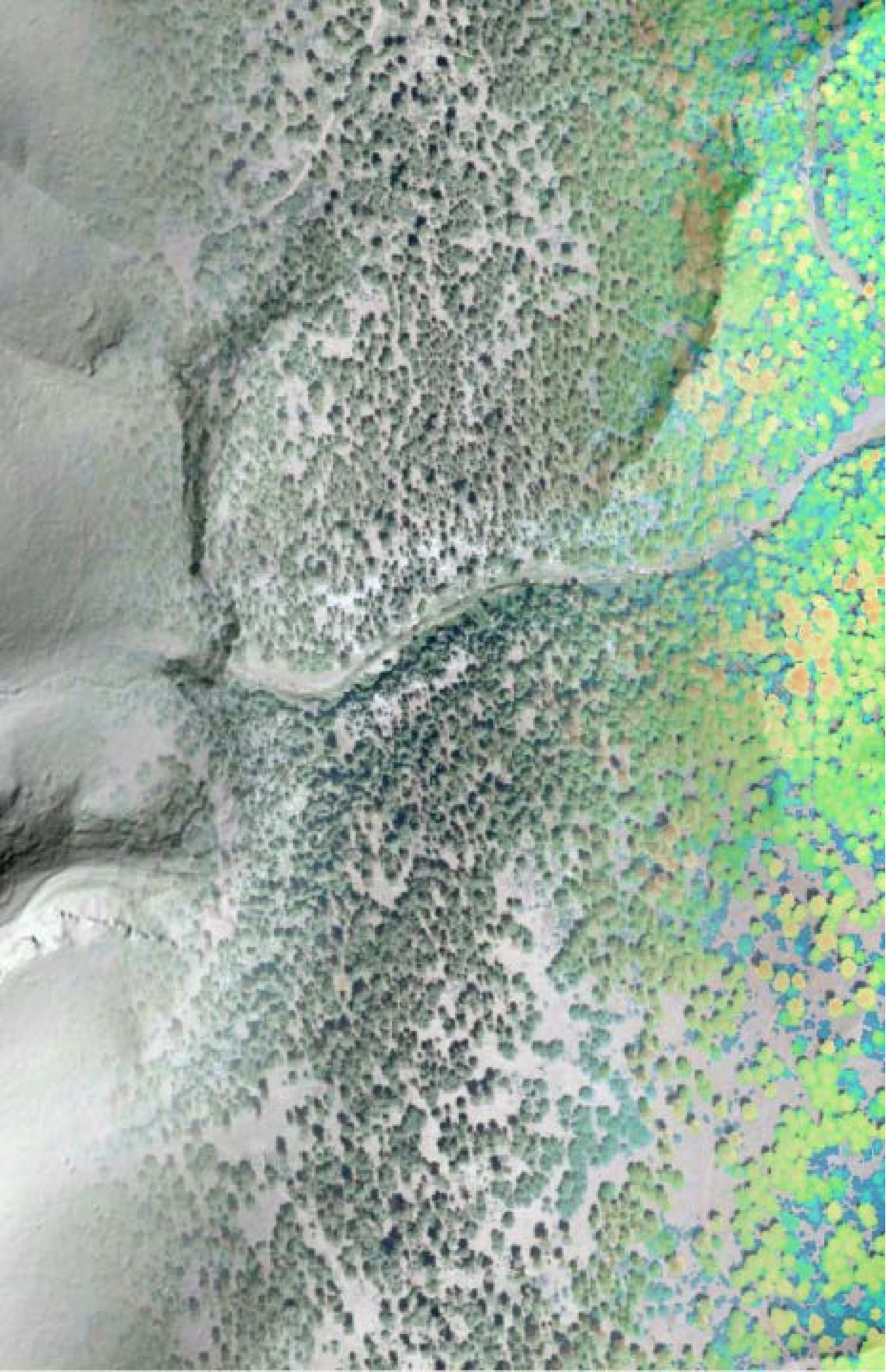
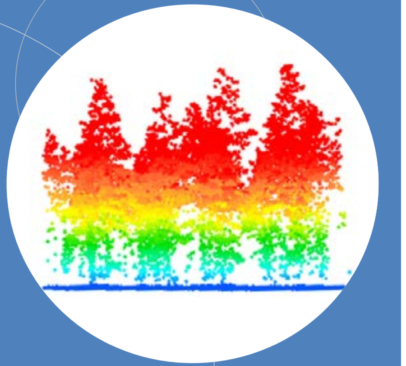


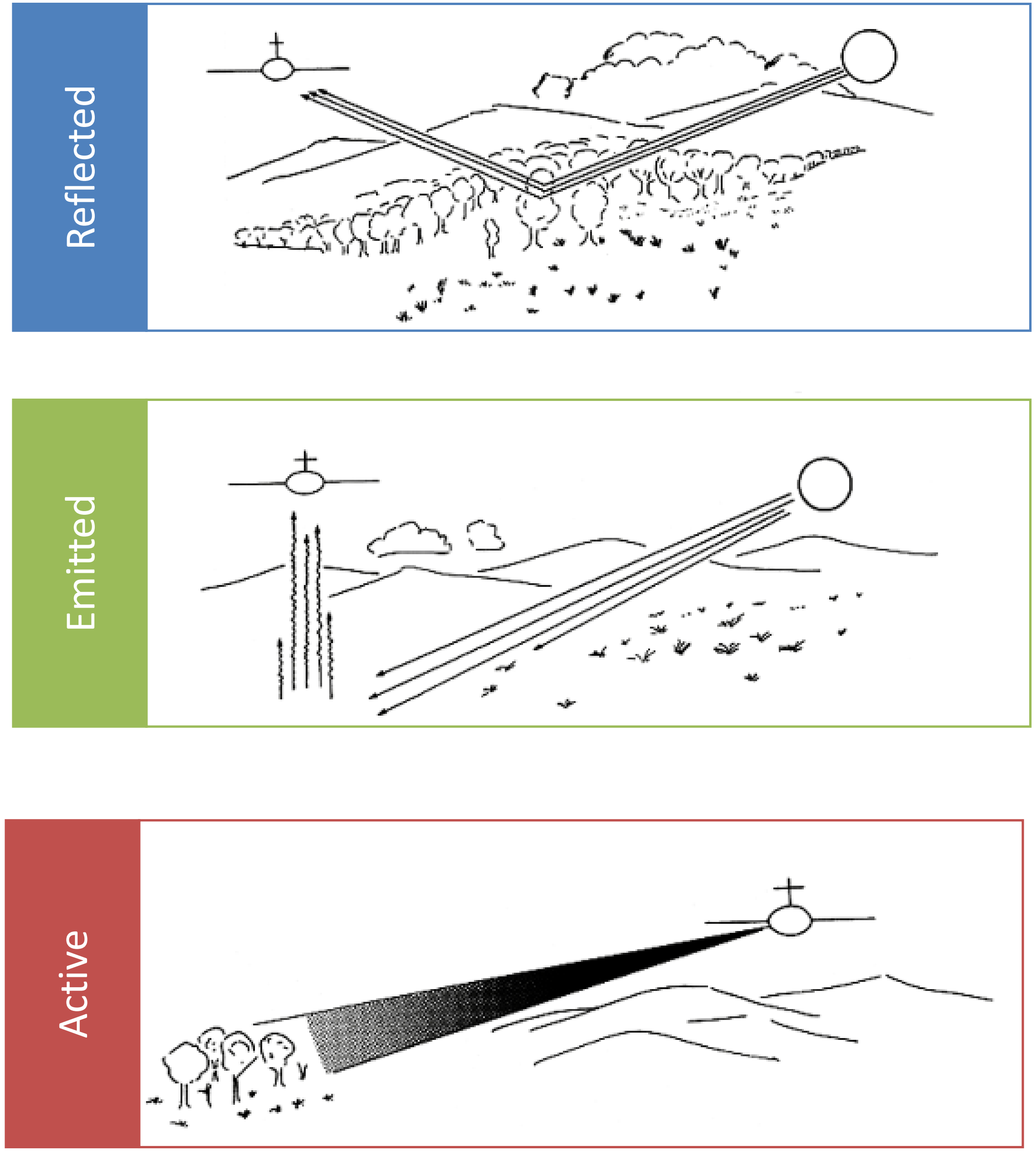
REMOTE SENSING 101 & LIDAR

MODERNIZING 4FRI IMPLEMENTATION - PROGRESS

REMOTE SENSING 101

- Lidar is an active sensor
- Pulse emitted with known direction, contacts something and reflected back to device
- Device recognizes these time-stamped, reflected photons
- Calculates the time between emission and return
- Produces a "cloud" of points





Campbell and Wynne 2011

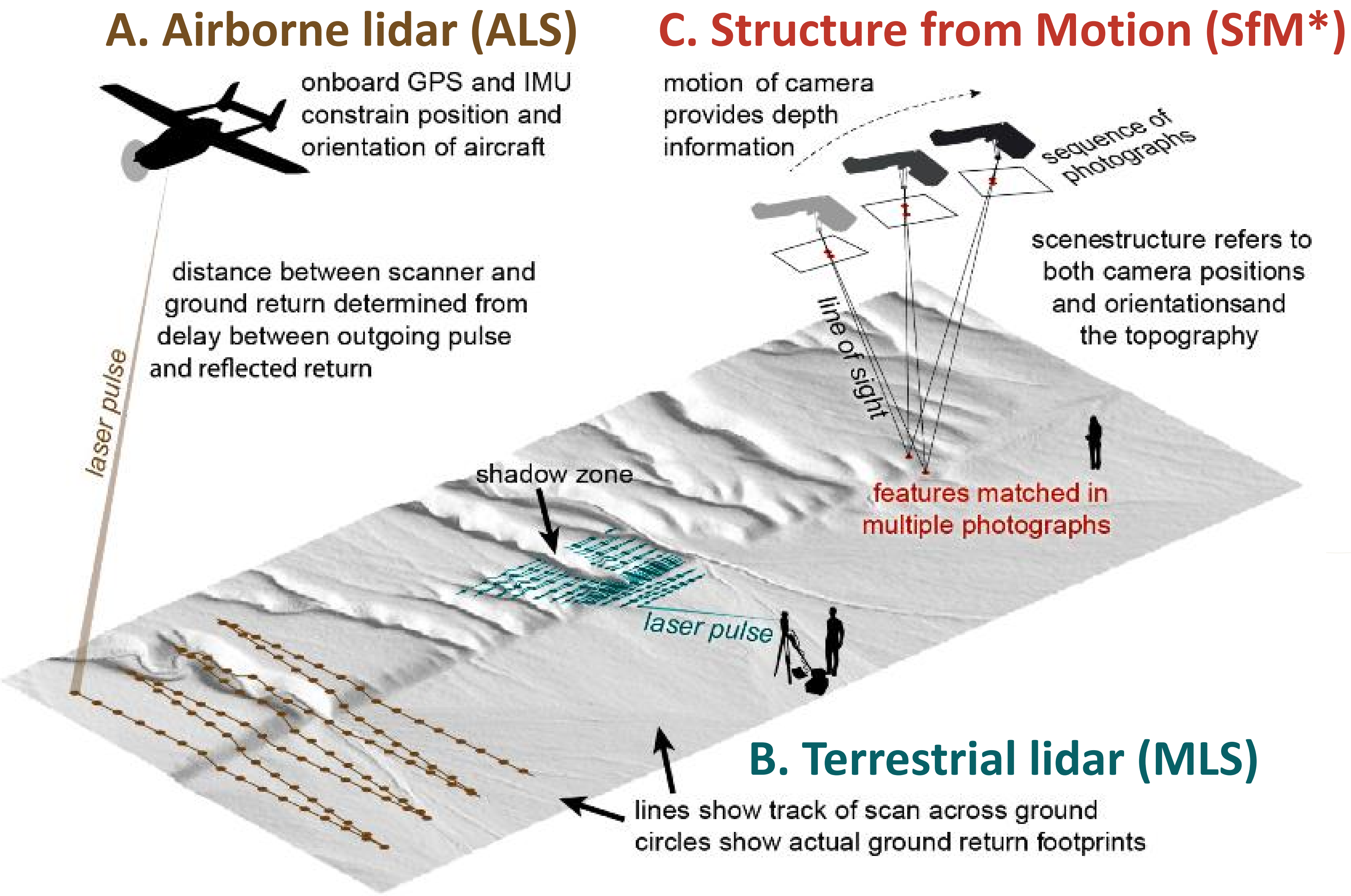
TYPES OF LIDAR

li·dar

/ˈlīdär/

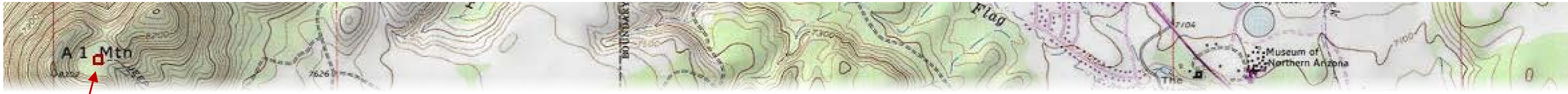
noun

a detection system which works on the principle of radar, but uses light from a laser.

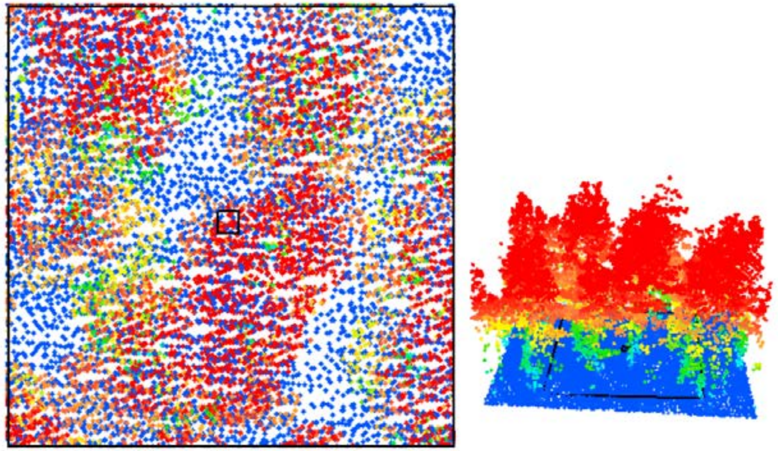


Adapted from: Johnson et al. 2014

NOT ALL LIDAR IS CREATED EQUAL

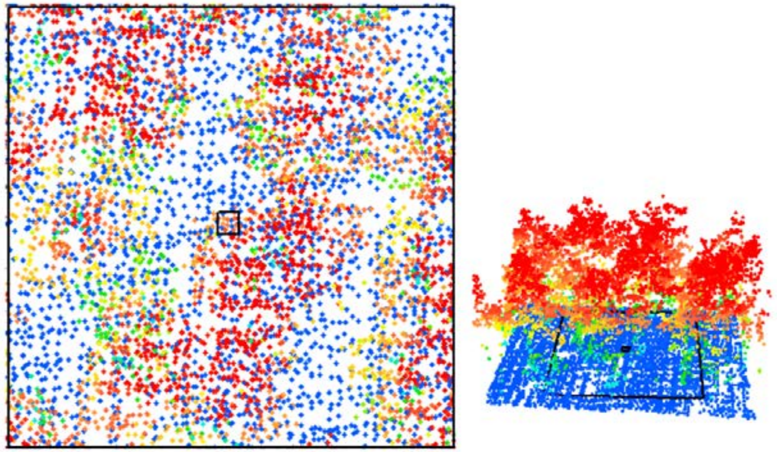


0.2 ha near A1 Mtn, Flagstaff, AZ



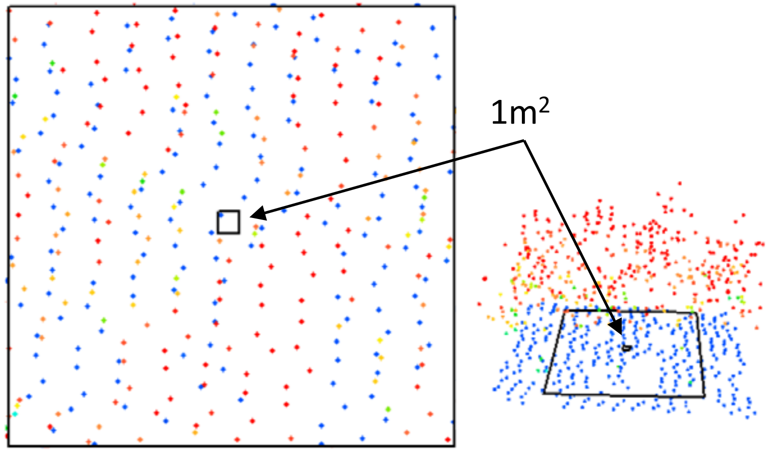
28.26 returns/m^2
0.19 m pt spacing
Quantum Spatial
2019

QL0*:
Accuracy: $RSME_z$ 5 cm
Pt density: ≥8 pulses/m^2



7.84 returns/m^2
0.36 m pt spacing
Sanborn Mapping
2013

QL1:
Accuracy: $RSME_z$ 10 cm
pt density: 8 pulses/m^2



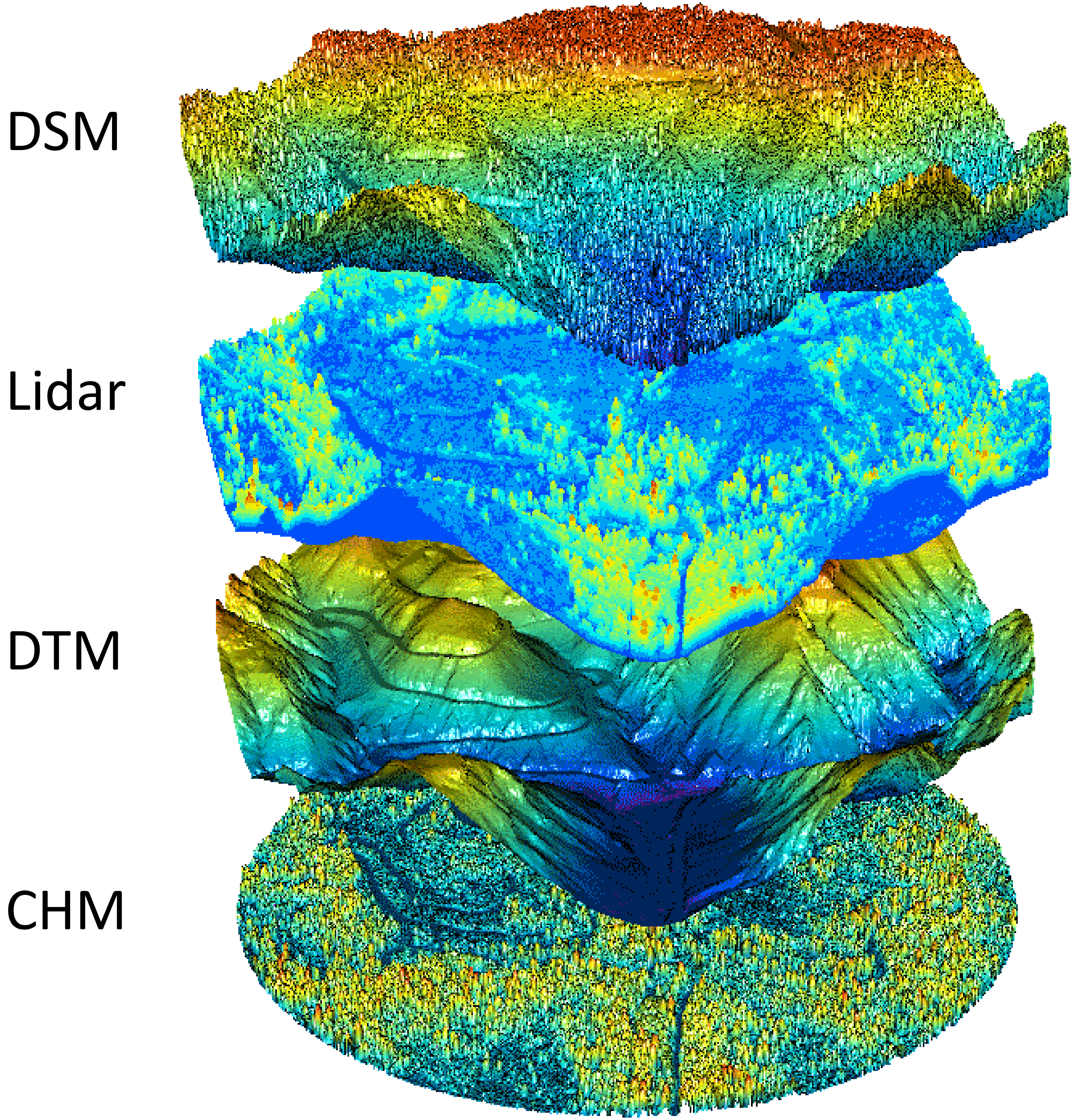
2.49 returns/m^2
0.63 m pt spacing
Who knows?
2009

QL2:
Accuracy: $RSME_z$ 10 cm
Pt density: 2 pulses/m^2

*Heidemann and Karl 2018

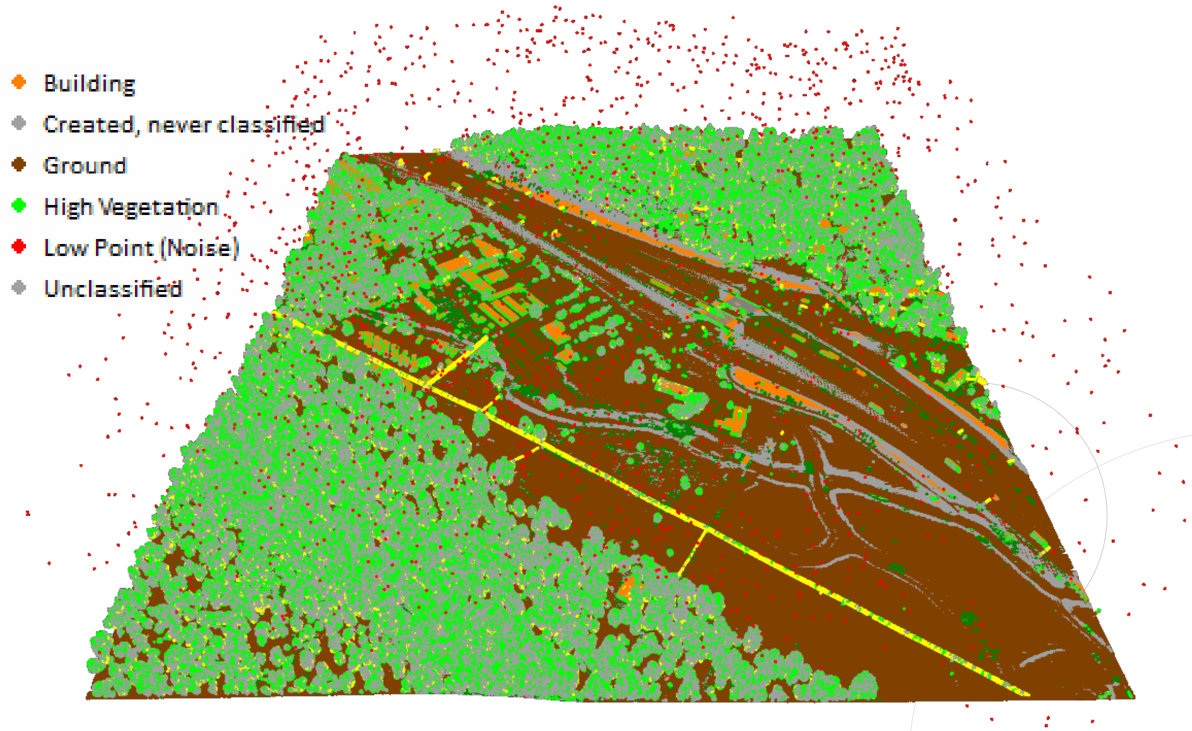
HOW IS IT USED?

- Classify and utilize the returns
- Create a digital surface model (DSM) from the first returns
- Or flip the point cloud and create a digital terrain model (DTM) from the ground returns
- Subtracting the DTM from (non-ground) returns to get height above ground level (i.e. a canopy height model or CHM)
- 1st-Order Products or Derivatives

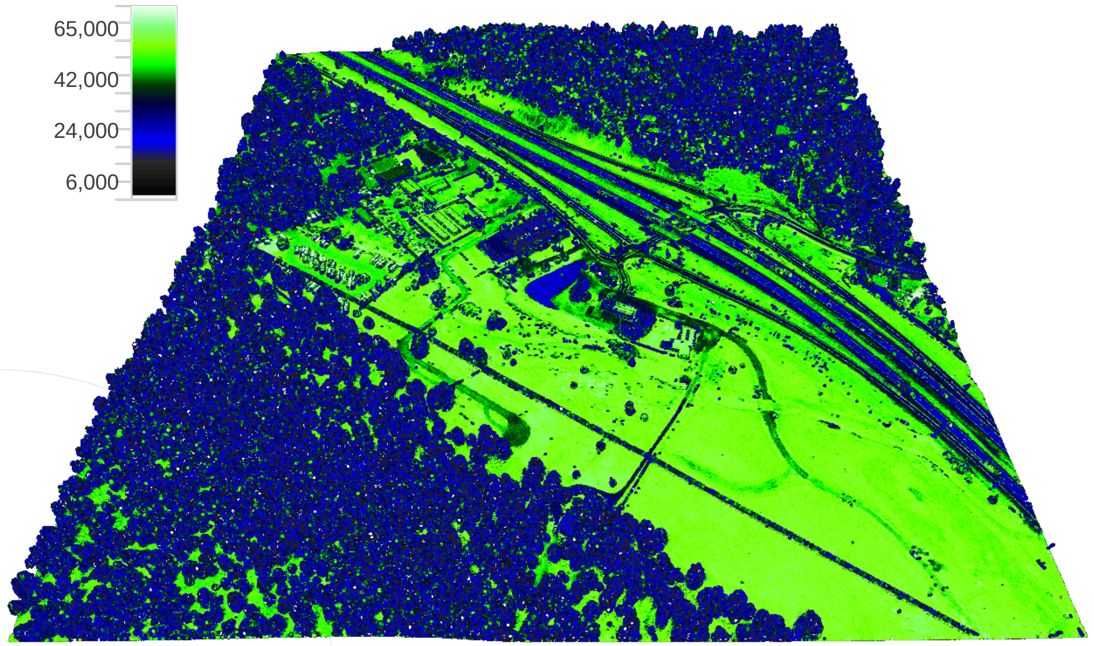


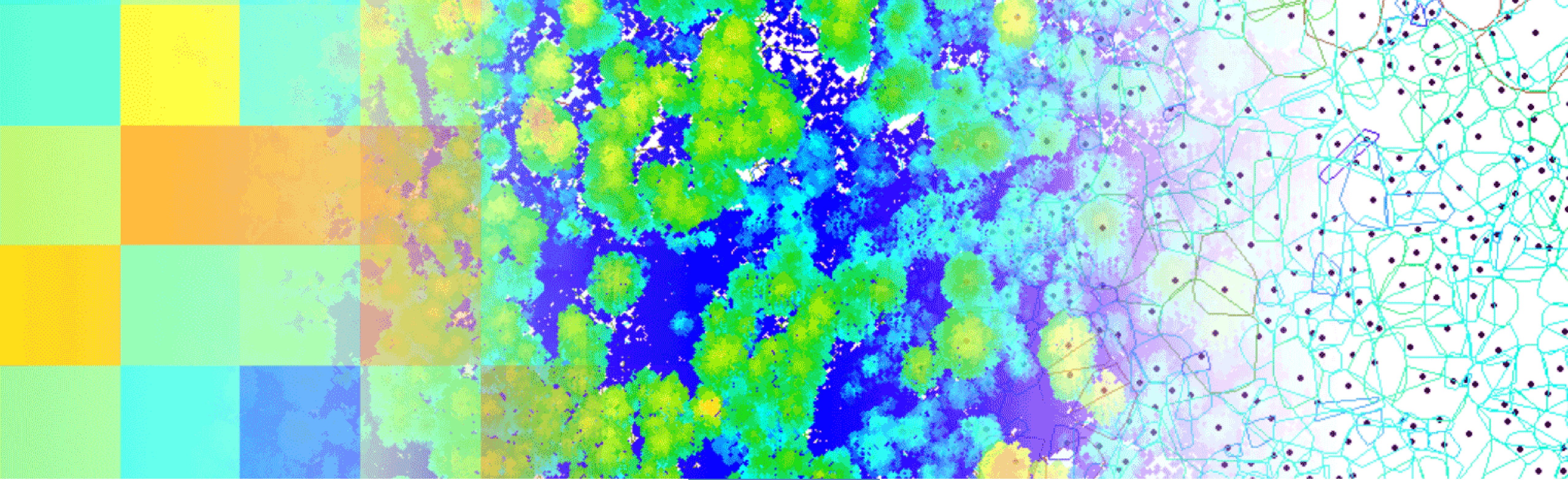
MORE ON USING LIDAR

Classification



Intensity



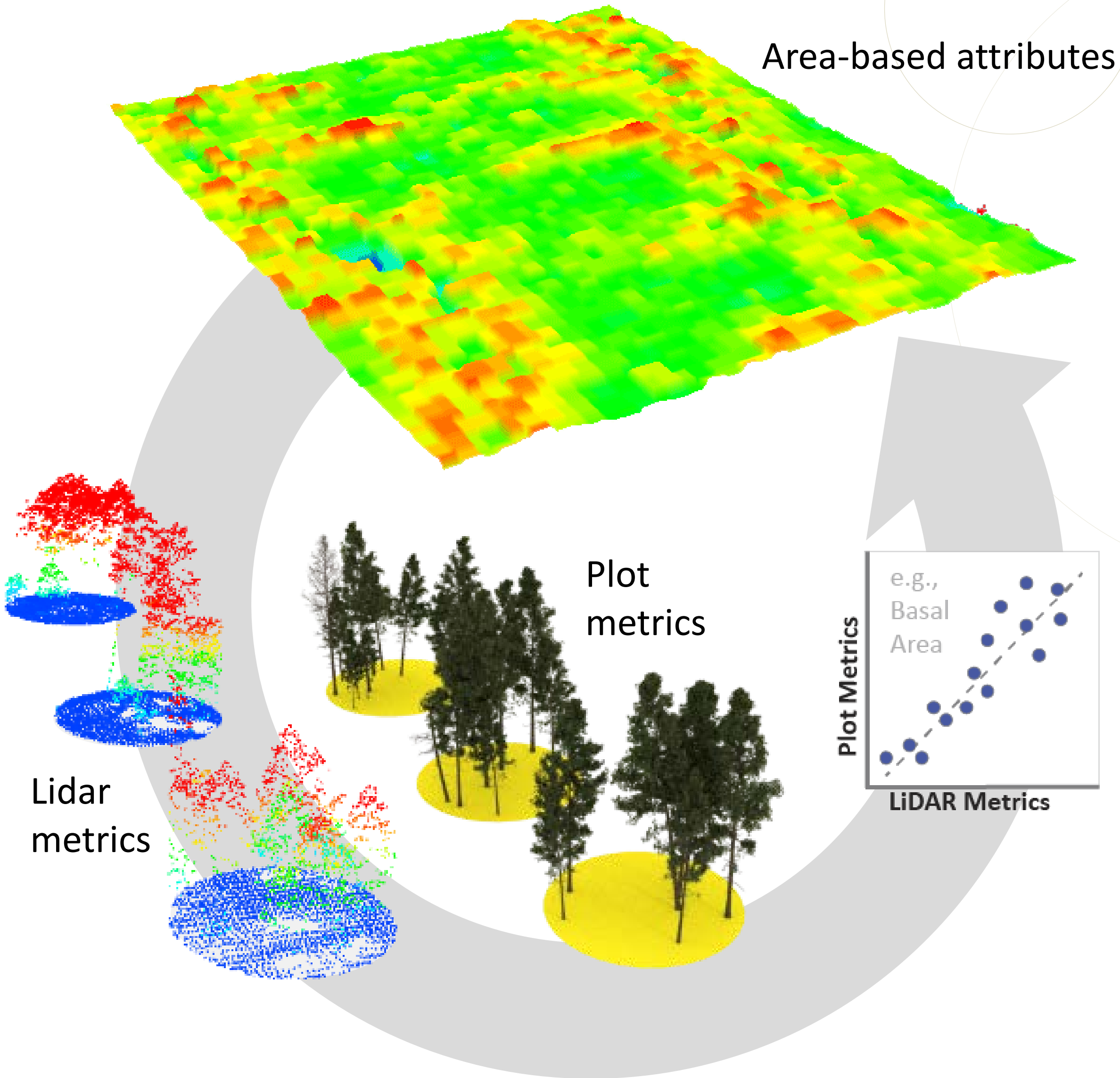


TWO MAIN APPROACHES IN FORESTRY

Area-based ⟷ Individual-based

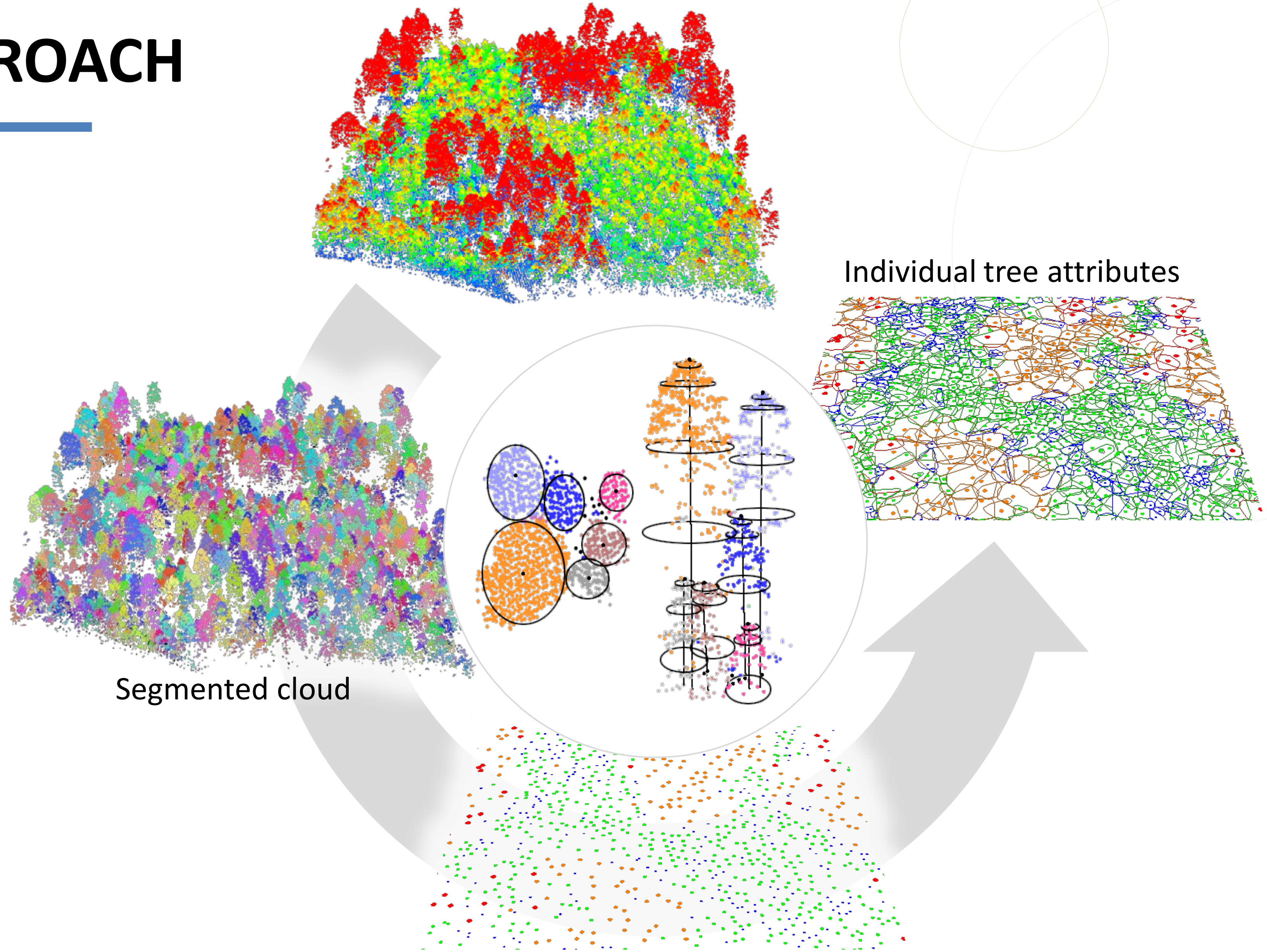
AREA-BASED APPROACH

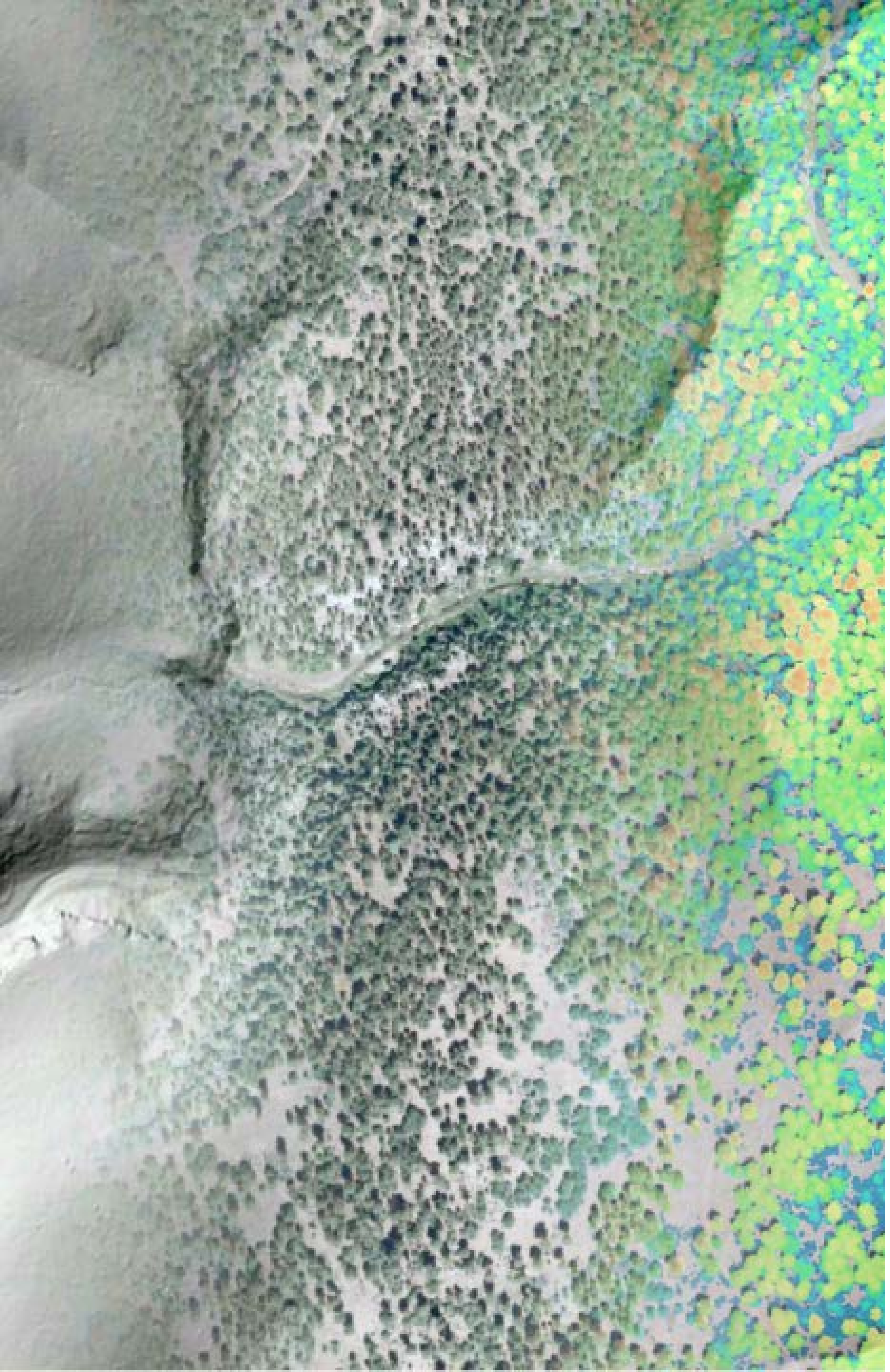
- Extract lidar data associated with sample locations
- Quantify lidar metrics
- Process plot data and develop relationships between lidar metrics and plot metrics
- Computer lidar metrics on a grid (i.e., raster)
- 2nd-Order Products or Derivatives



INDIVIDUAL-BASED APPROACH

- Normalize the point cloud
- Use algorithm to classify points into unique tree id’s
- Process points to quantify individual tree attributes
- Computer tree metrics for all trees (i.e., vector)
- ??-Order Products or Derivatives





LIDAR AVAILABILITY, STRATEGY, AND TRAINING

MODERNIZING 4FRI IMPLEMENTATION - PROGRESS

USDA

The Nature Conservancy

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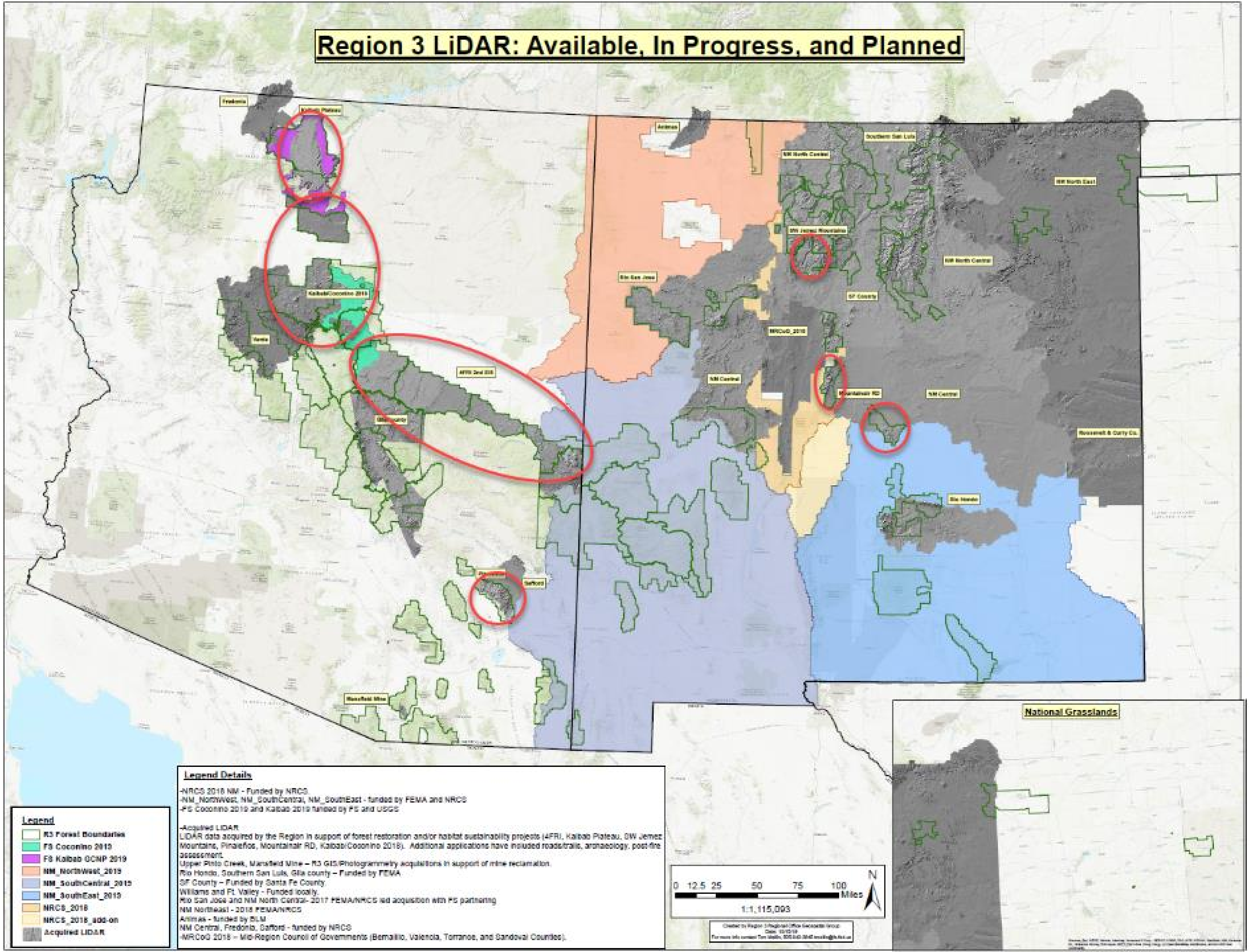
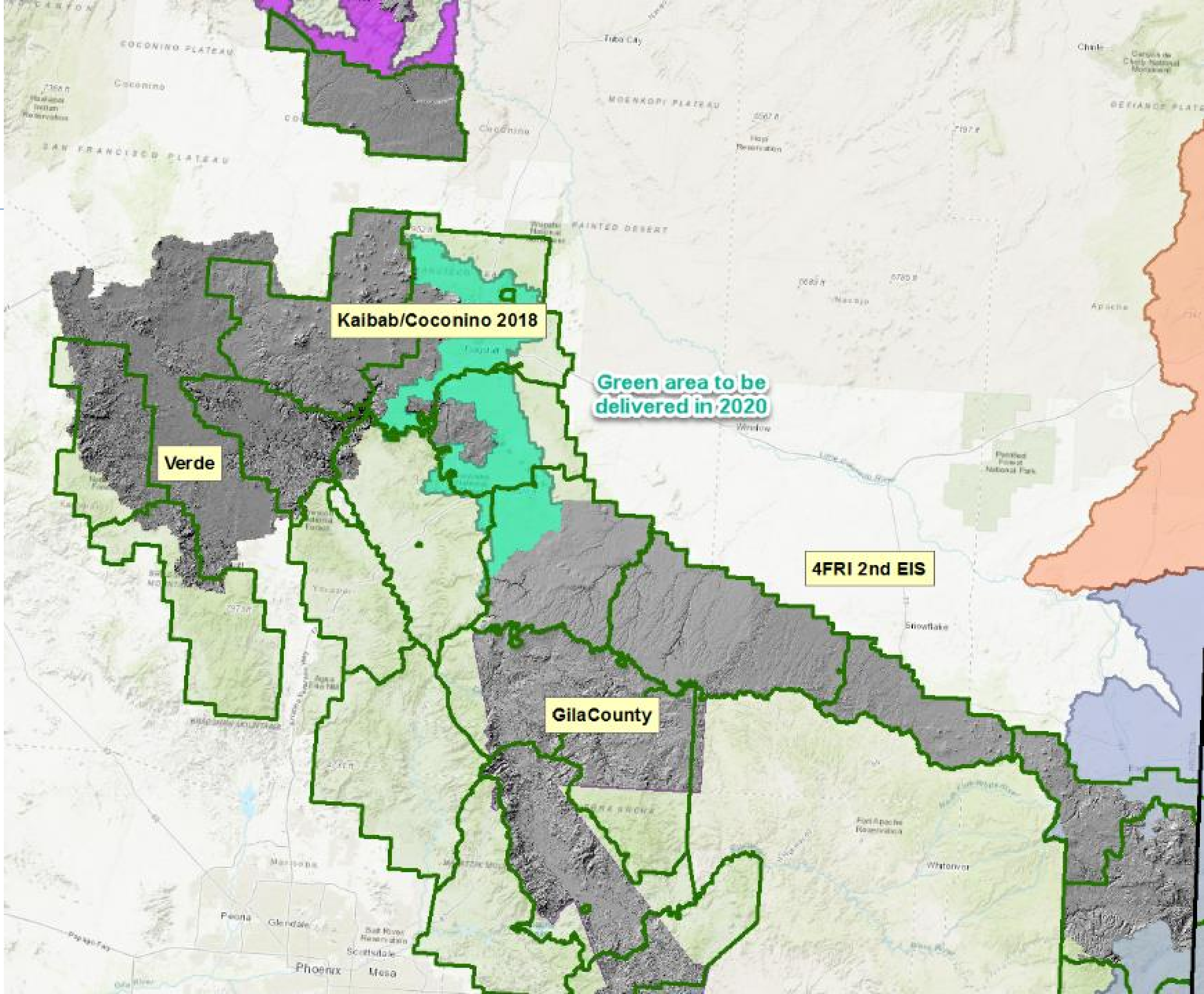
Ecological Restoration Institute

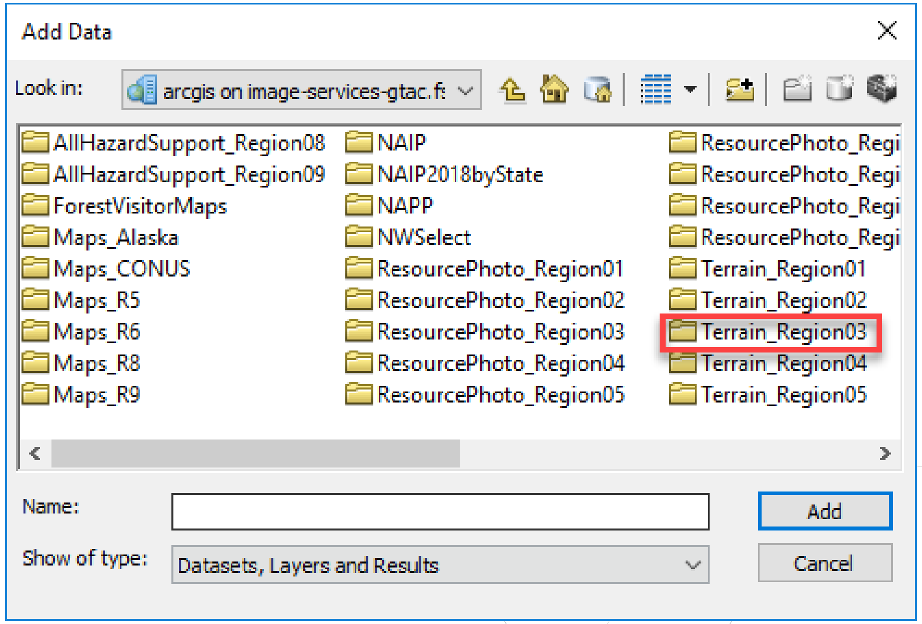

Region 3 LiDAR: Available, In Progress, and Planned
National Grasslands
Legend
R3 Forest Boundaries
FS Coconino 2019
FS Kaibab GCNP 2019
NM_Northwest_2019
NM_SouthCentral_2019
NM_SouthEast_2019
NRCS_2018
NRCS_2018_add-on
Acquired LIDAR
Legend Details
-NRCS 2018 NM - Funded by NRCS.
-NM_NorthWest, NM_SouthCentral, NM_SouthEast - funded by FEMA and NRCS
-FS Coconino 2019 and Kaibab 2019 funded by FS and USGS
-Acquired LIDAR
LIDAR data acquired by the Region in support of forest restoration and/or habitat sustainability projects (4FRI, Kaibab Plateau, SW Jemez Mountains, Pinaleños, Mountainair RD, Kaibab/Coconino 2018). Additional applications have included roads/trails, archaeology, post-fire assessment.
Upper Pinto Creek, Mansfield Mine – R3 GIS/Photogrammetry acquisitions in support of mine reclamation.
Rio Hondo, Southern San Luis, Gila county – Funded by FEMA
SF County – Funded by Santa Fe County
Williams and Ft. Valley - Funded locally.
Rio San Jose and NM North Central- 2017 FEMA/NRCS led acquisition with FS partnering
NM Northeast - 2018 FEMA/NRCS
Animas - funded by BLM
NM Central, Fredonia, Safford - funded by NRCS
-MRCoG 2018 – Mid-Region Council of Governments (Bernalillo, Valencia, Torrance, and Sandoval Counties).
0 12.5 25 50 75 100 Miles
1:1,115,093
N

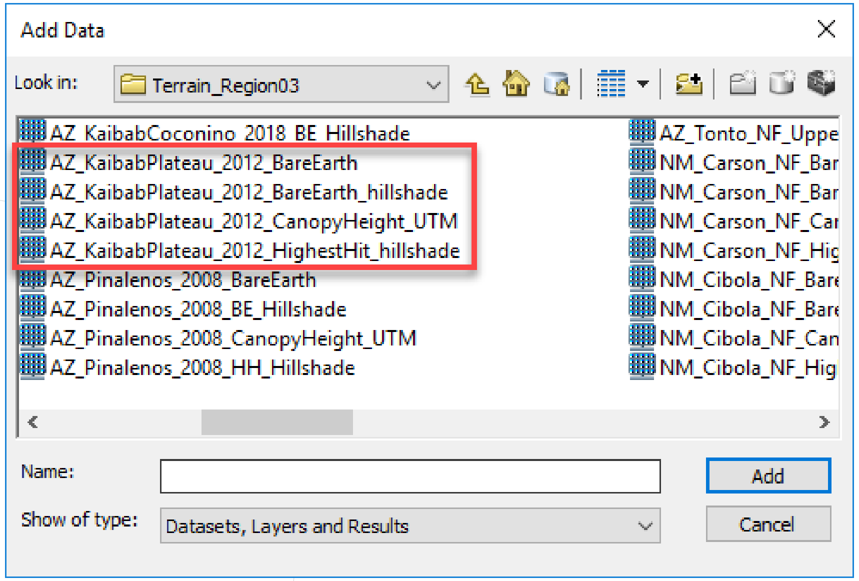
LIDAR COVERAGE FOR 4FRI



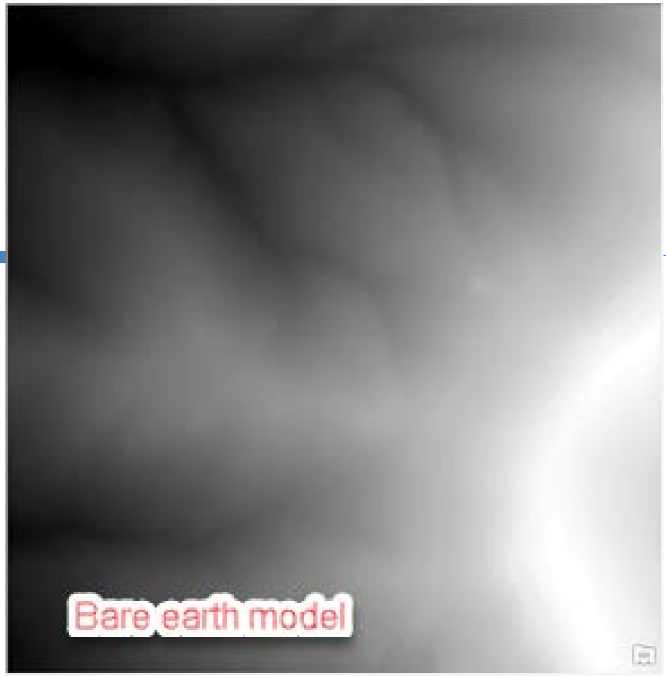
GTAC Image Server

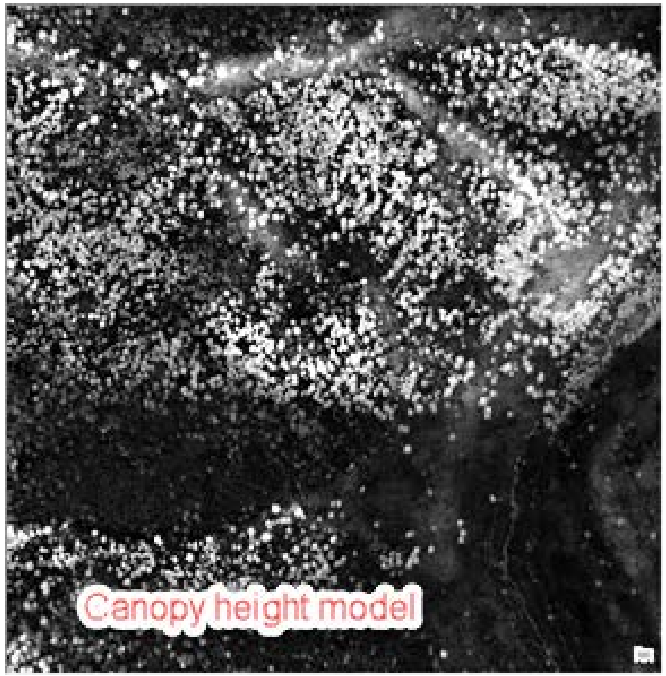
- Four standard lidar derivatives hosted on the Image Server
- https://image-services-gtac.fs.usda.gov/arcgis





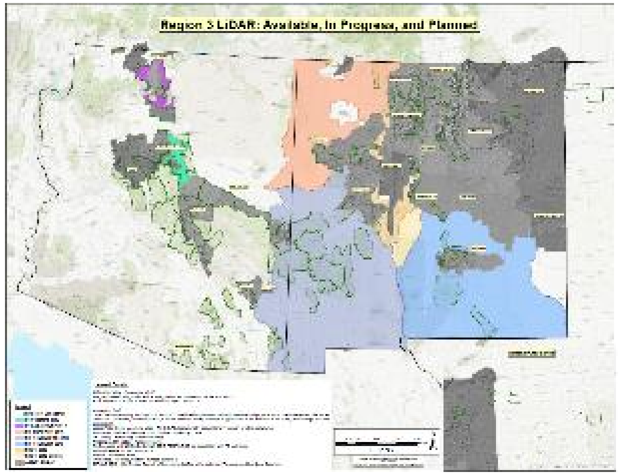
GTAC Image Server

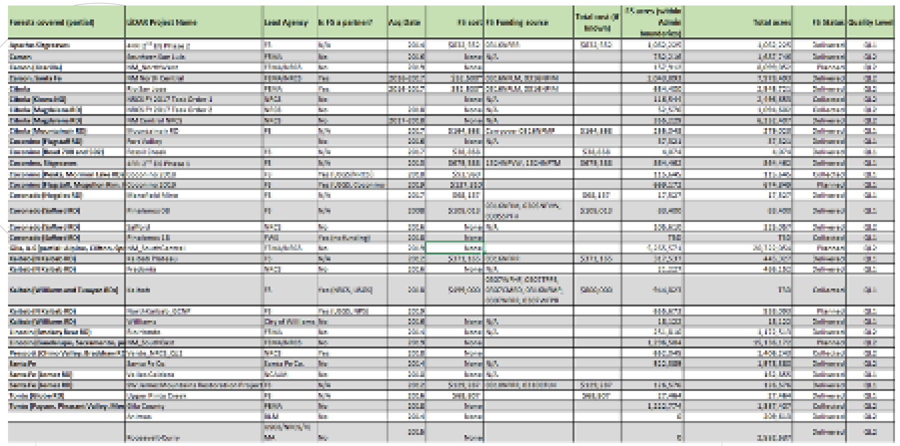


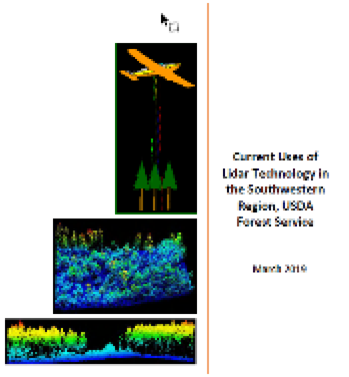


Regional Lidar Strategy

- SW Regional Restoration Committee requested a more comprehensive strategy for future investments in lidar
- Three phase process
  - Phase 1 – Develop maps and tables to document current and planned coverage by acres and type
  - Phase 2 – Gather and document how lidar information is being used in the Region
  - Phase 3 – Restoration Steering Committee to review info from Phase 1 & 2 and develop comprehensive strategy for budget discussions

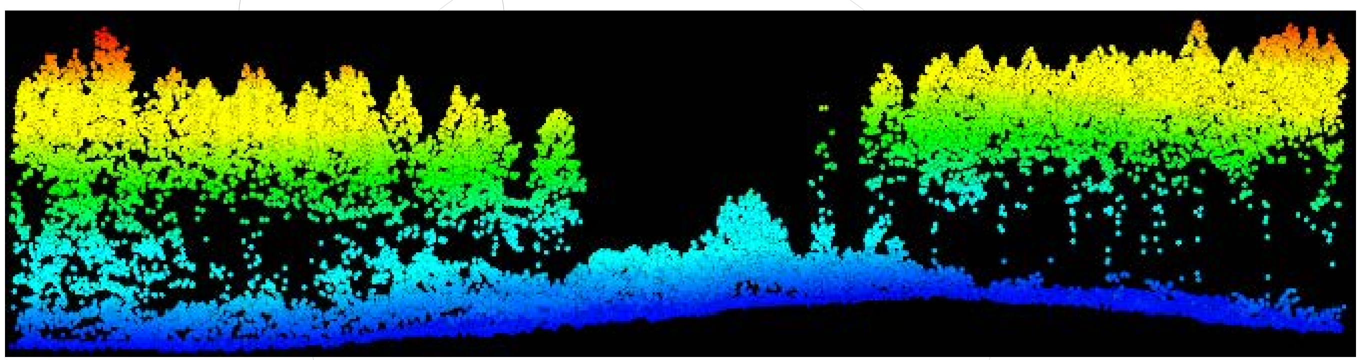






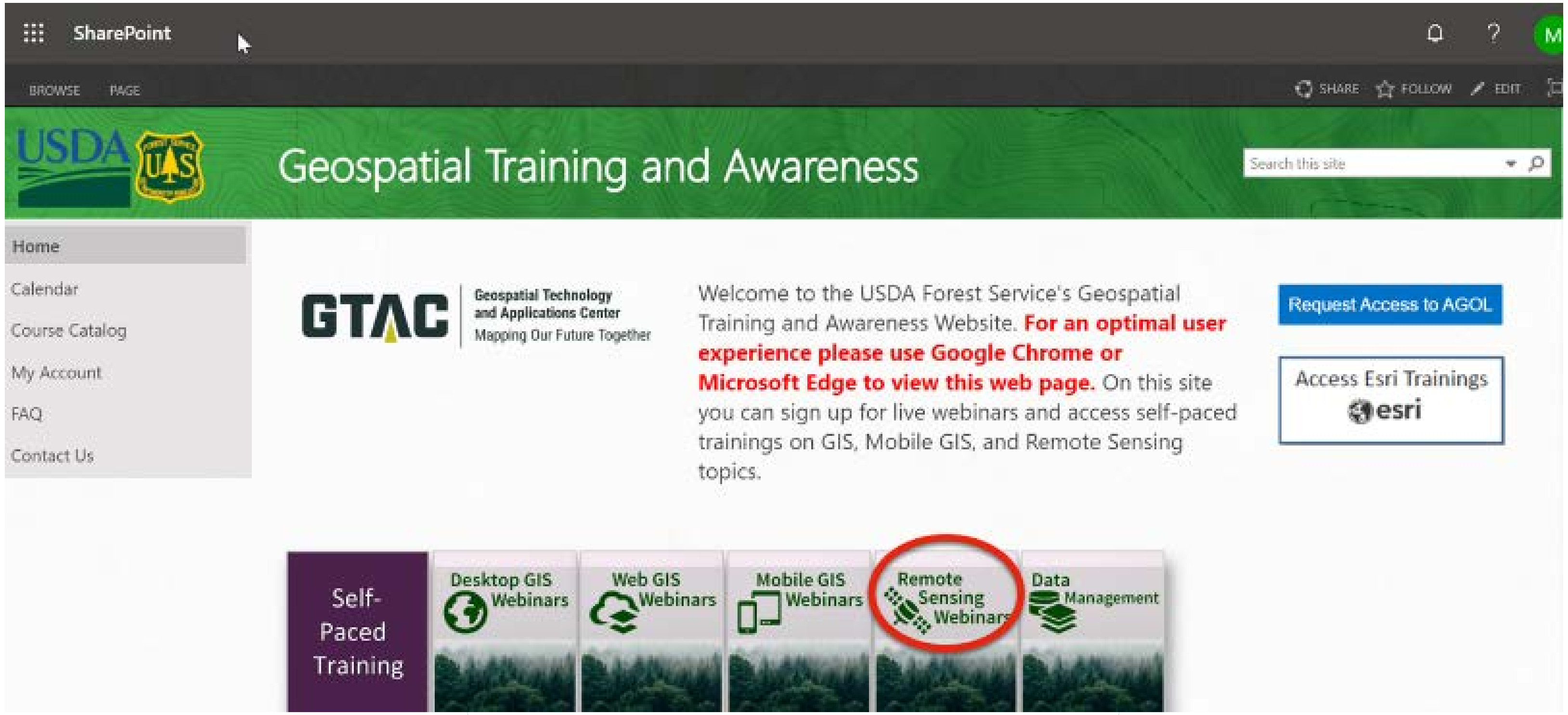
Regional Lidar Strategy Components

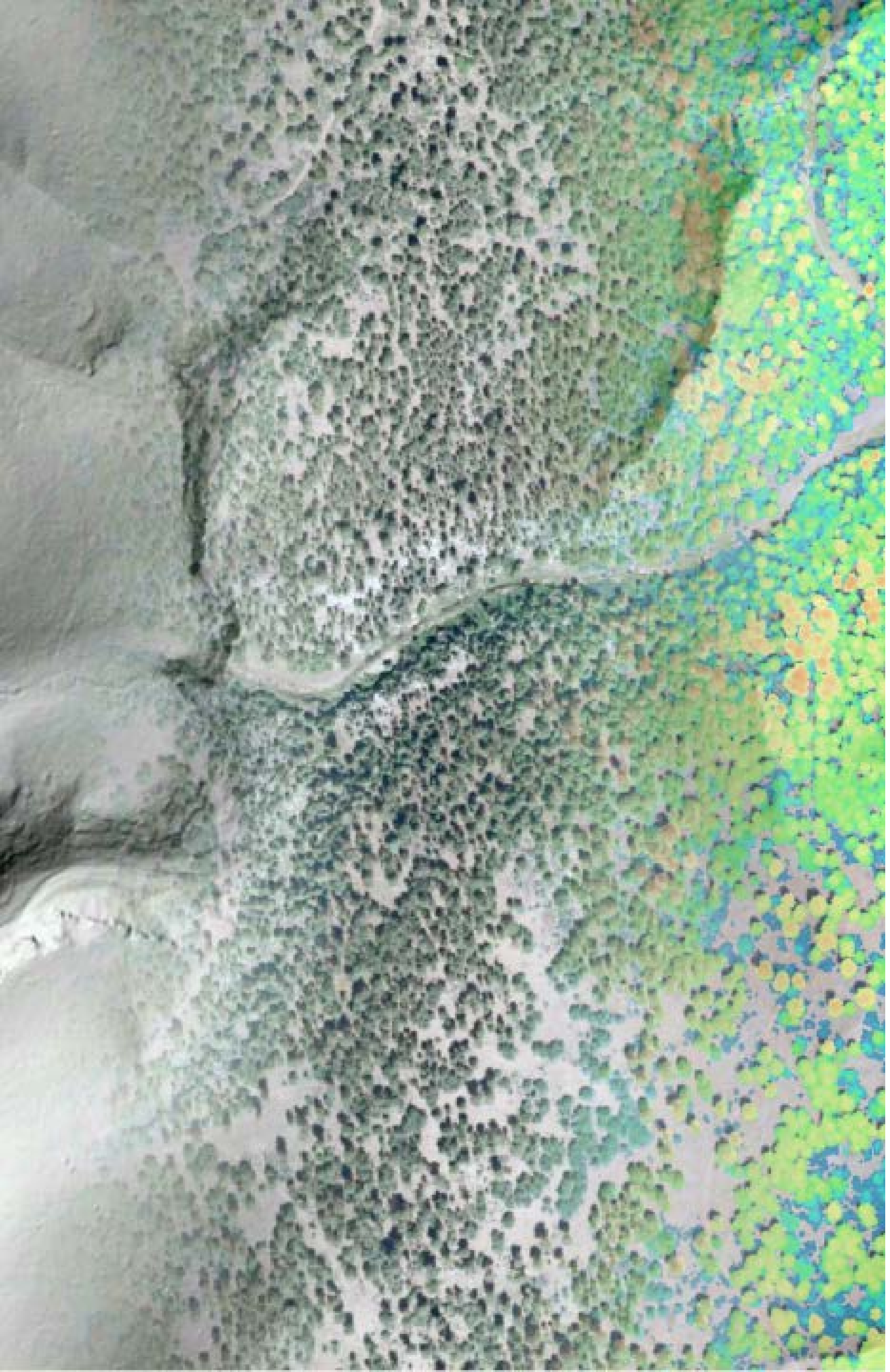
- Establishment of Regional Lidar Technical Group (RLTG)
  - Tom Mellin (Geospatial), Jack Triepke (EAP), Ryan Heaslip (Forestry), Will Reed (Heritage), Mark Christiano (GIS-Kaibab)
- Vetting of Lidar proposals
- Business case/Prioritization of acquisition areas.
- Awareness and Training



Geospatial Training

- https://usdagcc.sharepoint.com/sites/fs-gtac-tus/SitePages/Home%20Page.aspx
- Overview of Lidar Technology and FUSION Software
- Lidar Point Cloud Visualization
- Lidar Derivatives: Processing and Analysis





USES OF LIDAR FOR OPERABILITY, ACCESSIBILITY, AND FEASIBILITY

MODERNIZING 4FRI IMPLEMENTATION - PROGRESS

USDA

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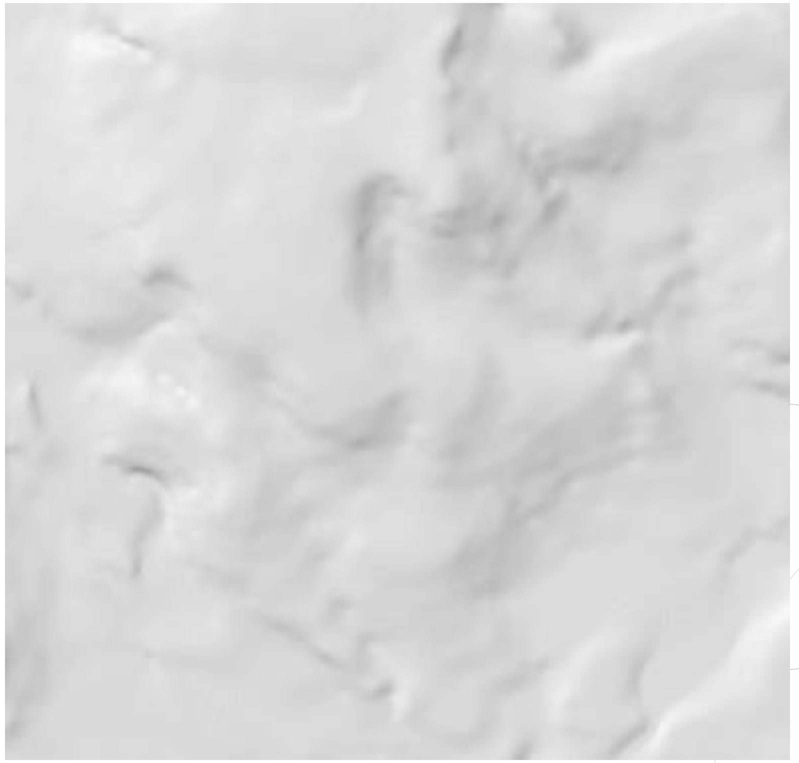
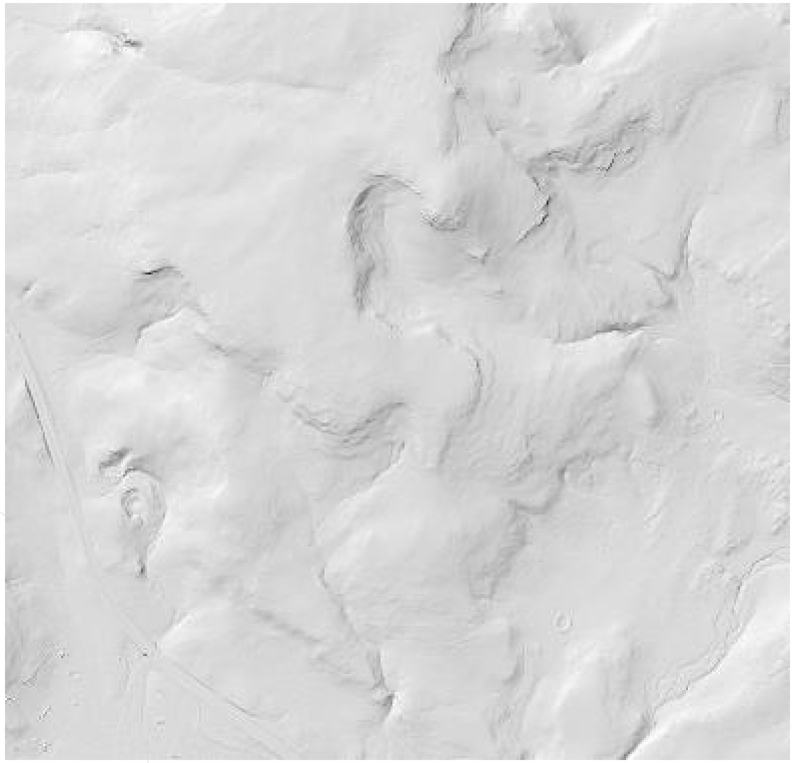
Ecological Restoration Institute

USES OF LIDAR FOR OPERABILITY, ACCESSIBILITY, AND FEASIBILITY

10m Resolution Digital Elevation Model

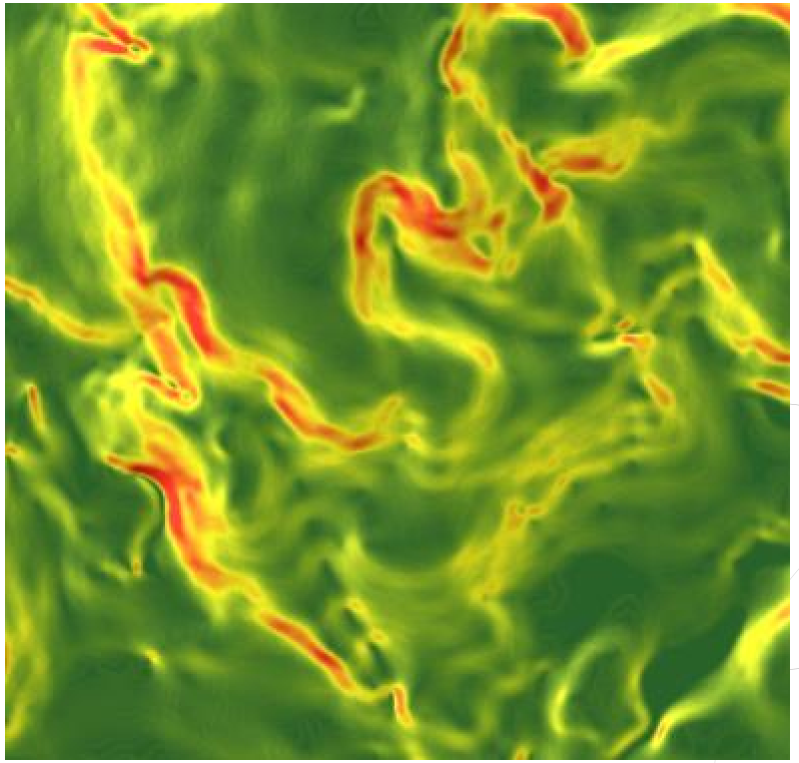


1m Resolution Digital Elevation Model

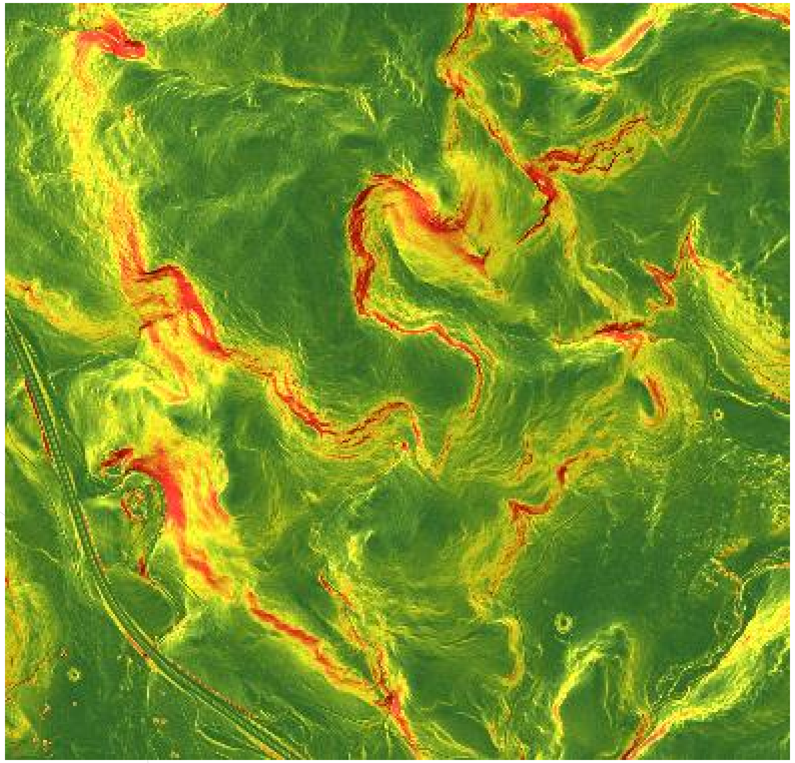


USES OF LIDAR FOR OPERABILITY, ACCESSIBILITY, AND FEASIBILITY

10m Resolution Digital Elevation Model

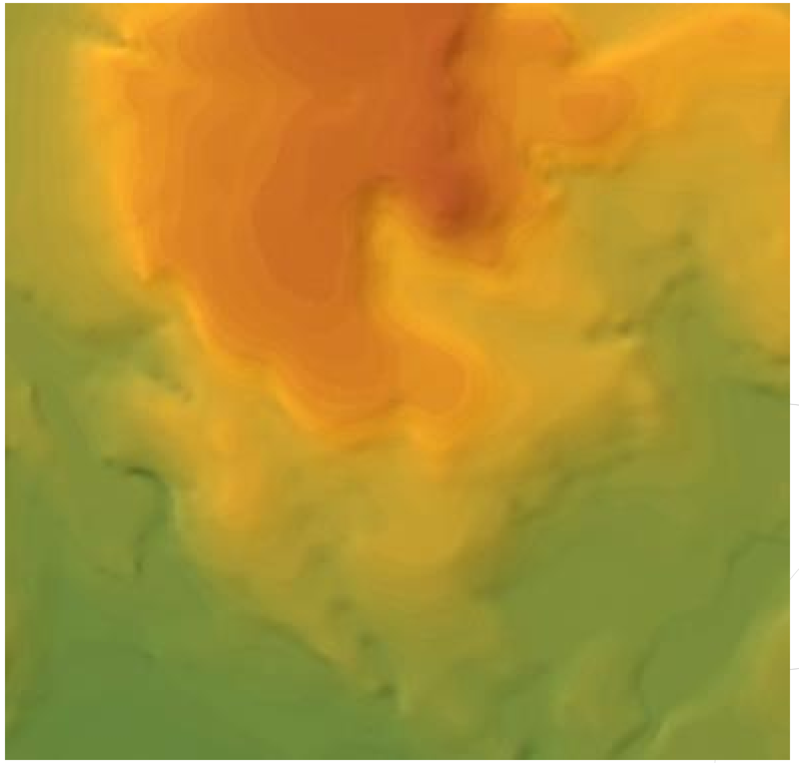


1m Resolution Digital Elevation Model

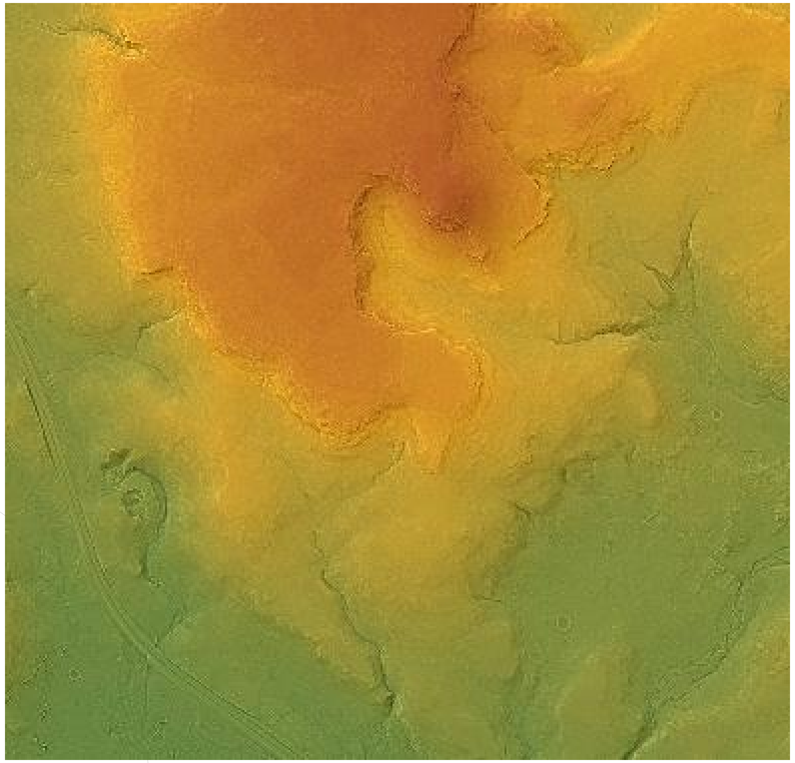


USES OF LIDAR FOR OPERABILITY, ACCESSIBILITY, AND FEASIBILITY

10m Resolution Digital Elevation Model

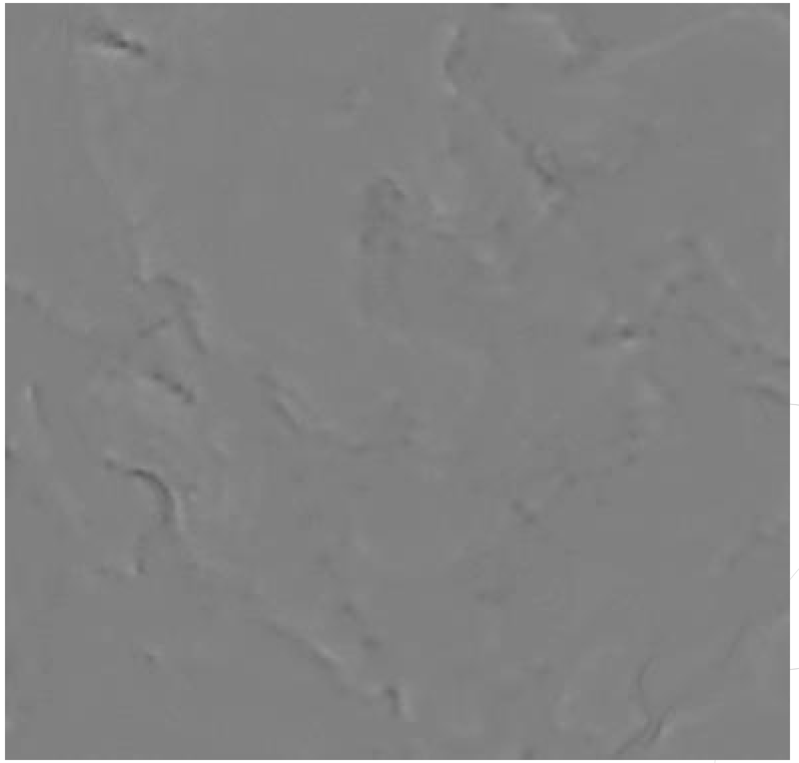


1m Resolution Digital Elevation Model

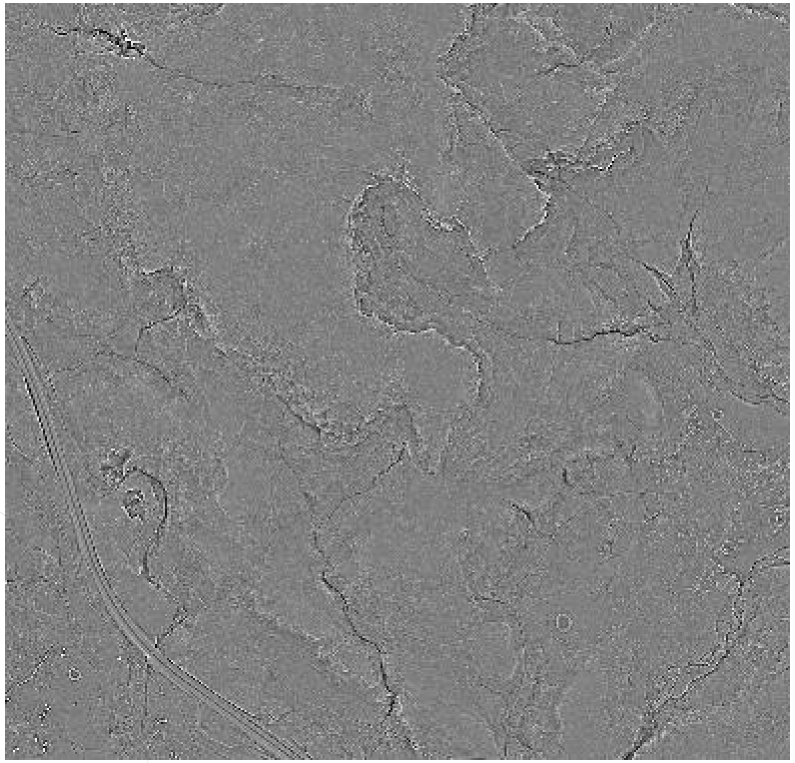


USES OF LIDAR FOR OPERABILITY, ACCESSIBILITY, AND FEASIBILITY

10m Resolution Digital Elevation Model

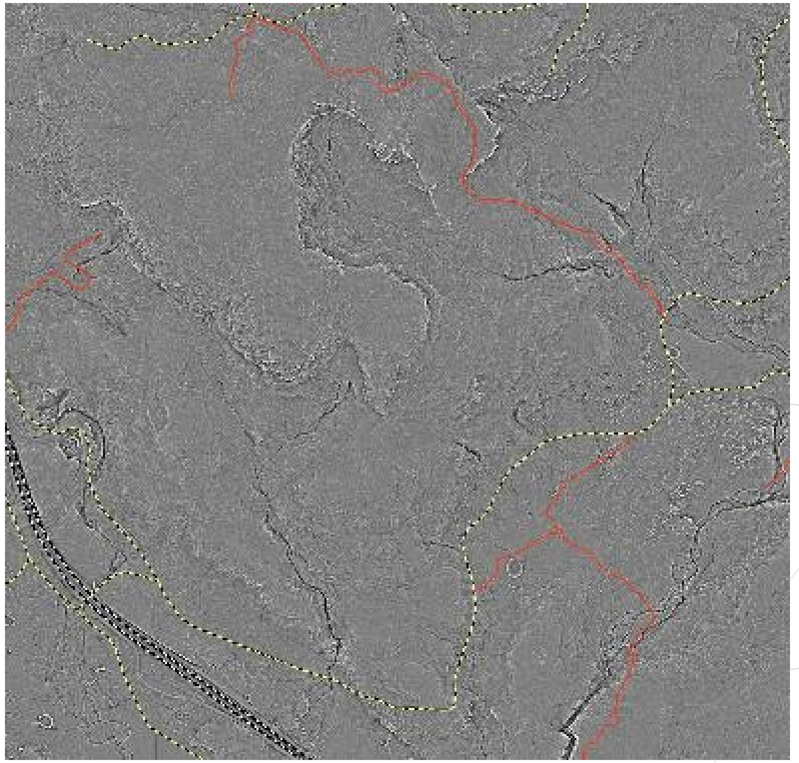


1m Resolution Digital Elevation Model

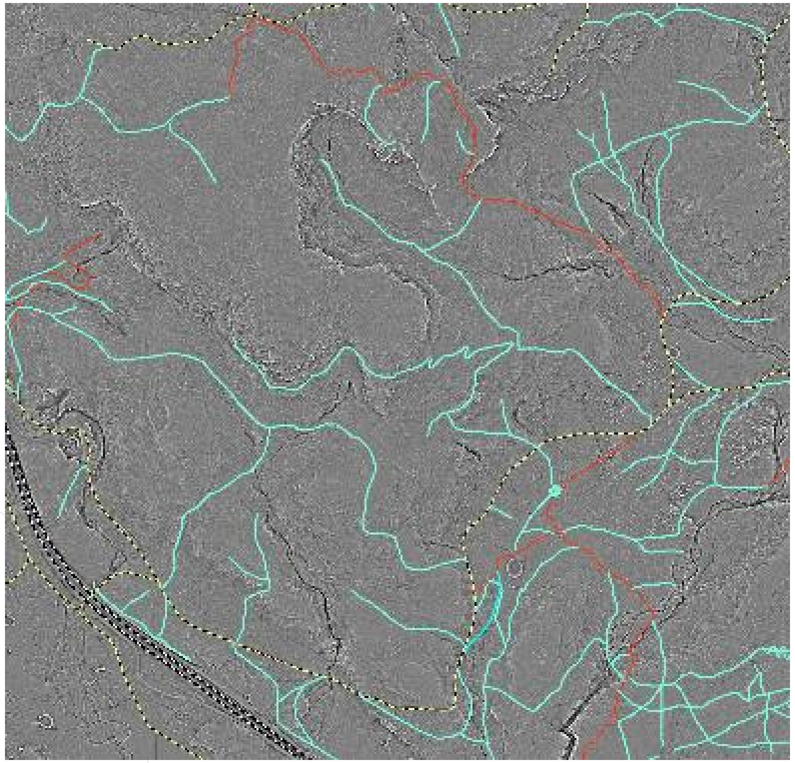


USES OF LIDAR FOR OPERABILITY, ACCESSIBILITY, AND FEASIBILITY

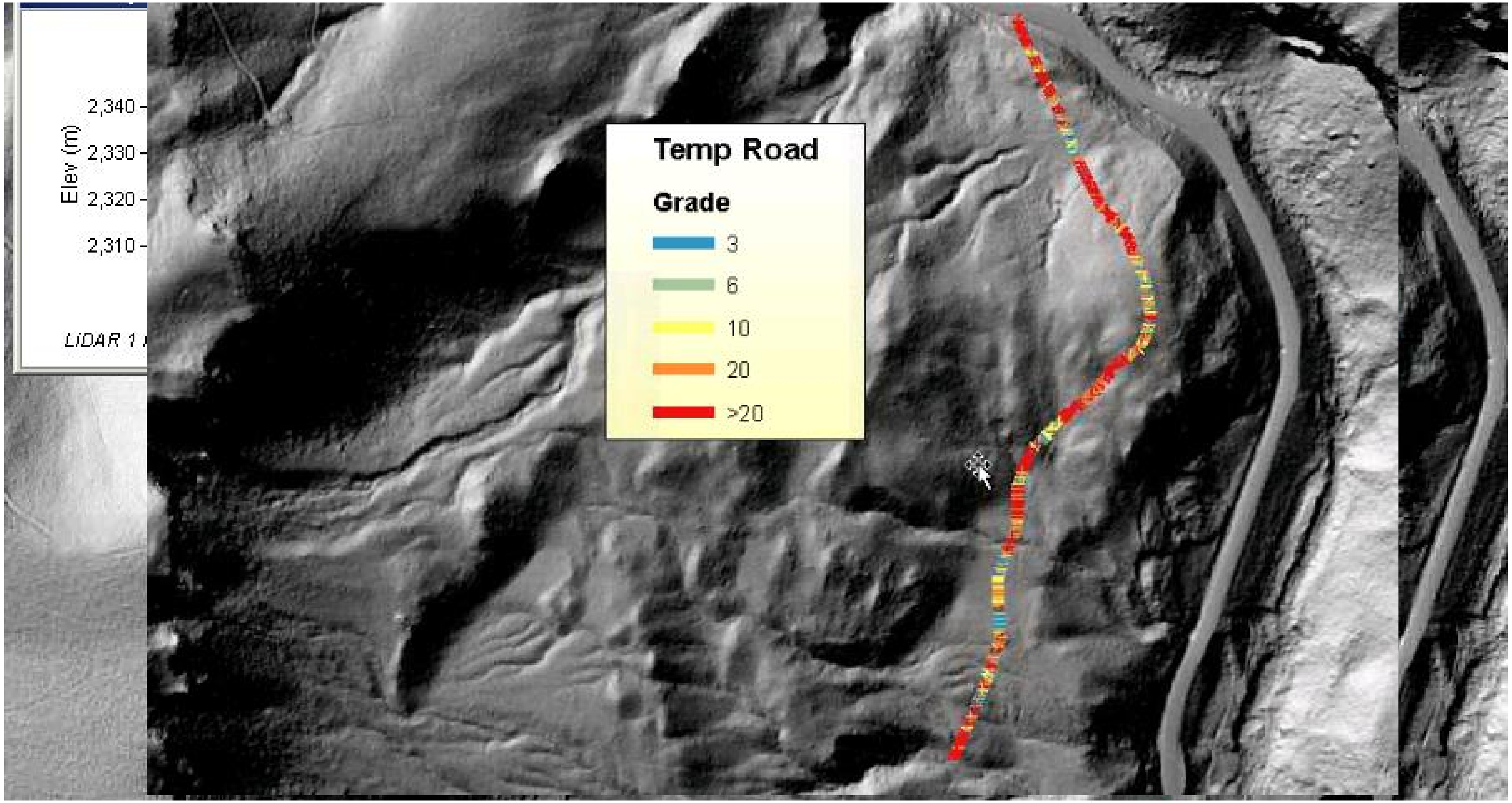
Existing Roads (Levels 2 & 1)



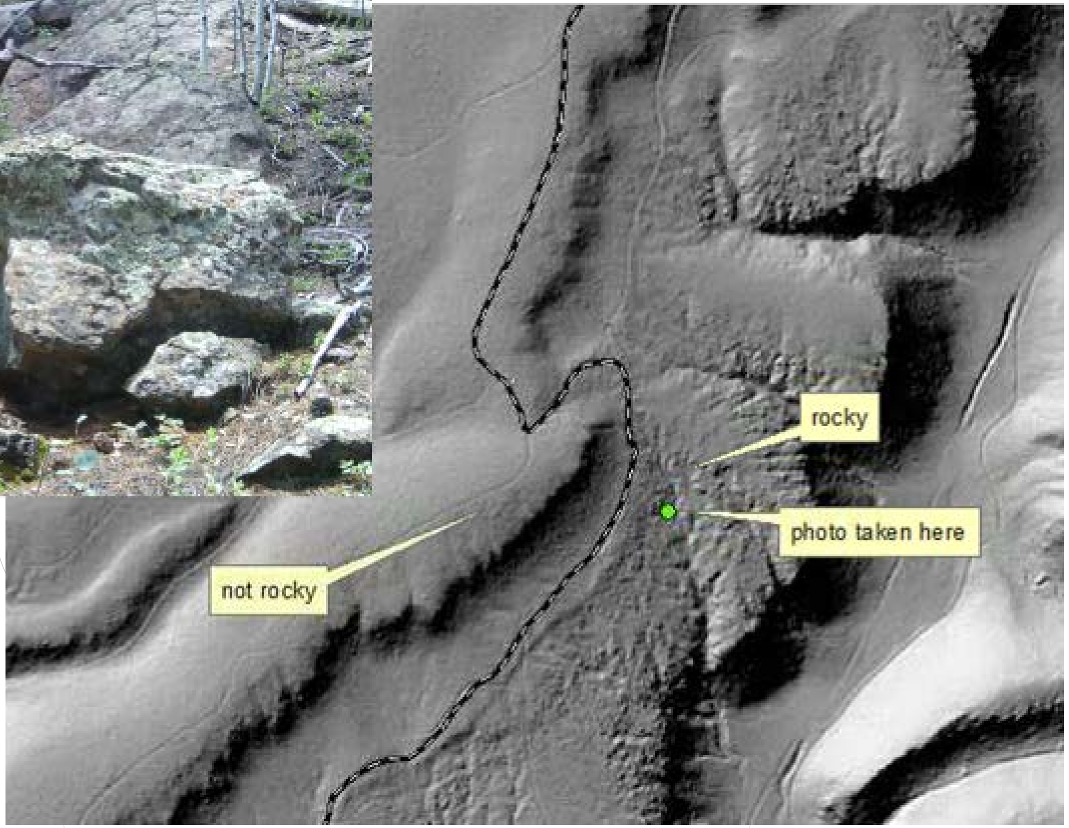
Additional Linear Features Identified from Lidar Digital Elevation Model



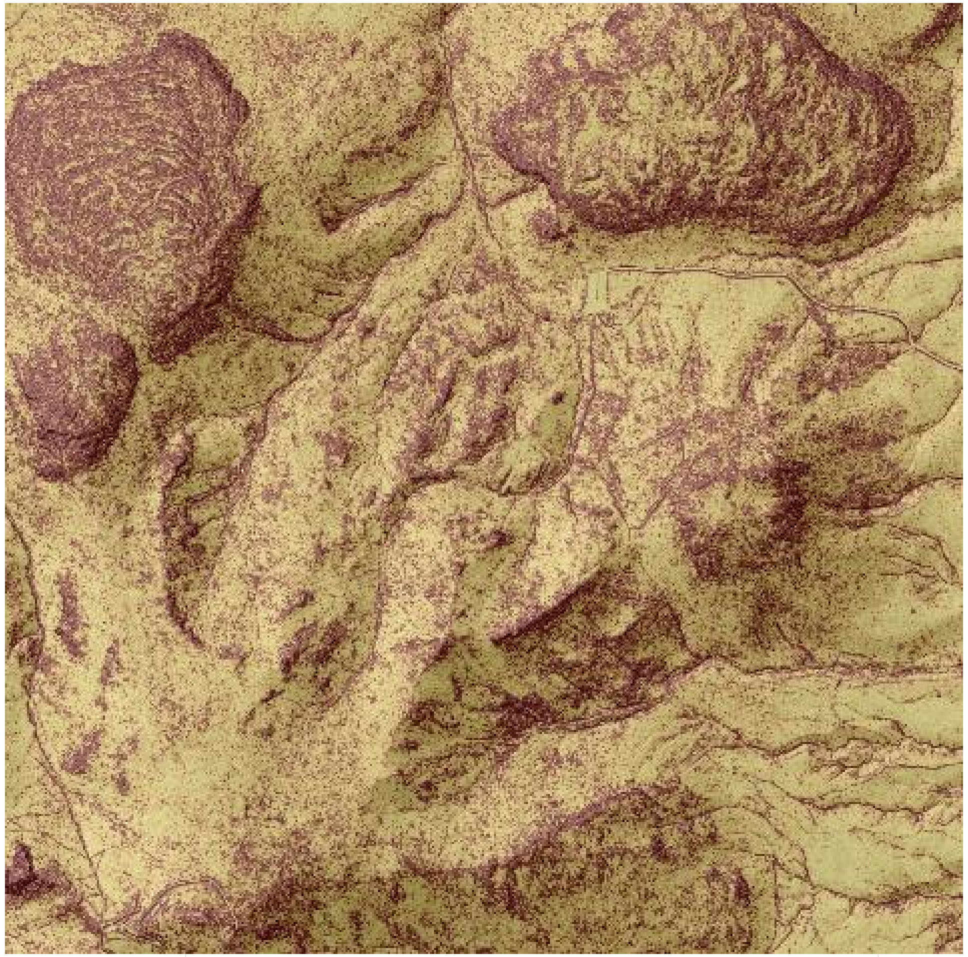
Operability – Santa Fe National Forest: Temp Road Example



Operability – Santa Fe National Forest: Operability Example



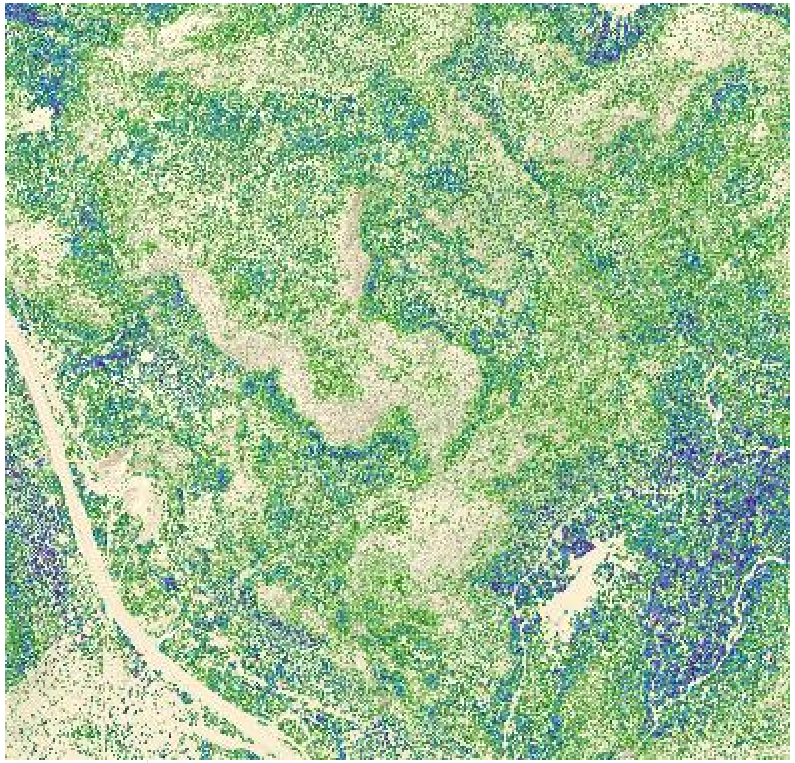
Operability – Bill Williams Mtn. Example



USES OF LIDAR FOR OPERABILITY, ACCESSIBILITY, AND FEASIBILITY

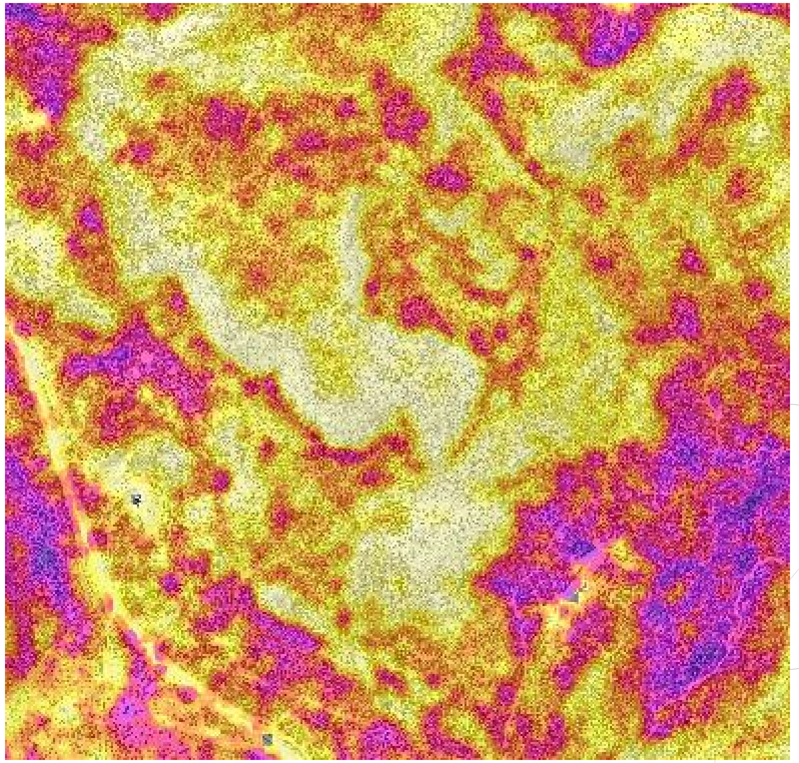
NAIP Imagery

1m Resolution Canopy Height Model

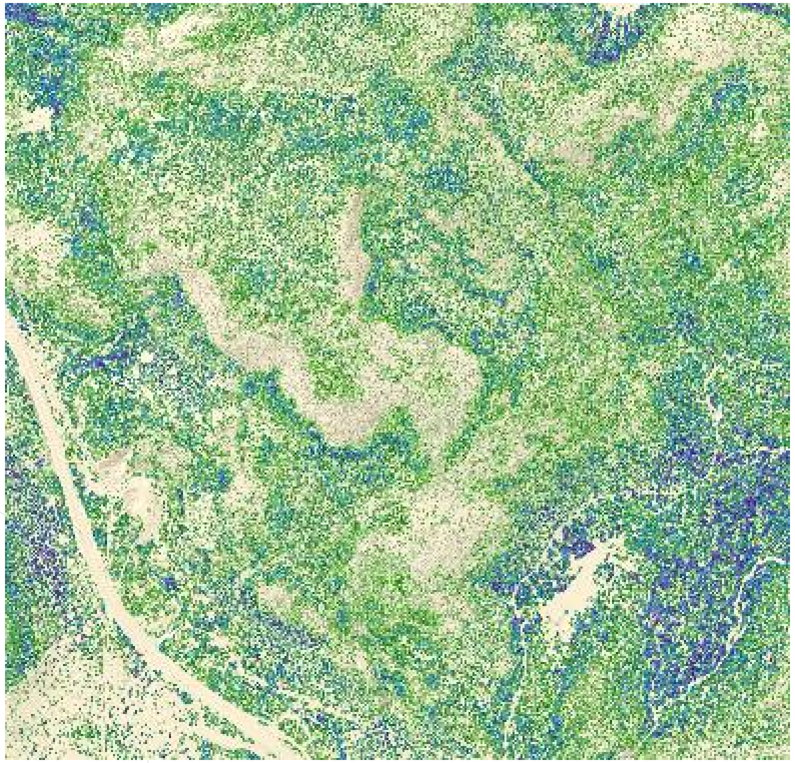


USES OF LIDAR FOR OPERABILITY, ACCESSIBILITY, AND FEASIBILITY

1m Mean Canopy Height
for 30m x 30m Neighborhood

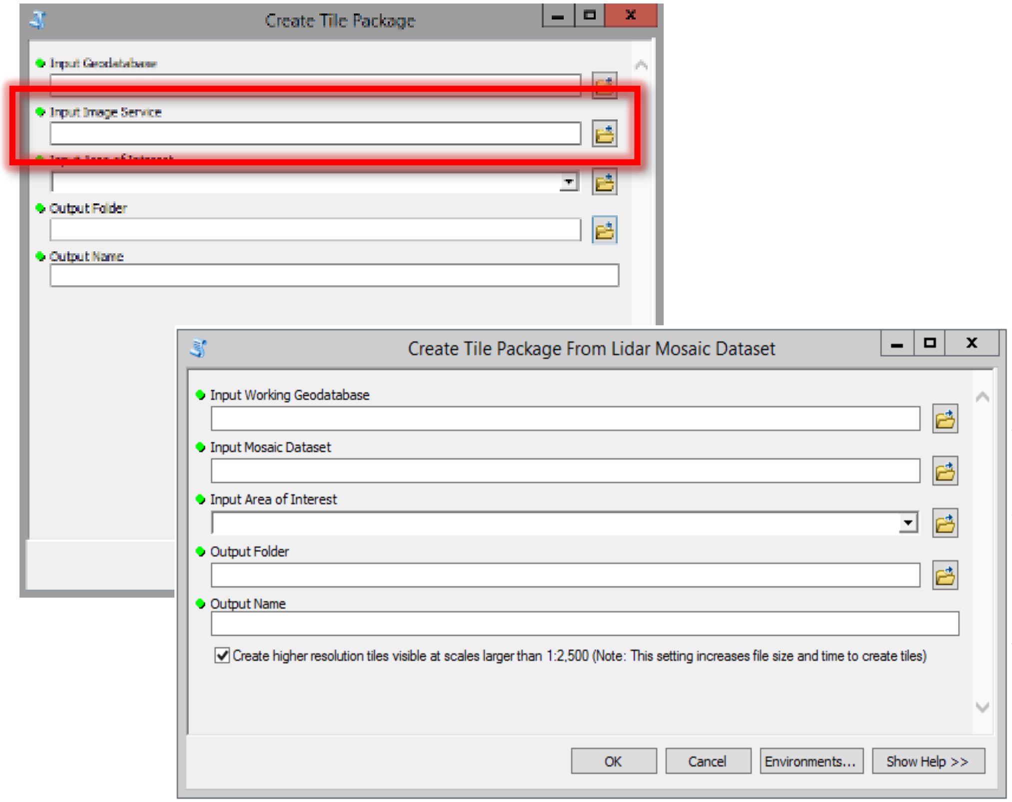


1m Resolution Canopy Height Model



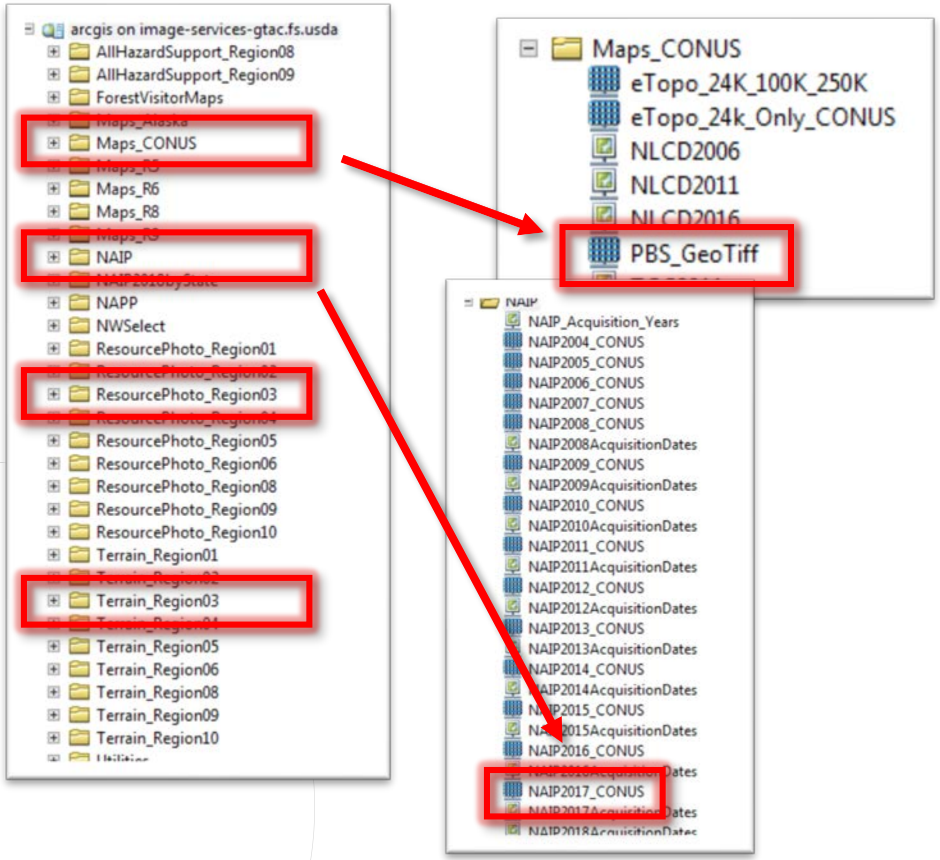
CREATE TILE PACKAGES FROM IMAGE SERVICES

Scripts



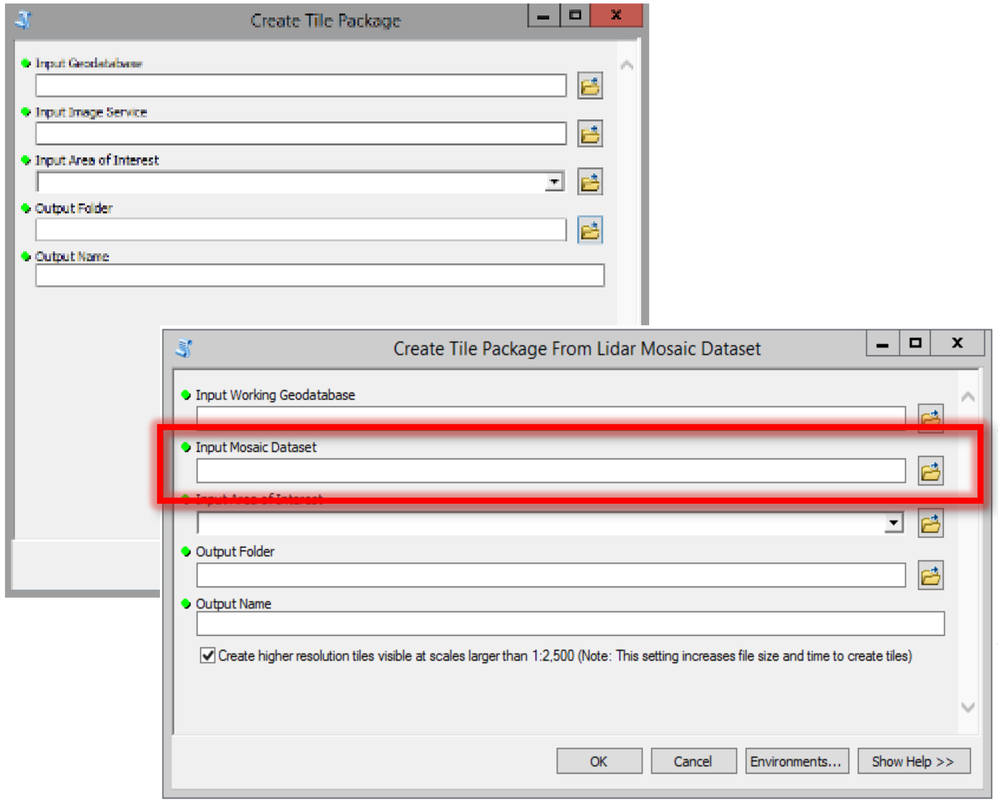
Forest Service Image Server:

https://image-services-gtac.fs.usda.gov/arcgis/services



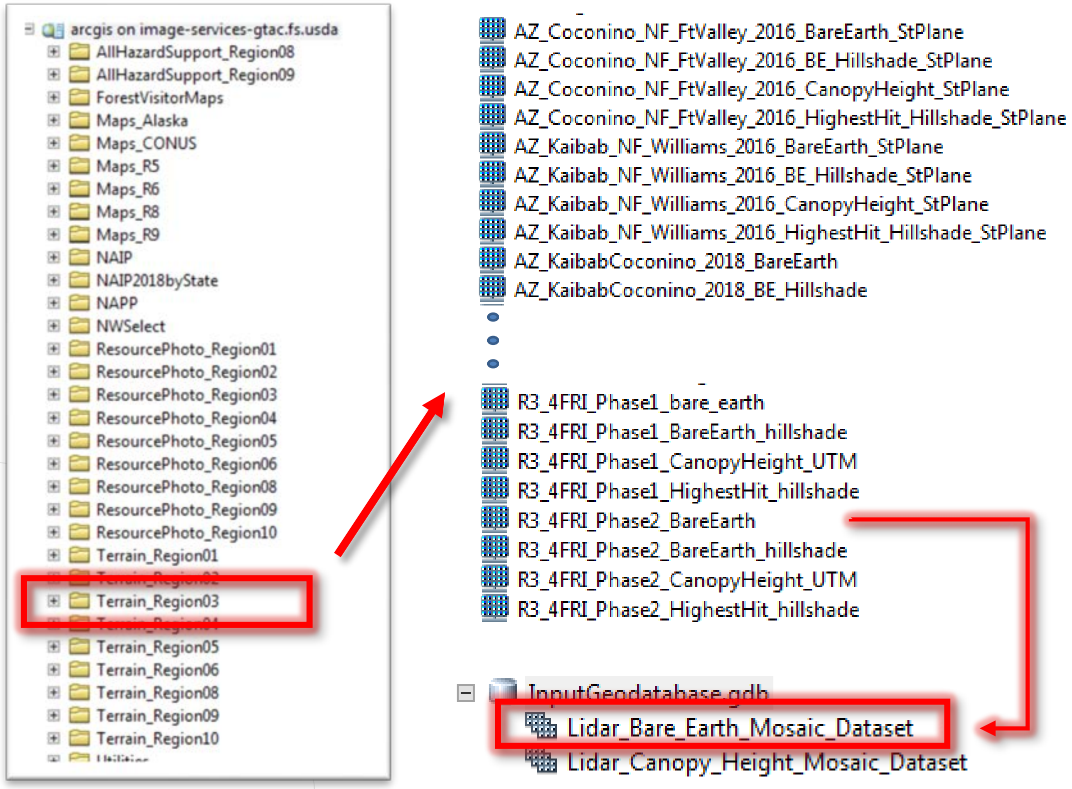
CREATE TILE PACKAGES FROM LIDAR MOSAIC DATASETS

Scripts



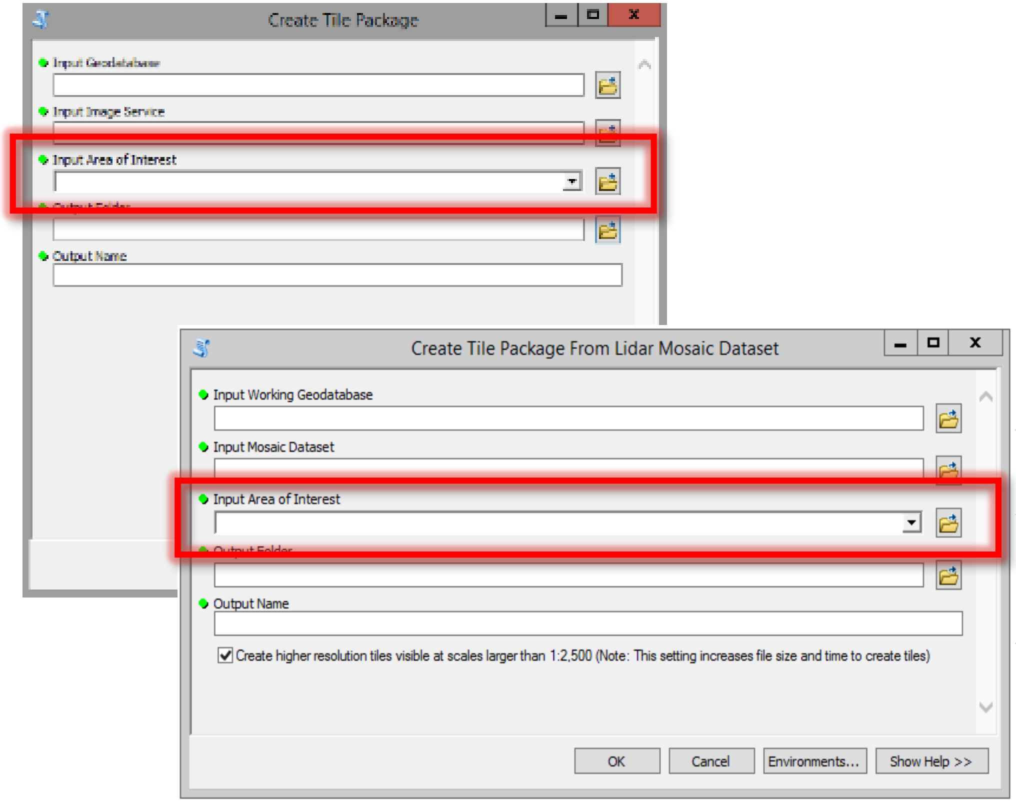
Forest Service Image Server:

https://image-services-gtac.fs.usda.gov/arcgis/services

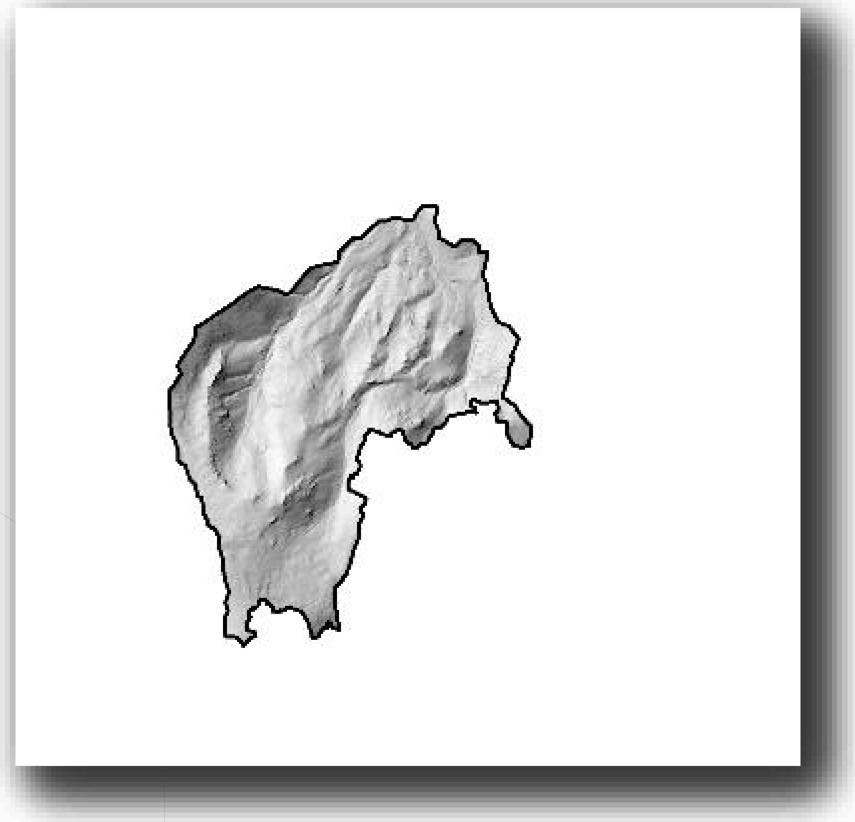


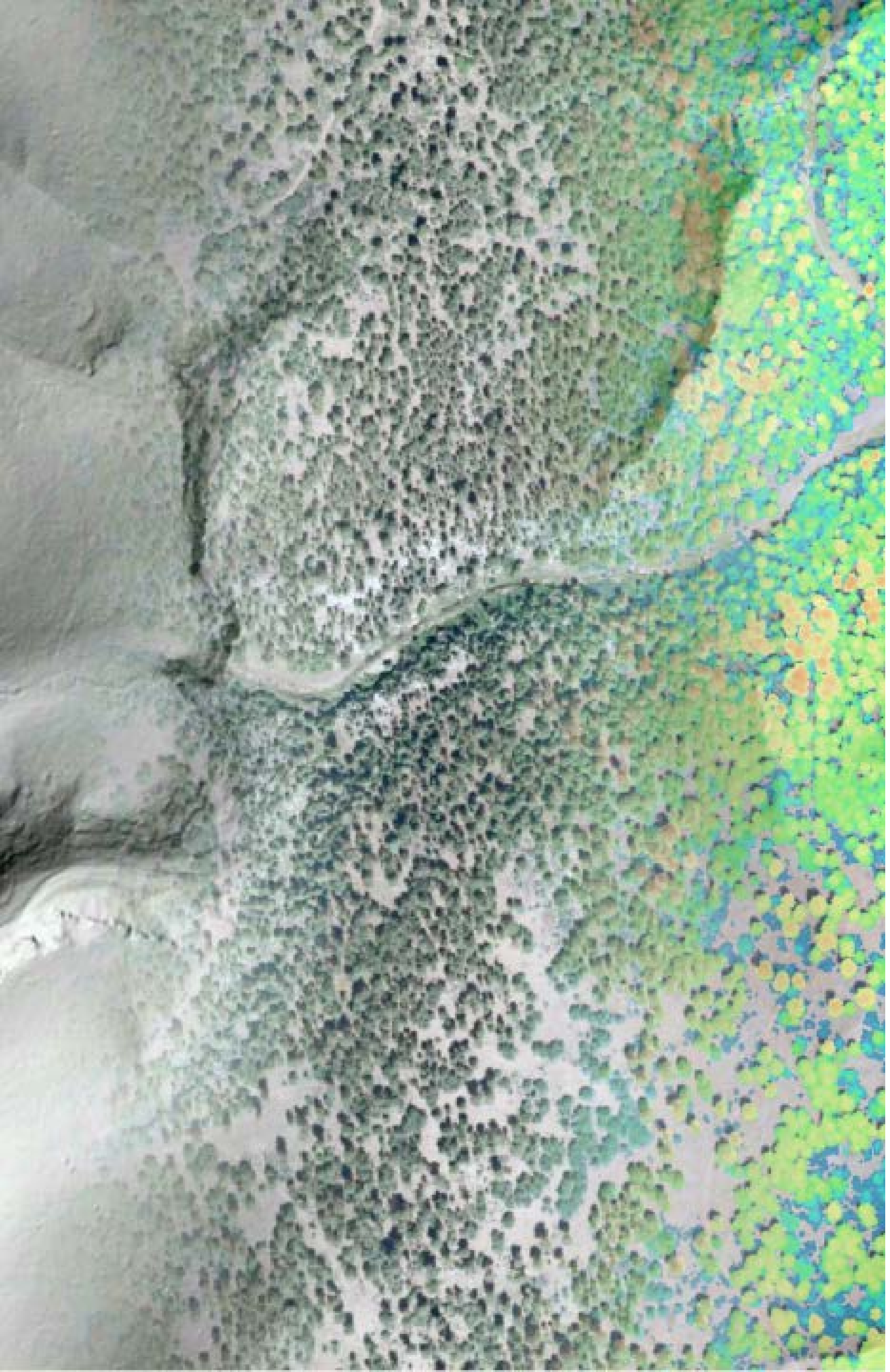
CREATE TILE PACKAGES – FOR YOUR AREA OF INTEREST

Scripts



Area of Interest



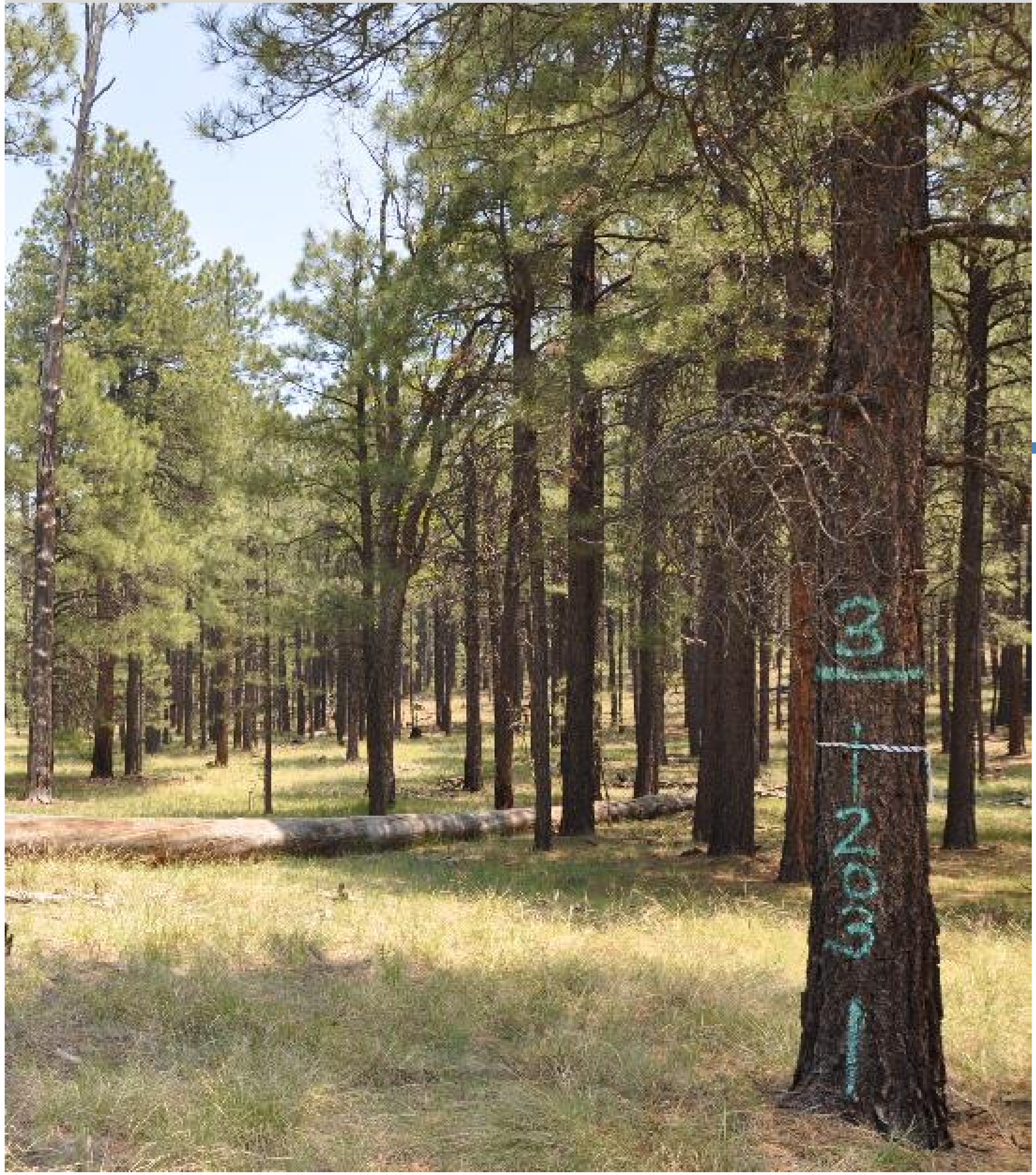


PRELIMINARY LESSONS INTEGRATING LIDAR WITH TWO-PHASED SAMPLING

MODERNIZING 4FRI IMPLEMENTATION - PROGRESS

WHAT DOES THIS WORK RESPOND TO?

As managers are asked to determine stand characteristics and obtain volume estimates to appraise and prepare timber sales for larger and larger landscapes, remote sensing and especially lidar, have to become integral components of the Forest Service's work pipeline.



WHAT WAS DONE?

Utilizing existing timber sales that occurred within lidar acquisition footprints, associated cruise plots were located using sub-meter gps and analyses is currently underway to assess the potential of lidar to increase the efficiency of existing cruising methods using a two-phase sample approach.

Two-phase sampling design is a sampling design where the sample selection is performed in two phases

- first phase the auxiliary variable x (lidar-derived estimates of volume to be removed)
- second phase the study variable y (cruise-derived estimates of volume to be removed)

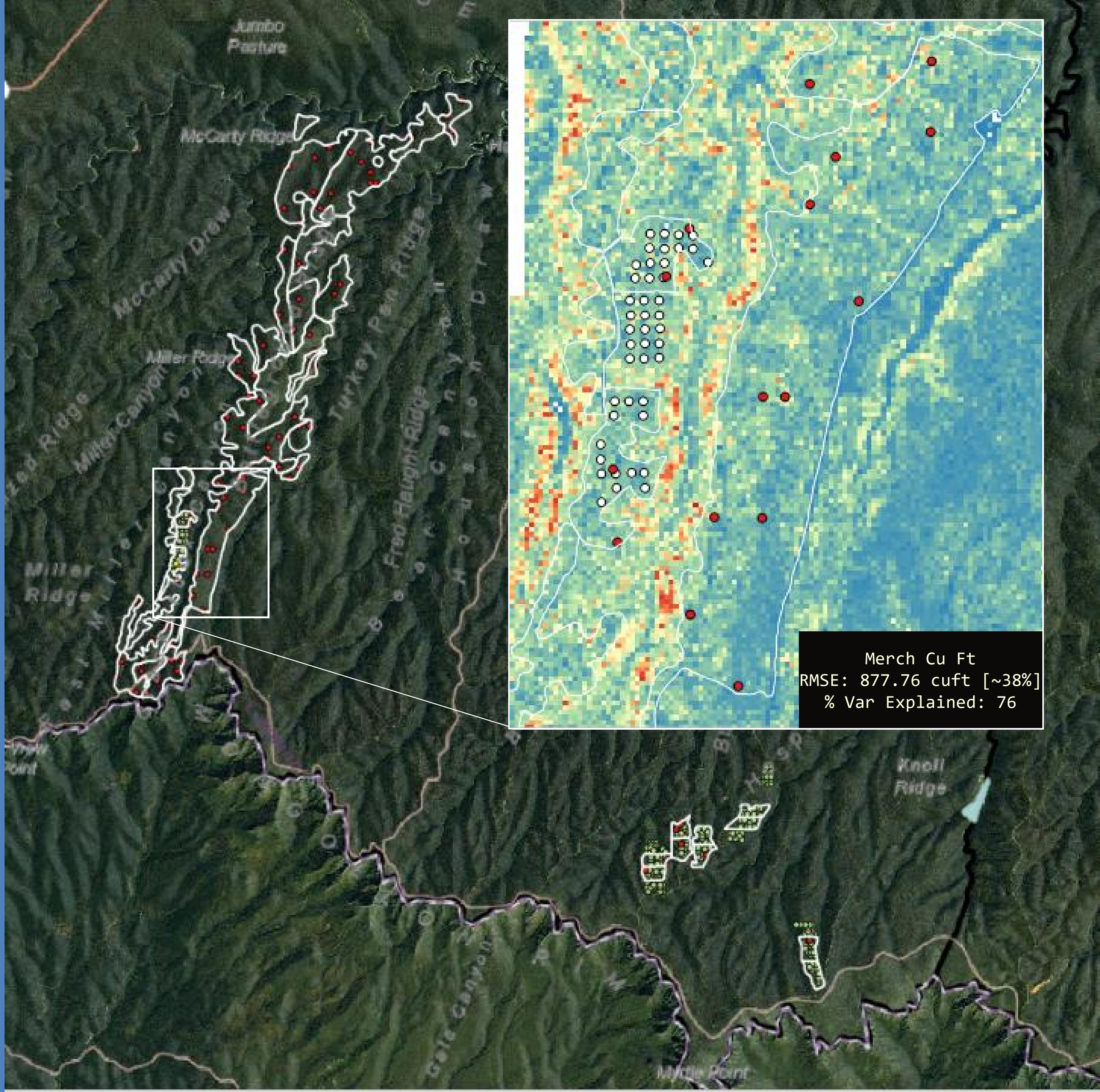
WHAT WAS THE PROCESS?

Identified potential timber sales

Collect existing/new fixed area plot data to be used in conjunction with lidar data

Determine a way to estimate volume removed (cruised) using lidar in the first phase.

Examine the reduction in plots required to achieve desires sample error in second phase.



WHAT WORKED

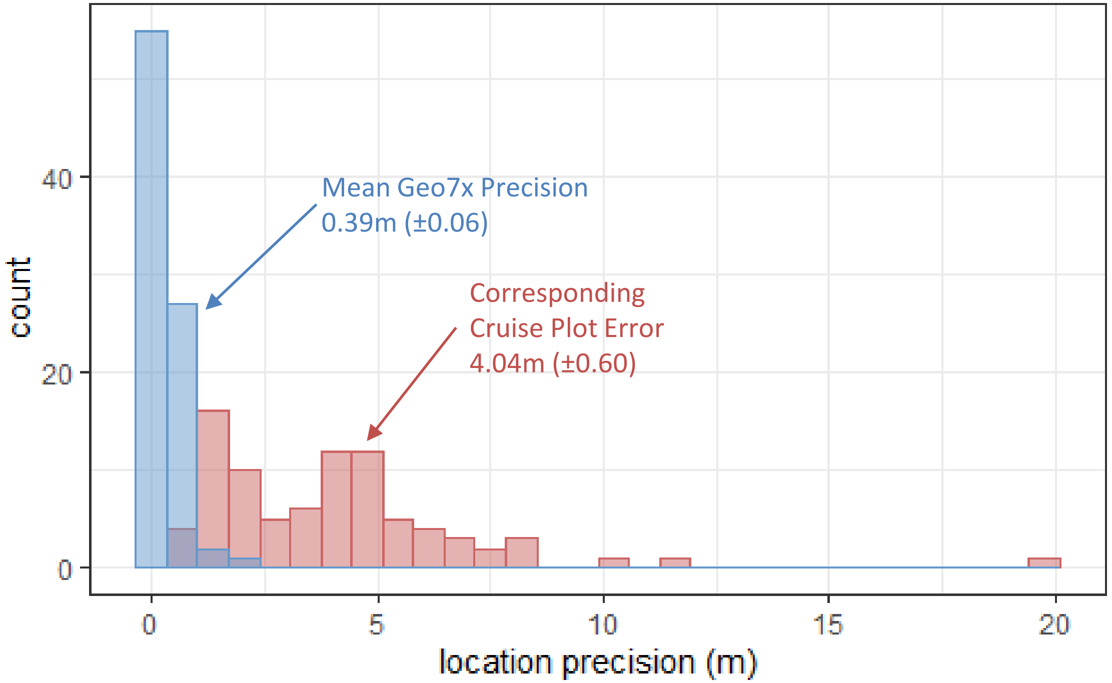
Well, it's ongoing….

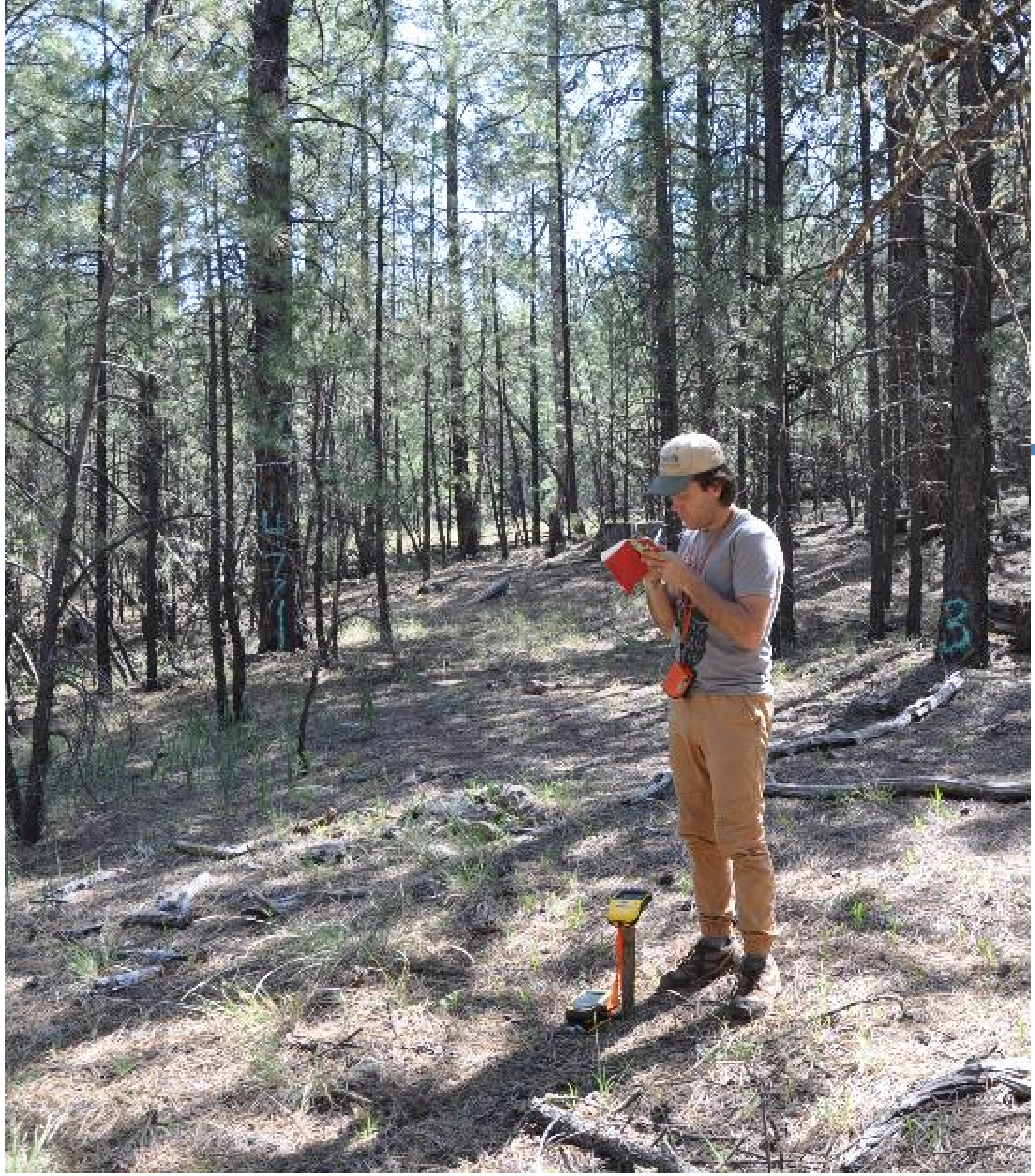
but I can offer some preliminary lessons learned/observations that will be key for implementation.

I'll come back to this at the end!

KEY POINTS FOR IMPLEMENTATION

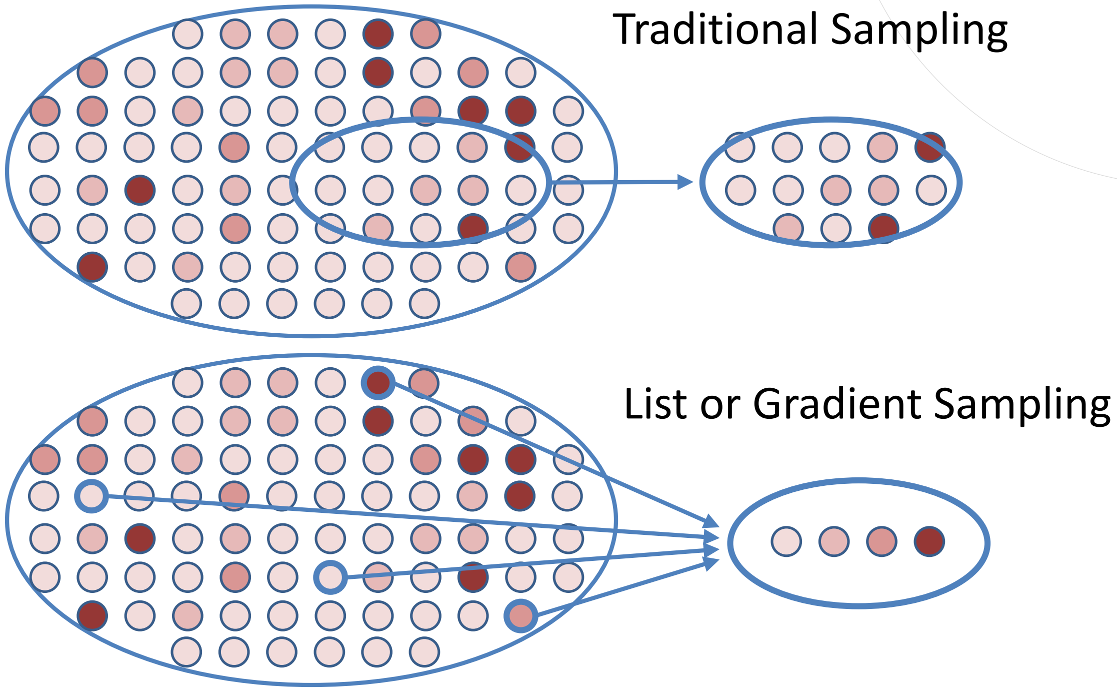
High accuracy (sub-meter) GPS locations are imperative.





KEY POINTS FOR IMPLEMENTATION

Sampling based on frequency will likely need to shift to list or gradient sampling when using remote sensing.



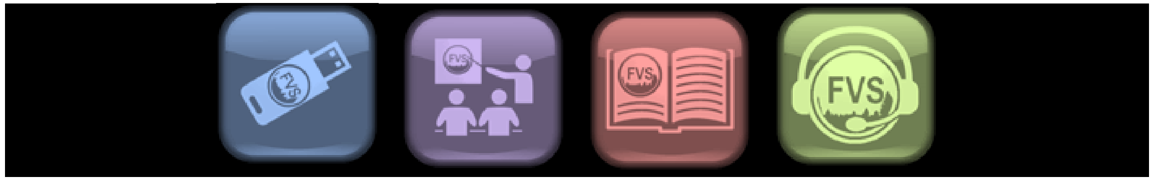
KEY POINTS FOR IMPLEMENTATION

With more and more prescriptions moving towards DxP, remote sensing's ability to estimate "volume removed" becomes increasingly difficult.

Remote sensing is best suited for estimating gross volume/biomass.

Solutions "simulating" silvicultural prescriptions and harvest activities may be necessary to obtain estimates.

Development, training, and support will be essential.



RECOMMENDATIONS

- Increase awareness/availability of high-accuracy GPS.
- Alterations in sample selection (list sampling) and sample design (geographically balanced sample) needed.
- Novel ways to model attributes of interest (e.g., stand characteristics or yield estimates following DxP) are needed.

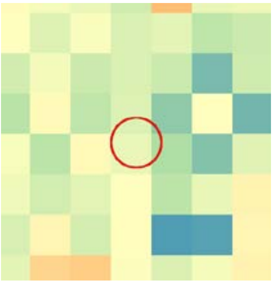
Javad’s TRIUMPH-2

RECOMMENDATION

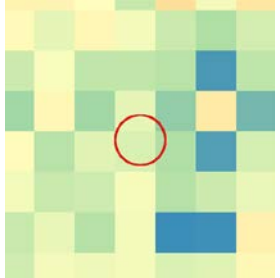
- Programming a DxP is… hard.
- 2PRS stemmed from a 3P approach (3PRS) utilizing aerial photo interpretation and maybe the need suggests an approach with new (old?) tools.
- First Phase calls of Relative Volume (removed) Index (RVI) in the office.
- List sampled plots visited for second phase estimates.

2017
NAIP

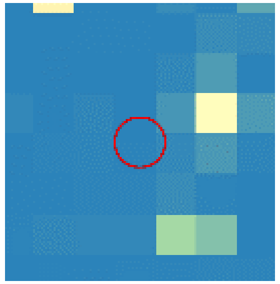
BA
152.7

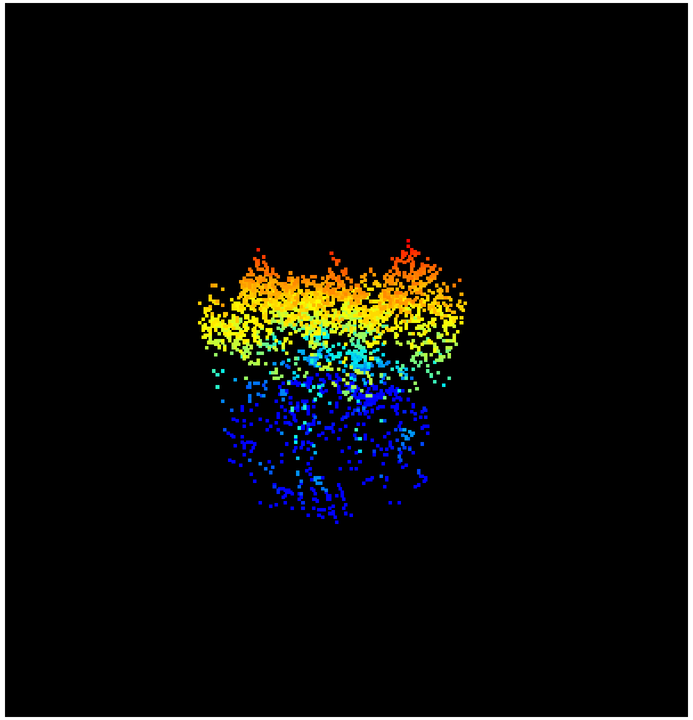


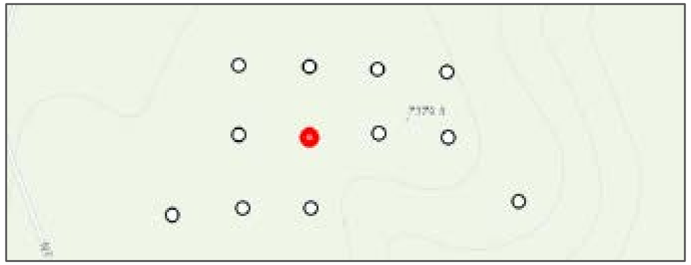
TPA ≥5”
35.6

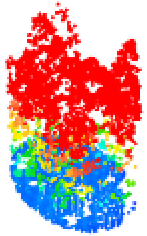


TPA <5”
35.6



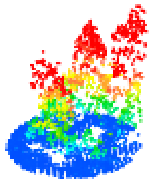


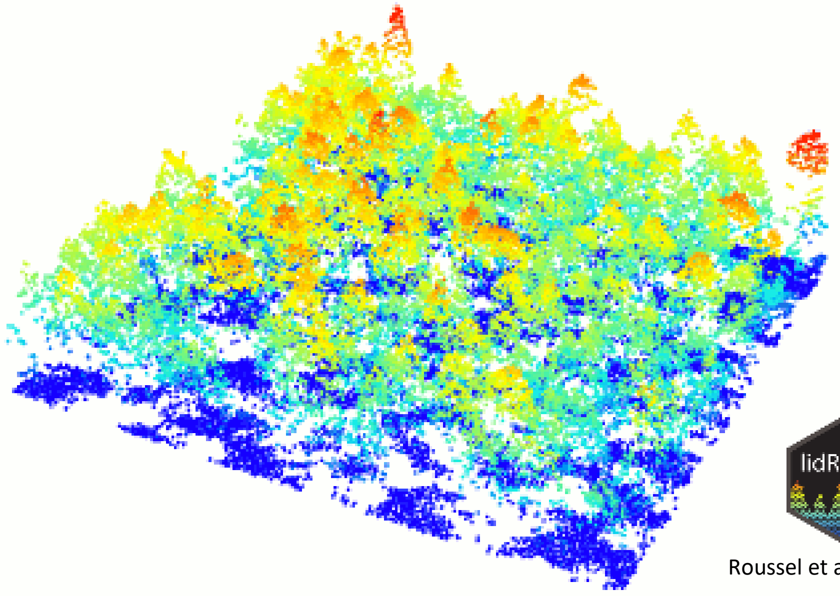




RVI: 1

RVI: 0





Roussel et al., 2019

USING LIDAR PRODUCTS TO ESTIMATE VOLUME

MODERNIZING 4FRI IMPLEMENTATION - PROGRESS

WHAT DOES THIS WORK RESPOND TO?

Using remotely sensed data products to estimate field based derivatives

Efficiencies

Industry Support

WHAT WAS DONE?

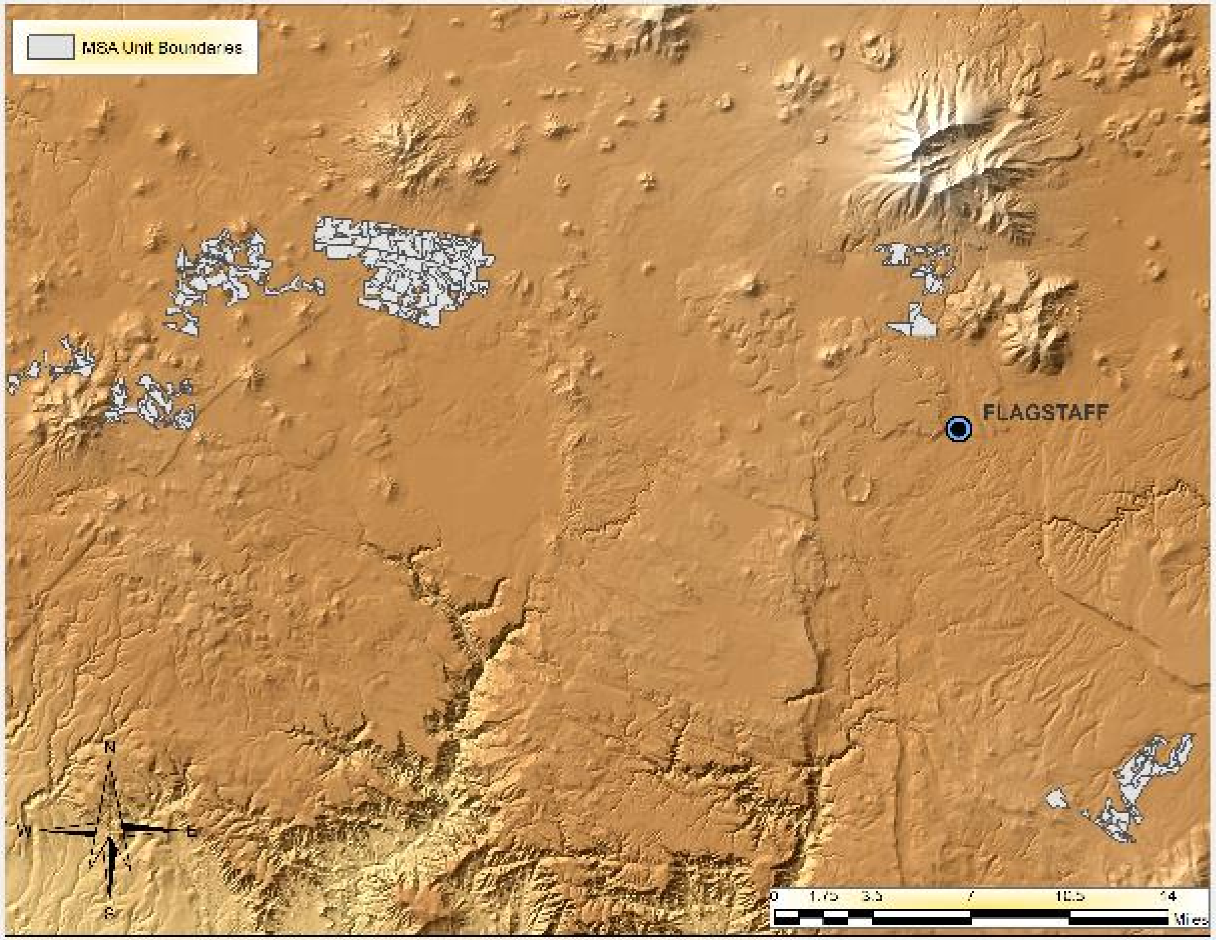
Approach…

Estimate Gross Volume with LiDAR

Compare to Volume Removed estimates from cruising

Develop Ratio of:

Predicted Total Existing Volume | Estimated Volume Removed



WHERE DID WE DO IT?

Coconino

Johnneys

Chimney Springs

Kaibab

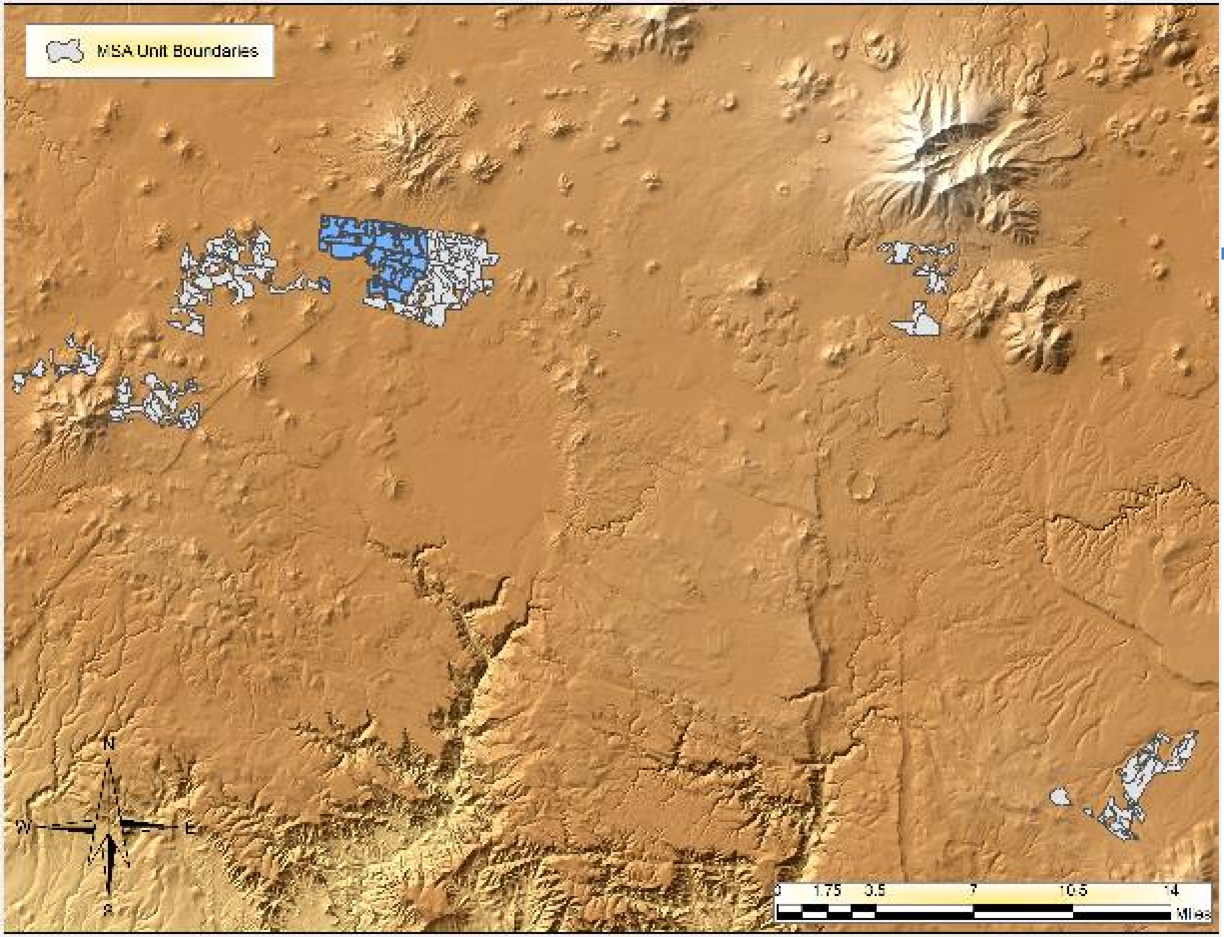
Moonset

Junction

Clover

Dude

Zorro



WHERE DID WE DO IT?

Coconino

Johneys

Chimney Springs

Kaibab

Moonset

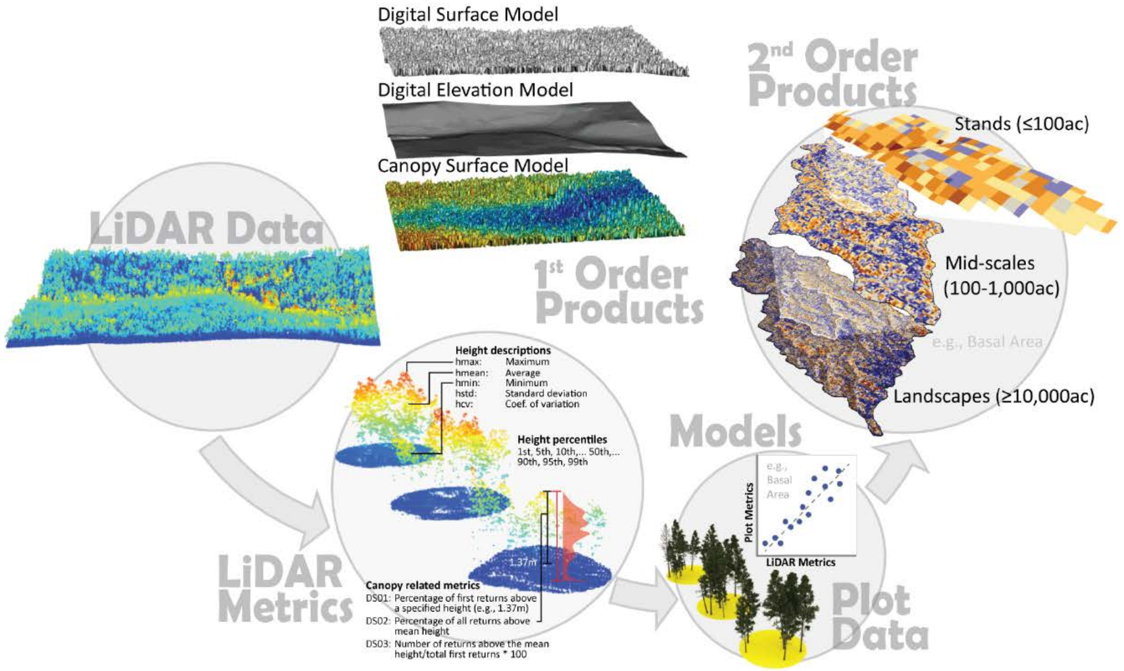
Junction

Clover

Dude

Zorro

PARKS WEST



Donager and Sanchez Meador 2019

WHAT WAS DONE?

Gross Volume Estimation - LiDAR 2nd Order products

1. *Area based volume predictions*
2. *Individual tree list volume predictions*

WHAT WAS THE PROCESS?

Estimate existing gross volume

1 Area-Based Approach

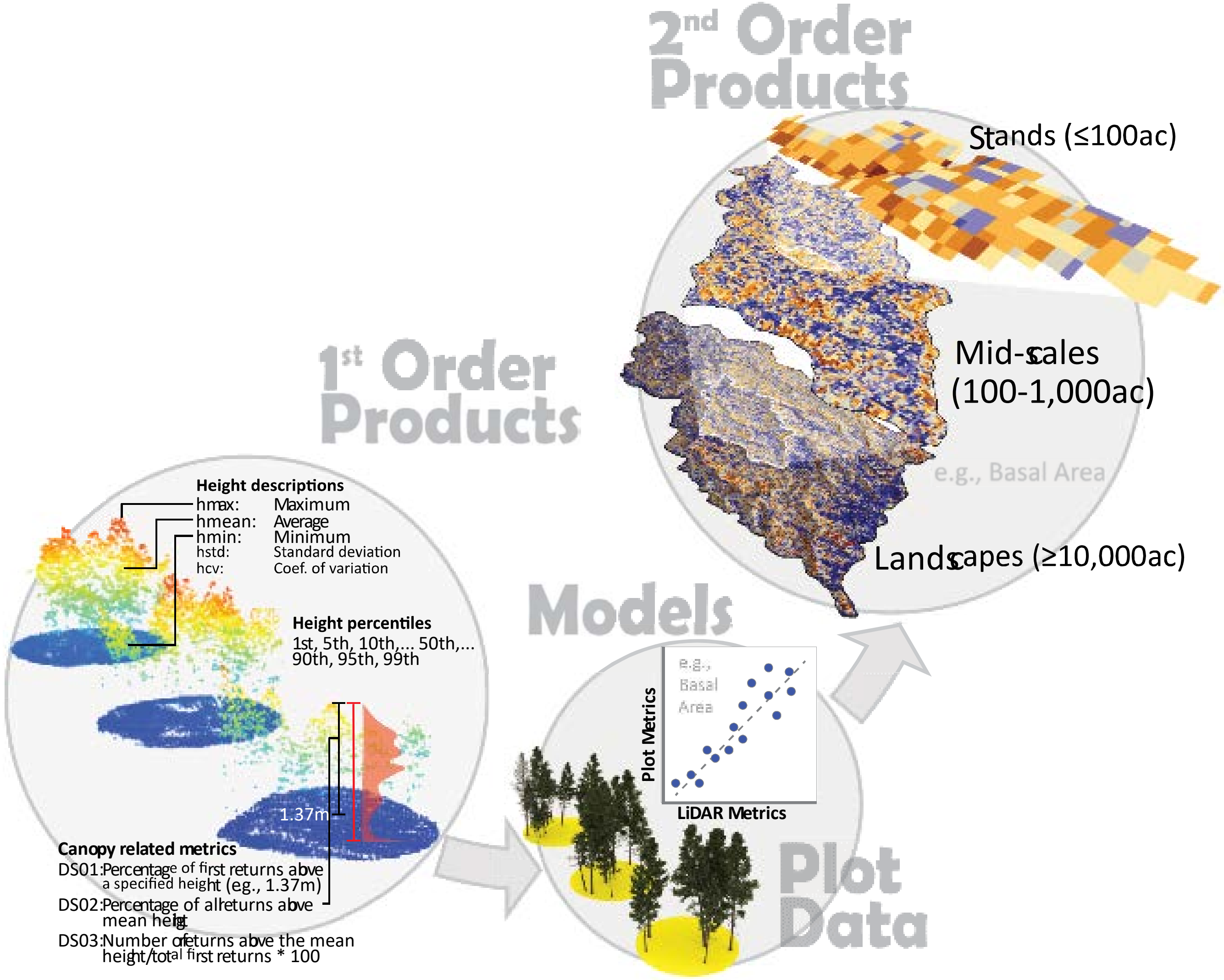
Plot data

and….

1st order products

Random Forest models

Raster of predicted volume



Donager and Sanchez Meador 2019

WHAT WAS THE PROCESS?

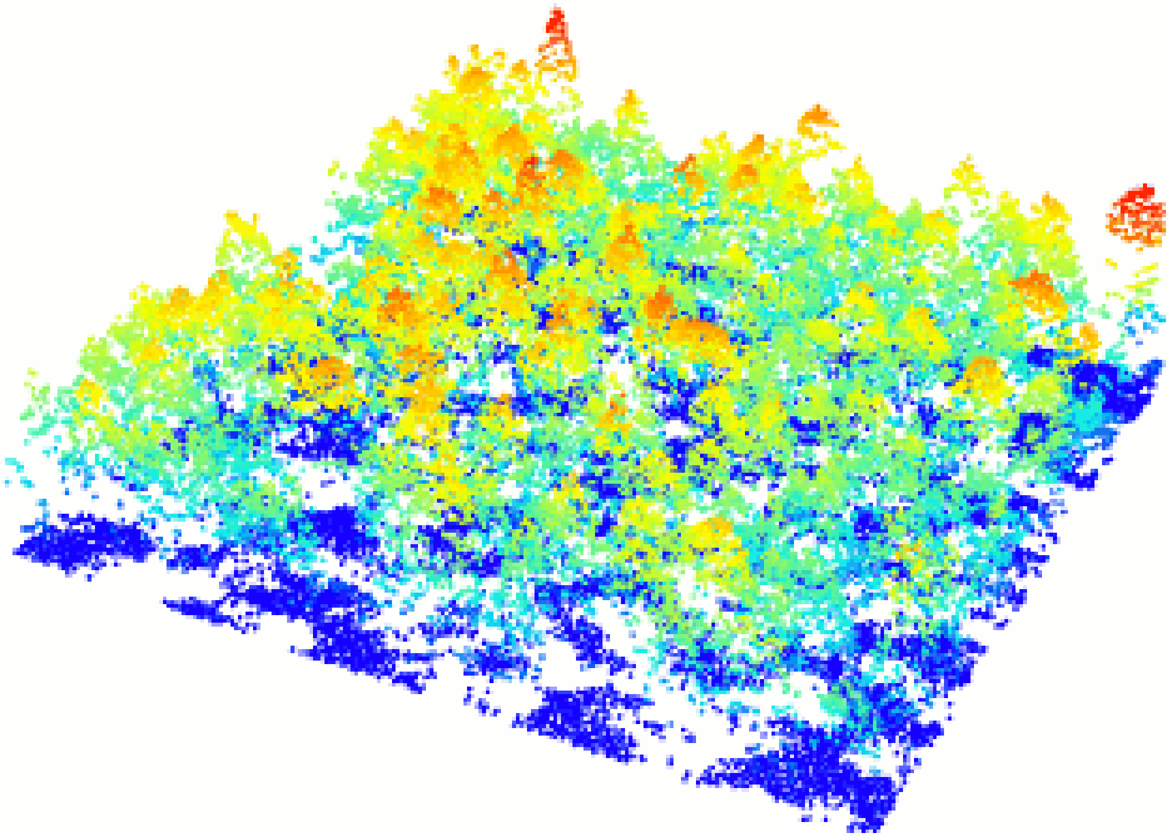
Estimate existing gross volume

2 Individual Tree Segmentation Approach

LiDAR point cloud segment individual trees

Predict diameter and volume for each tree

Summarize tree list by unit and strata



WHAT WAS THE PROCESS?

Estimate existing gross volume

2 Individual Tree Segmentation Approach

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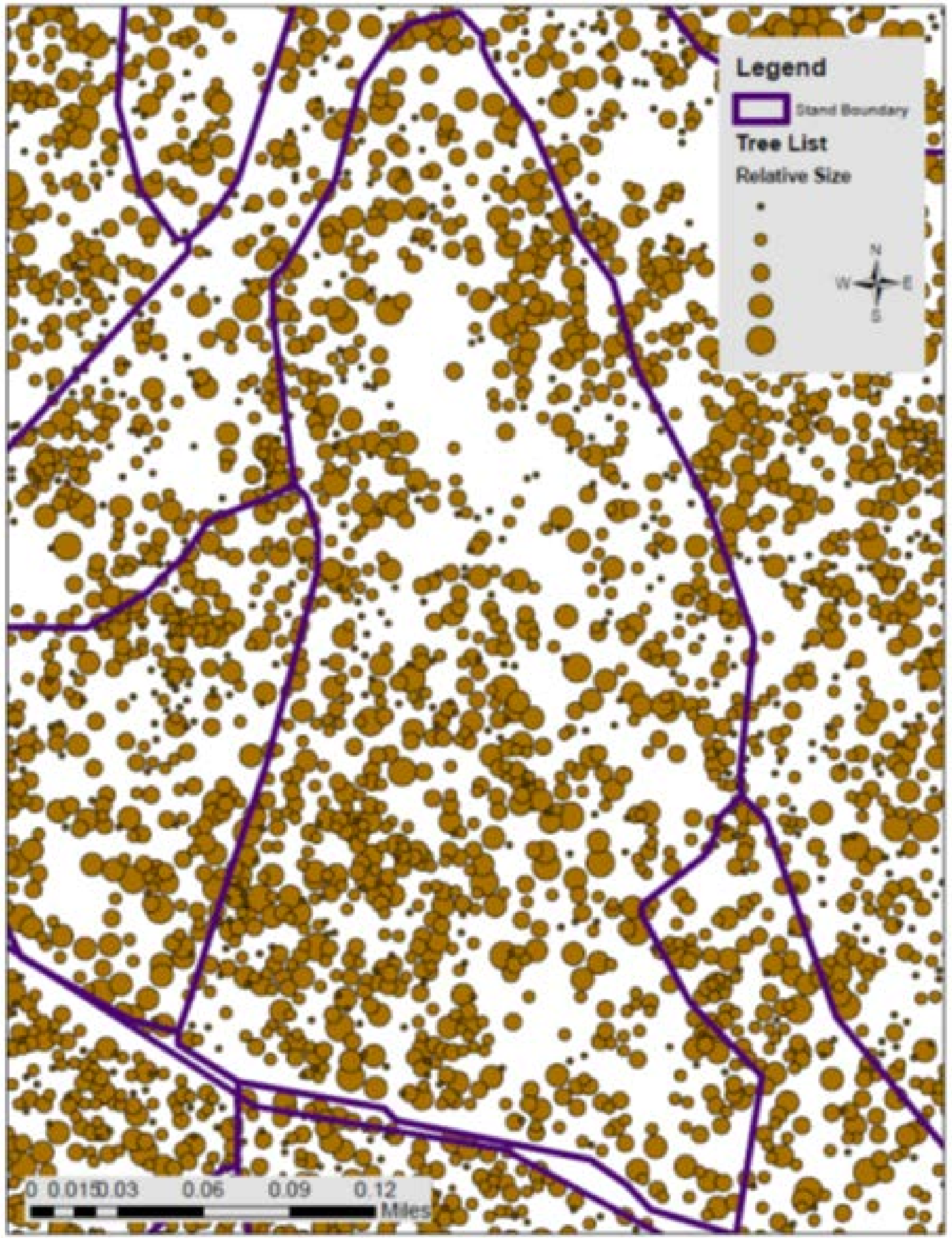


WHAT WORKED?

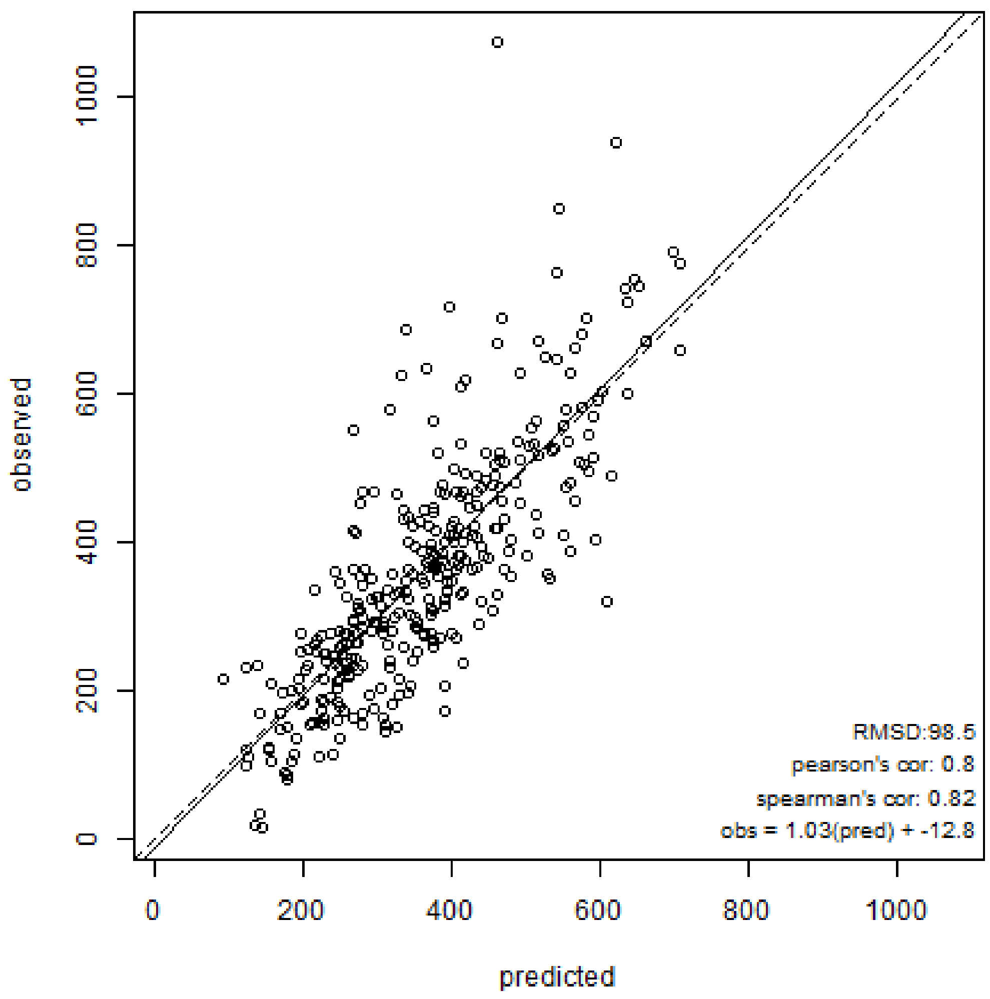
…and what didn’t?

WHAT WORKED?

Model Results

- 64% variance explained
- 27% error in estimates of validation plot data
- Very little bias in estimates

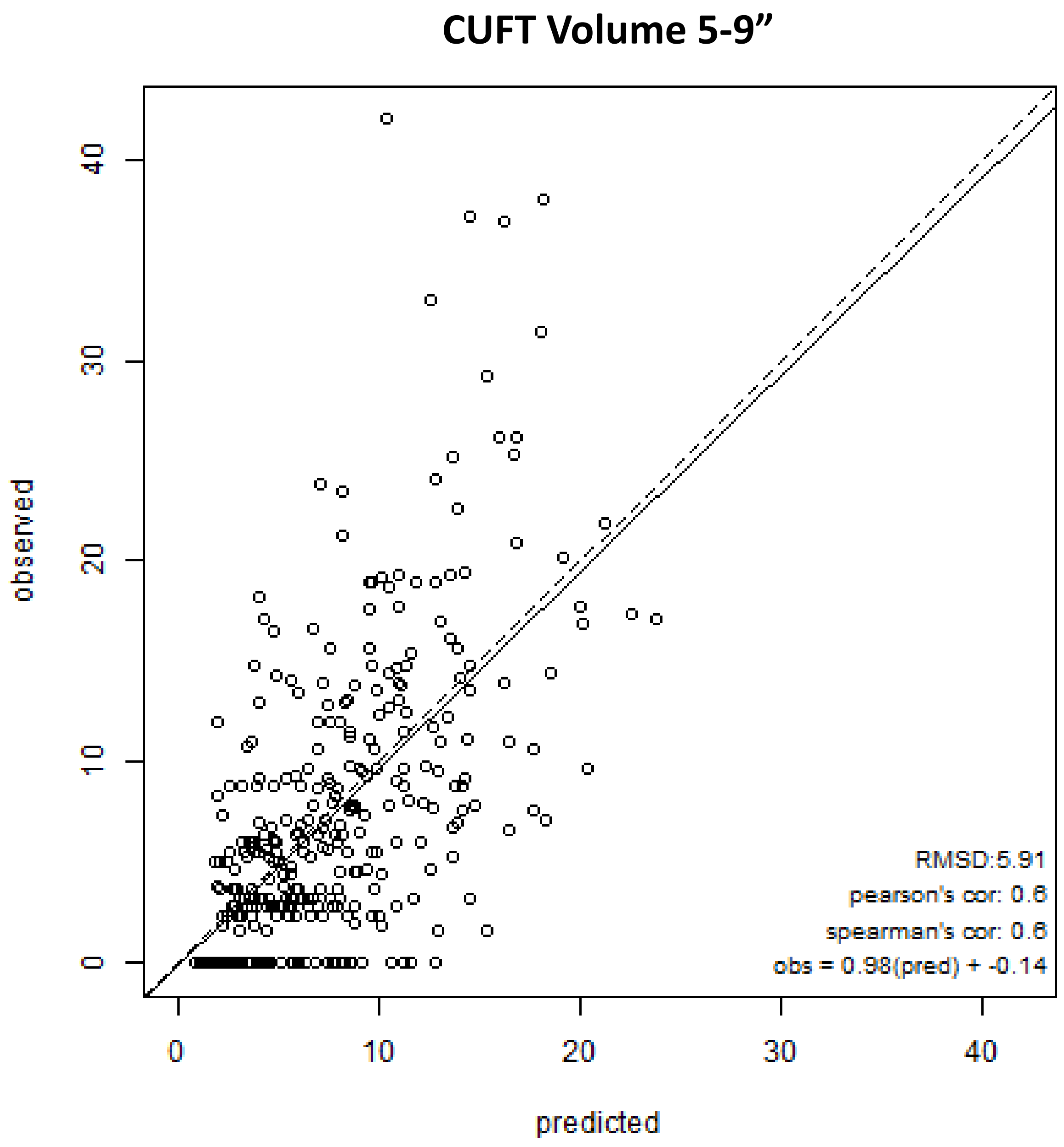
Total CUFT Volume >5”



WHAT DIDN'T?

Model Results

- 36% variance explained
- 82% error in estimates of validation plot data
- Underprediction in estimates where higher volume exists



WHAT WORKED?

Ratio

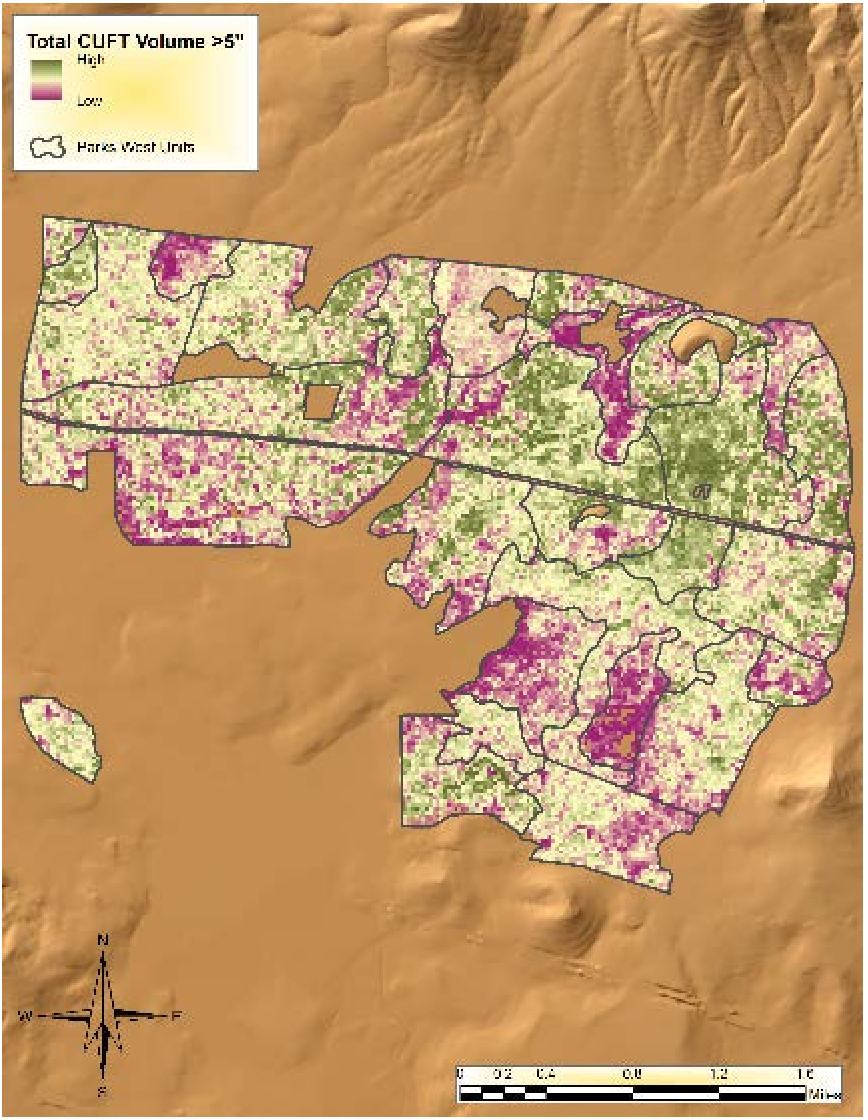
Estimated Volume Removed

Predicted Total Existing Volume

Project Area	Area-based Total Volume Ratio	ITS Total Volume Ratio
Coconino		
Johnneys	0.32	0.48
Chim. Springs	0.39	0.58
Kaibab		
Clover	0.48	0.56
Zorro	0.62	0.67
Dude	0.56	0.64
Junction	0.42	0.58
Moonset	0.48	0.57
Average	0.51	0.58
Stand. Dev.	0.10	0.06

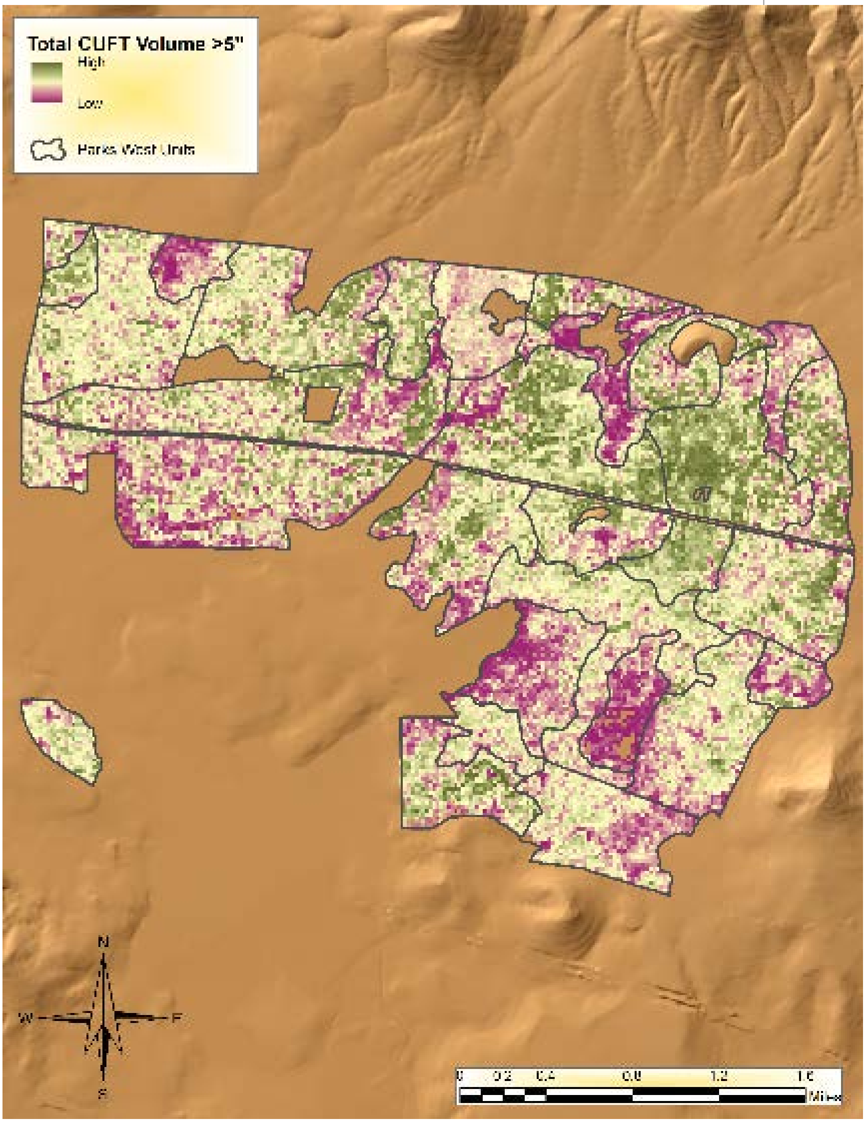
WHAT WORKED?

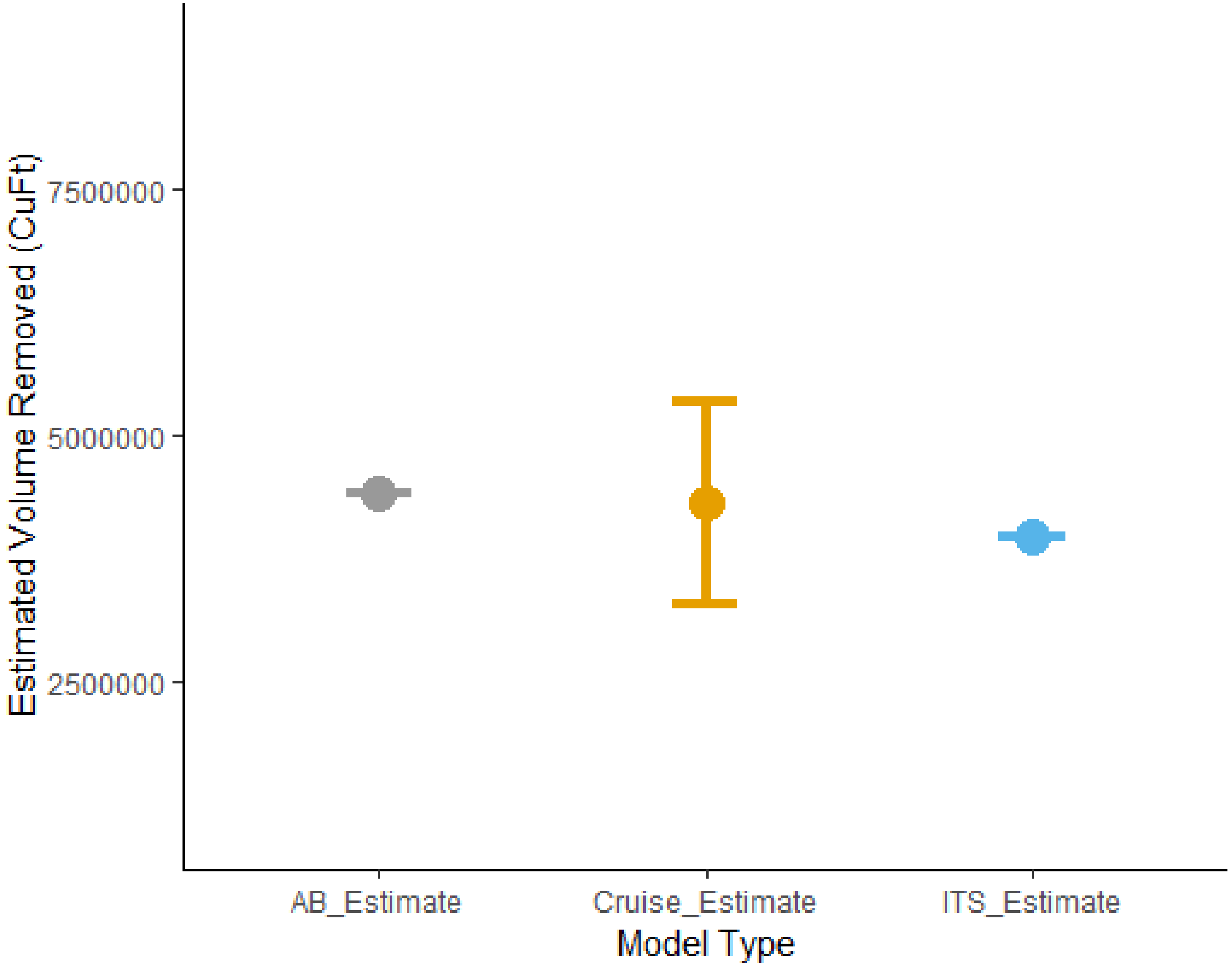
Volume Estimates



WHAT WORKED?

Volume Estimates





KEY POINTS FOR IMPLEMENTATION

WORK IN PROGRESS!!!!

Improved training dataset

- Stratified plot network to improve model
- Measurements of both total existing volume and volume removed base don Rx

Developing products requires spatial and modeling analysis skills

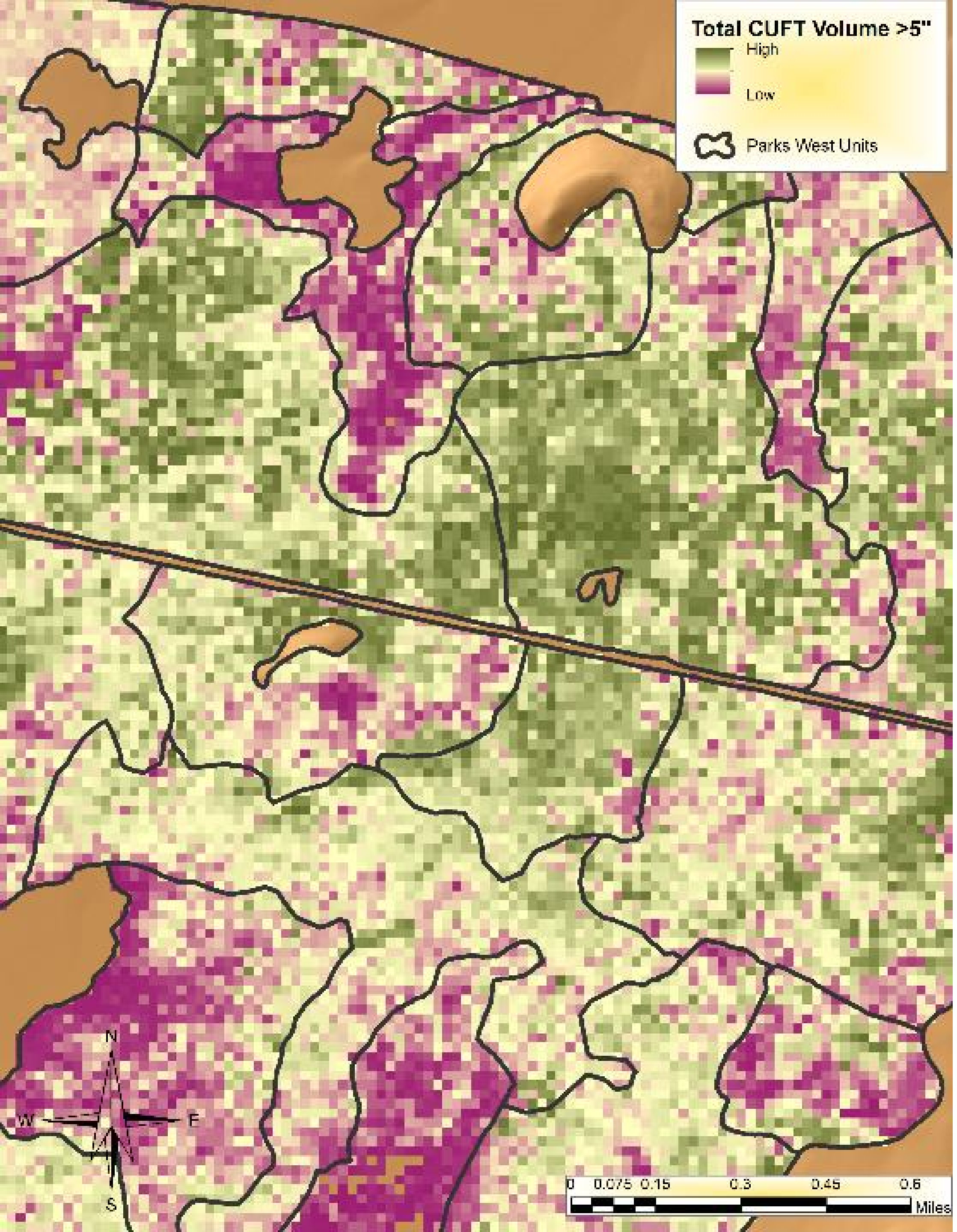
RECOMMENDATIONS

WORK IN PROGRESS!!!!

RECOMMENDATIONS

WORK IN PROGRESS!!!!

ECHO WHAT ANDREW SAID!!!!!



RECOMMENDATIONS

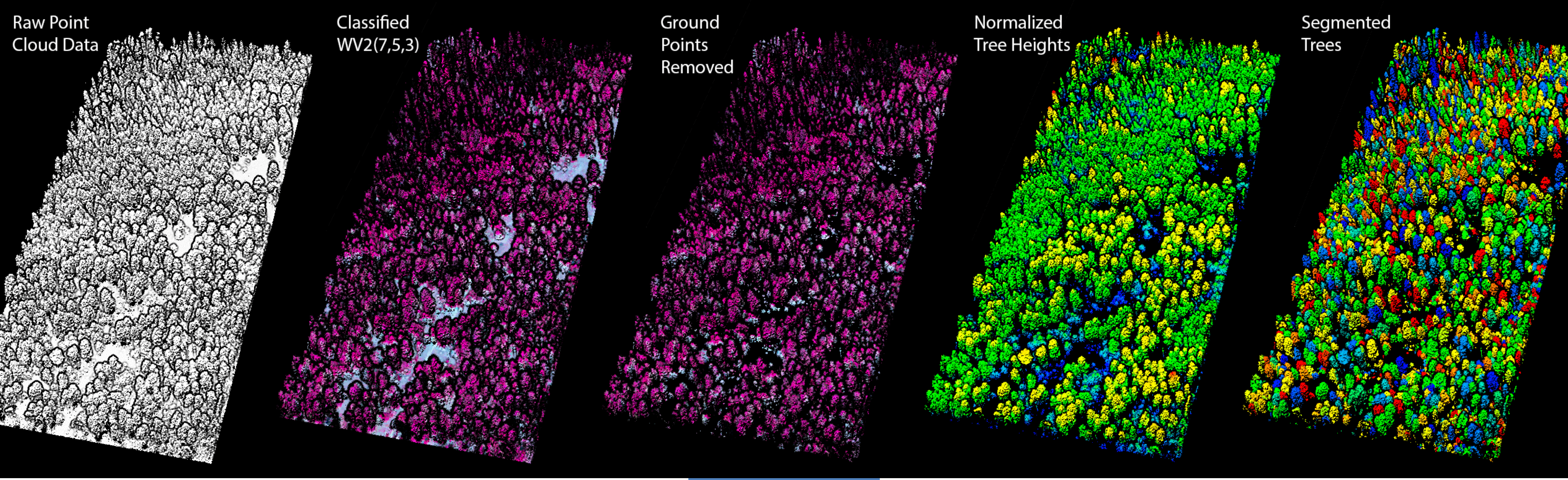
WORK IN PROGRESS!!!!

In addition to a potential cruising toolset…

Project implementation process

Economic/Operational feasibility

Landscape scale understanding/planning



THANK YOU

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USDA

The Nature Conservancy

NAU NORTHERN ARIZONA UNIVERSITY
Ecological Restoration Institute