Comparison of Sampled vs Census Level Lidar Approaches for -

Operational Forest Management Inventories

Western Mensurationists Annual Meeting

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Introduction To FBRI

- Non-profit public research corporation 501(c)3
- Founded in 2003 by James D. Arney
  - *Mission: Advancement of scientifically grounded and verified forest biometric practices in the forest industry*
  - *Focused on operational tools for forest managers*
- Forest Projection and Planning Software (FPS)
  - *Cruise compiler, growth and yield model, harvest scheduler, etc.*
  - *Distance-dependent growth model (relative tree location matters!)*
  - *Supports both traditional sample-based inventories and lidar ITD inventories*
- Supported by Member Organizations
  - *40+ member organizations*
    - *Tribal Governments, Timber Companies, Consulting and Forest Management Firms, Carbon Firms, Federal, State, and County Agencies, and Nonprofits*

Introduction To BLP

- Family Owned Company since the 1950’s
- Two Lumber Mills
  - *Princeton, Idaho*
  - *Clarkston, Washington*
- Owns and manages 70,000 acres of forestland
  - *Northern Idaho and South-Eastern Washington*
  - *Operational, stand-based inventory since 2006*
    - *Updated field-based cruising every 10 years*
    - *FPS growth and yield model used for harvest scheduling and planning, sustainability analysis, and long-term planning since 2006*
- Acquired lidar on all Idaho ownership in 2019

Operational Forest Management Inventories

What is an Operational Forest Management Inventory?

Purpose-built inventory to support forest management decisions

- Harvest scheduling
- Long-term sustainability analysis
- Asset tracking
- Allowable cut calculations

- ❑ Focuses on merchantable timber and key stand attributes
- ❑ Designed for accuracy, consistency, and repeatability across large areas
- ❑ Data informs tactical and strategic forest planning

Operational Forest Management Inventories

- Challenges in Inventory Design
  - Cost, accuracy, and update cycles
    - 2023 survey reported an average of $11.51/acre for field-based inventory cruising cost

      (Hemingway & Opalach 2024)
    - Sample accuracy
  - Spatial Resolution and responsiveness
    - Stand boundary changes with a sample-based inventory
  - Flexible, scalable systems are needed!

Halli Hemingway, Daniel Opalach, Integrating Lidar Canopy Height Models with Satellite-Assisted Inventory Methods: A Comparison of Inventory Estimates, Forest Science, Volume 70, Issue 1, February 2024, Pages 2–13, https://doi.org/10.1093/forsci/fxad047

Traditional vs Lidar Inventory Methods

- Traditional Field-Based Cruise Sampling
  - Plot based methods
  - Time-tested, but expensive (~$11.50/acre) and time-consuming
  - Sampling errors and generalization over large areas
- Lidar-Based Single Tree Inventory
  - Individual tree detection
  - Provides wall-to-wall coverage in a short amount of time
  - Cost ranging between $1.00 - $2.50 / acre depending on project size and scope
  - Intermediate and suppressed trees may not be well represented
- Common Ground: Use FPS for both
  - Traditional plot samples -> FPS stand table summaries
  - Lidar ITD trees -> FPS stand table summaries

Traditional vs Lidar Inventory Methods

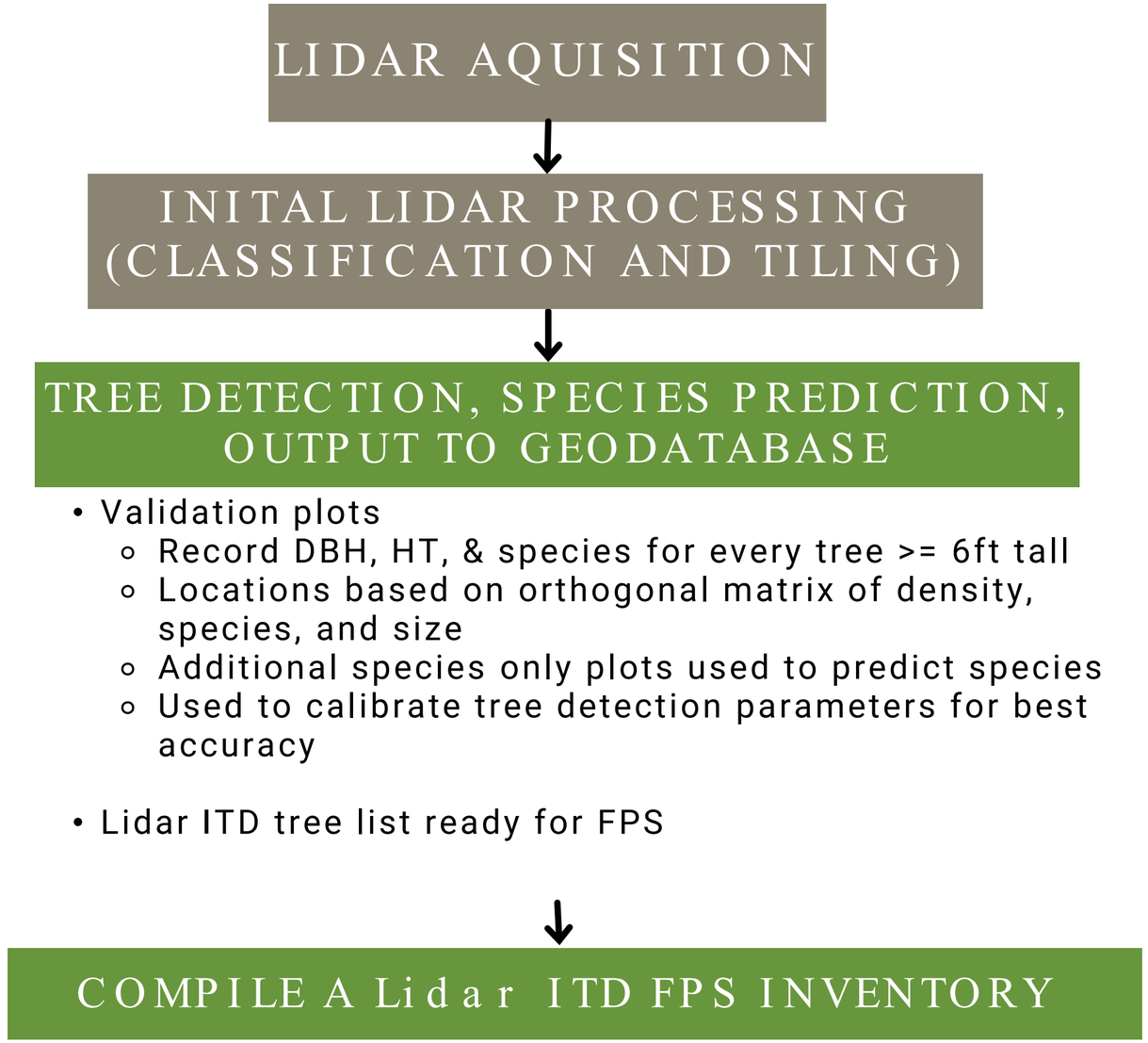
BLP Inventory Comparison

- Robust field-based, variable plot cruised FPS inventory
  - 828 stands selected for comparison to lidar estimates
    - Cruised from 2010 to 2019
    - Growth applied to bring all stands to a common 2019 year (custom BLP productivity model built in 2020)
      - FBRI SiteGrid Productivity Estimation

Halli Hemingway, Mark Kimsey, Estimating Forest Productivity Using Site Characteristics, Multipoint Measures, and a Nonparametric Approach, *Forest Science*, Volume 66, Issue 6, December 2020, Pages 645–652, https://doi.org/10.1093/forsci/fxaa023

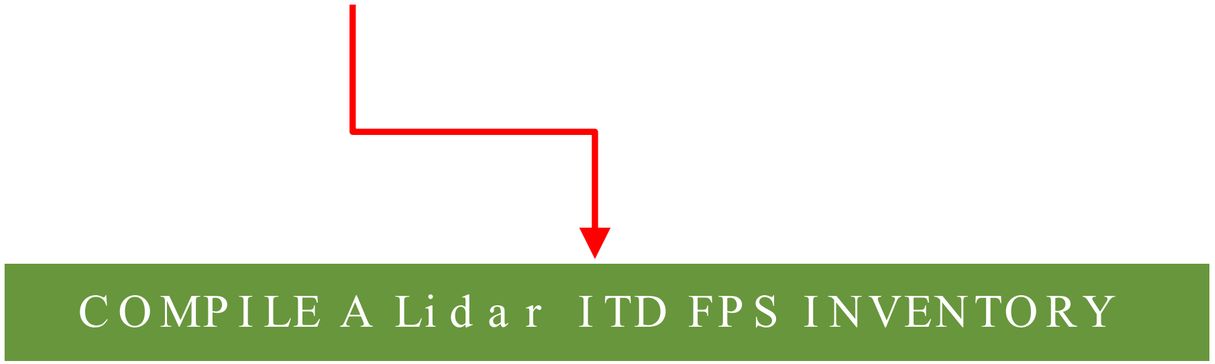
Traditional vs Lidar Inventory Methods

- Bennett Lumber Products, Inc (BLP) acquired lidar for ~59,000 acres in northern Idaho in 2019
  - ~8 ppm
  - classified and tiled



Traditional vs Lidar Inventory Methods

This is no a small task!



- **Over 8.5 million individual trees in this example**
- **Another project had over 300 million trees!**
- **FPS can handle both**

- **FBRI has developed a proven, tested method to make FPS work with hundreds of millions of tree records!**

Limitations: Species Prediction Accuracy

Table 3. Species classification confusion matrix results. Overall accuracy for timbered validation locations was 53.8%. Overall accuracy for nontimbered validation locations was 92.9%. PA, producer's accuracy; OE, omission error, UA, user's accuracy; CE, commission error. Tree species codes: NT, nontimber: PSME, *Pseudotsuga menziesii*; ABGR, *Abies grandis*; PIPO, *Pinus ponderosa*; LAOC, *Larix occidentalis*; PICO, *Pinus contorta*; THPL, *Thuja plicata*.

		Reference species								
		NT	PSME	ABGR	PIPO	LAOC	PICO	THPL	UA (%)	CE (%)
Classified species	NT	13	0	0	0	0	0	0	100.0	0.0
	PSME	0	2	0	1	1	0	1	40.0	60.0
	ABGR	0	0	2	2	0	0	0	50.0	50.0
	PIPO	0	1	1	4	0	0	1	57.1	42.9
	LAOC	0	0	0	0	0	0	0	0.0	100.0
	PICO	1	1	0	0	0	1	0	33.3	66.7
	THPL	0	2	0	1	0	0	5	62.5	37.5
	PA (%)	92.9	33.3	66.7	50.0	0.0	100.0	71.4		
	OE (%)	7.1	66.7	33.3	50.0	100.0	0.0	28.6		

Halli Hemingway, Daniel Opalach, Integrating Lidar Canopy Height Models with Satellite-Assisted Inventory Methods: A Comparison of Inventory Estimates, Forest Science, Volume 70, Issue 1, February 2024, Pages 2–13, https://doi.org/10.1093/forsci/fxad047

53.8% overall accuracy

- **Species prediction can be difficult in complex environments like northern Idaho with 9 different commercial tree species and complex topography.**
- **New modeling methods, higher density point clouds, and high-resolution imagery will increase species prediction accuracies going forward.**

Table 2. Species classification confusion matrix results. Overall accuracy was 54.7%. PA = producer's accuracy, OE = omission error, UA = user's accuracy, CE = commission error. Tree species codes are as follows; ABGR: *Abies grandis*, LAOC: *Larix occidentalis*, PIEN: *Picea engelmanii*, PSME: *Pseudotsuga menziesii*, PICO: *Pinus contorta*, PIMO: *Pinus monticola*, PIPO: *Pinus ponderosa*, THPL: *Thuja plicata*.

		Reference Species									
		ABGR	LAOC	PIEN	PSME	PICO	PIMO	PIPO	THPL	UA (%)	CE (%)
ALS classified species	ABGR	114	5	4	35	1	5	7	19	60.0	40.0
	LAOC	8	23	0	5	5	16	4	3	35.9	64.1
	PIEN	0	0	0	0	0	0	0	0	0.0	100
	PSME	52	4	2	82	4	1	21	26	42.7	57.3
	PICO	4	6	0	1	39	5	13	1	56.5	43.5
	PIMO	0	0	0	0	0	0	0	0	0.0	100
	PIPO	3	3	0	6	7	3	89	2	78.8	21.2
	THPL	7	12	1	8	1	2	1	31	49.2	50.8
	PA (%)	60.6	43.4	0.0	59.9	68.4	0.0	65.9	37.8		
	OE (%)	39.4	56.6	100	40.1	31.6	100	34.1	62.2		

54.7% overall accuracy

Sparks, Aaron M., and Alistair M.S. Smith. 2022. "Accuracy of a LiDAR-Based Individual Tree Detection and Attribute Measurement Algorithm Developed to Inform Forest Products Supply Chain and Resource Management" *Forests* 13, no. 1: 3. https://doi.org/10.3390/f13010003

Limitations: Lidar ITD of understory trees

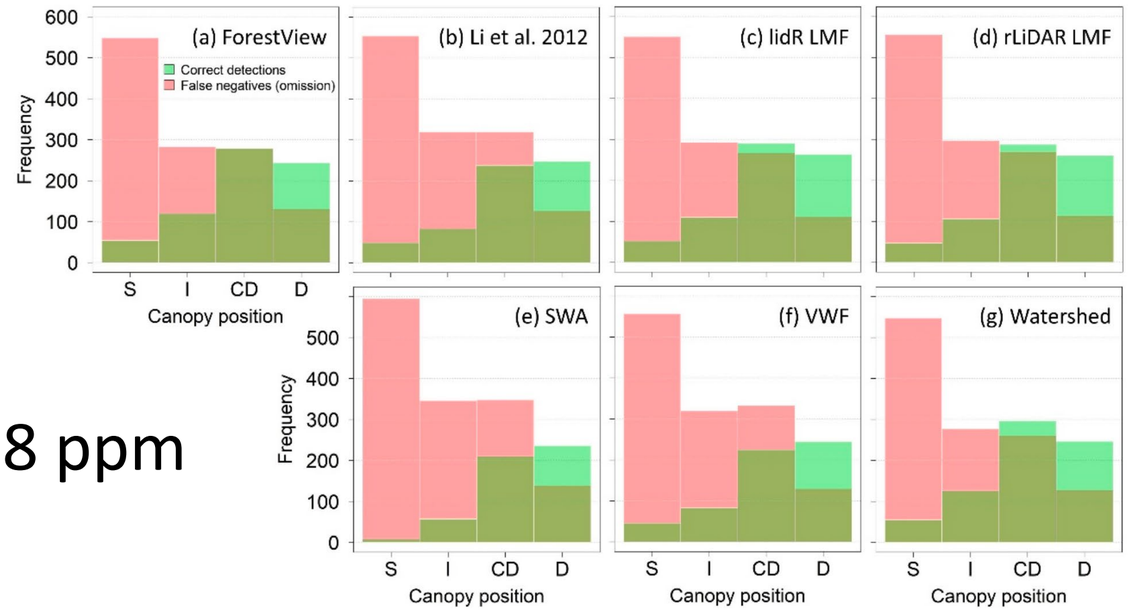
Intermediate and suppressed trees are underpredicted *(for point densities from 8 – 22 ppm)*

- *"Across all methods and for both ALS datasets, detection of intermediate trees was less than 31% and detection of suppressed trees was less than 13%."*

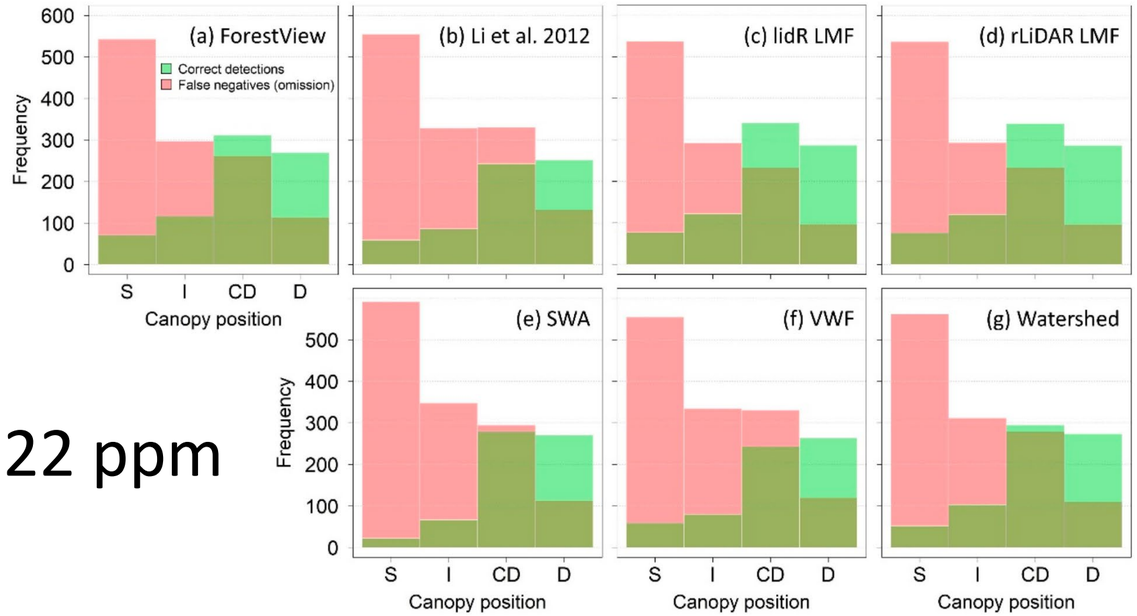
Sparks, A.M.; Corrao, M.V.; Smith, A.M.S. Cross-Comparison of Individual Tree Detection Methods Using Low and High Pulse Density Airborne Laser Scanning Data. *Remote Sens. 2022, 14, 3480. https://doi.org/10.3390/rs14143480*

Census?

8 ppm



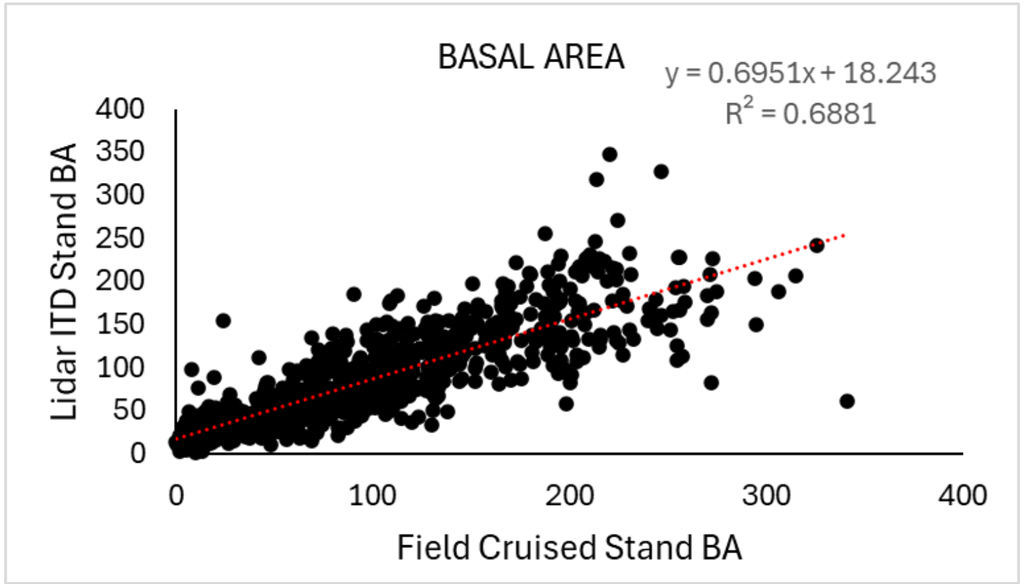
22 ppm

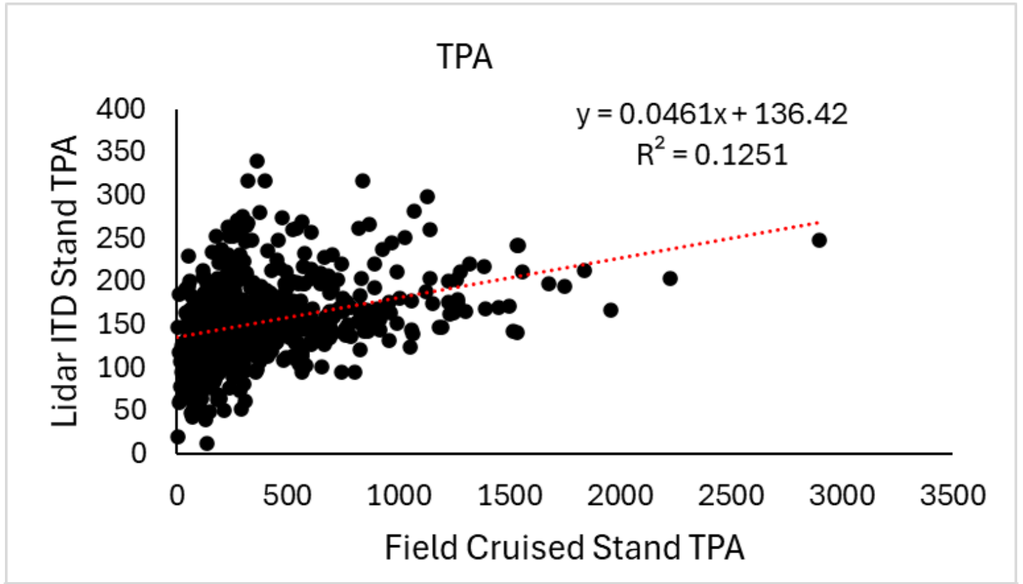


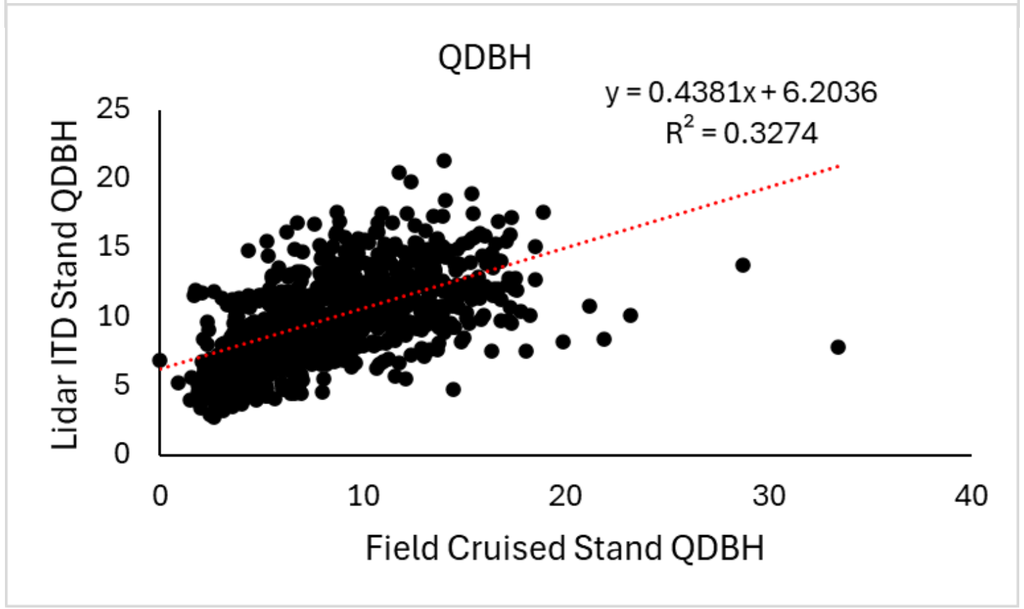
Traditional vs Lidar Inventory Methods

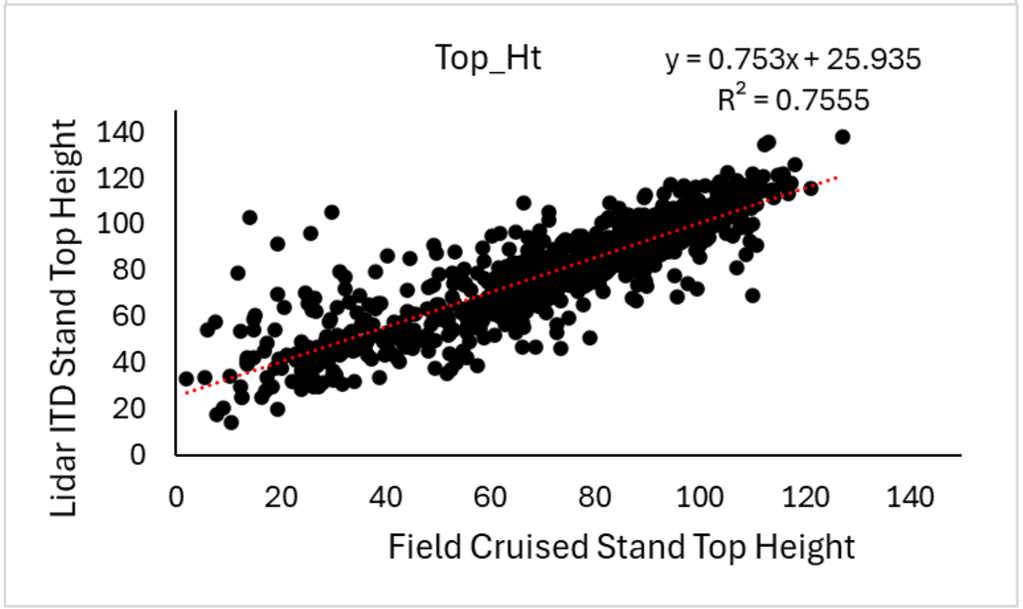
- Stand Comparison Metrics
  - Basal Area (BA)
  - Trees per Acre (TPA)
  - Quadratic Mean Diameter (QDBH)
  - Top Height (Top_Ht)
  - Relative Density (RD)
  - Board Feet per Acre (BF/Acre)
  - Total Forest Volume (by parcel or ownership)

Traditional vs Lidar Comparison Metrics

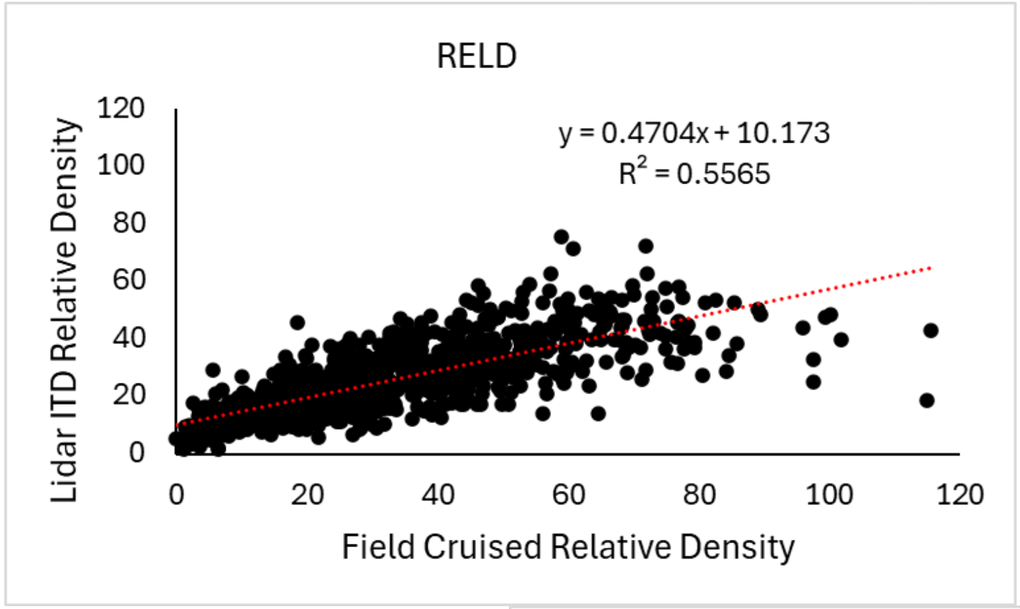


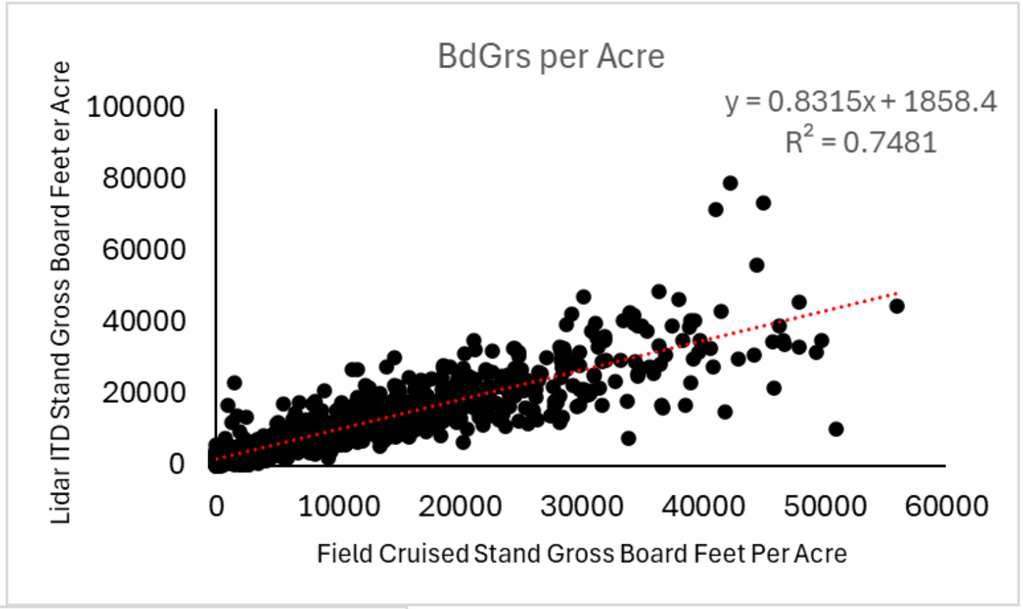


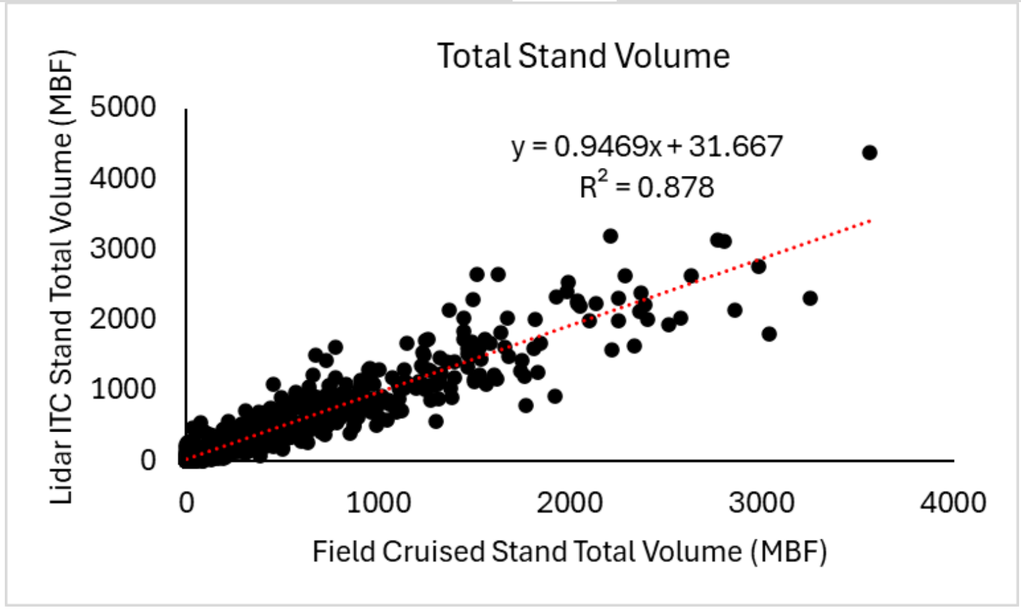




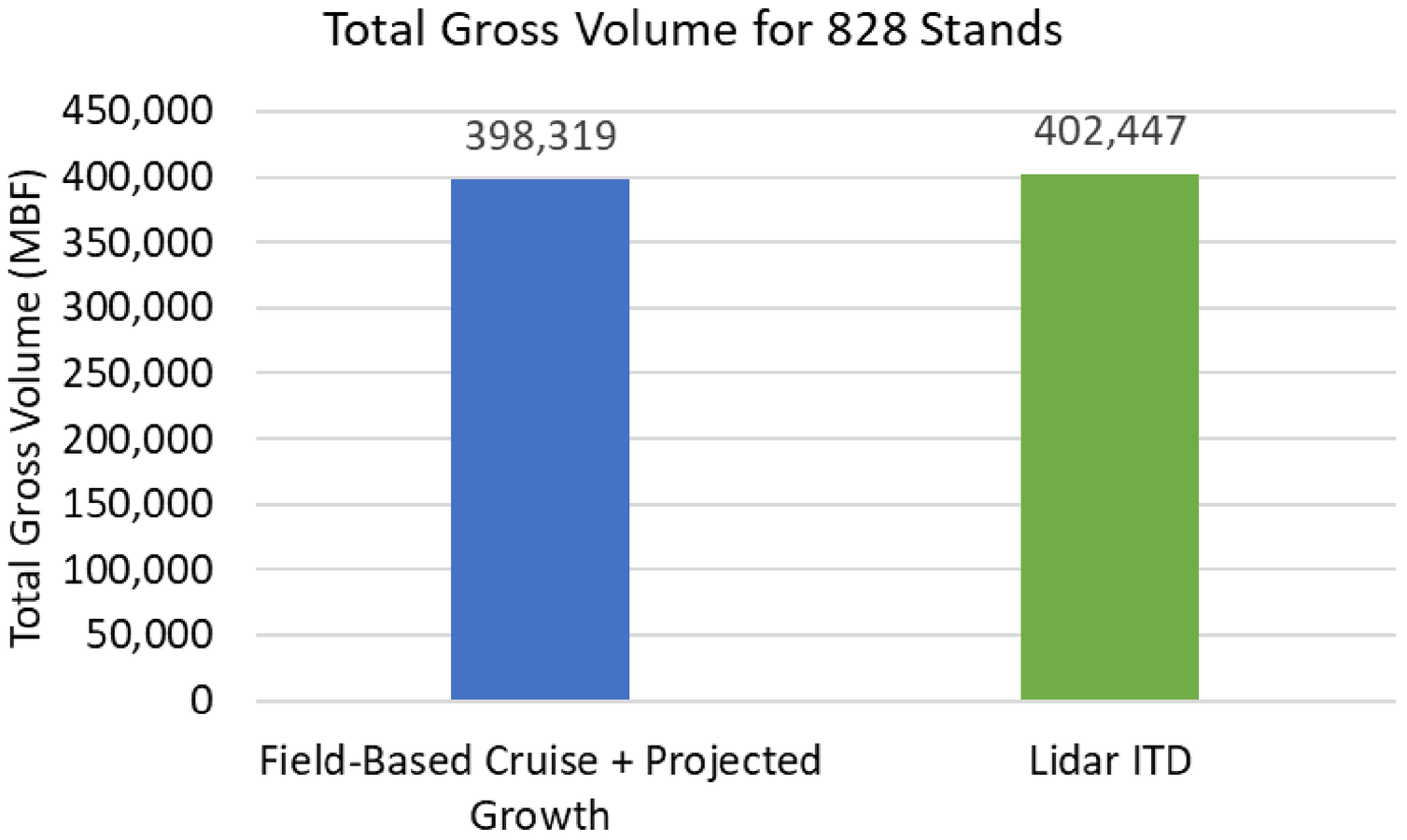
Stand -Level Comparison Metrics







Total Forest Volume Comparison

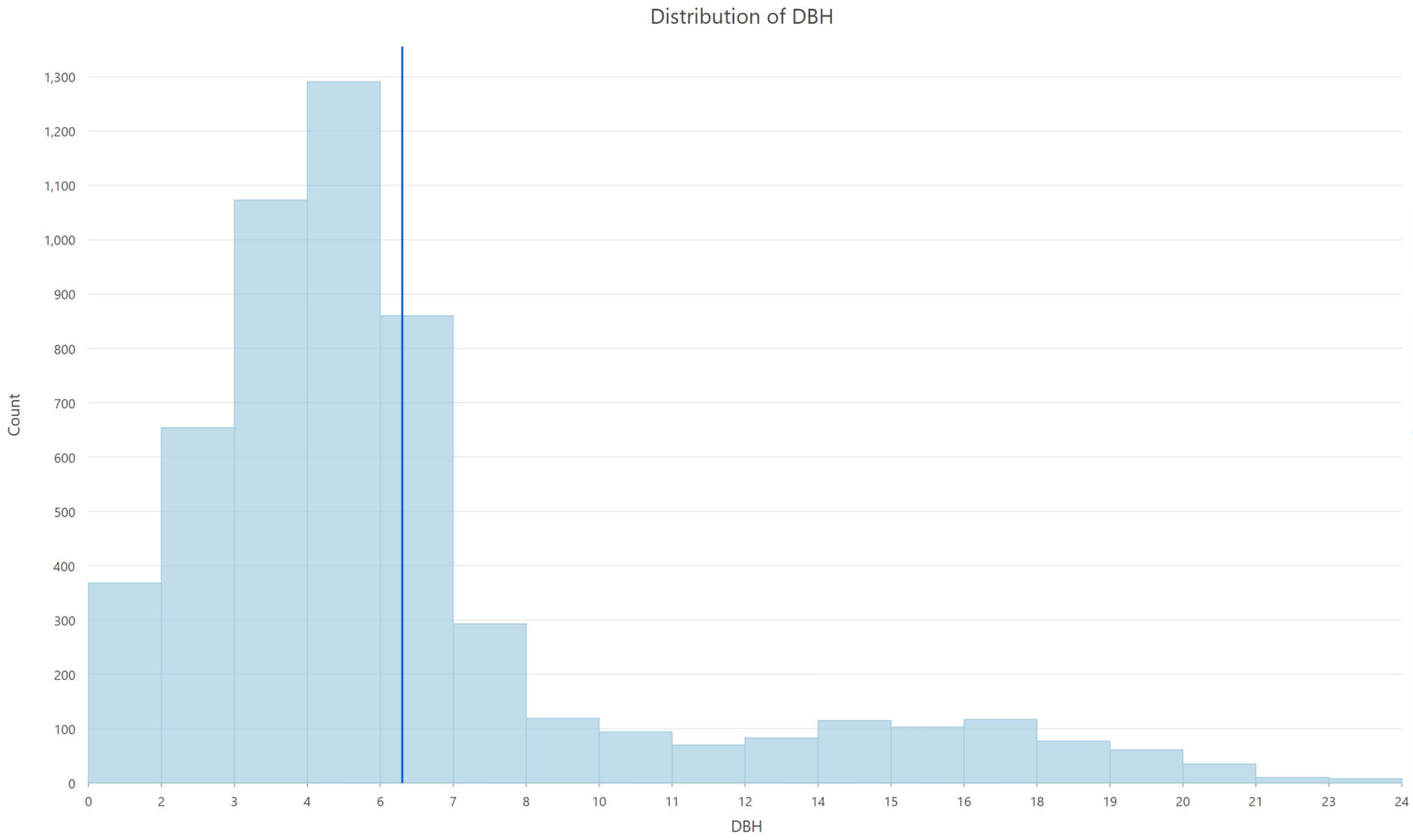


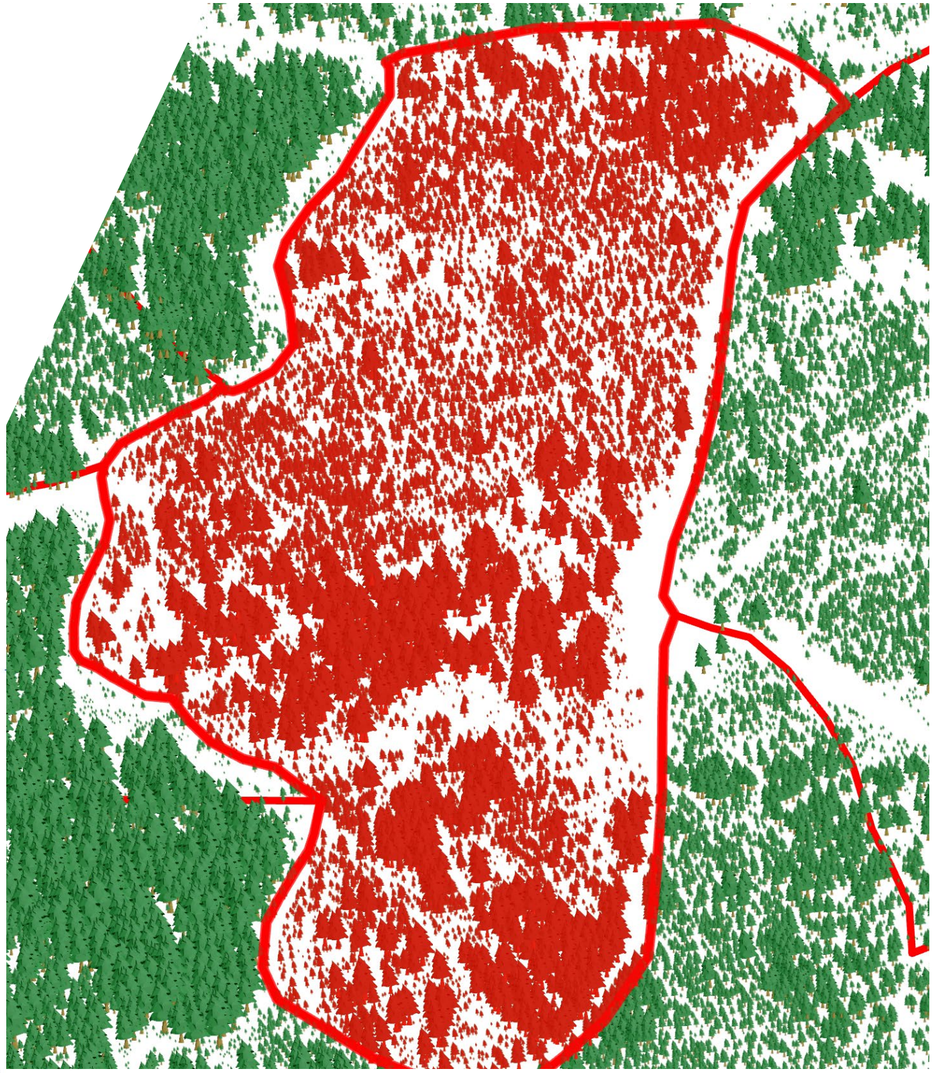
That’s a 1.3% difference!

Potential:

Lidar ITD Inventory

- **Stand or Unit Diameter Distributions**

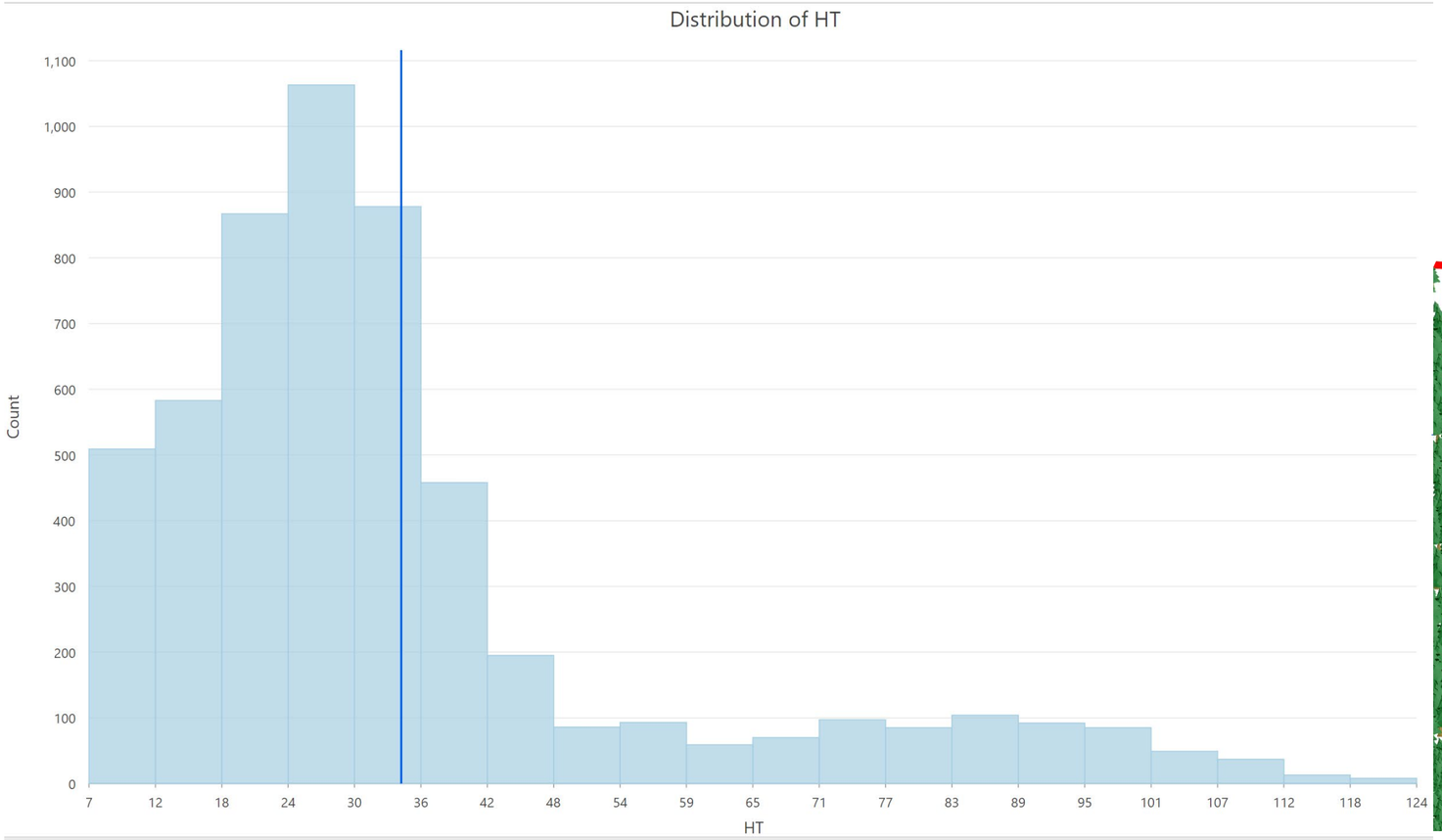


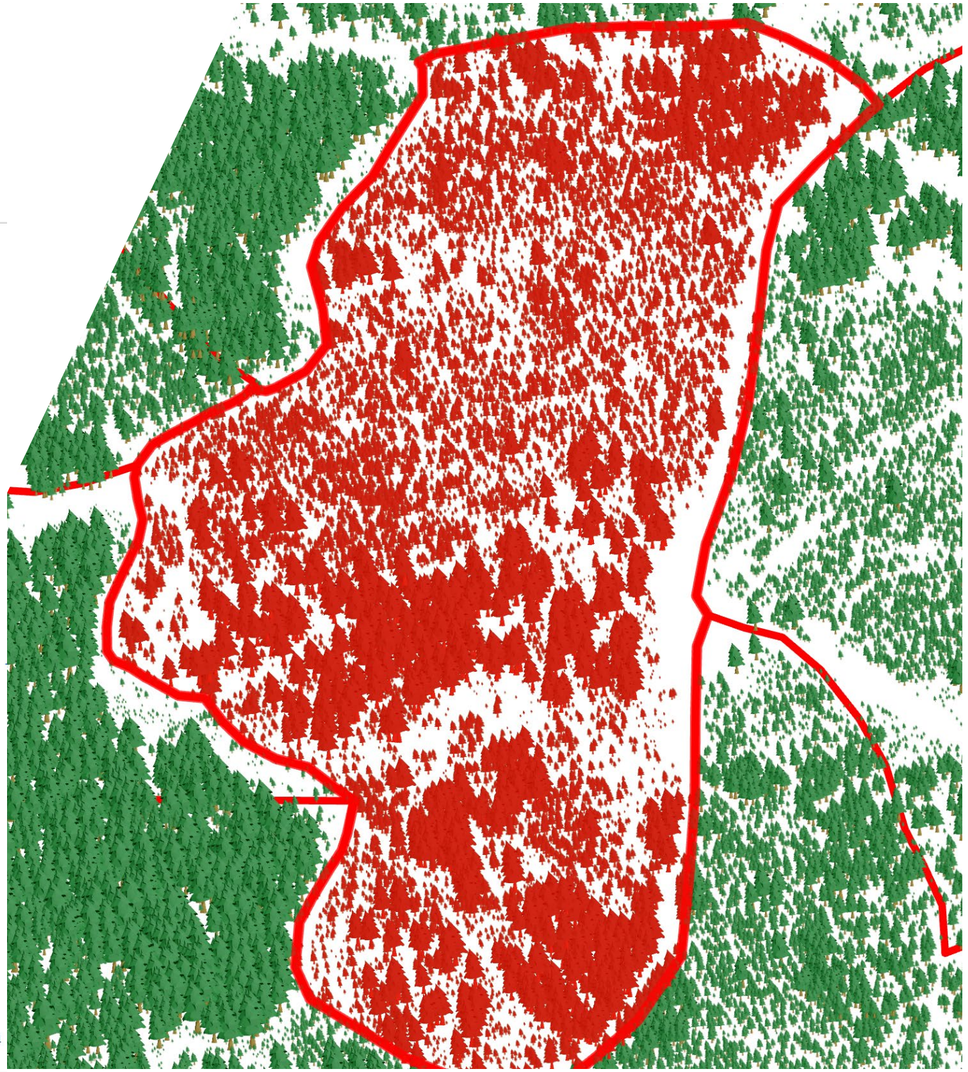


Potential:

Lidar ITD Inventory

- **Stand or Unit Height Distributions**

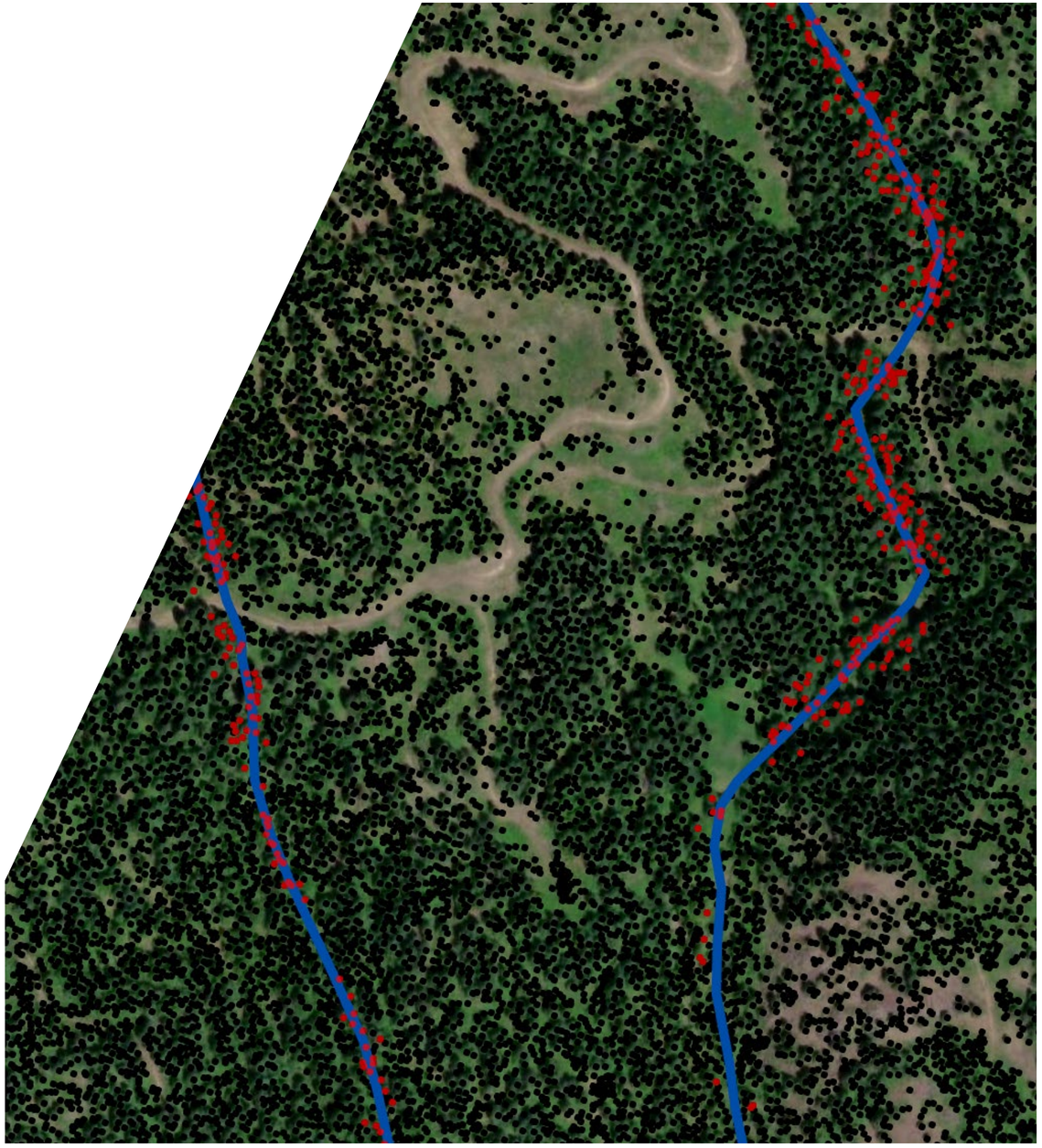




Potential:

Lidar ITD Inventory

- **LWD Recruitment**
  - Which trees have a large enough diameter at the point they could fall on a stream and are close enough to a stream to be potential LWD?



Service Options

FBRI Enterprise Services

-Processing Options

TREE DETECTION, SPECIES PREDICTION, OUTPUT TO GEODATABASE

COMPILE A Lidar ITD FPS INVENTORY

GROW A Lidar ITD FPS INVENTORY

-Potential Deliverables

- stand HT Distr.
- stand DBH DISTR.
- LWD Recruitment
- Stand Density Metrics
- Volume Estimates
- FPS Inventory Database (with membership)
- Future Estimates of all of the above


Thank you!