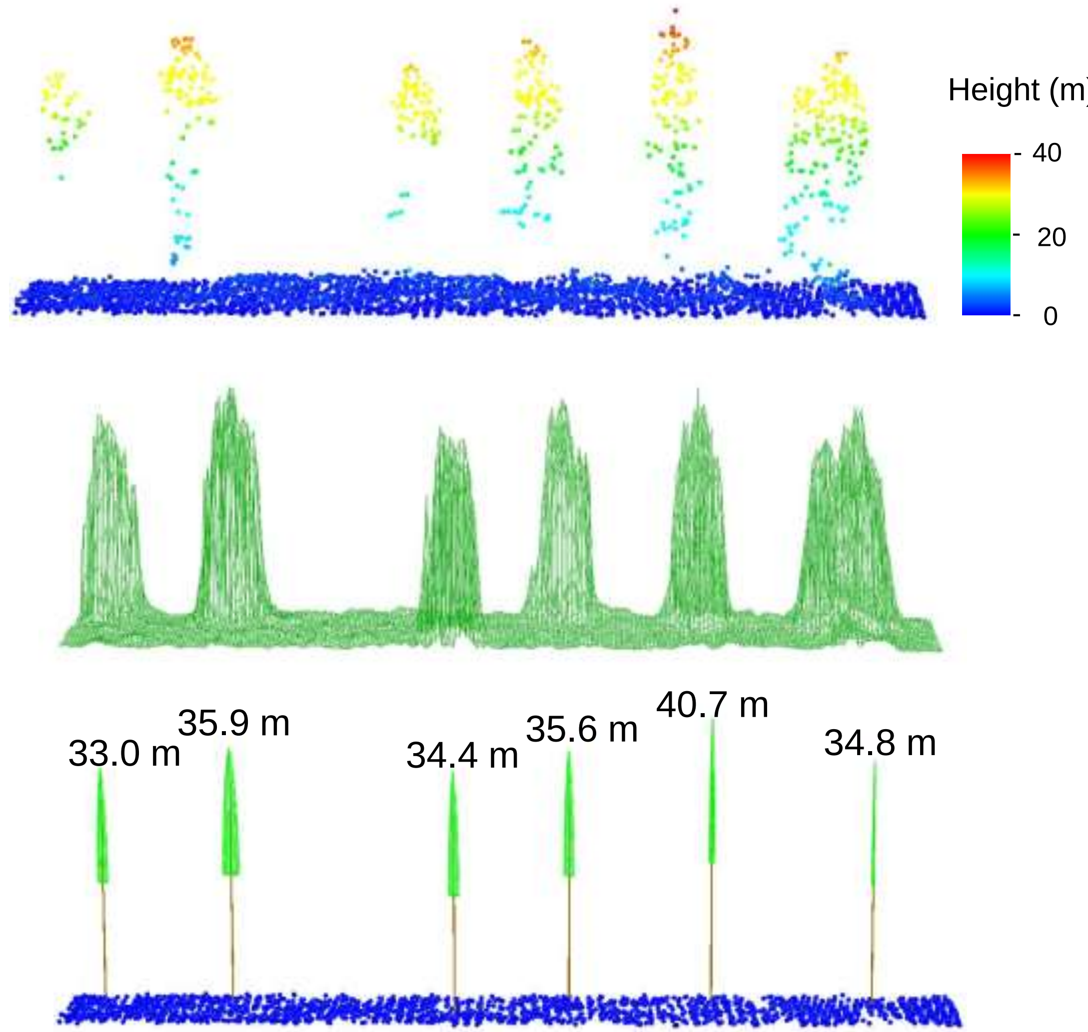
Tree Level Analysis

Step 1: Create Digital Surface Model (DSM)

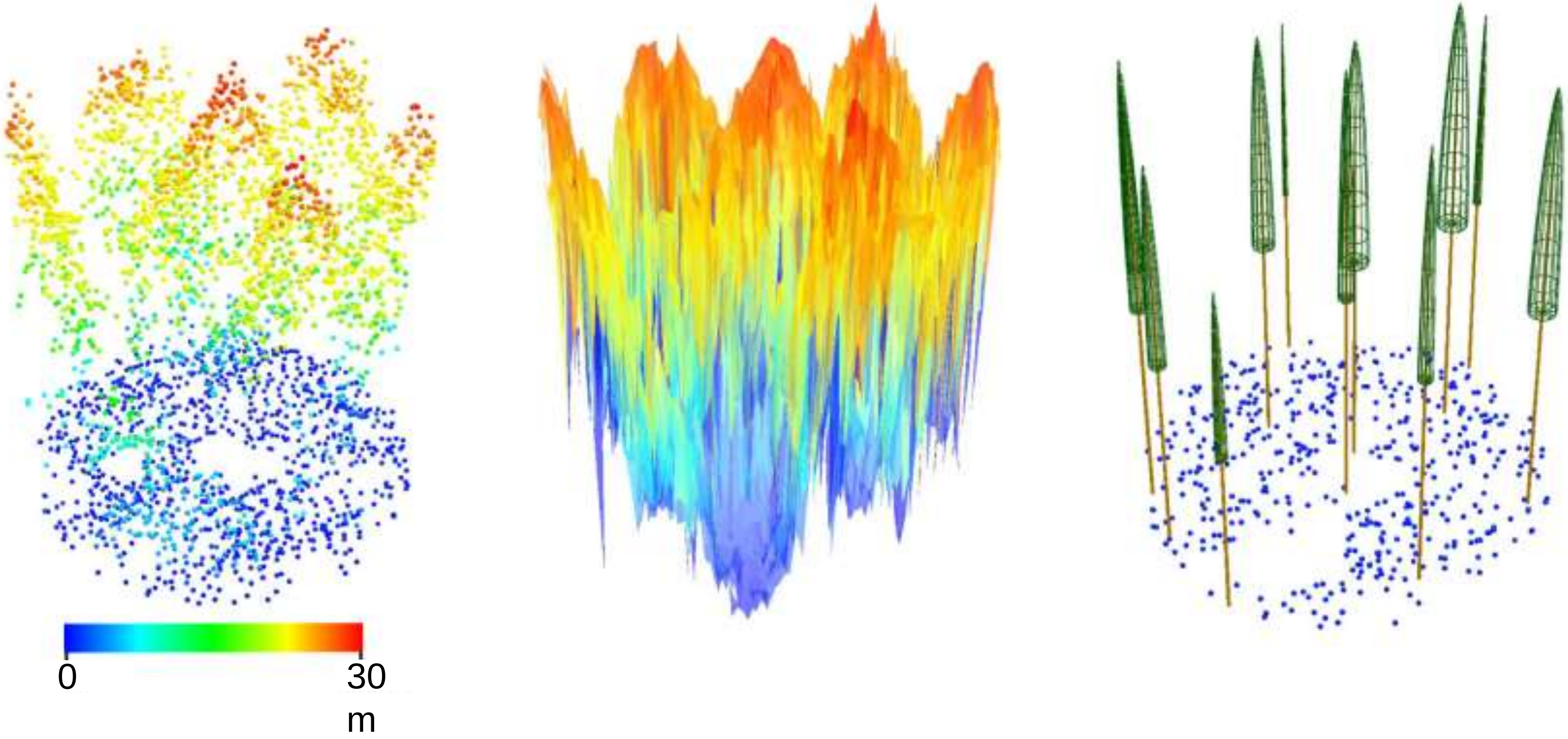
Step 2: Deploy algorithms to identify peaks in DSM

Difficult in dense canopies



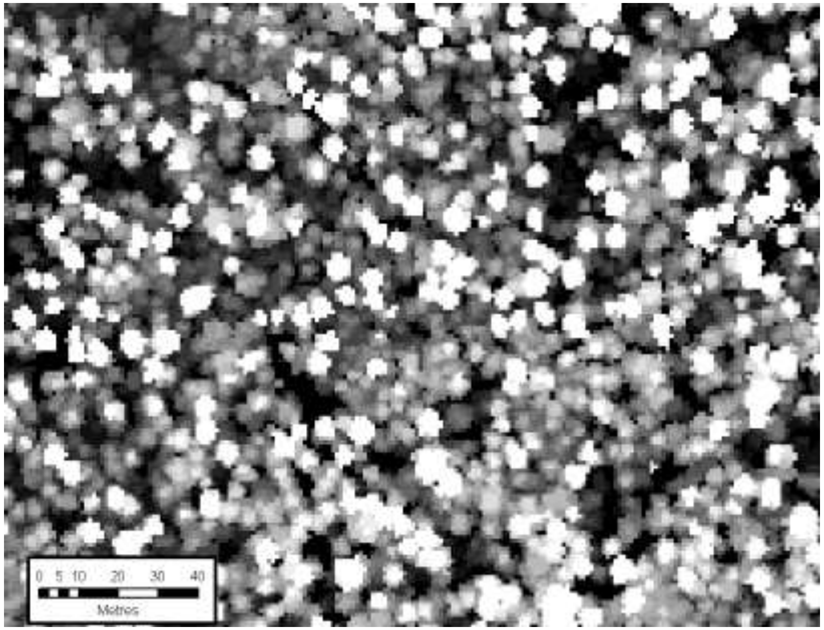
LiDAR visualizations produced with FUSION/LDA software – USDA Forest Service

Tree Level Analysis

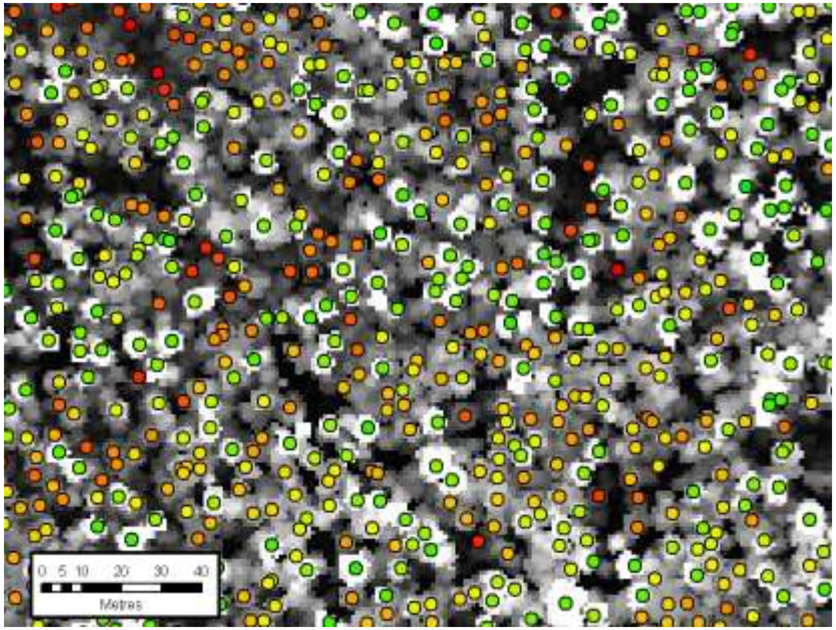


Tree Level Analysis

Identification of individual trees using a Digital Surface Model



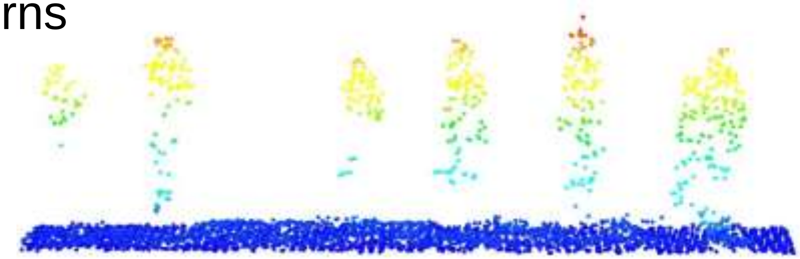
DSM



DSM with trees identified

Tree Level Analysis – Maximum Tree Height

- High levels of accuracy with differences generally < 1 m
- Some argue LiDAR heights are more accurate than field measurements of tree height
- The derivation of tree heights will be affected by:
  - Sampling density
    - High density improves changes of hitting tree top
  - Tree dimensions
    - A smaller crown will have fewer returns
  - Occlusion
    - Adjacent trees



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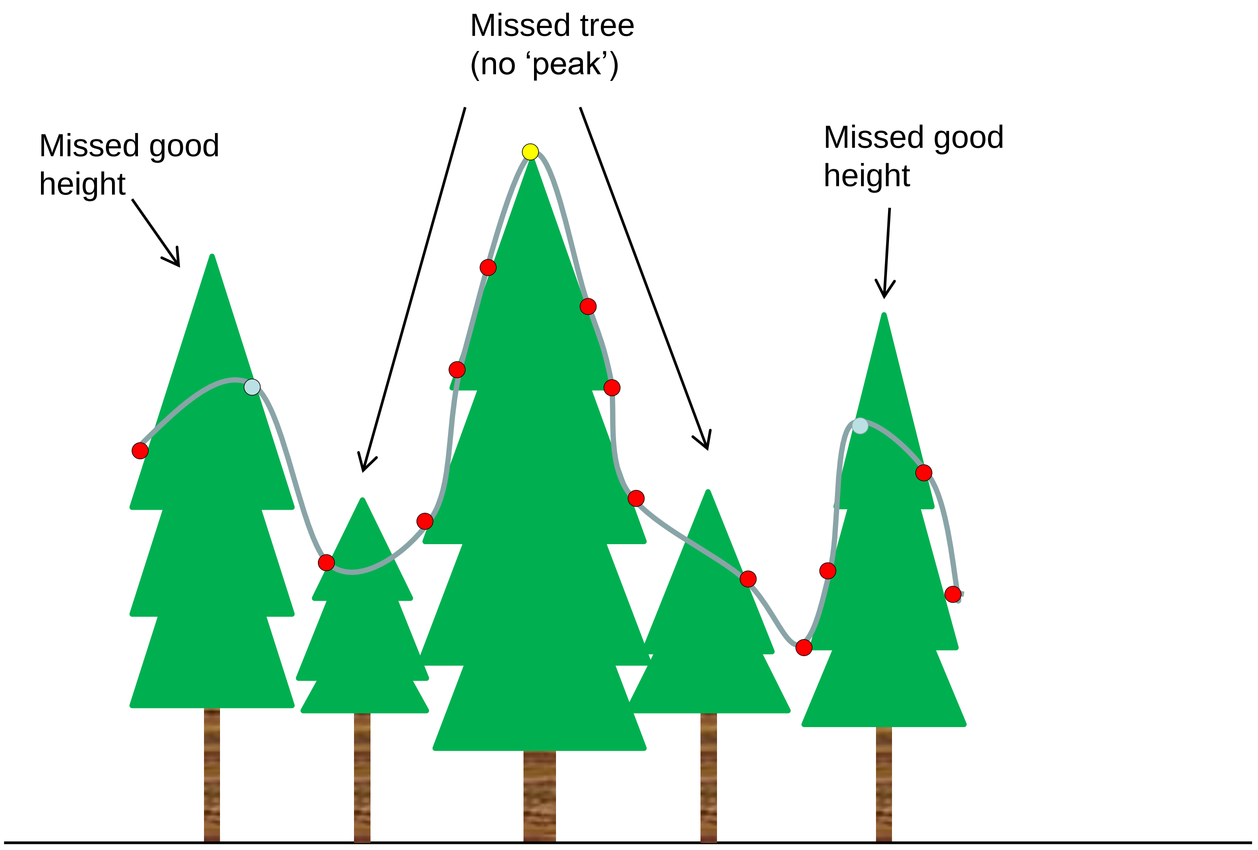
Tree Level Analysis – Maximum Tree Height

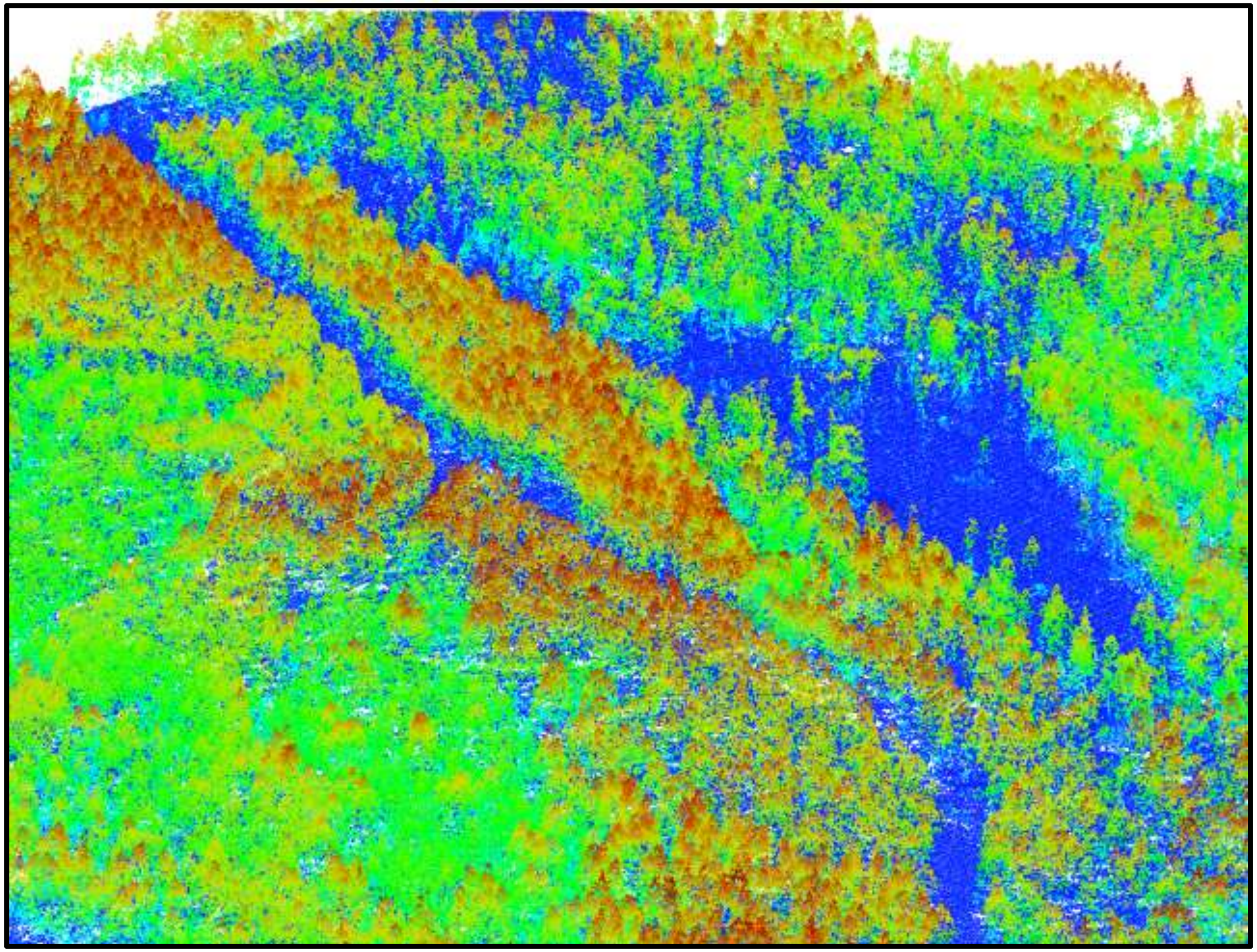
- Side Height
- Good Height
- Incorrect Height
- Interpolated Surface



Modified based on Zimble *et al.* 2003

Plot Level Analysis

LiDAR Point Cloud for Alex Fraser Research Forest

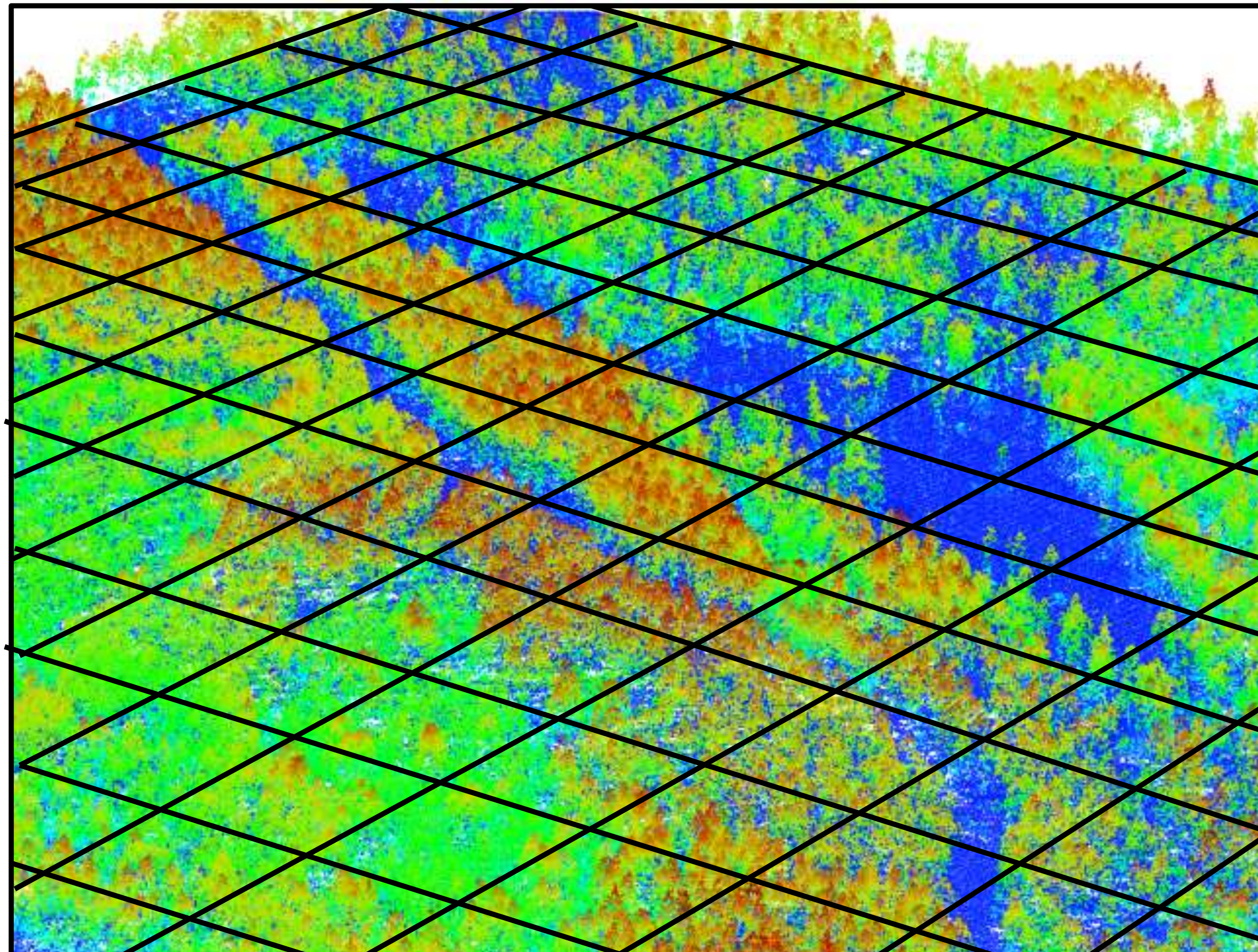


LiDAR visualizations produced with FUSION/LDA software – USDA Forest Service

Plot Level Analysis

- Summarize LiDAR data on a grid
- Use summary metrics to estimate forest attributes for each grid cell
- Must first develop relationships between LiDAR metrics and forest attributes

LiDAR Point Cloud for Alex Fraser Research Forest



LiDAR visualizations produced with FUSION/LDA software – USDA Forest Service

Plot Level Analysis

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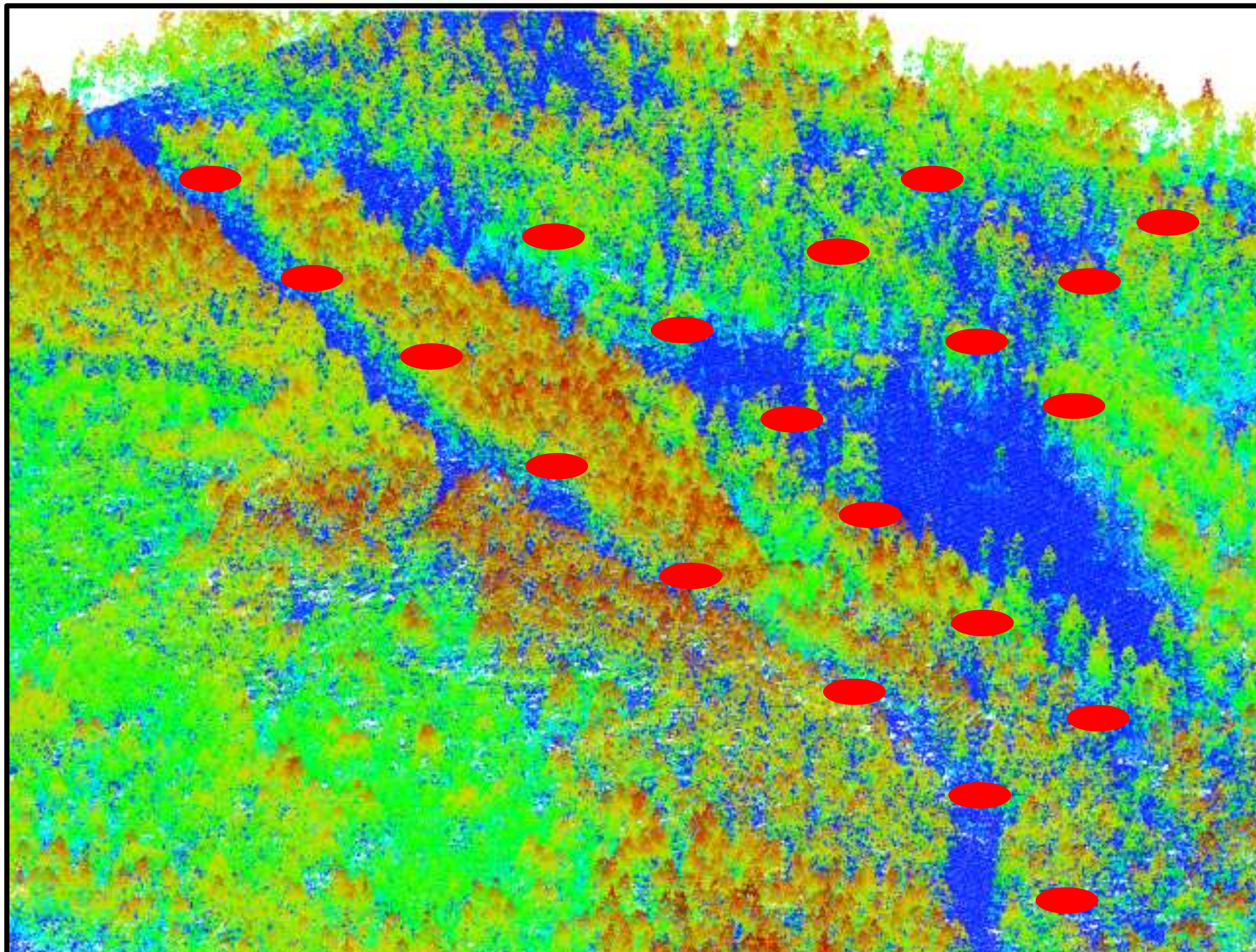
LiDAR Point Cloud for Alex Fraser Research Forest



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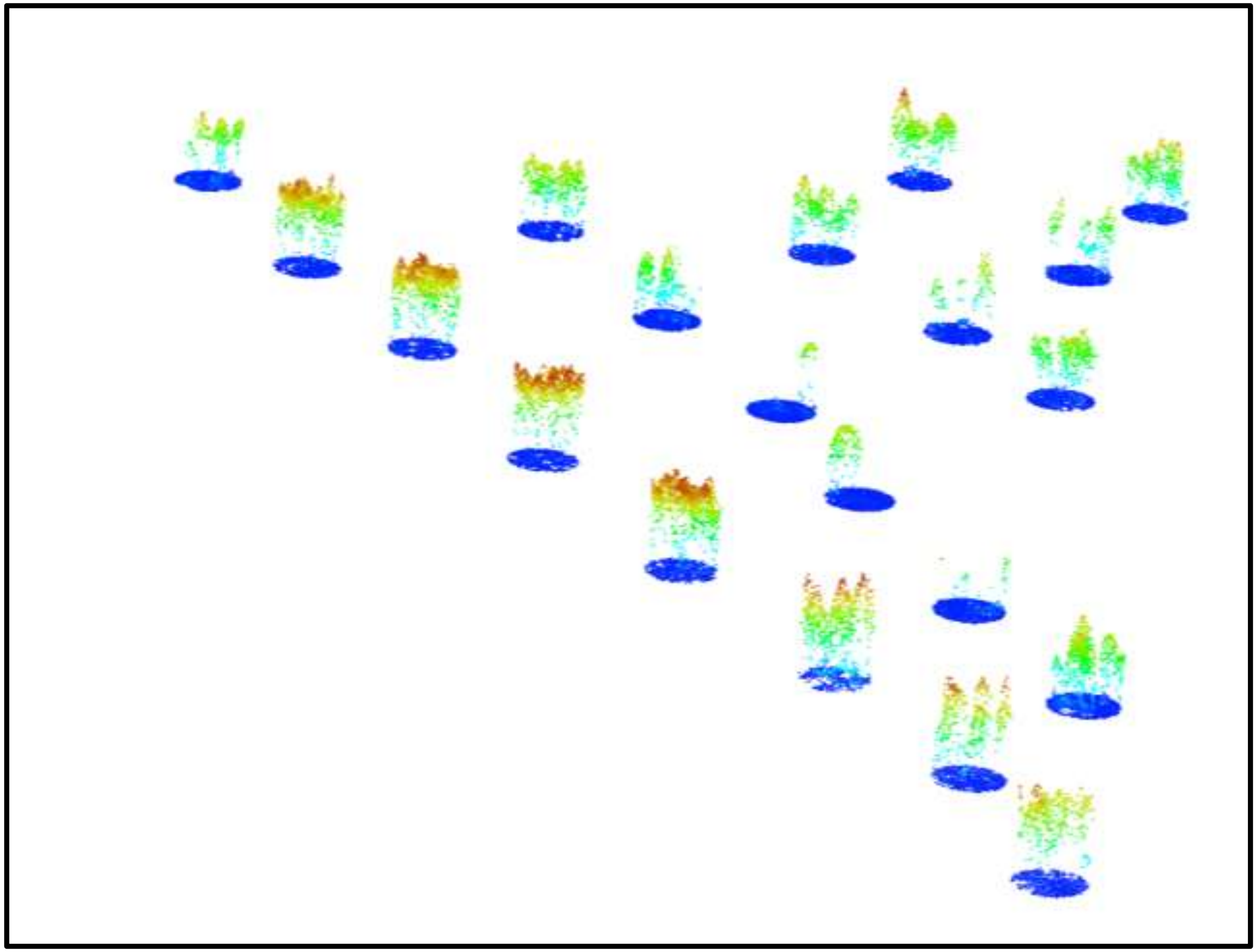
Plot Level Analysis

- Extract LiDAR data associated with each plot
- Summarize the LiDAR data within each plot
- Develop relationships between the LiDAR metrics and the plot level data

LiDAR Point Cloud for Alex Fraser Research Forest



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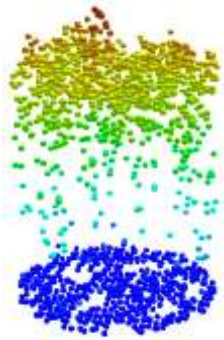
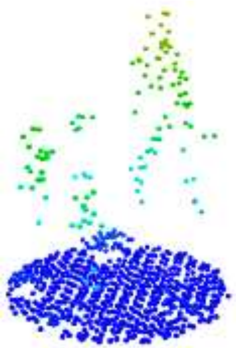
Plot Level Analysis

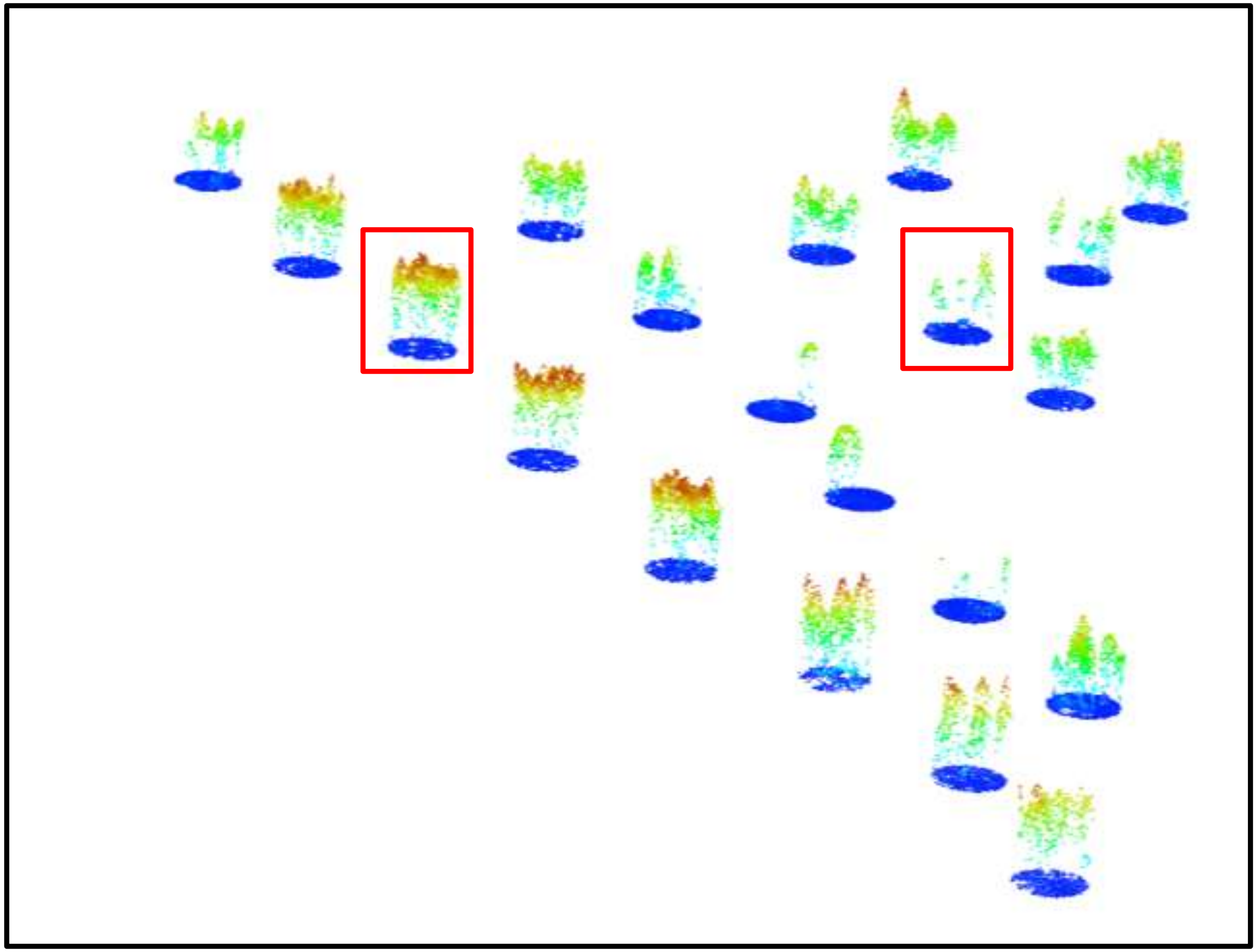


Site 1 –
High Volume Example



Site 2 -
Low Volume Example

LiDAR Point Cloud for Alex Fraser Research Forest



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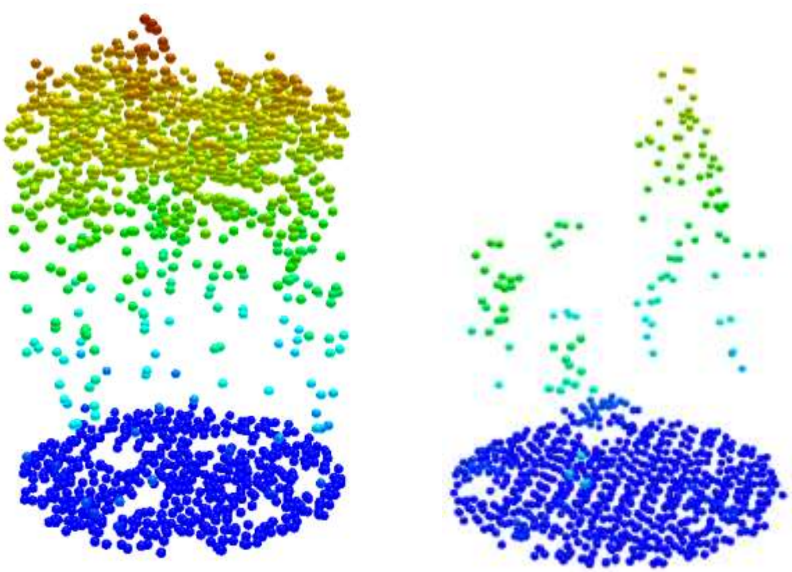
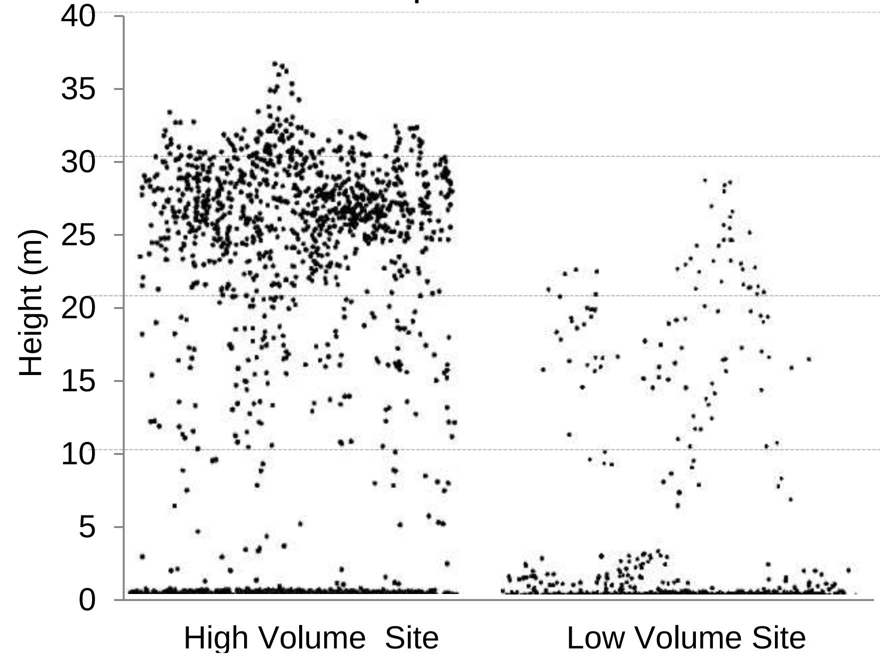
Plot Level Analysis

- Use first returns to calculate LiDAR metrics
    - Forest attributes calculated with first returns found to be more robust than using all returns (Bater et. al 2011)





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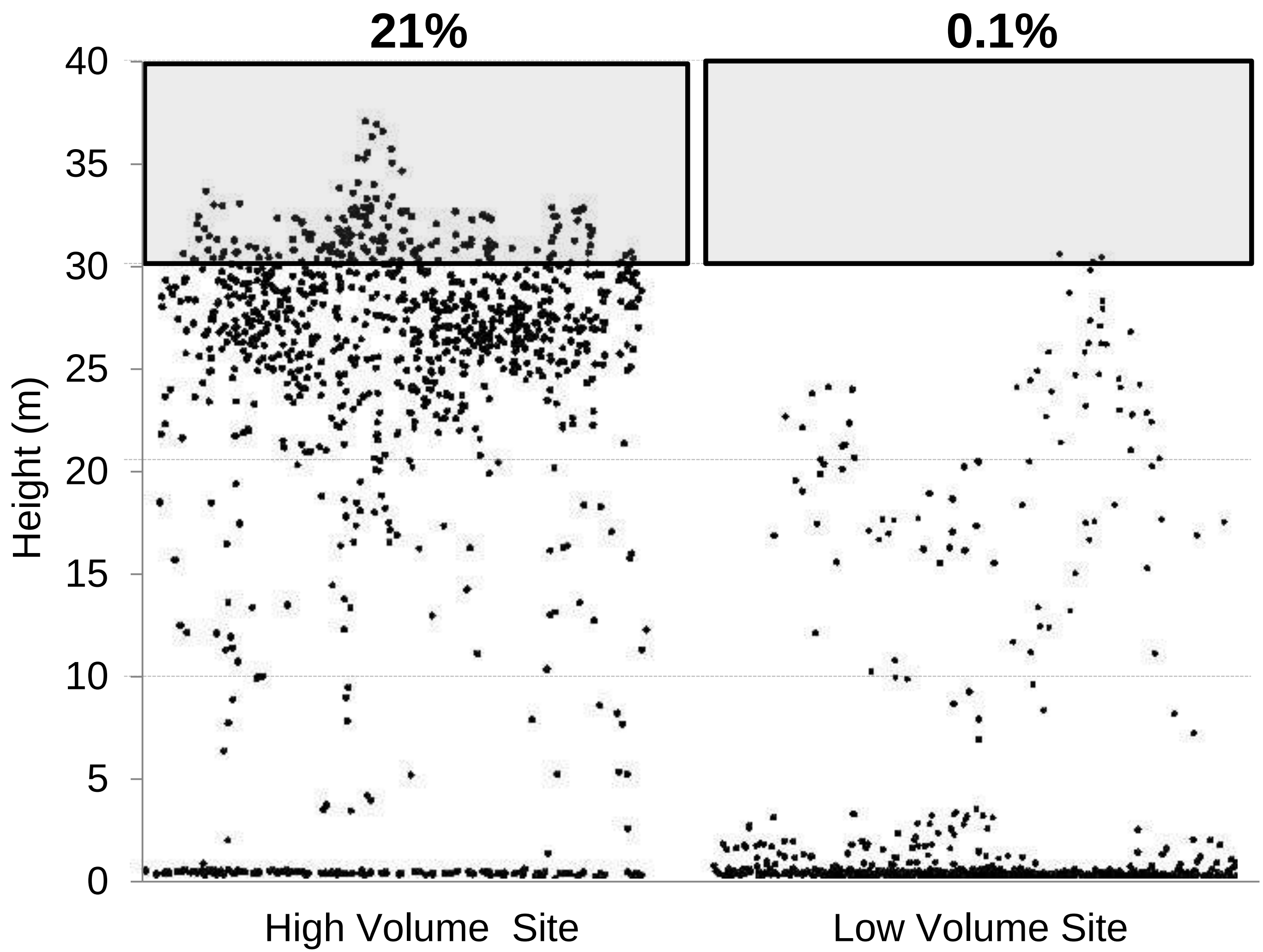
Plot Level Analysis

Calculate
Cover Metrics

Cover
30 – 40 m



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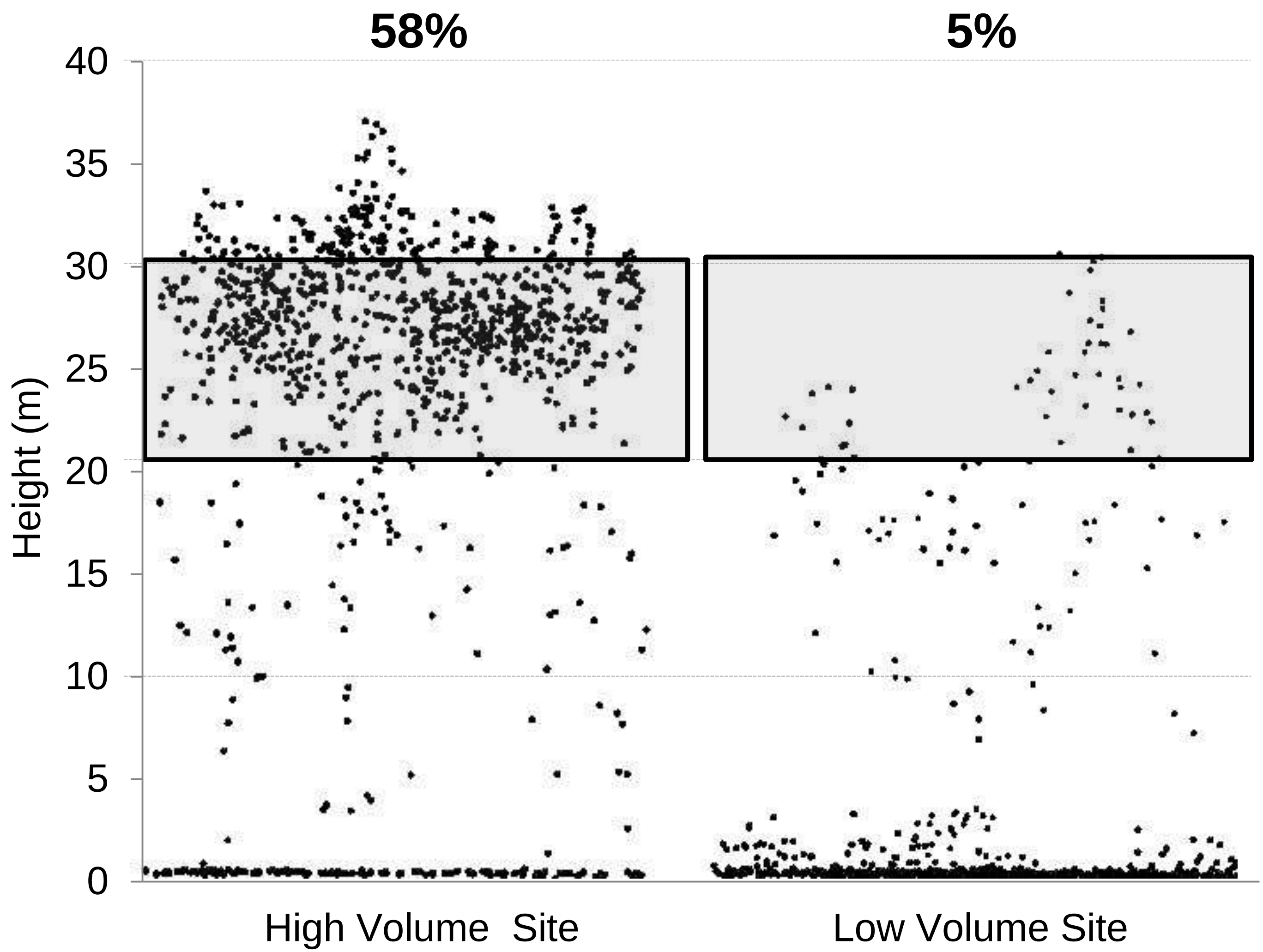
Plot Level Analysis

Calculate
Cover Metrics

Cover
20 – 30 m



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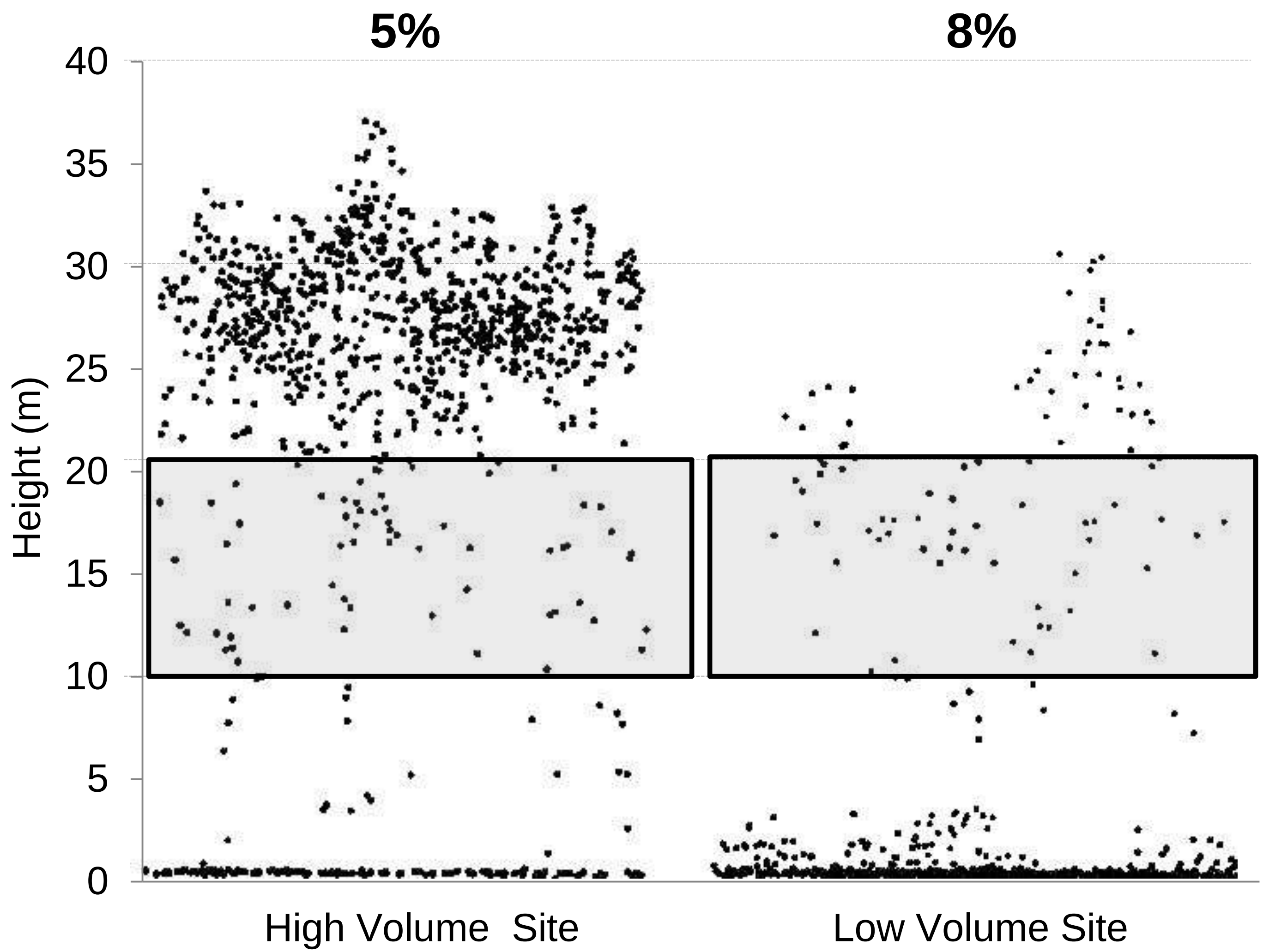
Plot Level Analysis

Calculate
Cover Metrics

Cover
10 – 20 m

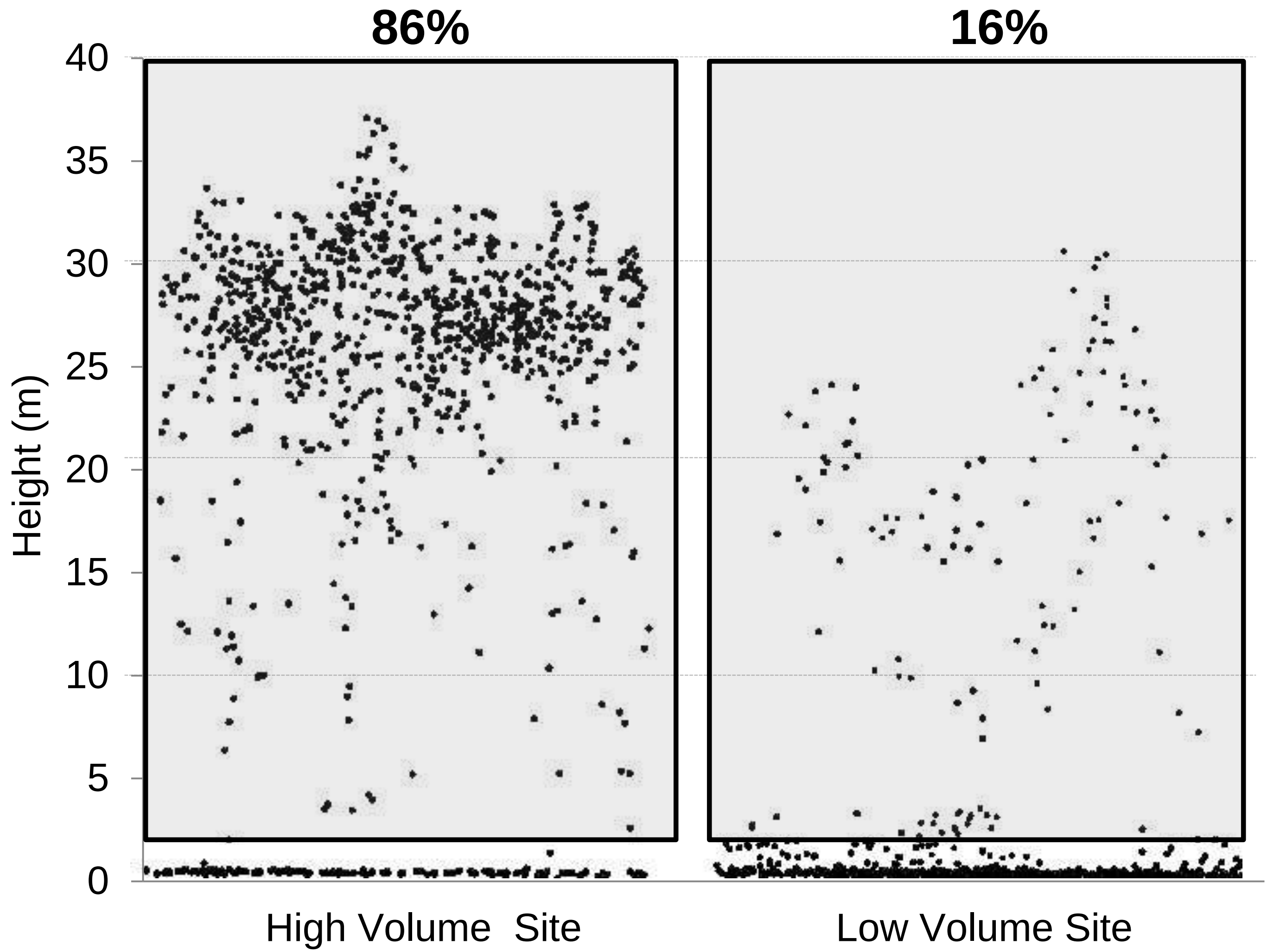


LiDAR visualizations produced with FUSION/LDA software – USDA Forest Service

Plot Level Analysis

Calculate
Cover Metrics

Cover
Above 2 m



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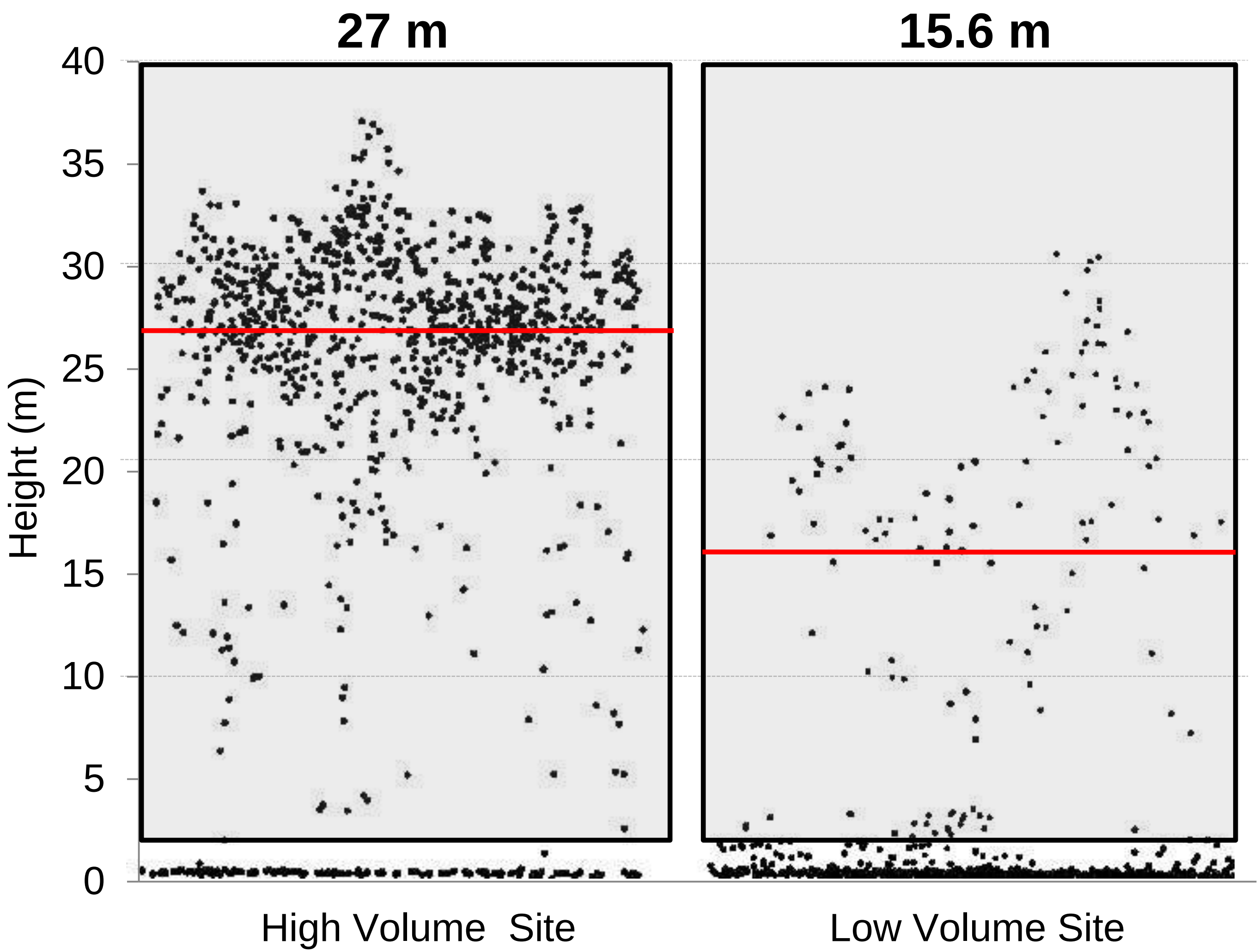
Plot Level Analysis

Calculate
Height Metrics

Mean
Height



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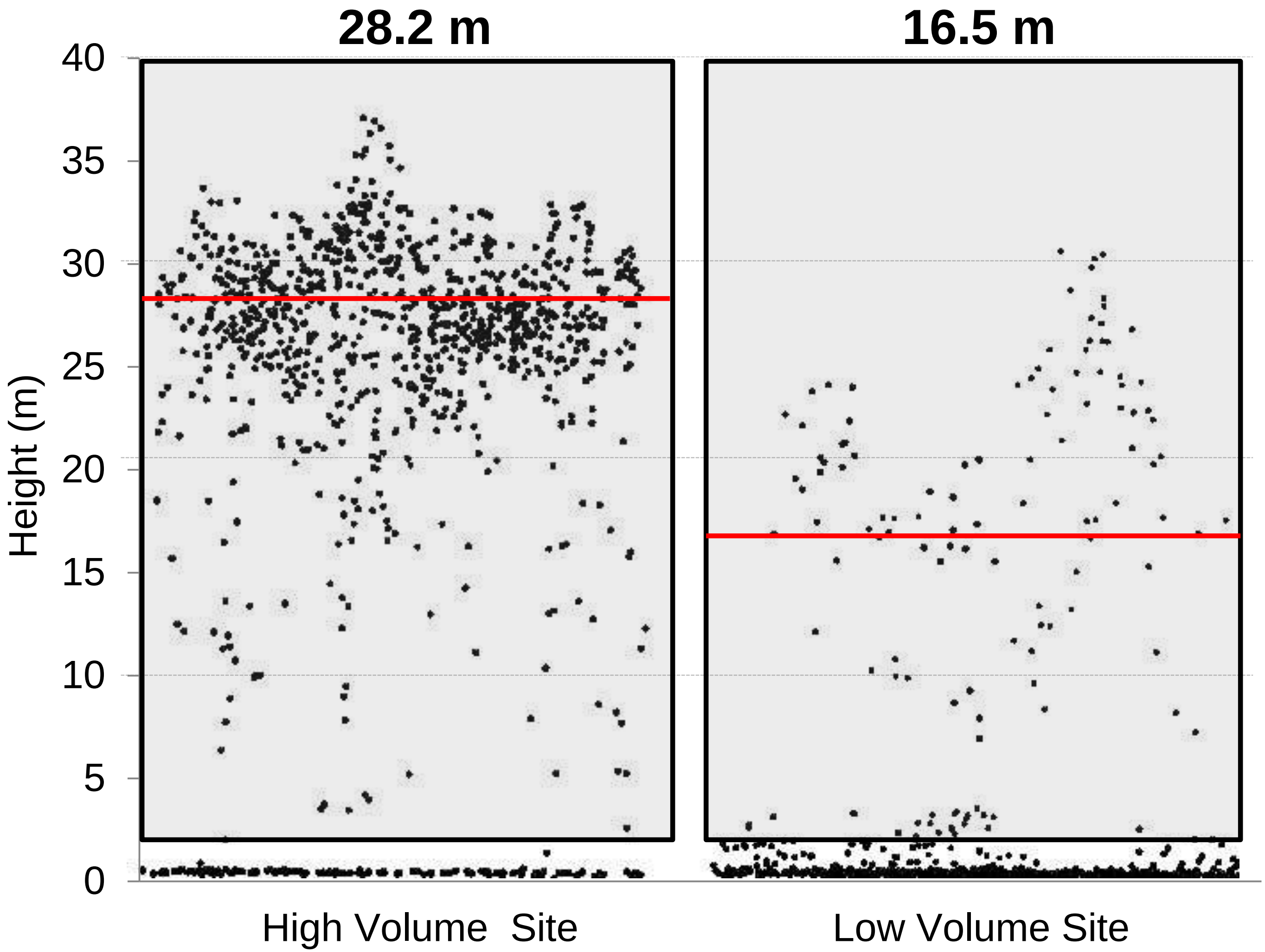
Plot Level Analysis

Calculate Height Metrics

50th Percentile



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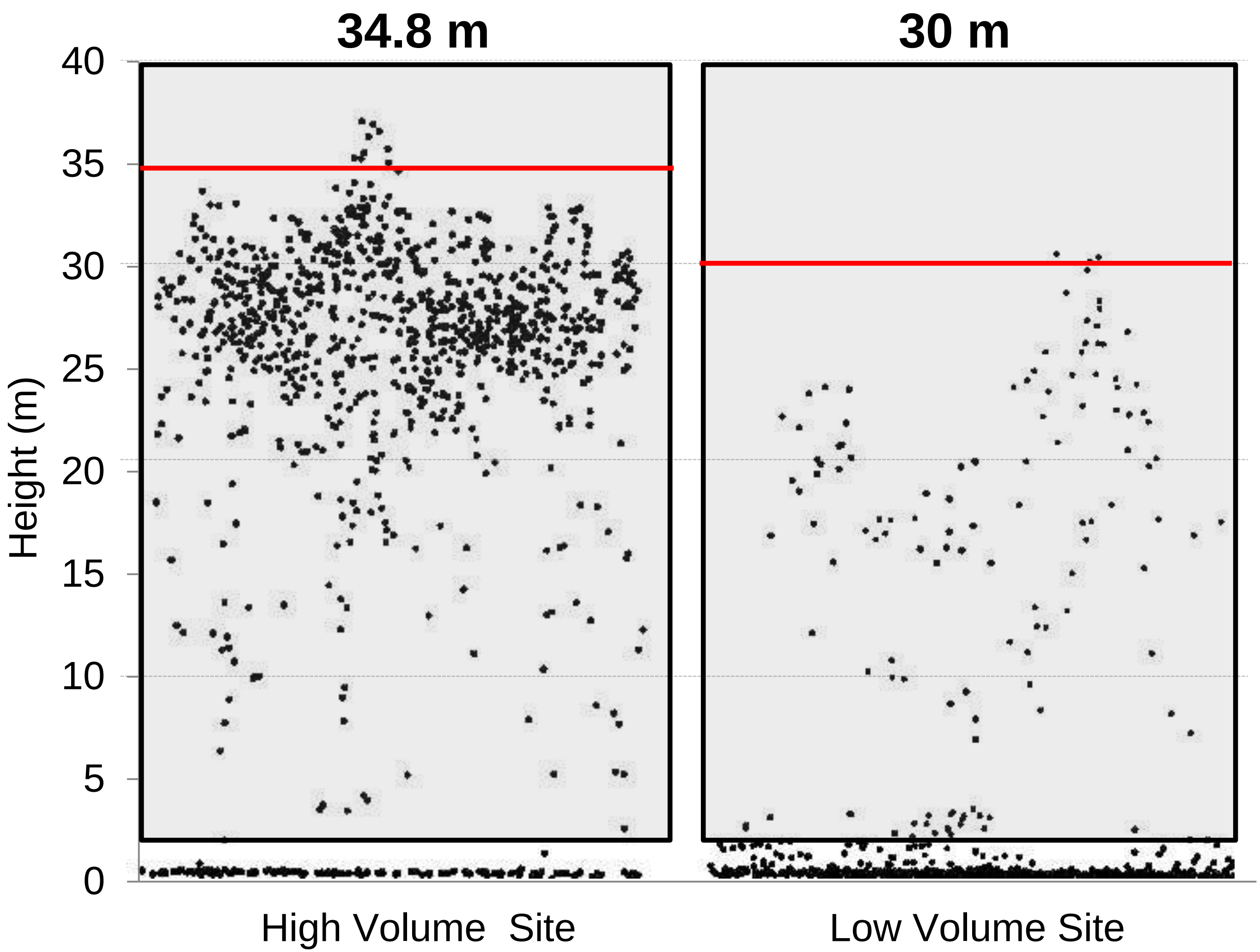
Plot Level Analysis

Calculate
Height Metrics

99th
Percentile



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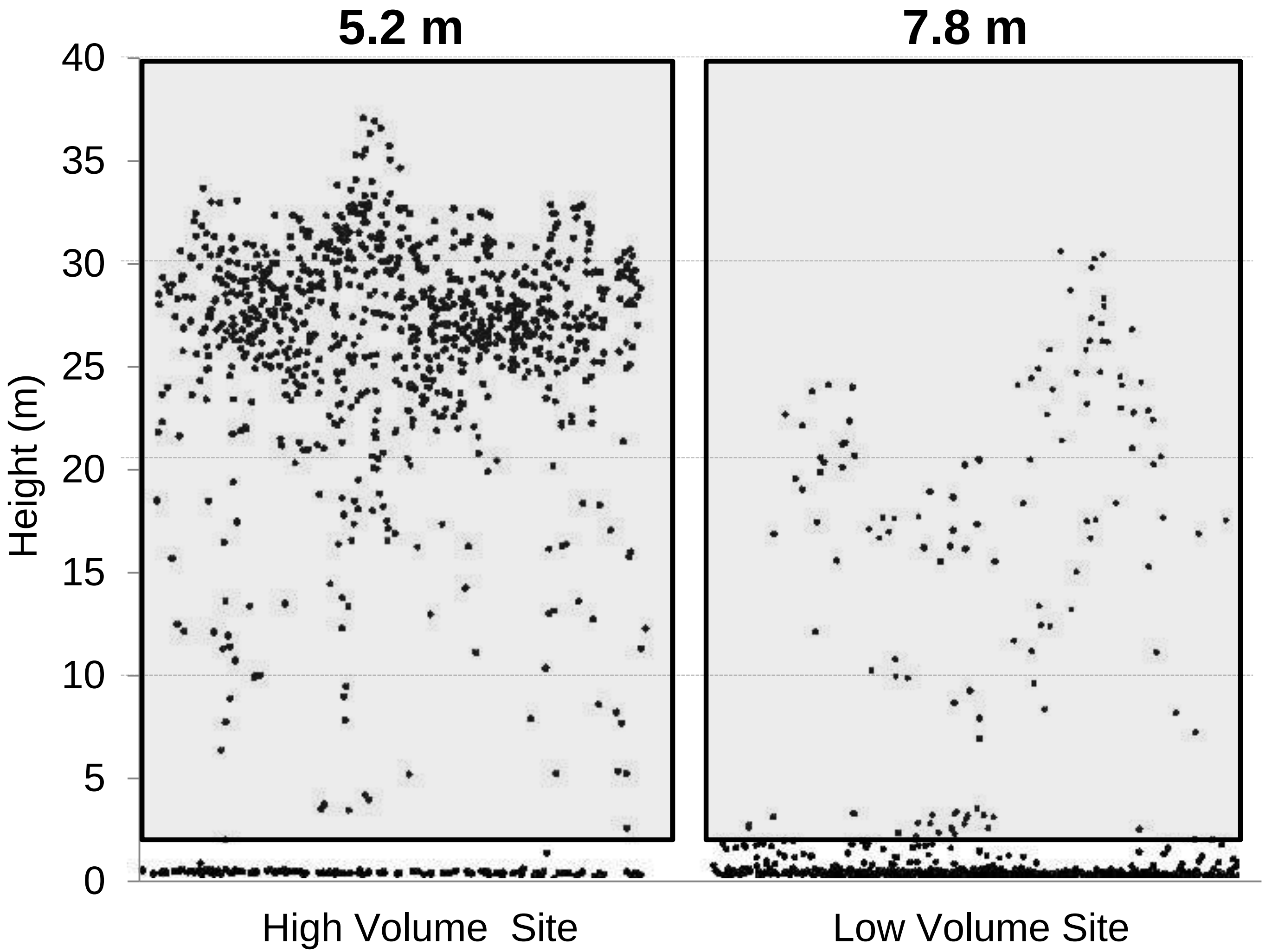
Plot Level Analysis

Standard Deviation



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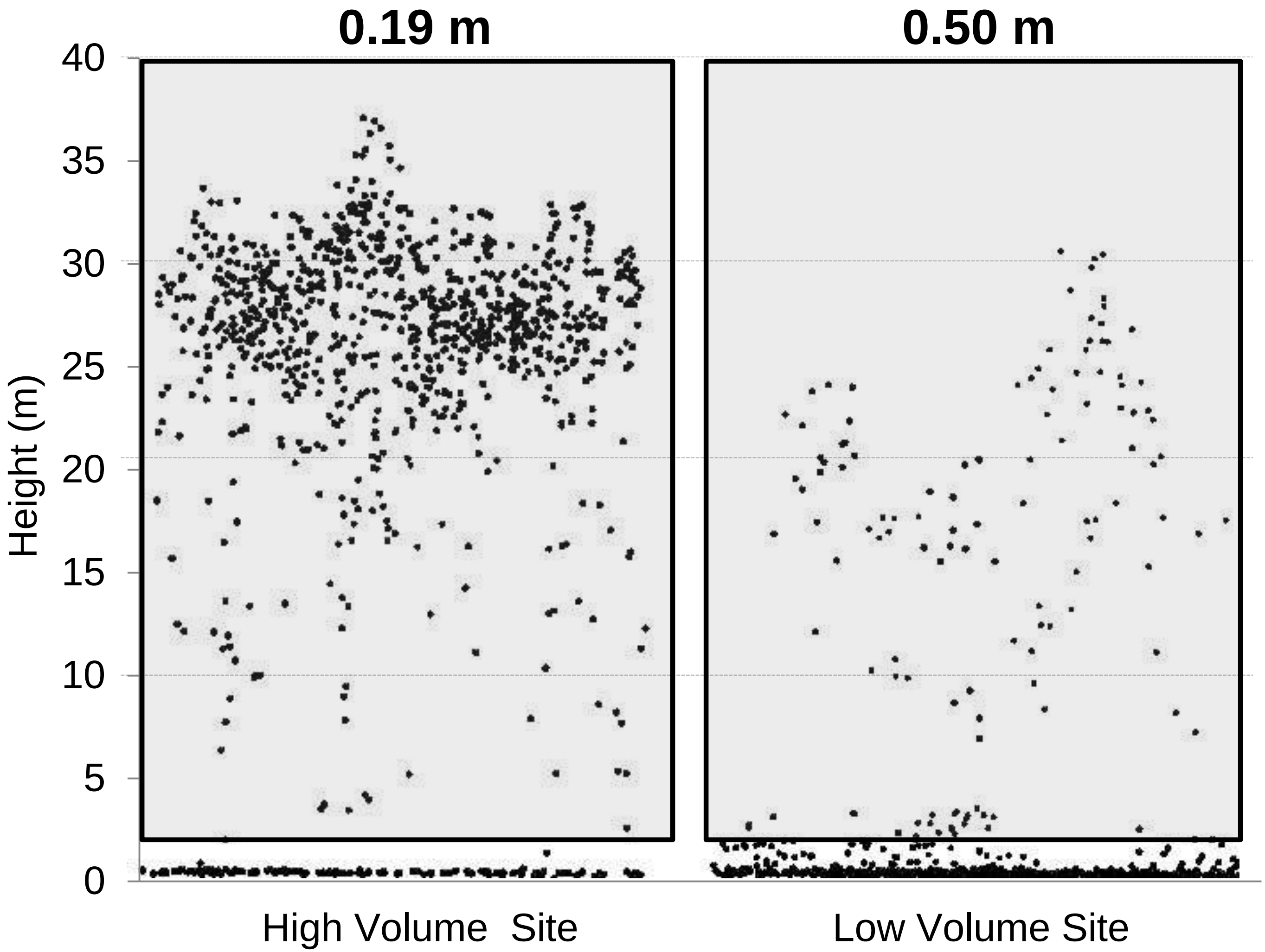
Plot Level Analysis

Coefficient of Variation

Measure of the structural diversity



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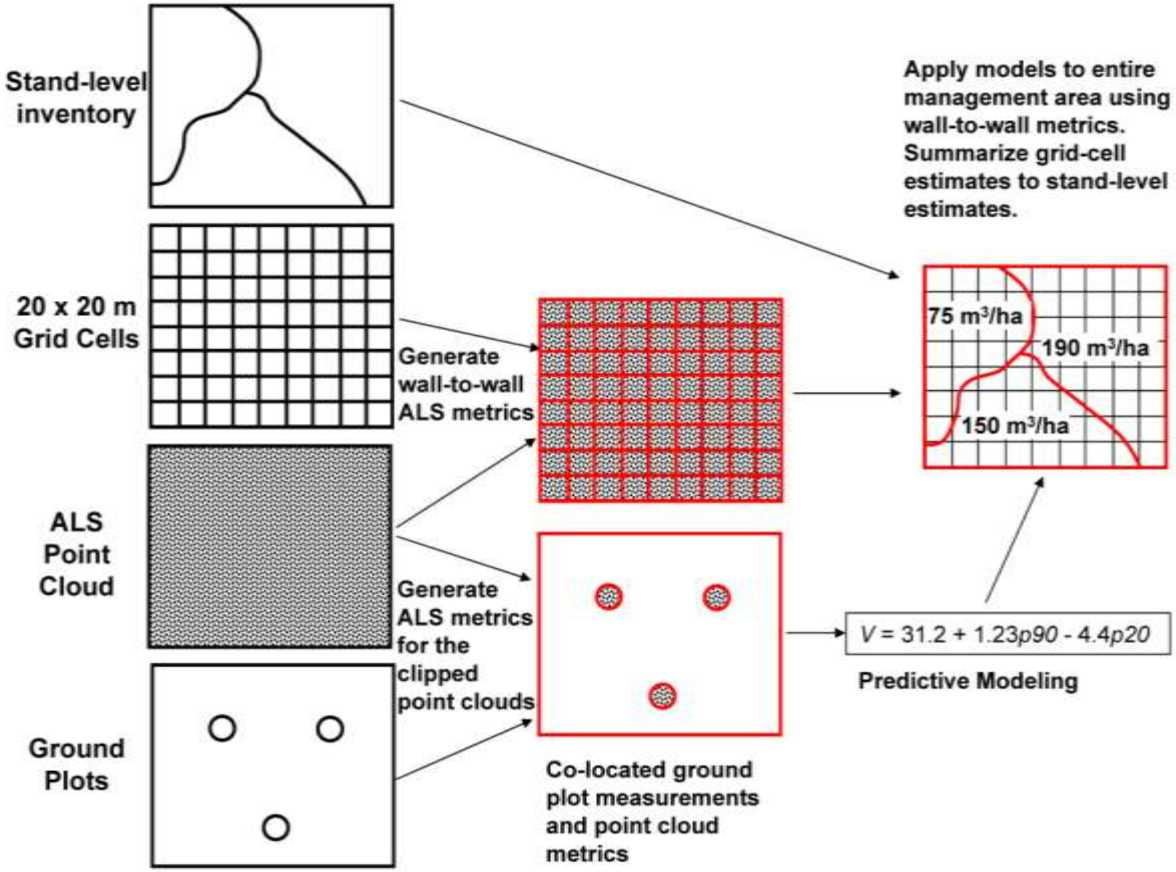
Plot Level Analysis

- Once metrics are calculated at the plot level:
  - Investigate the relationships between metrics and measured forest attributes
    - Mean tree height, dominant tree height, stem volume, basal area
  - Develop statistical models to predict forest attributes using several LiDAR metrics
    - Usually a combination of a height and cover metric
  - Statistical models are applied to gridded LiDAR metrics to predict forest attributes across the study area

Best Practices Guide

- Released July 2013
- Synthesizes 25 years of scientific research
- Available for download from CFS bookstore: **http://cfs.nrcan.gc.ca/publications?id=34887**

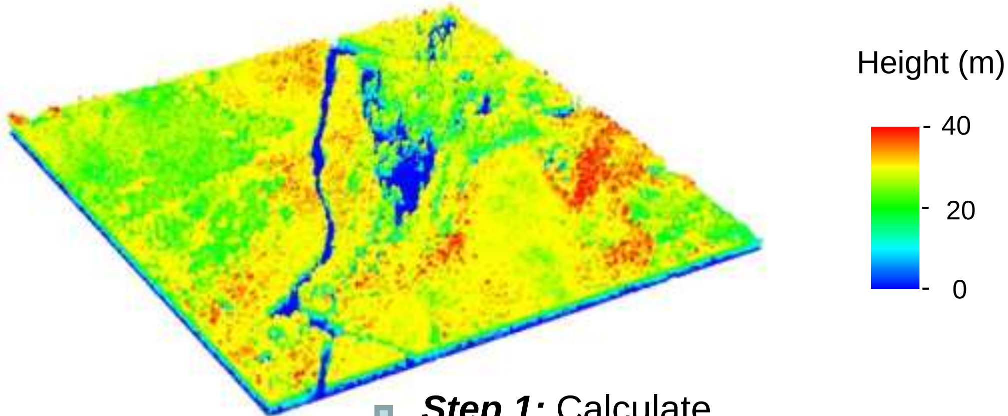
Area-based approach



1. Grid the point cloud
2. Calculate wall-to wall LiDAR metrics
3. Ground sample within the range of variability characterized by the LiDAR metrics
4. Clip the point clouds to the area corresponding to the ground plots
5. Develop model
6. Apply model

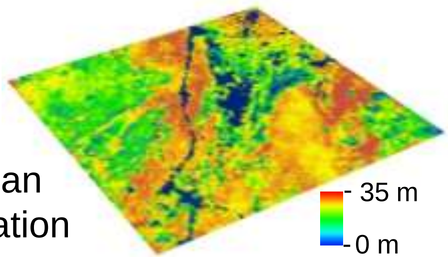
Deriving Forest Attributes

LiDAR point cloud

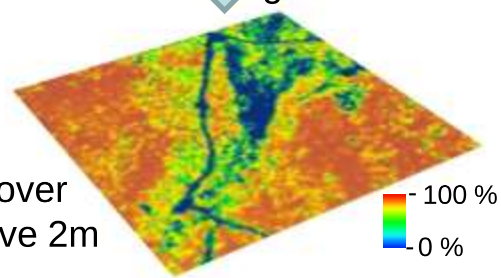


Step 1: Calculate gridded metrics

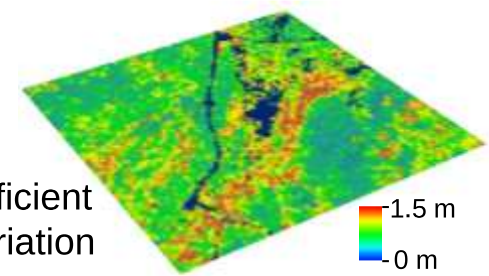
Mean elevation



Cover above 2m

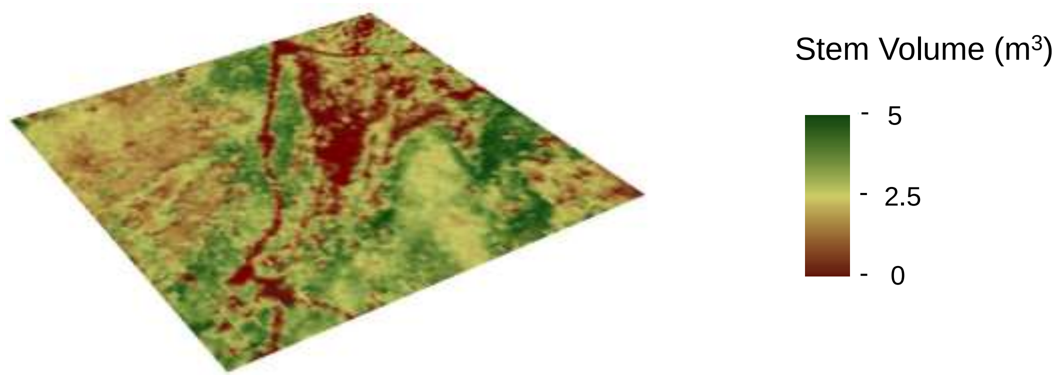


Coefficient of variation



Step 2: Apply statistical model

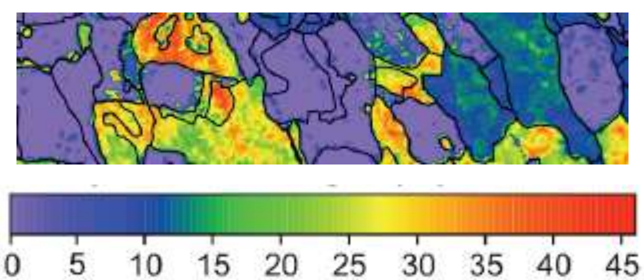
Stem volume estimation



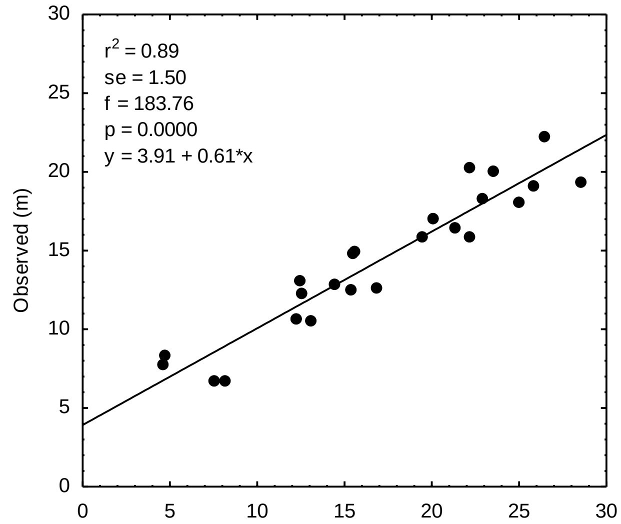
LiDAR visualizations produced with FUSION/LDA software – USDA Forest Service

How do we relate lidar to ground data?

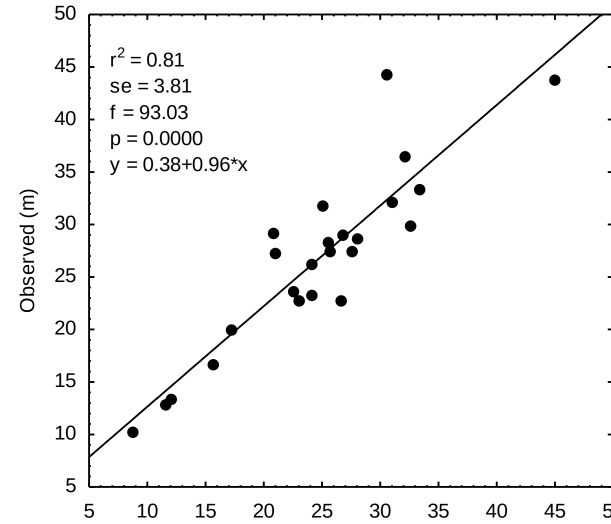
- GPS ground plot location
- Make ground measures
- Statistically relate ground measures to lidar metrics
- Can apply these relationships across all lidar grid cells (25 x 25m)
- Metrics not limited to height
- Inventory: Generalize by polygon (ht in m):



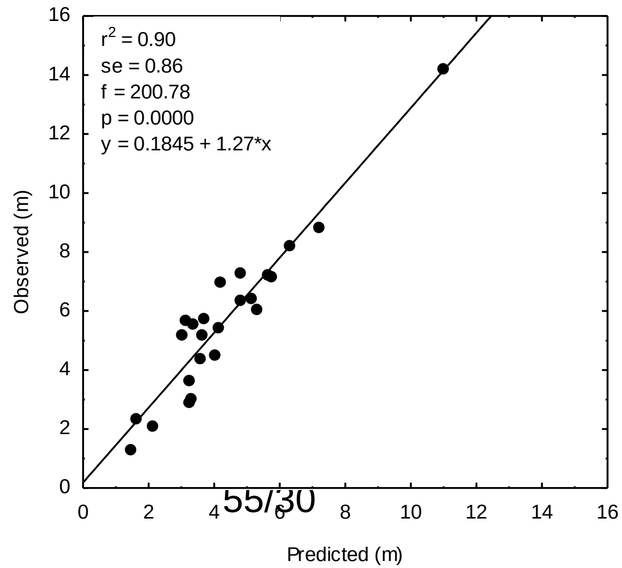
Mean tree height



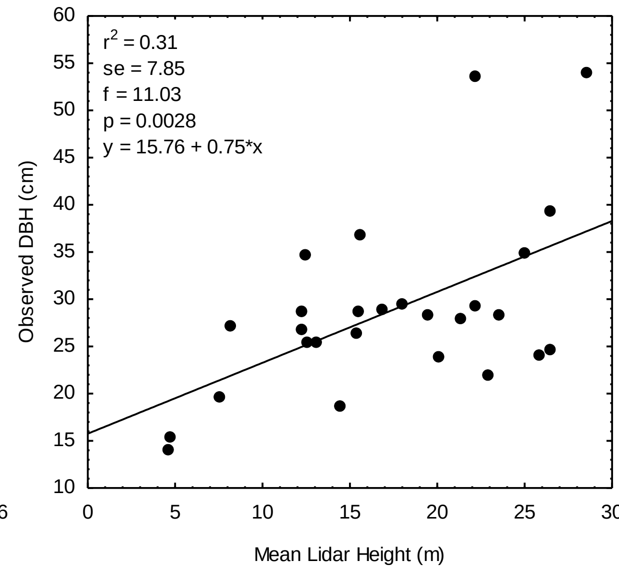
Maximum tree height



Variation of tree height



Mean diameter (dbh)



Example Equation and Results

Radius (m)	Plot Size (m^2)	Fitted OLS Regression Model	R^2	*SEE*
20	1257	$\hat{Y} = -51.3755 + 13.0245 \times Lh_{0.6} + 3.6330 \times CC_{0.0}$	0.960	38.64

$\hat{Y}$ – TAGB

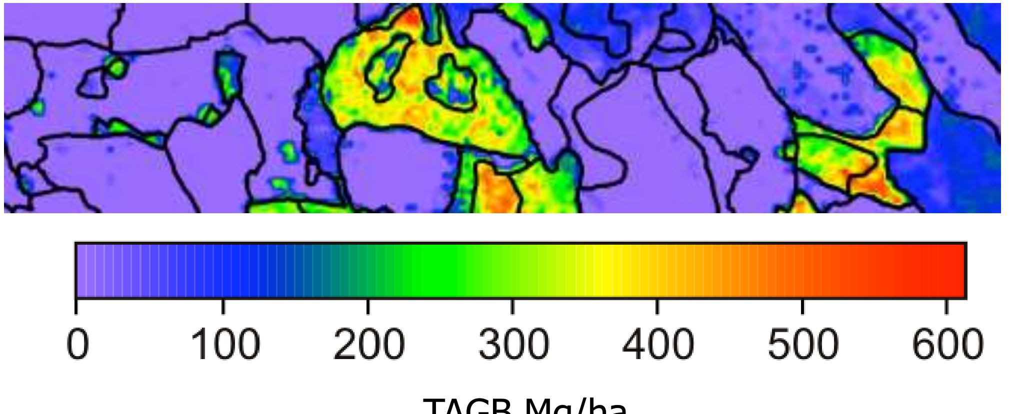
*Lh*0.5 – 50th percentile of laser canopy height (m).

*Lh*0.6 – 60th percentile of laser canopy height (m);

*CC*0.0 – canopy density (%) at 2 m above the ground surface.

R^2 – multiple coefficient of determination.

SEE – standard error of the estimate in transformed units.



I·R·S·S

Example of Multiple Regression Equations at the Plot Scale

Table 6

Relationships between logarithmic transformations of ground-based characteristics of the 200 m^2 sample plots (dependent variables) and laser-derived metrics from stepwise multiple regression analysis

Dependent variable[a]	Predictive model[b]	R^2	RMSE	κ
Young forest (n = 56)				
$\ln h_L$	$0.46 + 1.149\ln h_{90l} - 0.28\ln h_{maxl}$	0.95	0.06	5.0
$\ln h_{dom}$	$0.568 + 1.169\ln h_{90l} - 0.286\ln h_{maxl}$	0.93	0.07	5.0
$\ln d_g$	$-0.867 + 0.217\ln h_{10l} + 0.665\ln h_{80l} - 0.805\ln d_{80f}$	0.78	0.12	3.1
$\ln N$	$15.99 - 1.182\ln h_{80l} + 3.08\ln d_{80f}$	0.68	0.28	1.8
$\ln G$	$3.492 + 0.536\ln h_{10f} + 1.388\ln d_{50f}$	0.89	0.14	2.2
$\ln V$	$3.473 + 1.336\ln h_{meanl} + 1.477\ln d_{50f}$	0.93	0.16	2.0
Mature forest, poor site quality (n = 36)				
$\ln h_L$	$0.285 + 1.01\ln h_{90f} - 0.107\ln h_{50l}$	0.86	0.05	2.2
$\ln h_{dom}$	$-0.0187 + 1.002\ln h_{maxf}$	0.74	0.08	1.0
$\ln d_g$	$0.206 + 0.77\ln h_{90l} - 0.312\ln d_{80l}$	0.54	0.12	1.4
$\ln N$	$11.24 + 1.195\ln h_{0f} - 1.662\ln h_{maxf} + 1.156\ln d_{20l}$	0.65	0.30	1.7
$\ln G$	$4.253 + 4.304\ln h_{50f} - 4.022\ln h_{60f} + 0.584\ln d_{90f}$	0.69	0.21	8.5
$\ln V$	$4.951 - 1.278\ln h_{30f} + 5.994\ln h_{50f} - 3.8\ln h_{60f} + 0.766\ln d_{90f}$	0.80	0.20	11.7
Mature forest, good site quality (n = 52)				
$\ln h_L$	$0.35 + 0.529\ln h_{90f} + 0.355\ln h_{maxf}$	0.82	0.07	5.9
$\ln h_{dom}$	$0.525 + 0.23\ln h_{80f} + 0.637\ln h_{maxf} + 0.084\ln d_{10l}$	0.85	0.07	4.3
$\ln d_g$	$0.441 + 0.64\ln h_{90l} - 0.277\ln d_{90l}$	0.39	0.12	1.7
$\ln N$	$10.33 - 0.487\ln h_{0l} - 0.667\ln h_{cvf} + 1.187\ln d_{50f}$	0.50	0.35	1.9
$\ln G$	$3.608 + 2.629\ln h_{80l} - 2.157\ln h_{maxf} + 1.26\ln d_{50f}$	0.75	0.21	3.8
$\ln V$	$3.151 + 3.027\ln h_{80l} - 1.66\ln h_{maxf} + 1.223\ln d_{50f}$	0.80	0.22	3.8

[a] h_L = Lorey's mean height (m), h_{dom} = dominant height (m), d_g = mean diameter by basal area (cm), N = stem number (ha^{-1}), G = basal area ($m^2\ ha^{-1}$), V = volume ($m^3\ ha^{-1}$).

Source: Næsset 2002