An Evaluation of Single-Date and Multi-Date Lidar Acquisitions to Predict Site Index in the Pacific Northwest, USA

Suchana Aryal (2nd year, Ph.D)

April 15th, 2025

College of Forestry
Department of Forest Engineering, Resources, & Management

Oregon State University

OUTLINE

01. Motivation

02. Research Objectives

03. Methods

04. Results

Forest Productivity Measures:

Help us understand stand growth dynamics through time and support forest management

Forest Productivity Measures:
Key for Managing Forests & Understanding Stand Growth

Site Index (SI)

Most common and widely accepted quantitative measure of forest productivity in the United States (Carmean, 1975; Skovsgaard & Vanclay, 2008).

Forest Productivity Measures:
Key for Managing Forests & Understanding Stand Growth

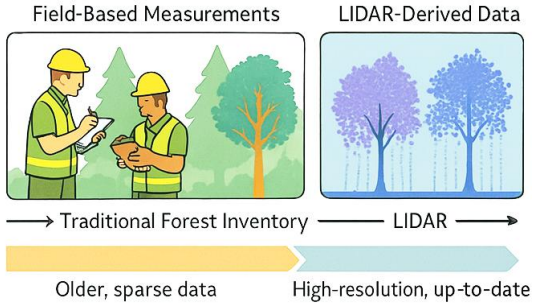
Site Index (SI)
Most common and widely accepted quantitative measure of forest productivity in the United States (Carmean, 1975; Skovsgaard & Vanclay, 2008).

Conventional Method

Makes site index a costly forest attribute

01 Motivation

One straightforward single-date lidar site index approach is to leverage stand ages from existing stand data and substitute lidar heights for stand heights.



There have been promising results for age-independent site-index estimates.

For example, Noordermeer et al. (2018) used multi-date lidar to successfully (R2=0.8) infer site index from site curves with an age-independent approach but fared poorer than modeling field-measured site index with single-date lidar.

01 Motivation

There have been promising results for age-independent site-index estimates.

For example, Noordermeer et al. (2018) used multi-date lidar to successfully (R2=0.8) infer site index from site curves with an age-independent approach but fared poorer than modeling field-measured site index with single-date lidar.

In contrast, Moan et al. (2025) found equivalent performance between the field-based lidar site index and the age-independent multi-date lidar site index.

01 Motivation

There have been promising results for age-independent site-index estimates.

For example, Noordermeer et al. (2018) used multi-date lidar to successfully (R2=0.8) infer site index from site curves with an age-independent approach but fared poorer than modeling field-measured site index with single-date lidar.

In contrast, Moan et al. (2025) found equivalent performance between the field-based lidar site index and the age-independent multi-date lidar site index.

Socha et al. (2020) used multi-date lidar to fit new site index curves using both ABA and ITD type inferences. They found that it was feasible, especially with ITD, to fit site index curves from multi-date lidar that were equivalent to field-based site index curves.

*Area-based approach (ABA); Individual tree detection (ITD)

01 Motivation

There have been promising results for age-independent site-index from multi-date photogrammetric heights (e.g., Véga and St-Onge, 2009; Janiec et al., 2024).

01 Motivation

These developments in age-independent site index represent an exciting opportunity in forest monitoring.

However, the relative performances of single-date lidar site index and age-independent multi-date lidar site index are still unclear, especially for west coast USA forests.

02 Objective

This study aims to compare the age-independent multi-date lidar site index with the single-date lidar site index.

03 Methods

Figure 1

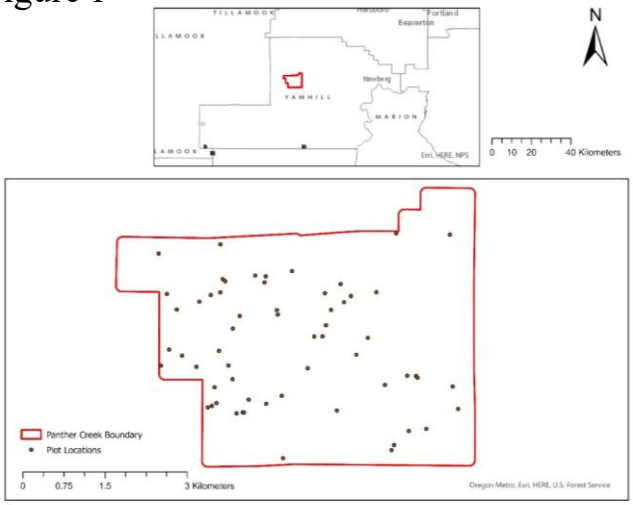
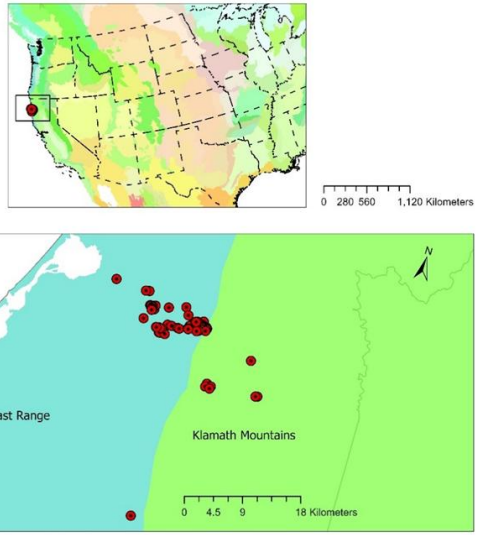
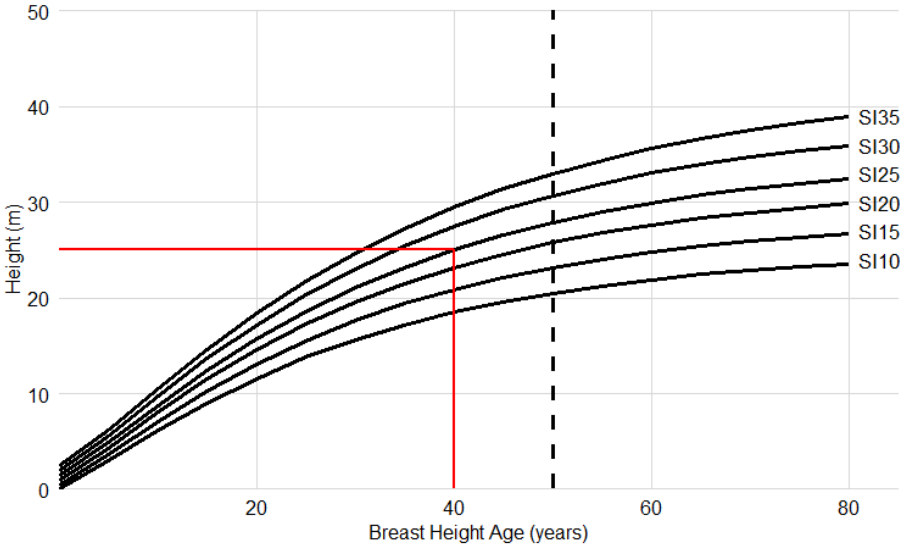


Figure 2



Site Index: *Reference Site Index*

03 Methods



Note: Age-height pairs rarely land exactly on a site index, and the nearest site index curve is used, where in operational practice, continuous site index values (e.g., 25.55 m) are also used.

Figure 3. Example selection of site curve (e.g., 25 m) which most closely matches the observed age-height pair. The red lines represent field-measured age and height. Site index (expected height at age 50) is listed on the right side.

Lidar Site Index: *Multi-date*

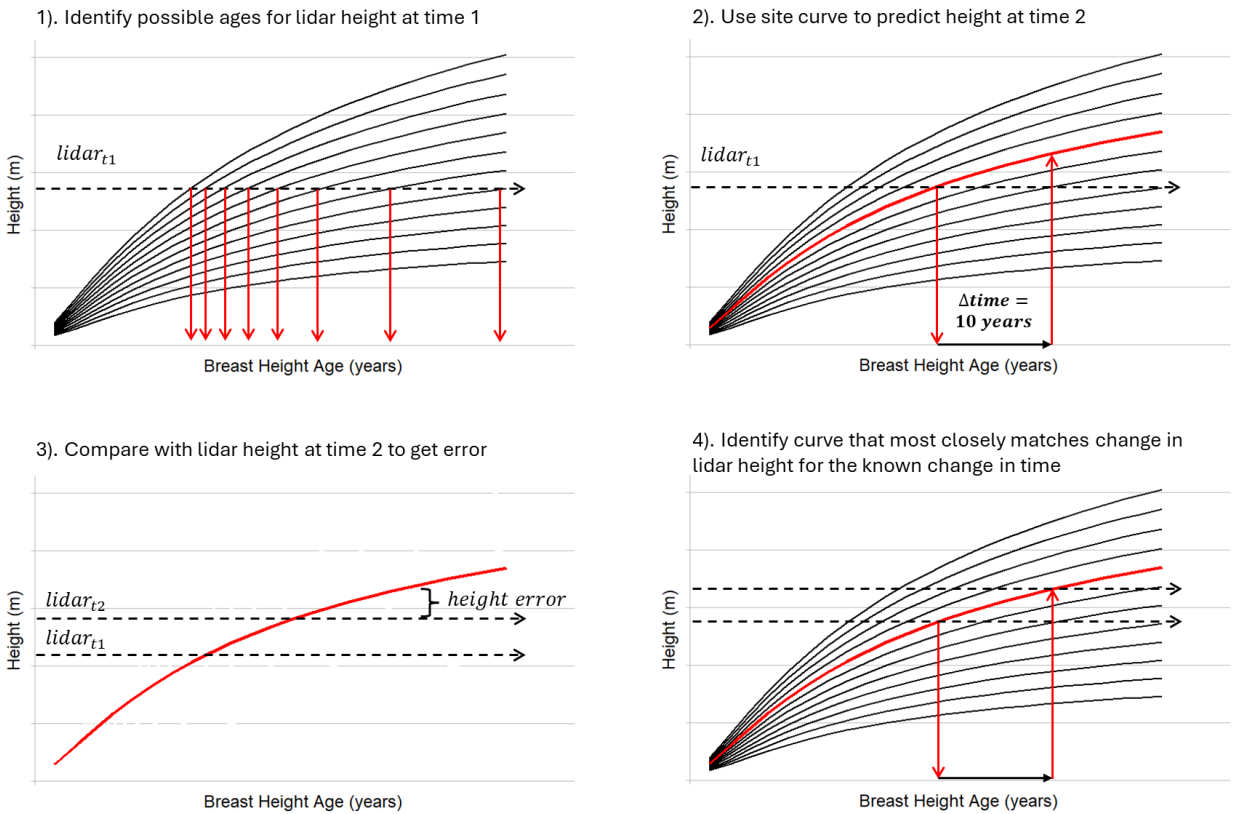


Figure 4. Demonstration of heuristic approach to select site curve from two lidar heights for a single plot, as implemented in R.

The site index curves are intersected with lidar heights at time 1 and time 2 and used alongside the fixed time between lidar collections (Δt), for example, 10 years in this demonstrative figure. The site curve in panel 4 is selected which results in the smallest height error for lidar height at time 2.

Lidar Site Index: *Single-date*

03 Methods

1 . Match the lidar height to predefined site index curves and derive the possible age (A, B, C, ...) at breast height.

2) Compare the derived age to the field inventory age to identify the curve that minimizes the error.

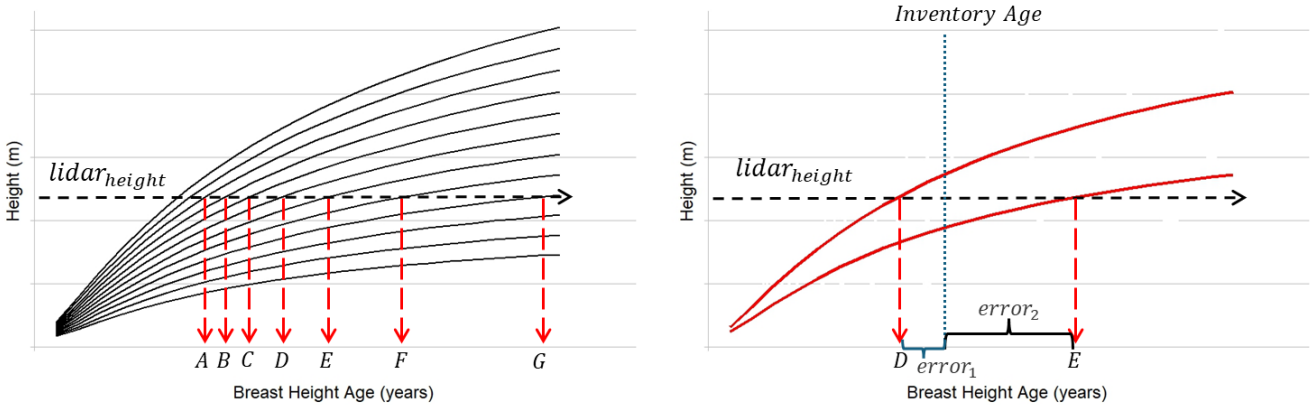


Figure 5. Demonstration of site index estimation using lidar height and field age approach. In this approach, lidar-derived heights are matched to predefined site index curves. For each plot, the best-fit site index curve is selected by minimizing the age difference between the estimated age from the curve and the field-measured age, using the lidar height to identify the closest height along the selected curve.

Site Index:

Multi-date field-based height-growth

Multi-date Lidar Approach

📍 2009 Lidar → Lidar Height 1

📍 2015 Lidar → Lidar Height 2

Compare Δ Height → Match to Site Index Curve

03 Methods

Site Index:

Multi-date field-based height-growth

Field Height Growth Approach

📍 2009 → Field Height 1

📍 2015 → Field Height 2

Compare Δ Height → Match to Site Index Curve

04 Results

Table 1. Performance metrics comparing site index predictions derived from multi-date field height-growth

Scenario	Reference Equation	n	outliers	Bias (m)	SD (e) (m)	Min Error (m)	Max Error (m)	RMSE (m)	RRMSE (%)
Full	King's*	60	2	1.97	6.36	-28.78	15.36	6.6	19
Cleaned	King's	58		2.27	4.69	-8.68	12.96	5.17	15
Full	HS's**	60	1	2.88	8.70	-21.09	22.98	9.1	26
Cleaned	HS's	58		3.29	8.18	-17.59	22.98	8.75	25

**Hann and Scrivani's

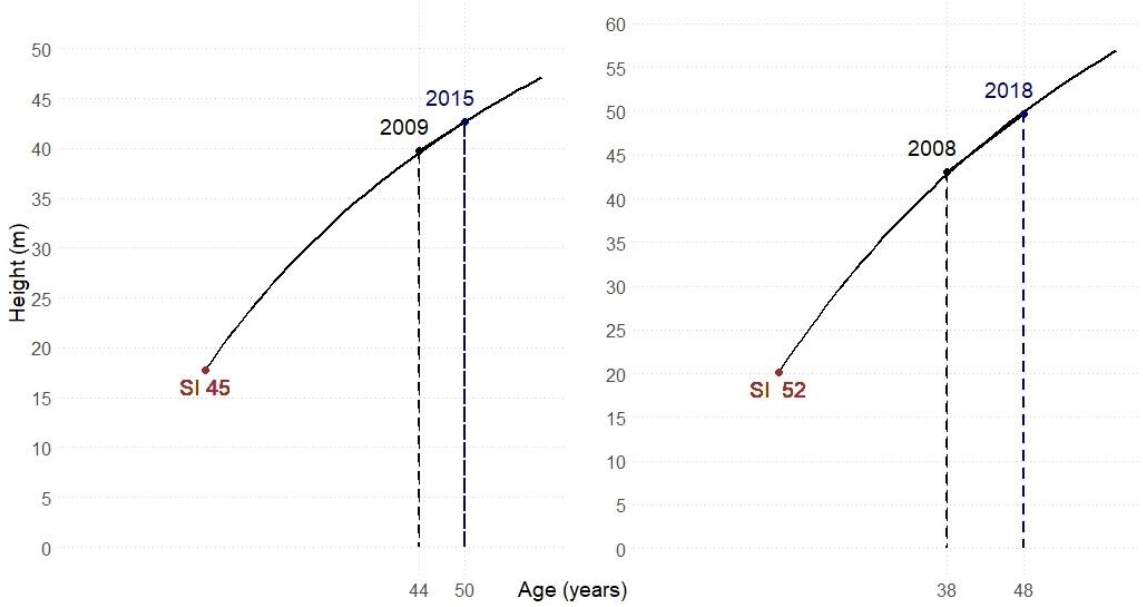


Figure 6. Representation of curve matching based on the change in LiDAR heights and change in time.

Table 2. Multi-date Lidar site index prediction performance statistics.

Curve	Dataset	n*	Bias (m)	SD (e) (m)	Min Error (m)	Max Error (m)	RMSE (m)	RRMSE (%)
King's*	Site1	49	1.76	3.99	-8.42	12.14	4.32	12
HS's**	Site1	55	0.91	9.21	-22.47	18.33	9.18	25
King's	Site2	75	4.06	2.95	-2.63	11.33	5.01	13
HS's	Site2	70	9.41	3.26	0.69	16.46	9.95	27

*** Outliers were filtered based on their residual percentile
Site1 total (n) = 60; Site2 total (n) = 77

Table 3. Single-date Lidar site index prediction performance statistics.

Curve	Dataset	n*	Bias (m)	SD (e) (m)	Min Error (m)	Max Error (m)	RMSE (m)	RRMSE (%)
King's*	Site1	101	-2.32	3.90	-11.03	7.36	4.52	13
HS's**	Site1	120	-2.15	9.77	-23.96	19.93	9.9	29
King's	Site2	71	-0.87	3.41	-8.19	8.83	3.50	9
HS's	Site2	77	0.44	4.36	-10.10	11.3	4.35	12

*** Outliers were filtered based on their residual percentile
Site1 total (n) = 120; Site2 total (n) = 77

04 Results

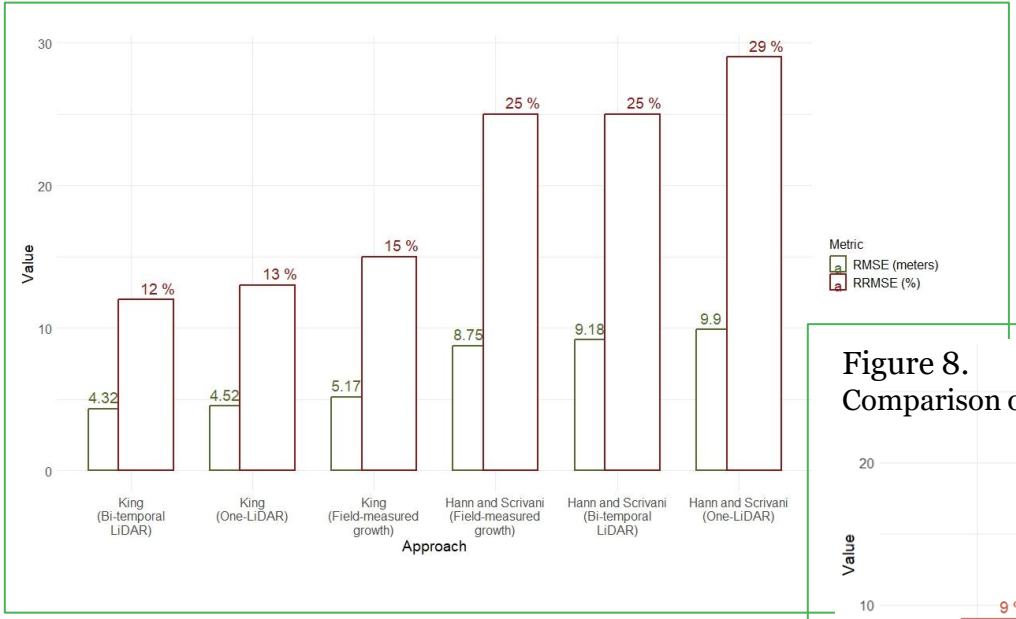


Figure 7. Comparison of performance metrics for Site1

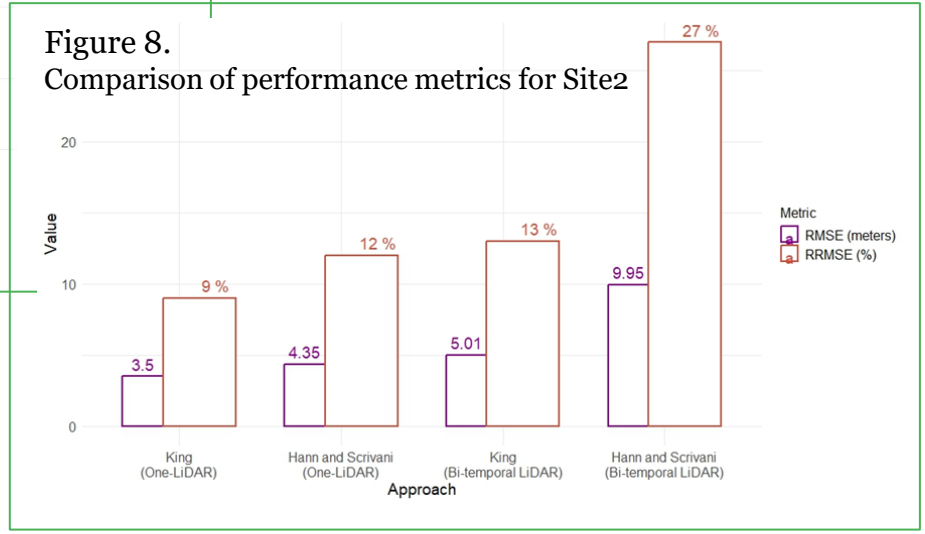


Figure 8.
Comparison of performance metrics for Site2

Thoughts....

Sensitivity of SI Estimation

Error metrics for different approaches varied between the reference site index, highlighting the sensitivity of site index to varying local conditions, tree selection criteria, and dataset characteristics.

Thoughts....

Sensitivity of SI Estimation

Error metrics for different approaches varied between the reference site index, highlighting the sensitivity of site index to varying local conditions, tree selection criteria, and dataset characteristics.

Practical considerations for the two approaches

Multi-date needs acquisitions sufficiently far apart in time to reliably characterize height growth; while single-date approach needs age.

Thoughts....

Sensitivity of SI Estimation

Error metrics for different approaches varied between the reference site index, highlighting the sensitivity of site index to varying local conditions, tree selection criteria, and dataset characteristics.

Practical considerations for the two approaches

Multi-date needs acquisitions sufficiently far apart in time to reliably characterize height growth; while single-date approach needs age.

Height growth can inform site index estimation

Field-based height growth can support hybrid or retrospective analysis where repeated measurements are available but age data is lacking.

Conclusion

1. Height growth (lidar-based; field-based) can be used to infer site index.
2. Single-date: Landsat archives as a viable alternative of age information.
3. Multi-date: Use of multi-date photogrammetric point clouds as a promising alternative.

Thank you!!

Suchana Aryal

aryalsuc@oregonstate.edu

College of Forestry

Department of Forest Engineering, Resources, & Management

Oregon State University