Assessing Site Productivity from Remote Sensing and historic information

PREPARED FOR:
KTTD

PREPARED BY:
Alex Bilyk
Margaret Penner
Murray Woods

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1 Introduction

Site index is the most widely accepted method for estimating forest site quality in North America (Carmean 1996) and site index equations have been calibrated for most of the commercial species in Ontario (Carmean et al. 2006; Carmean & Lenthall 1989; Sharma & Parton 2018a, 2018b, 2019; Sharma et al 2015; Subedi & Sharma 2010, 2011, 2013). Traditionally, site index has been estimated from an estimate or measurement of age and height at a single point in time. Some site index equations can also be reformulated to be age independent and estimate site index from two measurements of height (Solberg et al. 2019). Age is one of the more difficult inventory attributes to assess/predict and consequently one of the less reliable attributes. In contrast, height estimates from LiDAR are very reliable. This project will compare site index estimates from a) inventory age and height, b) change in height (age-independent) and c) field assessments of age and height.

This project will focus on area-based estimates of height change (Tompalski et al. 2021). A number of options for investigating change in height will be investigated including direct estimation (estimating change in height from change in LiDAR attributes) and indirect estimation (estimating change in height from independent estimates of height at time 1 and time 2).

Generally SI equations have three variables – age, height and SI. Generally the equations are written with top height as function of age and SI. And the equations are generally fit in this form.

$$Height = f(age, SI)$$

LiDAR is very good at estimating height. Age is difficult to photo interpret. It can be obtained from silvicultural records, from performance surveys and time since disturbance (e.g., fire, harvesting). Some studies are using Landsat to estimate time since disturbance.

With estimates of height at two different times, assuming SI is constant, there are two equations with two unknowns (age and SI). These can be solved for SI.

$$Height_1 = f(age_1, SI)$$

$$Height_2 = f(age_1 + t_2 - t_1, SI)$$

2 Methods

Several options for estimating SI are explored.

1. Single snapshot – uses age (from ground sample or from inventory) and a measure of height (ground CDHt, p99 or max)

   $SI = f(age, height)$

2. Change – two measurements of height (or more), does not require age

   $SI = f(\Delta height)$ – only requires LiDAR height and elapsed years

   $SI = f(\Delta LiDAR)$ – only requires LiDAR chagne and elapsed years

For option 1, SI is estimated directly.

Option 2 uses a direct search to estimate SI. Most of the boreal conifers use the following equation form.

$$Ht_2 = \frac{a_0}{1 - \left(1 - \frac{a_0}{Ht_1}\right) \cdot \left(\frac{Age_1}{Age_2}\right)^{a_1}}$$

Age is breast height age.

When $Age_2 = 50$, then SI_{50}, the SI at reference age 50.

The equation can be rewritten as a function of age.

$$Age_1 = \left[\frac{\left(1 - \frac{a_0}{SI}\right)}{\left(1 - \frac{a_0}{Ht_1}\right)}\right]^{\frac{1}{a_1}} \cdot 50$$

With two heights, a direct search (trying a sequence of SI guesses) is implemented to find the SI that results in the difference in predicted ages ($Age_2 - Age_1$) closest to the difference in measurement years ($Year_2 - Year_1$).

3 Preliminary results

Preliminary results are given for VSN plot 254 in the RMF (FCTEM2001006PGP or VSN930254). This is a jack pine plantation.

Table 1. The field measurements are given for Plot 254 & 354. Just and added complication. Plot 354 was aged in 2018 and the average breast height age was 89.

Plot	Species composition	Msmt year	Breast height age (years)	Basal area (m2/ha)	Gross total volume (m3/ha)	Dom/Codom height (m)
254	Pj100	2001	21	24.5	115	12.2
	Pj100	2006	26	29.4	160	14.5
	Pj100Sb0	2013	33	34.2	211	16.3
	Pj100	2018	38	33.0	268	16.8
354	Sb97Po2Pj1Bf0	2001	79	37.5	194	13.6
	Sb97Po2Pj1Bf0	2006	84	38.5	208	16.4
	Sb97Pj2Po1	2013	91	40.7	228	17.1
	Sb 99 Pt 1	2018	96	38.4	291	16.2

The corresponding LiDAR information for the same plot is given.

Table 2. The LiDAR measurements are given for Plot 254 & 354

Plot	Year	p99	max
254	2005	12.906	14.57
	2018	17.13	18.81
354	2005	15.0044	16.61
	2018	17.08	18.93

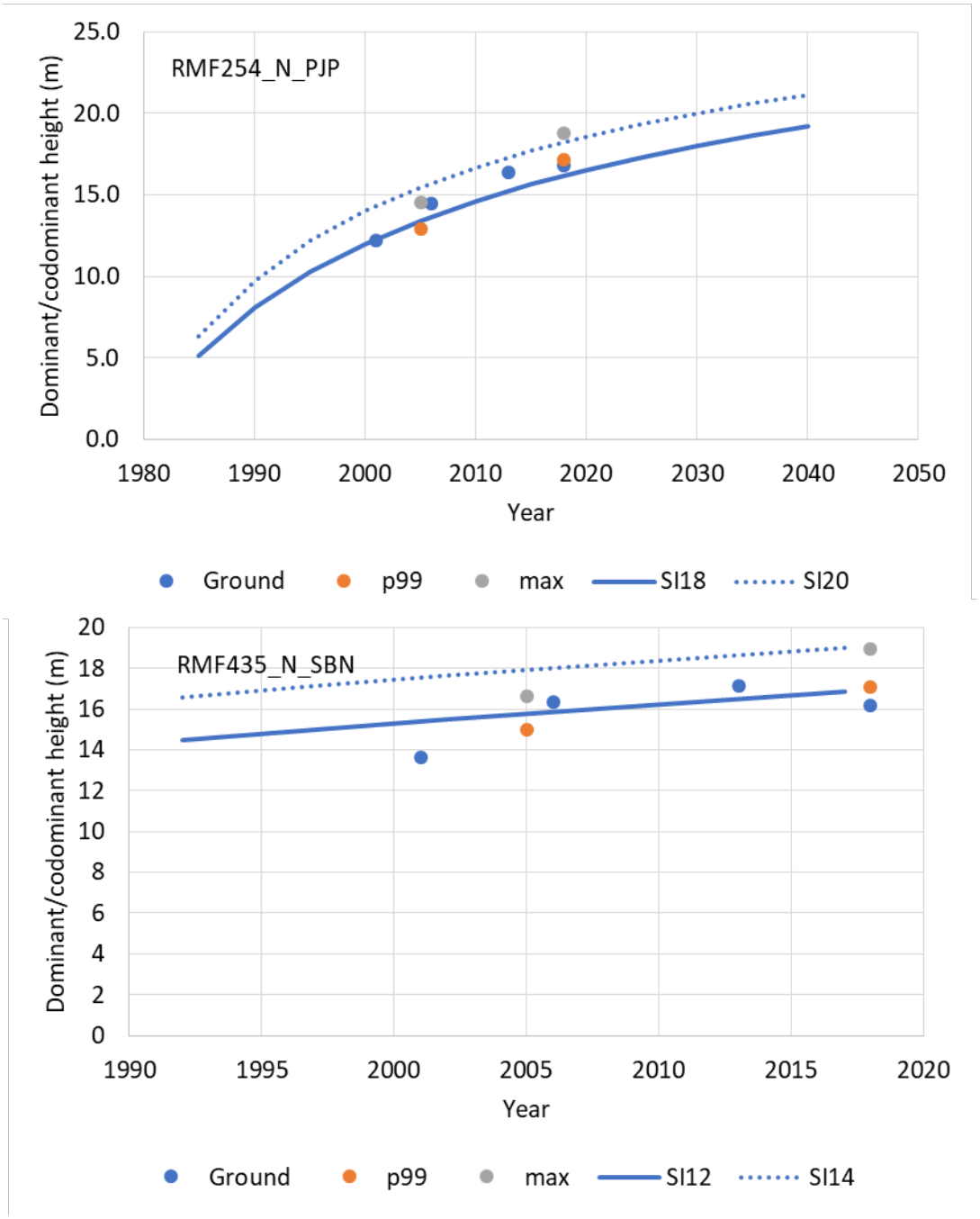

Figure 1. The field and LiDAR heights are given for plot 254 and 435.

Table 3. SI predictions are given for plots 254 and 435. For plot 435, the height declined between measurements 3 and 4 so SI could not be estimated for that interval.

Option	Source	Measurement	SI 254 (m)	SI 435 (m)
Single measurement	Ground	1	20.5	9.6
Single measurement	Ground	2	20.7	11.5
Single measurement	Ground	3	20.3	11.4
Single measurement	Ground	4	19.5	10.2
Two measurements	Ground	msmt 1 vs. 2	21.5	24.8
Two measurements	Ground	msmt 2 vs. 3	18.5	11.1
Two measurements	Ground	msmt 3 vs. 4	9.7	NA
Two measurements	Ground	msmt 1 vs. 2	21.5	24.8
Two measurements	Ground	msmt 1 vs. 3	19.9	19.3
Two measurements	Ground	msmt 1 vs. 4	17.9	12.5
Two measurements	LiDAR p99	2005 vs 2018	20.1	14
Two measurements	LiDAR Max	2005 vs 2018	21.6	16.7

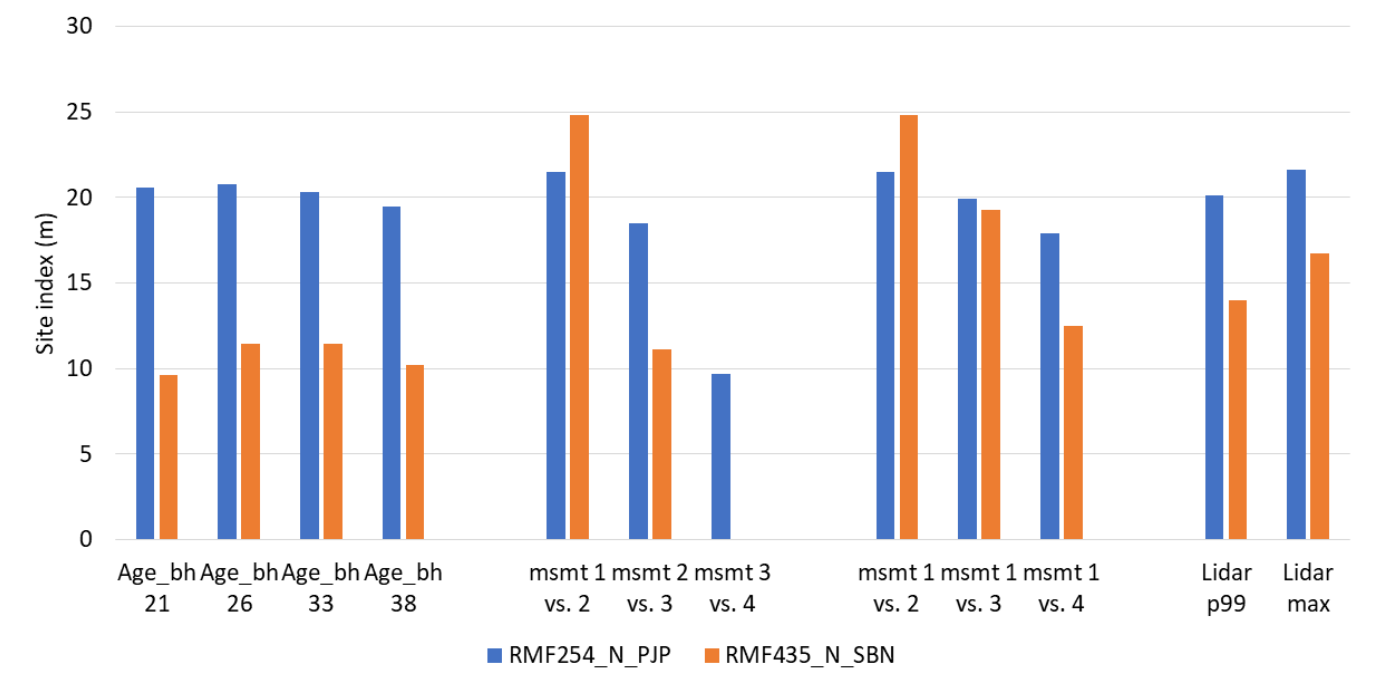

Figure 2. The SI estimates are given for two plots. Plot 254 is an immature jack pine plantation and plot 435 is a mature black spruce natural stand.

3.1 Limitations

The SI equations are non-decreasing functions of age (or time). As a consequence, it is not possible to estimate SI if the height decreases over time.

3.2 SI references

Table 4. The site index curve references are given by species.

Species	Origin	Reference	Total or breast height age
White Pine	Natural	Parresol & Vissage (1998)	Total age
	Planted	Sharma & Parton (2019) table 2	Breast height age
Red pine	All	Buckmann et al. (2006)	Total age
	Planted	Sharma & Parton (2018a) – Table 4	Breast height age
Jack pine	Natural	Sharma & Reid (2017) Table 4	Breast height age
	Planted	Sharma et al. (2015) Table 2	Breast height age
Black spruce	Natural	Sharma & Reid (2017) Table 4	Breast height age
	Planted	Sharma et al. (2015) Table 2	Breast height age
White spruce	Natural	Carmean (1996) figure 17, which is originally from Alemdag (1991)	Breast height age
	Planted	Sharma & Parton (2018b) Table 2	Breast height age
Balsam fir	All	Carmean (1996) figure 18	Breast height age
Trembling aspen	All	Carmean et al. (2006)	Breast height age
White birch	All	Carmean (1996) figure 14	Breast height age
Tamarack	All	Carmean (1996) figure 16	Breast height age
Hemlock	All	Carmean et al. (1989) figure 127	Total age
White ash	All	Carmean et al. (1989) figure 13	Total age
Black ash	All	Carmean et al. (1989) figure 14	Total age
Red oak	All	Carmean et al. (1989) figure 48	Total age
Elm	All	Carmean et al. (1989) figure 53	Total age
Basswood	All	Carmean et al. (1989) figure 51	Total age
Beech	All	Carmean et al. (1989) figure 11	Total age
Black cherry	All	Carmean et al. (1989) figure 34	Total age
Yellow birch	All	Carmean et al. (1989) figure 6	Total age
Hard maple	All	Carmean et al. (1989) figure 3	Total age
Cedar	All	Carmean et al. (1989) figure 57	Total age

4 Literature cited

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