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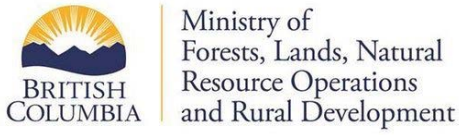
BC ROADSIDE BIOMASS VOLUME ASSESSMENT AND GHG BENEFITS – BIOS APP ADD-ONS

TSA LEVEL UPDATES + ROADSIDE VOLUME ESTIMATOR

CONTRACT NUMBER: FPI BC-TT AGREEMENT



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This report presents the development highlights for the BiOS app completed in 2018-2019 by FPI. An updated methodology is defined to help FLNRORD fully integrate the BiOS app data point collection into the Forest BioGis web platform. A visual roadside pile volume estimator was also developed and implemented into the BiOS app. This visual estimator will need to be calibrated and further developed with roadside pile recovery trials performed in various BC conditions. Finally, a four-year development plan is proposed to have a fully validated set of tools in the Forest BioGIS web platform and the BiOS app.

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DECISION-SUPPORT TOOLS FOR THE BIOECONOMY

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 (Forest BioGIS) for the development of the British Columbia (BC) forest bioeconomy. 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 with 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 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 m^3 (42% of Canada harvest). This harvest of merchantable roundwood generates logging residues of about 10 million oven-dry tonnes (odt) per year (assuming 0.15 odt/m^3). The BC Wildfire Act and Wildfire Regulation stipulate that the forest industry dispose 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, which could have been put to good use, 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 allows 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.

This document serves as the application update framework to be used by, (1) the ArcGis experts within FLNRORD to integrate data captured by the app with the Forest BioGIS platform to improve TSA level estimates and, (2) by the FPI app developers to build a visual field estimator of roadside residue pile volumes. The addition of up-to-date biomass data captured by the app will be useful to verify, update and improve biomass estimates for the province.

UPDATE TSA LEVEL ESTIMATES USING BIOS APP

The Forest BioGIS platform is an interactive map of BC shown on the FLNRORD ArcGis Online (AGOL) account (Figure 1). The key features of Forest BioGIS are a user-friendly set of interactive maps which show location, type and amount of residual fibre generated by harvest activities, and economic feasibility to utilize them. The site will also incorporate climate change and socio-economic impacts of utilizing residual fibres and serve multiple government key priorities and business areas.

The key components of Forest BioGIS are:

- Base Layer – FPInterface outputs plus other spatial data (e.g., historic and projected harvest and disturbances, existing and hypothetical mill facilities, road maps, fibre flow and exports, etc.) + App data input and verification
- Forest Management Layer – AAC planning and harvest activities that affect roadside residual fibre over time
- Fibre Flow Layer – optimal fibre flow from roadside to mill gate based on transportation costs and mill assumptions
- Environmental and Socio-economic Layer – impacts of the fibre flow on jobs, GDP, carbon benefits, as well as rural development and First Nations

Data provided by the BiOS app will be used to improve and verify the estimate of biomass availability shown in the base layer of the map.

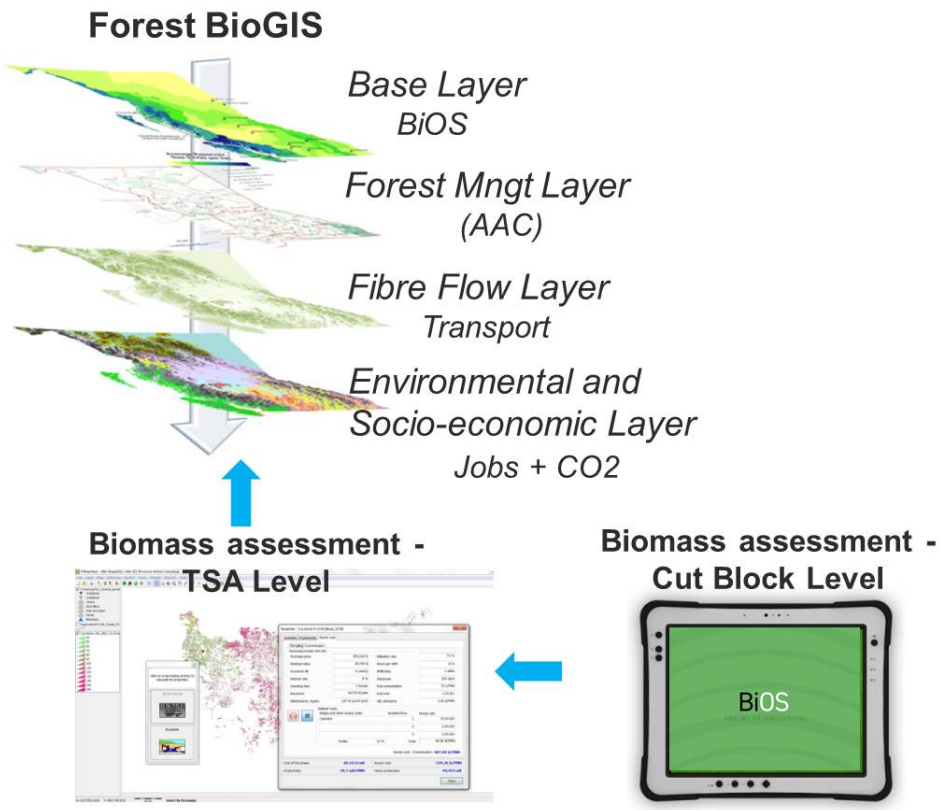

Figure 1. BC Forest BioGIS interactive platform.

TSA update workflow

This section presents the mechanics (concept development) of how such a dynamic between the two tools (BiOS app & Forest BioGIS) can be implemented. The Forest BioGIS interactive map will show TSA-level biomass availability results produced by FPInterface studies for individual TSA. To better map out the residual biomass for the whole province, FLNRORD mandated FPI to complete a series of biomass supply analysis using FPInterface. A total of 11 TSA's have been analyzed representing a combined annual allowable cut (AAC) of 28 M m^3 (Table 1). An additional 25 TSA's, for a combined total AAC of 26 M m^3, will be analyzed using FPInterface in the coming years. A priority list of new TSAs, for which biomass supply analyses will be conducted with support of the harvest planning data from Forest Analysis and Inventory Branch (FAIB), will be generated.

The BiOS app will serve to verify and improve the results generated from BC Forest BioGIS. To implement this successfully, a workflow needs to be developed showing the mechanics of how the data provided from app users at the cutblock level can be used to update information at the TSA level.

Table 1. FPI biomass supply analysis using FPInterface

TSA completed	Year completed	Harvest raster	AAC (m^3)	TSA not completed	AAC (m^3)
Prince George	2012	2011-2031	8,350,000	Okanagan	3,078,405
Mackenzie	2013	2011-2031	4,500,000	Fort St John	2,115,000
Williams Lake	2012	2011-2031	3,000,000	Morice	1,900,000
Quesnel	2011	2009-2029	2,607,000	Dawson Creek	1,860,000
Kamloops	2016	2015-2035	2,300,000	Fort Nelson	1,625,000
100 Mile House	2014	2013-2033	1,948,002	Merritt	1,500,000
Lakes "Burns lake"	2012	2012-2032	1,648,660	North Island	1,248,100
Fraser	2018	2014-2034	1,241,602	Sunshine Coast	1,204,808
Strathcona	2018	2012-2032	1,200,000	Kispiox	1,087,000
Bulkley	2017	2009-2059	852,000	Pacific	865,700
Arrowsmith	2018	2014-2034	348,000	Nass	865,000
Total AAC			**27,995,264**	Cranbrook	808,000
				GBR North	803,000
				Boundary*	670,142
				Kootenay Lake*	640,000
				Lilooet	570,000
				Arrow*	500,000
				Invermere	496,720
				Golden	485,000
				Soo	480,000
				Kalum	424,000
				Cascadia	402,818
				Robson Valley	363,559
				Revelstoke	225,000
				Cassiar	196,000
				Total AAC	**25,755,752**

*Arrow, Boundary and Kootenay will be completed by end of fiscal year 2018-2019.

In April 2011, a process for estimating available forest-origin biomass for BC Timber Supply Areas using FPInterface was established and demonstrated for the Quesnel TSA (1st of 11) (Friesen and Goodison, 2011). The FPInterface analysis used 20-year harvest and road network plans for Crown land (volume based tenures) provided by BC FLNRORD and excluded area-based Tree Farm Licenses (TFL). All planned blocks were assumed to be clearcut harvested, processed at roadside and accessible to comminution operations.

To acquire the appropriate polygon layer for use in FPInterface, the Vegetation Resource Inventory (VRI) polygons with stand attributes, the Timber Harvesting Land Base (THLB) polygons and proportions, and the 20-year harvest raster were intersected (Friesen and Goodison, 2011). The 20 year harvest raster is a point in time snapshot. It indicates which polygons (pixels of 1 ha each) are expected to be harvested in each of the next 20 years. No attempt was made to model possible growth or mortality during the 20 year horizon. The large number of polygons (pixels) per TSA (> 60,000) slowed down the performance of FPInterface. The solution for improvement of analysis was to aggregate pixels to reduce the number of calculations required to find spatial paths between product origins and mills. Aggregation rules grouped pixels (cut blocks) of identical harvest year within a 10 km radius. The final layer utilized in FPInterface corresponds to groups of pixels ranging in size from 0.5 ha to 250 ha depending on the TSA. This layer, for each TSA, will be uploaded to Forest BioGIS.

Forest BioGIS update procedure

TSA biomass estimates shown in the base layer of the Forest BioGIS interactive map will present biomass availability in the same raster layer (pixels) used in the FPInterface analyses (Figure 2). The fine-grain detail of the BiOS app data will allow updating each grouping of pixels on the map. Each individual pixel on the map will have a series of attributes detailing harvest practices and stand type information used in the FPInterface analyses (references 2, 3, 4, 5, 8, 9, 10, 11, 12, 13, 14). The new data coming from the BiOS app and synchronized to the base layer of the Forest BioGIS map will be used to update the information (attributes) at the pixel level. A 500 m buffer (78.5 ha) will be used around each BiOS data collection point and all pixels included within this buffer zone will have their attributes updated which will serve to update the original TSA estimates.

FPInnovations has advanced GIS-compatible tool which is used to aggregate cut blocks (polygons) of a shapefile by a given method (by attribute, by location, by proximity or by roadshed) and create a new one better suited for use in FPInterface. Some elements of this tool can be used to perform the buffer around the BiOS data points shown on the Forest BioGIS base layer. A specific ArcGIS Online (AGOL) server application will be required to update the attributes of the base layer which includes the original FPInterface biomass estimates at the harvest raster level (pixels). This AGOL programming should be completed by the owner/administrator of the site from the Forest Analysis and Inventory Branch (FAIB).

Here is a set of instructions to help identify which tasks can be done by the user and which tasks require FPI and/or FLNRORD staff assistance:

- FLNRORD - Attributes shown to users on the Forest BioGIS interactive map should be presented in different formats.
    - A summary of attributes collected from the BiOS app should be shown in a list format to appear when user of the Forest BioGIS platform selects a given BiOS (field assessment) point on the map (Table A1).

- Users should have the ability to select individuals or groupings of polygons from the harvest raster planning to obtain forest inventory information (from VRI) and biomass estimates shown in a table format (Table A2).
- Biomass estimates shown can come either from previous FPInterface analysis (see Table 1 for all TSA analyzed so far) or present updated information based on BiOS app collected data (only use "Field" type collected data to update Forest BioGIS and not "Test" type data which will be commonly used for various feasibility analysis but not related to any actual harvest/recovery operation).
- Import FPInterface output shapefiles to the interactive map of Forest BioGIS . This work should be planned for the 11 TSA's for which we already have data and executed in 2019-2020 fiscal year.
- Functioning of Forest BioGIS requests: Users of the site should have the option to choose from fields of the BiOS app, or the harvest raster info used in the various FPInterface analyses, or the FPInterface outputs (Table A2).

- FPI to extract the information from the FPInterface output results of previous systems (done in 2018-2019)

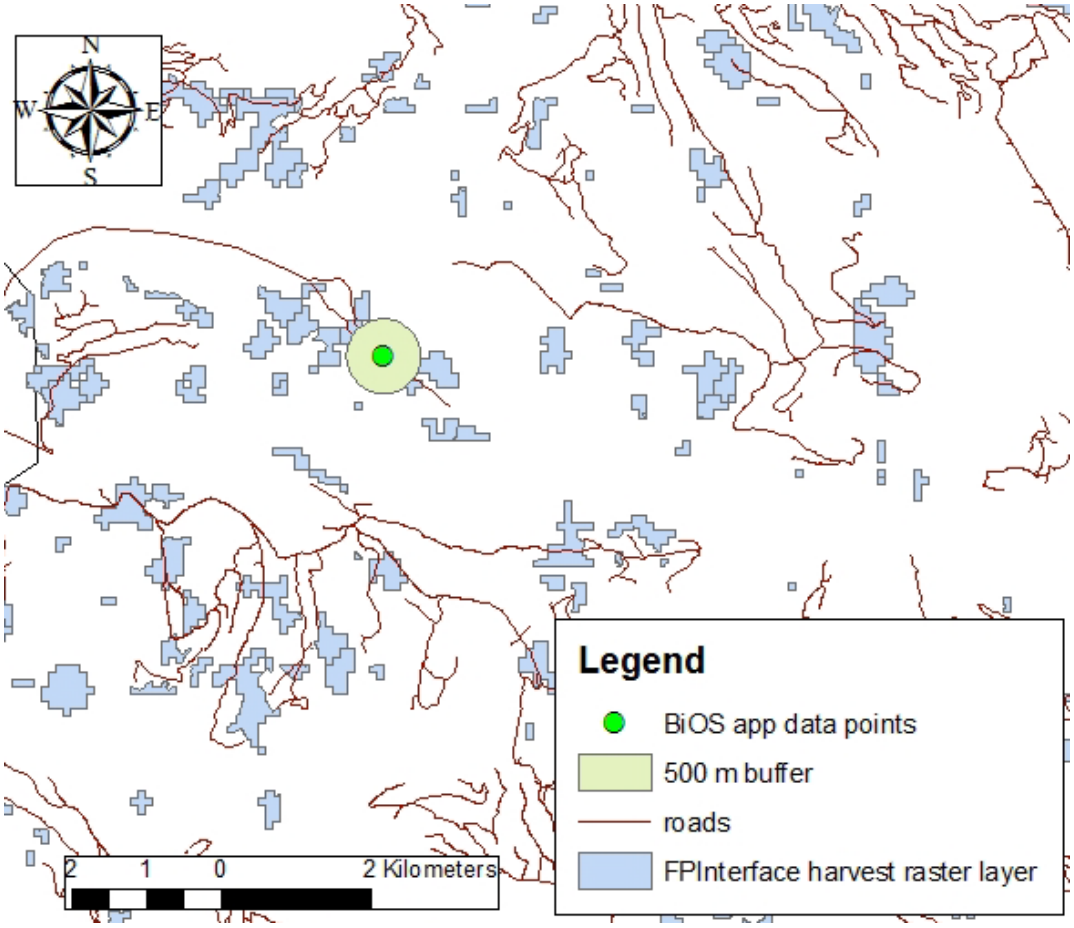

Figure 2. BC Forest BioGIS info update using BiOS app data.

ROADSIDE PILE VOLUME ESTIMATOR

FPInnovations has completed biomass recovery trials done throughout Canada to validate the biomass flow. All biomass trials are unique with respect to harvest equipment used, stand composition, landscape and many more. To help conduct these validation trials, FPInnovations cruise methodologies have been harmonized in a reference guide (Volpé, Reynolds and Spencer, 2013) which provides pre and post-harvest instructions on the layout
(plot location, # of plots, size of plots) and the cruise data required to estimate roadside pile volume. Another important feature of this guide is a section on roadside assessment of residue piles. FPInnovations developed a methodology to assess roadside biomass pile weight based on bulk volume which is based on the best available techniques given limited field data. Assessing the bulk volume and even height/width/length of biomass piles involves subjective guess work. There is a definite need for guidelines on how to measure biomass piles (with pictures and examples). The steps presented in the guide will be implemented in the app to cover the most common roadside pile shapes that can be encountered in the field. However, field validation trials will be required to verify and adjust this methodology as it is presented below (i.e.: Mackenzie biomass validation trial). Spencer (2017) provides additional information on best practices when it comes to roadside residue handling and piling practices.

The pile volume estimator will be a phase in the project creation wizard that will allow the user to get a quick visual estimate of the volume (apparent m^3) and mass (odt) of the pile and will be used to compare to the BiOS calculated roadside volume. The major steps involved in estimating the biomass volume stored in roadside residue piles are:

1- Pile bulk (apparent) volume assessment
    a. Pile measurements for length, width and height
    b. Pile shape catalogue
    c. Estimate apparent volume of most common shapes such as the ones presented in Hardy (1996)
2- Bulking factors
    a. Define a list of bulking factors according to pile species mix, biomass type and pile shape

The bulking factor provides a measure of the volume change that can be expected during processing. The bulk density provides a measure of the "fluffiness" of a material in its transported form (Figure 3).

Figure 3. Bulking factors of various biomass types.

Each individual pile at the cutblock level is measured and defined in the project wizard of the app to provide an estimation of roadside biomass at the cutblock level. The biomass flow in the report produced by the app will show both the regular BiOS estimate (from inventory data and default system recovery efficiency) and the roadside biomass visual estimate (based on field measurements). Figure 4 represents the full workflow used in the visual estimator. Following the outcomes of the validation trials, an additional step might be added to include a measure for piece dimension (i.e.: top diameter and length of tops).

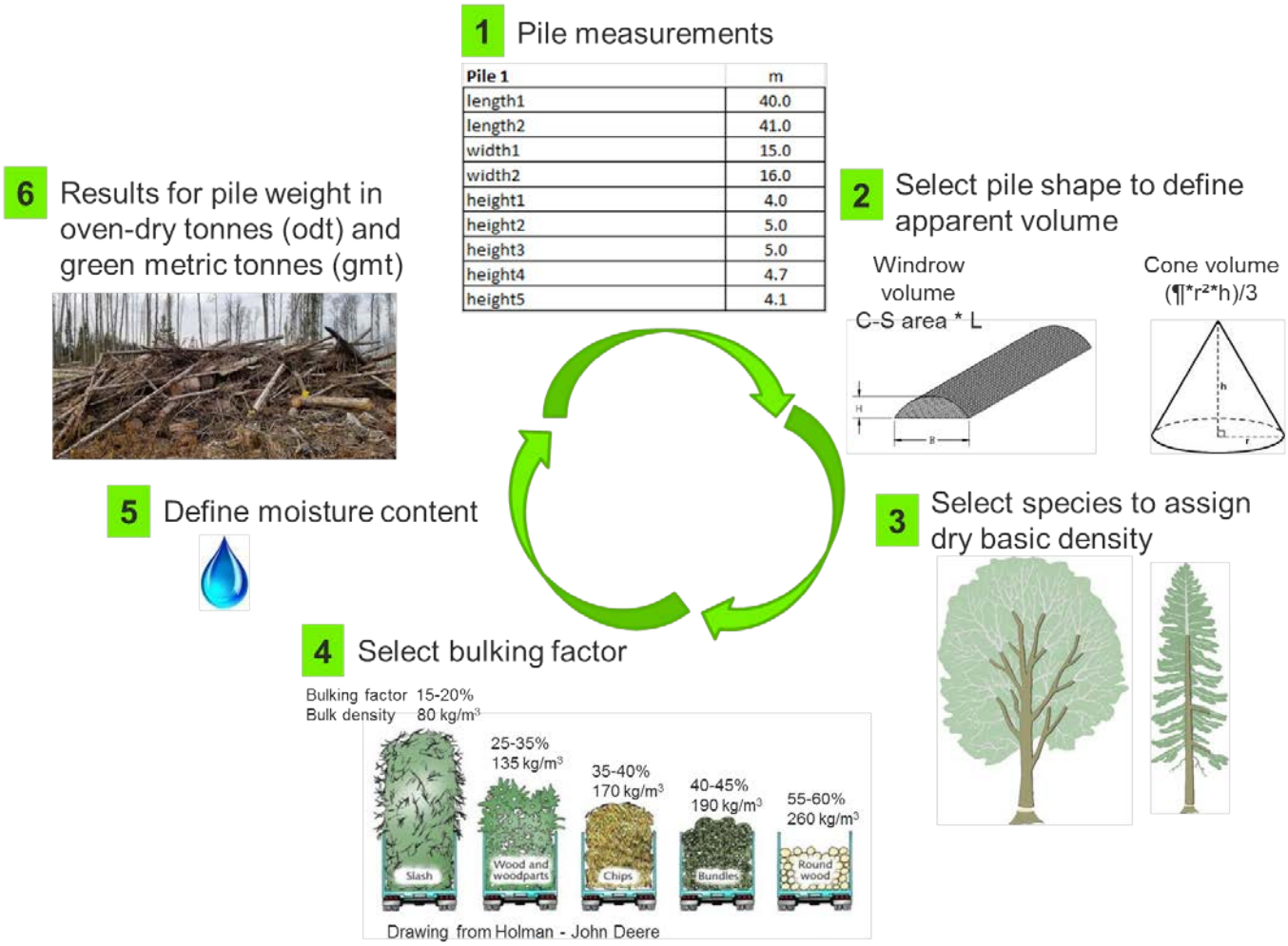

Figure 4. Workflow used in the visual estimator.

2018-2019 BIOS APP DEVELOPMENTS

The BiOS app development needs were identified after consultations with multiple Branches within FLNRORD including: Innovation, Bioeconomy and Indigenous Opportunities (IBIO), Timber Pricing Branch (TPB), Forest Tenure Branch (FTB), B.C. Timber Sales, and the Forest Analysis and Inventory Branch (FAIB). A list of features to develop was created from these consultations and approved by FLNRORD on August 8th, 2018 (Table 2).

Table 2. Features developed and fixed in BiOS app 2.0

2018-2019 BiOS app developments and improvements		
Need	Activity	Description
Original development plan approved August 8th, 2018	Add user registration certification	Add "must fill" requirement of user info at App installation (all 4 fields required). Use App analytics to populate user database
	Add Project type requests	When creating a project: Add field for Off-site or Field survey. + Add to data sent to ArcGis Online (i.e.: project type, company name, etc.)
	BC project synchro only	Synchronization of outputs from app to BioArcGis is only for BC projects. Using block geolocation (real location or manual pick list)
	Update TSA level estimates in AGOL using BiOS App data – concept development	Concept development required before App add-on can be created. FPI planning and support to create this feature is required. Create workflow. How can the data provided from a single cutblock be used to update the planning information at the TSA level + Server application required to update TSA subdivisions
	Parameter updates	Carbon content set at 50% to be consistent with other FLNRORD estimates
		Calorific value set to low heating value
		Default topping diameter (cm) set at 10 cm
	Roadside pile volume estimator	Create catalog in Project wizard + detailed edit. Roadside piles with associated dimensions (to be measured on the ground) and using a list of bulking factors according to pile species mix and biomass type. Add an on-site volume measurement to reporting engine. Biomass flow shows BiOS estimate + on the ground estimation
	Version upgrade to App stores (BiOS App 2.0)	App upgrades available for download
Bug fixes (Cross-platform with unique code base was used)	Nomenclature inconsistances	$/PMH instead of odt/PMH, Save vs SAVE, etc.
	User Interface (UI) design improvements	Improved navigation in project wizard with separate phases for biomass recovery and transport
		Edit button for Truck Configuration does not appear
		Font size harmonization between iOS and Android
		Some values aren't retained in the project wizard environment when editing a machine or truck (i.e.: recovery date). Also dates in the past cannot be selected (this issue is now fixed)
		List of projects doesn't scroll properly to the bottom when longer than page height
		Profile page: Insert in bold "For users located in British Columbia only." before the rest of the current "consent to share data" text.
		Review date & time formats

	User Experience (UX) design improvements	Set pre-piling recovery efficiency to 100%
		Correct biomass flow negative values when roadside recovery efficiency is above 75%
		Include transport distance into trucking cost ($/PMH) shown in detailed edit
		Automatic transport distance didn't work with network connection is some instances. Issue now fixed.
		Updated default chipper/grinder productivities (with and without pre-piling)
		User location (Lat/Long coordinates) didn't register without Wi-Fi. This issue is now fixed for tablets equipped with GPS.
		Improved process time in project wizard. Avoid the app to validate form entries when going back, only validate when going forward
		Project name is not updated in dashboard top bar after rename in site information page
Required improvements asked by users at the October 17 workshop in Mackenzie, BC	Add product distribution	Add option for Decay-waste-breakage % from merch volume. % taken from merch odt estimate shown in biomass flow. Add default recovery efficiency of 95% for this volume
	Change Carbon to CO2eq	In the report, change "Carbon emitted" to "GHG emissions (CO2eq.)" using GHG emissions for Off-road Diesel Tier 4 engines of 2.743 kg CO2 eq/L from the IPCC 5th assessment report (see table below)
	Add Avoided GHG (CO2eq) from utilization (recovery) instead of roadside piling/burning	Cambero et al. 2015 - Table 5 on page 67 shows 1,630 kg CO2eq/ODt for burning forest residues at roadside

The equivalent emission factor for diesel combustion used in the app is based on the fifth assessment report of the Intergovernmental Panel on Climate Change (IPCC) showing a 2.743 kg $CO2_{eq}$/L of diesel for Global Warming Potential (GWP) (IPCC 2014) (Table 3).

Table 3. Equivalent emission factor for diesel combustion

	Mass (kg)/L	GWP factor[a] (kg $CO2_{eq}$)	GWP (kg $CO2_{eq}$/L)
CO2	2.681	1	2.681
CH4	0.000073	28	0.002044
N20	0.000227	265	0.060155
TOTAL			2.743199

[a] Global Warming Potential (GWP) estimates come from the IPCC AR5, WGI, Chapter 8, Table 8.A.1

NEXT STEPS

Biomass validation trials

A series of development activities are required to bring the app from a base tool to a more complete and 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 and is 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. In BC, there have only been two BiOS validation trials (Figure 5). Multiple validation trials are required over the coming years in various stand conditions, harvest treatment types and operating systems for the BiOS app to provide accurate information at the cutblock level. Given the variability of ecosystems in BC, FPInnovations suggests at least one validation trial per forested Biogeoclimatic (or ecological) zone according the Biogeoclimatic Ecosystem Classification (BEC) program (Figure 4). Given that there are 14 recognized forested zones; FPInnovations recommends a total validation dataset of 20 trials with some zones, such as the Coastal Western Hemlock, requiring more than one to capture variance within the zone. These are minimum requirements to consider the BiOS app fully validated for BC conditions. Two trials have been completed in Powell River (2011) and Williams Lake (2011) and a third one is nearly completed in Mackenzie (2019).

This validation plan should be implemented using a mid-term (2019 to 2023) approach to provide flexibility from a field logistics viewpointdue to limitations in where and when these trials can be completed. Snow accumulations and fire seasons control when trials can be conducted in most areas and harvesting operations tend to stay in the same area as long as they can thus limiting the exposure to different ecotypes.

For 2019-2020, FPInnovations proposes to complete three BiOS field validation trials measuring technical biomass recovery efficiency under various sites conditions, treatment types and harvest practices that will help to refine the estimated biomass flow. Included in these trials will be a roadside pile volume assessment detailing pile shape and geometry, along with measurement of pile bulk density on at least 10 logging residue piles.

After the completion of all validation trials in 2023, a full year will be required to update, validate and calibrate the app in 2024.

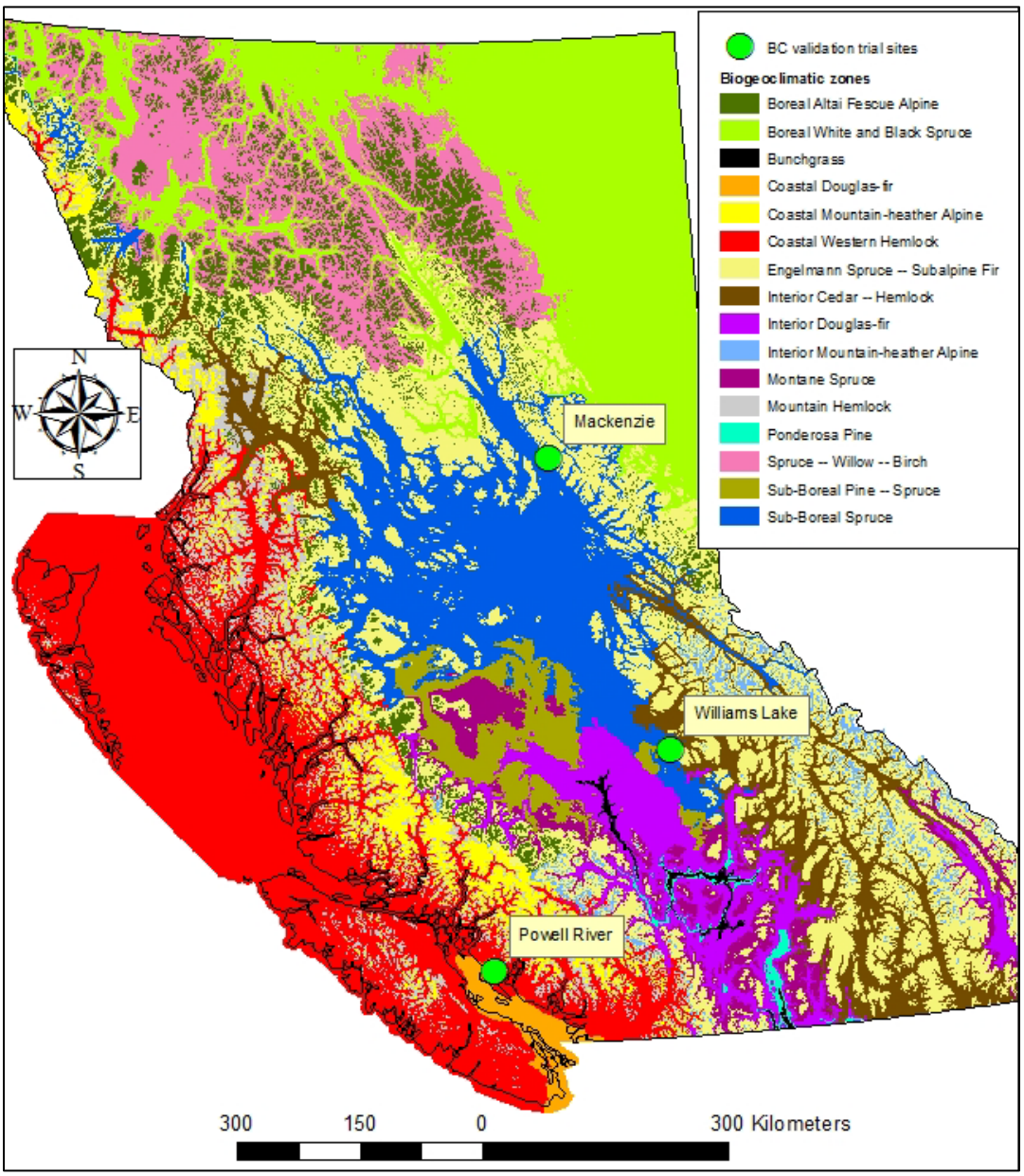

Figure 5. BiOS validation trial sites and Biogeoclimatic zones.

Note: On this map FPI wouldn't perform biomass validation trials for the following 5 poorly treed zones: (1) Boreal Altai Fescue Alpine, (2) Bunchgrass, (3) Coastal Mountain – heather Alpine, (4) Interior Mountain – heather Alpine, and (5) Spruce-Willow-Birch.

FPInterface TSA data and Forest BioGIS integration

Extracting the information from the FPInterface output results (from the 11 TSA FPInterface analyses) and importing them into the interactive map of Forest BioGIS needs to be done. This work should be planned for and executed in the 2019-2020 fiscal year by FAIB, with support from FPInnovations (as required). The ultimate goal is to be able to measure the biomass availability, economic feasibility and carbon footprint of the supply chain for new bioenergy projects in BC. Using the biomass estimates at the pixel level determined by the FPInterface analysis, users of Forest BioGIS will be able to select a location on the map and from a determined supply distance "range" they will get a quick and reliable assessment of the potential for this site to develop the bioeconomy.

I. POTENTIAL SCHEDULE OF TSAS TO COMPLETE IN FPINTERFACE

A total of 22 FPInterface TSA analyses will be required after March 2019. To finalize developing the estimates of available biomass for 20-year harvest rasters, FPInnovations proposes a schedule of 5 to 6 FPInterface TSA analyses per year in for the next four years to cover all BC forests (Table 4). After the completion of the FPInterface analyses for all TSA's in 2023, FPInnovations recommends pursuing these strategic biomass analyses on a continual basis to maintain and update the information available on the FLNRORD biomass portal. As of 2023, the oldest information on the biomass portal will already be dating back to 2009. FPInnovations suggests a maximum spread of 10 to 15-years between analyses for any given TSA. With a total of 36 TSA's, this means an average of 3 to 4 FPInterface TSA analyses each year starting in 2023.

Table 4. FPI biomass supply analysis left to be completed in FPInterface

TSA to complete	Year to be completed	Harvest raster	AAC (m^3)
Okanagan	2019-2020	t.b.d.[a]	3,078,405
Fort St John	2019-2020	t.b.d.	2,115,000
Morice	2019-2020	t.b.d.	1,900,000
Dawson Creek	2019-2020	t.b.d.	1,860,000
Fort Nelson	2019-2020	t.b.d.	1,625,000
Merritt	2019-2020	t.b.d.	1,500,000
North Island	2020-2021	t.b.d.	1,248,100
Sunshine Coast	2020-2021	t.b.d.	1,204,808
Kispiox	2020-2021	t.b.d.	1,087,000
Pacific	2020-2021	t.b.d.	865,700
Nass	2020-2021	t.b.d.	865,000
Cranbrook	2020-2021	t.b.d.	808,000
GBR North	2021-2022	t.b.d.	803,000
Lilooet	2021-2022	t.b.d.	570,000
Invermere	2021-2022	t.b.d.	496,720
Golden	2021-2022	t.b.d.	485,000
Soo	2021-2022	t.b.d.	480,000
Kalum	2022-2023	t.b.d.	424,000
Cascadia	2022-2023	t.b.d.	402,818
Robson Valley	2022-2023	t.b.d.	363,559
Revelstoke	2022-2023	t.b.d.	225,000
Cassiar	2022-2023	t.b.d.	196,000
Total AAC			**22,603,110**

[a] To be determined

Full BiOS app implementation with Forest BioGIS

Open-source data for the bioenergy and bioproducts sector already exist with such products as maps that forecast the availability of logging residues in Canada provided by NRCan (Barette et al. 2018). These maps provide a very coarse biomass estimate at the pixel level (10 km × 10 km) for branches and needles/leaves for two species group (softwood and hardwood). Quebec also recently made public an interactive map of forest inventory data (both recent and historical values) (DIF-MFFP 2019). The developments being put forward by BC are aligned with other jurisdictions that are allowing the general public to have access to large amounts of data freely and openly via easily accessible platforms.

The TSA-level update methodology described in this report will need to be implemented by the geomatics experts at FLNRORD (Forest Analysis and Inventory Branch, Data BC), owner of the Forest BioGIS portal.

An open maps viewer published by FLNRORD through an easily accessible web portal will allow biomass ventures to quickly assess the biomass potential surrounding a particular community, along with the supply cost and carbon footprint.

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APPENDICE 1 – FOREST BIOGIS / BIOS APP TABLES

Table A1. Forest BioGIS data fields to populate using BiOS app

Forest BioGIS data at the BiOS app data point location	
Current BiOS app synchronized data	New list of attributes to show per point location
ProjectName	Surveyor company
RecoveredBiomass_ODT	Surveyor name
BiomassRatio	Type of project (off-site or field)
FuelConsumptionIn_LperODT	Cut block name "Project name"
Recovery_CarbonEmittedInTonnes	Harvest date (roundwood)
Transport_CarbonEmittedInTonnes	Recovery date (residues)
CarbonDeliveredInTonnes	Available biomass (ODT)
CarbonRatio	Recoverable biomass (ODT)
TransportDistance_KM	Mill destination
	Transport distance to mill (KM)
	Fuel consumption (L/ODT)
	GHG emissions for Recovery activities (tonnes CO2eq)
	GHG emissions for Transport activities (tonnes CO2eq)
	Carbon delivered (tonnes)
	Avoided GHG (tonnes CO2eq)
	Carbon Ratio (delivered/emitted)

Table A2. Forest BioGIS harvest raster data fields to update using BiOS app

Forest BioGIS data at the pixel level	
Data attributes	Source
Harvest period	Harvest raster info used in FPInterface analysis
Block ID	Harvest raster info used in FPInterface analysis
Total m^3/ha for each species[a]	Harvest raster info used in FPInterface analysis
Total m^3/ha for all species	Harvest raster info used in FPInterface analysis
Avg. m^3/stem for each species	Harvest raster info used in FPInterface analysis
Harvest system[b]	Harvest raster info used in FPInterface analysis
Cut type (clearcut or partial cut)	Harvest raster info used in FPInterface analysis
% merch harvest removal by species	Harvest raster info used in FPInterface analysis
Shape area (ha)	Harvest raster info used in FPInterface analysis
Available biomass for each species (odt/ha)	FPInterface outputs
Total available biomass (odt/ha)	FPInterface outputs
Recoverable biomass for each species (odt/ha)	FPInterface outputs
Total recoverable biomass (odt/ha)	FPInterface outputs
Harvested roundwood (odt/ha)	FPInterface outputs
Biomass ratio (odt biomass/odt roundwood)	FPInterface outputs
Recovery season	FPInterface outputs
Destination mill	FPInterface outputs

Transportation distance (km)	FPInterface outputs
Recovery cost ($/odt)	FPInterface outputs
Transport cost ($/odt)	FPInterface outputs
Supply cost ($/odt)	FPInterface outputs
Topping diameter (cm) per species	FPInterface outputs
Carbon emissions for Recovery activities (tonnes)	FPInterface outputs
Carbon emissions for Transport activities (tonnes)	FPInterface outputs
Carbon delivered (tonnes)	FPInterface outputs
Carbon Ratio (delivered/emitted)	FPInterface outputs
Total m^3/ha for each species	BiOS app data from "Field" type surveys
Total m^3/ha for all species	BiOS app data from "Field" type surveys
Avg. m^3/stem for each species	BiOS app data from "Field" type surveys
Harvest system	BiOS app data from "Field" type surveys
Cut type (clearcut or partial cut)	BiOS app data from "Field" type surveys
% merch harvest removal by species	BiOS app data from "Field" type surveys
Available biomass for each species (odt/ha)	BiOS app data from "Field" type surveys
Total available biomass (odt/ha)	BiOS app data from "Field" type surveys
Recoverable biomass for each species (odt/ha)	BiOS app data from "Field" type surveys
Total recoverable biomass (odt/ha)	BiOS app data from "Field" type surveys
Harvested roundwood (odt/ha)	BiOS app data from "Field" type surveys
Biomass ratio (odt biomass/odt roundwood)	BiOS app data from "Field" type surveys
Recovery season	BiOS app data from "Field" type surveys
Destination mill	BiOS app data from "Field" type surveys
Transportation distance (km)	BiOS app data from "Field" type surveys
Recovery cost ($/odt)	BiOS app data from "Field" type surveys
Transport cost ($/odt)	BiOS app data from "Field" type surveys
Supply cost ($/odt)	BiOS app data from "Field" type surveys
Topping diameter (cm) per species	BiOS app data from "Field" type surveys
Carbon emissions for Recovery activities (tonnes CO2eq)	BiOS app data from "Field" type surveys
Carbon emissions for Transport activities (tonnes CO2eq)	BiOS app data from "Field" type surveys
Carbon delivered (tonnes)	BiOS app data from "Field" type surveys
Avoided GHG (tonnes CO2eq)	BiOS app data from "Field" type surveys
Carbon Ratio (delivered/emitted)	BiOS app data from "Field" type surveys

[a] Table A3 for complete list of species; [b] Table A4 for complete list of harvest systems

Table A3. List of species (columns to create in attributes table of harvest raster in Forest BioGIS)

Forest BioGIS and BiOS	
Softwood	Hardwood
SW-White spruce	AT-Trembling aspen
SB-Black spruce	DR-Red alder
SE-Engelmann spruce	EP-White birch
SS-Sitka spruce	MB-Bigleaf maple (put as Silver maple in FPInt)
SX-Hybrid spruce	VB-Choke cherry (put as Black cherry in FPInt)

BA-Subalpine fir	CB-Black cottonwood
FD-Douglas fir	
BA-Amabilis fir (put as Pacific silver fir in FPInt)	Other hardwood species to choose from in BiOS list of species, but not common in BC
FG-Grand fir	
FP-Pacific silver fir	
PL-Lodgepole pine	
PW-Western white pine	
PA-Whitebark pine (put as Western white pine in FPInt)	
PJ-Jack pine	
PY-Ponderosa pine	
PS-Shore pine	
YC-Yellow cedar	
CW-Western red cedar	
HW-Western hemlock	
HM-Mountain hemlock	
TW-Western yew (put as Western red cedar in FPInt)	
LW-Western larch	

Table A4. List of available harvest systems in FPInterface and BiOS app

FPInterface and BiOS app	
FPInterface	BiOS App
Full tree	Full tree
Cut-to-length (shortwood)	Harvester-Forwarder
Manual full tree	Manual tree-length
Manual cut-to-length	At-the-stump-processing
Full tree with roadside slashing	Full tree with roadside processing
Manual tree-length	Full tree with roadside chipping
At-the-stump-processing	Full tree with loader-forwarder (hoe chucking)
At-the-stump-delimbing	
Cut-to-length with roadside chipping	
At-the-stump processing with roadside chipping	
Full tree with roadside processing	
Full tree with roadside processing or chipping	
Full tree with delimbing or roadside chipping	
At-the-stump manual delimbing with roadside slashing	
Manual full tree with roadside processing	

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