Comparison of Multi-Platform LiDAR Sensors for Efficient Forest Inventory

Ergin C. Cankaya | Dr. Robert Froese

University of Alberta

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Forest Growth & Yield Lab

WESTERN MENSURATIONISTS ANNUAL MEETING

MOSCOW, IDAHO

Motivation and Objectives

📌 Gap
Lack of rigorous, multi-sensor (TLS–MLS–DLS) comparisons across structurally diverse forest conditions.

🎯 Solution
Conduct a systematic evaluation of platform-specific performance in both simple and complex forest structures.

🌍 Objectives
1. Assess sensor accuracy for tree count, DBH, and height.
2. Compare data collection and processing time under varying structural complexity.

Study Sites

MPB-PSP Network

- Long-term PSP establishment since 1960, old-growth forest,
- 5–10-year remeasurement,
- Nested plot design (Tree, regen, sapling),
- PSP-9 (4 subplots) were selected, and plot sizes are 1012 m^2.

Vanderwell (VAN) CTs

- Private land owned,
- White spruce plantation (former farmland), 30 years old,
- 500 m^2 and nine rectangular plots,
- Randomized complete block with control, 33%, 50% RD.

Blue Ridge Lumber (BRL) CTs

- Blue Ridge, Alberta (West Fraser Division),
- Naturally regenerated lodgepole pine stand, 50 years old,
- 500 m^2 and nine rectangular plots,
- Randomized complete block with control, 33%, 50% RD.

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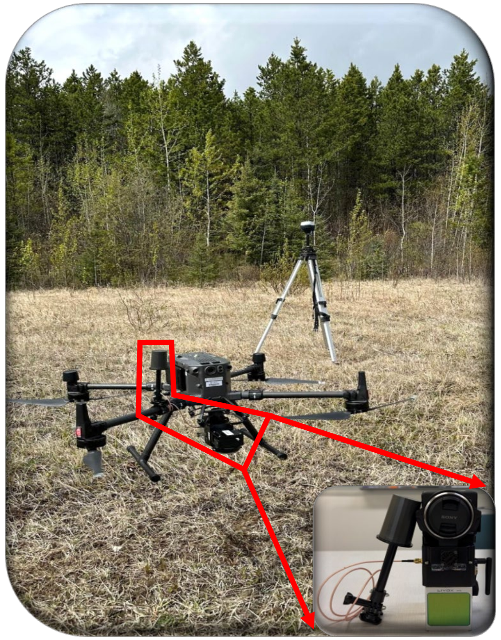
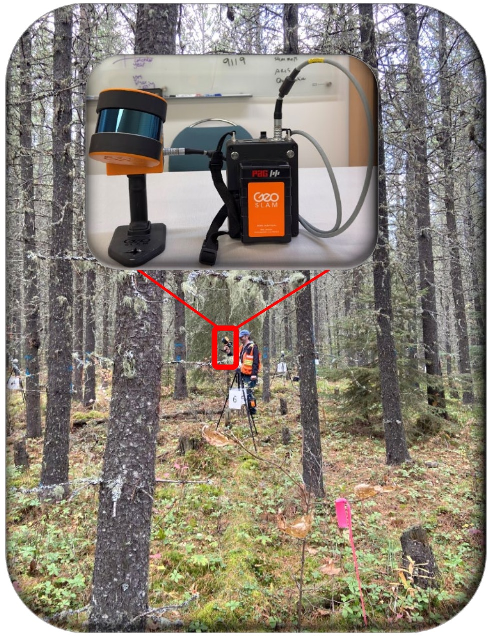
Materials and Surveying Procedure





Drone LS DATA

DJI M300 RTK - R2A lidar

Collected in 2024

Point Rate: 200,000 points/s

Flight parameters:

80/80 m overlaps, 4 m/s flight speed at 80 m altitude

Point Density: ~900 points/m²

×5 →

Mobile LS DATA

GeoSLAM's Zeb Horizon - SLAM

Collected in 2024

Scanning rate: 300,000 points/s.

Range: 100 m.,

Operation: Same path was scanned twice

Point Density: ~4,500 points/m²

×10 →

Terrestrial LS DATA

Leica RTC360

Collected in 2024

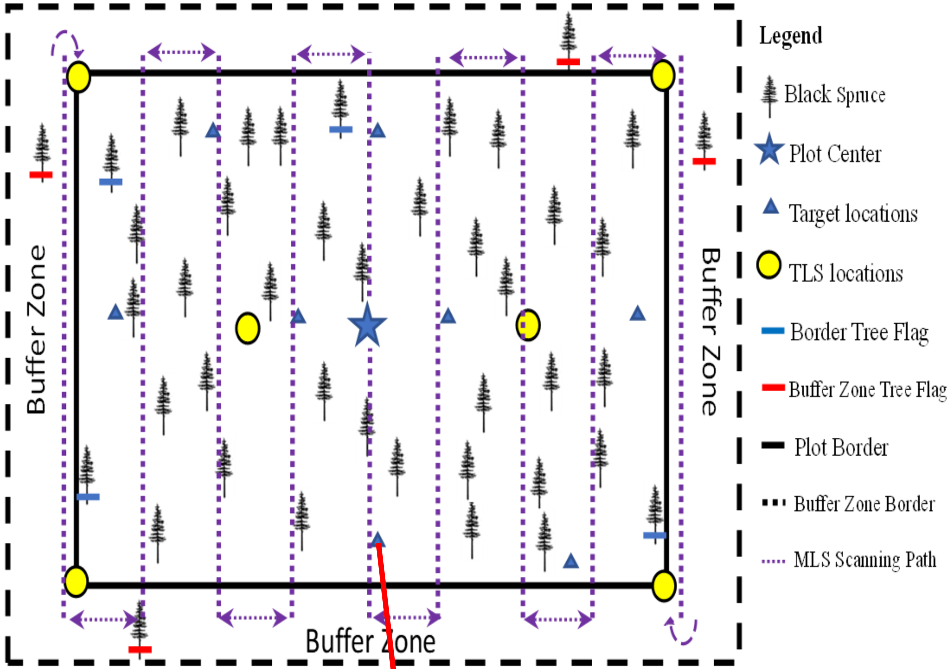
Scanning rate: 2 million points/s.

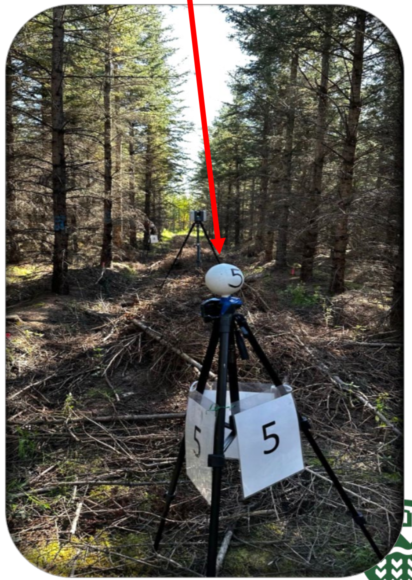
Range: 120 m.

Operation: Double-scan, high density

Point Density: ~45,000 points/m²

Surveying Procedure





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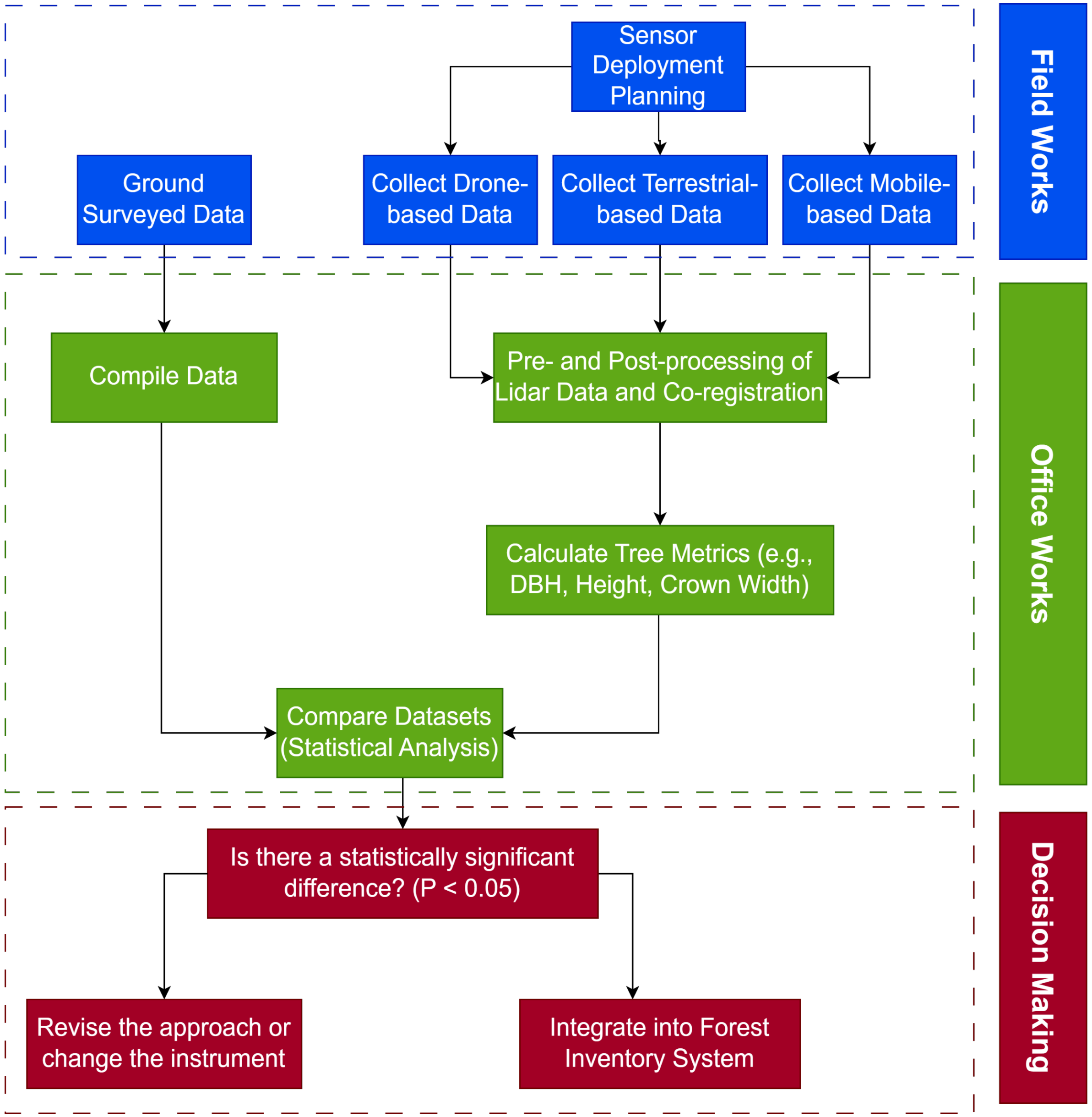
Method: *General Workflow*



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Method: *Drone (D)-based Lidar Sensor*

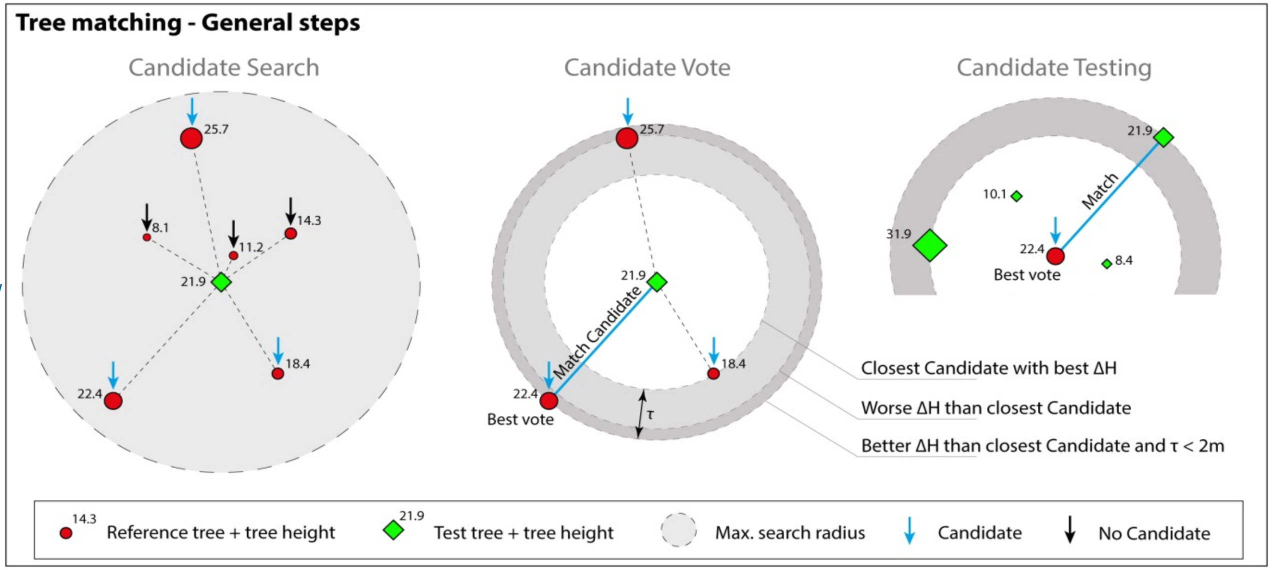
1. Data collection using DLS,

2. Pre-processing (Noise filter, ground classification, height normalization)

3. Detect tree locations based local maxima filter-variable window,

4. Feature extraction
   a. $Height_{tree} = Z_{max} – Z_{ground}$,
   b. Tree matching procedure (for species)
   c. DBH was estimated by Alberta-specific H-DBH models (Huang, 2016)

5. Validation and accuracy assessment



Rules:

Candidate Search Radius: 5-m. horizontally (X and Y)

Candidate Vote: 3-m. vertically (Z)

Candidate Testing: Closest height

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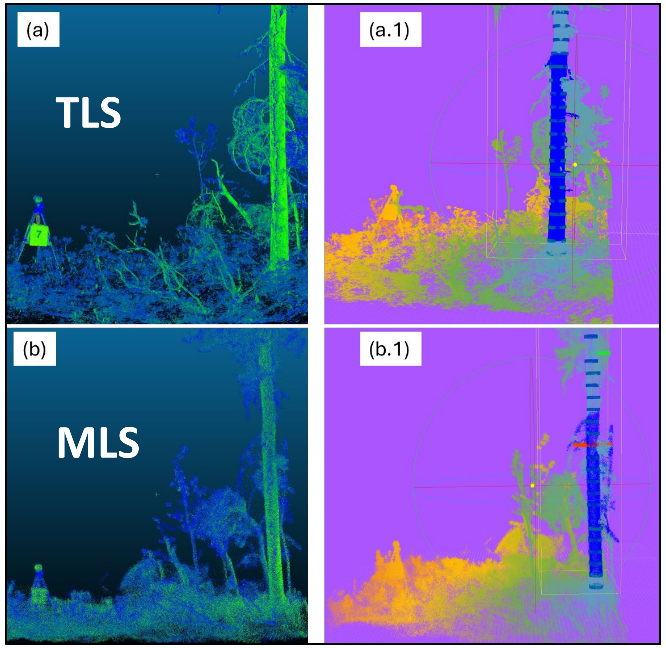
Method: *Terrestrial (T) and Mobile (M)-based Lidar Sensors*

Data Preparation

1- Acquisition

2- Registration
(ICP: CloudCompare)

3- Data Preparation
(SOR, CSF, IDW: lidR-R)

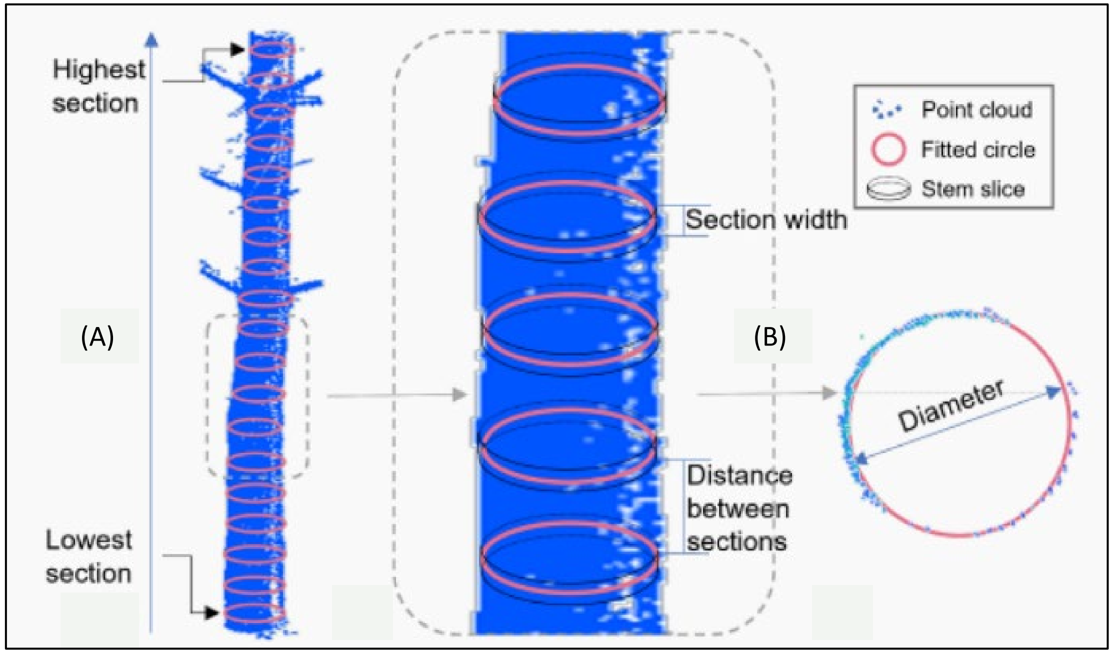


Feature Extraction

4- Stem detection
(Hough Transformation: TreeLS-R)

5- Height derivation **(A)**
(Z_{max} - Z_{ground}: Custom-R)

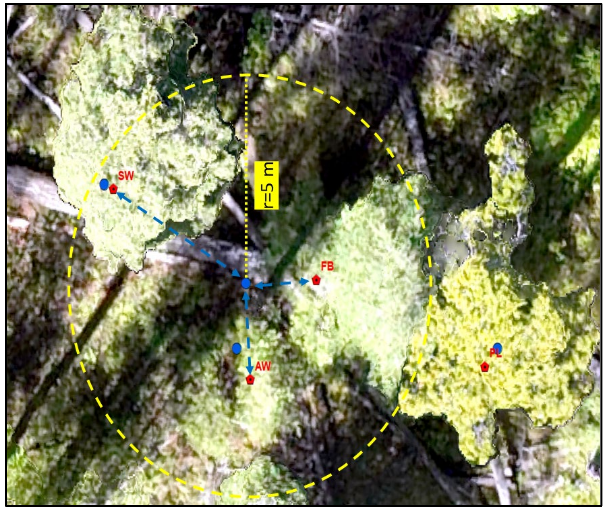
6- DBH estimation **(B)**
(RANSAC and Circle Fitting: Custom-R)



Accuracy

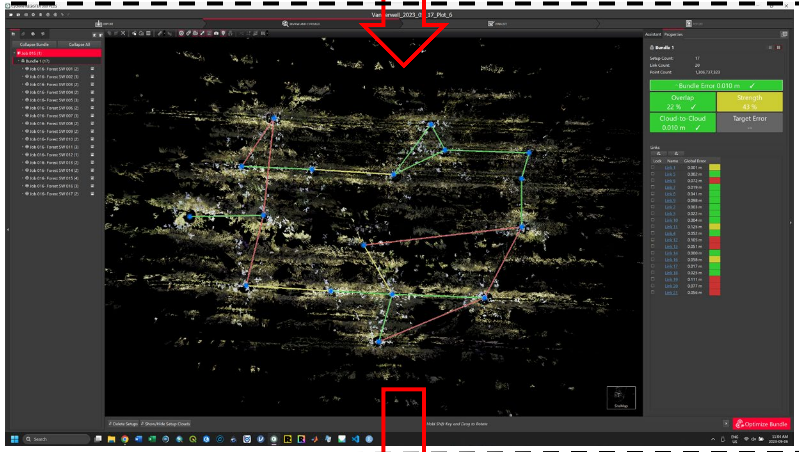
7- Automated Tree Matching:
5-m. horizontally (X and Y)
3-m. vertically (Z)

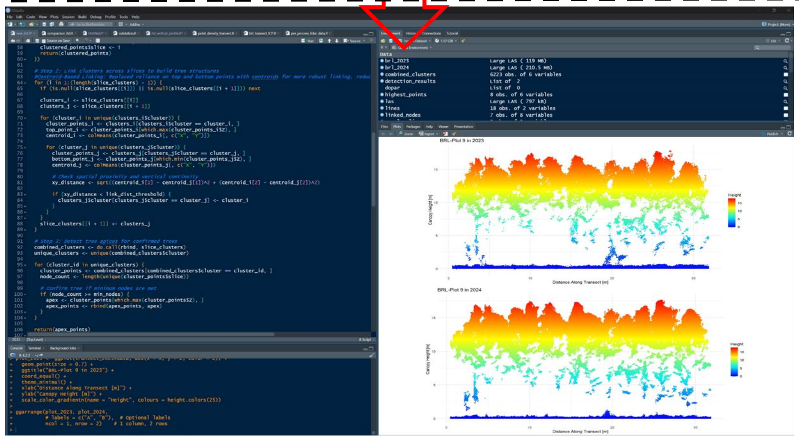
8- Validation (RMSE, Bias)



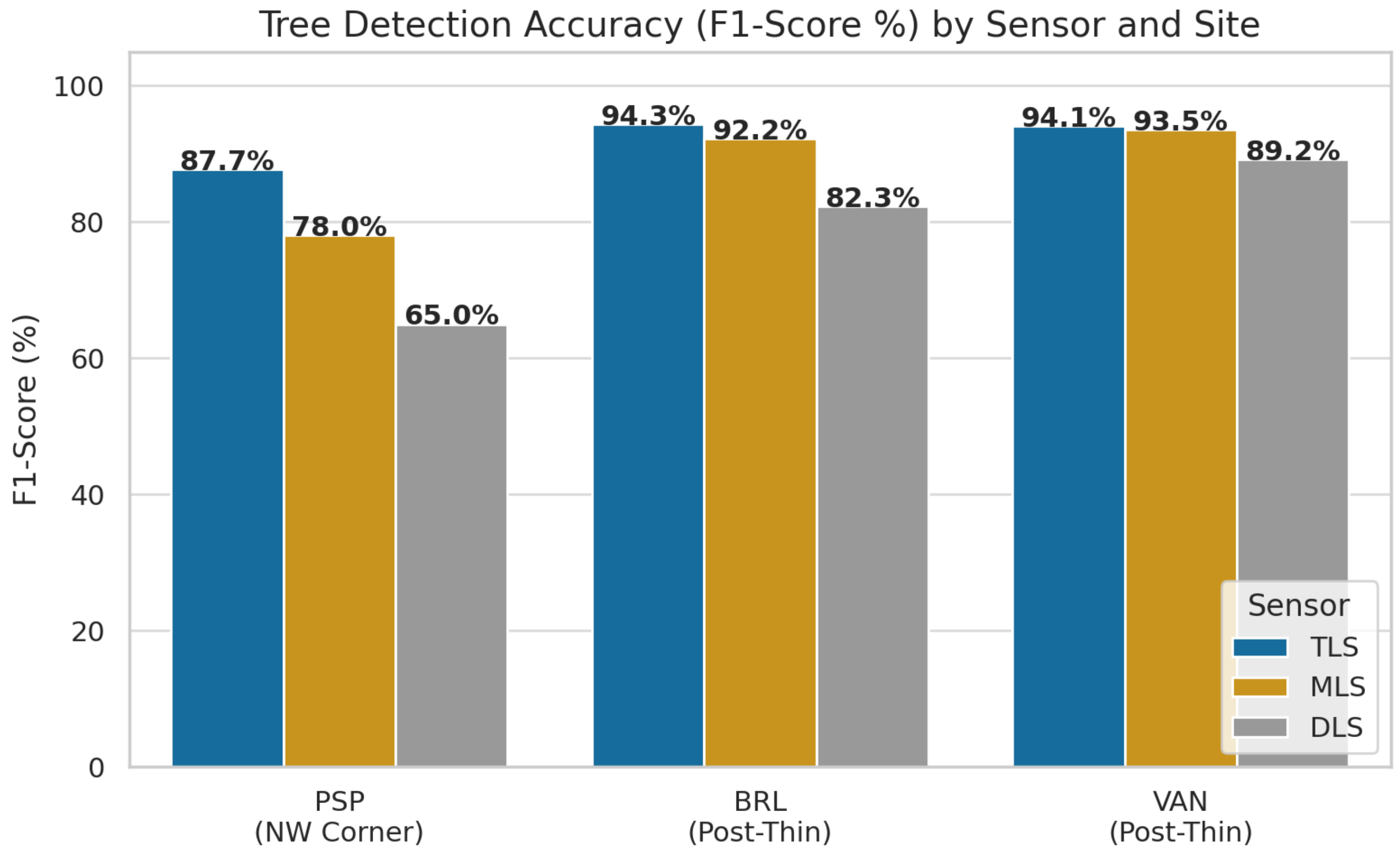
Method: *Time Investments*

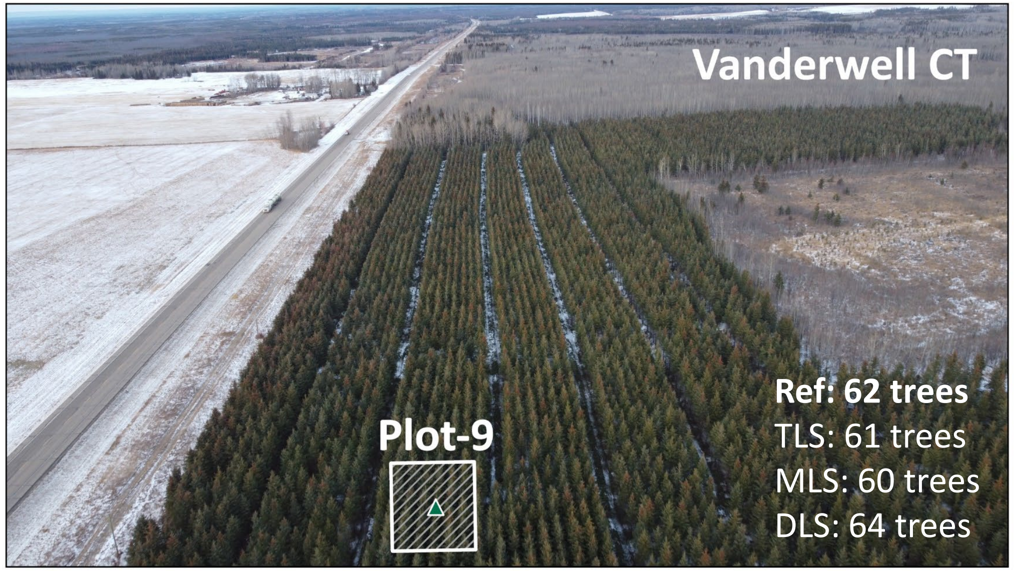
PHASE	PRIMARY TASKS
Data Collection	• Set up RTK/PPK • Deploy & survey sphere targets • Acquire DLS flight lines • Scan TLS positions • Walk MLS scan path
Compilation & Pre-processing	• Export LAS files • Register TLS/MLS scans • Co-register all sensors • Quality control checks
Post-processing & Reporting	• Batch metrics extraction • Generate CHM & tables • Export reports & logs

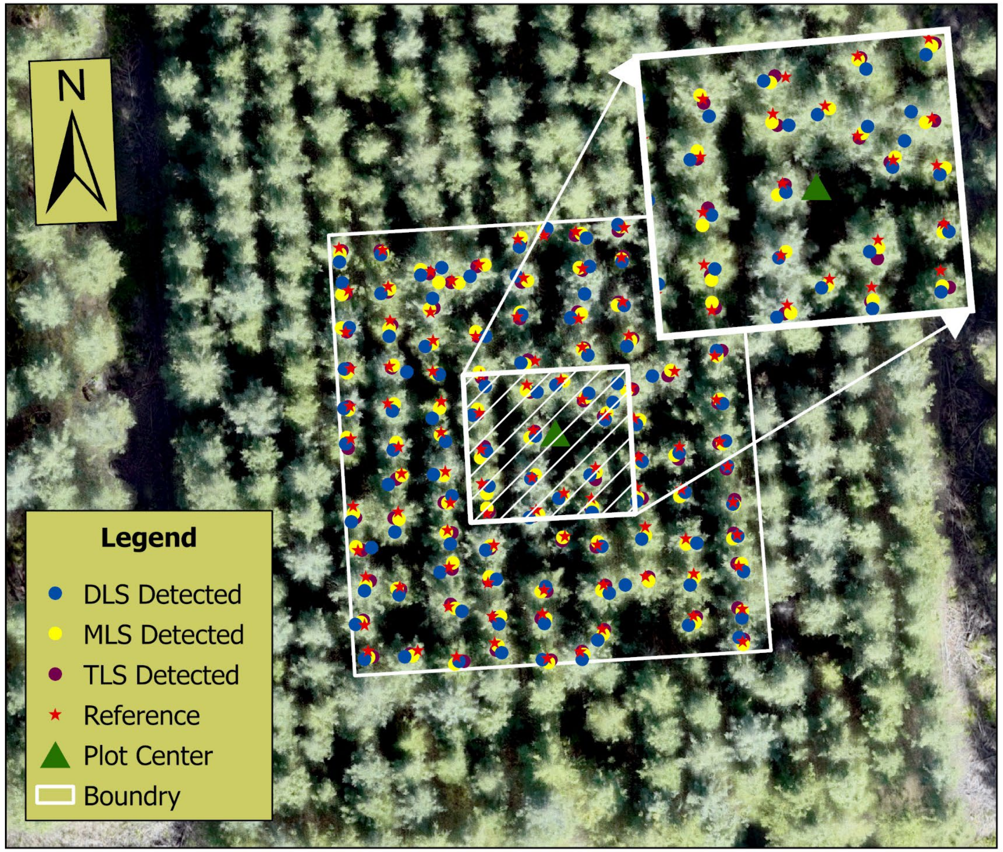




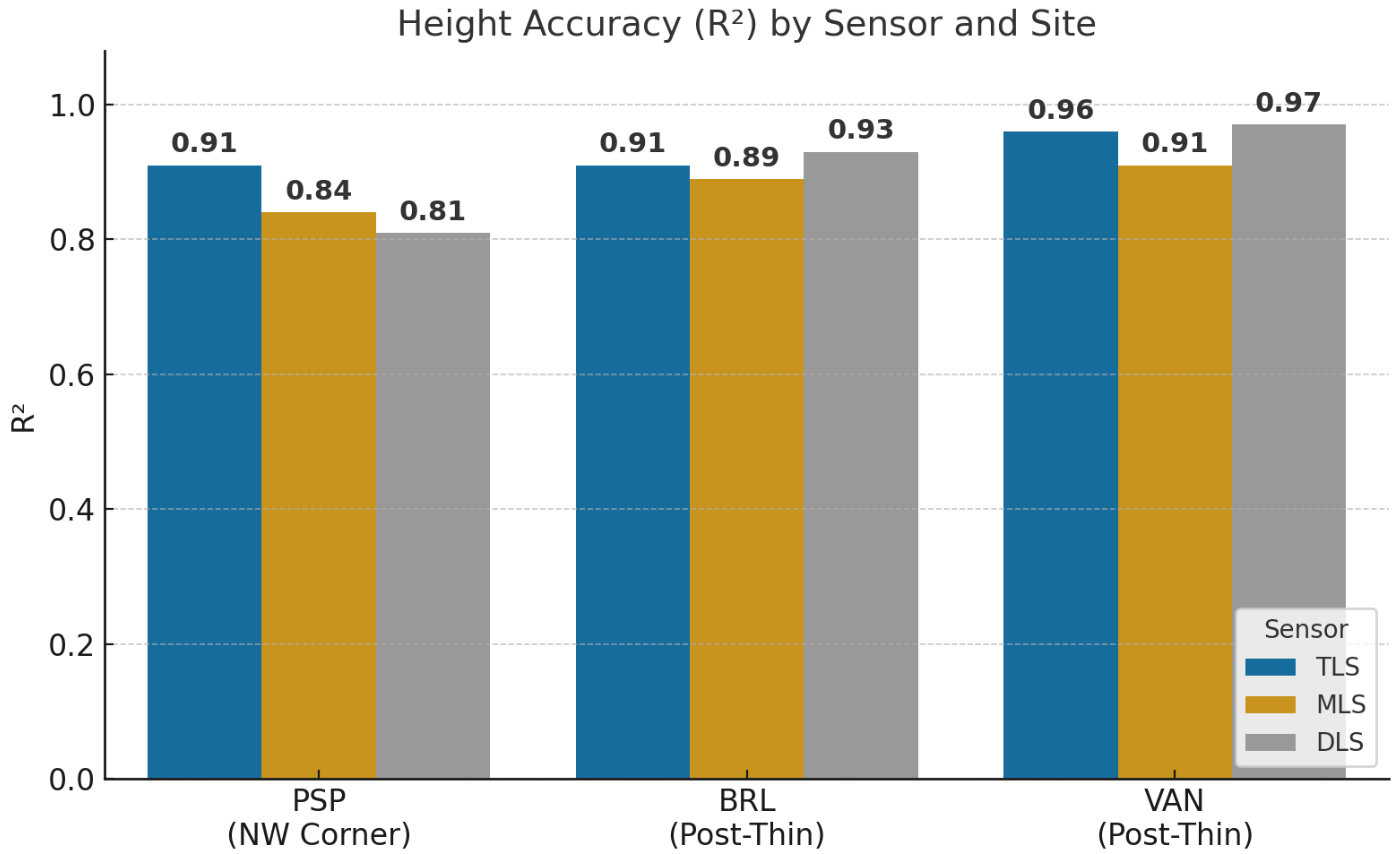
Result: *Tree Detection Accuracy*







Result: *Accuracy of Height Across Sensors and Forest Conditions*



	RMSE		
Sites	**DLS**	**MLS**	**TLS**
PSP (NW Corner)	5.1 m	3.6 m	2.2 m
BRL (Post-Thin)	0.6 m	1.1 m	0.8 m
VAN (Post-Thin)	0.4 m	0.9 m	0.5 m

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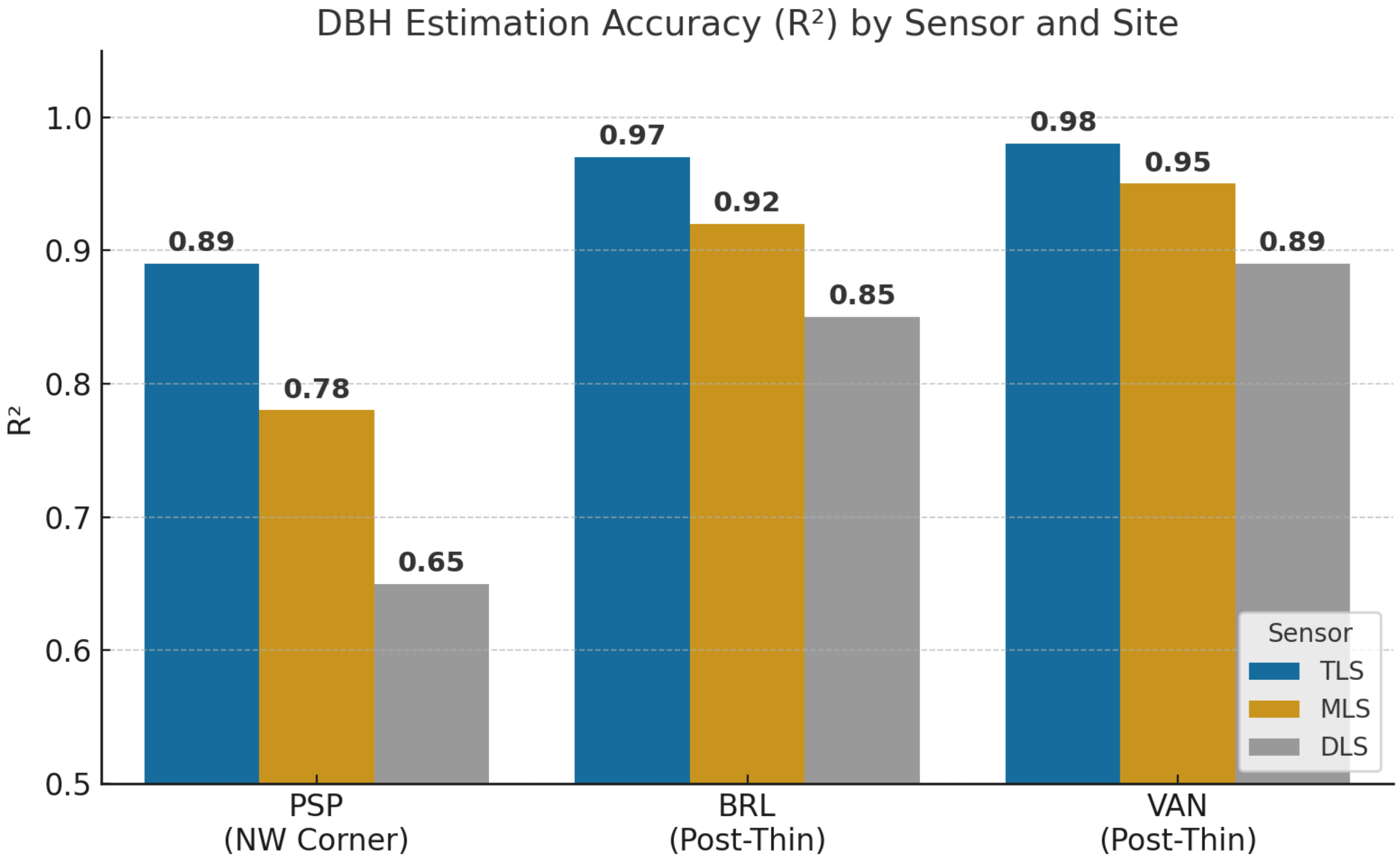
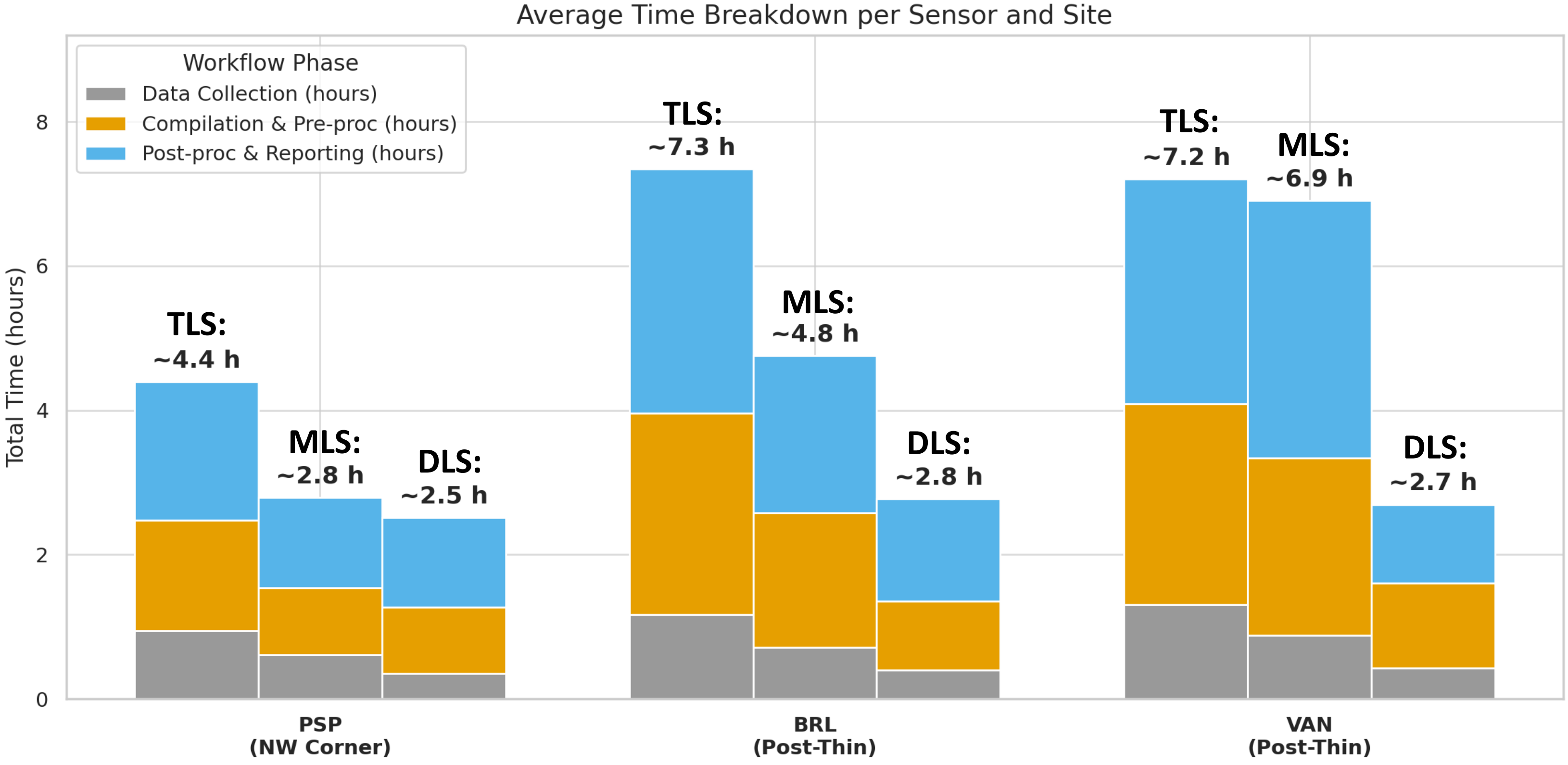
Result: *Accuracy of DBH Across Sensors and Forest Conditions*



	RMSE		
Sites	***DLS**	**MLS**	**TLS**
PSP (NW Corner)	3.9	2.6	1.1
BRL (Post-Thin)	2.2	1.3	0.4
VAN (Post-Thin)	1.1	0.7	0.2

**DBH estimated from height-derived allometric equations.*

Result: *Time investment*



🗺️ Scanning Coverage

Post-thinning lidar collected at BRL and VAN

Targeted scan at PSP 9 (NW Corner)

🔑 Key Insights

TLS was slowest:

6.5 h in VAN → 2.5× longer than DLS, 1.5× longer than MLS

DLS was fastest:

Completed all plots in ~2.5–2.8 h

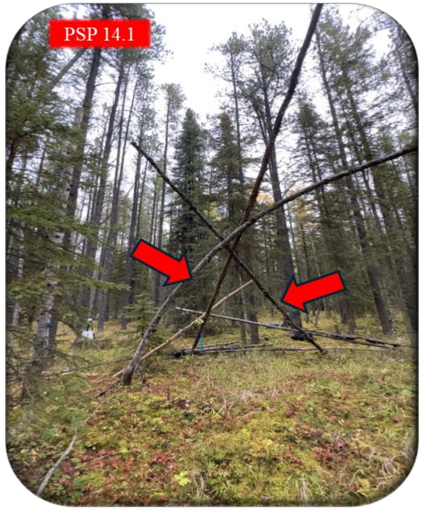
Post-processing = biggest time cost:

~60% of total in VAN–MLS

~50% in BRL–TLS

Challenges: *Field Conditions and Sensor Limitations*

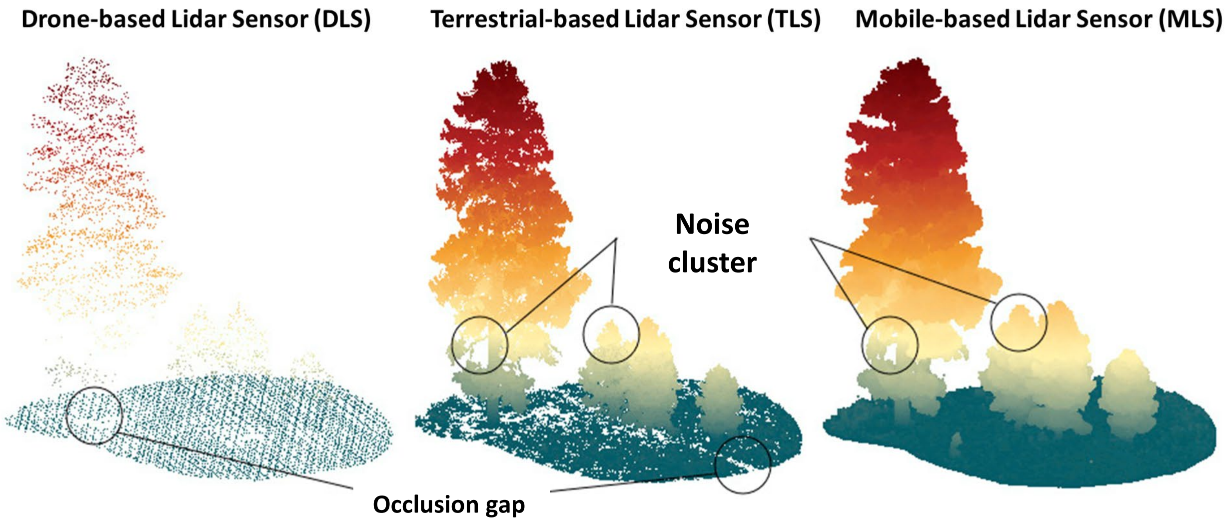
Large Fallen Trees



Severely Leaning Trees

Dense Lower Branching

Overlapping Branches



CONSEQUENCES:

↑ Data volume → increased memory & storage demands

↑ Processing time → bottlenecks in operational workflows

↑ Computational load → need for high-performance systems

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Summary of Findings and Practical Recommendations

Conclusion

- **TLS** was the most accurate across all sites, especially for DBH ($R^2 > 0.95$), but required the longest time (~2.5× DLS in PSPs-complex sites).
- **DLS** was the **most time-efficient** (**~2.5–2.8 hours/plot**) but less accurate in complex understory, particularly for DBH.
- **MLS** offered a **balance** between accuracy and efficiency, though still affected by positional noise in denser stands.
- **Post-processing was the dominant time phase**, reaching up to **60% of total time** with MLS in VAN and 50% with TLS in BRL.

Recommendation

- Use **DLS** for rapid large-area inventories where ground detail is less critical.
- Use **TLS** for high-precision needs and detailed stem mapping.
- Use **MLS** as a logistically flexible option for operational inventories.
- Consider **hybrid sensor integration** (e.g., TLS/MLS for stems + DLS for canopy).
- Focus on **automating post-processing** to reduce overall workflow time.

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THANK YOU

Ergin C. Cankaya
PhD Candidate

Alberta Government

FOREST RESOURCE IMPROVEMENT ASSOCIATION OF ALBERTA (FRIAA)

FOREST GROWTH ORGANIZATION OF WESTERN CANADA