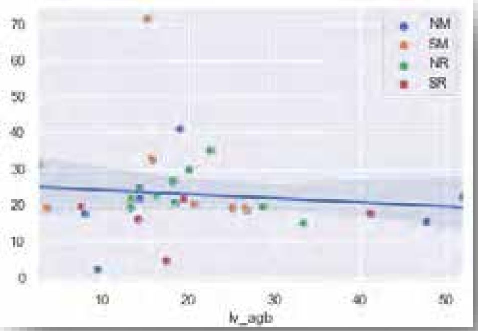


Automation and machine learning is key to managing and unlocking large drone-derived datasets

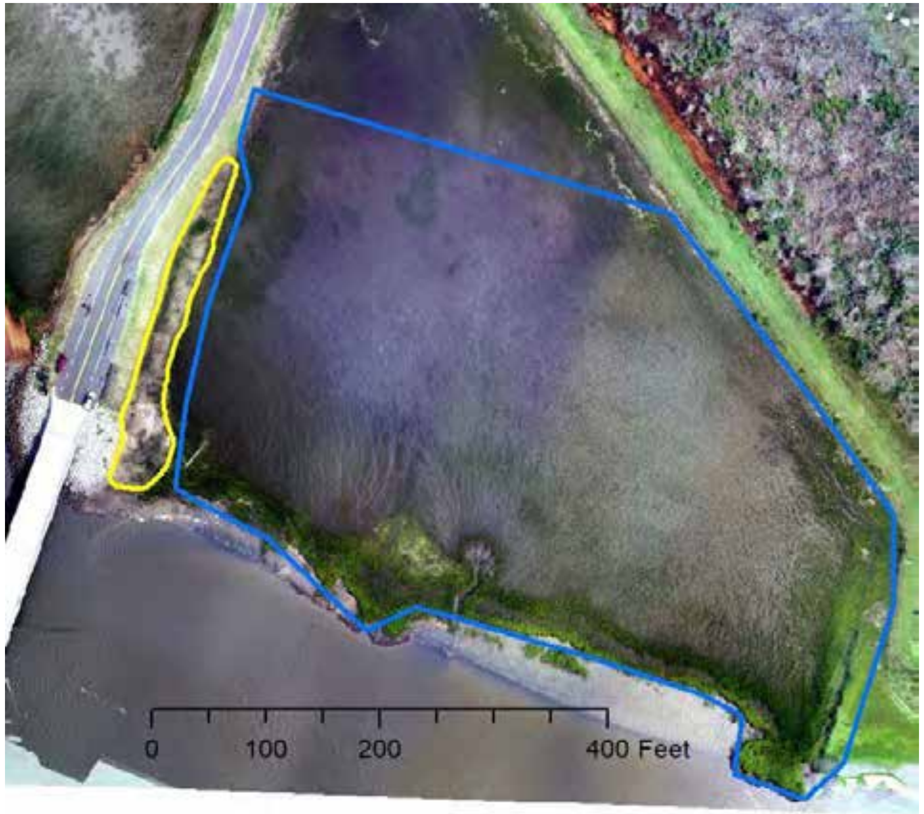


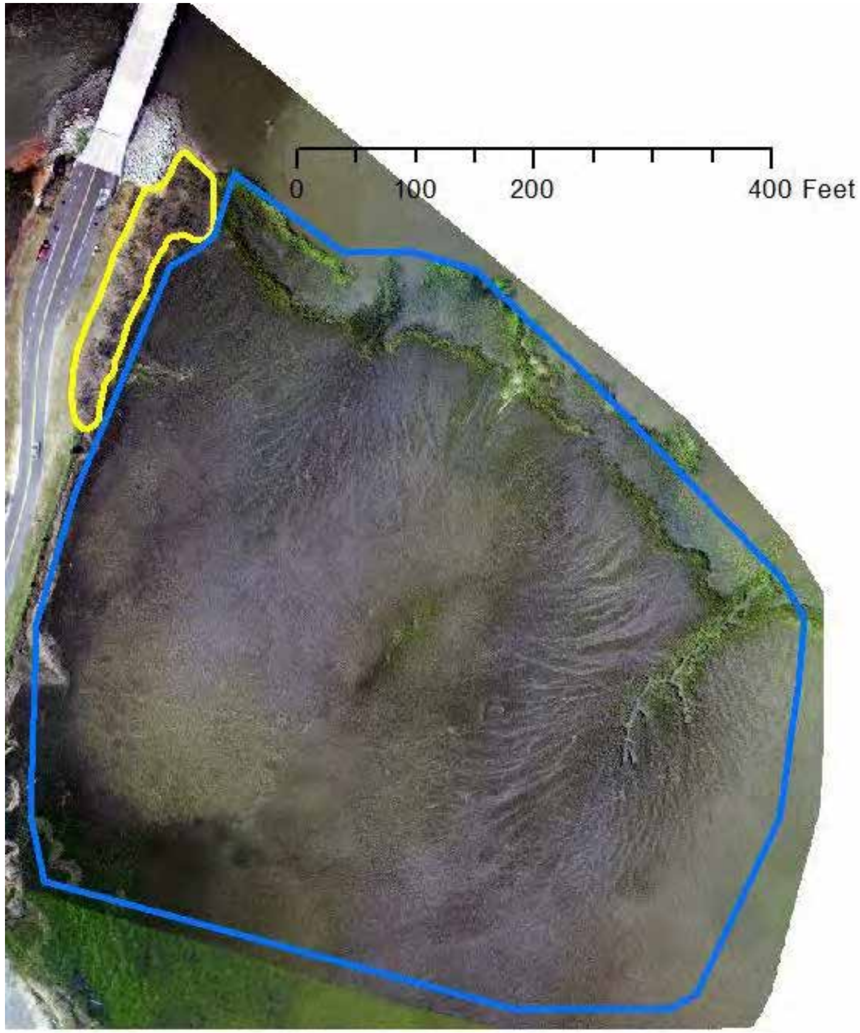


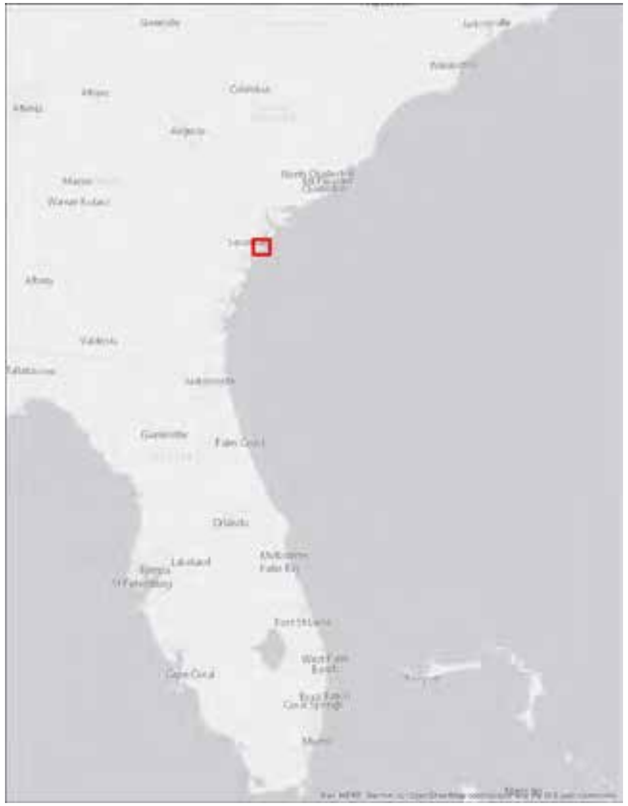





Ft. Pulaski, GA







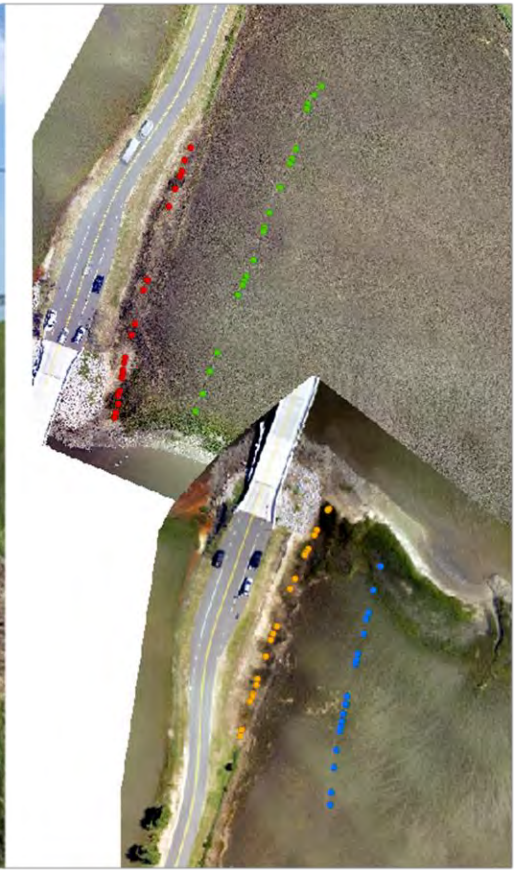
The park bridge was replaced with a new adjacent bridge

The adjacent tidal marsh was restored and replanted

Traditional Field Collection

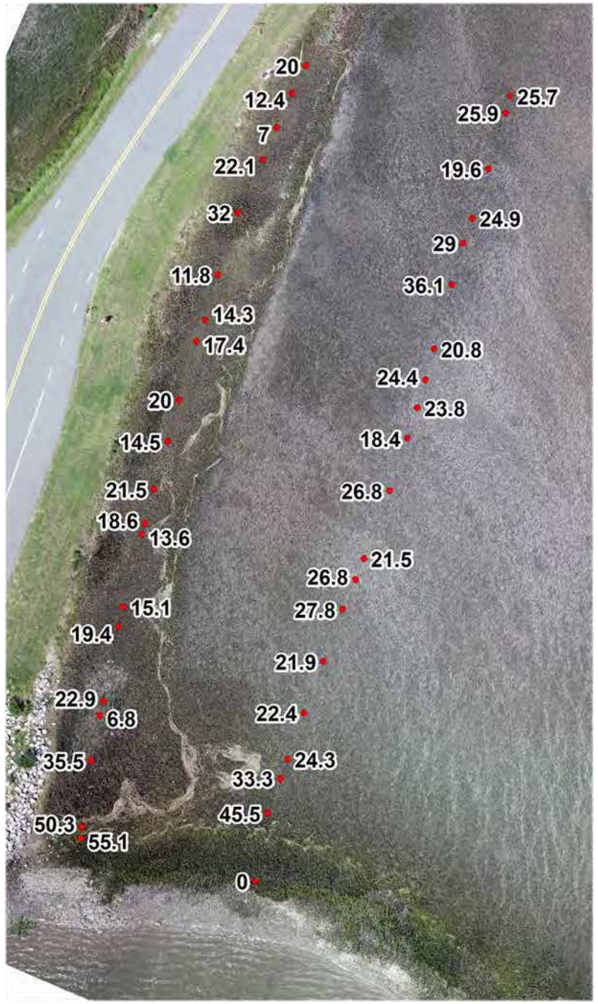


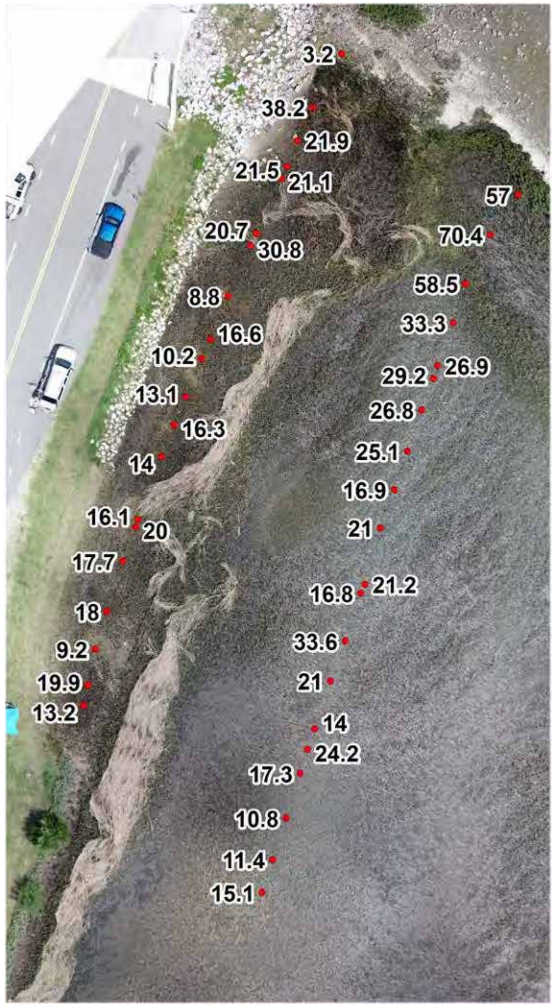




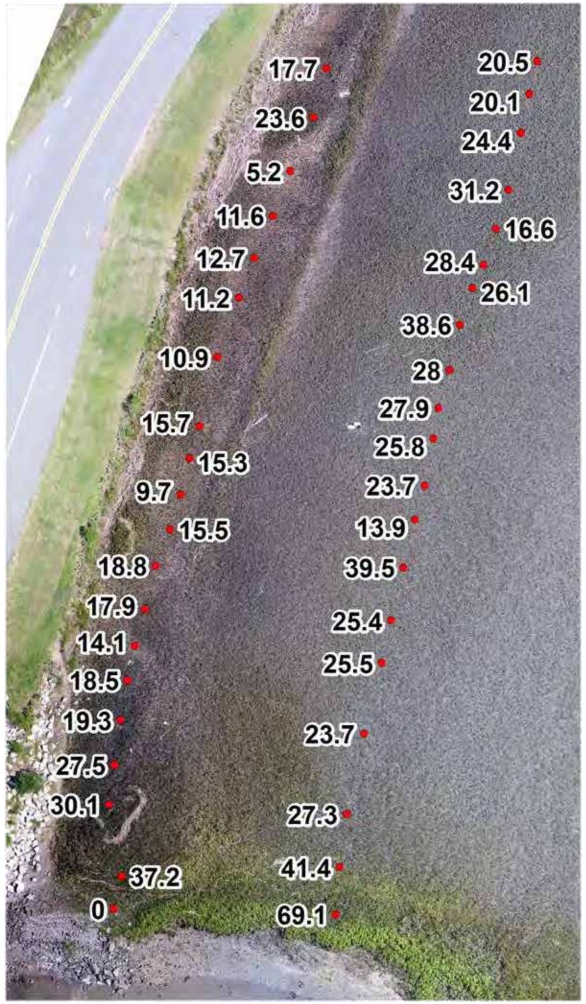
Traditional Field Collection

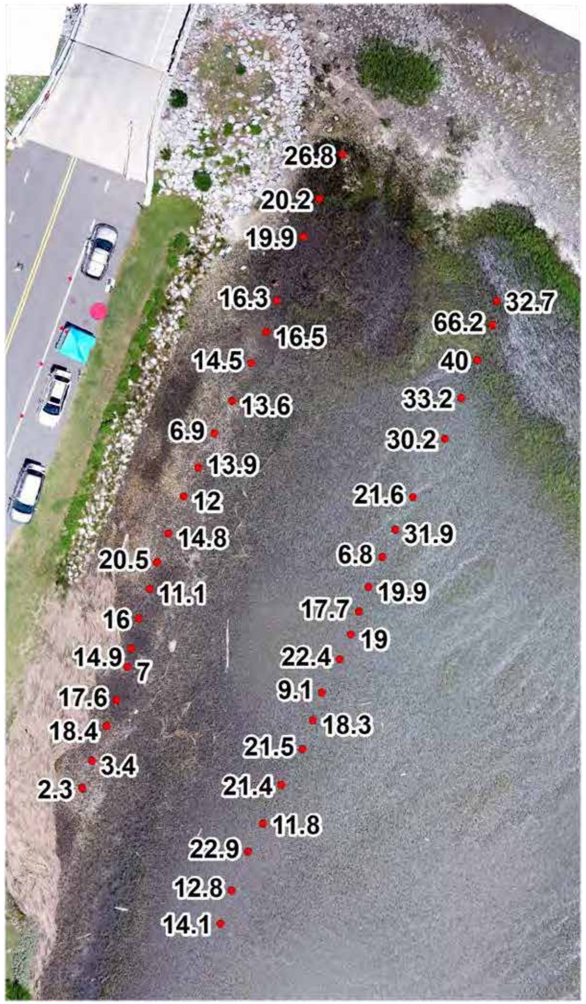
North **2021** South



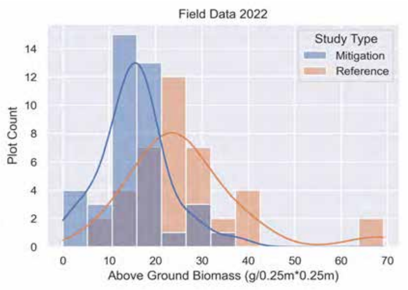


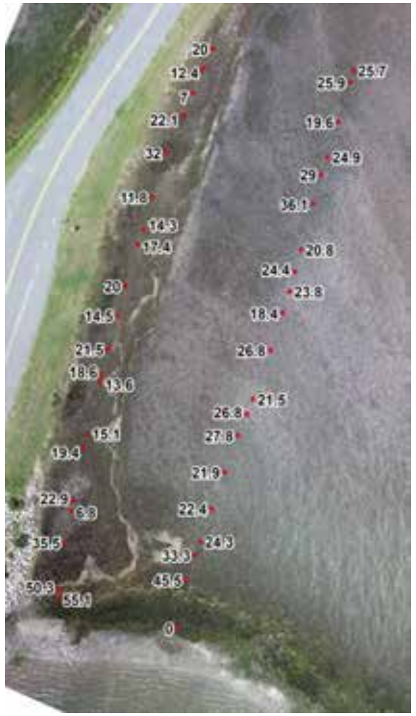
North **2022** South

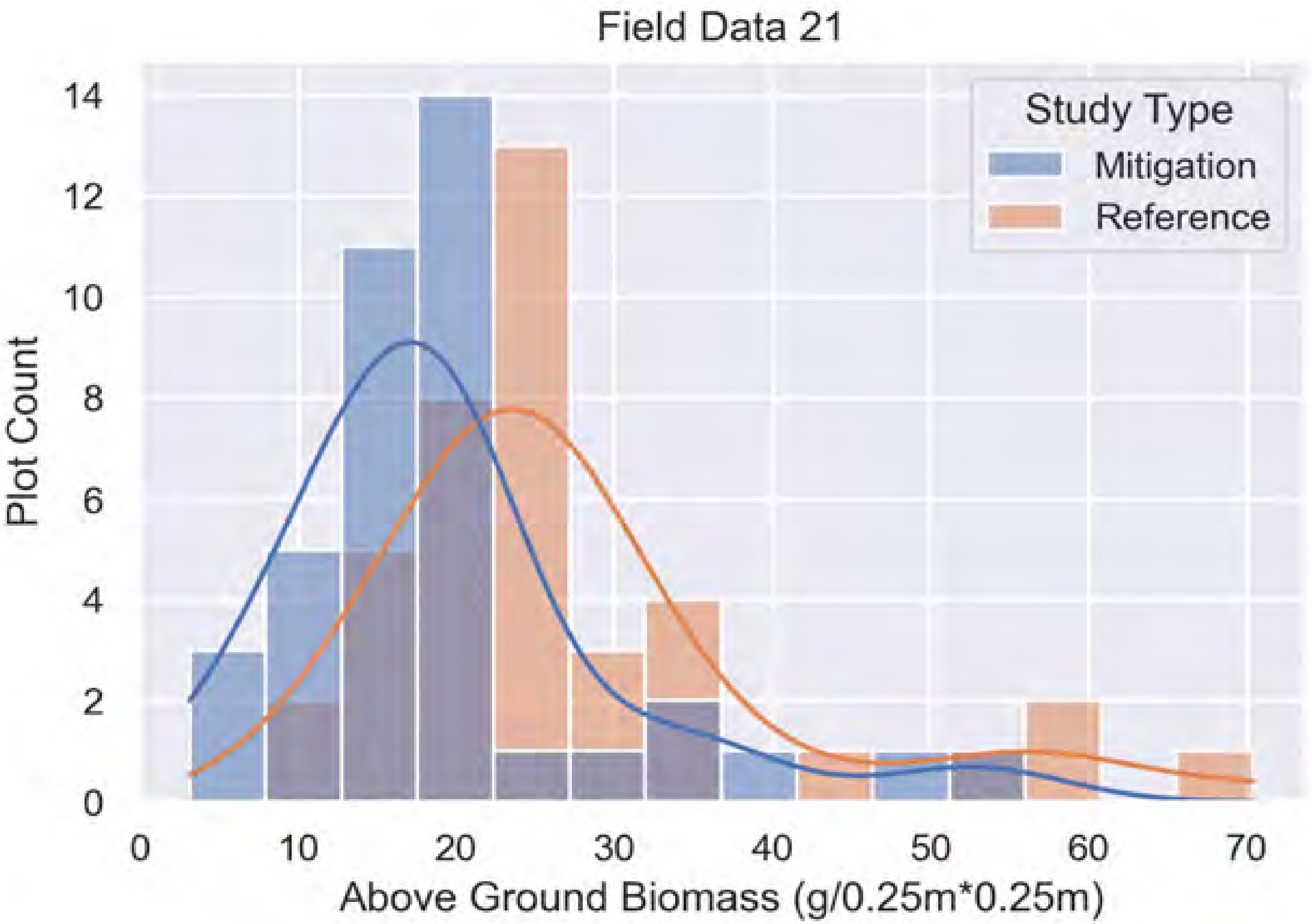


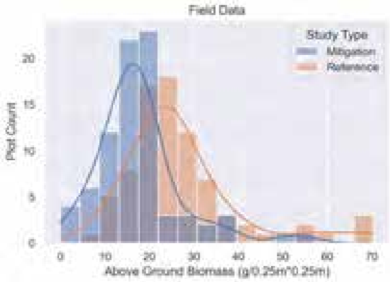


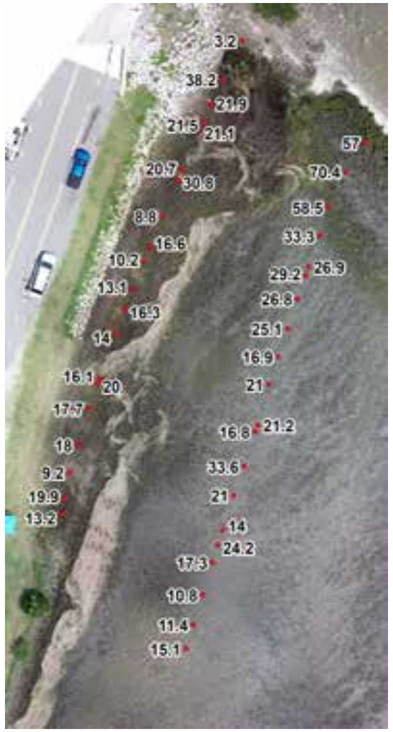
Traditional Field Collection







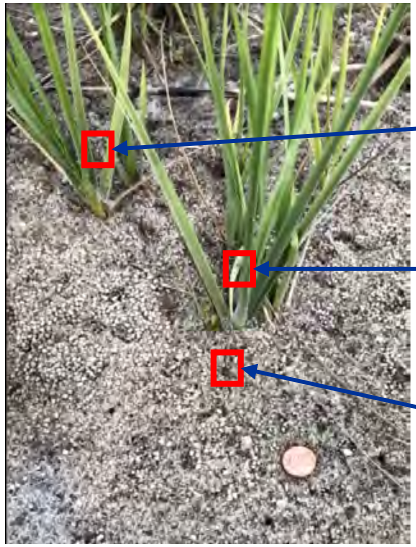




Fractional Vegetative Cover

Fractional Vegetation Coverage (FVC)

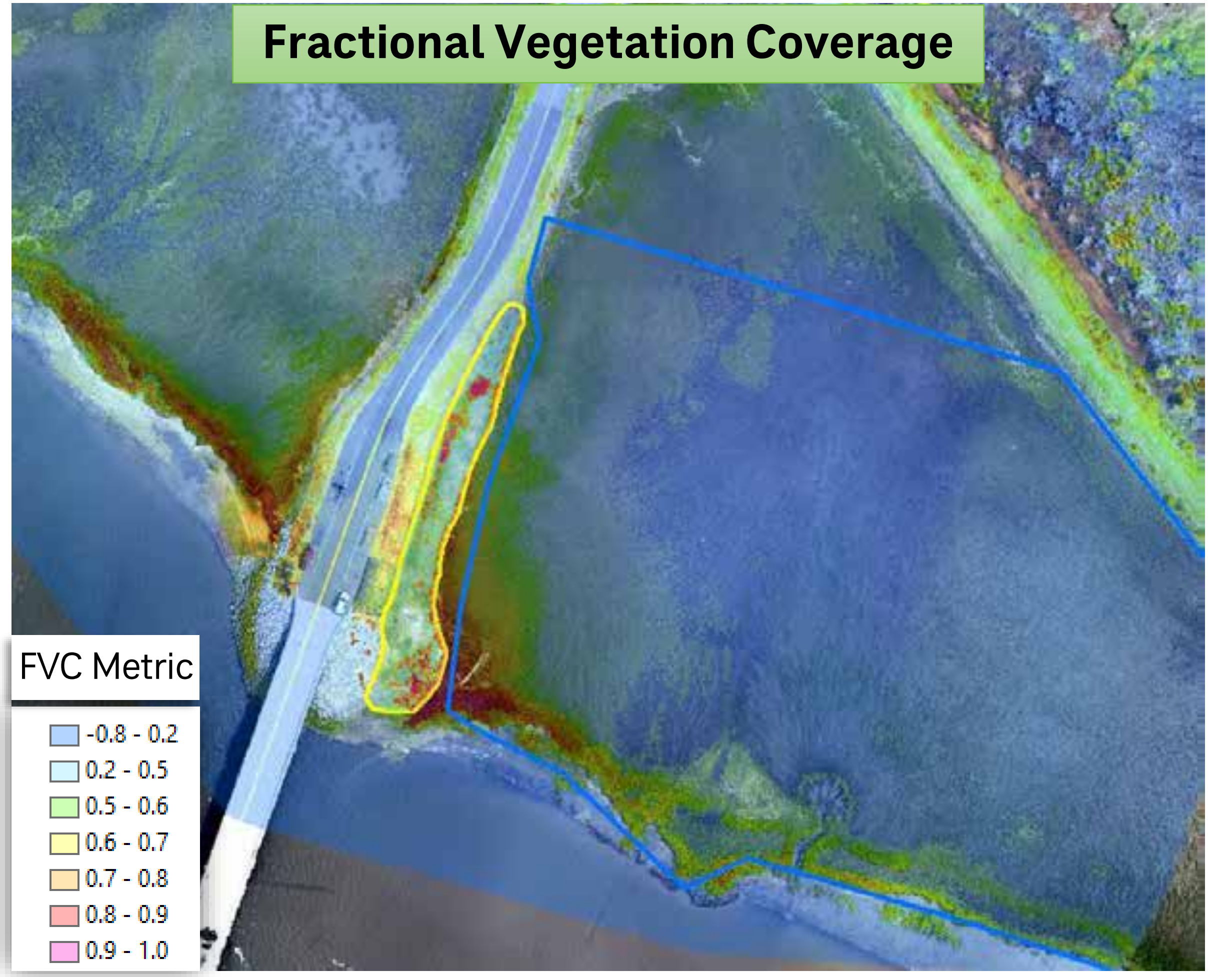
$$\frac{NDVI - NDVI_{soil}}{NDVI_{veg} - NDVI_{soil}}$$



NDVI of Target

$NDVI_{veg}$ (100%)

$NDVI_{soil}$ (100%)



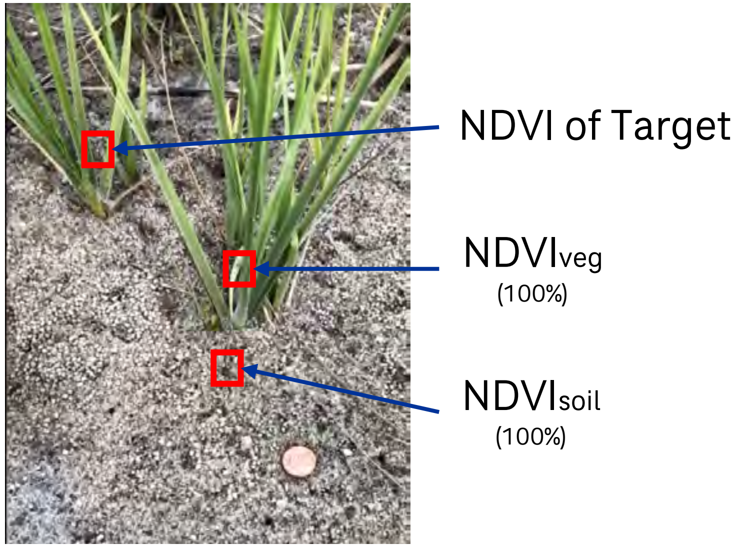
Mitigation Area

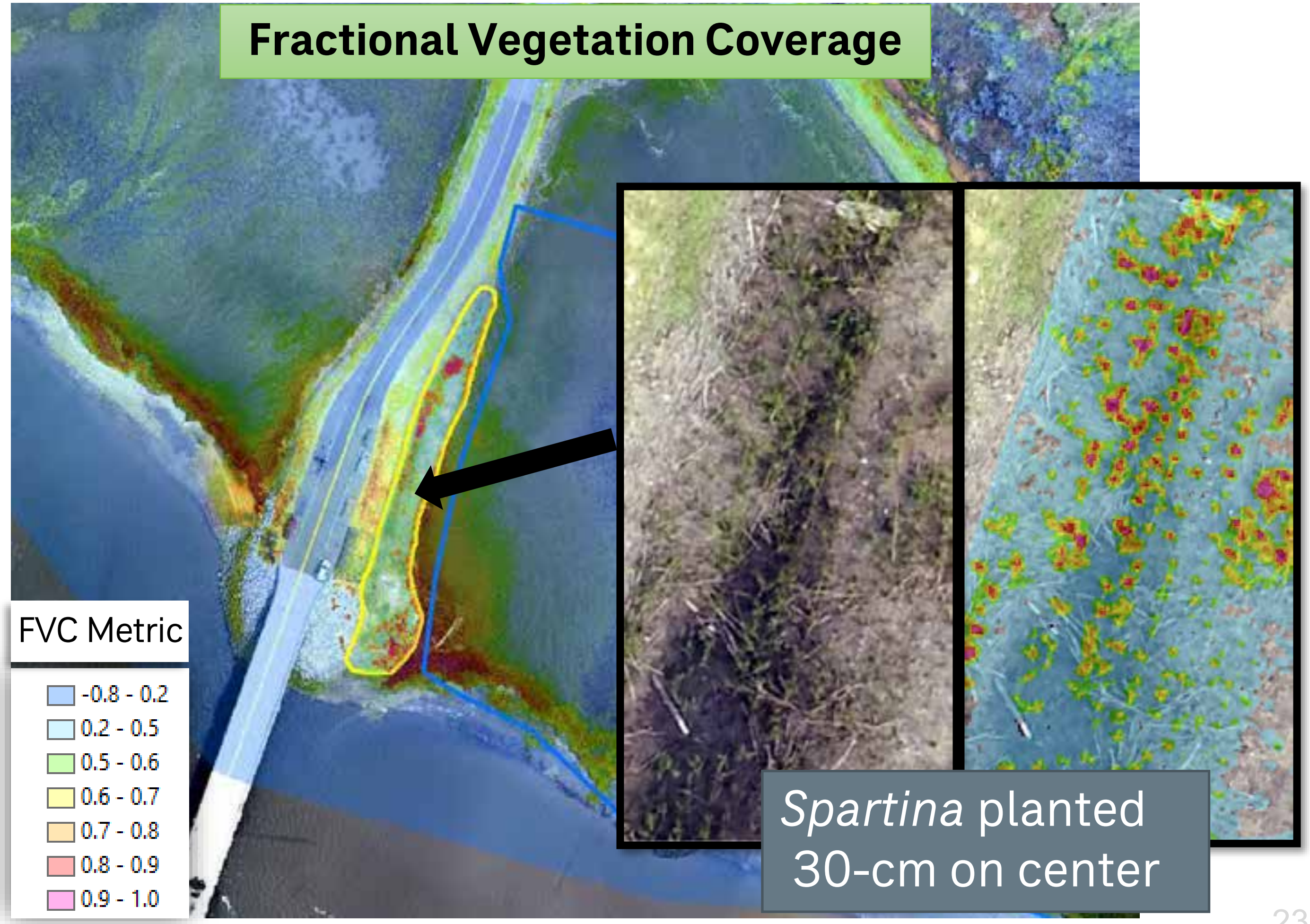
Reference Area

Fractional Vegetative Cover

Fractional Vegetation Coverage (FVC)

$$\frac{NDVI - NDVI_{soil}}{NDVI_{veg} - NDVI_{soil}}$$

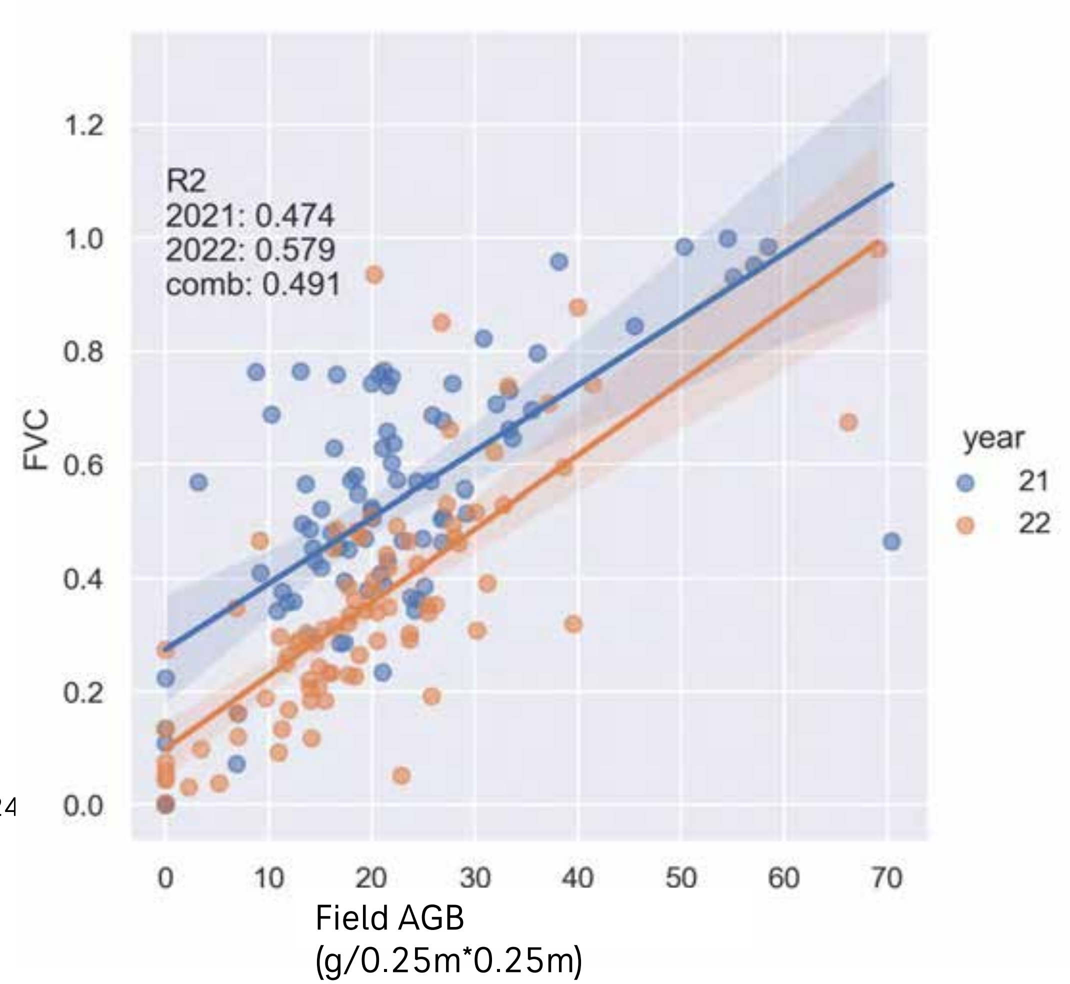


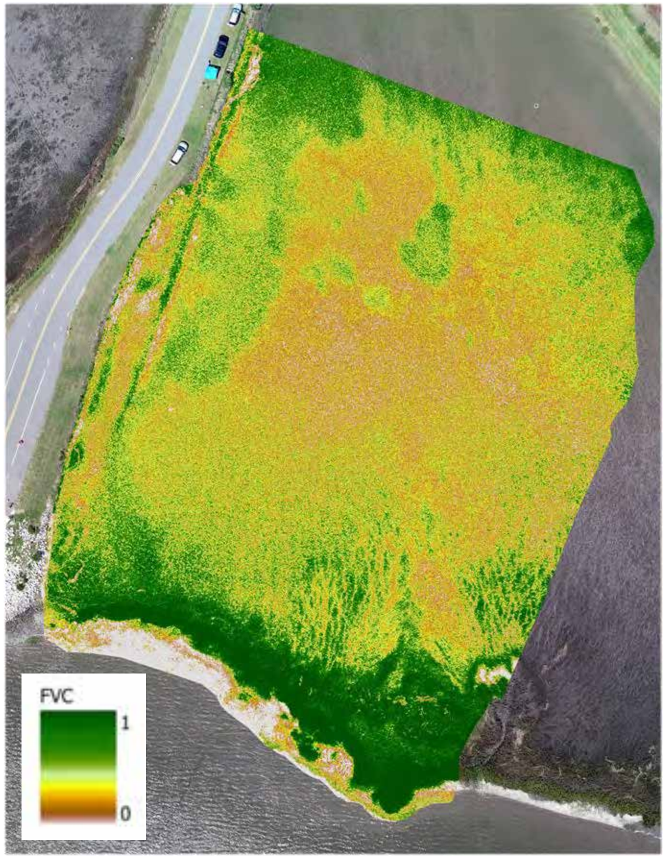


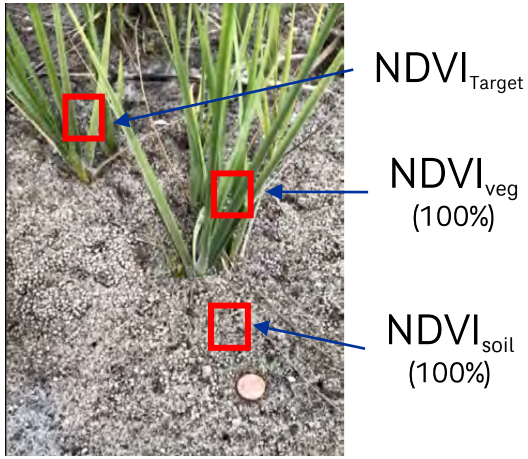
Mitigation Area

Reference Area

Fractional Vegetation Coverage (FVC)

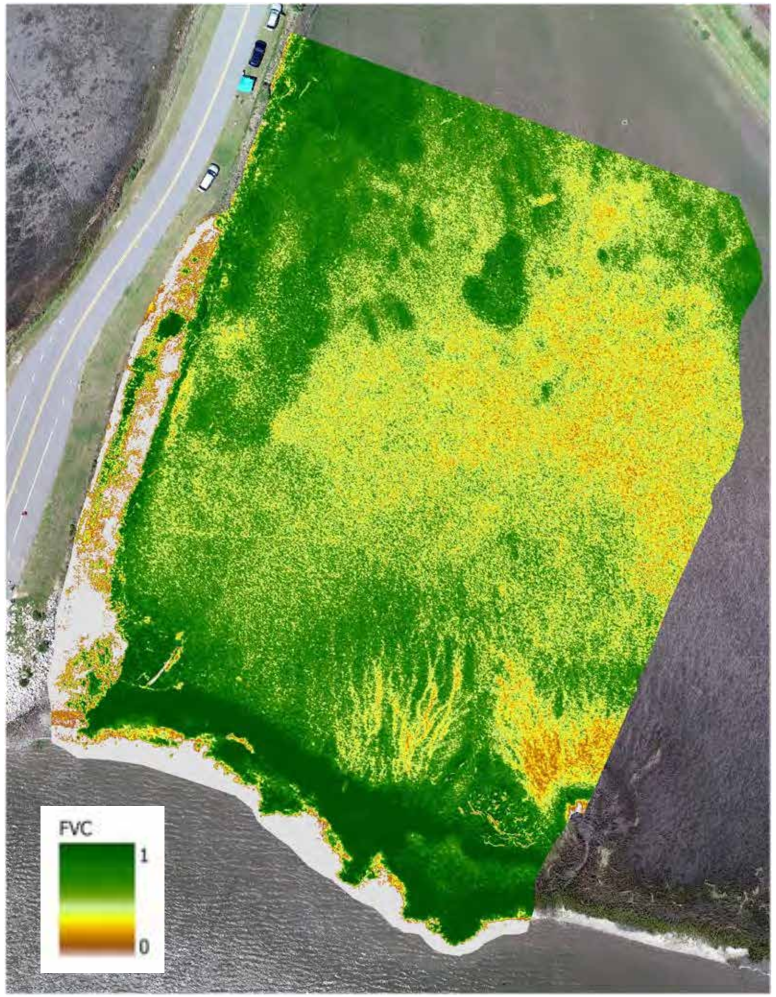




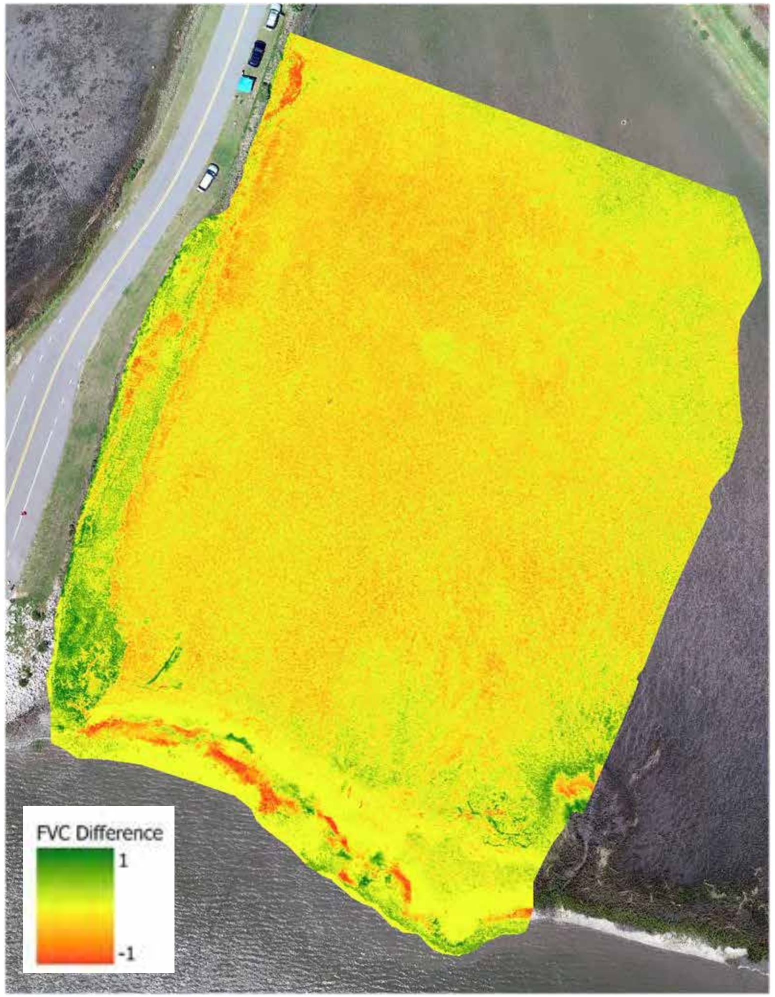


Fractional Vegetation Coverage (FVC)

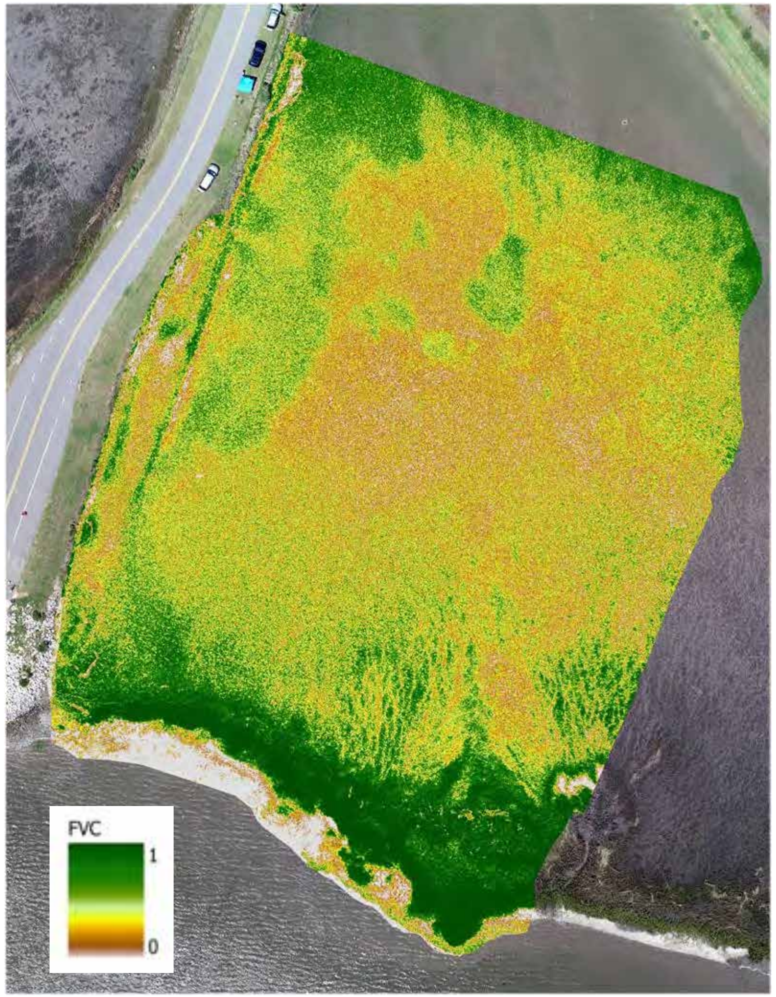
2018



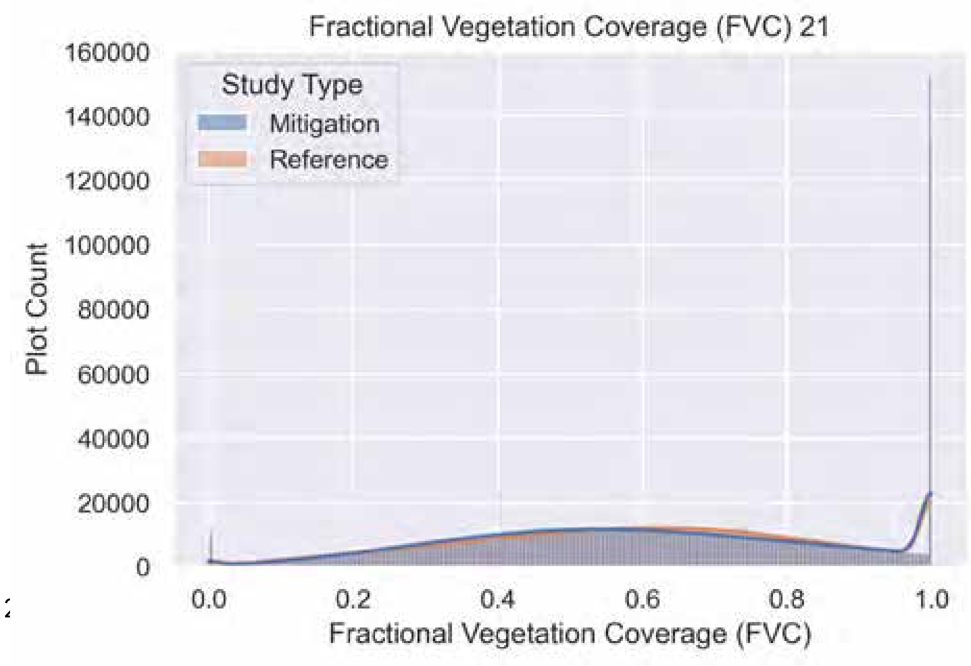
2022 - 2018

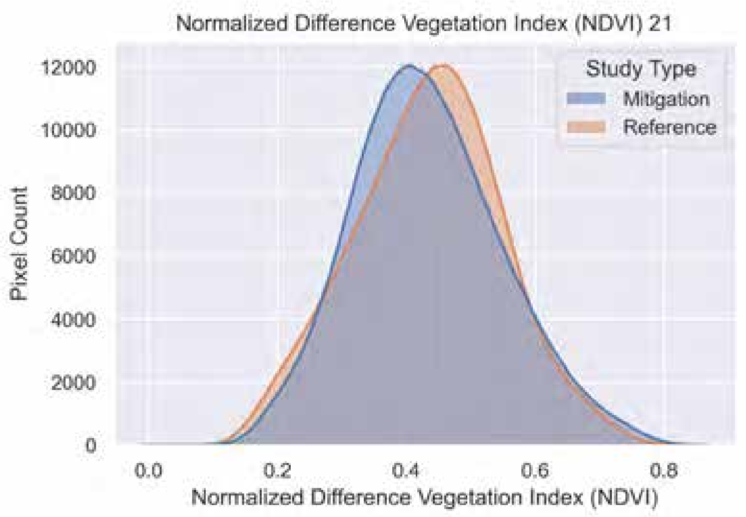


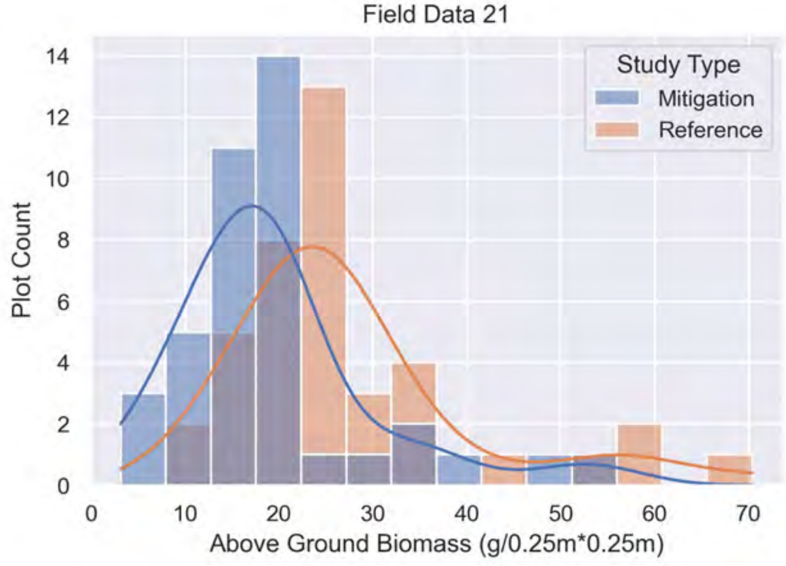
2022

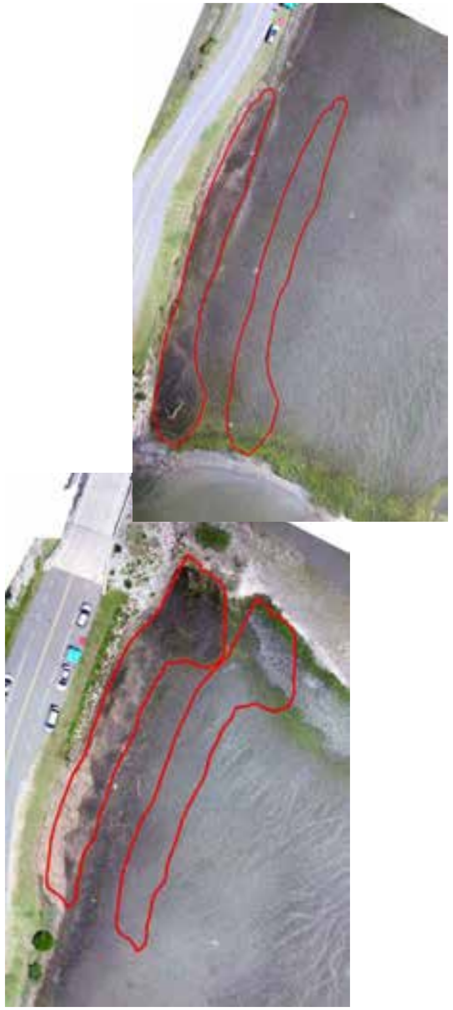


Fractional Vegetation Coverage (FVC)





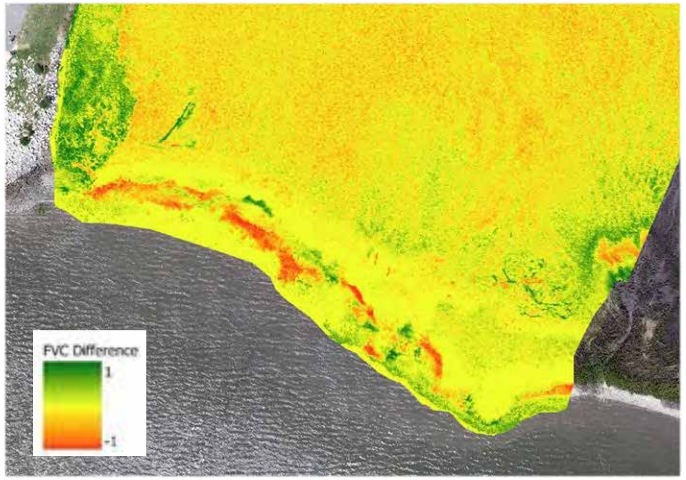




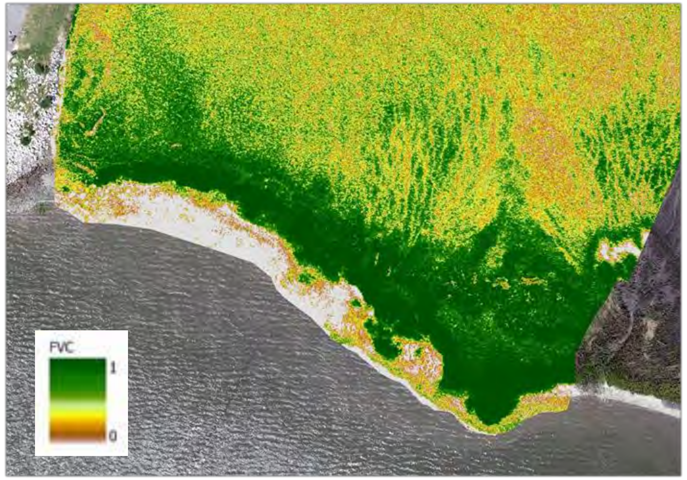
Shoreline Erosion

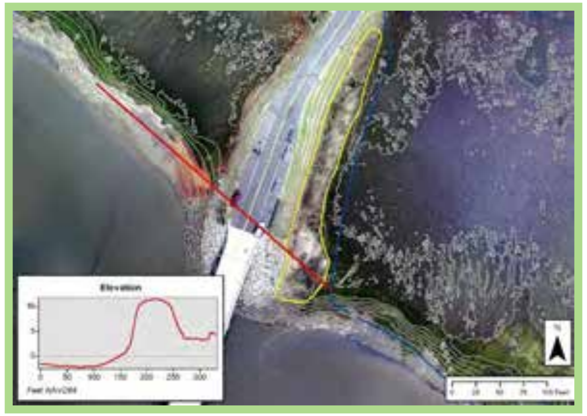
2018

2022 - 2018

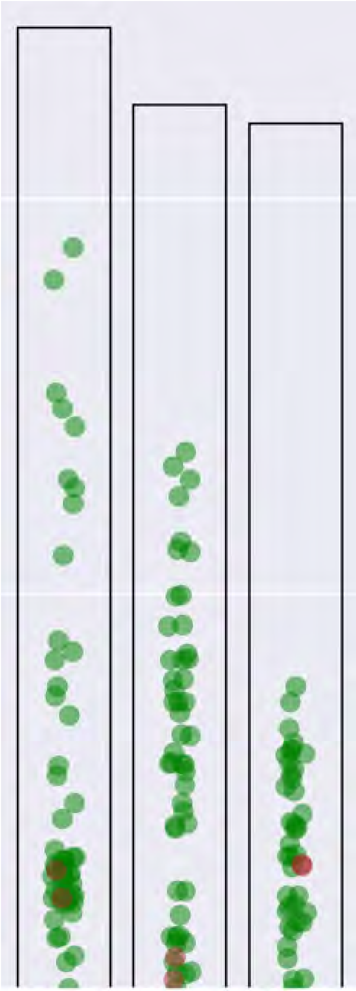


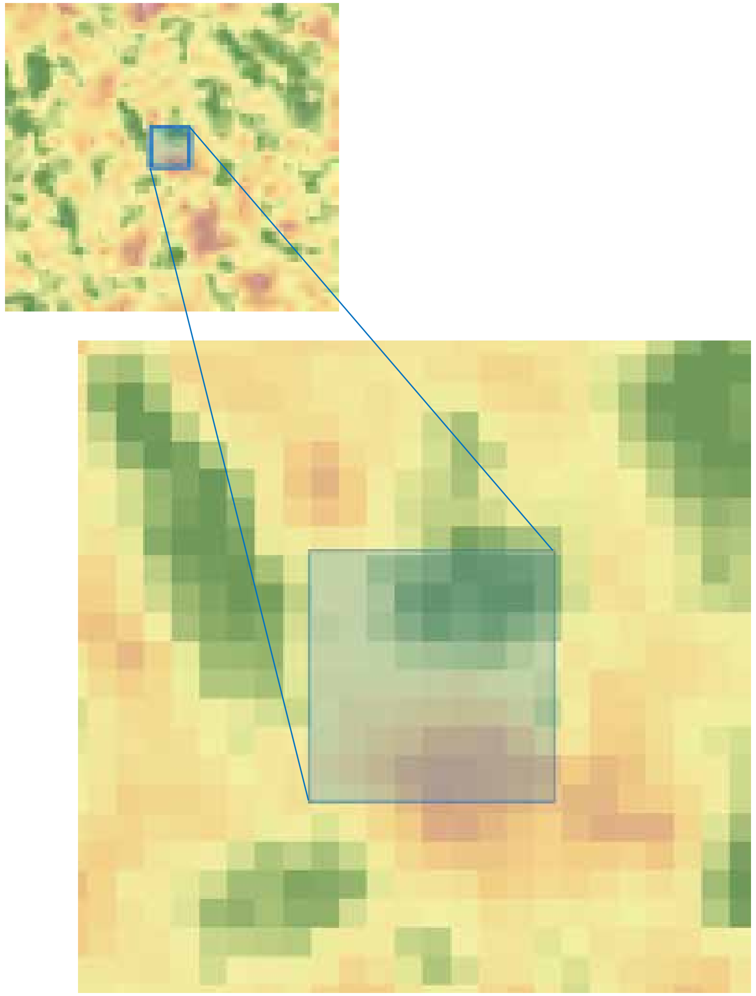
2022



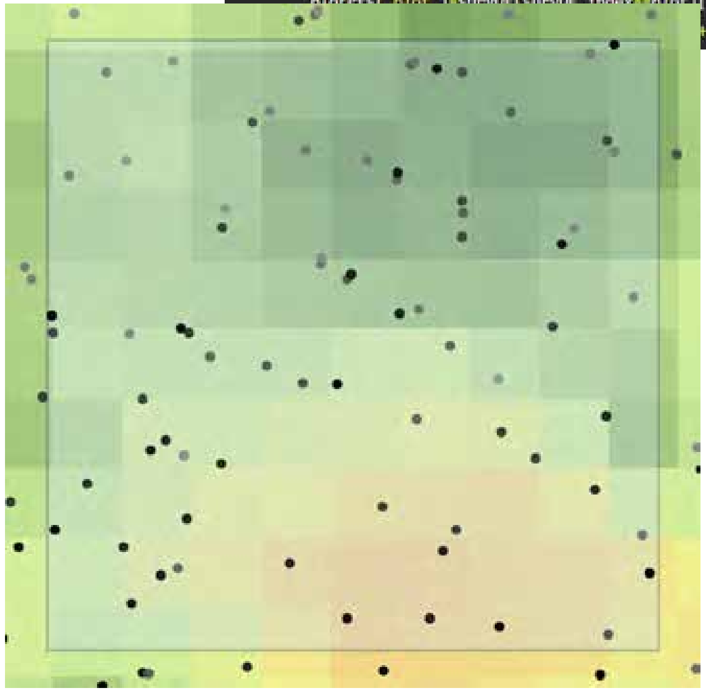


Biomass Model Parameters

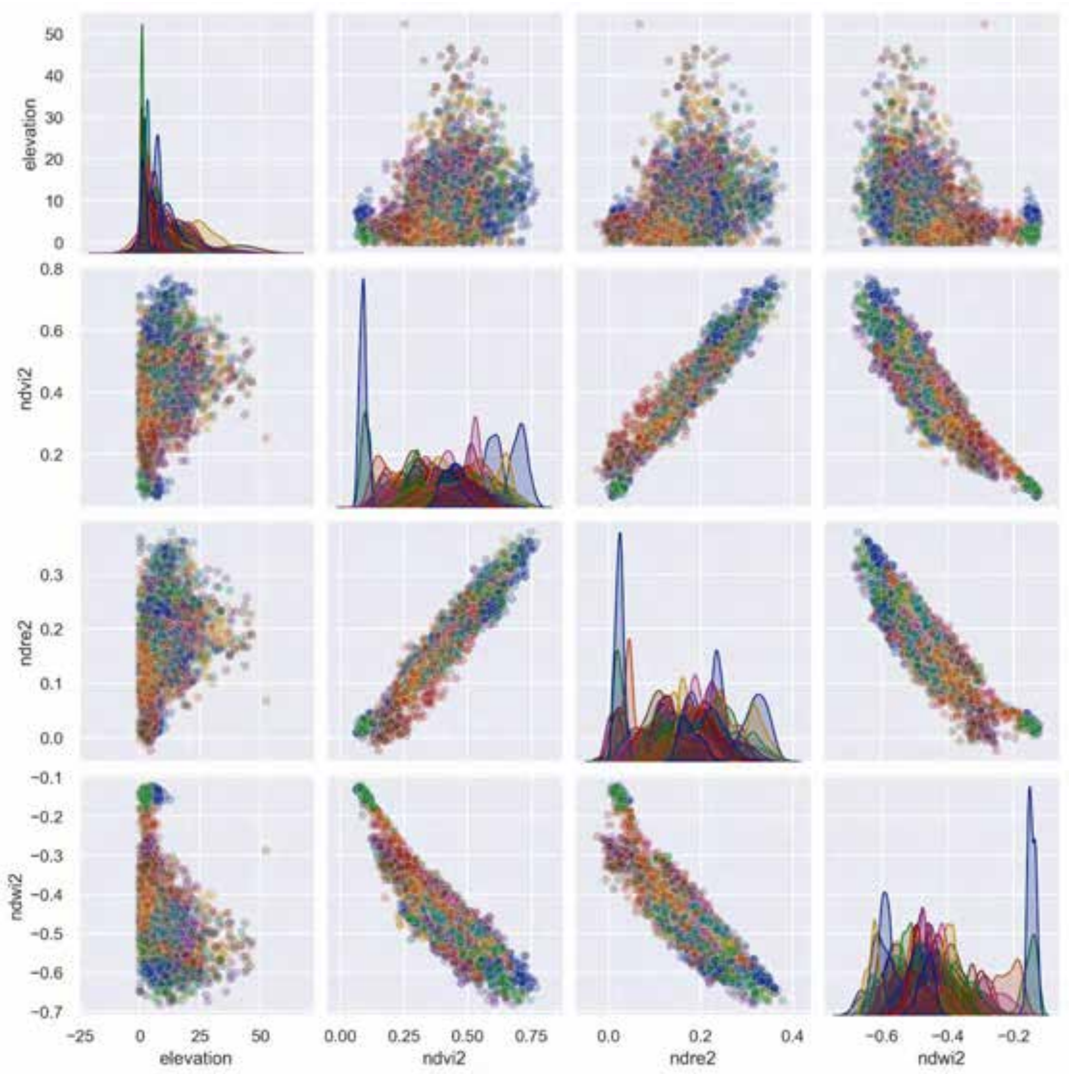




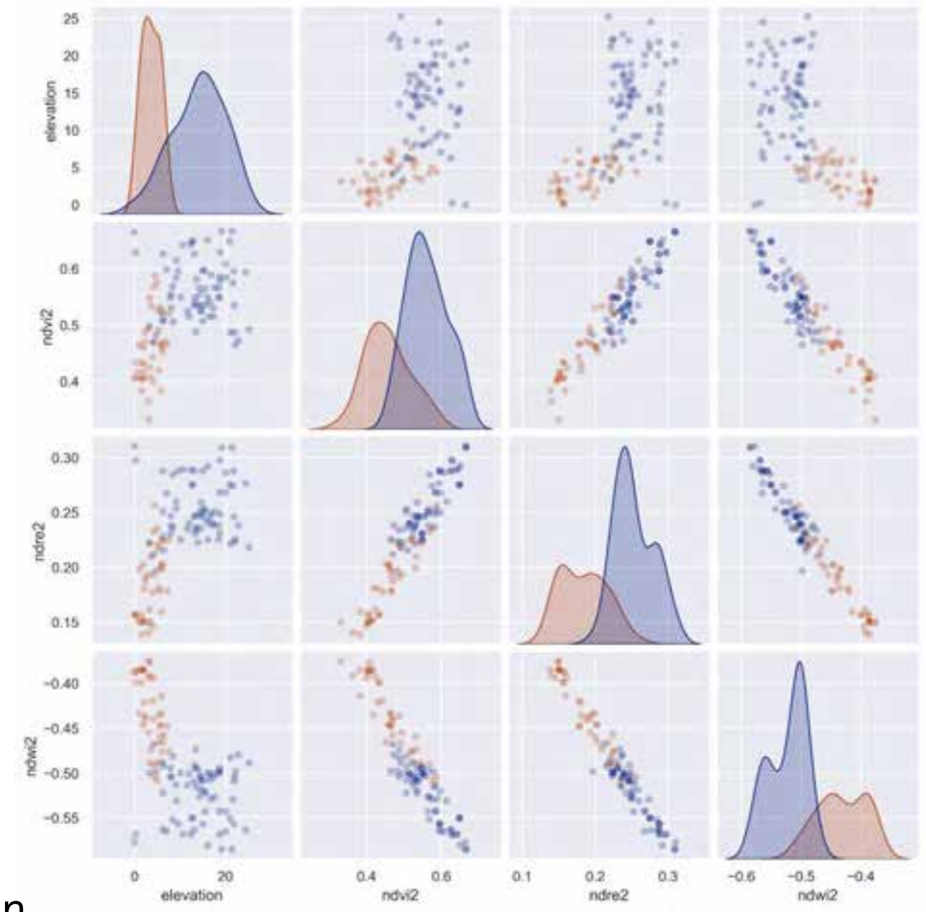
```
for plot in survDF.index:
    print("processing plot: {}".format(survDF[survDF.index==plot]['plot_id'].values))
    ptx=survDF[survDF.index==plot]['x_coord'].values[0]
    pty=survDF[survDF.index==plot]['y_coord'].values[0]
    #get plot extents
    yma=pty+ps
    ymi=pty-ps
    xma=ptx+ps
    xmi=ptx-ps
    #list of all elevations
    plotPts=pcDF[(pcDF['x']<xma)&(pcDF['x']>xmi)&(pcDF['y']<yma)&(pcDF['y']>ymi)][['x',
    #normalize against plot minimum and convert to cm
    plotPts['elevation']=(plotPts['z']-min(list(plotPts['z'].values)))*30.48
    #get corresponding raster values
        #iterate point elevs and pull NDVI values
    for i2 in range(0, len(idx)):
        with rasterio.open(os.path.join(inP, idx[i2][i])) as src:
            plotPts[cols[i2]]=plotPts.apply(lambda x: cellVal(x.x, x.y, src), axis=1)
    plotPts['plot']=survDF[survDF.index==plot]['plot_id'].values[0]
                                             +cols])
```



Biomass Model Parameters

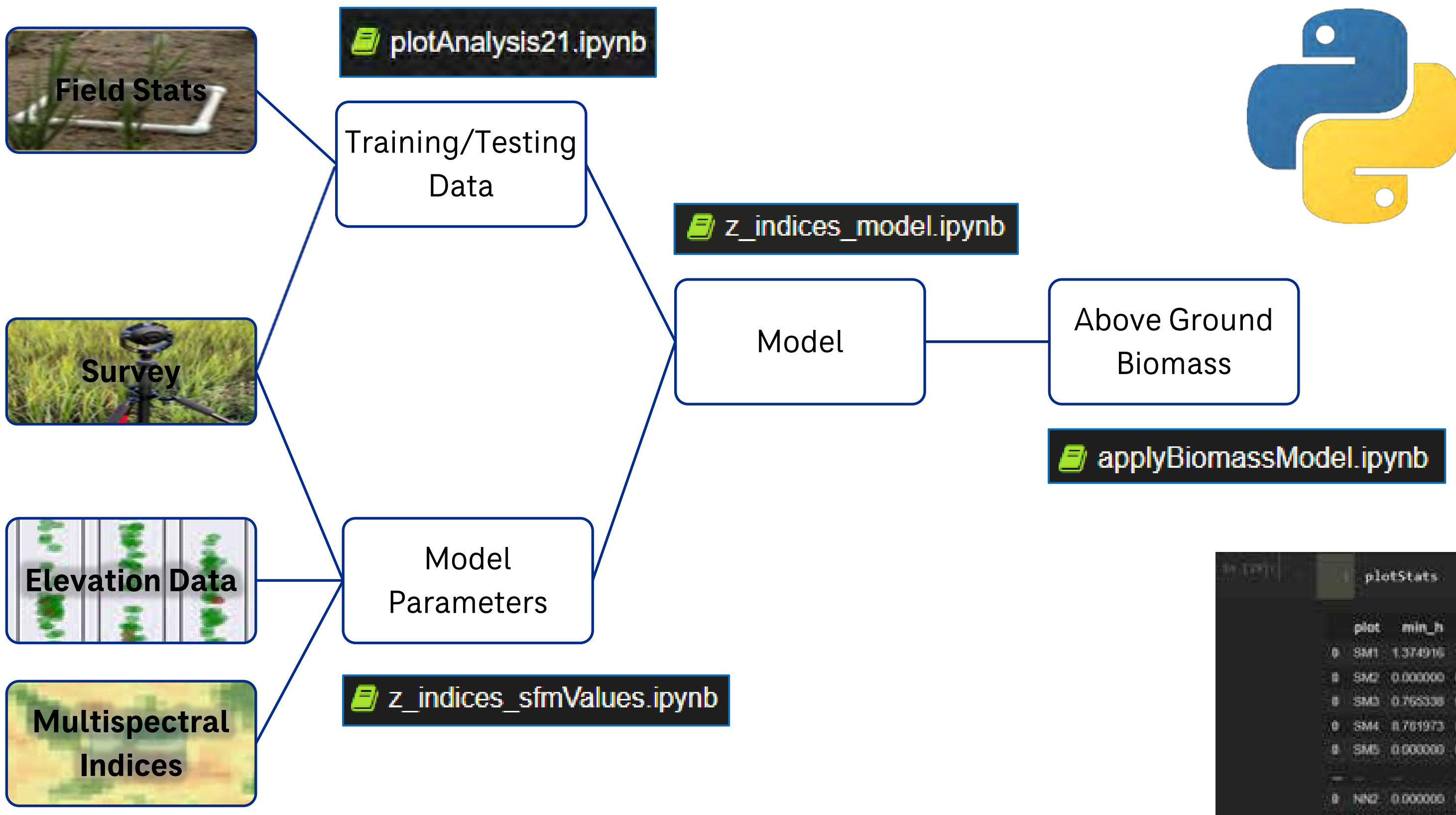


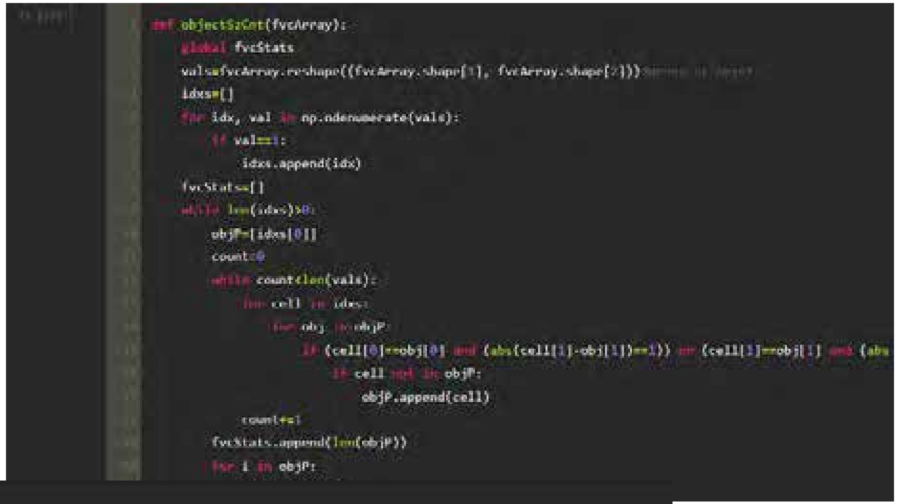
- Minimum
- 5th percentile
- 25th percentile
- 50th percentile
- 75th percentile
- 90th percentile
- Maximum
- Mean
- Standard Deviation
- Interquartile Range
- Kurtosis
- Skewness
- Variance
- Coefficient of Variation
- Mean Absolute Deviation (AAD)
- Median Absolute Deviation (MAD)
- Standard Deviation/Mean



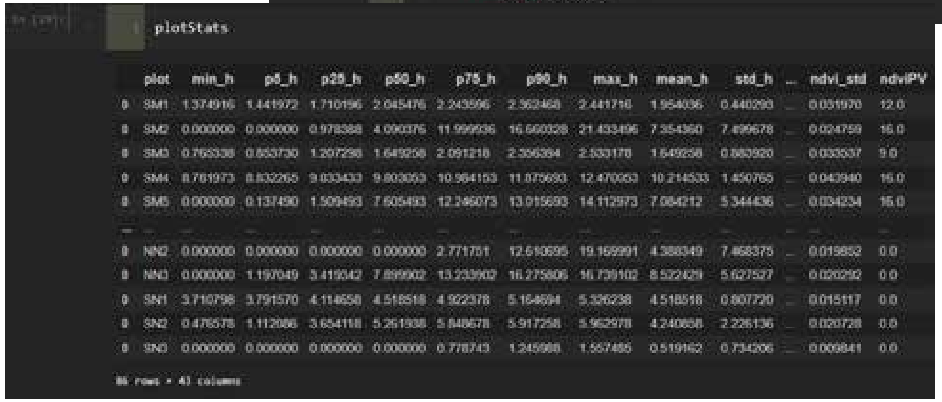
Estimating vegetation biomass and cover across large plots in shrub and grass dominated drylands using terrestrial lidar and machine learning
Kyle E. Anderson, Nancy F. Glenn, Lucas P. Spaet, Douglas J. Shinneman, David S. Pilliod, Robert S. Arkleb, Susan K. McIlroy, DeWayne R. Derryberry

Above Ground Biomass Model





```
def objectSzCnt(fvcArray):
    global fvcStats
    vals=fvcArray.reshape((fvcArray.shape[1], fvcArray.shape[2]))
    idxs=[]
    for idx, val in np.ndenumerate(vals):
        if val==1:
            idxs.append(idx)
    fvcStats=[]
    while len(idxs)>0:
        objP=[idxs[0]]
        count=0
        while count<len(vals):
            for cell in idxs:
                for obj in objP:
                    if (cell[0]==obj[0] and (abs(cell[1]-obj[1])==1)) or (cell[1]==obj[1] and (abs
                        if cell not in objP:
                            objP.append(cell)
            count+=1
        fvcStats.append(len(objP))
        for i in objP:
```

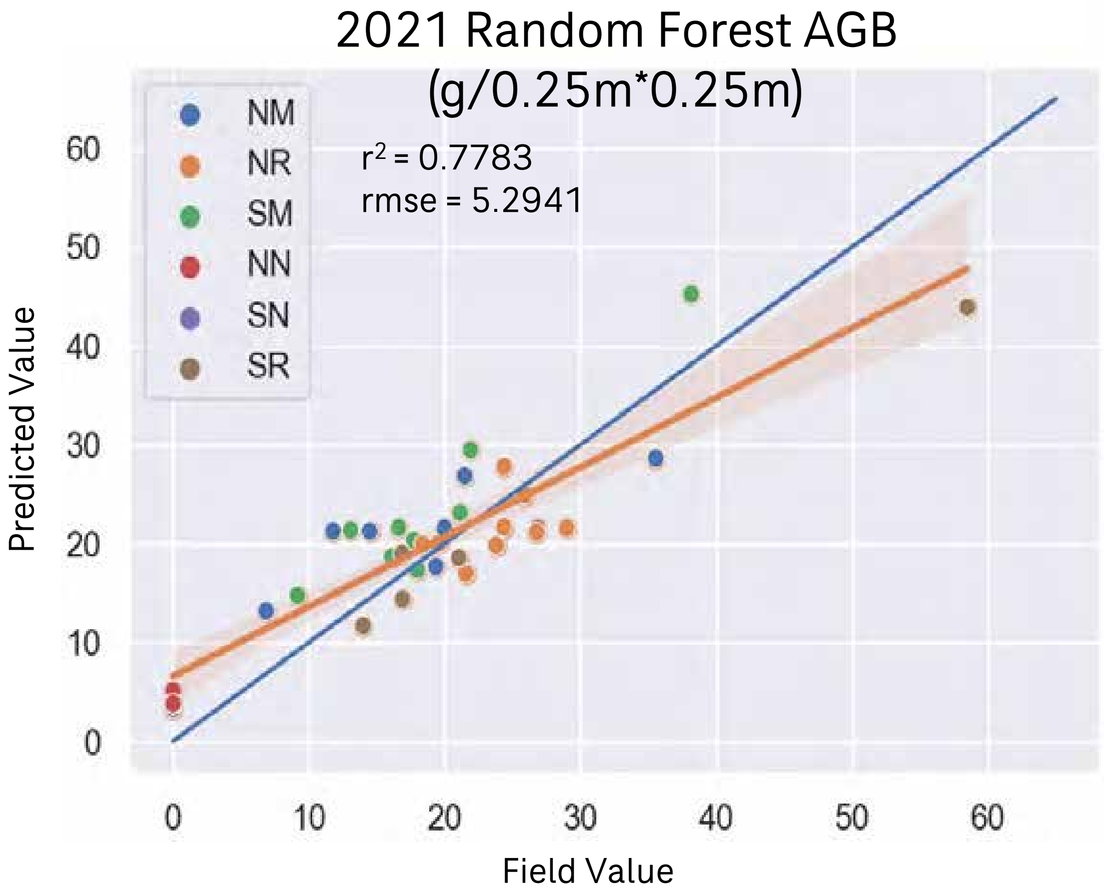


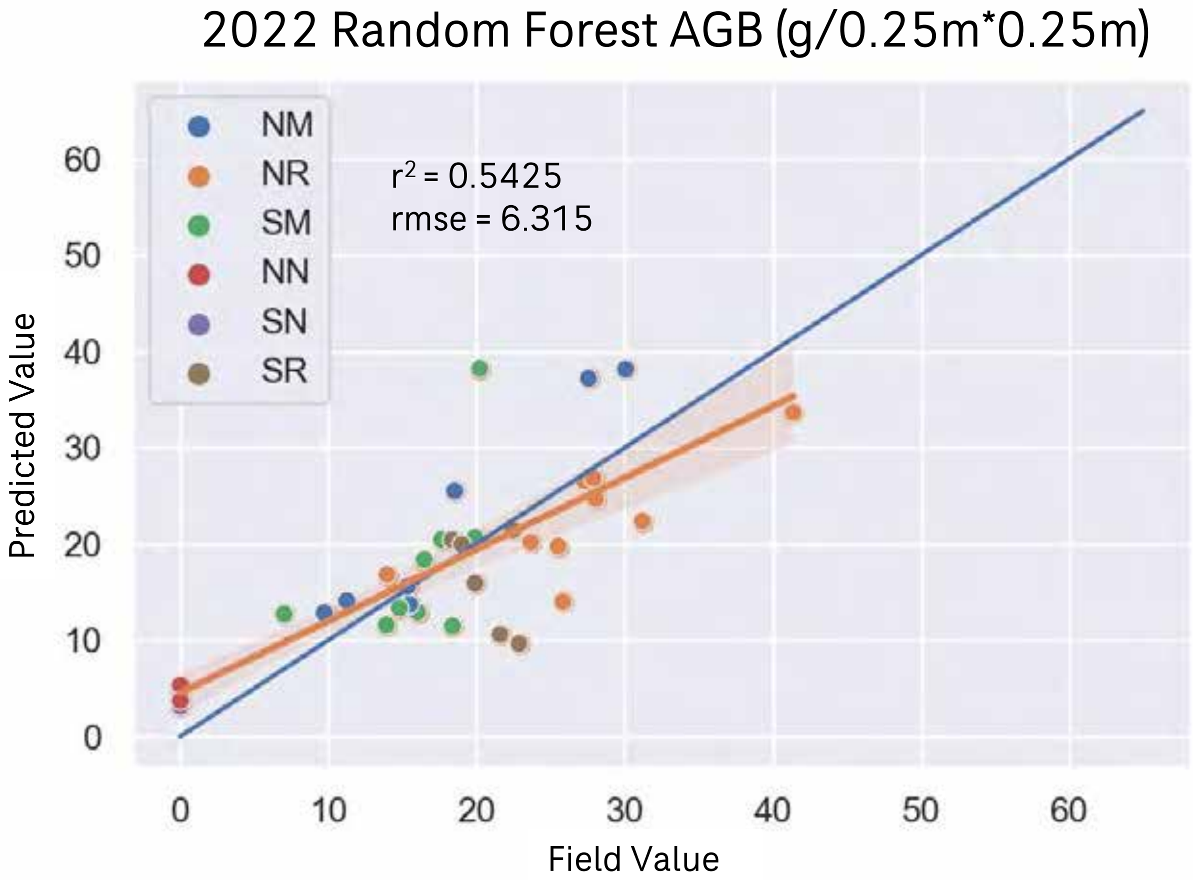
plotStats

	plot	min_h	p5_h	p25_h	p50_h	p75_h	p90_h	max_h	mean_h	std_h	...	ndvi_std	ndviPV
0	SM1	1.374916	1.441972	1.710196	2.045476	2.243596	2.362468	2.441716	1.954036	0.440293	...	0.031970	12.0
0	SM2	0.000000	0.000000	0.978388	4.090376	11.999936	16.660328	21.433496	7.354360	7.499678	...	0.024759	16.0
0	SM3	0.765338	0.853730	1.207298	1.649258	2.091218	2.356394	2.533178	1.649258	0.883920	...	0.033537	9.0
0	SM4	8.781973	8.832265	9.033433	9.803053	10.984153	11.875693	12.470053	10.214533	1.450765	...	0.043940	16.0
0	SM5	0.000000	0.137490	1.509493	7.605493	12.246073	13.015693	14.112973	7.084212	5.344436	...	0.034234	16.0
...	...	...	...	...	...	...	...	...	...	...	...	...	...
0	NN2	0.000000	0.000000	0.000000	0.000000	2.771751	12.610695	19.169991	4.388349	7.468375	...	0.019852	0.0
0	NN3	0.000000	1.197049	3.419342	7.899902	13.233902	16.275806	16.739102	8.522429	5.627527	...	0.020292	0.0
0	SN1	3.710798	3.791570	4.114658	4.518518	4.922378	5.164694	5.326238	4.518518	0.807720	...	0.015117	0.0
0	SN2	0.476578	1.112086	3.654118	5.261938	5.848678	5.917258	5.962978	4.240858	2.226136	...	0.020728	0.0
0	SN3	0.000000	0.000000	0.000000	0.000000	0.778743	1.245988	1.557485	0.519162	0.734206	...	0.009841	0.0

86 rows × 43 columns

Biomass Model Results



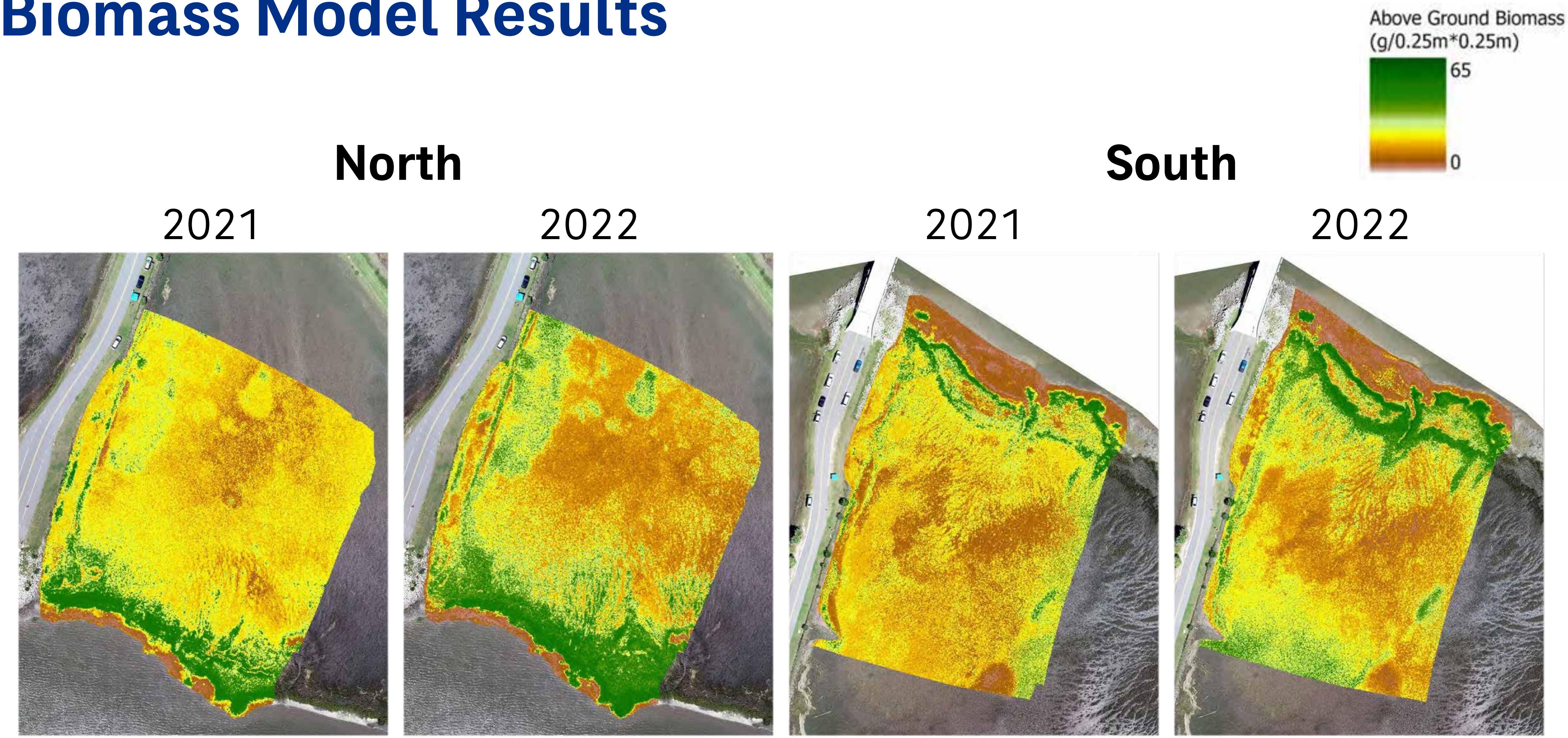


- scikit-learn
  - random forest
- Training/Testing
  - 60%/40%

Biomass Model Results

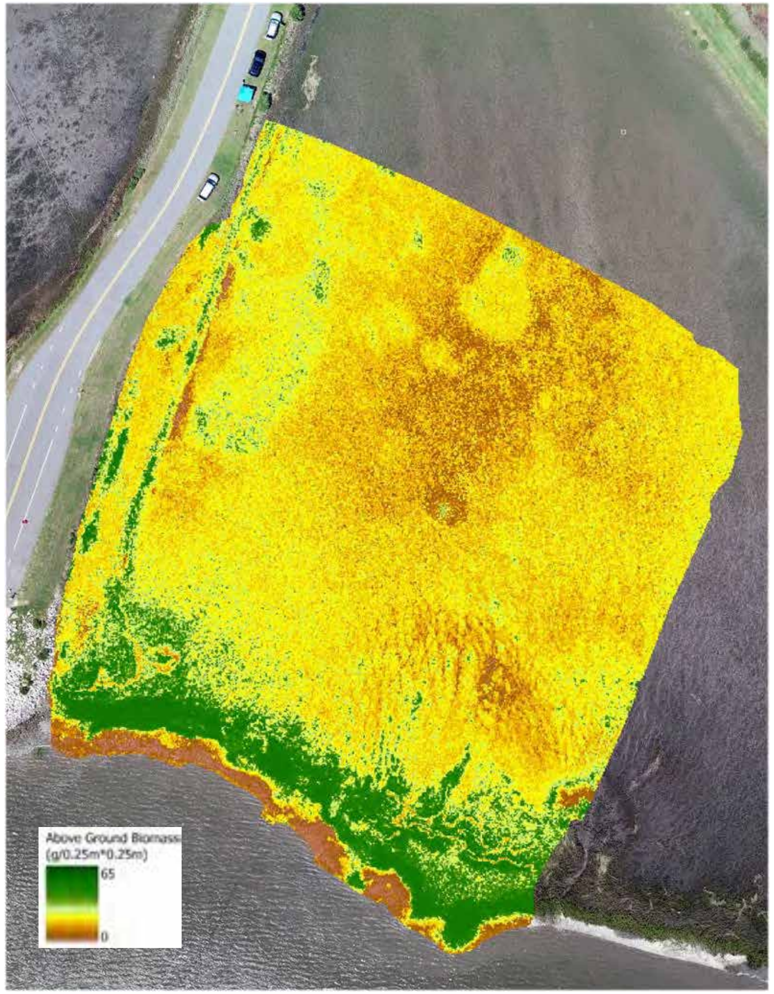
North | **South**

2021 | 2022 | 2021 | 2022

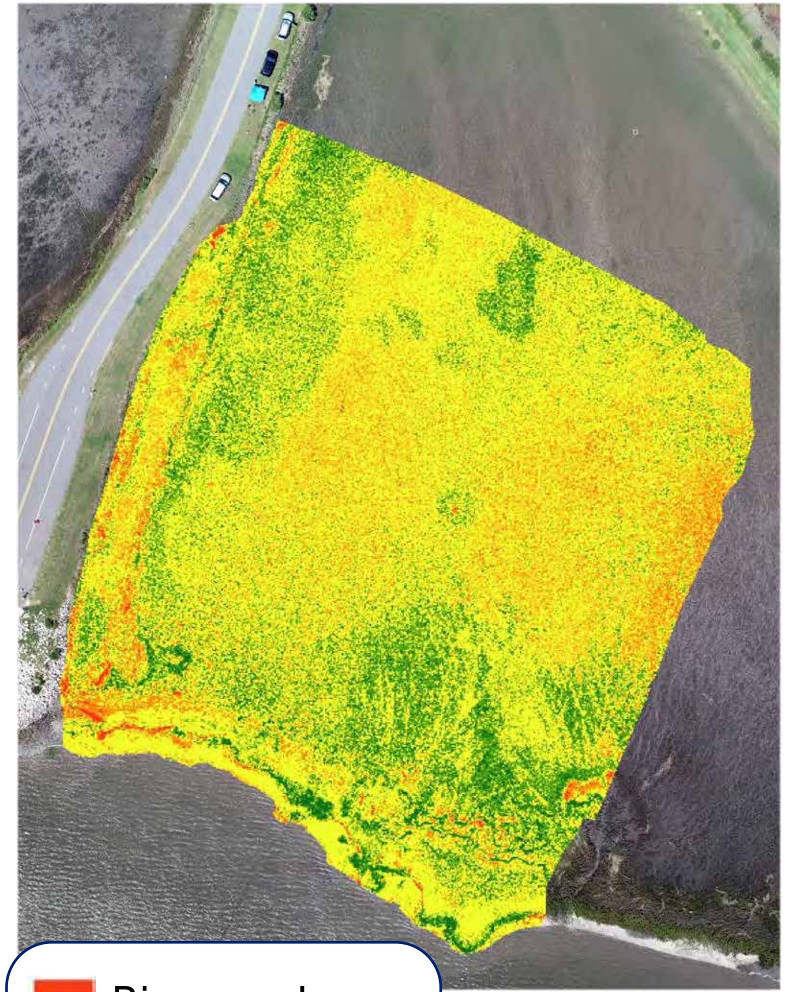


Biomass Model

2021



2022 - 2021

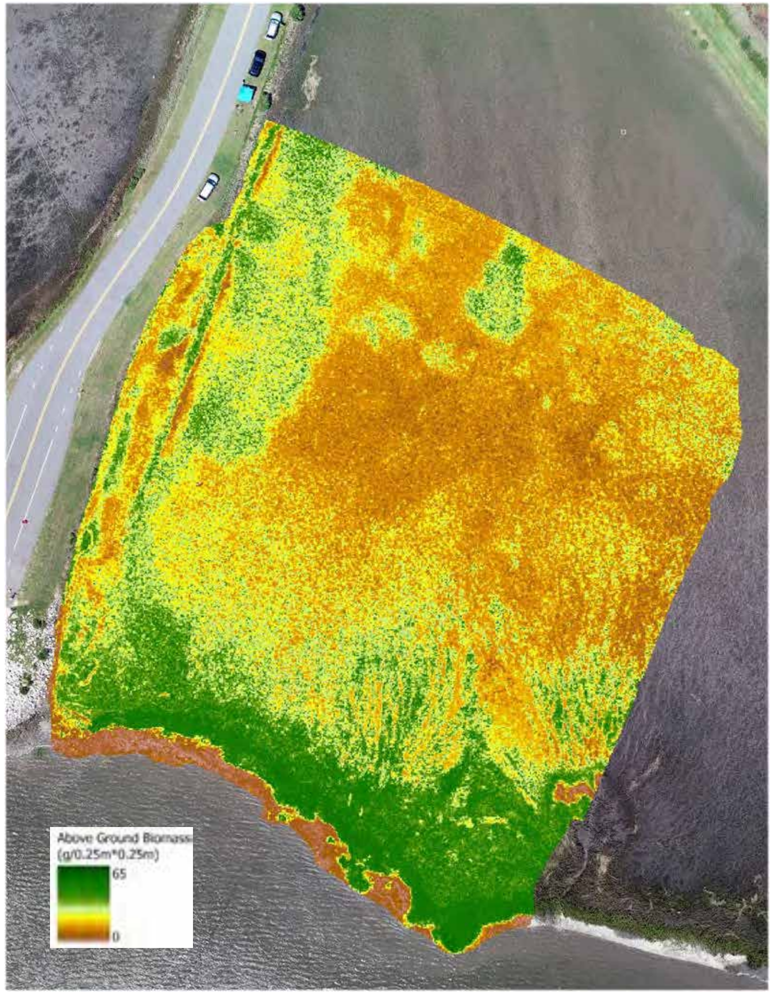


Biomass Loss

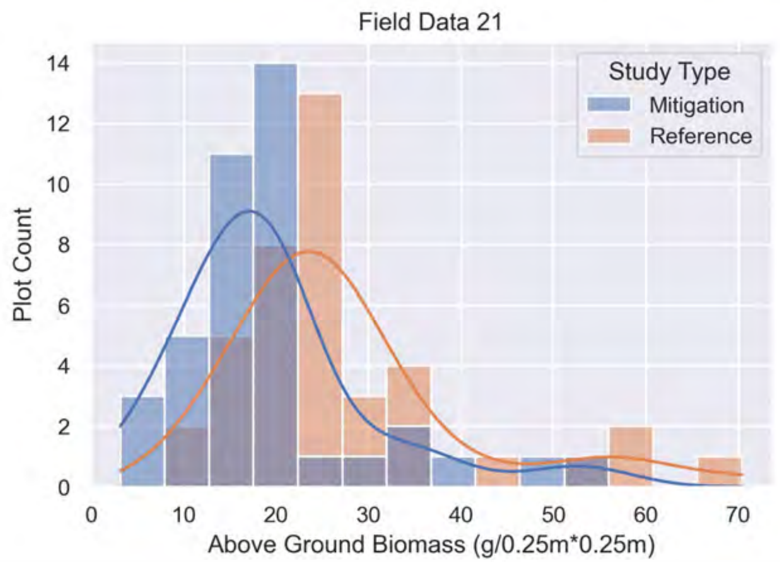
Biomass Stable

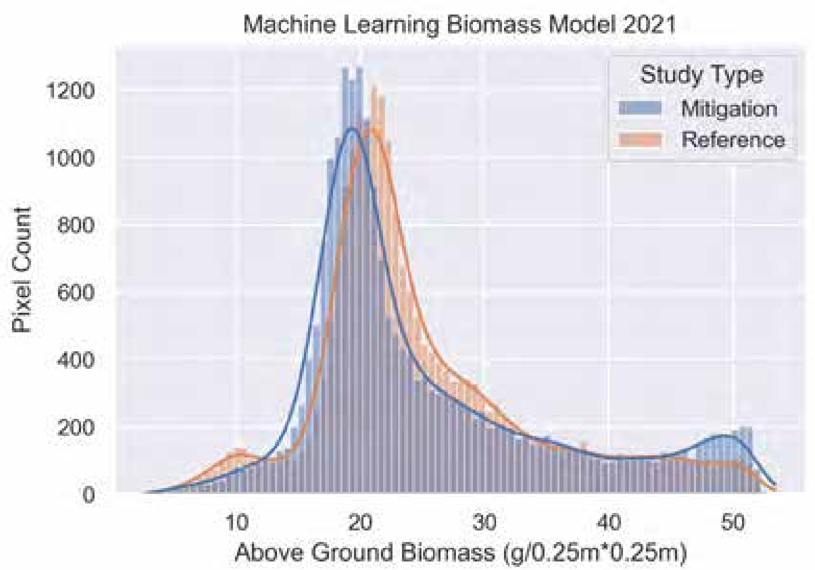
Biomass Gain

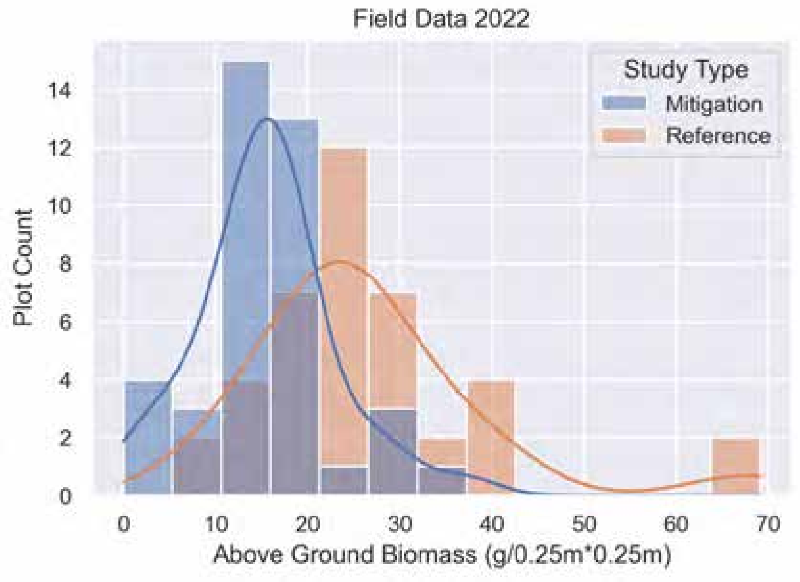
2022

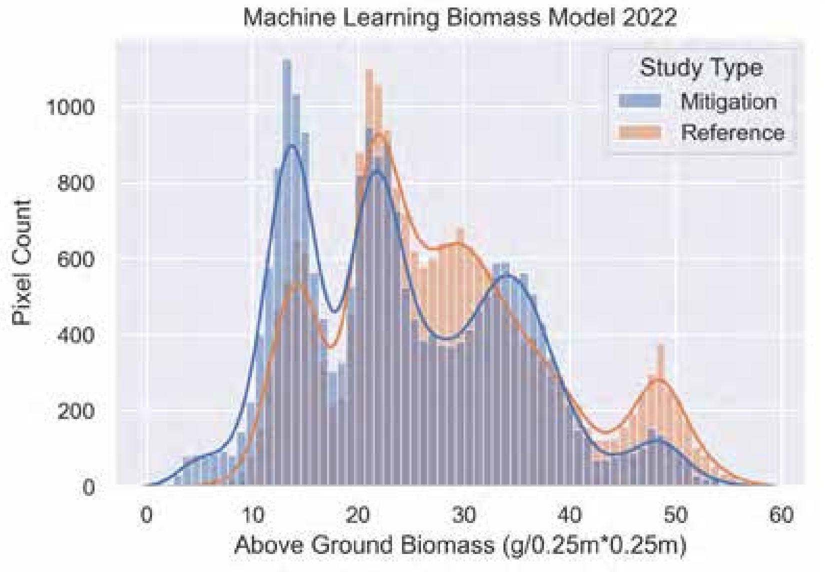


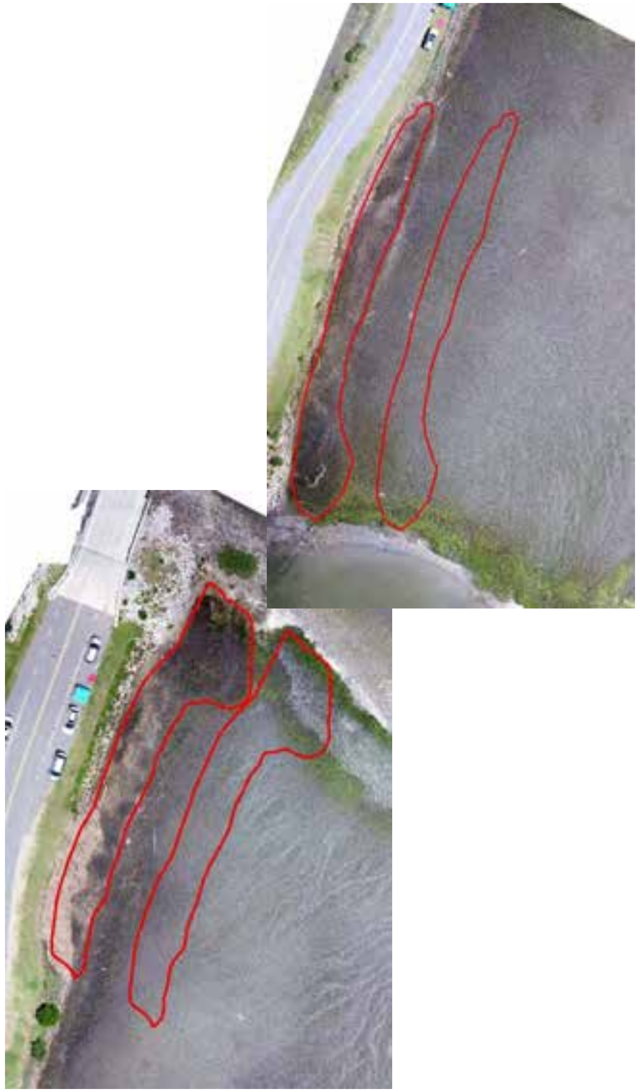
Biomass Model Results



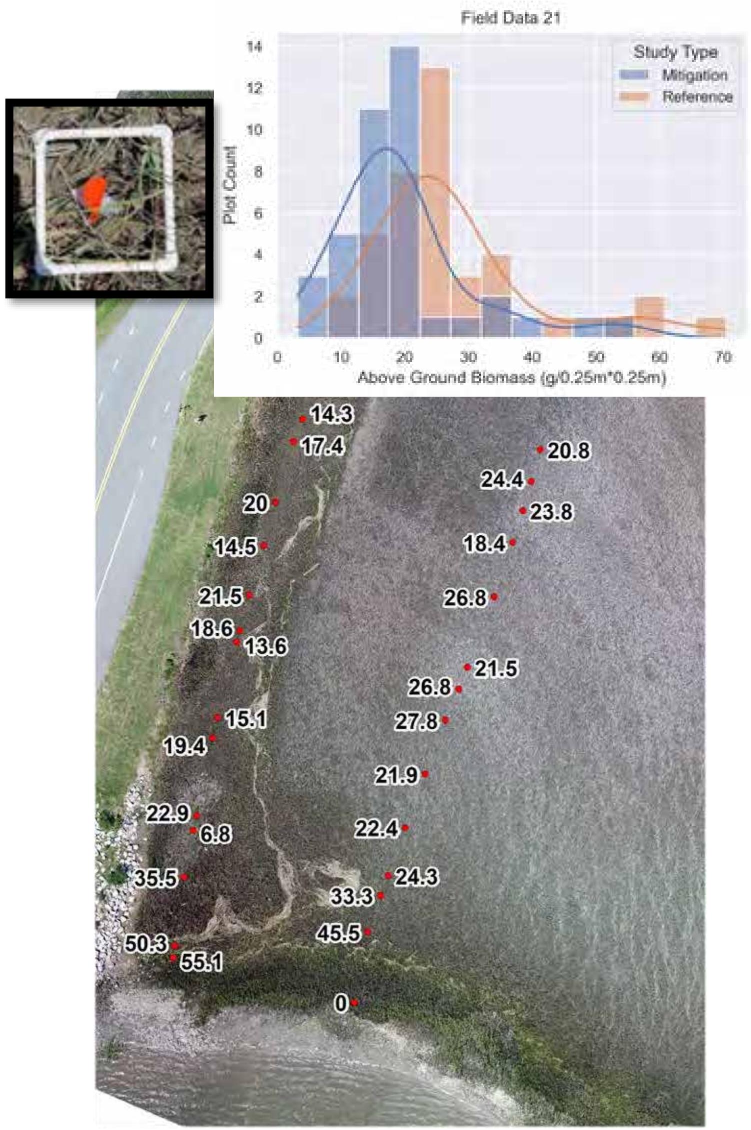


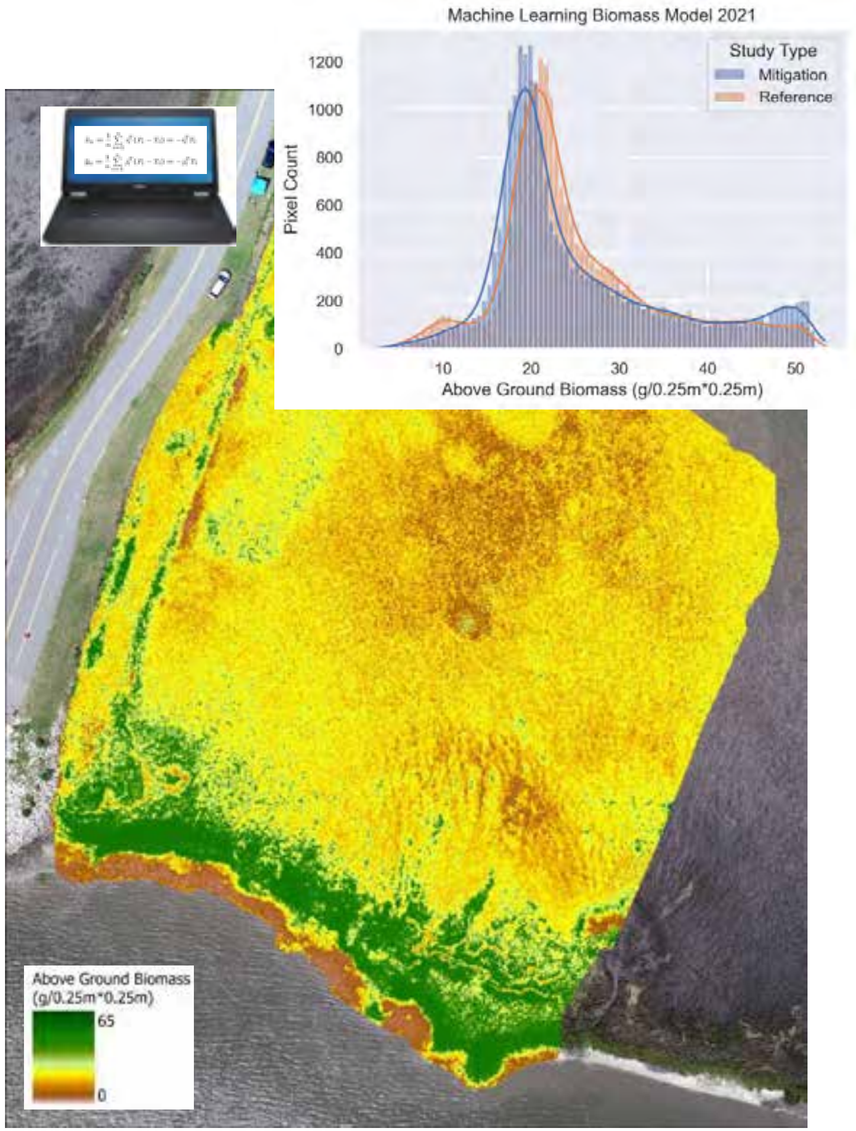




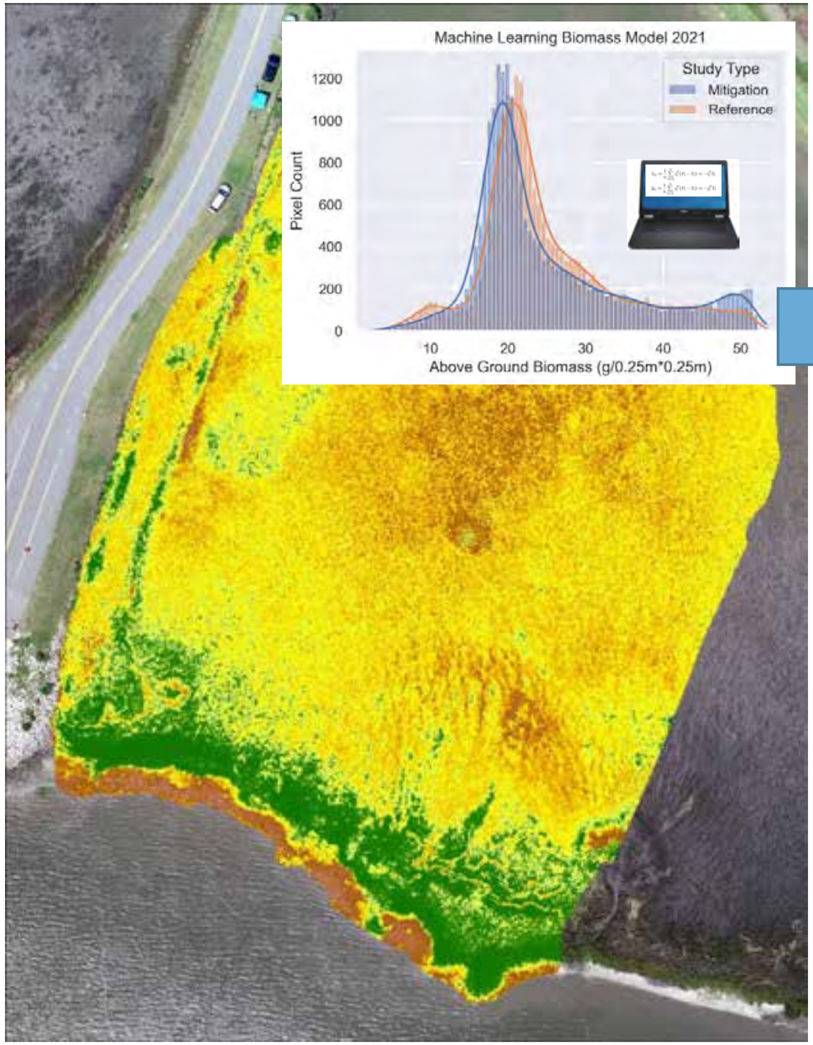


Methods Comparison





Drone Data for Permit Compliance



US Army Corps of Engineers ®

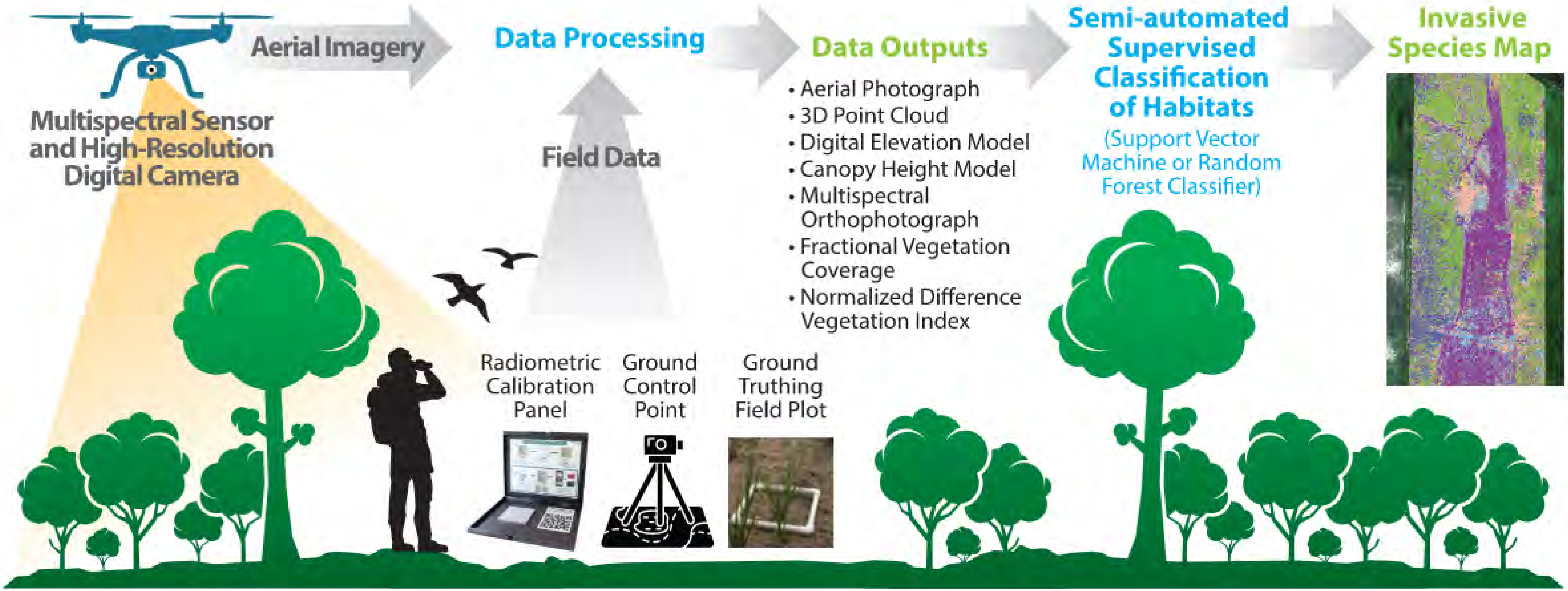
Drone-derived machine learning model provided to USACE for evaluation of mitigation success

Invasive Species Identification & Mapping

- Hillsborough County, Florida
- Mixed upland/wetland site
- 100+ acres
- 20+ species/classes of interest

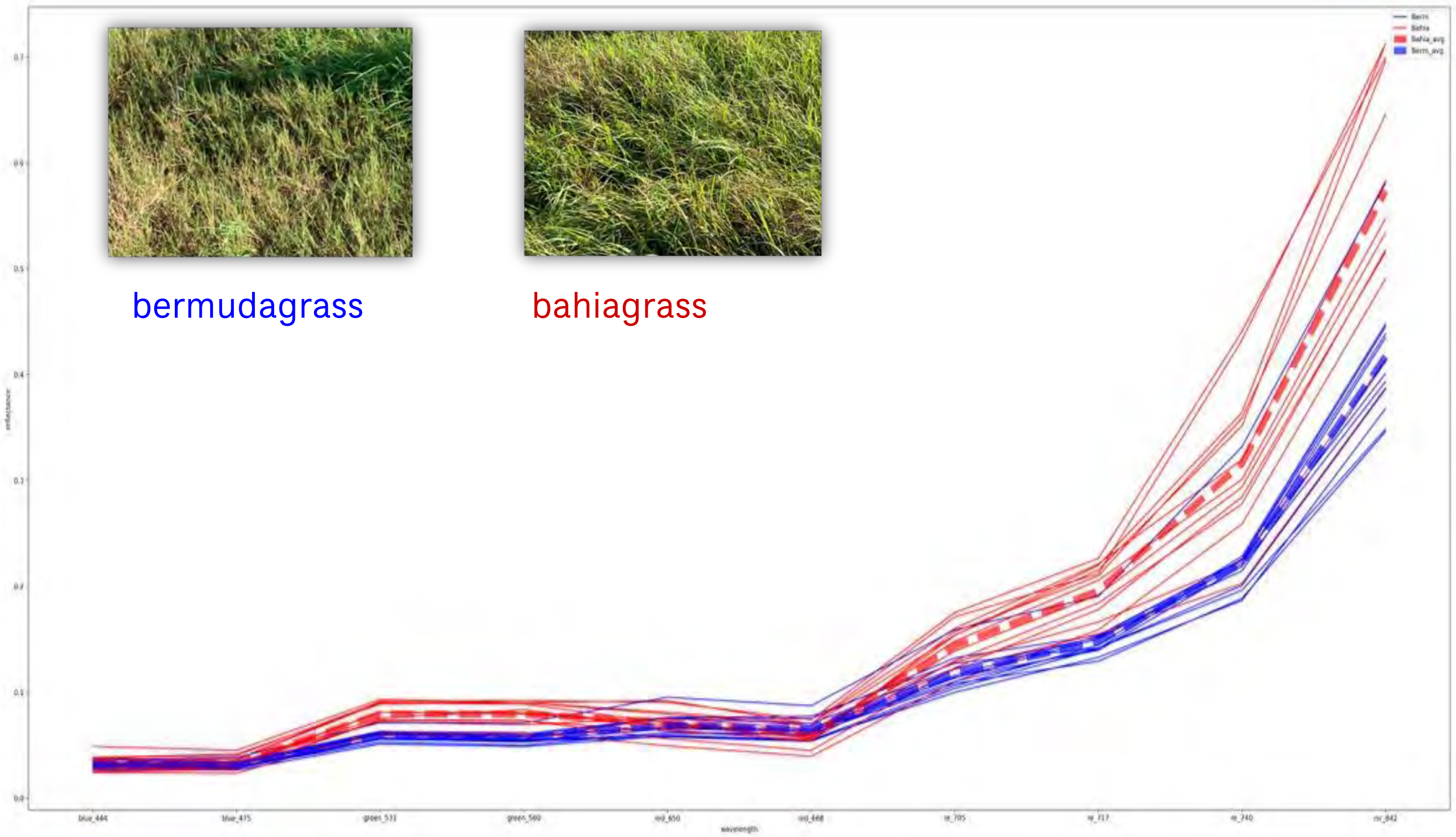
We know there are invasive species, but
- what are they?
- how much is there?
- where are they?

Invasive Species Identification & Mapping

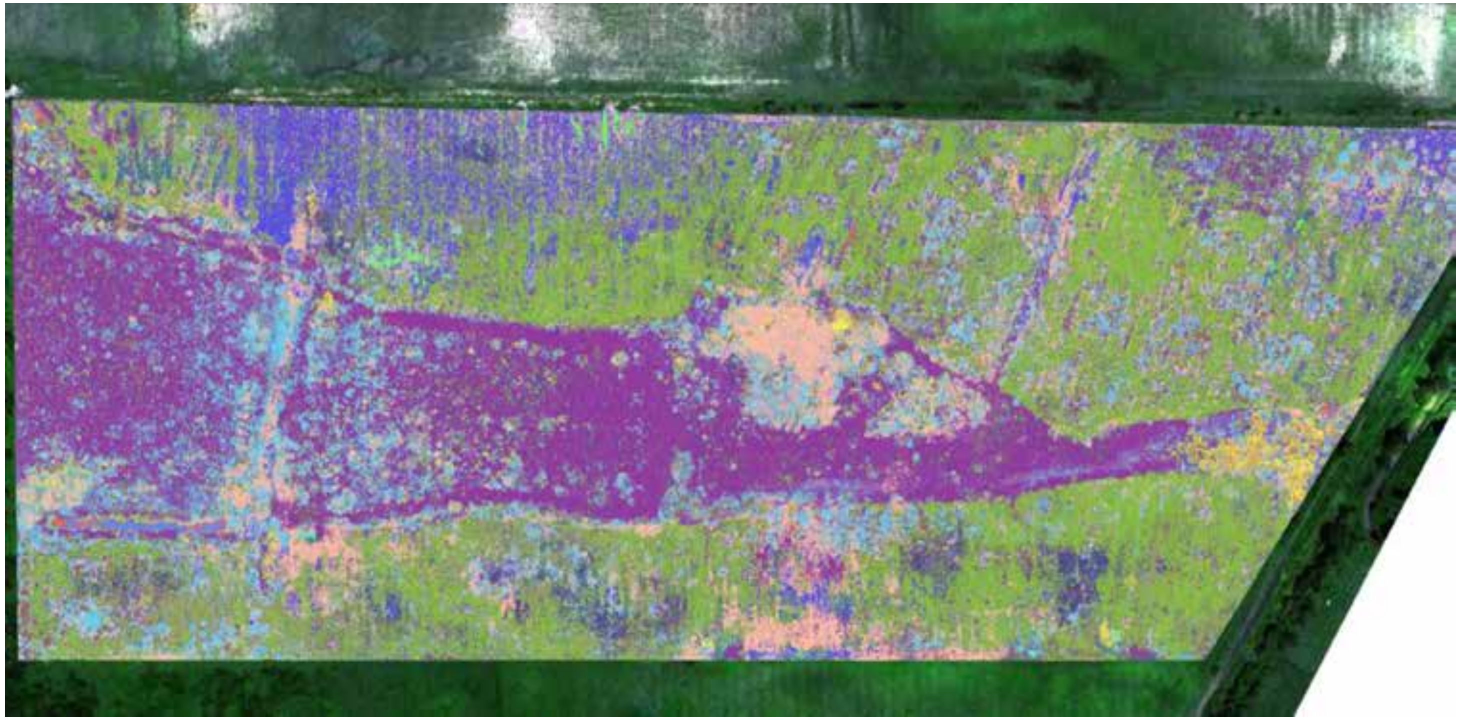


Invasive Species Identification & Mapping

- Collect field samples
  - Patent-pending collection method
  - Training & testing data
- Machine learning models
  - Maximum likelihood
  - SVM
  - Random forest
- Accuracy assessment
- Adjust parameters
- Repeat



Invasive Species Identification & Mapping



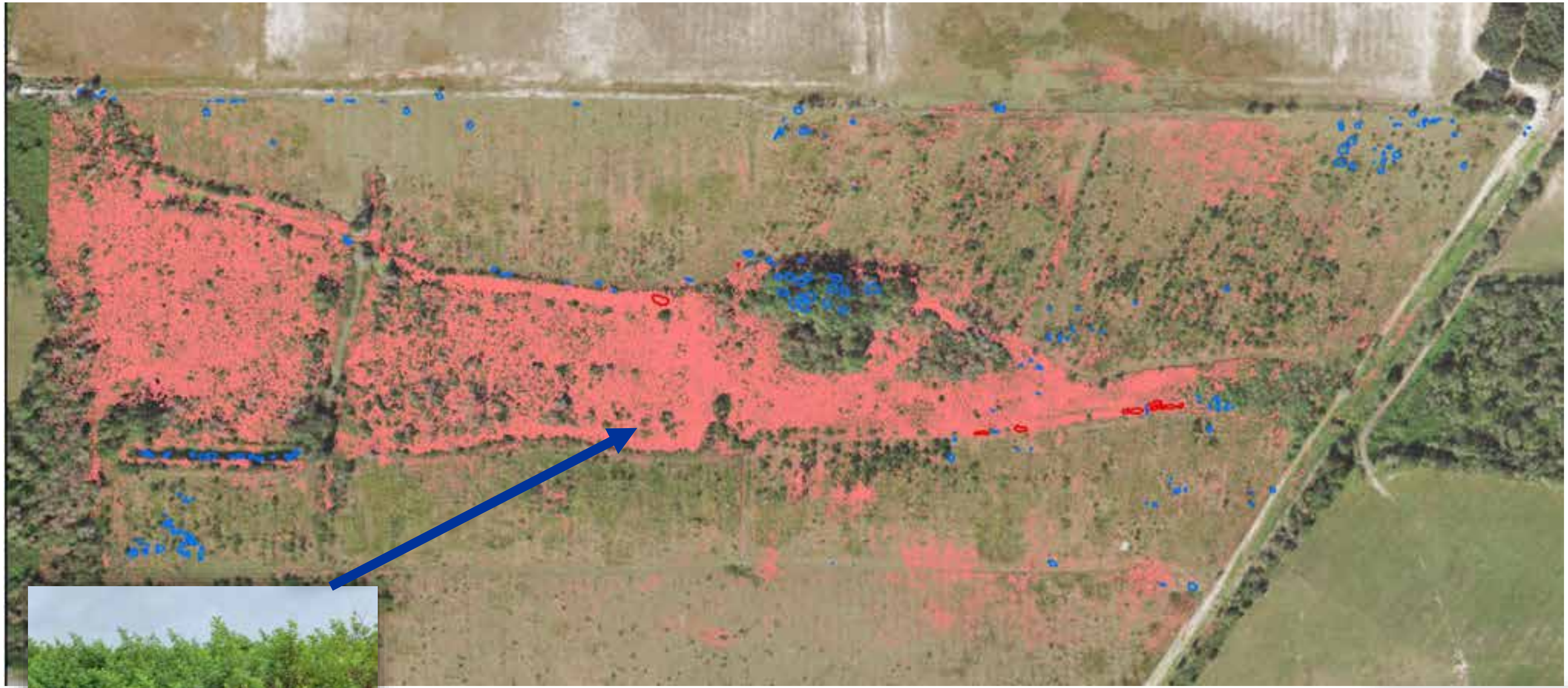
Legend

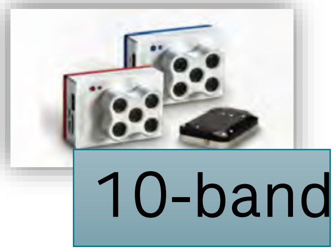
- bahiagrass ☆
- bare
- brazilian pepper ☆
- cabbage palm
- cogongrass ☆
- dead shrub
- dogfennel
- hairy indigo ☆
- primrose willow ☆
- oak
- pine
- red maple
- submerged aquatic
- smutgrass ☆
- water
- wax myrtle
- willow

Overall species accuracy: > 80%
Functional grouping (grasses, broadleaves, shrubs): 90%

☆ Invasive Species

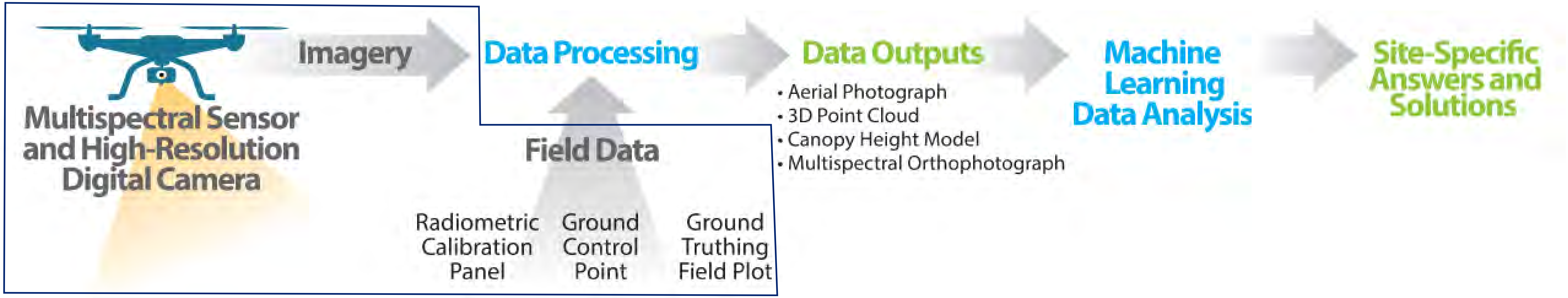
10 band data can produce informative maps for particular species



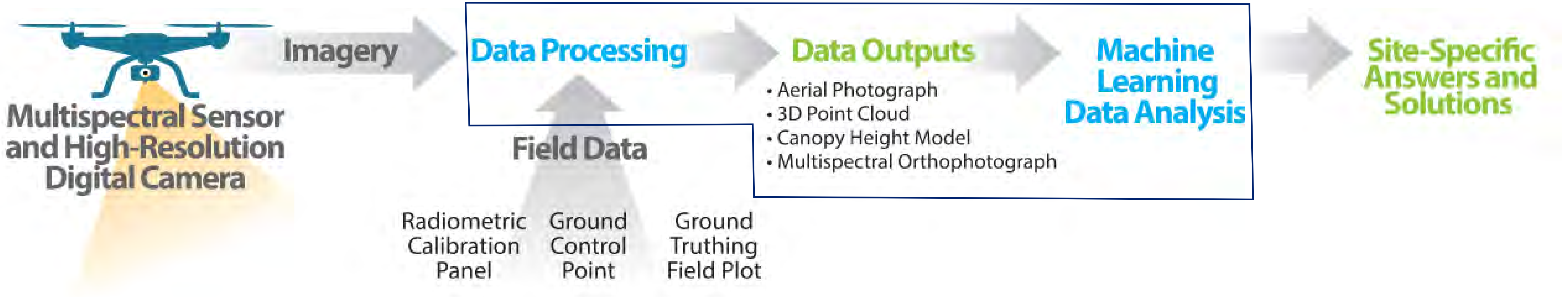


Digital Pipeline for Evaluation of Environmental Resources

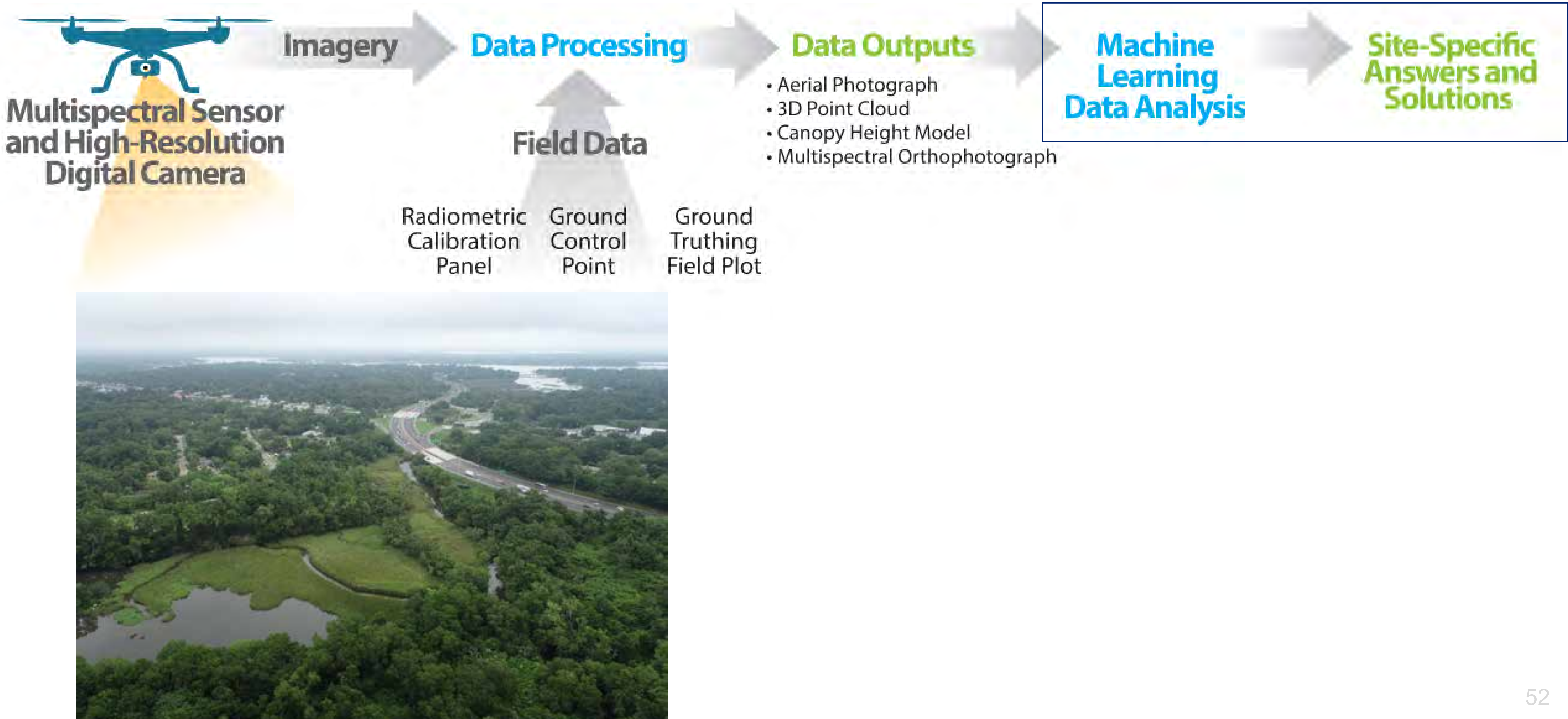
Digital Pipeline for Evaluation of Environmental Resources



Digital Pipeline for Evaluation of Environmental Resources



Digital Pipeline for Evaluation of Environmental Resources



Digital Pipeline for Evaluation of Environmental Resources

Multispectral Sensor and High-Resolution Digital Camera

Imagery → Data Processing → Data Outputs → Machine Learning Data Analysis → Site-Specific Answers and Solutions

Field Data → Data Processing

- Radiometric Calibration Panel
- Ground Control Point
- Ground Truthing Field Plot

Data Outputs
- Aerial Photograph
- 3D Point Cloud
- Canopy Height Model
- Multispectral Orthophotograph

Environmental Data

US Army Corps of Engineers

Florida Department of Environmental Protection

NATIONAL MARINE FISHERIES SERVICE

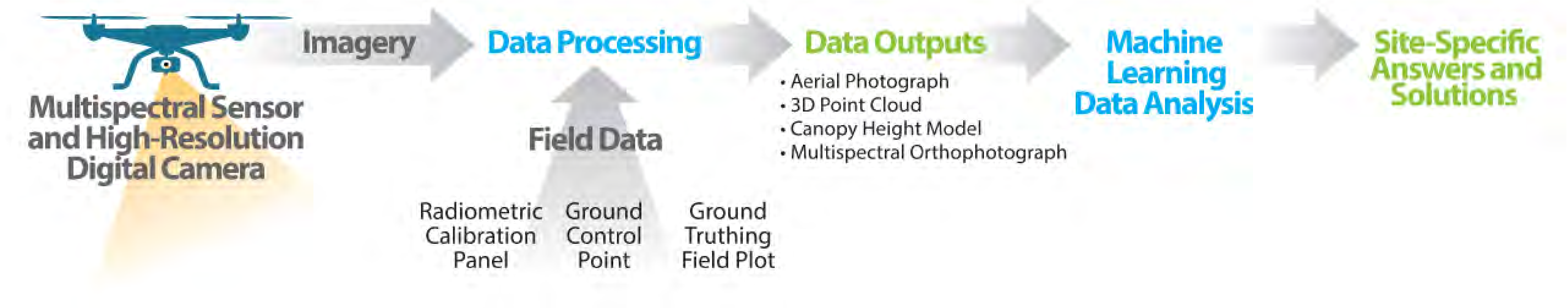
UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

U.S. FISH & WILDLIFE SERVICE

Public Stakeholders

Sky Wave at CDM Smith is leveraging remote sensing and machine learning to analyze sites and develop solutions

Check out more at: cdmsmith.com/skywave



sky wave™

Sky Wave is led by multi-disciplinary experts who create integrated solutions to your challenges.

- Surveyors
- Engineers
- Geologists
- Scientists
- FAA-certified drone pilots
- Remote sensing scientists
- Artificial intelligence engineers

Q&A