Remote Sensing Validation for Tree Location and Height in the Oberteuffer Research and Education Forest, Oregon

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TECHNICAL RELEASE • OCTOBER 2025 25-TR-24

INTRODUCTION

Unmanned Aerial Systems (UAS) technologies are increasingly being adopted in operational forestry. With the integration of deep learning methodologies, forestry practitioners are more commonly using UAS-derived imagery to accurately identify individual tree locations—supporting precise regeneration surveys in young stands as well as post–pre-commercial thinning assessments in mid-rotation stands.

This study demonstrates the extended utility of UAS technology to not only collect accurate tree locations but also collect more complex forest metrics, like tree height. By combining UAS-derived RGB imagery with Structure from Motion (SfM) analysis, researchers were not only able to map individual tree locations but also reliably estimate tree heights.

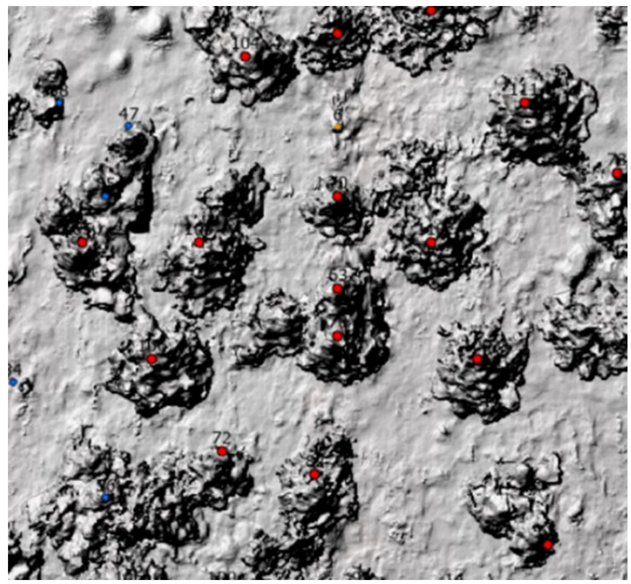
The research was conducted in the Oberteuffer Research and Education Forest (ORE Forest), a 113-acre property managed by Oregon State University's College of Forestry. Located in Union County, Oregon, the forest features diverse mixed-conifer stands dominated by ponderosa pine (*Pinus ponderosa*), Douglas-fir (*Pseudotsuga menziesii*), and western larch (*Larix occidentalis*). Actively managed for both education and research, the ORE Forest serves as a living demonstration of sustainable silvicultural practices under even- and uneven-aged management regimes.

APPLICATION

The primary goal of this research project was to evaluate the potential accuracy and cost effectiveness of specific remote sensing technologies envisioned to supplement more traditional methods of collecting forest metrics, such as tree heights and stand density.

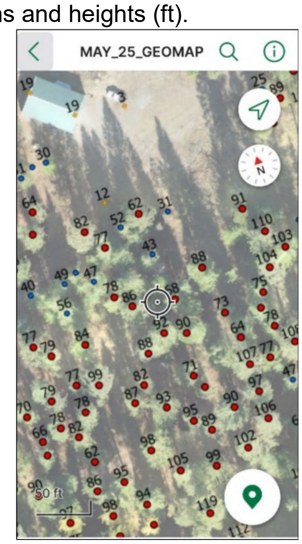
With approval from Oregon State University Forestry Extension, on October 25, 2024, staff with Data Analytics & Remote Sensing (DARS LLC), acquired 511 high-resolution RGB images using a DJI Mavic 3 Enterprise UAS. The imagery was processed to create orthomosaic aerial photos, Digital Surface Models (DSM), Digital Terrain Models (DTM), and 3D point clouds. **(Figure 1.)** Individual tree segmentation and height estimation were conducted using Structure from Motion (SfM) methodologies. Output tree features, which included tree location and height measurements for virtually every tree on the property were imported into ArcGIS Pro to create georeferenced PDFs suitable for field navigation.

Figure 1. Digital Surface Model (DSM) / 3-d point cloud of tree locations



On May 27, 2025, staff with Forest & Habitat Professionals (FHP) returned to the **ORE Forest** to collect field measurements to test the validity of the UAS-collected data. Using geo-referenced digital maps (**Figure 2**), created by **DARS**. Researchers were able to field locate 23 randomly selected trees, using the **Avenza** app on an iPhone. Field measurements for each tree were then collected. Tree height was measured using a Suunto clinometer and a 100 ft Spencer logging tape.

Figure 2. Screenshot of **Avenza** Mapping App – Showing tree locations and heights (ft).



RESULTS

UAS-Derived Tree Locations

Researchers were able to easily locate individual trees in the field using the digital map, as well as perform ocular evaluations of tree locations using the orthomosaic aerial photograph, as illustrated in (**Figure 3**).

Figure 3. Tree locations and heights overlaid on a UAS derived orthomosaic photograph.

UAS-Derived Tree Height

Individual trees were randomly selected and measured in the field. The resulting field measurements and corresponding UAS-derived measurements are included in **(Table 1.)**

Table 1. Field Measured vs. UAS Tree Heights

Tree #	Species	Field Measured Height (ft.)	UAS-Derived Height (ft.)
1	Ponderosa Pine	117	115
2	Ponderosa Pine	110	112
3	Ponderosa Pine	110	110
4	Ponderosa Pine	116	100
5	Ponderosa Pine	116	110
6	Douglas-fir	55.5	57
7	Douglas-fir	60	56
8	Westen Larch	108	102
9	Ponderosa Pine	104	109
10	Ponderosa Pine	74	56
11	Douglas-fir	60	63
12	Ponderosa Pine	70	71
13	Douglas-fir	76	71
14	Douglas-fir	21	18
15	Douglas-fir	46	51
16	Douglas-fir	98	106
17	Ponderosa Pine	116	112
18	Westen Larch	108	108
19	Ponderosa Pine	104	106
20	Douglas-fir	57	48
21	Ponderosa Pine	117	120
22	Westen Larch	88	89
23	Douglas-fir	107	107

The resulting data was plotted on a scatter graph. **(Figure 4)**. Subsequent linear regression analysis was performed with the following results.

Linear Regression (UAS Height vs. Field Height)

- Fitted Slope: 0.999 (essentially 1.0)
- Fitted Intercept: –1.73 ft
- R^2: 0.952 (very strong fit)
- Adjusted R^2: 0.950

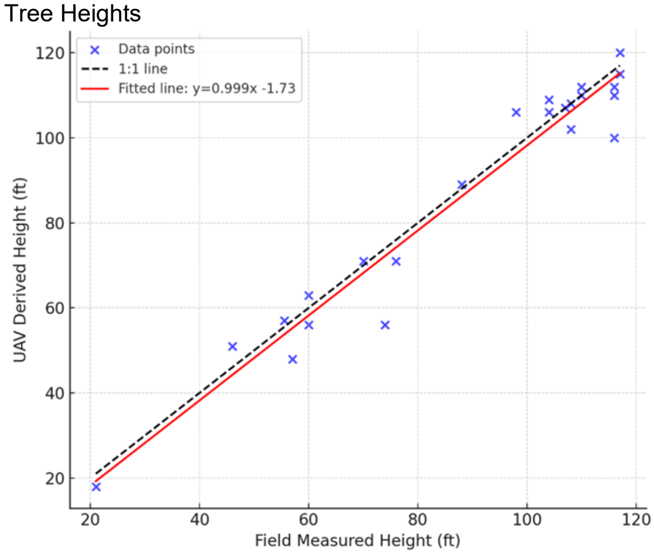
Hypothesis Tests (vs 1:1 line)

- Slope vs 1: $p < 0.0001$ → slope is statistically different from 1, but the difference is extremely small (0.999 vs 1).
- Intercept vs 0: $p = 0.707$ → intercept is not significantly different from 0.

Interpretation

- The UAS height measurements scale almost perfectly with field measurements (slope ~1).
- The intercept suggests UAS tends to underestimate by ~1.7 ft, but this bias does not appear to be statistically significant.
- The relationship between UAS and field heights is extremely strong ($R^2 \approx 0.95$).

Figure 4. Scatterplot of Field-Measured vs. UAS - Derived Tree Heights



SPECIFICATION AND COST

Data Analytics and Remote Sensing (DARS) provided the following deliverables for this study:

- High-resolution orthomosaic imagery (< 2 cm pixels);
- X/Y coordinates and height measurements for all trees;
- Georeferenced PDF's, suitable for use on smartphones and/or tablets in the field;
- Digital file formats suitable for use in ArcGIS and other GIS software.

DARS was able to collect the imagery and create these deliverables at a cost that was less than $10/acre.

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CONCLUSION

This study validates the use of UAS-derived RGB imagery and Structure from Motion (SfM) analytical tools to accurately estimate tree locations and tree heights. With accuracy as high as (+/- 5%) for tree height and the ability to accurately identify individual tree locations, this methodology should be expected to supplement and significantly reduce the time and expense of traditional field-based collection of forest metrics.

ACKNOWLEDGMENTS

We thank the **Oregon State University (OSU) Research Forest System, OSU Forestry Extension staff and specifically Stephen A. Fitzgerald, Professor Emeritus** for their support of this project**.** We would also like to thank **the Oberteuffer family** for their enduring commitment to forestry education and research. Remote sensing data collection and analysis were conducted by **Data Analytics and Remote Sensing (DARS) LLC**, and field validation by **Forest and Habitat Professionals (FHP) LLC**.

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