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Enhanced Forest Inventory vs Field Inventory

Preliminary Comparison of Inventory Results

Technical Note

Harvesting and Operations

INTRODUCTION

The Northern Hardwoods Research Institute undertook this preliminary research initiative to compare Enhanced Forest Inventory (EFI) to traditional Field Inventory—block cruising inventory data. The objective being to validate the use of this data in the context of adaptive harvest-based silviculture prescriptions (NHRI's SPS) and operations planning. Field inventory (FI) requires important investments in time and resources; it is an expensive data acquisition method. Because the Province of New Brunswick has pioneered the development of EFI variables, we investigated the opportunity to use the information as a potential replacement for traditional FI methods. Nine variables where retained from the 47 available EFI variables. The limited number of EFI variables that we explored where chosen according to their usefulness in precision block planning applications. See Table 1.

HIGHLIGHTS

- **New-Brunswick is a leader in EFI data and modelling. Our forest sector is privileged and will benefit greatly from this very promising tool.**
- **This is a preliminary study based on limited plot data. Furthermore, the EFI data used was the best available data at the time - EFI data and modelling are constantly being improved in New Brunswick.**
- **Our preliminary results, based on comparison of EFI data with FI data, indicate a significant gap between the two methods; which seems to translate into a lack of precision of EFI data for certain metrics.**
- **EFI data tends to overestimate key forest metrics like; merchantable basal area, merchantable tree density and gross merchant volume. These are all essential forest management metrics which have important implications on forest management planning and operations.**
- **The current disparity between EFI data and FI data is to be expected as EFI data and modelling are currently being refined in New Brunswick. Progress is being made as NBERD adds about 500 new plots to the EFI data set each year.**

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Table 1. Selected variables considered in the study and definitions according to the NB DNRED EFI Data Dictionary (2019-11-04).

Variable	Definition	Unit
LHT	Lorey's height - average height of all trees≥ 3 cm, weighted by basal area.	m
BLC	Basal area weighted base to live crown of merchantable trees.	m
LCR	Computed % of BLC/AvgHt.	proprotion
BAm	Merchantable stand basal area.	m2/ha
QMDm	Merchantable quadratic mean diameter.	cm
THPm	Merchantable number of trees/ha > 9 cm DBH.	count/ha
GMV	Gross merchantable volume.	m3/ha
PSgmv	Average piece size, gross merchantable volume/merchantable stems.	m3/tree
HWper	Estimated % of HW composition (0-100). Contractor proprietary method.	proportion

One must keep in mind that the EFI are generated for 20m X 20m plot based on LiDAR points while the field inventory (FI) is done with a BAF2 angle gauge. Therefore, the comparisons are not statistically robust because of obvious differences in the way data are generated and in the differences in respective protocols.

METHODOLOGY

The NHRI field inventory was acquired as part of the NHRI Precision Block Planning Initiative in Northern New Brunswick—stands that were dominated by hardwoods and scheduled for operations in 2019-2020. The process requires establishing a plot center and selecting trees with a BAF 2 angle gauge. The DBH, risk and form of each selected tree is measured. Also, the height and the base live crown of every fifth tree is measured. Only merchantable trees are measured in the plot (>9.1cm). The data is then compiled in a Excel spreadsheet which automatically calculates forest variables. The DNR_Horner volume table is used to calculate the FI gross merchantable volume. Three distinctives methods where used in the comparison and each method offered a different sample size. Statistical testing was conducted to find if the mean differences where significant. For all three methods the same tests where used. First, a Shapiro-Wilk normality test was conducted on both FI and EFI. If both inventory were normally distributed, a F test to compare two variances was conducted. If the variances where statistically equal, a Student t test was conducted. If the variances were not statistically equal, a Welch Two Sample t-test was conducted. If one or more of the inventories was not normally distributed a Wilcoxon-Mann-Whitney test was conducted. These statistical tests where computed using R studio.

Method 1: Superimposed plots.

To make this comparison possible, the NHRI team used *ArcGIS Pro* to superpose georeferenced field plots so that they match the locations of EFI plots. The GPS paired with SxBlue technology is estimated to bring the field inventory plot to a 1 m precision. The EFI data is then compared plot for plot with the field inventory data. Only the EFI plots that are effectively matched with an FI plot are compared. Two analyses where conducted for this method. In the first analysis, each plot was viewed as part of one database and the statistical testing was done on all the plots. In the second analysis, the plots where divided by blocs. This was to determine if the EFI was more precise in some specific forest stands.

Method 2: Proximity within 10-meter radius.

In the 2019 season of the NHRI Precision Block Planning Initiative, a large amount of field data was collected. Many blocks were covered with semi-random plots that were not placed on the standard LiDAR 20m grid for the EFI comparison study. Using the *Near* function in *ArcGIS Pro* we were able to match some of the FI plots with the EFI plots. A ten-meter radius was established for maximum proximity. If no EFI plots where present within a ten-meter radius of an FI plot, this FI plot was not kept for analysis. Only one EFI plot for each FI plot was retained. If two EFI plots were within the ten-meter radius, the closest one to the FI plot was the one retained. Like in the superimposed plot method, two analyses were conducted. One with all the plots in the database and one with the plots being divided by blocs.

Method 3: Inventory vs EFI for the entire block.

In this method, the compilation results of the field inventory for a block are compared to the means of all the EFI data points within the same block. Seven blocs were chosen from the NHRI database for this comparison. Statistical testing was done on the mean values of all the seven blocks to determine tendencies.

RESULTS

Method 1: Superimposed plots.

The superimposed plot method contained two blocks which made up a total of 45 field plots. When these plots where compared individually to the EFI plots, notable differences were noticed. Most of the statistical testing results indicate that the mean values are significantly different, expect for base live crown and surprisingly, hardwood composition percentage. The EFI's mean values for the merchantable basal area, merchantable number of trees/ha and gross merchantable volume variables are higher than the FI's mean values of the same variables (Table 2). The field inventory data always shows higher variances then the EFI data (Tables 3 and 4).

Table 2. Statistical results for the superimposed plot method.

		LHT (m)	BLC (m)	LCR (%)	BAm (m2/ha)	QMDm	TPHm (stems/ha)	GMV (m3/ha)	PSgmv (m3/tree/ha)	Hwper (%HW)
$\bar{x}$	FI	15,21	6,99	0,55	22,76	21,23	977,49	136,36	0,17	0,56
$\bar{x}$	EFI	14,00	6,90	0,49	25,11	18,92	1148,18	163,37	0,15	0,47
Hypothesis		H1	H0	H1	H1	H1	H1	H1	H1	H0
Nb of plots	45									

Table 3. Descriptive statistics of field inventory data for the superimposed plot method.

	FI								
	LHT (m)	BLC (m)	LCR (%)	BAm (m2/ha)	QMDm	TPHm (stems/ha)	GMV (m3/ha)	PSgmv (m3/tree/ha)	Hwper (%HW)
AVERAGE	15,21	6,99	0,55	22,76	21,23	977,49	136,36	0,17	0,56
Std DEV	2,92	2,18	0,09	10,57	3,73	574,17	64,96	0,08	0,31
VAR	8,53	4,75	0,01	111,70	13,93	329669,51	4220,21	0,01	0,09
Min	6,40	2,30	0,39	4,00	16,23	137,14	23,34	0,07	0,00
Q1	14,00	5,70	0,48	16,00	18,11	506,21	95,34	0,10	0,29
Med	15,13	7,25	0,54	20,00	21,04	938,28	117,38	0,15	0,62
Q3	16,55	8,13	0,61	28,00	23,21	1356,70	164,06	0,21	0,80
Max	22,20	11,87	0,83	46,00	31,27	2356,13	307,09	0,43	1,00

Table 4. Descriptive statistics of EFI data for the superimposed plot method.

	EFI								
	LHT (m)	BLC (m)	LCR (%)	BAm (m2/ha)	QMDm	TPHm (stems/ha)	GMV (m3/ha)	PSgmv (m3/tree/ha)	Hwper (%HW)
AVERAGE	14,00	6,90	0,49	25,11	18,92	1148,18	163,37	0,15	0,47
Std DEV	1,93	1,27	0,05	5,04	2,36	191,26	48,72	0,05	0,14
VAR	3,74	1,62	0,00	25,45	5,58	36578,90	2373,36	0,00	0,02
Min	10,80	4,10	0,37	14,90	15,40	852,00	72,84	0,07	0,21
Q1	12,60	6,10	0,46	21,10	17,00	968,00	127,42	0,11	0,36
Med	13,90	7,10	0,49	25,30	19,00	1132,00	170,20	0,14	0,47
Q3	15,30	7,80	0,53	28,70	20,30	1293,00	198,96	0,17	0,55
Max	19,20	9,40	0,57	36,00	27,30	1584,00	287,71	0,30	0,74

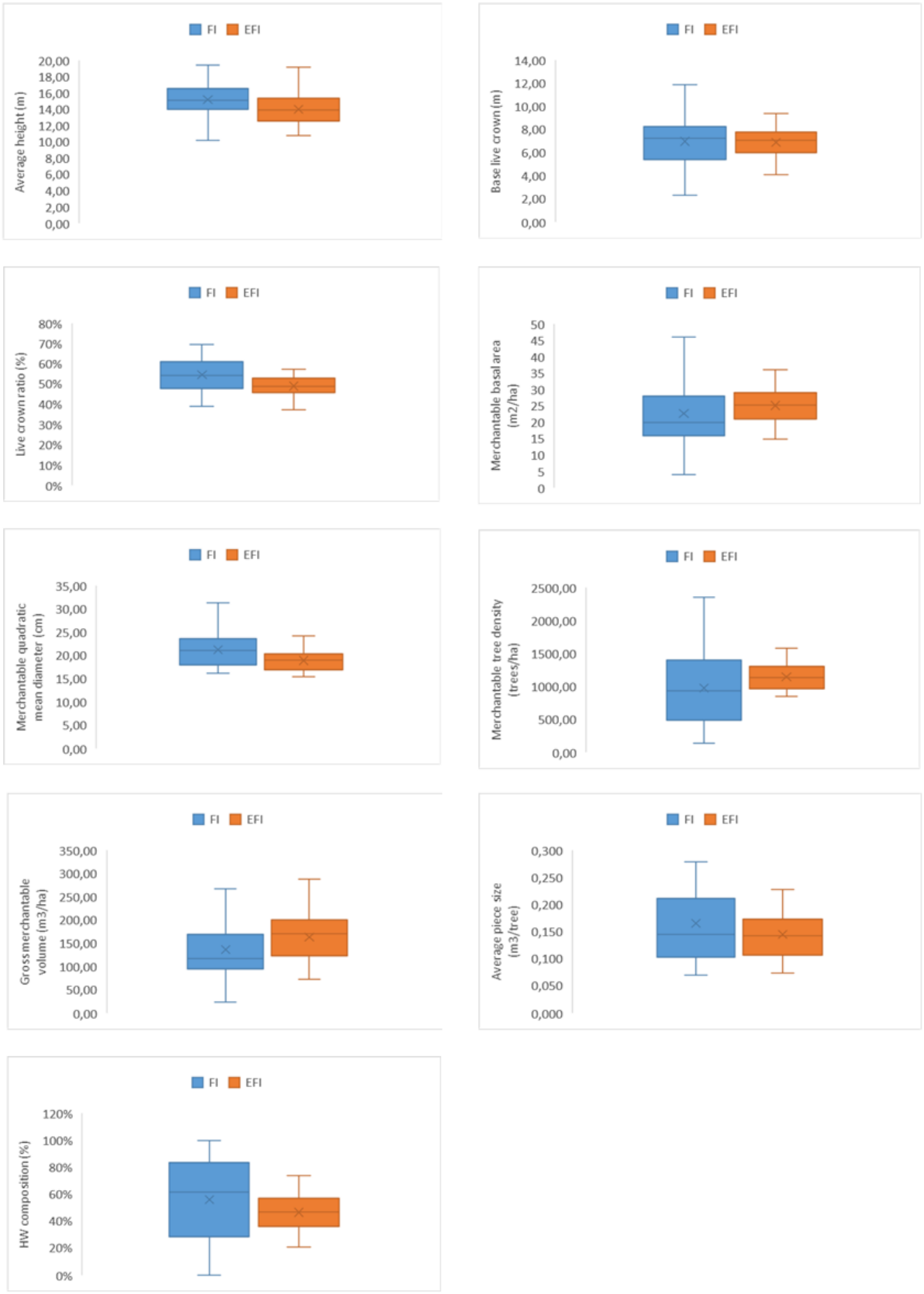

Figure 1. Box-plot graphs of FI and EFI variables for the superimposed plot method.

Method 2: Proximity within 10-meter radius.

There where 301 FI plots to compare in this method. Even though this is the method with the largest sample, the results are still unprecise. When comparing plots, it was noticed that highly heterogeneous blocs caused the biggest value differences. This is especially true in blocs where the canopy is inconsistent. The biggest mean differences for the entire sample are observed in the number of merchantable trees density variable, seconded by the hardwood composition percentage. Important differences are also observed for the gross merchantable volume. The most precise variable is, without surprise, the average height (Figure 2). Statistical testing, with the entire sample, found no similar means for this method. Similar mean were sometime found when the testing was done on individual blocs, mostly on the average height variable.

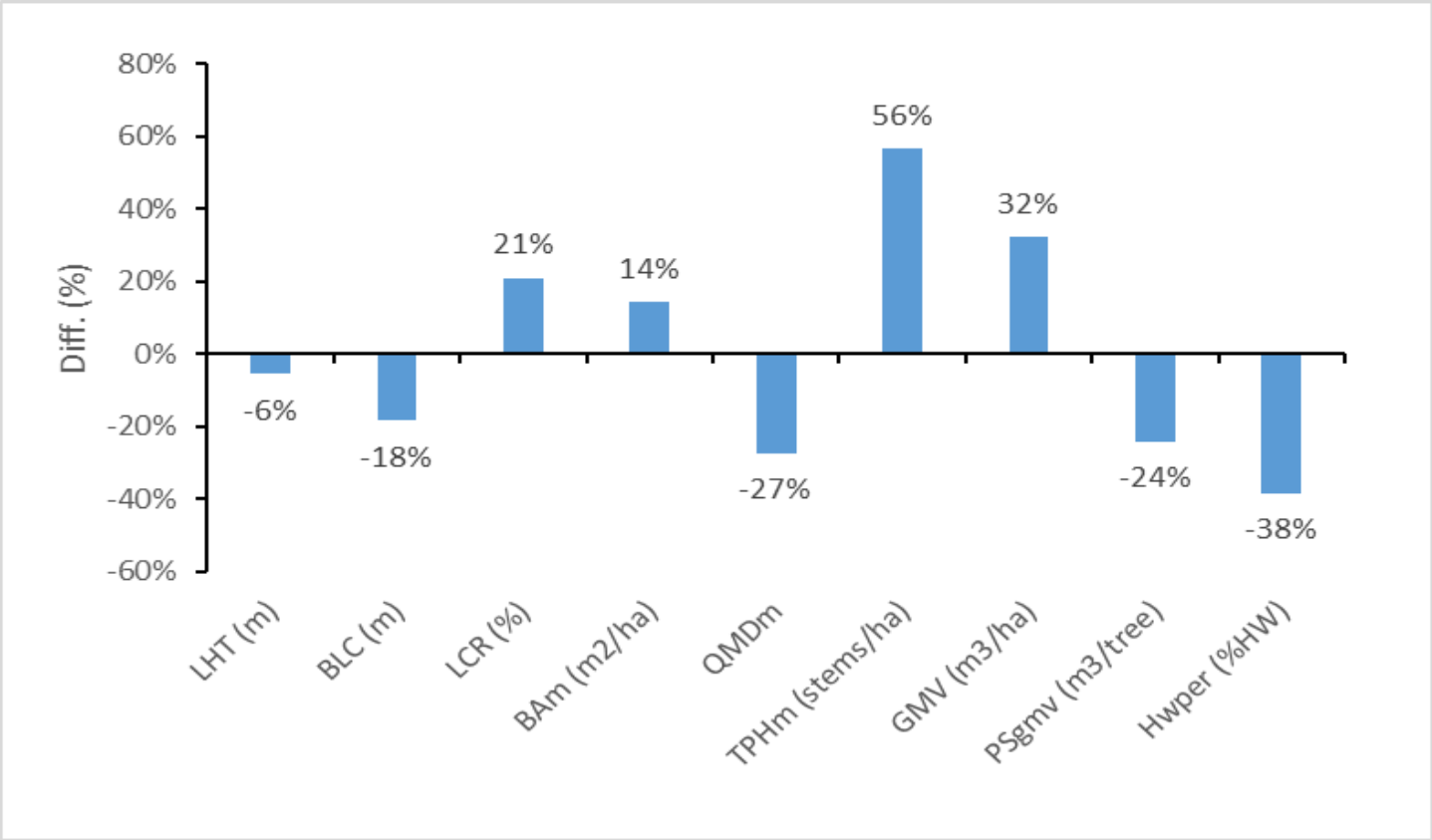

Figure 2. Mean differences comparisons for the proximity within 10-meter radius method as a variance of field inventory.

Method 3: Inventory vs EFI for the entire block.

To ensure precision, blocs with more than 10 plots and a coverage around one plot per hectare were chosen. Even with these efforts, the results seem off. When the blocs are compared individually, very precise average height values are found for 5 of the 7 blocs. Precise merchantable basal area were found for two blocs. When the average values of all the blocs are compared together, the results are a little less promising. The biggest difference in merchantable tree density for any method is observed (figure 3). Statistical testing determined that the means for average height was similar.

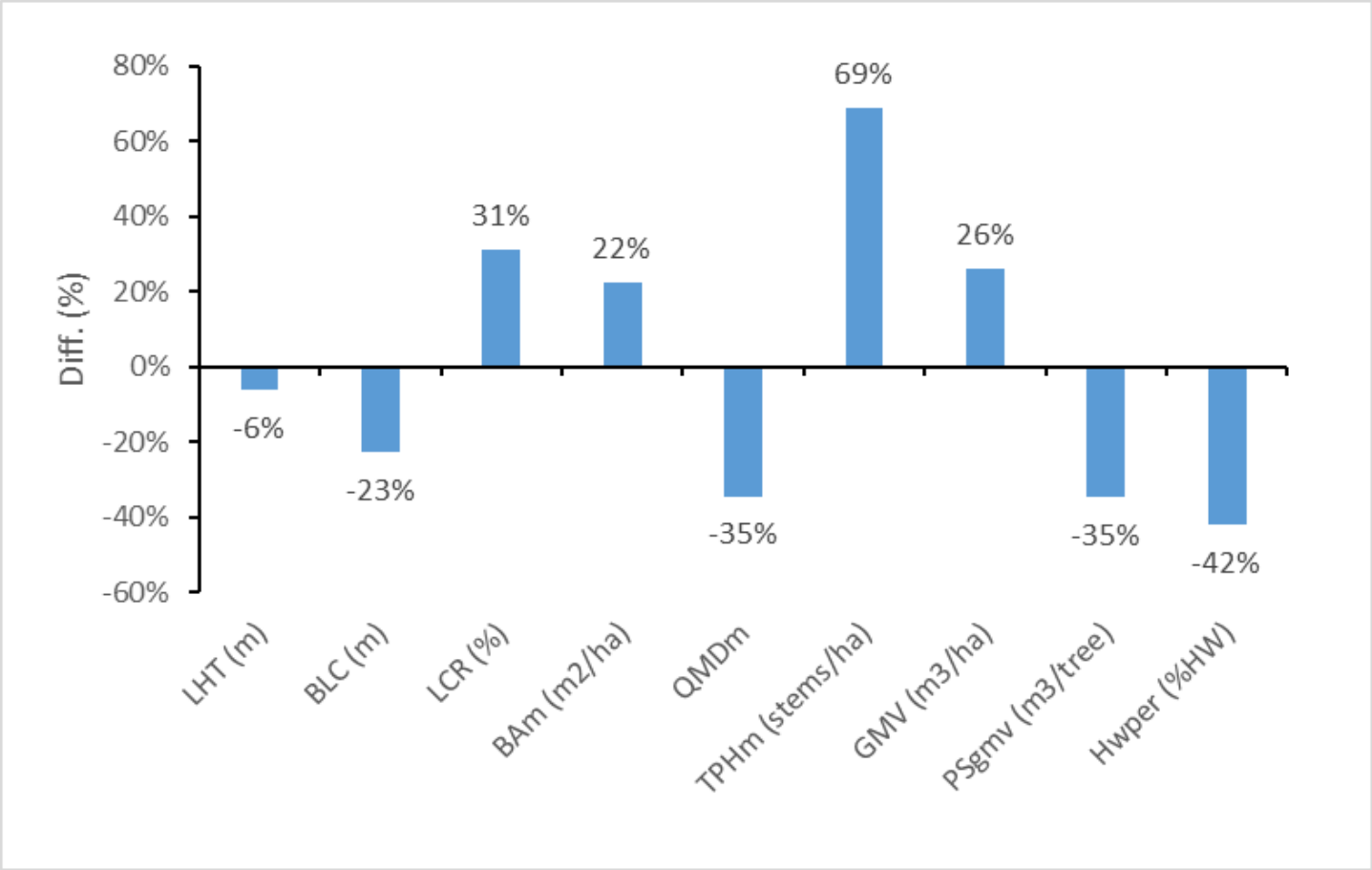

Figure 3. Mean differences comparisons for the Inventory vs EFI for the entire block method as a variance of field inventory.

CONCLUSION

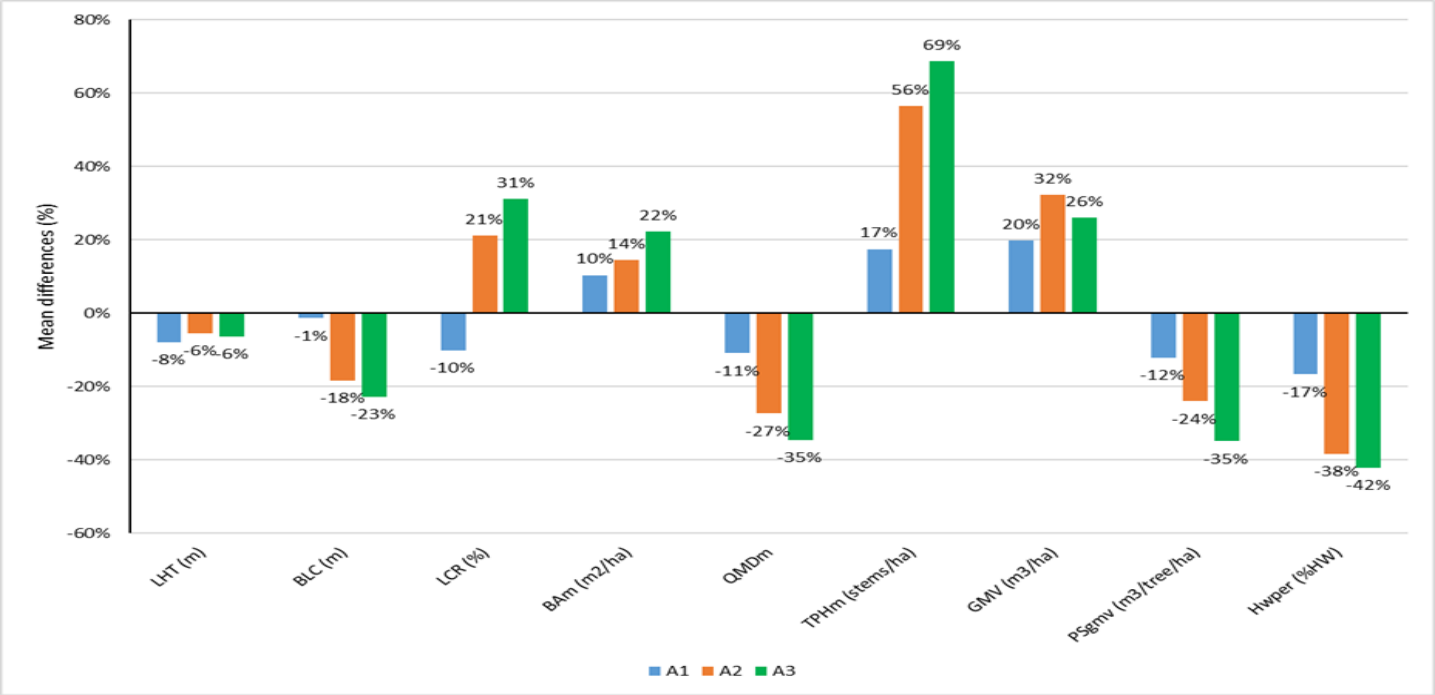

Figure 4. Mean differences for all three-comparison methods as a variance of field inventory.

General tendencies like higher mean values for the merchantable basal area, merchantable number of trees/ha and gross merchantable volume in the EFI's data are observed in all the analysis methods (Figure 4). The EFI seems to constantly overestimate these three variables when compared to traditional field inventory data. Higher FI variances for all variables were observed in all the analysis methods. This could be explained by the field measurements not being bounded by the limits of an algorithm, as it is the case for EFI metrics. A proportion of height differences are surely explained by the field measuring method. An hypsometer will most likely not be as accurate as LiDAR sensing. Plus, in a field plot only the height of every fifth tree is measured, which might be an under-sampling. Observed statistical mean differences may be less significant when considering an acceptable error range. For the superimposed plot method, the FI average height is 15,21 m while the EFI's is 14,00 m. Even though there is a statistically significant difference these two averages are still relatively close. The EFI was more likely to offer statistically similar mean with the FI for the hardwood composition percentage variable in blocks where the hardwood composition percentage was between 52 and 67 percent (field measured values). This was only observed with the superimposed plot method, but for all the analysis methods the EFI data seems to underestimate hardwood composition (Figure. 4). In the field data there are plots where only hardwoods trees are measured while no EFI plots offers a Hwper of 100%. For the Inventory vs EFI for entire bloc method, further analysis found a mean difference between the FI's and EFI's gross merchantable volume of 41,87 m^3/ha.

These preliminary results point towards a tendency of over and underestimation of key variables when using EFI data. This was expected considering that both FI and EFI are imperfect models of reality. This only confirms the need for further research to improve the EFI dataset. NBERD invests time and resources year after year to improve this very promising tool. Considering that the data used was the best available at the time of the study and that the EFI's dataset is constantly improved, results in further studies are expected to show higher precision. Until theses refinements are made, and we are confident of the accuracy of EFI data for some key metrics, field inventory will remain an important step in the forest management process—for both planning and operations.

REFERENCES

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