Assessment of individual tree detection methods using ALS data

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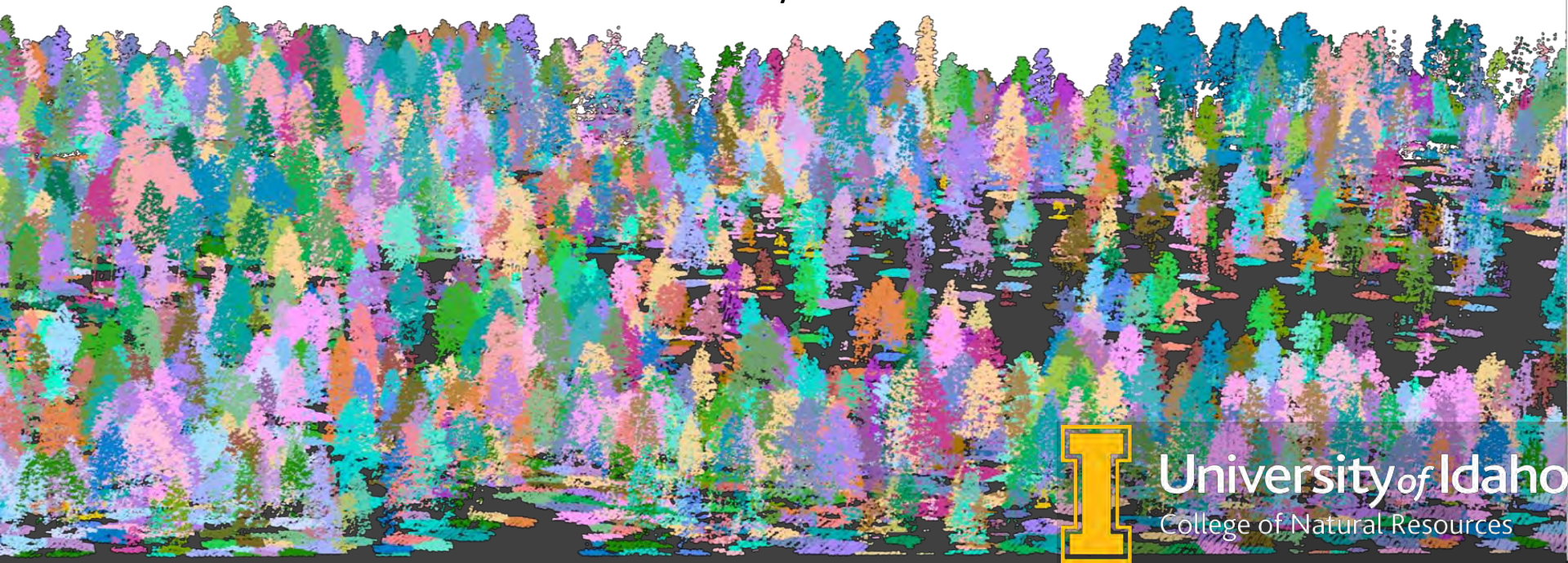
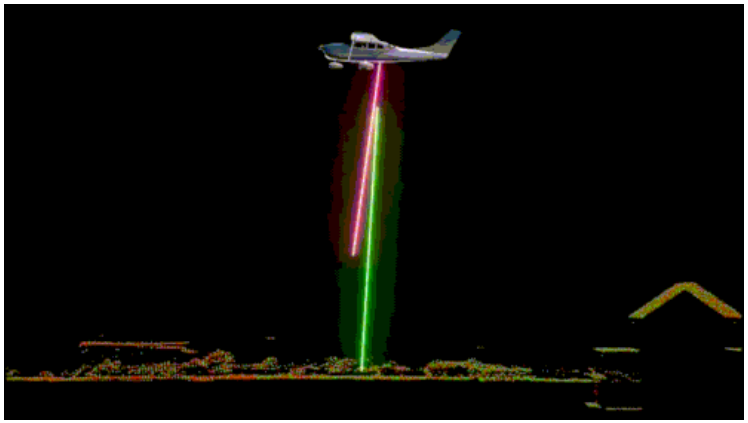


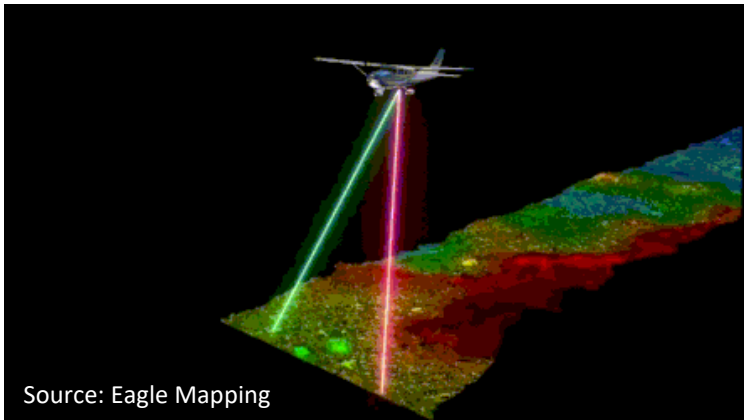
Outline

- Research motivation
- Input data and ITD method variants
- ITD method assessment using UIEF benchmark dataset
- Preliminary results

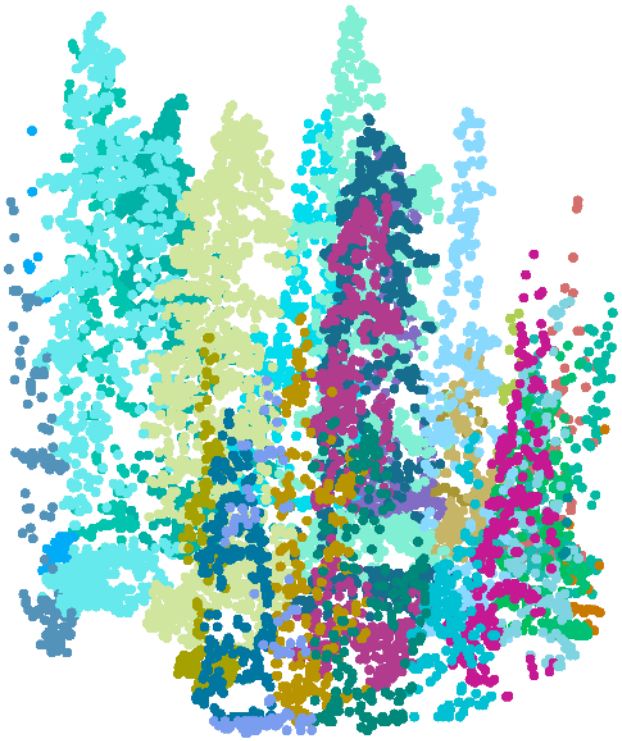
ALS based ITD

- Airborne LiDAR (aka airborne laser scanning - ALS)





- Individual tree detection (ITD) identifies individual trees and allows for crown delineation, precise tree locations and attributes (e.g., height, DBH, species)



Research motivation

- ITD is a keystone of precision forestry and *may* allow forest management to:
  - Move beyond sample-based inventory to near-census inventory (in other words…what is out there?)
  - Inform harvest planning and optimize harvesting and other forest operations
  - Conduct product tracking – 'from tree to table'
  - Develop more accurate tree lists for improved growth and yield modeling
  - Characterize tree scale growth, injury and mortality via multi-temporal datasets
  - …

Research motivation

- Numerous ITD methods, but few studies compare using benchmark dataset (any validation is time consuming and costly)
- End users need to know how these methods perform across varying forest composition and structure conditions
- Product developers need to know what to prioritize for improving ITD methods

Research motivation

- **Overarching objective:** assess the accuracy of commonly-used and accessible ITD methods in mixed coniferous forest with diverse stand structure and composition using a benchmark dataset

Input ALS and preprocessing

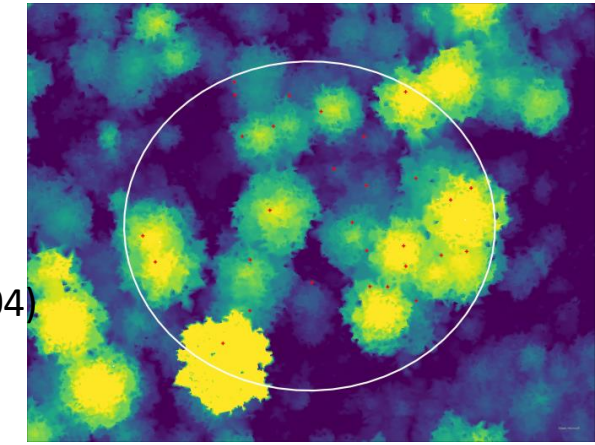
- 2 ALS datasets
  - 8 ppm^2 ALS data acquired in summer of 2018
  - 16 ppm^2 ALS data acquired in summer of 2021

- Crown height models (10, 25, 50cm) computed using pit-free methodology and recommended parameters for low- and high-density LiDAR (Khosravipour et al. PERS 2014)

ITD methods

- Point-cloud based
  - Li et al. PERS 2012

- Crown height model based
  - Local max filter fixed radius
    - lidR (Roussel et al. RSE 2020)
    - rlidar (Silva et al. CJRS 2017)
  - Local max filter variable radius
    - Variable window filter (Popescu and Wynne PERS 2004)
    - Spatial wavelet analysis (Strand et al. IJRS 2006)
  - Watershed (Vincent and Soille 1991)



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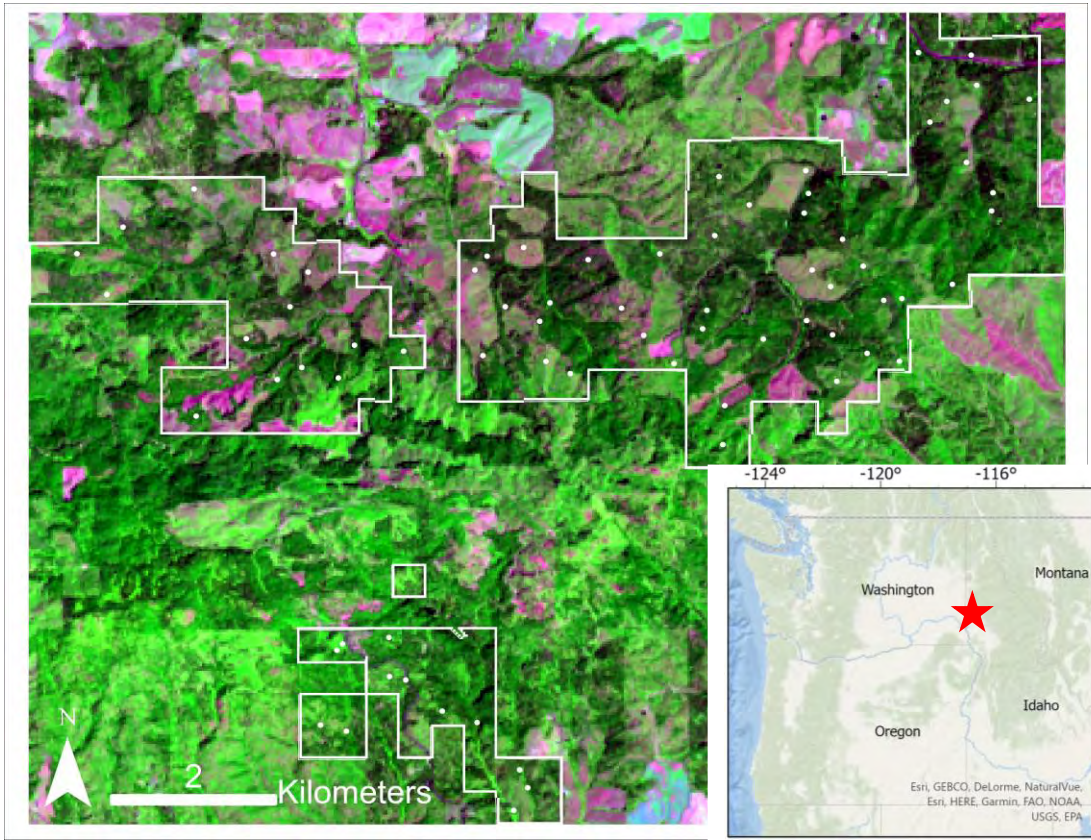
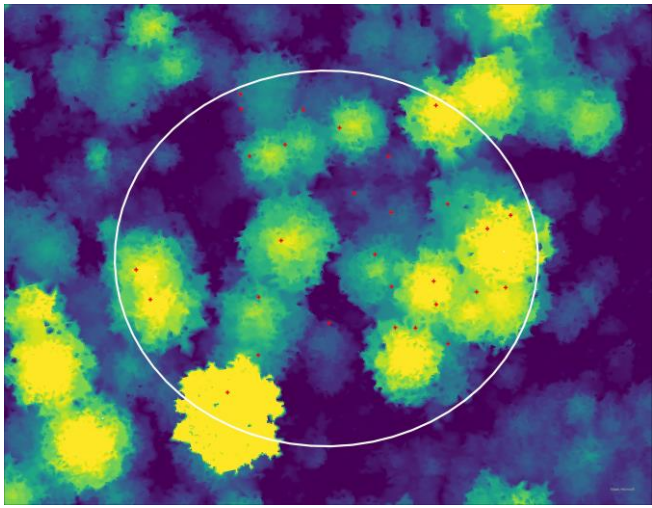
- Palouse Range, north-central Idaho
- Mixed conifer forest, dominant species include:
  - *Pseudotsuga menziesii*
  - *Abies grandis*
  - *Thuja plicata*
  - *Larix occidentalis*
  - *Pinus ponderosa*
- Actively managed for timber, research and education purposes



Landsat 8
July 2020
fc754

University of Idaho Experimental Forest

Field Validation Dataset



- 67, 13 m radius plots established to capture structure and composition variability across UIEF in summer 2020
- All trees >1.5 m height were stem mapped
- 1,987 measured trees, 11 species
- Height, DBH, species, canopy position recorded for each tree (summary table below)

Metric	Minimum	Maximum	Median	Mean	SD
Tree Density (trees/ha)	18.8	1846.7	508.8	542.7	386.7
Basal Area (m^2/ha)	0.4	111.6	31.3	31.9	23.0
DBH (cm)	5.1	137.2	19.1	23.2	14.6
Height (m)	6.1	40.9	14	15.9	7.6

ITD method variants and matching

ITD Method variants

- Crown dimension parameters and search window size of 1.5, 2.5, 3.5 m tested (2.5 m is average crown diameter for the UIEF)

- Input CHMs of 10, 25, 50 cm

Matching ALS detected and Reference trees

- Candidate reference tree list selected within 2.5 m of ALS detected tree

- Candidate reference tree within 2 m in height and with lowest combined height and distance error matched with ALS-detected tree

Accuracy assessment

ITD accuracy metrics

- Recall (inversely related to omission error)
- Precision (inversely related to commission error)
- F-score (harmonic mean of recall and precision)

$$r = \frac{TP}{TP + FN}$$

$$p = \frac{TP}{TP + FP}$$

$$\text{F-score} = 2 \times \frac{r \times p}{r + p}$$

TP: correct detection
FN: false negative (omission error)
FP: false positive (commission error)

*Results stratified by canopy cover to quantify canopy cover effects on accuracy

Height accuracy for matched trees

- Regression based equivalence test using ±25% region of equivalence (Robinson et al. 2005)

ITD accuracy results

- Large variation depending on input parameters
- Generally, most accurate methods used 50 cm CHM (25 cm for 8 ppm^2) and search window size equal to- or smaller than average crown diameter (2.5 m)
- Highlights of the most accurate (in terms of F-score) method variants…

	16 ppm^2 ALS			8 ppm^2 ALS		
Method	**recall**	**precision**	**F-score**	**recall**	**precision**	**F-score**
Li 2012	0.40	0.56	0.46	0.46	0.55	0.48
	0.37	**0.64**	**0.46**	**0.40**	**0.67**	**0.48**
	0.29	0.70	0.41	0.35	0.73	0.46
lidR local max filter	0.51	0.40	0.45			
	0.41	0.67	0.50			
	0.33	0.71	0.44			
	0.48	0.50	0.47			
	0.38	0.72	0.47			
	0.29	0.75	0.42			
	0.50	0.41	0.45	0.48	0.51	0.47
	0.40	0.69	0.48	0.41	0.71	0.51
	0.31	0.73	0.44	0.36	0.74	0.47
	0.44	0.58	0.48	**0.45**	**0.61**	**0.50**
	0.36	0.72	0.44	0.38	0.73	0.49
	0.28	0.73	0.42	0.33	0.76	0.44
	0.45	0.62	0.48	0.47	0.54	0.48
	0.39	0.72	0.48	0.41	0.69	0.50
	0.33	0.71	0.44	0.36	0.73	0.47
	0.45	**0.62**	**0.48**	0.47	0.54	0.48
	0.37	0.71	0.48	0.39	0.71	0.50
	0.31	0.73	0.44	0.34	0.74	0.45
rlidar local max filter	0.42	0.58	0.46			
	0.21	0.73	0.33			
	0.11	0.80	0.20			
	0.40	0.64	0.47	**0.41**	**0.63**	**0.49**
	0.25	0.73	0.39	0.28	0.72	0.42
	0.15	0.73	0.27	0.21	0.75	0.35
	0.44	**0.62**	**0.47**	0.45	0.55	0.48
	0.33	0.74	0.46	0.35	0.71	0.47
	0.22	0.73	0.37	0.25	0.74	0.39
Spatial wavelet	**0.35**	**0.75**	**0.46**			
	0.32	0.75	0.42	**0.33**	**0.68**	**0.42**
	0.25	0.79	0.37	0.27	0.68	0.38
Variable window filter	0.44	0.67	0.49			
	0.44	0.67	0.49	**0.39**	**0.72**	**0.49**
	0.43	**0.71**	**0.50**	0.39	0.71	0.49
	0.33	0.71	0.42			
	0.34	0.70	0.42	0.31	0.77	0.42
	0.34	0.73	0.42	0.31	0.76	0.42
Watershed (Fusion)	0.57	0.23	0.32			
	0.47	0.52	0.45	0.51	0.40	0.42
	0.40	**0.70**	**0.50**	**0.41**	**0.51**	**0.45**

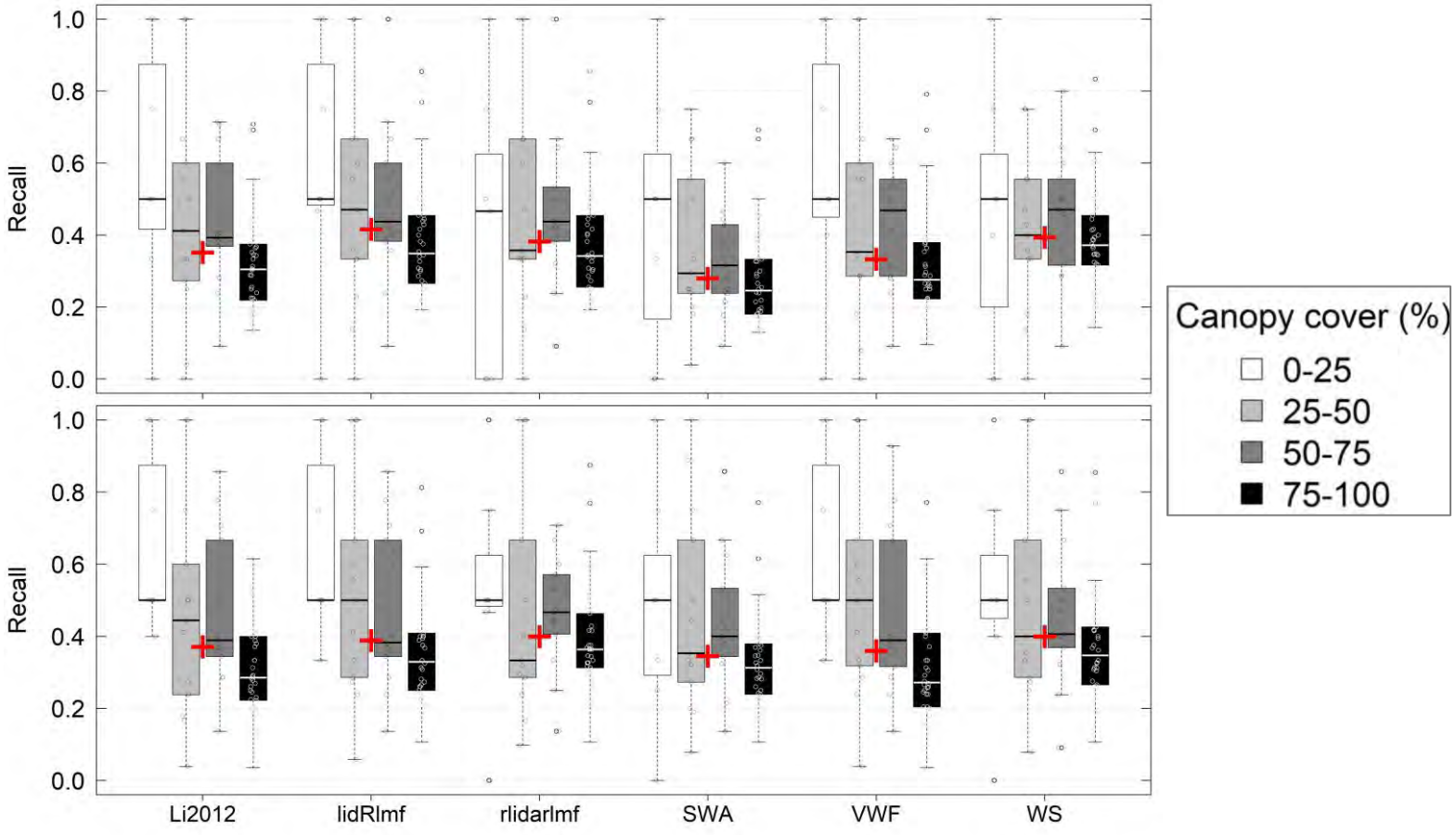
ITD accuracy results

Recall

(inversely related to omission error – i.e., trees in the validation dataset that were missed)

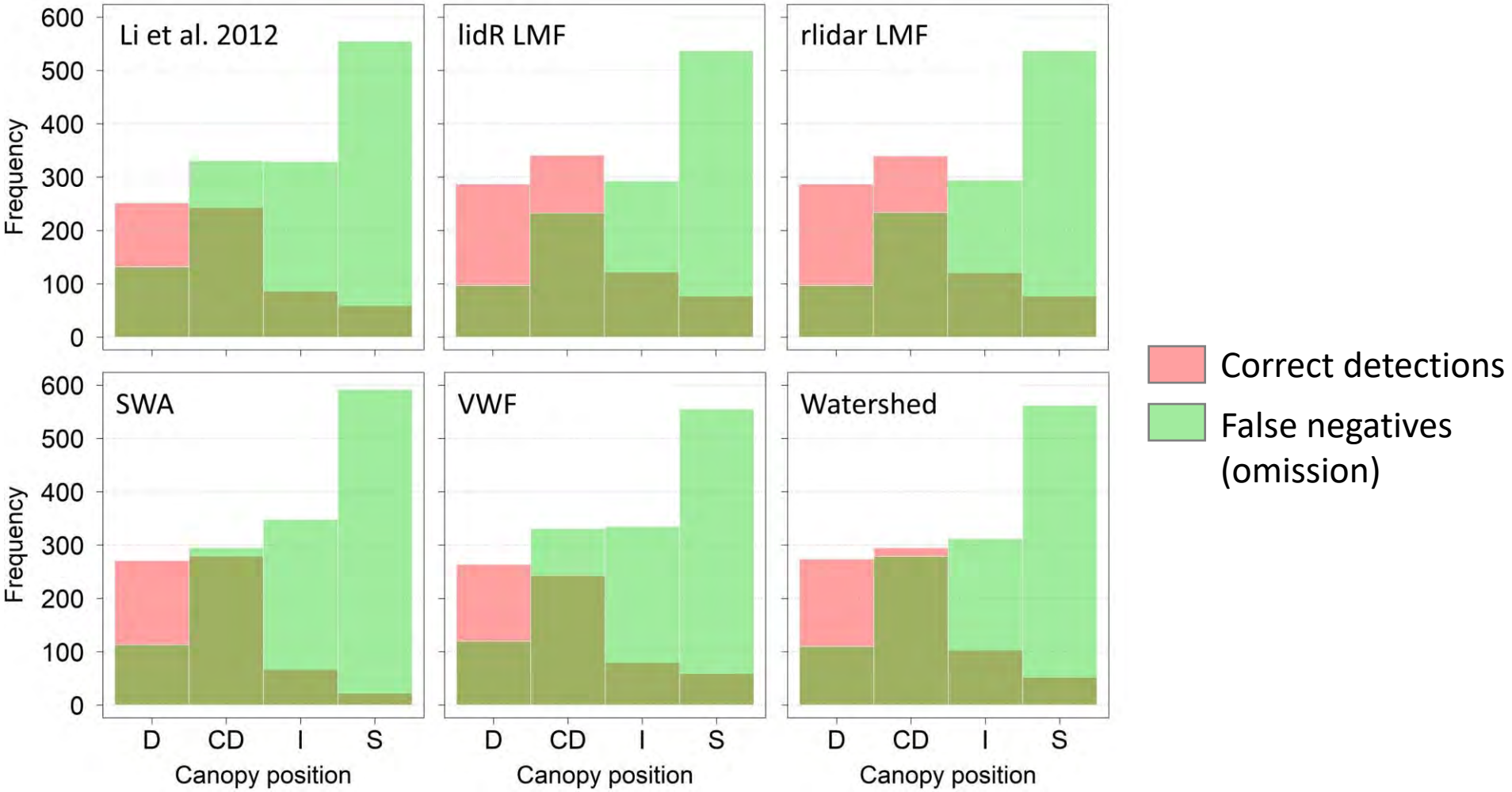
8 ppm^2

16 ppm^2



ITD accuracy results

Omission errors in relation to canopy position



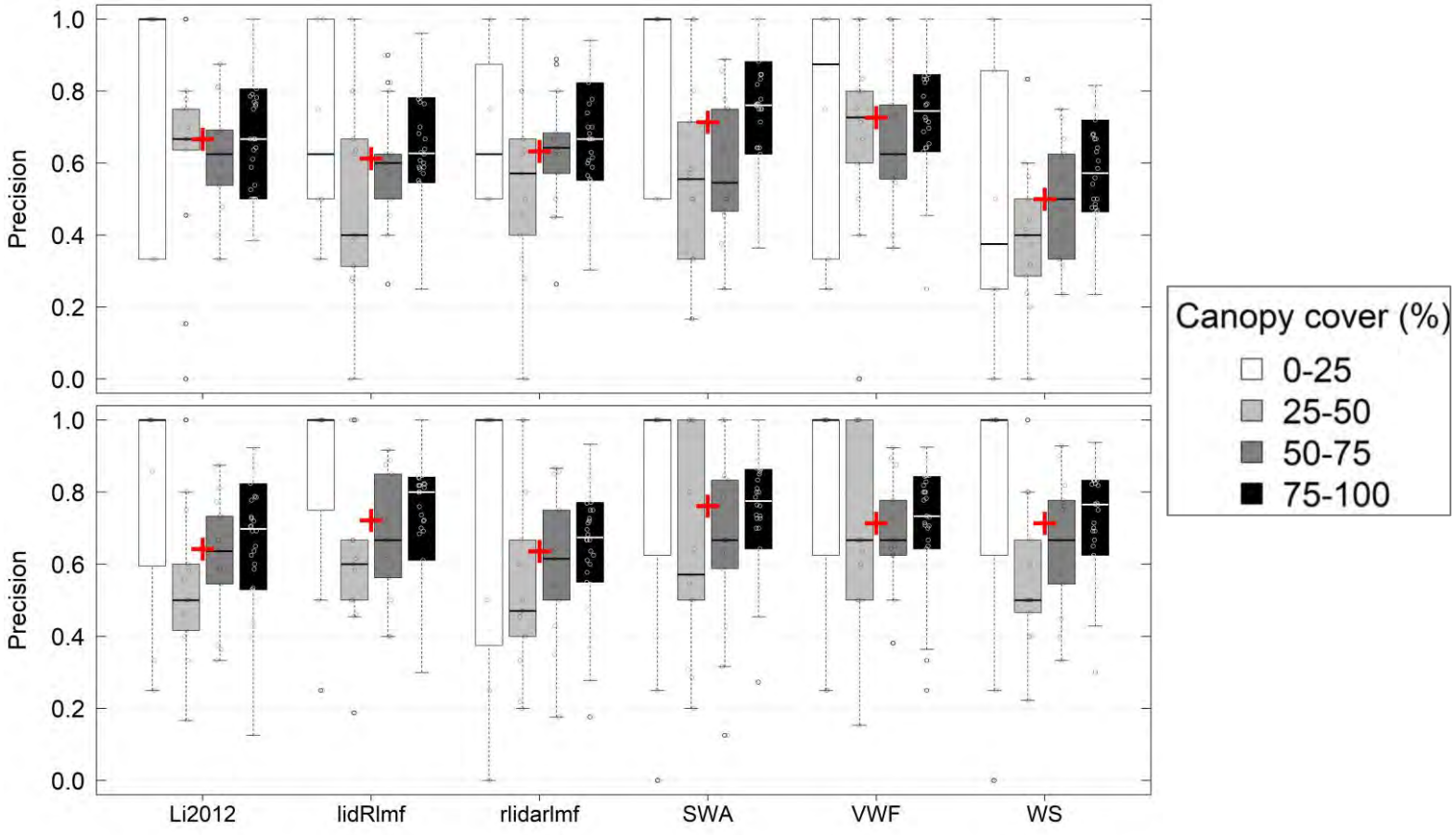
ITD accuracy results

Precision

(inversely related to commission error – i.e., trees erroneously included, not in validation dataset)

8 ppm^2

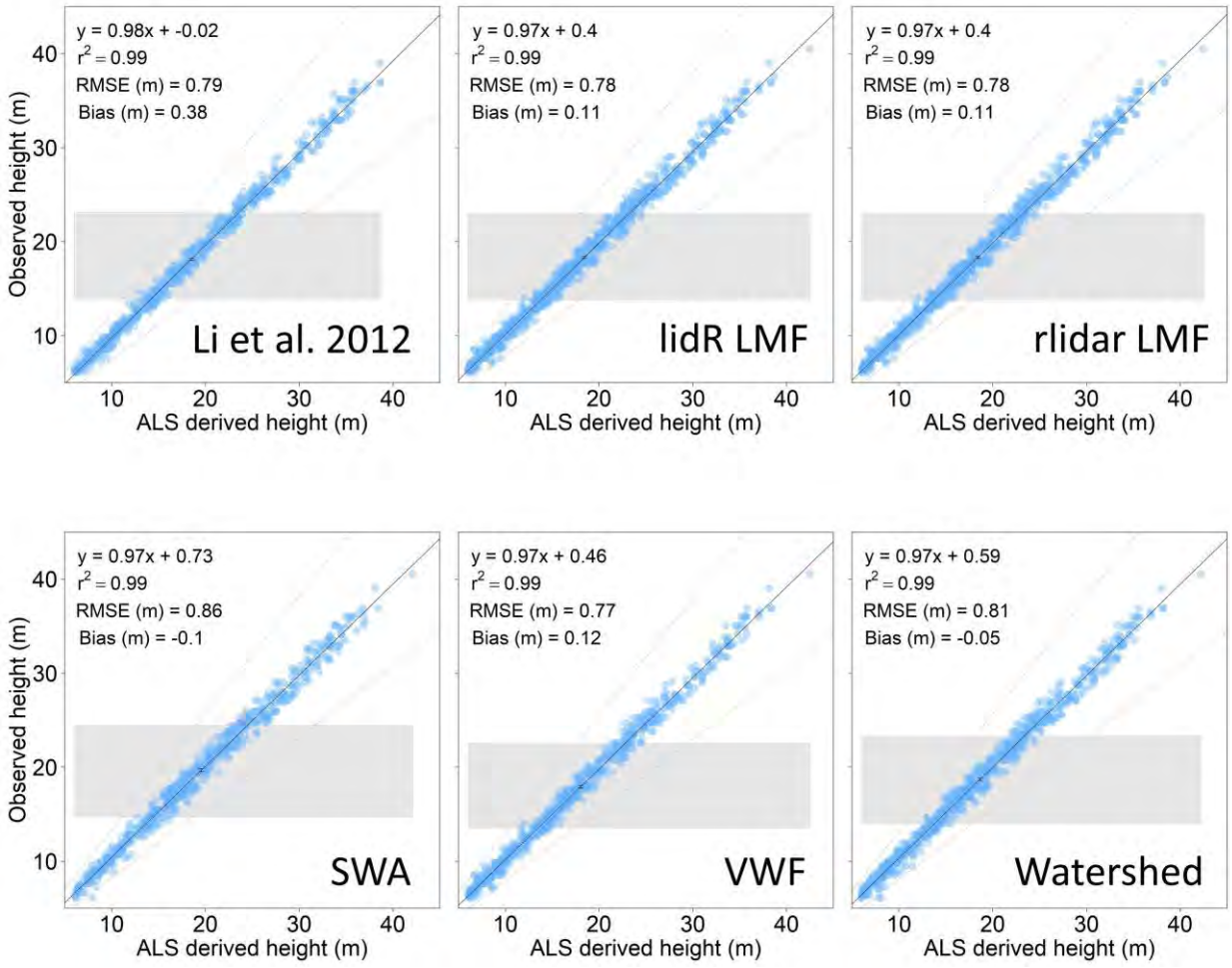
16 ppm^2



ITD accuracy results

Height accuracy

- ALS-derived height for detected trees equivalent to field measured height for top methods using both ALS datasets
- Bias and RMSE similar across methods



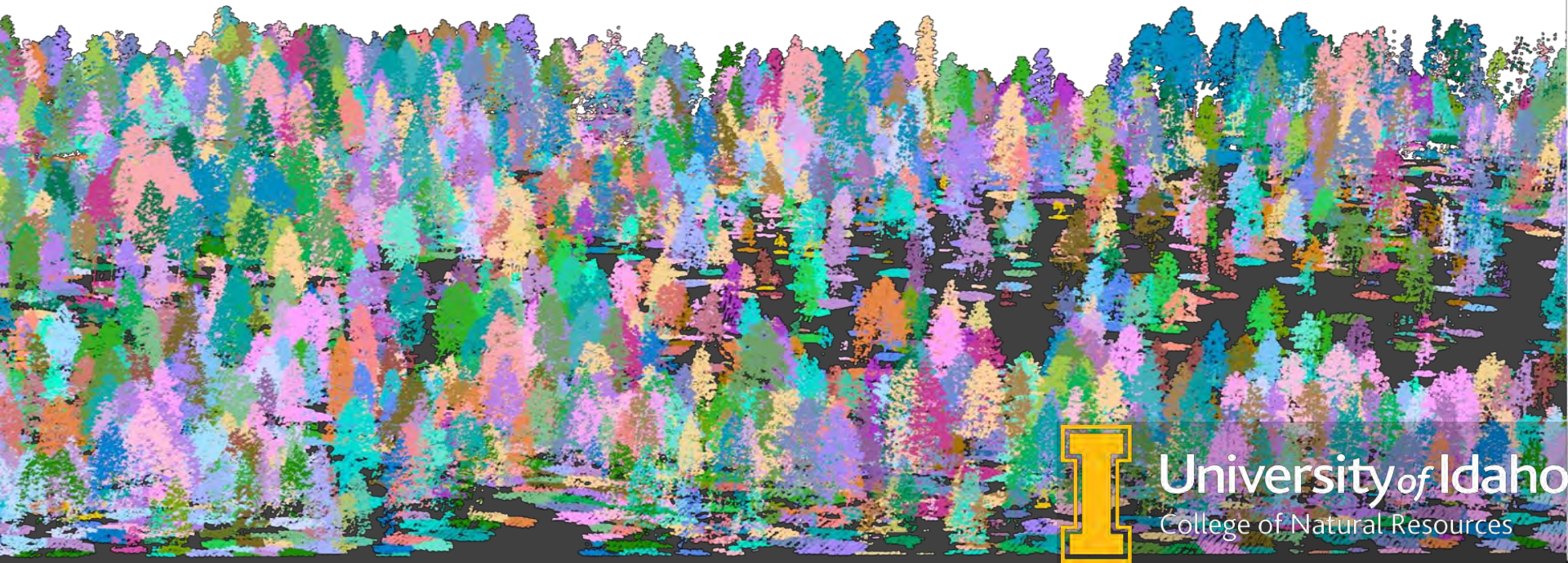
Some preliminary take-aways

- Canopy cover/tree density was found to be a larger driver of accuracy than method choice
- All methods had high omission error associated with intermediate and suppressed trees
- CHM based, fixed search window size methods generally had lower omission errors across all canopy positions compared with other ITD methods
- Using 16 ppm^2 vs 8 ppm^2 ALS resulted in an average 6% increase in F-score
- Nearly all CHM-based methods had highest accuracy when implemented with 50 cm CHM (25 cm CHM for 8 ppm^2 ALS), and search window size smaller than average tree crown diameter

Acknowledgements

NORTHWEST MANAGEMENT, INC.

University of Idaho
College of Natural Resources



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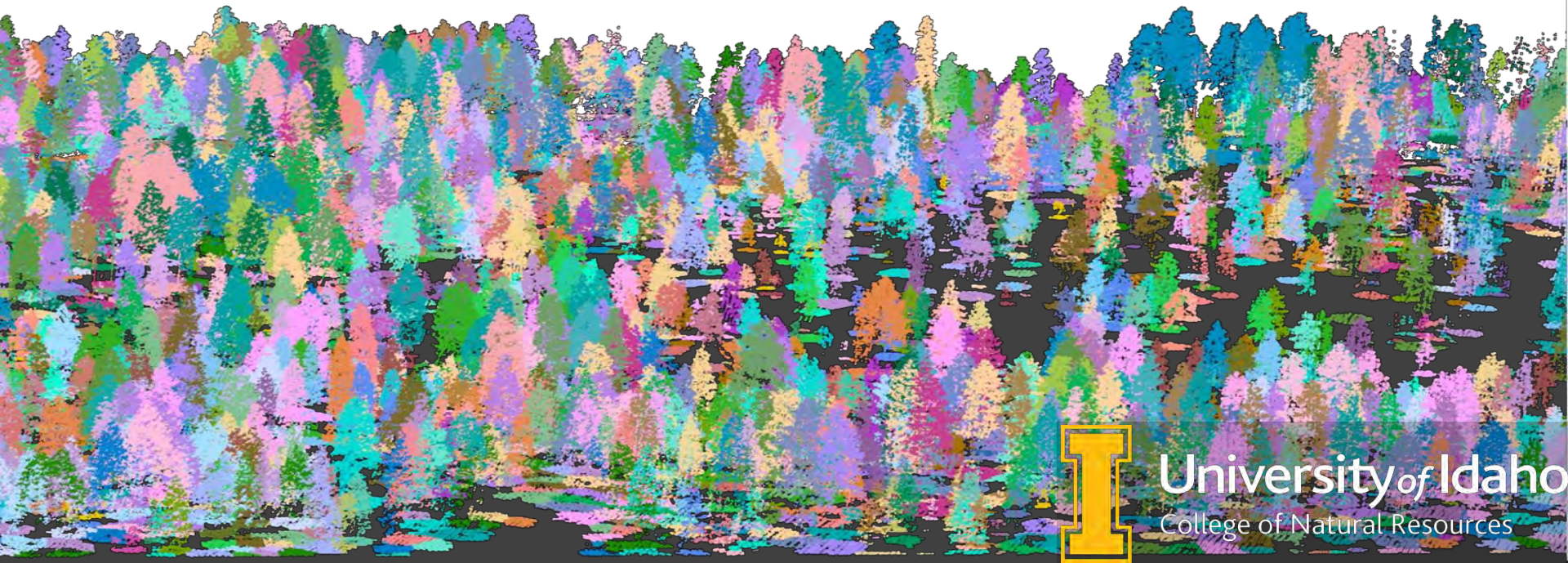
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