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VALIDATION OF FPINNOVATIONS BiOS APP IN WILLIAMS LAKE, BC:
METHODOLOGY AND RESULTS

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ABSTRACT:

FPInnovations completed the fourth validation of the FPBiOS app in the summer of 2020. A cutblock located in the IDFdk3 near Williams Lake, BC was chosen. This validation required researchers to measure available biomass in the field, including dispersed volume, residual pile volume and leftover residual pile volume on site after the secondary harvest. After measurements were completed, the values collected were compared with the outputs calculated by BiOS. The BiOS app recovered biomass estimate came within 4% of the actual biomass recovered in the field.

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INTRODUCTION

Background

The BiOS mobile application project is a key part of a larger initiative within the Ministry of Forests, Lands and Natural Resource Operations and Rural Development (FLNRORD) aiming to develop a Forest Residual Biomass Geographic Information System for the development of the British Columbia (BC) forest bioeconomy (Forest BioGIS). The interactive map developed by FLNRORD will show location, type and amount of residual fibre generated by harvest activities, and economic feasibility to utilize them to produce advanced bio-materials. Forest BioGIS will improve area planning and support decision makers by having a better understanding of the fibre potential located in each Timber Supply Area (TSA). As a key feature of the BC Forest BioGIS interactive map, the BiOS app will help to serve the purpose of developing the forest bioeconomy cluster(s) for advanced biomaterial manufacturing in BC and may support other related government key priorities like GHG targets.

The need for such an interactive tool comes from the BC commitment to reducing greenhouse gas emissions to 80% below 2007 levels by 2050. The forest harvest levels in BC are massive, with an average annual harvest from 2005 to 2015 of 67 M m3 (42% of Canada harvest). The harvest of this merchantable roundwood generates logging residues to the amount of about 10 million oven-dry tonnes (odt) per year (assuming 0.15 odt/m3). The BC Wildfire Act and Wildfire Regulation stipulate that the forest industry dispose of leftover slash and wood residues to abate fire hazards. The most common practice for reduction of fuel loading by forest tenure holders is to pile and burn. In 2015, it is estimated that 2.5 M odt of forest fibre was piled and burned in BC. The emissions generated by this practice are equivalent to those from 1 M cars (1/3 of all BC cars).

The BiOS app was introduced to both iOS and Android platforms in February 2018. This first version of the app utilized the core of the BiOS and Carbon modules of FPInterface to present a full biomass flow and carbon accounting of supply chain operations. The BiOS app serves foresters to quantify the amount of logging residues generated following logging operations and measure the supply chain cost and carbon footprint. Data collected by the app to update Forest BioGIS will mainly come from users such as logging contractors, secondary users of harvest residual fibre and FLNRORD field technicians. The BiOS mobile app will be utilized in a larger information system (Forest BioGIS) to provide data to industry which will help to improve biomass utilization and support the bio-economy and mitigate GHG emissions from existing slash burning operations.

BiOS application validation – Williams Lake, BC

A series of development activities are required to bring the app from a base tool to a completer and more validated asset. For this reason, in-field validation trials to assess roadside pile volume and density are required. These field trials should be done in cooperation with industry leaders that show an interest in the Forest BioGIS platform.

FPInterface is a validated tool with multiple productivity studies performed across Canada for the last 40 years used to build machine productivity equations for various stand types and operating conditions. BiOS has also been validated in the Boreal forest across Canada and is well calibrated to perform TSA-level estimates. Given the variability of ecosystems in BC, FPI suggests completing at least one validation trial per forested Biogeoclimatic (or ecological) zone according to the Biogeoclimatic Ecosystem Classification (BEC) program. There are 14 recognized forested zones in BC. Some zones (e.g. Coastal Western Hemlock) may need more than one validation trial to capture the variance. Therefore, at least 20 trials are recommended to fully validate the BiOS app for BC conditions. Two less comprehensive trials were completed in Powell River (2011) and Williams Lake (2011). A fully comprehensive first, second and third trial were recently completed in Mackenzie (2019), Powell River (2020) and Topley (2020), respectively.

This document will outline the methodology utilized in the 2020 Williams Lake trial and present the field results compared to the BiOS App results.

METHODOLOGY

Note: Many parts of the Methodology section will reference the BiOS App in terms of the data entry tabs and the data fields required to create the app's report in order to compare the App's results and the field trial results. For a full list of values entered in the BiOS App for this trial, please see Appendix I.

Site and operation description

Site characteristics

Location

The 27.7-hectare cutblock (W1216) chosen for the trial is located near the Williams Lake Airport and is approximately 17.6 km from the Atlantic Power plant in Williams Lake, BC (Figure 1). This site was not far enough from the airport (>7km) for a UAV to measure the residue piles.

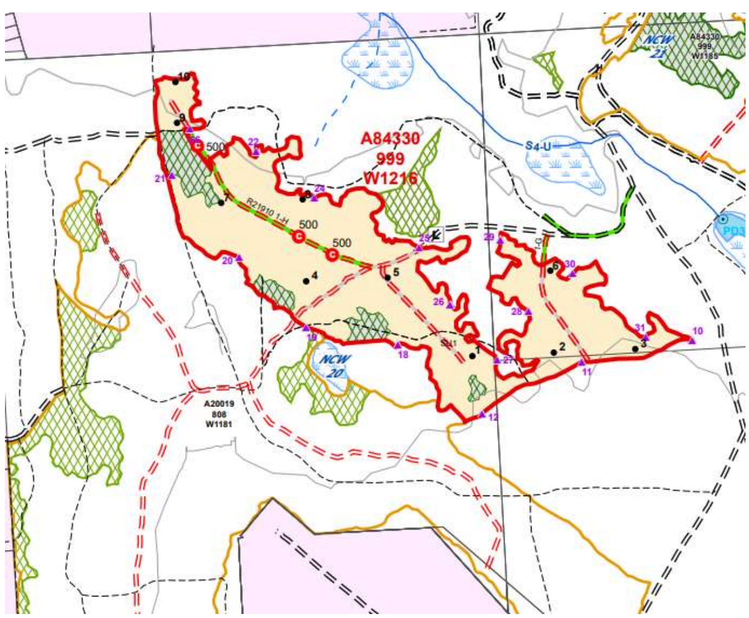

Figure 1. Map for cutblock W1216.

Biogeoclimatic zone

Cutblock W1216 is located in the Interior Douglas Fir (IDF) biogeoclimatic zone, Fraser Dry Cool (dk3) variant (Figure 2). According to the government of BC 's BCWEB website "The IDFdk3 Variant is the most extensive variant (8953 km2) of the IDFdk Subzone in the Cariboo Forest Region. It includes a broad area of the level to gently rolling Fraser Plateau east of the Fraser River valley, from the southeastern limits of the Region northwestward to about Williams Lake."

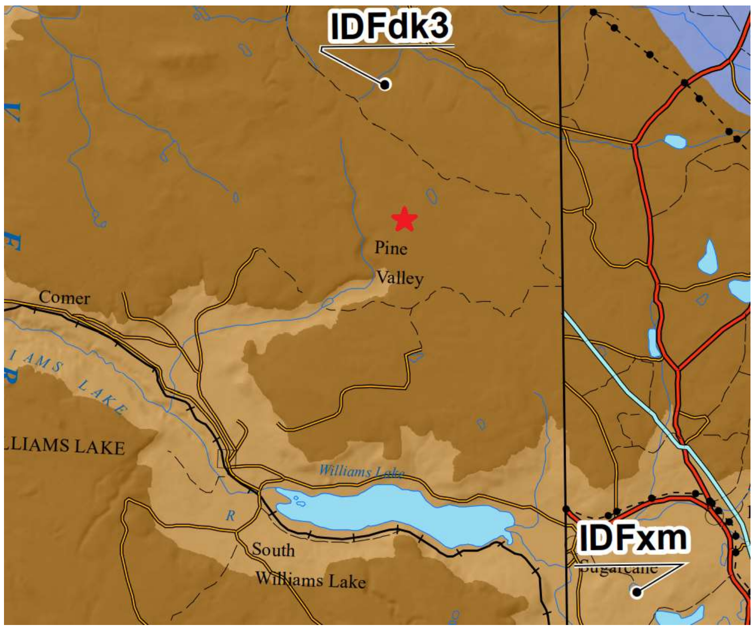

Figure 2. Biogeoclimatic zone map. Block location is denoted by the red star.

Stand description

The cutblock was timber cruised to FLNRORD standards (1.0 plots/ha, 6 BAF prism) in early 2018 and was harvested later that year. The stand was mainly composed of Douglas-fir, hybrid spruce and lodgepole pine with a minor component of trembling aspen (Table 1). The cruise compilation summary can be found in Appendix IV. A wildfire occurred on site in the summer of 2017.

Table 1. Stand description from timber cruise results

Species	Gross merchantable volume (m^3/ha)	Stems per hectare	Gross merchantable volume per tree (m^3)	% of stand (by volume)
Interior Douglas-fir	109.7	293.6	0.38	66%
Hybrid spruce	37.6	92.5	0.42	22%
Lodgepole pine	18.8	41.1	0.47	11%
Trembling aspen	1.7	2.4	0.74	1%

Operational characteristics

Primary harvest

The cutblock was harvested in 2018 with a feller-buncher, skidder and processor combination, where processing occurred at roadside. All merchantable sized (diameter at breast height > 10 cm) coniferous trees, with the exception of a few large Douglas-fir veterans, were felled. Trembling aspen trees were left standing. The residues at roadside were piled for burning and left as windrow shaped piles (Figure 3).

Figure 3. Residue pile located in trial cutblock.

Secondary harvest

The secondary harvest occurred in August 2020. Machinery included a CBI 6800 horizontal grinder (see Figure 4), and a John Deere 2454D log loader with a grapple attachment (Figure 5).

Figure 4. CBI 6800 horizontal grinder.

Figure 5. John Deere 2454D log loader with grapple attachment.

The log loader was used to feed the residue into the grinder.

Four tandem drive trucks with 53ft walking floor trailers were used to transport hog fuel to the power plant (Figure 6). Residue was ground directly into the chip trailers.

Figure 6. Tandem drive truck with 53ft walking floor trailer.

Stand and residue measurements

In order to compare and validate the theoretical results from the BiOS App to the trial results, all portions of stand fibre needed to be measured in the field including standing volume (none in this trial), volume located in the dispersed area of the cutblock, residue pile volume, secondary harvest volume and volume left after the secondary harvest.

Standing residual trees

BiOS entry

The BiOS App calculates the volumes of trees left standing after the primary harvest based on initial inputs by the user. In this trial all volumes were set to 100% harvest removal for coniferous stems, except for Douglas-fir, which was set at to 98% to account for a few standing veterans (Figure 7 for harvest removal field). Deciduous stems were set at 0% harvest removal.

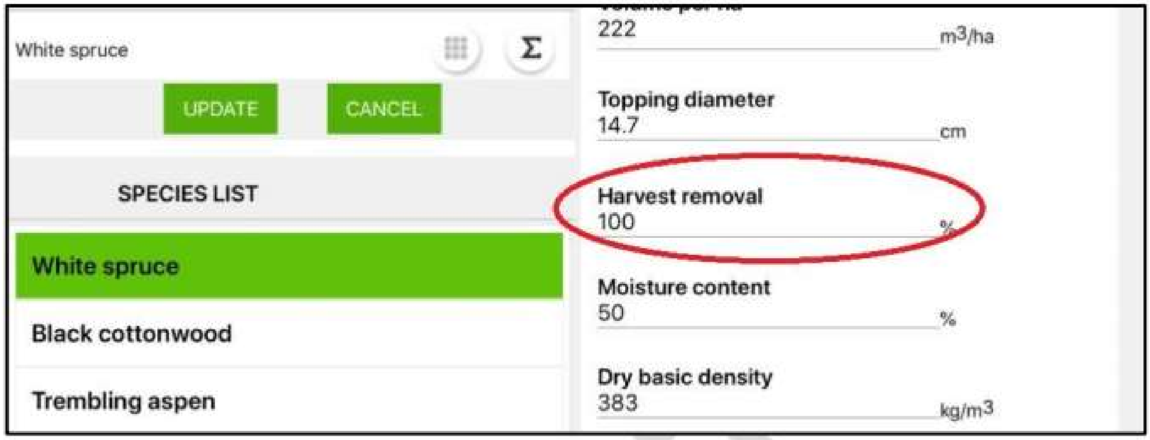

Figure 7. Species Operations data entry page; specifically harvest removal entry field.

<u>Field measure</u>

No coniferous trees were left standing in this cutblock (other than a very few Douglas-fir stems), therefore no field measurements were performed for standing residual coniferous trees. The volume for the deciduous trees was captured in the timber cruise and was not measured by researchers during the secondary harvest due to the acceptable rigor and accuracy of provincial timber cruising.

Dispersed volume

<u>BiOS</u>

The BiOS app estimates dispersed residues using a default, at the stump, recovery factor which is applied to the total amount of residues generated by the logging operation based on data entered into the app in the Biomass Operations tab. Most of the time, dispersed volume is not targeted by secondary users due to the prohibitive cost associated with harvesting it.

<u>Field measure</u>

The line transect method is used to collect dispersed volume data in the field (see Appendix II for full method).

Total dispersed volume for the cutblock is then calculated by multiplying the average volume of the dispersed plots by the area of the cutblock (27.7 ha).

Roadside pile measurement

In the other validation trials, four different methods of residue pile volume calculation were used and then compared to derive the best method of pile data collection. Unfortunately, proximity to the Williams Lake Airport prevented the use of the UAV to collect apparent (geometric) pile volumes. For this validation, the section on UAV pile measurement has been removed. For those interested in the UAV method, please reference the Mackenzie, Powell River or Topley validation trial reports. The following sections describe how each method works.

I. Manual Measurement Method (3M)

The manual measurement method, or 3M, requires the following steps:

1. Measure width of pile in metres
2. Measure length of pile in metres
3. Measure height of pile in metres. If height is irregular, determine average of multiple heights.
4. Determine a shape of the pile from the following list (Note: all piles for this trial were windrows)
    a. Cone (haystack),
    b. Windrow,
    c. Oriented pile
5. Determine a factor for each pile based on pile shape. Pile shape factors are as follows:
    a. Cone (haystack) – 0.4
    b. Windrow – 0.6
    c. Oriented pile - 0.5

Note: These are the factors that have consistently been used in past FPI reports and projects.

6. To determine apparent volume of the pile (Note: this is not fibre volume), multiply the length, width, height and pile shape factor.

The calculated apparent volume will then be used to determine pile density once harvested volume and the volume remaining after secondary harvest has been derived (discussed in the Pile density section of the Methodology).

II. GPS Measure Method (GMM)

The GPS Measure Method, or GMM, is similar to the 3M except that a GPS is used to determine the area or footprint of the pile. The GMM requires the following steps:

1. Set GPS track feature to one point per second.
2. Walk around the pile, holding the GPS above the pile edge.
3. When the pile has been circumnavigated, create a waypoint with a pile name.
4. Measure height of pile in metres. If height is irregular, determine average of multiple heights.
5. Determine a shape of the pile from the following list (Note: all piles for this trial were windrows):
    a. Cone (haystack),
    b. Windrow,
    c. Oriented pile
6. Determine a factor for each pile based on pile shape. Pile shape factors are as follows:
    a. Cone (haystack) – 0.4
    b. Windrow – 0.6
    c. Oriented pile - 0.5
7. To determine apparent volume of the pile (Note: this is not fibre volume), multiply the area of the pile derived by GPS, height and pile shape factor.

The calculated apparent volume will then be used to determine pile density once harvested volume and the volume remaining after secondary harvest has been derived (discussed below in the Pile density section of the Methodology).

III. BiOS Pile Volume Visual Estimator Method (VEM)

The BiOS Pile Volume Estimate Method, or VEM, is an automated derivative of the 3M method, located in the BiOS app. To use the VEM method, users need to follow these steps:

1. In the Visual Estimator function, click 'Add Pile' (Figure 8).

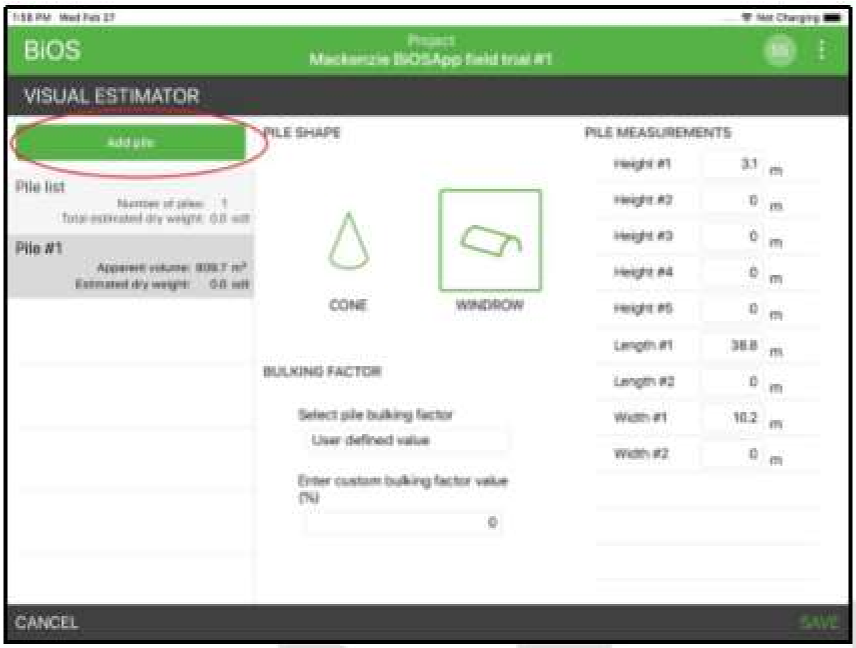

Figure 8. Add pile button in BiOS visual estimator.

2. Select a pile shape. Note: currently there are only two shapes (conical and windrow) available (Figure 9). More shapes are planned for future versions.

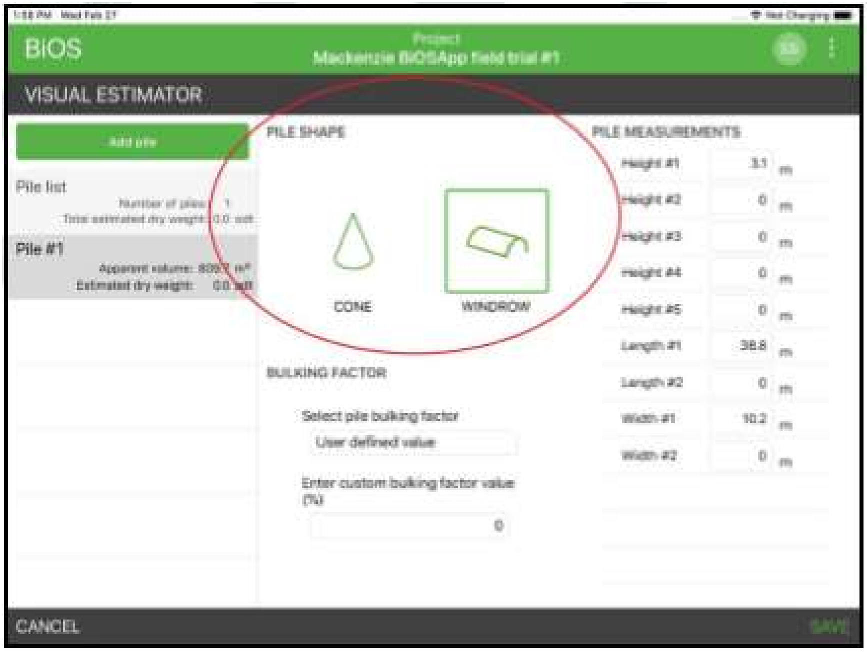

Figure 9. Pile shape buttons in BiOS visual estimator.

3. Enter the height, length and width values collected in the field. The cone shape requires a height and diameter (Figure 10).

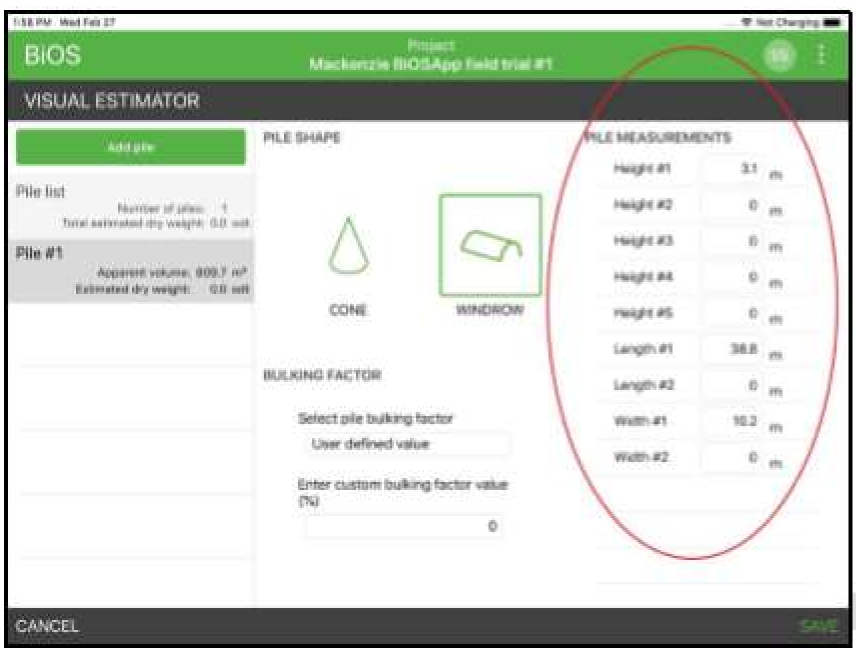

Figure 10. Pile measurement entry fields in BIOS visual estimator.

4. Choose a pile bulking factor from the list or enter a value manually (Figure 11).

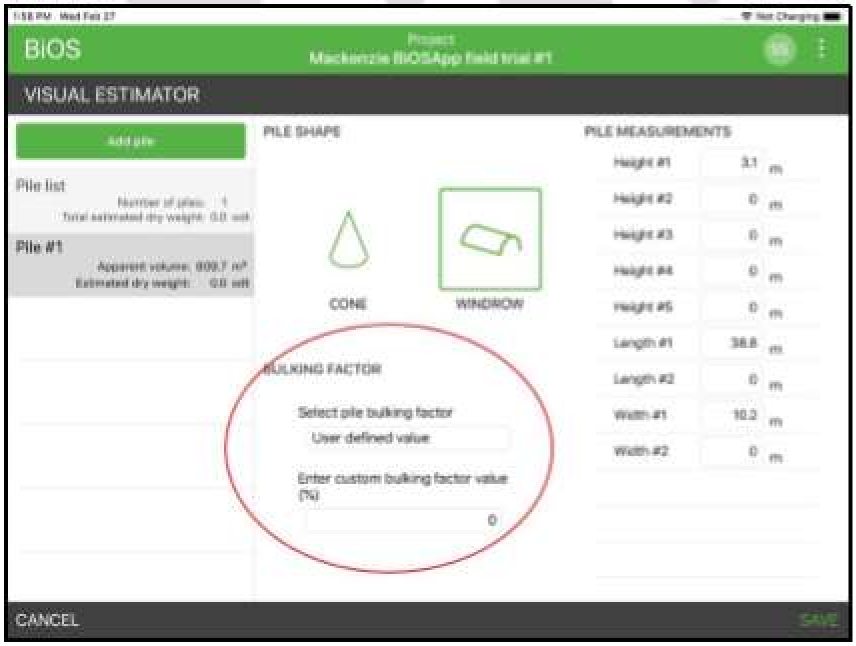

Figure 11. Bulking factor choice via drop-down in BiOS visual estimator.

For each pile, the visual estimator will calculate the apparent volume and estimate an oven dry weight of the fibre in the pile. A summary with the number of piles and the total estimated oven dry weight of the piles is calculated and located in the upper left corner of the screen (Figure 12).

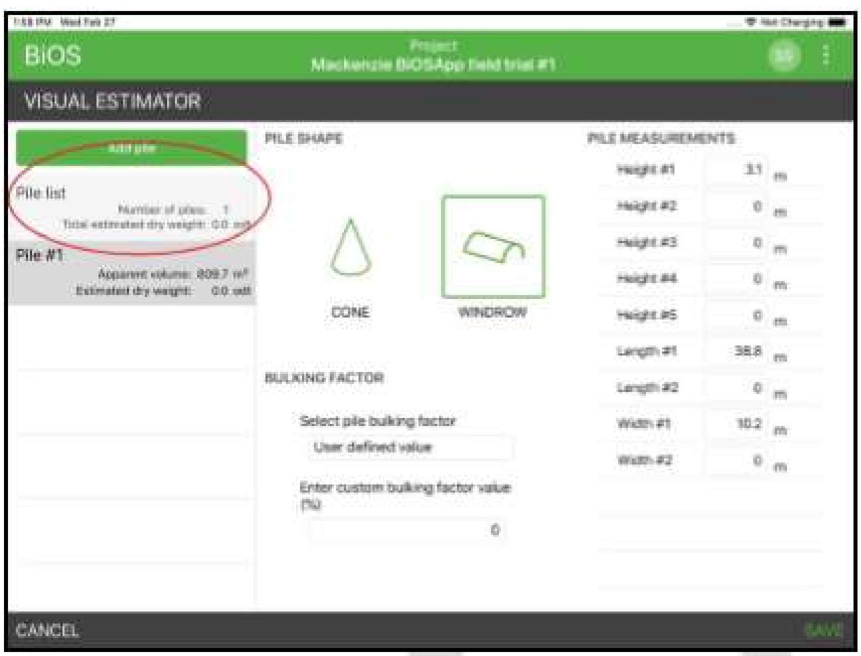

Figure 12. Pile counter and dry weight calculation.

Comminution

The volume harvested from each pile was monitored by a researcher in the field. Load slips containing the green weight of each load were provided by Tsi Del Del Enterprises and were cross referenced with individual residue piles. Hog fuel samples (1 litre) were collected from multiple loads and moisture content analysis was performed in the FPInnovations Vancouver lab. For a detailed explanation of moisture content analysis methodology, please see Appendix III.

Post-harvest measurement

After each pile was harvested, leftover volume within the pile footprint was quantified using a line transect survey. For description of line transect survey methodology, please see Appendix II.

Pile density

A summary of oven dry weight for each pile was calculated to derive pile density. Pile density can be defined as the measured volume of the pile divided by the oven dry weight of the pile.

BiOS comparison

The BiOS reporting phase tabulates the results generated from the inputs entered by the user. These results are displayed in five sections including:

- Biomass recovery
  - Area
  - Recovered biomass (odt)
  - Average moisture content (%)
  - Biomass yield (odt/ha)
  - Biomass / merchantable (odt/m^3)
  - Low heating value (MJ/kg)
  - Fuel consumption (L/odt)
  - GHG emissions (tonnes)
- Biomass transport
  - Distance to end use (km)
  - Operational road length (km)
  - Primary road length (km)
  - Public or paved road length (km)
  - Fuel consumption (L/odt)
  - GHG emissions (tonnes)
- Biomass supply cost
  - Recovery – stump to roadside ($/odt)
  - Transport – roadside to mill ($/odt)
- Species breakdown chart
  - Carbon delivered (tonnes)
  - Avoided GHG (tonnes CO2eq)
  - Odt of biomass
  - Odt/m^3

    - Odt/ha
- Biomass flow diagram
    - Total fibre (odt)
    - Merchantable volume harvested (odt)
    - Available biomass (odt)
    - Natural losses (odt)
    - Uncut trees (odt)
    - Cutover residues (odt)
    - Roadside volume (odt)
    - Roadside volume not recovered (odt)
    - Net roadside volume (odt)
    - Visual estimator volume (odt)
    - Recovered (%)
    - Biomass ratio (%)

The comparison in this report will focus only on the results displayed in the Biomass Flow Diagram of the report created by BiOS as these were the measurable outputs.

BiOS calculates greenhouse gas, or GHG, emissions for the biomass recovery and transport phase of an operation. It also calculates the volume of carbon delivered and the volume of avoided GHG by not burning the residue hauled to roadside. As there was not a viable way to measure greenhouse gas during the trial, the BiOS results for GHG's were not validated.

RESULTS AND DISCUSSION

Standing residual trees

Cruise data was provided by Tsi Del Del and a summary can be viewed in Table 1. A more comprehensive version can be found in Appendix IV. In the primary harvest, 100% of the coniferous stems were harvested and 0% of the deciduous stems were harvested.

Conversion from cubic metres to oven dry tonnes was completed using the dry basic density for each species (Table 2).

Table 2. Volume of standing trees, pre-secondary harvest

Species	Gross merchantable volume (m^3)	Dry basic density (oven dry kg/m^3)	Gross merchantable volume (oven dry tonnes/ha)
Douglas-fir	[redacted]	[redacted]	0
Hybrid spruce			0
Lodgepole pine			0
Trembling aspen	48	387	1.7
Total			1.7

Dispersed volume

Five plots were completed in the dispersed area of the cutblock. Dispersed volume results for each plot can be found in Table 3. The total volume in the dispersed area of the cutblock was 113.6 oven dry tonnes (4.1 oven dry tonnes per hectare multiplied by 27.7 hectares).

Table 3. Dispersed volume

Plot	m^3/ha	odt/ha
1	8.1	3.6
2	10.7	4.7
3	10.1	4.4
4	4.6	2.0
5	18.3	8.0
Average		4.1

Pile measurements

As described in the Methodology section of this report, there were three methods of pile measurement used to determine geometric volume of residual piles.

I. Manual Measurement Method (3M)

Total apparent volume for the 3M method was 9,234 m^3 (Table 4).

Table 4. Pile dimensions using the Manual Measurement Method

Pile dimensions using the Manual Measurement Method							
Pile name	**Length (m)**	**Width (m)**	**Height (m)**	**Shape**	**Shape factor**	**Pile area (m^2)**	**Apparent volume (m^3)**
1	6.0	7.0	1.8	Windrow	0.6	42.0	45.4
2	21.0	7.0	1.7	Windrow	0.6	147.0	149.9
3	24.3	6.8	1.7	Windrow	0.6	165.2	168.5
4	31.0	6.3	1.8	Windrow	0.6	195.3	210.9
5	25.6	5.2	1.8	Windrow	0.6	133.1	143.8
6	12.6	5.5	1.7	Windrow	0.6	69.3	70.7
7	13.1	5.2	1.9	Windrow	0.6	68.1	77.7
8	8.4	5.3	1.8	Windrow	0.6	44.5	48.1
9	24.3	5.4	1.7	Windrow	0.6	131.2	133.8
10	27.5	5.8	1.8	Windrow	0.6	159.5	172.3
11	26.4	6.4	1.9	Windrow	0.6	169.0	192.6
12	17.0	5.4	1.9	Windrow	0.6	91.8	104.7
13	8.6	4.5	1.7	Windrow	0.6	38.7	39.5
14	6.3	12.0	2.0	Windrow	0.6	75.6	90.7
15	11.0	4.8	1.8	Windrow	0.6	52.8	57.0
16	23.4	5.5	2.2	Windrow	0.6	128.7	169.9
17	6.3	5.0	2.3	Windrow	0.6	31.5	43.5
18	10.0	4.0	2.1	Windrow	0.6	40.0	50.4

19	8.0	4.8	1.6	Windrow	0.6	38.4	36.9
20	11.5	5.0	2.4	Windrow	0.6	57.5	82.8
21	11.9	6.2	1.8	Windrow	0.6	73.8	79.7
22	78.9	8.1	2.3	Windrow	0.6	639.1	881.9
23	19.1	4.3	2.0	Windrow	0.6	82.1	98.6
24	17.2	6.1	2.2	Windrow	0.6	104.9	138.5
25	12.4	4.9	1.8	Windrow	0.6	60.8	65.6
26	23.9	5.5	2.0	Windrow	0.6	131.5	157.7
27	19.4	5.1	2.0	Windrow	0.6	98.9	118.7
28	12.8	5.4	1.6	Windrow	0.6	69.1	66.4
29	26.9	4.3	2.0	Windrow	0.6	115.7	138.8
30	16.8	4.3	2.0	Windrow	0.6	72.2	86.7
31	31.0	8.0	2.4	Windrow	0.6	248.0	357.1
32	34.0	7.0	2.0	Windrow	0.6	238.0	285.6
33	49.9	7.6	1.9	Windrow	0.6	379.2	432.3
34	30.2	7.0	2.3	Windrow	0.6	211.4	291.7
35	22.9	5.0	2.0	Windrow	0.6	114.5	137.4
36	32.0	4.5	1.8	Windrow	0.6	144.0	155.5
37	26.0	6.0	2.0	Windrow	0.6	156.0	187.2
38	38.3	7.3	1.7	Windrow	0.6	279.6	285.2
39	17.1	4.3	1.7	Windrow	0.6	73.5	75.0
40	20.0	9.0	2.2	Windrow	0.6	180.0	237.6
41	29.4	6.3	2.0	Windrow	0.6	185.2	222.3
42	47.2	7.2	1.9	Windrow	0.6	339.8	387.4
43	22.0	5.5	1.9	Windrow	0.6	121.0	137.9
44	14.7	5.2	2.0	Windrow	0.6	76.4	91.7
45	29.0	6.9	2.4	Windrow	0.6	200.1	288.1
46	13.3	5.8	1.6	Windrow	0.6	77.1	74.1
47	46.6	6.4	1.8	Windrow	0.6	298.2	322.1
48	11.8	5.3	1.7	Windrow	0.6	62.5	63.8
49	43.4	12.0	2.3	Windrow	0.6	520.8	718.7
50	19.6	6.6	2.0	Windrow	0.6	129.4	155.2
51	30.9	6.8	2.0	Windrow	0.6	210.1	252.1
52	12.4	9.0	2.3	Windrow	0.6	111.6	154.0
Total							**9233.8**

II. GPS Measure Method (GMM)

Total apparent volume for the GMM method was 10,665 m^3 (see Table 5).

Table 5. Pile dimensions using the GPS Measure Method

Pile dimensions using the GPS Measure Method					
Pile name	**Height (m)**	**Shape**	**Shape factor**	**Pile area (m^2)**	**Apparent volume (m^3)**
1	1.8	Windrow	0.6	49.1	53.0
2	1.7	Windrow	0.6	157.2	160.3
3	1.7	Windrow	0.6	166.3	169.6
4	1.8	Windrow	0.6	174.6	188.6

5	1.8	Windrow	0.6	139.8	151.0
6	1.7	Windrow	0.6	78.3	79.9
7	1.9	Windrow	0.6	133.1	151.7
8	1.8	Windrow	0.6	79.8	86.2
9	1.7	Windrow	0.6	200.9	204.9
10	1.8	Windrow	0.6	223.3	241.2
11	1.9	Windrow	0.6	219.0	249.7
12	1.9	Windrow	0.6	131.5	149.9
13	1.7	Windrow	0.6	77.6	79.2
14	2.0	Windrow	0.6	67.9	81.5
15	1.8	Windrow	0.6	78.9	85.2
16	2.2	Windrow	0.6	206.5	272.6
17	2.3	Windrow	0.6	66.7	92.0
18	2.1	Windrow	0.6	41.0	51.7
19	1.6	Windrow	0.6	38.4	36.9
20	2.4	Windrow	0.6	77.4	111.5
21	1.8	Windrow	0.6	64.2	69.3
22	2.3	Windrow	0.6	602.1	830.9
23	2.0	Windrow	0.6	153.7	184.4
24	2.2	Windrow	0.6	104.3	137.7
25	1.8	Windrow	0.6	84.0	90.7
26	2.0	Windrow	0.6	143.9	172.7
27	2.0	Windrow	0.6	132.1	158.5
28	1.6	Windrow	0.6	77.3	74.2
29	2.0	Windrow	0.6	159.1	190.9
30	2.0	Windrow	0.6	92.1	110.5
31	2.4	Windrow	0.6	315.5	454.3
32	2.0	Windrow	0.6	314.2	377.0
33	1.9	Windrow	0.6	298.6	340.4
34	2.3	Windrow	0.6	282.1	389.3
35	2.0	Windrow	0.6	188.2	225.8
36	1.8	Windrow	0.6	262.0	283.0
37	2.0	Windrow	0.6	126.2	151.4
38	1.7	Windrow	0.6	225.9	230.4
39	1.7	Windrow	0.6	141.2	144.0
40	2.2	Windrow	0.6	174.6	230.5
41	2.0	Windrow	0.6	223.7	268.4
42	1.9	Windrow	0.6	312.8	356.6
43	1.9	Windrow	0.6	125.4	143.0
44	2.0	Windrow	0.6	93.5	112.2
45	2.4	Windrow	0.6	211.6	304.7
46	1.6	Windrow	0.6	84.8	81.4
47	1.8	Windrow	0.6	277.7	299.9
48	1.7	Windrow	0.6	60.3	61.5
49	2.3	Windrow	0.6	546.3	753.9
50	2.0	Windrow	0.6	190.0	228.0
51	2.0	Windrow	0.6	270.9	325.1
52	2.3	Windrow	0.6	121.4	167.5
Total					**10644.8**

III. BiOS Pile Volume Estimate Volume (VEM)

Total apparent volume for the VEM method was 10,206.5 m^3 (see Table 6) and because the visual estimator uses a bulking factor in its calculations, it provided an estimated dry weight of 877.5 oven dry tonnes.

Table 6. Pile dimensions using the BiOS Pile Volume Estimate Method

Pile dimensions using the BiOS Pile Volume Estimate Method							
Pile name	**Length (m)**	**Width (m)**	**Height (m)**	**Shape**	**Apparent volume (m^3)**	**Bulking factor (%)**	**Estimated dry weight (oven dry tonnes)**
1	6.0	7.0	1.8	Windrow	49.9	20.0	4.3
2	21.0	7.0	1.7	Windrow	164.9	20.0	14.2
3	24.3	6.8	1.7	Windrow	185.4	20.0	15.9
4	31.0	6.3	1.8	Windrow	232.0	20.0	20.0
5	25.6	5.2	1.8	Windrow	158.1	20.0	13.6
6	12.6	5.5	1.7	Windrow	77.8	20.0	6.7
7	13.1	5.2	1.9	Windrow	85.4	20.0	7.3
8	8.4	5.3	1.8	Windrow	52.9	20.0	4.5
9	24.3	5.4	1.7	Windrow	147.2	20.0	12.7
10	27.5	5.8	1.8	Windrow	189.5	20.0	16.3
11	26.4	6.4	1.9	Windrow	211.9	20.0	18.2
12	17.0	5.4	1.9	Windrow	115.1	20.0	9.9
13	8.6	4.5	1.7	Windrow	43.4	20.0	3.7
14	6.3	12.0	2.0	Windrow	99.8	20.0	8.6
15	11.0	4.8	1.8	Windrow	62.7	20.0	5.4
16	23.4	5.5	2.2	Windrow	186.9	20.0	16.1
17	6.3	5.0	2.3	Windrow	47.8	20.0	4.1
18	10.0	4.0	2.1	Windrow	55.4	20.0	4.8
19	8.0	4.8	1.6	Windrow	40.6	20.0	3.5
20	11.5	5.0	2.4	Windrow	91.1	20.0	7.8
21	11.9	6.2	1.8	Windrow	87.7	20.0	7.5
22	78.9	8.1	2.3	Windrow	970.1	20.0	83.4
23	19.1	4.3	2.0	Windrow	108.4	20.0	9.3
24	17.2	6.1	2.2	Windrow	152.3	20.0	13.1
25	12.4	4.9	1.8	Windrow	72.2	20.0	6.2
26	23.9	5.5	2.0	Windrow	173.5	20.0	14.9
27	19.4	5.1	2.0	Windrow	130.6	20.0	11.2
28	12.8	5.4	1.6	Windrow	73.0	20.0	6.3
29	26.9	4.3	2.0	Windrow	152.7	20.0	13.1
30	16.8	4.3	2.0	Windrow	95.4	20.0	8.2
31	31.0	8.0	2.4	Windrow	441.9	20.0	38.0
32	34.0	7.0	2.0	Windrow	314.2	20.0	27.0
33	49.9	7.6	1.9	Windrow	475.6	20.0	40.9
34	30.2	7.0	2.3	Windrow	320.9	20.0	27.6
35	22.9	5.0	2.0	Windrow	151.1	20.0	13.0
36	32.0	4.5	1.8	Windrow	171.1	20.0	14.7
37	26.0	6.0	2.0	Windrow	205.9	20.0	17.7
38	38.3	7.3	1.7	Windrow	313.7	20.0	27.0
39	17.1	4.3	1.7	Windrow	82.5	20.0	7.1

40	20.0	9.0	2.2	Windrow	261.4	20.0	22.5
41	29.4	6.3	2.0	Windrow	244.5	20.0	21.0
42	47.2	7.2	1.9	Windrow	426.2	20.0	36.6
43	22.0	5.5	1.9	Windrow	151.7	20.0	13.0
44	14.7	5.2	2.0	Windrow	100.9	20.0	8.7
45	29.0	6.9	2.4	Windrow	317.0	20.0	27.3
46	13.3	5.8	1.6	Windrow	81.5	20.0	7.0
47	46.6	6.4	1.8	Windrow	354.3	20.0	30.5
48	11.8	5.3	1.7	Windrow	70.2	20.0	6.0
49	43.4	12.0	2.3	Windrow	790.6	20.0	68.0
50	19.6	6.6	2.0	Windrow	170.8	20.0	14.7
51	30.9	6.8	2.0	Windrow	277.4	20.0	23.8
52	12.4	9.0	2.3	Windrow	169.4	20.0	14.6
Total					**10206.5**		**877.5**

Pile volume method comparison

The apparent volumes derived from each pile measurement method can be found in Table 7.

The total apparent volume for the GMM and VEM were similar. The apparent volume for 3M was approximately 12.5% lower than the other methods. This is likely due to the difficulty of measuring pile width along windrow shaped piles using the string box method.

Table 7. Apparent volumes of residue measurement methods

Apparent volumes of residue measurement methods							
Pile name	**3M**	**GMM**	**VEM**	**Pile name**	**3M**	**GMM**	**VEM**
1	45.4	53.0	49.9	27	118.7	158.5	130.6
2	149.9	160.3	164.9	28	66.4	74.2	73.0
3	168.5	169.6	185.4	29	138.8	190.9	152.7
4	210.9	188.6	232	30	86.7	110.5	95.4
5	143.8	151.0	158.1	31	357.1	454.3	441.9
6	70.7	79.9	77.8	32	285.6	377.0	314.2
7	77.7	151.7	85.4	33	432.3	340.4	475.6
8	48.1	86.2	52.9	34	291.7	389.3	320.9
9	133.8	204.9	147.2	35	137.4	225.8	151.1
10	172.3	241.2	189.5	36	155.5	283.0	171.1
11	192.6	249.7	211.9	37	187.2	151.4	205.9
12	104.7	149.9	115.1	38	285.2	230.4	313.7
13	39.5	79.2	43.4	39	75.0	144.0	82.5
14	90.7	81.5	99.8	40	237.6	230.5	261.4
15	57.0	85.2	62.7	41	222.3	268.4	244.5
16	169.9	272.6	186.9	42	387.4	356.6	426.2
17	43.5	92.0	47.8	43	137.9	143.0	151.7
18	50.4	51.7	55.4	44	91.7	112.2	100.9
19	36.9	36.9	40.6	45	288.1	304.7	317.0
20	82.8	111.5	91.1	46	74.1	81.4	81.5
21	79.7	69.3	87.7	47	322.1	299.9	354.3
22	881.9	830.9	970.1	48	63.8	61.5	70.2
23	98.6	184.4	108.4	49	718.7	753.9	790.6

24	138.5	137.7	152.3	50	155.2	228.0	170.8
25	65.6	90.7	72.2	51	252.1	325.1	277.4
26	157.7	172.7	173.5	52	154.0	167.5	169.4
				Total	**9233.8**	**10644.8**	**10206.5**

As stated in the Mackenzie validation trial report, when piles are measured, care should be taken to describe the method used as there is significant variance between the measurement methods.

Comminution

Load volume and moisture content

Over the course of the trial, 53.5 loads of hog fuel were comminuted in cutblock W1216 and hauled to the local power mill. The average load size was 18.7 green tonnes or 14.7 oven dry tonnes (the half load was removed from the average). Average moisture content was 21.7%. A total of 1001.9 green tonnes or 778.7 oven dry tonnes (28.1) were hauled from the cutblock.

Pile volume

Volume for each pile was calculated from the volume hauled during comminution (Table 8) and the volume left in each footprint.

Table 8. Pile volumes in oven dry tonnes

Pile	Volume (odt)	Pile	Volume (odt)
1	2.4	27	10.4
2	14.9	28	6.8
3	6.9	29	12.4
4	13.1	30	6.2
5	10.9	31	31.6
6	6.6	32	25.2
7	9.2	33	34.1
8	5.1	34	26.3
9	12.8	35	20.5
10	16.1	36	18.3
11	15.3	37	11.6
12	9.7	38	25.4
13	2.8	39	9.1
14	6.5	40	16.9
15	5.4	41	18.8
16	17.1	42	36.7
17	5.5	43	14.3
18	3.2	44	8.1
19	2.4	45	18.3
20	5.4	46	6.3

21	2.7	47	29.1
22	66.8	48	6.6
23	13.3	49	75.8
24	5.3	50	16.5
25	5.4	51	21.8
26	11.7	52	7.2
		Total	**790.5**

Post-harvest measurement

After piles were comminuted, line transect surveys were performed within the pile footprint. A total of 11.8 oven dry tonnes left in the pile footprint after harvest (Table 9).

Table 9. Volume found within pile footprint after comminution in oven dry tonnes

Pile	Volume in footprint (odt)	Pile	Volume in footprint (odt)
1	0.06	27	0.12
2	0.21	28	0.10
3	0.22	29	0.21
4	0.23	30	0.12
5	0.23	31	0.29
6	0.05	32	0.03
7	0.13	33	0.39
8	0.03	34	0.37
9	0.03	35	0.25
10	0.67	36	0.21
11	0.35	37	0.19
12	0.14	38	0.30
13	0.01	39	0.19
14	0.03	40	0.23
15	0.05	41	0.30
16	0.60	42	0.20
17	0.03	43	0.26
18	0.01	44	0.02
19	0.21	45	1.32
20	0.01	46	0.01
21	0.08	47	0.25
22	0.79	48	0.02
23	0.66	49	0.36
24	0.02	50	0.53
25	0.04	51	0.04
26	0.49	52	0.11

		Total	11.8

Pile density

Pile density was calculated by dividing the fibre volume (harvested and leftover), in oven dry kg, for the pile, by the **apparent volume**, in cubic metres, for the pile. This was done for each pile and for each method of pile measurement (Table 10). Average pile densities varied from 70.0 oven dry kg per cubic metre for the GMM method (GPS footprint) to 86.0 oven dry kg per cubic metre for the 3M method (string box measure). All three methods were moderately close in density with minor differences attributed to variance in shapes that deviated from the 'smooth' shapes created by the 3M and VEM methods.

Table 10. Pile density for three residue pile measurement methods

Pile density for three residue pile measurement methods				
Pile name	Volume (oven dry tonnes)	3M (od kg/m^3)	GMM (od kg/m^3)	VEM (od kg/m^3)
1	2.4	52.0	44.5	47.2
2	14.9	99.2	92.8	90.2
3	6.9	40.8	40.5	37.1
4	13.1	62.3	69.7	56.6
5	10.9	75.6	72.0	68.7
6	6.6	93.5	82.8	85.0
7	9.2	118.1	60.4	107.3
8	5.1	105.8	59.0	96.2
9	12.8	95.6	62.4	86.9
10	16.1	93.5	66.8	85.0
11	15.3	79.5	61.3	72.2
12	9.7	92.6	64.6	84.2
13	2.8	70.2	35.0	63.9
14	6.5	71.4	79.5	64.9
15	5.4	94.2	63.1	85.7
16	17.1	100.6	62.7	91.4
17	5.5	125.5	59.3	114.1
18	3.2	64.1	62.5	58.3
19	2.4	65.2	65.2	59.2
20	5.4	65.6	48.7	59.6
21	2.7	34.3	39.4	31.2
22	66.8	75.7	80.4	68.9
23	13.3	134.9	72.1	122.6
24	5.3	38.5	38.8	35.0
25	5.4	81.6	59.0	74.1
26	11.7	73.9	67.5	67.2
27	10.4	87.5	65.5	79.6
28	6.8	102.8	92.0	93.5
29	12.4	89.7	65.2	81.5
30	6.2	71.4	56.0	64.9
31	31.6	88.5	69.6	71.5

32	25.2	88.2	66.8	80.2
33	34.1	78.8	100.1	71.6
34	26.3	90.1	67.5	81.9
35	20.5	148.9	90.6	135.4
36	18.3	118.0	64.8	107.2
37	11.6	62.2	76.9	56.6
38	25.4	89.0	110.2	80.9
39	9.1	121.2	63.1	110.2
40	16.9	71.0	73.2	64.6
41	18.8	84.8	70.2	77.0
42	36.7	94.7	102.9	86.1
43	14.3	103.3	99.7	94.0
44	8.1	88.6	72.5	80.6
45	18.3	63.5	60.0	57.7
46	6.3	84.8	77.1	77.1
47	29.1	90.3	96.9	82.1
48	6.6	103.8	107.7	94.3
49	75.8	105.4	100.5	95.8
50	16.5	106.5	72.5	96.8
51	21.8	86.3	67.0	78.5
52	7.2	46.6	42.8	42.3
Average		**86.0**	**70.0**	**78.0**

Of the three pile measurement methods that were attempted, the GPS measure method was considered to have the most accurate shape and apparent volume methodology for the ground-based measurement methods. It is recommended that the Visual Estimator in BiOS adopt the ability to track the pile outline with GPS to improve on its current methodology.

Average density between the different methods varies, therefore, it is recommended that the method of pile measurement be identified when reporting residue pile density.

BiOS comparisons

The BiOS App creates a report which is summarized in a flowchart format (Figure 13). The information in the flowchart was the focus of the Williams Lake BiOS validation. The entire list of BIOS inputs, in the order they were entered into the app, can be found in Appendix I.

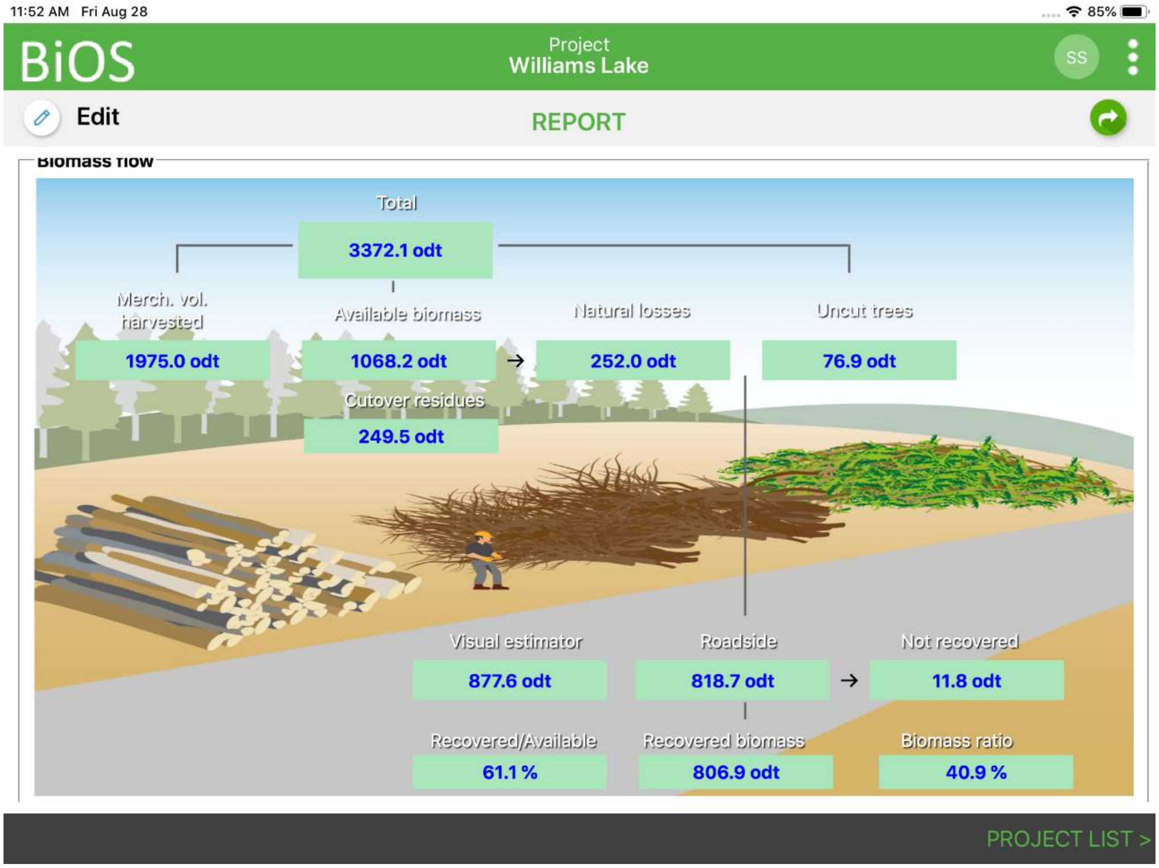

Figure 13. Biomass flowchart produced by the BiOS app for Williams Lake cutblock.

In order to compare the data in the flowchart with the actual results found in the field, Table 11 was created to ease analysis. Each line in the table describes one aspect of the flowchart except for Line 1, which depicts topping diameter (arguably one of the biggest influences on BiOS calculations).

Table 11. Comparison of BiOS calculated results and field trial results

Reference line	BiOS flowchart field	BiOS calculated results	Field trial results	Difference between BiOS and field trial results
1	Topping diameter (cm)	12.1	12.1	n/a
2	Total fibre (odt)[a]	3372.1	3261.6	3.4%
3	Merchantable volume harvested (odt)	1975.0	2027.8	-2.6%
4	Available biomass (odt)	1068.2	904.9	18.0%
5	Natural losses (odt)	252.0	252.0	n/a
6	Uncut trees (odt)	76.9	76.9	n/a

7	Cutover residues (odt)	249.5	114.4	118.1%
8	Visual estimator (odt)	877.6	790.5	11.0%
9	Roadside (odt)	818.7	790.5	3.6%
10	Recovered biomass (odt)	806.9	778.7	3.6%
11	Not recovered (odt)	11.8	11.8	0.0%

[a] Standing tree (merchantable stem + tops, branches and leaves)

Line 1 – Topping diameter

Line 1 displays the topping diameter used by BiOS and the measured results in the field analysis. Topping diameter is used in BiOS to determine the proportion of the volume of total fibre in the cutblock that is considered merchantable or within merchantable size specifications. Topping diameter was entered as 12.1 cm in BiOS to match the average butt diameter of 'top' pieces measured in the residue piles.

Line 2 – Total fibre

'Total fibre' in Line 2 is the total volume of woody fibre in the cutblock. This includes merchantable fibre, available biomass, natural losses (needles and leaves) and uncut trees. The BiOS predicted volume of 3372.1 oven dry tonnes is within 3.4% of the actual total volume 3261.6 oven dry tonnes derived from the field results. The difference between the two values is within acceptable parameters.

Line 3 – Merchantable volume harvested

Merchantable volume describes the proportion of total woody fibre considered merchantable by the BiOS app after entering the inputs for the Species Operations Tab. BiOS estimated merchantable volume for the trial cutblock to be 1975.0 oven dry tonnes. The merchantable volume harvested value of 2027.8 oven dry tonnes was provided by Tsi Del Del Enterprises and represents the actual volume hauled during the primary harvest. The BiOS result was 2.6% less than the cruise estimate.

Line 4 – Available biomass

BiOS calculates the 'Available biomass' located in Line 4 of Table 11 by subtracting the merchantable volume, natural losses and uncut trees from total fibre. To determine available biomass in the actual results column, the leftover (not recovered in the flowchart), recovered and cutover residues were added together. The BiOS result, 1068.2 oven dry tonnes and the actual result, 904.9 oven dry tonnes, were 18.0% different. While this may seem like a significant difference, the cause was due to the fire that occurred in the cutblock area prior to harvest. The fire caused a significant reduction in the cutover residues (Line 7), lowering the amount 'available biomass' while still leaving the roadside volume created during the primary harvest. If the fire had not occurred and the cutover residues were similar to the volumes calculated by BiOS, the available biomass volumes would have been much closer. Therefore, although the values in Line 4 were 18.0% different, this deviation is considered acceptable under the circumstances.

Line 5 – Natural losses

'Natural losses' from Line 5 in Table 12 describes the volume of leaves or needles in the cutblock that have fallen off due to season of harvest (no leaves in winter), or time from initial harvest (after one year, 70% of needles and 100% of leaves fall off). As the secondary harvest occurred more than two years after the primary harvest (and a wildfire), naturals losses were 252.0 odt. Data collection for natural losses is virtually impossible even when needles and leaves are attached to branches, so the BiOS value was utilized for both the BiOS and field trial results.

Line 6 – Uncut trees

In BiOS, 'Uncut trees' is the volume attributed to trees left standing after the primary harvest. A very small number of Douglas-fir trees and all trembling aspen were left standing within the cutblock. Due to the scattered nature of the Douglas-fir trees and the complete retention of the trembling aspen, the BiOS value was used for both the BiOS and field trial results.

Line 7 – Cutover residues

'Cutover residue' described in Line 7 of Table 12 describes the volume of fibre that is left in the dispersed area of the cutblock and will not be harvested. This volume is calculated based on the 'Technical losses at the stump' value found on the Biomass Operations data entry tab. The default for this value is set at 30%. The BiOS predicted value of 249.5 odt was 118.1% higher than the measured field results of 114.4 odt. The reason for this was stated in the above section 'Line 4 – Available biomass' (wildfire removal of dispersed volume) and was found to be within acceptable parameters given the circumstances.

Line 8 – Visual estimator

The visual estimator calculated volume is independent of the rest of the BiOS flow calculations. This indicator is useful to assess the volume per pile and was compared with the field result's total pile volume. The visual estimator predicted 877.6 oven dry tonnes of volume within the residue piles at roadside. This was 11% higher than the 790.5 oven dry tonnes of roadside volume found in the piles (both harvested and left in the pile footprints). The difference between these two values is likely a result of the difference between the actual packing value of the piles versus the 20% default value for loose slash available in BiOS. If the value were consistently found to be higher in future cutblocks of similar profiles, the user could manually reduce the packing ratio to better reflect the actual conditions.

Line 9 - Roadside

The BiOS calculation for roadside volume in Line 9 of Table 12 consists of all the volume that is hauled to roadside. To determine roadside volume for the actual field results, total hauled volume was added to the leftover pile volume to get 790.5 oven dry tonnes. This was different from the

BiOS calculation of 818.7 oven dry tonnes by 3.6%. The difference between the two values is within acceptable parameters.

Line 10 – Recovered biomass

The BiOS calculation for recovered biomass in Line 10 of Table 12 consisted of the roadside biomass volume that was comminuted and transported during the secondary harvest. The BiOS calculation for recoverable biomass of 806.9 oven dry tonnes was 3.6% different than the measured field result of 778.7 oven dry tonnes. The difference between these two values is within acceptable parameters.

Line 11 – Not recovered

The not recovered value in Line 11 of Table 12 consists of the volume left at roadside after the secondary harvest. BiOS calculates this using the Recovered Technical Efficiency Value found in the pre-piling and comminution functions of the Biomass Operations Tab. In the field, line transect surveys were completed to determine volume. The BiOS volume for 'not recovered' was 11.8 oven dry tonnes (assuming an average roadside recovery technical efficiency of 90%) and was identical to the value of 11.8 oven dry tonnes calculated in the field.

Overall analysis of comparison

In all of the categories found in Table 12, the BiOS values and the actual field results were very close, the slight deviation of the dispersed volume lost in the wildfire notwithstanding. This speaks well about the allometric equations utilized by BiOS for the species present in the cutblock (Lambert et al. 2005, Ung et al. 2008, Standish et al. 1985).

The positive results of this validation trial under less than perfect conditions (e.g. wildfire) also confirms the robustness of the model and its forecasting abilities.

Although the visual estimator results were close, a technique may be needed to better estimate the appropriate bulking factor for different residue profiles. This may be accomplished by offering more options than those currently provided, that fill gaps between the choices (ie, partially aligned tops, or densely piled slash).

Greenhouse gas results

BiOS calculates greenhouse gas emissions in the Biomass Recover, Biomass Transport and Species Breakdown portion of the overall report.

For this validation, biomass recovery emissions were calculated by BiOS at 8.4 tonnes (CO2eq) and biomass transport emissions were calculated at 3.1 tonnes (CO2eq) for a total of 11.5 tonnes (CO2eq).

In the Species breakdown portion of the report it states that 403.5 tonnes of carbon were delivered, which constitutes a 35:1 ratio of delivered to emitted carbon (delivery distance 17.6 km). The report also states that 1315.3 tonnes of greenhouse gas were avoided in roadside burning. Validation of greenhouse gas reductions were outside the scope of this project, however, given the increasing interest in this topic there are opportunities to expand the validation of BiOS to quantify this metric.

CONCLUSION

FPInnovations completed a field validation of the FPBiOS App in August 2020. A cutblock located in the IDFdk3 biogeoclimatic zone near Williams Lake, BC was chosen. This validation required researchers to measure available biomass in the field, including dispersed volume, residual pile volume and volume left over on site after the secondary harvest. After measurements in the field were completed, the values collected were compared with the outputs calculated by BiOS.

Of the three pile measurement methods that were attempted, the GPS measure method was considered to have the most accurate shape and apparent volume methodology. It is recommended that the Visual Estimator in BiOS adopt the ability to track the pile outline with GPS to improve on its current methodology. Discussions should occur regarding the addition of more pile bulking factor options to better improve estimator volume predictions.

Although there was a discrepancy between the calculated cutover volume and the measured cutover volume due to wildfire, the field result for recovered biomass was within 4% of the BiOS predicted outputs. Overall, this validation displays a very favourable outcome for predicting recovered biomass in this biogeoclimatic zone and species profile.

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APPENDIX I – BIOS APP DATA ENTRY

Run	Tab	Area
1	Project Information	27.7

Run	Tab	Data source	Species	Volume/ha	Top dia	Harvest removal	Decay waste breakage	MC	Dry basic density	Green density	Volume /stem
1	Species Operations	Cruise + Field	Fd	109.7	12.1	98	5	21.7	450	577	0.38
			Sw	37.6	12.1	100	5	21.7	383	491	0.42
			Pl	18.8	12.1	100	56	21.7	409	524	0.47
			At	1.7	12.1	0	66	21.7	387	496	0.74

Run	Tab	Average Skid Distance	Harvest Data	Harvest Method
1	Logging Operations	150	06/01/2018	Full tree with roadside processing

Run	Tab	Technical Losses at the Stump	Recovery Date	Pre-piling	Comminution
1	Biomass Operations	30%	08/06/2020	on (30%)	Grinder (90%)

Run	Tab	Truck Configuration	Destination	Distance
1	Transport	Semi with 3 axles	Williams Lake Plywood (very near the power plant)	User defined (4.3km operational, 3.8km primary, 9.5km public)

Run	Tab	Piles	Pile Type	Ht1	L1 (or diameter)	W1	Bulking Factor	Apparent Volume	Est Dry Weight
1	Visual Estimator	1	WR	1.8	6.0	7.0	20		
		2	WR	1.7	21.0	7.0	20		
		3	WR	1.7	24.3	6.8	20		
		4	WR	1.8	31.0	6.3	20		
		5	WR	1.8	25.6	5.2	20		
		6	WR	1.7	12.6	5.5	20		
		7	WR	1.9	13.1	5.2	20		
		8	HS	1.8	8.4	5.3	20		
		9	WR	1.7	24.3	5.4	20		
		10	WR	1.8	27.5	5.8	20		
		11	WR	1.9	26.4	6.4	20		
		12	WR	1.9	17.0	5.4	20		
		13	WR	1.7	8.6	4.5	20		
		14	HS	2.0	6.3	12.0	20		
		15	WR	1.8	11.0	4.8	20		
		16	WR	2.2	23.4	5.5	20		
		17	WR	2.3	6.3	5.0	20		
		18	WR	2.1	10.0	4.0	20		
		19	WR	1.6	8.0	4.8	20		
		20	WR	2.4	11.5	5.0	20		
		21	WR	1.8	11.9	6.2	20		
		22	WR	2.3	78.9	8.1	20		
		23	WR	2.0	19.1	4.3	20		
		24	WR	2.2	17.2	6.1	20		
		25	WR	1.8	12.4	4.9	20		
		26	WR	2.0	23.9	5.5	20		
		27	WR	2.0	19.4	5.1	20		
		28	WR	1.6	12.8	5.4	20		
		29	WR	2.0	26.9	4.3	20		
		30	WR	2.0	16.8	4.3	20		
		31	WR	2.4	31.0	8.0	20		
		32	WR	2.0	34.0	7.0	20		
		33	WR	1.9	49.9	7.6	20		
		34	WR	2.3	30.2	7.0	20		
		35	WR	2.0	22.9	5.0	20		
		36	WR	1.8	32.0	4.5	20		
		37	WR	2.0	26.0	6.0	20		
		38	WR	1.7	38.3	7.3	20		
		39	WR	1.7	17.1	4.3	20		
		40	WR	2.2	20.0	9.0	20		
		41	WR	2.0	29.4	6.3	20		
		42	WR	1.9	47.2	7.2	20		
		43	WR	1.9	22.0	5.5	20		
		44	WR	2.0	14.7	5.2	20		
		45	WR	2.4	29.0	6.9	20		
		46	WR	1.6	13.3	5.8	20		
		47	WR	1.8	46.6	6.4	20		
		48	WR	1.7	11.8	5.3	20		
		49	WR	2.3	43.4	12.0	20		
		50	WR	2.0	19.6	6.6	20		
		51	WR	2.0	30.9	6.8	20		
		52	WR	2.3	12.4	9.0	20		

APPENDIX II – LINE TRANSECT SURVEY METHODOLOGY

- Volume leftover after the secondary harvest was assessed using line transect methodology
- Starting location within the pile footprint should be chosen randomly. Number of plots within the footprint should be determined in the field to adequately represent the size of the footprint.
    - At least two 10 m transects per plot.
    - The transect bearing selection should be done by spinning the compass wheel and randomly stopping on a given bearing.
    - The minimum length of pieces that cross the transect to be measure is 30 cm.
- Tallied pieces over 5 cm in diameter can be identified by species or group (softwood & hardwood) depending on site conditions and relevance to study (species was not collected for this trial). Pieces with a diameter less than 5 cm (down to 1 cm) are only to be tallied (counted) regardless of species or group.
- Not to be tallied:
    - Non-commercial species or brush species that won't become a full-grown tree.
    - Roots
    - Stumps
    - Trees with root ball (roots in the ground) attached counts as standing and not as slash on the ground
    - Slash height (site assessment factor)
    - Pieces with more than 50% rot (it breaks apart easily)

[1]**Van Wagner. 1968.** The Line Intersect Method in Forest Sampling. Forest Science.

APPENDIX III – MOISTURE CONTENT ANALYSIS

Analyzing the Moisture Content of Biomass Samples

Objective: to find the moisture content percentage *mc* (%) (% by weight, wet basis) of a biomass sample.

Work space: This procedure should be performed in laboratory conditions.

Materials and equipment:

- Digital scale with a capacity of at least 2000 g and accuracy of 0.1g
- Drying oven
- Clean sample weighing tray, able to hold at least 300 g of biomass
- 6 L (>1 kg) of biomass sample (3 replicates of at least 300 g each)

Procedures:

Step 1
Follow the procedures for *Separating Biomass Samples* to separate 3 replicates of at least 300 g each from one sample of at least 1 kg of biomass.

Step 2
Weigh the empty sample tray and record its weight (tare) m_t.

Step 3
Load the material of a replicate into a weighing tray. Weigh the loaded tray and record the weight m_{we}.

Step 4
Load the tray into the oven and set to 105°C.
Keep the tray in the oven until constant mass is obtained[2].

Step 5
Weigh the loaded tray and record the weight of the dry material m_{dry}.

Step 6
Calculate moisture content *mc* (%) according to the following formula:
$mc\ (\%) = [(m_{we} - m_{dry}) / (m_{we} - m_t)] \times 100$

Step 7
Analyze the 3 replicates and report the average.

[2] Mass constancy is obtained when the mass lost between two weights taken 60 minutes apart is not exceeding 0.2% of the total lost in mass (EN-TS 14774-1:2009). The drying time will depend on the particle size and the thickness of the sample in the tray, and may vary between 5 and 24 hours (overnight).

APPENDIX IV – CRUISE COMP SUMMARY

FOR APPRAISAL PURPOSE			PERCENT REDUCTION APPLIED				Section Page: 4 Main Page: 68
Timber Pricing Branch - 2017.01			Extended Block Summary (Average Line Method)				A84330-999April 2018.cpm
CompMatePC 1.4.1.0			Useless Volume Excluded				2018-04-06 10:08:34 AM
License Number: A84330	PSYU: 89 - Williams Lake - 123	Region: 3 - Cariboo	Licencee: Tolko Industries Ltd.	Compiled By: Infinite Forestry Solutions Ltd.			
Cutting Permit: 999	FIZ: H	District: 2 - Cariboo Chilcotin	Cruised By: DWB Consulting Services Ltd.	Els Armstrong, RFT, ATE			
Net Area: Block: 216	Description: W1216	Plots in Block: 10	TUs: TUs: All : 27.0				

		Total	Conifer	Decid.	F	S	PL	E	AT
Utilization Limits									
Min DBH	cm (M)				17.5	17.5	12.50	17.5	17.5
Stump Ht	cm (M)				30	30	30.00	30	30
Top Dia	cm (M)				10.0	10.0	10.00	10.0	10.0
Log Len	m				5.0	5.0	5.00	5.0	5.0
Volume and Size Data									
Gross Merchantable	m3	4650	4602	48	3038	1042	521		48
Net Merchantable	m3	4120	4103	16	2883	994	227		16
Net Merch - All	m3/ha	153	152	1	107	37	8		1
Net Merch - Live	m3/ha	77	77	1	45	32			1
Net Merch - DP	m3/ha	75	75		62	5	8		
Distribution	%	100	100		70	24	6		
Decay	%	4	3	42	3	2	10		42
Total Cull (DWB)	%	11	11	66	5	5	56		66
Stems/Ha (Live & DP)		429.6	427.2	2.4	293.6	92.5	41.1		2.4
Avg DBH (Live & DP)	cm	26.1	26.0	30.4	26.4	25.1	25.8		30.4
Snags/Ha									
Avg Snag DBH	cm								
Gross Merch Vol/Tree	m3	0.40	0.40	0.74	0.38	0.42	0.47		0.74
Net Merch Vol/Tree	m3	0.36	0.36	0.25	0.36	0.40	0.20		0.25
Avg Weight Total Ht	m	22.7	22.7	27.2	22.8	22.7	21.8		27.2
Avg Weight Merch Ht	m	17.2	17.2	21.1	17.4	16.7	16.9		21.1
Avg 5.0 m Log Net	m3	0.14	0.14	0.07	0.14	0.14	0.13		0.07
Avg 5.0 m Log Gross	m3	0.14	0.14	0.19	0.14	0.15	0.14		0.19
Avg # of 5.0 m Logs/Tree		2.80	2.79	3.84	2.71	2.84	3.25		3.84
Net Immature	%	95.8	96.2		94.6	100.0	100.0		
Slope Average	%	9							
Burn Volume	%	98.2	98.4	58.0	100.0	93.4	100.0		58.0
Heavy Burn Volume	%	0.9	1.0				17.2		
Blowdown Volume	%	5.8	5.7	20.2	0.3		100.0		20.2
Insect Volume	%								
Partial Cut %	%	80.8	86.0	5.0	81.2	100.0	100.0		5.0
LRF and Log Summary									
Net Merch - Stud	%	60.1	60.3		62.5	55.1	55.5		
Net Merch - Small Log	%	86.4	86.4	84.7	80.7	100.0	100.0		84.7
Net Merch - Large Log	%	13.6	13.6	15.3	19.3				15.3
Avg LRF All	bdft/m3				174.8	183.3	178.2		156.2
Statistical Summary									
Coeff. of Variation	%	47.0	46.9	169.9	57.8	153.1	150.4		169.9
Two Standard Error	%	38.4	38.2	143.5	47.4	125.5	122.6		143.5
Number and Type of Plots		MP = 10	CP = 0						
Number of Potential Trees		50							
Plots/Ha		0.4							
Cruised Trees/Plot		5.0							

FLAGS: Compile All Trees, Dry Belt Fir

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