NV5 Geospatial

Integrating imagery into the lidar classification workflow

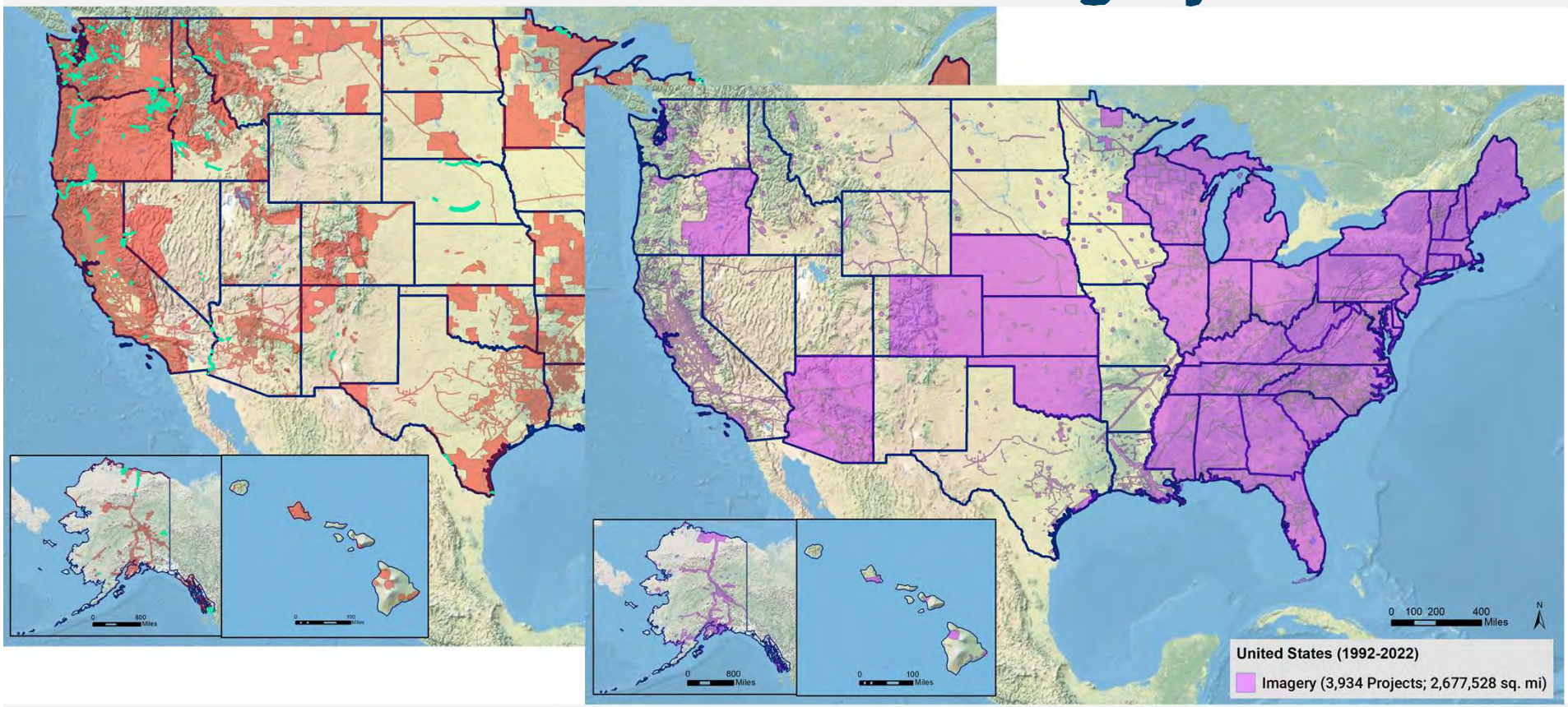
Andrew Brenner
Senior Program Director

Quantum Spatial is now NV5 Geospatial

What We Do

Full spectrum of geospatial support services on land and in the marine/coastal environment

We collect a lot of lidar and imagery



Overview

Enhancing science and understanding to manage our world responsibly

Key Datasets

Ray tracing

Segmentation

Classification

Questions

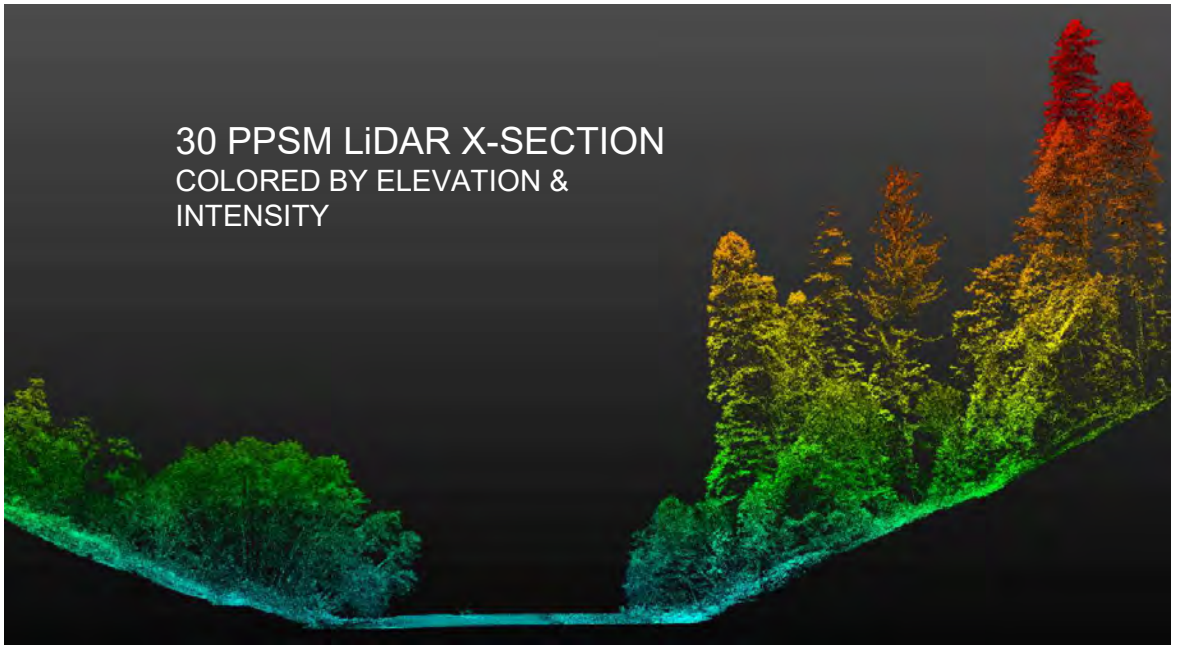
Key Datasets

Lidar is now foundational to forestry

- Height
- Structure
- Site conditions
- Height growth

Need field data

- Remote sensing enhances the use of field data does not replace it
- Field data for remote sensing is different than for general forestry



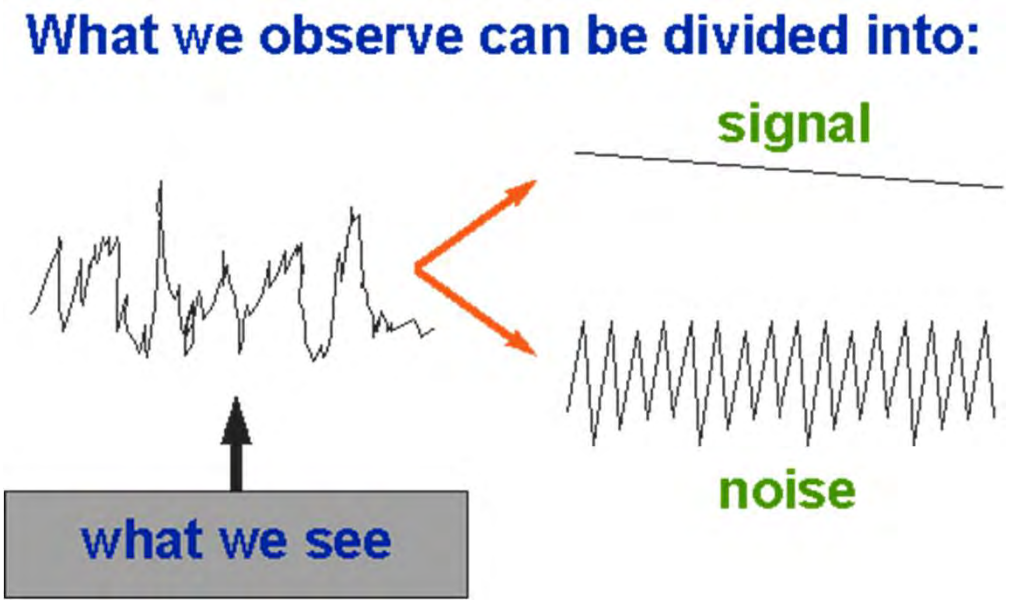
Quality of Lidar and Imagery

Quality of lidar

- Pulse density
- Quality of point classification
- Spatial accuracy
- Ratio of real returns vs. spurious returns
- Scan angle
- Footprint size

Quality of imagery

- Pixels size
- Number of wavebands
- Spatial accuracy
- Atmospheric conditions
- Frame vs. line scanner
- Resampling



Ref: https://blog.solidsignal.com/tutorials/nice-and-easy-what-is-snr-signal-to-noise-ratio/

Field Data Collection

Underlying principles

- Field data collection is needed to build relationships for almost all forest analyses of value
- Ideal plot data collection is a fixed area plot with all stems located, enumerated and measured
- Each forest will have different allometric relationships so the more we understand about the trees the better we can remove variance in the prediction
- Using data collected that was not designed for remote sensing analysis can be problematic
- Need specific sampling and plot design for remote sensing analysis that is different from standard forestry practices

Courtesy F4Tech

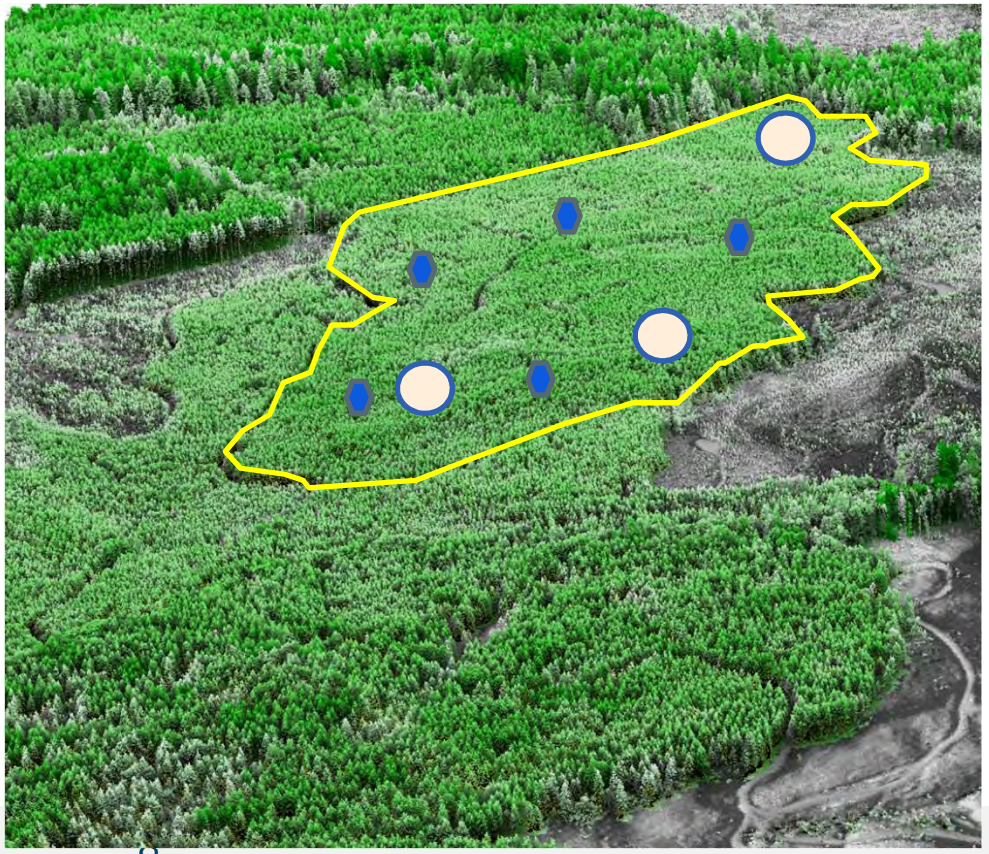
Field Data

Need to be able to relate field data to the remote sensing data

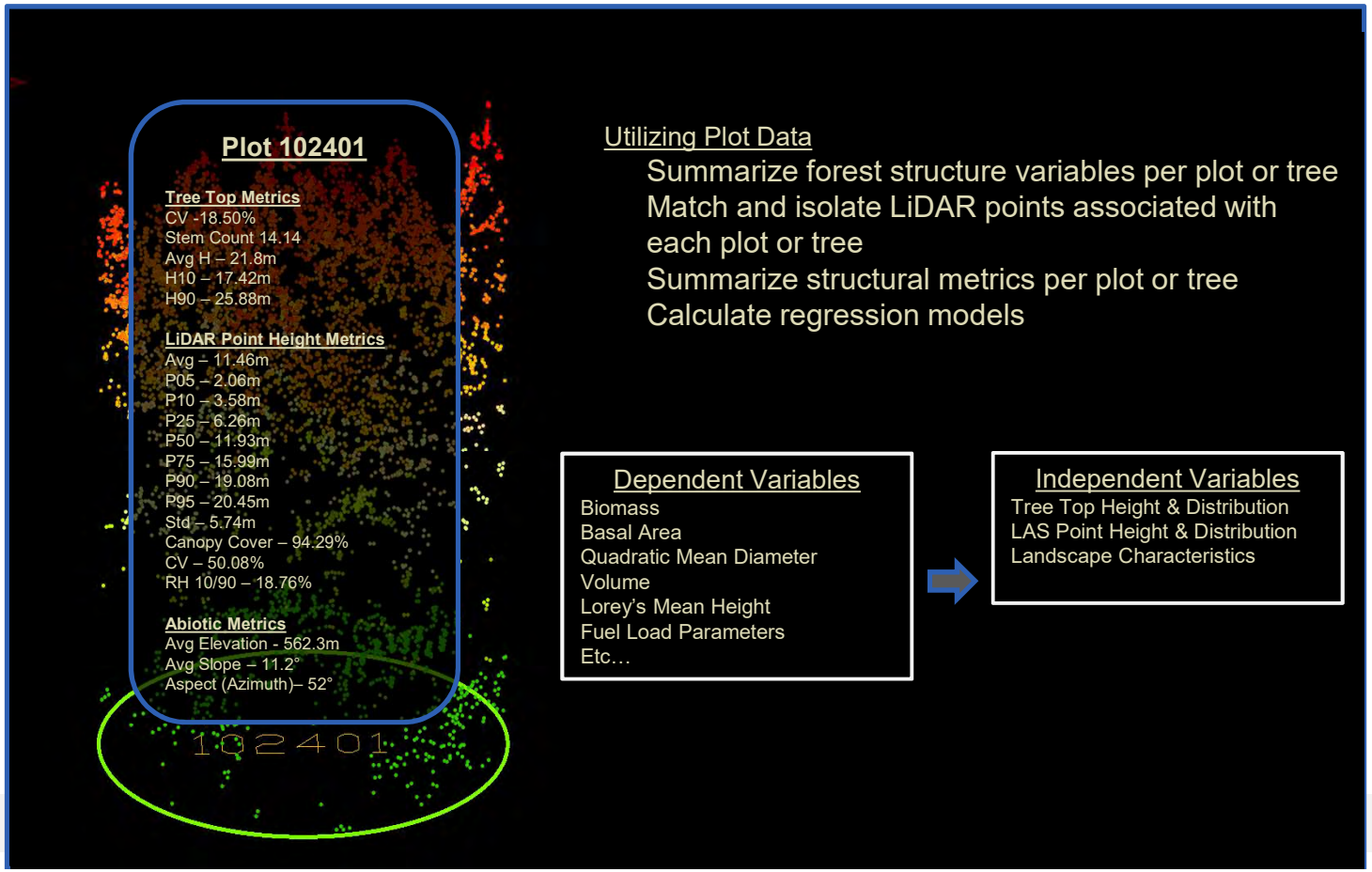
- Location
- Overstory tree delineation
- Attributes that are desired for analysis

Tree – plot - stand

- Plot design
  - Variable area
  - Fixed area
- Data summarization
  - Tree
  - Plot
  - Stand



Analysis


Plot 102401
Tree Top Metrics
CV -18.50%
Stem Count 14.14
Avg H – 21.8m
H10 – 17.42m
H90 – 25.88m
LiDAR Point Height Metrics
Avg – 11.46m
P05 – 2.06m
P10 – 3.58m
P25 – 6.26m
P50 – 11.93m
P75 – 15.99m
P90 – 19.08m
P95 – 20.45m
Std – 5.74m
Canopy Cover – 94.29%
CV – 50.08%
RH 10/90 – 18.76%
Abiotic Metrics
Avg Elevation - 562.3m
Avg Slope – 11.2°
Aspect (Azimuth)– 52°
102401
Utilizing Plot Data
Summarize forest structure variables per plot or tree
Match and isolate LiDAR points associated with each plot or tree
Summarize structural metrics per plot or tree
Calculate regression models
Dependent Variables
Biomass
Basal Area
Quadratic Mean Diameter
Volume
Lorey's Mean Height
Fuel Load Parameters
Etc…
Independent Variables
Tree Top Height & Distribution
LAS Point Height & Distribution
Landscape Characteristics

Integration with imagery

Challenges are

- Wide variations in imagery and how it is collected
- Spectral, spatial, & temporal quality varies
- Lack of robust normalization between missions/sensors
- Introduce noise into statistics

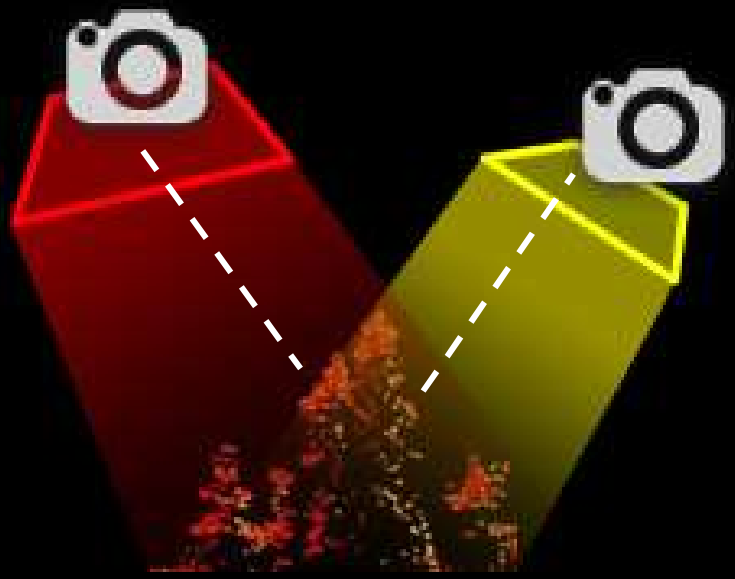
Our solution is

- Directional colorization process for lidar based on origin point of pulse and image
- True ortho colorization
- No tree lean or occlusion
- Support refined segmentation
- Improved spectral signature for classification

Colorization Approach

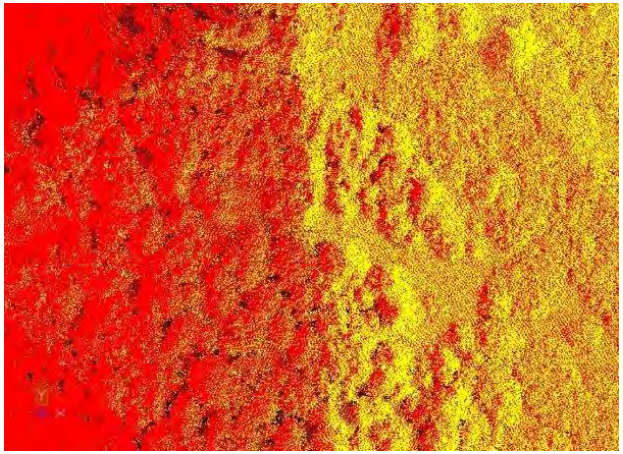
Lidar

True ortho color



Point Specific Pixel Assignment

- Can be 4 band, multi-temporal, thermal or hyperspectral
- Can assign indices rather than bands
- Puts the correct pixel on the correct point in the canopy
- Improves classification accuracy



Ray-Tracing of Imagery

Standard Ortho

Ray Traced

Segmentation Over Imagery

Segmentation Over Ray Traced

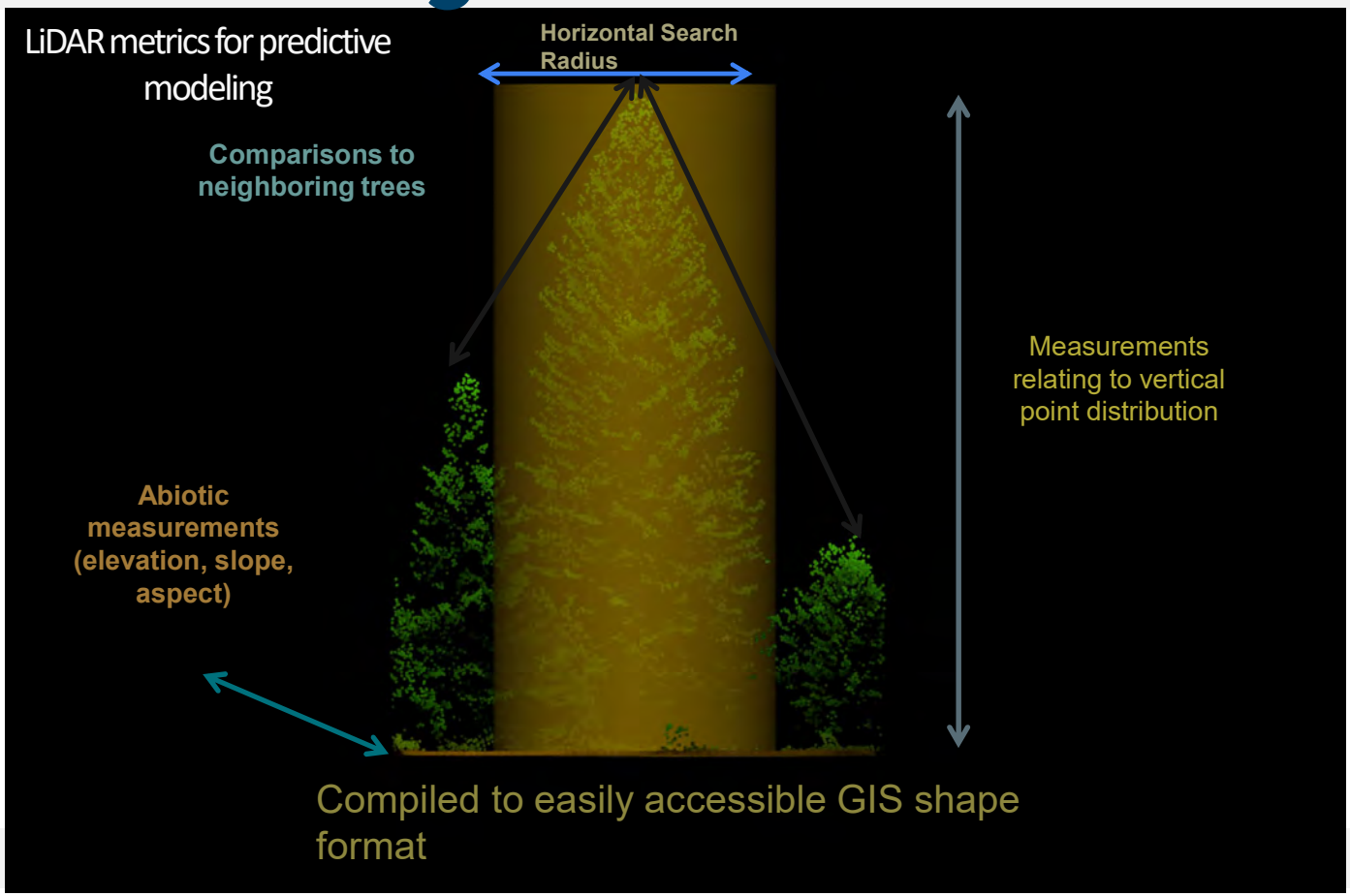
The ray traced imagery provides a visually chaotic, but spatially accurate reflection of the spectra in each tree polygon.

The species classification could not be successful without it.

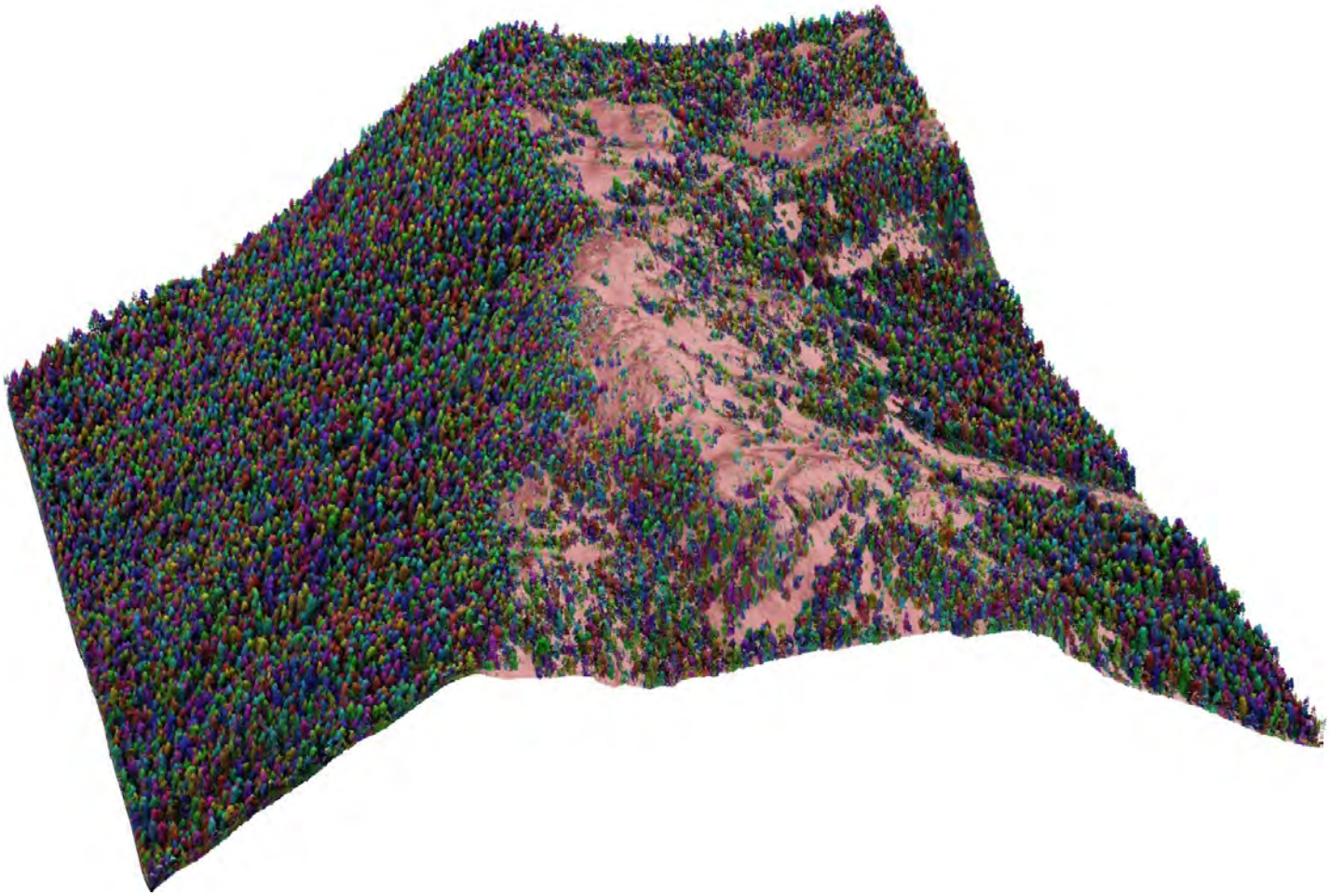
Individual Tree Segmentation
Tree Polygons
Ray Traced Imagery

Lidar point colorization

Geometric Segmentation



Conifer Forest



Machine Learning Segmentation

- **Machine learning takes a different approach**

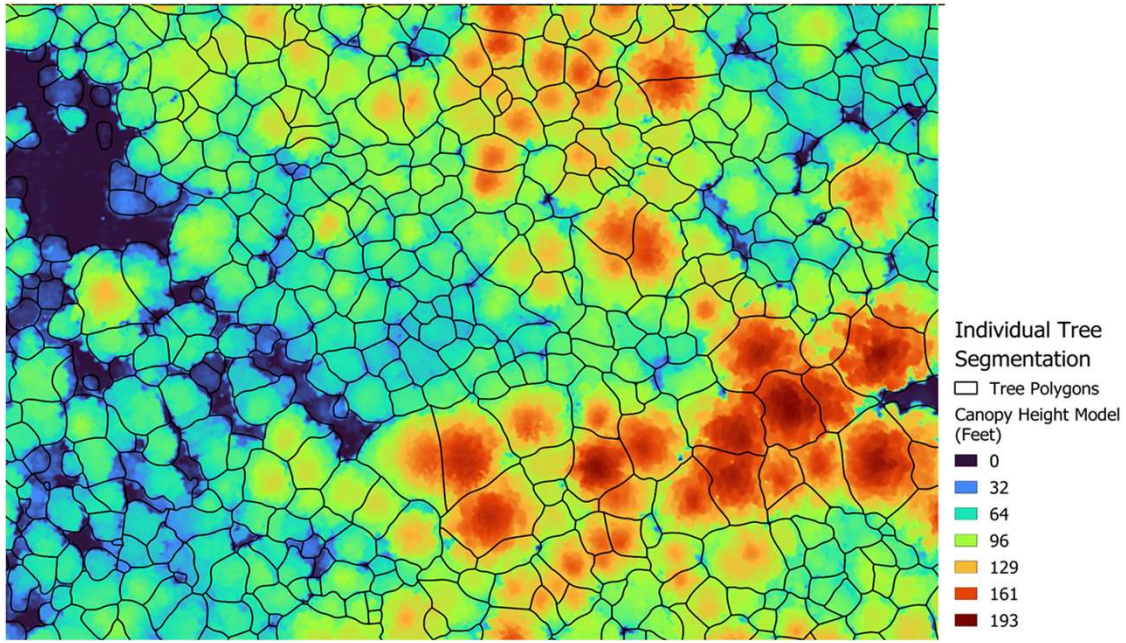
- Uses many examples of the trees and matches what it sees in the data stack to the tree examples
- Need field data, as much as you can get

- **Deep learning/automata based approach**

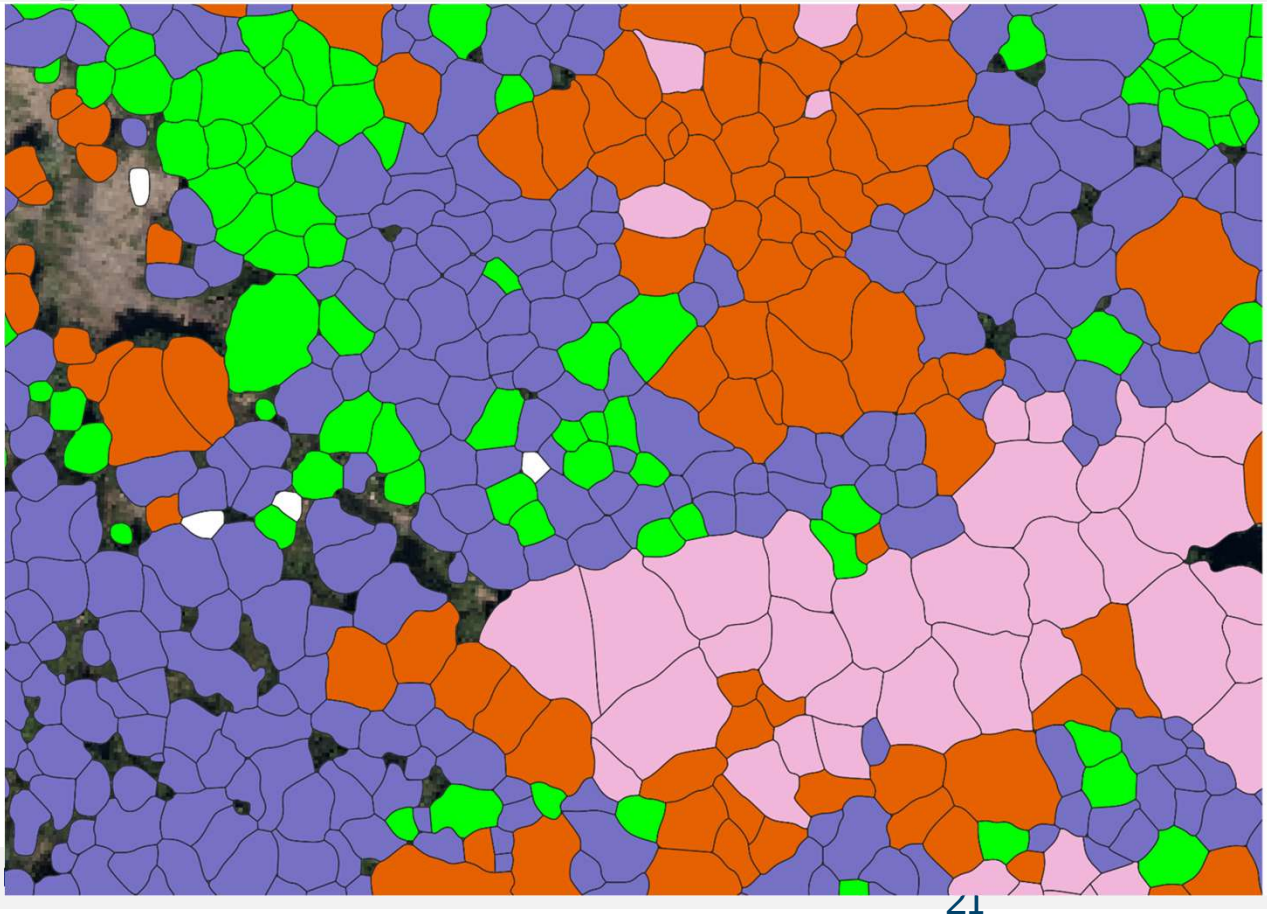
- Deep learning models used to generate probabilistic estimates of tree stem locations, canopy, and regions of canopy edge
- Stem locations represent seed for competitive automata models
- Trees ‘compete’ for space and area based on a set of predicted deep learning variables
- Final crown boundaries are refined through heuristic (self learning) reshaping algorithms

Machine Learning Segmentation

- **Ray Traced Imagery**
  - The ray traced imagery provides spatially accurate spectra for each tree polygon.
  - Significantly improves the value of the imagery for classification
- **Training data**
  - Tree stem locations
  - Additional trees photo-interpreted from the point cloud
  - Larger quantities of training data improve classification accuracy
  - Larger plots are better



Species Classification

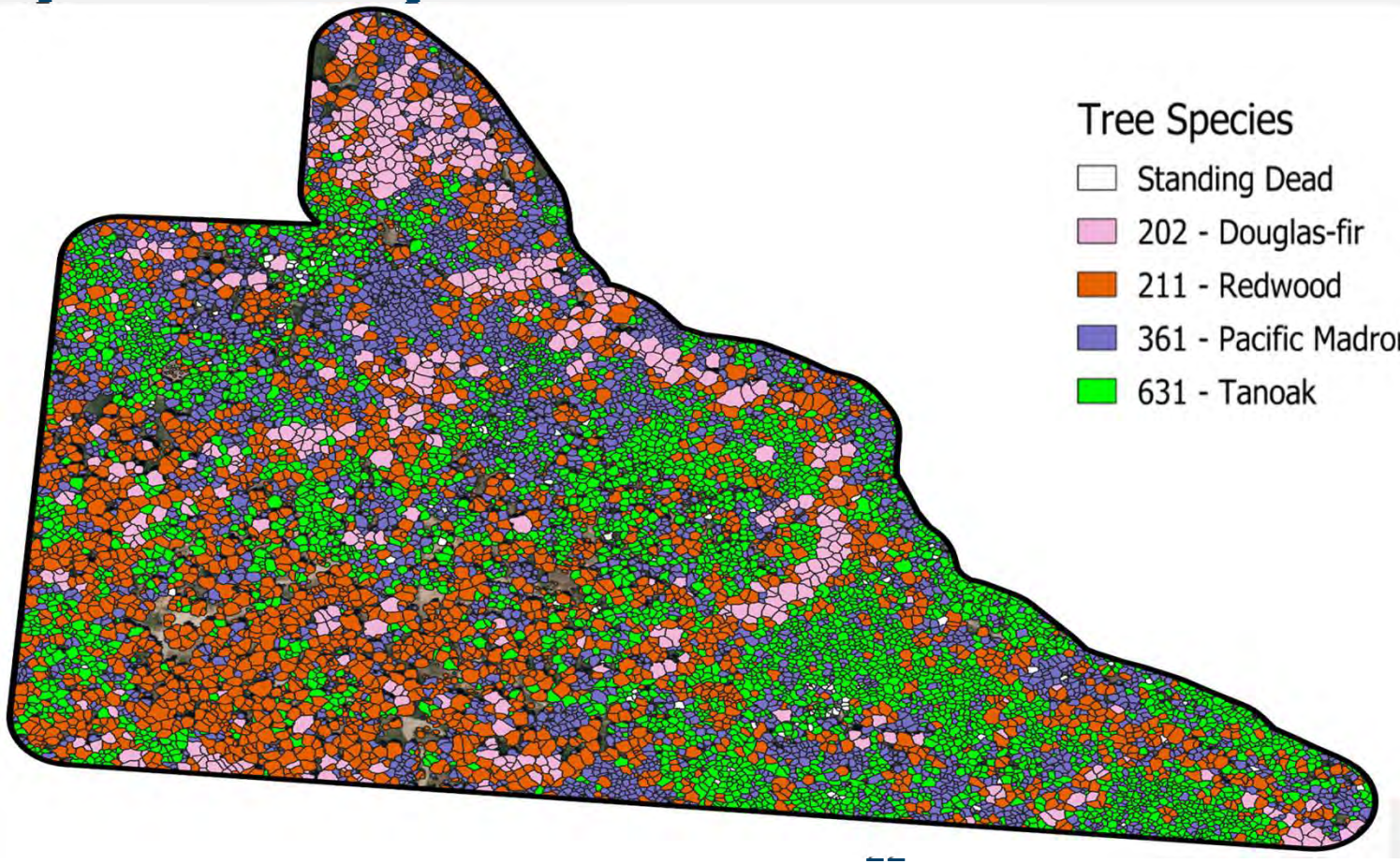


Field data were assigned to matching tree polygons. Then additional species labels were assigned based on photo interpretation.

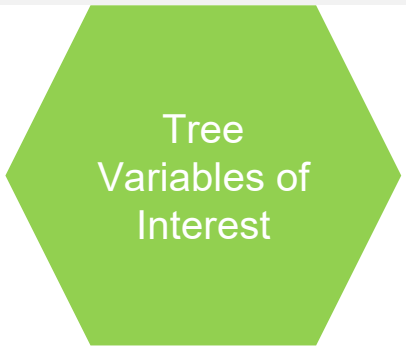
25% of reference data were withheld for validation.

Overall Accuracy: 94.22%
CI: 89.63% - 97.19%
Kappa: 91.72

Species Map

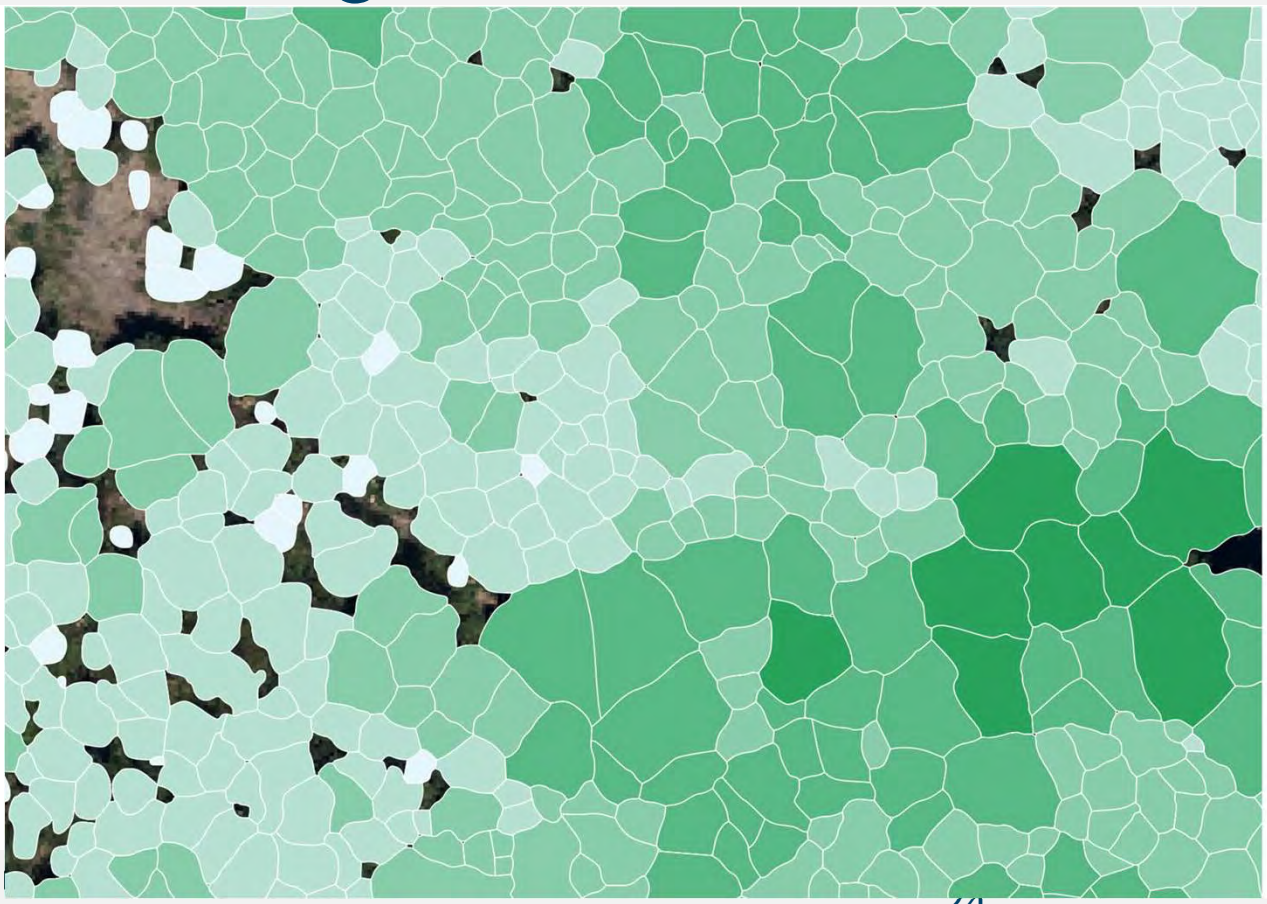

Tree Species
Standing Dead
202 - Douglas-fir
211 - Redwood
361 - Pacific Madrone
631 - Tanoak

Metrics



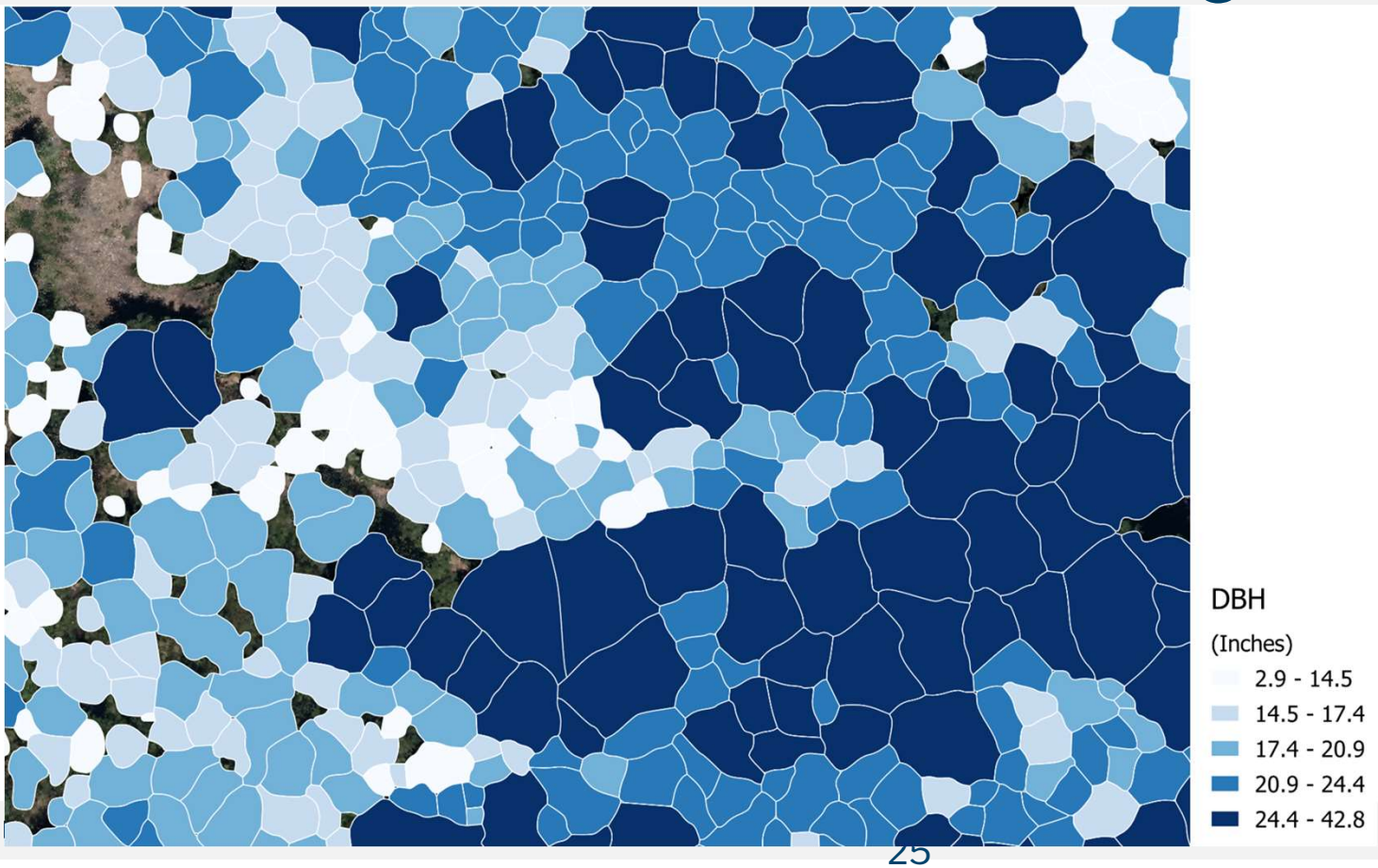
- **Reliable tree segments important**
  - Segmentation accuracy is dependent on the forest character
    - Tree density
    - Tree type
    - Forest complexity
  - Does not capture sub-dominant and understory trees

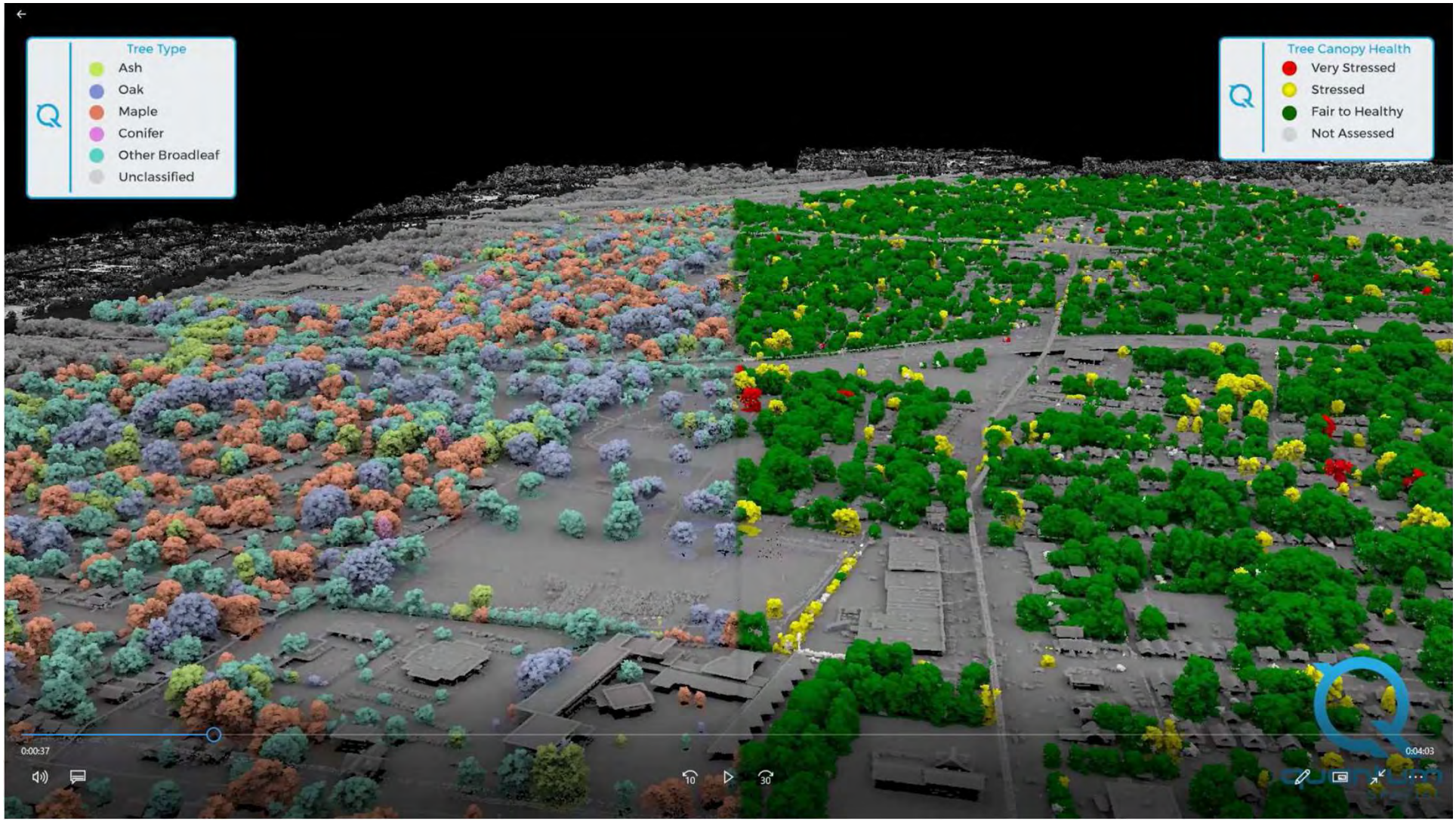
Tree Height



Tree height is measured by the 95th height percentile of the lidar point cloud within each tree polygon.

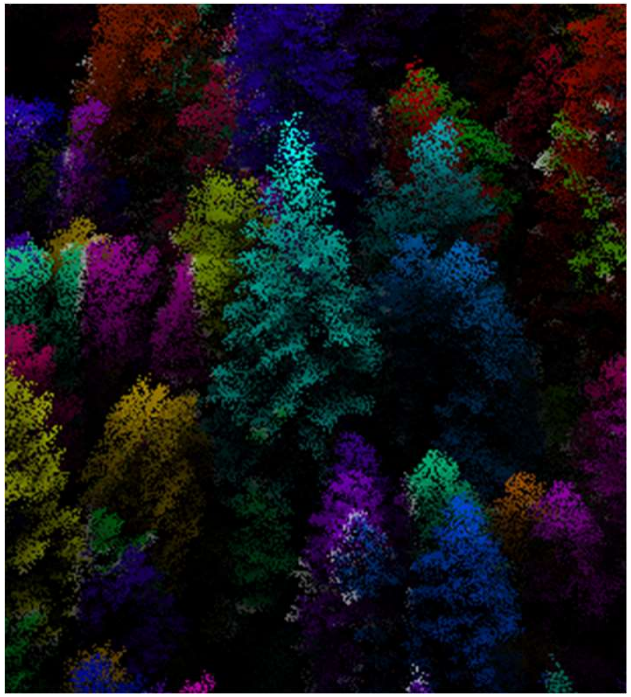
Predicted Diameter at Breast Height




Tree Type
Ash
Oak
Maple
Conifer
Other Broadleaf
Unclassified
Tree Canopy Health
Very Stressed
Stressed
Fair to Healthy
Not Assessed
0:00:37
0:04:03

Summary

- Not all lidar or imagery is born equal
- Field data collection will remain critical to creating good inventory information, but data collection approaches will need to change
- To integrate imagery into a point cloud for individual tree delineation ray tracing is valuable
- Segmentation can be created from geometric or machine learning approaches
- Individual tree methods are good for standard forestry and other applications but miss sub-canopy components
- Individual tree delineation will change our understanding of the forest and how we manage both forest information and the forests themselves



Questions?

Contact
andrew.brenner@NV5.com
734-680-6424