AWARE

SECOND ANNUAL GENERAL MEETING

PROGRAM

Madawaska Historical Museum, Edmundston, NB

May 16-18th, 2017

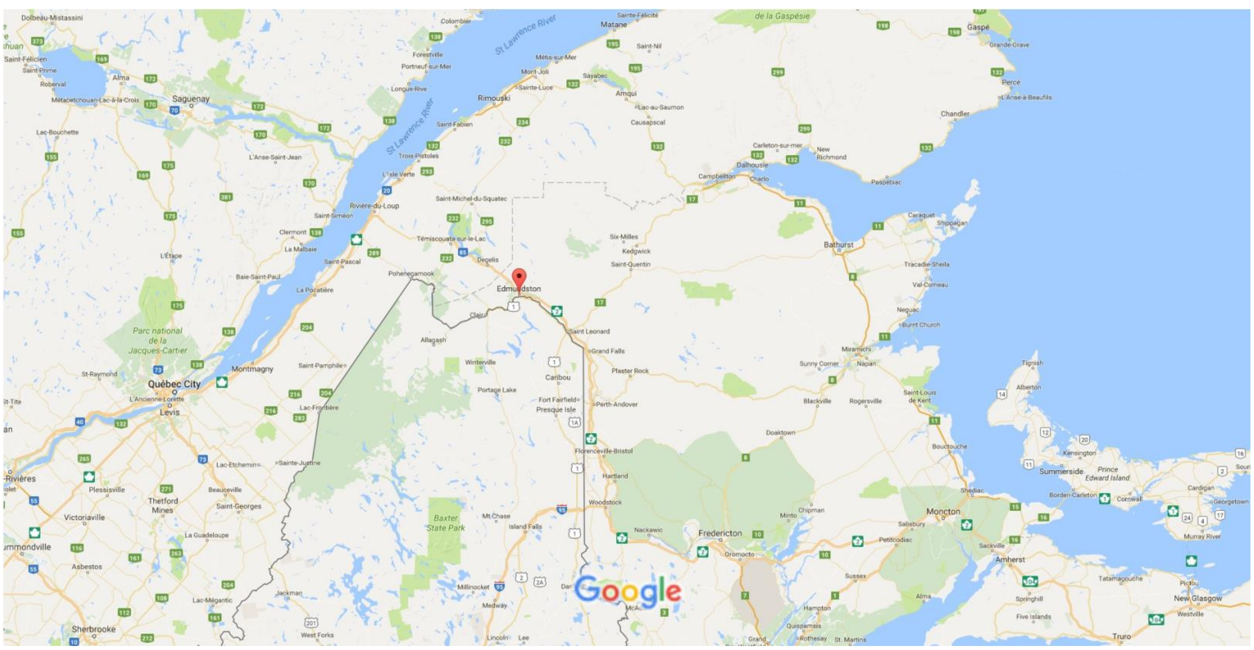
AGM LOCATION

AWARE's 2nd Annual General Meeting will be held at the Historical Museum of Madawaska in Edmundston, New Brunswick.

Address: 195 boulevard Hébert, Edmundston NB, E3V 2S8

GETTING TO EDMUNDSTON

Edmundston is located in Western New Brunswick near the border between Quebec and New Brunswick. Unfortunately, there are no commercial flights to Edmundston. For those travellers who are not within driving distance to Edmundston, the closest airports are Quebec City, Fredericton and Presque-Isle in Maine, USA. Car rental agencies are located at all three airports.



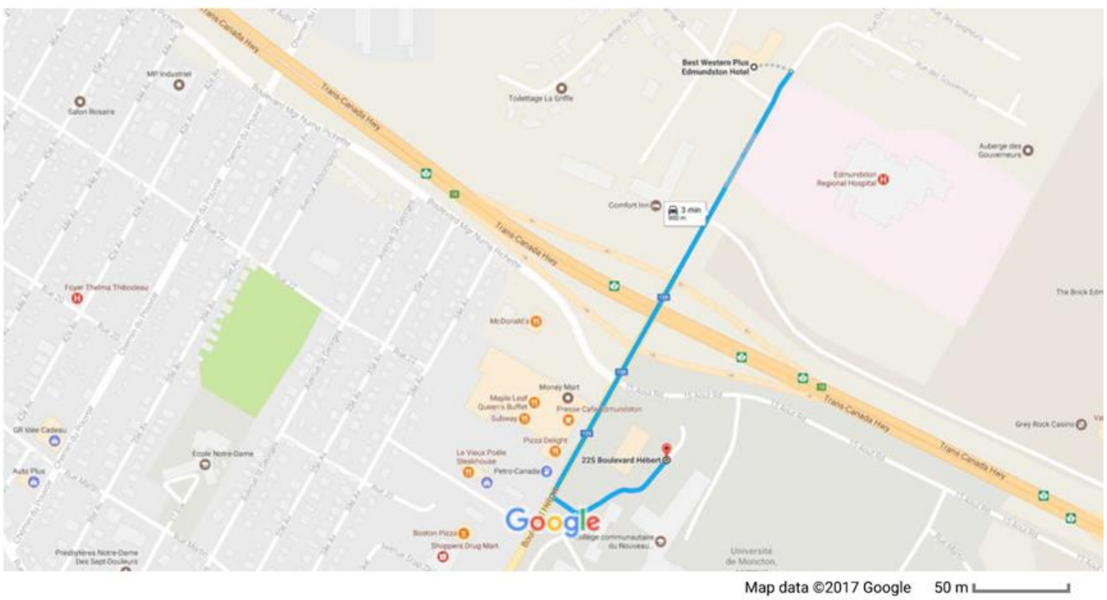
City	Distance to Edmundston	Estimated Driving Time
Quebec City, QC	321 km	3 h 47 min
Fredericton, NB	272 km	2h 39 min
Presque-Isle, ME, USA	101 km	1 h 18 min

ACCOMMODATION

For those making their own travel plans, a block of rooms has been reserved for AWARE participants at the Best Western Edmundston. These rooms are available for $110 and include breakfast. These rooms can be reserved by calling the front desk at 1-888-735-0001 or reserving online.

http://book.bestwestern.com/bestwestern/groupSearch.do?groupId=I52RI9I7

The Best Western is within walking distance of the AGM, approximately 500 m from the Madawaska Historical Museum.



Best Western Plus Edmundston Hotel

280 Boulevard Hébert, Edmundston, NB E3V 0A3

1. Head southwest on Boulevard Hébert toward Rue des Gouverneurs/Rue des Seigneurs — 700 m
2. Turn left — 41 m
3. Turn left — 150 m

225 Boulevard Hébert

Edmundston, NB E3V 2S7

SCHEDULE

<table>
<tr><th>Time</th><th>Tuesday</th><th>Wednesday</th><th colspan="2">Thursday</th></tr>
<tr><td>8:30 AM</td><td rowspan="28">field trip - JDI BlackBrook Forest</td><td>AWARE Overview - Coops</td><td colspan="2" rowspan="2">AWARE Theme II - Q15a, Q17a</td></tr>
<tr><td>9:00 AM</td><td rowspan="2">Sorin Popescu, TAMU</td></tr>
<tr><td>9:20 AM</td><td colspan="2">AWARE Theme III - Q19</td></tr>
<tr><td>9:40 AM</td><td>NB gov -Adam Dick</td><td colspan="2" rowspan="2">AWARE CC Theme - Q21,Q22,Q23</td></tr>
<tr><td>10:00 AM</td><td>NHRI - Gaetan Pelletier</td></tr>
<tr><td>10:20 AM</td><td>break</td><td colspan="2">break</td></tr>
<tr><td>10:40 AM</td><td>JD Irving presentation</td><td colspan="2" rowspan="4">Open Discussion</td></tr>
<tr><td>11:00 AM</td><td rowspan="3">AWARE Core Site Updates</td></tr>
<tr><td>11:20 AM</td></tr>
<tr><td>11:40 AM</td></tr>
<tr><td>12:00 PM</td><td rowspan="3">lunch</td><td colspan="2" rowspan="3">lunch</td></tr>
<tr><td>12:20 PM</td></tr>
<tr><td>12:40 PM</td></tr>
<tr><td>1:00 PM</td><td rowspan="3">AWARE Theme I - Q1,Q2,Q3</td><td rowspan="5">Workshop 1 - Photogrammetric Point Clouds/RLAS and lidr software packages</td><td rowspan="5">Steering Committee Meeting</td></tr>
<tr><td>1:20 PM</td></tr>
<tr><td>1:40 PM</td></tr>
<tr><td>2:00 PM</td><td rowspan="2">AWARE Theme II - Q6,Q7</td></tr>
<tr><td>2:20 PM</td></tr>
<tr><td>2:40 PM</td><td>break</td><td colspan="2">break</td></tr>
<tr><td>3:00 PM</td><td rowspan="3">AWARE Theme II - Q8,Q10,Q11</td><td rowspan="4">Workshop 2 - Introduction to UAVs</td><td rowspan="4">Steering Committee Meeting</td></tr>
<tr><td>3:20 PM</td></tr>
<tr><td>3:40 PM</td></tr>
<tr><td>4:00 PM</td><td rowspan="3">AWARE Theme II - Q12,Q13,Q14</td></tr>
<tr><td>4:20 PM</td><td colspan="2" rowspan="2"></td></tr>
<tr><td>4:40 PM</td></tr>
<tr><td>5:00 PM</td><td rowspan="3"></td><td colspan="2" rowspan="3"></td></tr>
<tr><td>5:20 PM</td></tr>
<tr><td>5:40 PM</td></tr>
<tr><td>6:00 PM</td><td rowspan="3"></td><td rowspan="3"></td><td colspan="2" rowspan="3"></td></tr>
<tr><td>6:20 PM</td></tr>
<tr><td>6:40 PM</td></tr>
<tr><td>7:00 PM</td><td rowspan="3">Student Social Night</td><td rowspan="3">AGM Dinner</td><td colspan="2" rowspan="3">The unofficial straggler's dinner that may or may not happen depending on how much budget is left</td></tr>
<tr><td>7:20 PM</td></tr>
<tr><td>7:40 PM</td></tr>
</table>

TUESDAY, MAY 16th

No technical sessions on Tuesday

Black Brook Forest Field Trip

Location: Black Brook Forest

8:30 AM – 5:30 PM

We will visit JD Irving's Black Brook Forest, approximately 30 minutes away from Edmundston. At the Black Brook forest, we will hear AWARE researchers talk about their research in the context of the sites used to gather data or make predictions.

This field trip is a full day and lunch and snacks will be provided. Attendees should wear appropriate footwear and clothing in case of inclement weather.

Meeting Point will be in the hotel lobby of the Best Western Hotel, Edmundston.

Student Social Night

Location: TBD

7:00 PM – 10:00 PM

WEDNESDAY, MAY 17th

Technical sessions run for the entire day, followed by the AWARE AGM dinner.

Technical Presentations

8:30 AM	Nicholas Coops, UBC. "AWARE Overview"
9:00	Sorin Popescu, TAMU.
9:40	Adam Dick, NB DNR.
10:00	Gaetan Pelletier, NHRI.
10:20	break
10:40	Daniel Arsenault, JD Irving.
11:00	AWARE Core Site Updates
12:00	lunch
1:00 PM	AWARE Theme I talks
2:00	AWARE Theme II talks, Q6, Q7
2:40	break
3:00	AWARE Theme II talks, Q8, Q10, Q11, Q12, Q13, Q14
5:00	finish
7:00	AGM Social Dinner (location TBD)

THURSDAY, MAY 18th

Technical sessions continue until noon. The afternoon session consists of the steering committee meeting and two workshops.

Presentations

Technical Presentations and Proceedings

8:30 AM	AWARE Theme II talks, Q15, Q17
9:10	AWARE Theme III talks, Q19
9:30	AWARE CC talks Q21, Q22, Q24
10:30	break
11:00	Open Discussion
12:00	Lunch

Afternoon Sessions

Steering Committee Meeting (by invitation only)

Location: TBD

1:00 PM – 4:00 PM

Workshop I – Photogrammetric Point Clouds/Introduction to RLAS and lidr

Location: Amphitheatre

1:00 PM – 2:30 PM

Workshop II – Introduction to UAVs

Location: Amphitheatre

3:00 PM – 4:30 PM

7:00 PM The unofficial straggler's dinner that is entirely depend on extra budget

AWARE Technical Presentations

Question 2: Time since Fire as a Driver of Wood Properties in the Boreal Forest

Kaysandra Waldron[1], David Auty[2], and Alexis Achim[1]

[1]Faculté de foresterie, géographie et géomatique, Université Laval, Quebec City, Qc, G1V 0A6, Canada
[2]School of Forestry, Northern Arizona University, Flagstaff, AZ 86011, USA.

Natural disturbance regimes are known to be highly related to structural variability and species composition in forest ecosystems. In the boreal forest of eastern Canada, time since fire is a major driver of stand characteristics such as composition, productivity, structural variability and deadwood proportion. In areas where fire return interval is long, the structural variability of stands is high, which in turn may have an effect on wood properties. Previous studies have shown that there is a difference in wood mechanical properties of black spruce between irregular stands (unaffected by a fire since at least 200 years) and regular stands (regenerated from a fire in the 200 previous years). Our work aimed to evaluate the impact of tree and stand characteristics measurable by LiDAR on black spruce (*Picea mariana*) wood properties, taking into consideration the time since fire. Linear models including ecological and/or geographic explanatory variables were defined a priori and compared to each other using the AICc. The Shannon stand diversity index and time since fire were the best variables for predicting the variation of wood strength and stiffness between sites. These results suggest that aerial LiDAR could provide valuable information on the distribution of wood mechanical properties at a large scale for black spruce.

Question 3: A Comparison of Direct and Indirect Strategies to Map Forest Attributes using Forest Plot Data, ALS Transects, Satellite Images and Spatially Comprehensive Data: Test Case for the Boreal Forest of Newfoundland, Canada

Mélodie Bujold[1], Richard Fournier[1] and Joan Luther[2]

[1] Department of Applied Geomatics, Université de Sherbrooke, 2500 boul. de l'Université, Sherbrooke, QC, J1K 2R1, Canada
[2] Natural Resources Canada, Canadian Forest Service, 26 University Drive, Corner Brook, NL A2H 5G4, Canada

Planning, managing and monitoring forest resources over large areas, in the context of sustainable resource management, requires accurate maps of forest attributes, namely stand composition and structure. However, the acquisition of a sufficient number of field plots for reliable prediction of forest attributes is both costly and time-consuming. These limitations are further amplified for large forest areas. This research project was designed to overcome these constraints by developing an indirect strategy involving two steps and combining forest plots, airborne laser scanner (ALS) transects and spatially comprehensive data layers for mapping forest attributes of conifer forests in Newfoundland, Canada.

In the first step, relationships were modeled between the ALS data and measurements from ground plots. In this step, forest attribute prediction was spatially limited to the area where ALS data were collected. Potential surrogates ALS plots (pixels covered by ALS with total volume predicted in step one) were limited to the forest area and to the range of total volume measured in forest plots of Newfoundland. The Spatially Balanced Local Pivotal sampling method was applied to sample the surrogate plots required in the second step. This method selected samples with a high degree of spatial balance and that were well spread in the auxiliary space. The selection of the auxiliary variables to use with the local pivotal method was based on a theoretical approach. Variables with the strongest relationship to the variable of interest were selected for each type of spatially comprehensive data available (topographic, geographic, climatic, spectral, radar).

In the second step, predictions for the area covered by ALS data were expanded to the spatially comprehensive area. A comparison was performed to determine if prediction accuracies of the indirect strategy were equivalent or better than those of a direct strategy using an empirical relationship between the values measured in forest plots and the more spatially comprehensive data. The performance of both parametric (regression) and non-parametric (random forests) methods were analysed and compared for both the direct and indirect strategies.

Question 4: Prediction of FRI attributes in Different Forest Types in Ontario Using a Core Set of ALS Metrics

van Ewijk, Karin[1], Treitz, Paul[1], Caspersen, John[2], Jones, Trevor[3], Woods, Murray[4], Pitt, Douglas[5]

[1] Department of Geography and Planning, Queen's University, Kingston, Ontario, K7L 3N6, ekyv@queensu.ca; paul.treitz@queensu.ca
[2] Faculty of Forestry, University of Toronto, Toronto, Ontario, M5S 3B3, john.caspersen@utoronto.ca
[3] Forest Research and Monitoring Section, Ontario Ministry of Natural Resources and Forestry, Sault Ste. Marie,Ontario, P6A 3H3, trevor.jones2@ontario.ca
[4] Ontario Ministry of Natural Resources and Forestry, Forest Resource Inventory Unit, North Bay, Ontario, P1A 4L7, murray.woods@ontario.ca
[5] Natural Resources Canada, Canadian Wood Fibre Centre, Canadian Forest Service, Sault Ste. Marie, Ontario, P6A 2E5, doug.pitt@canada.ca

To date, many airborne laser scanning (ALS) metrics have been developed to predict key Forest Resource Inventory (FRI) attributes. With this multitude of ALS metrics, however, two major issues arise: i) strong inter-correlations exist between metrics causing problems for feature selection and model generalization; and ii) a large subset of these metrics can be linked to only a few forest stand characteristics, mainly related to the vertical stand structure [1]. The goal of our research is to identify a core set of ALS metrics that: (i) relate to all aspects of stand structure that 'drive' the FRI attributes; (ii) have stable correlations between metrics and with FRI attributes across different forest types; and (iii) have high predictive power for the estimation of FRI attributes within these types using a non-parametric modeling approach. Our study sites includes two temperate mixedwood forests in central Ontario (i.e., Petawawa Research Forest (PRF) and Haliburton Forest) and one northeastern Ontario boreal mixedwood forest (i.e., Hearst Forest).

To identify a core set of ALS metrics for modeling specific FRI attributes (i.e., basal area (BA), quadratic mean diameter-at-breast height (QMDBH) and stem density (SD)), we analysed a number of commonly used ALS metrics, derived from the height and intensity of ALS returns, and other, less common, metrics derived from the leaf area density profile, and digital terrain and canopy model such as gap fraction and texture indices. We then tested several feature selection methods to determine the optimal combination of ALS metrics for each of the forest types that maximized the predictive model performance of the FRI attributes using the Random Forest algorithm. FRI predictive models, utilizing a full set, a forest specific or 'local' core set, and an across forests or 'regional' core set of ALS metric, were subsequently compared using Repeated Measure ANOVA and Equivalence tests[2].

Our initial Principal Component Analysis (PCA) results indicated that the three forest types consistently identify similar ALS metric groupings in ordination space, which could be characterized as a structural, intensity, and combined leaf area density, texture and terrain metrics group. Initial analyses of ALS metrics and FRI attributes also indicated consistent correlations between ALS metric groups and FRI attributes and the usefulness of some of the less common ALS metrics. For all three FRI attributes and across the forest types, our validation models that included 'local' subsets of ALS metrics performed best in terms of Root Mean Square Error (RMSE) and bias, except for the BA and SD estimations in the PRF, where the full set of ALS metrics yielded the best predictive results. However, no significant differences between predictive models with full, local core, and regional core sets of ALS metrics were observed. The regional core sets of ALS metrics for the three FRI attributes mainly included ALS metrics from the structural and intensity group but also one texture and LAD metric.

References:

[1] Bouvier, M. *et al.* (2015). *Remote Sensing of Environment*, 156, 322-334.

[2] Robinson, A.P. *et al.* (2005). *Tree Physiology*, 25, 903-913.

Question 6: Imputing Tree Lists for New Brunswick Spruce Plantations through Nearest-neighbour Matching of Airborne Laser Scan and Inventory Plot Data

Sean M. Lamb[1], David A. MacLean[1], Chris R. Hennigar[1], Douglas G. Pitt[2]

[1]University of New Brunswick, Faculty of Forestry and Environmental Management, P.O. Box 4400, Fredericton, NB, E3B 5A3, Canada.
[2]Canadian Wood Fibre Centre, Canadian Forest Service, 1219 Queen St. E., Sault Ste. Marie, ON, P6A 2E5, Canada.

Light detection and ranging (LiDAR) has greatly improved spatial resolution and accuracy of operational forest inventories, but it shares the problem with all inventory methods of being a single-point-in-time estimate. We evaluated a method that seeks the nearest-neighbor matches of stand structural variables estimated from LiDAR to those in a library of sample plots (over 5500 plot measurements) to impute tree lists for LiDAR grid cells across 83 000 ha of spruce (Picea sp.) plantations in New Brunswick, Canada. Matches were determined based on planted species and minimum sum of squared difference between six inventory variables. Forest inventory variables obtained by the plot matches were highly correlated ($r = 0.91–0.99$) with those measured on 98 plots used to validate the method. Basal area distributions derived from plot matching were statistically equivalent to those observed on the validation plots 86% of the time ($\alpha = 0.05$). When we aggregated the predictions for all validation plots, there was no difference between predicted and actual basal area distributions by planted species and species compositions were similar. Plot matching is a valid method to impute tree lists for LiDAR cells that combines the wealth of existing plot data with high resolution LiDAR-derived variables.

Question 7: Improving LiDAR-derived Estimates for Describing Stem Size Distribution

Christopher Mulverhill and Nicholas Coops

Integrated Remote Sensing Studio, Faculty of Forestry, University of British Columbia, 2424 Main Mall, Vancouver, BC., V6T 1Z4
chris_mulverhill@yahoo.com

Operational forest inventories inform harvesting strategies by featuring measurements and models relating to timber dimensions and composition. These inventories provide information such as a Stem Size Distribution (SSD), which is a frequency distribution of tree diameters in a stand. The SSD can be used directly to describe stand attributes such as structure and age, or indirectly as inputs to models that can describe timber quality or forecast growth. In order to survey large areas of land quickly and effectively, forest managers are turning to remote sensing technologies such as airborne Light Detection and Ranging (lidar). My research uses lidar metrics of vertical forest structure in a boreal mixedwood system to parameterize and implement model functions characterizing the SSD of forest stands. In addition to comparing different probability functions (PDFs) for describing the shape of a SSD, I also explore different ways of parameterizing the functions. Although Maximum Likelihood Estimation (MLE) is currently the most popular way of deriving empirical parameters, I also use a recursive approach that minimizes the overall difference between a PDF and the observed frequencies of diameters. Preliminary results indicate that SSD estimates can be improved when the recursive approach is used with the inclusion of additional ecological predictors. We found SSD estimates most accurately fit the empirical distribution when plots were initially stratified by categorical variables such as dominant species before estimating the SSD function parameters using a combination of lidar metrics and other ecological variables. By improving the process for parameterizing and implementing models for these distributions, we can provide a more accurate means of describing forest structure, which will then contribute to more informed decision-making by forest managers and timber companies in regards to managing forests to maximize both their economic and ecological values.

Question 8: How does Scan Angle Affect Metrics Derived from an ALS Point Cloud in a Turbid Medium?

Jean-Romain Roussel[1], Martin Béland[1], John Caspersen[2], Alexis Achim[1]

[1] Faculté de foresterie, géographie et géomatique, Université Laval, Quebec City, Qc, G1V 0A6, Canada
[2] Faculty of Forestry, University of Toronto, Toronto, Ontario, M5S 3B3

The area based approach is a method used to map the forest resource over large areas using ALS data. It consists of deriving metrics from the point cloud distribution into contiguous pixels. However, points are not evenly sampled over the studied area. In particular, pulse density can vary locally and scan angle varies with the oscillating mirror. Several studies were dedicated to empirically regress the scan angle effects, which led to inconsistent results. We developed a theoretical and physical model that explains and quantifies such effects for a relatively dense deciduous forest canopy. Applying our model to real data gave a very good fit between the reality and the theory.

Question 10: Modeling Site Productivity through LiDAR-derived Terrain Indices and High Resolution Soil Attribute Mapping

Shane Furze and Paul A. Arp

Forest Watershed Research Centre, Faculty of Forestry and Environmental Management
University of New Brunswick, P.O. Box 44555, Fredericton, NB E3B 6C2.
Furze.shane@gmail.com

This project focuses on improving forest plantation growth predictions based on digital terrain and soil modelling. In this, soil properties are considered to change continuously as affected by increasing ridge-to-valley soil moisture content and by landform type and position. Currently, soil information is spatially represented by tessellated boundaries, omitting the spatial variations of the growth-affecting soil attributes. It is hypothesized that some of this variation can be captured through application of high-resolution LiDAR-derived digital elevation models which applies already-developed topographic and hydrological algorithms, including the cartographic depth-to-water index. These protocols must be adjusted to differentiate the influences that specific landforms pose on soil attributes and drainage classes. Unique spatial disaggregation techniques are being formulated to covert soil and geomorphologic boundaries into continuums to better understand soil attribute variation. The goal of this research is development of predictive models for plantation height growth over age by updated soil, topographic, landform position, and hydrological regimes with plantation species referring to white, black, red, and Norway Spruce.

Q11: How can Semi-Global Matching (SGM) Techniques Be Used, When Paired with Existing LiDAR Terrain Models, to Predict Forest Stand Growth?

Tristan Goodbody and Nicholas Coops

Integrated Remote Sensing Studio, Faculty of Forestry, University of British Columbia, 2424 Main Mall, Vancouver, BC., V6T 1Z4

The underlying motivation for this research is to assess how stand structure, species, and regeneration impact the derivation of accurate forest inventory information using digital aerial photogrammetry techniques across a range of platforms and data models. To assess the capacity of the technology, forests of differing stand structures will be examined to determine how and to what extent characteristics such as height, canopy cover, density, and species can be accurately derived from Digital Aerial Photogrammetry (DAP) under specific image capture and data model circumstances. By examining how stand structure can influence the accuracy and applicability of DAP, forest managers can better understand the conditions where the technology can be useful for inventory purposes, as well as where and when the technology will be limited.

The focus of this project is to use aerial imagery collected over the Gordon Cosens Forest in Ontario to produce DAP point clouds and assess the potential for the technology to differentiate and detail areas affected and unaffected by Spruce Budworm (*Choristoneura fumiferana)* both spectrally, and structurally. DAP structural metrics paired with field sample data will facilitate the estimation of forest inventory parameters such as height, volume, and basal area. The production of predictive forest inventory models is an important step to improving local and landscape level forest management knowledge, and the assessment of DAP point clouds to generate these data is necessary to understand the current successes and limitations of the technology.

This presentation will first touch on results achieved in multiple British Columbia sites where DAP point clouds were used to detail regeneration status. The presentation will then transition into the first AWARE site in this project, The Gordon Cosens Forest, and cover the procedures used to generate and spectrally and structurally stratify DAP point clouds for locating representative field measurement sites.

Question 12: Multi-sensor measurement of forest growth over near-decadal periods in Slave Lake, Alberta.

Joseph Rakofsky, Nicholas C. Coops, Piotr Tompalski, Joanne C. White, Peter L. Marshall

Integrated Remote Sensing Studio, Faculty of Forestry, University of British Columbia, 2424 Main Mall, Vancouver, BC., V6T 1Z4

The development of 3-D point clouds to measure forest structural variables has shown marked promise as a cost-effective and spatially extensive means of supplementing current inventory methods. One mode of application could be to invest in a single acquisition of site-wide light detection and ranging (LiDAR) data to develop an accurate digital terrain model (DTM) with subsequent assessments using digital aerial photogrammetry (DAP), though past research has almost exclusively utilized single sensors, and assessed relatively short growth periods. The objective of this research is to investigate how 3-D remote sensing can be used to measure forest growth in a managed mixedwood boreal forest near Slave Lake in central Alberta. Two different sensors are utilized: LiDAR and DAP, and the data was acquired from 7 to 9 years apart. Two approaches exist to measure forest growth with remotely sensed data: direct and indirect methods. The direct method estimates growth using differences between point-cloud metrics at the initial and final time steps while the indirect method uses differences between estimates of the variable in question. Field data and corresponding remote sensing data was obtained for 31 plots. LiDAR data for the start of the growth period was obtained between 2006 and 2008, while DAP data for the end was from 2015. Preliminary stepwise regression model results for Lorey's mean height, basal area and total volume using the indirect approach will be presented. These results will be incorporated into a comparison of the 2 growth modeling methods.

Question 15a: Quantification of Spruce Budworm Defoliation using Hemispherical Imagery and Hyperion Hyperspectral Satellite Data

Shawn Donovan[1] and Dr. David A. MacLean[2]

[1] MScF student; [2] Professor;
Faculty of Forestry and Environmental Management, University of New Brunswick,
P.O. Box 4400, Fredericton, NB, E3B 5A3, Canada

A significant forest health issue in eastern Canada is the damage caused by periodic eastern spruce budworm (*Choristoneura fumiferana* Clem.) (SBW) outbreaks, which covered 52 million hectares at the peak of the last outbreak in 1975. SBW larvae reach extreme population levels and repeatedly consume the current-year foliage of spruce and balsam fir trees, resulting in tree growth reduction and mortality averaging 85% in mature fir stands. The current SBW outbreak has reached 7 million hectares of defoliation in Quebec in 2016 based on aerial surveys, and populations are low but increasing in neighbouring New Brunswick. A large $18 million project to develop and test early intervention strategies against SBW is underway and is testing several remote sensing platforms to assess SBW defoliation, including airborne hyperspectral (CASI and SASI) sensors, EO-1 Hyperion satellite, and Digital Globe WorldView3 satellite. This project will complement those efforts.

Most studies of SBW effects quantify defoliation as a percentage of current-year foliage removed. However, resulting effects on tree growth or survival are actually a function of the foliage remaining on a tree, not foliage that is removed. Therefore, the first objective of this project is to use hemispherical canopy images within plots with detailed repeated defoliation measurements to estimate changes in Leaf Area Index (LAI) caused by SBW defoliation. The EO-1 Hyperion satellite has shown promising results in predicting SBW defoliation validated with coarse-scale aerial survey defoliation data (Huang, 2015, MScE thesis at UNB). The second objective of this project, therefore, will test the use of Hyperion hyperspectral data to estimate SBW defoliation, using the Huang (2015) methods but a much more accurate data set of defoliation measured on over 8000 trees, >1500 branches, and 75 plots in 2014 to 2016.

Question 17A : A Multi-indicator Framework for Mapping the Potential Impacts of Forest Management Activities on Aquatic Ecosystem Services

Aurélie Schmidt[1*], Richard A. Fournier[2] and Joan E. Luther[3]

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2. *Département de géomatique appliquée, Université de Sherbrooke, 2500 boul. de l'Université, Sherbrooke, QC, J1K 2R1, CANADA, 819-821-8000 ext. 63209, Richard.Fournier@USherbrooke.ca*
3. *Natural Resources Canada, Canadian Forest Service - Atlantic Forestry Centre, 26 University Drive, Corner Brook, A2H 5G5, Canada, 709-637-4917, JoanE.Luther@Canada.ca*

Forest ecosystems provide services for human well-being, such as climate regulation, water regulation, clean water provision, and soil conservation. The Millennium Ecosystem Assessment (2005) highlighted the importance of integrating Ecosystem Services (ESs) into decision-making processes. Since then, ESs have gained wide attention. Aquatic Ecosystem Services (AESs) are amongst the most important to consider when making land management decisions to sustain quality of life. Therefore, in a forestry context, it is important to assess how forest management activities affect AESs. A key requirement for mapping AESs is to find proxies that quantify the impacts of forest activities on AESs. Developing a spatially-explicit mapping method that takes into account the ecological processes inherent in AESs is particularly challenging.

In this project, we developed a multi-indicator framework for quantifying, mapping and evaluating potential impacts of planned forest management activities, especially harvesting, on three critical AESs: (1) clean water provision, (2) flood control, and (3) recreational fishing. The research was conducted in a forest-dominated landscape of western Newfoundland where there is a requirement to integrate forest and water management in order to maintain environmental quality. AESs maps derived using the multi-indicator framework show the potential supply of current clean water provision service as well as potential following planned forest activities. The multi-indicator framework offers an interesting alternative, which is less complex than hydrologic physical models and less subjective than expert opinions. Thus, the multi-indicator framework can be used to help forest managers to plan, manage and monitor forest resources to ensure the sustainable supply of AESs.

Question 19: The Use of Terrestrial LiDAR for Enhanced Forest Inventory

Abdoulnaime Safia and Richard Fournier

Department of Applied Geomatics, Université de Sherbrooke, 2500 boul. de l'Université, Sherbrooke, QC, J1K 2R1,Canada.

During the last decade terrestrial LiDAR (TLidar) is an emerging technology that has high potential for forestry applications. It provides a detailed three-dimensional (3D) point cloud representation at individual-tree and stand-level forest structures from which a wide range of attributes can be extracted. Consequently TLidar offers the opportunity to expand on the estimation of new attributes beyond what is measured using classic field work of forest inventory. The presentation will describe three sets of algorithms involving the use of TLiDAR for forest inventory. The first set of algorithms provide information on a forest plot that can routinely be extracted from TLiDAR from existing algorithms, including stem diameter at breast height, tree height, a map of tree position, digital terrain model and canopy height model. The second set of new algorithms are those currently being developed at the Université de Sherbrooke and that are being validated prior to being placed into an operational context. These algorithms are designed to process the TLiDAR point cloud to estimate automatically the stem taper of all trees in a plot, to isolate automatically tree crown, to support spatial analysis of tree growth/competitionand to quantify tree branchiness for wood quality assessment. The third set of algorithm relates to explicit 3D representation of tree component. More specifically, it deals with several limitations that are intrinsic to TLiDAR acquisition system. This includes signal occlusion, over- and under sampling and noise. The proposed procedure, called L-Vox, uses a voxel representation of the point cloud. Spatial distribution of canopy components are described through a new structural index called the Relative Density Index (RDI). The use of the RDI will applied to the assessment of budworm damage.

Question 21: Identifying Individual Tree Species at Petawawa Research Forest Using Airborne Multispectral liDAR

Jean-François Prieur[b], Rachel Perron[a], Benoît St-Onge[a], Richard Fournier[b], Murray Woods[c], Brindusa Cristina Budei[a], Paul Treitz[d]

[a] Département de Géographie, Université du Québec à Montréal

[b] Département de Géomatique Appliquée, Université de Sherbrooke

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Petawawa Research Forest (PRF), situated 200 km west of Ottawa near Chalk River, Ontario, is the oldest continuously operated research forest in Canada. It is a mixed mature forest that covers 10,000 ha and is representative of the Great Lakes-St. Lawrence forest region. Among the species found at this site, we sought to automatically identify 10 broadleaved and 8 needleleaved species. Our specific goal is to develop a robust individual tree species identification method applicable across different forest types and tree sizes. For this, we will be using ALS point clouds and multispectral data, obtained from concomitant imagery, or coming directly from multispectral lidar. Such data was acquired by Teledyne Optech's Titan multispectral lidar system flown over the PRF in July 2016.

With multispectral lidar, more classification features can be derived. In addition to the usual 3D metrics, or single channel intensities, 3-channel spectral signatures or NDVI-like features can be created. This increases our ability to identify features that have a low sensitivity to variations caused by tree age or site characteristics. 3D features are designed to capture variations in tree proportions (e.g. crown area to height ratio), shape (e.g. slope of the crown profile) or porosity (e.g. height difference between 1st and 2nd returns). Intensity features are designed to capture intensity characteristics for the overall crown (e.g. mean intensity), along a vertical gradient (e.g. intensity difference between 1st and 2nd returns) or along a radial gradient (mean intensity by concentric ring). Furthermore, normalized differences between the different channels' intensities serve to generate NDVI-like features that are known to be very effective in optical image analysis. One of our research hypotheses is that the additional information content of multispectral data is more effective (as compared to 'standard' 1064 nm lidar) as the number of species to classify increases. We also anticipate that the intensity-based features will be less sensitive than 3D features to changes in tree size among a given species.

Training of the species classification model is based on approximately 1500 individual tree crowns that have been delineated (with SEGMA software) and their species identified during previous field work at the PRF. We have trained a few different models (random forest, SVM, k-NN, CN2, Naïve Bayes, etc.) to identify species. For each type of classifier, a general model (all species and all sizes), and height stratified models (all species per height stratum) were trained. We demonstrate that lidar multispectral signatures are generally more useful (contribute strongly to the overall classification accuracy), and are more robust to changes in tree size, compared to the 3D features.

Question 22: Identifying Individual Tree Species in Planted and Natural Stands at Black Brook Forest Using Airborne liDAR

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The Black Brook forest in New Brunswick covers more than 2000 km^2. It is comprised of planted and natural stands managed by JD Irving. Airborne lidar and Ultracam images were acquired over the entire area in 2012. Our goal was to use this data to identify the species of every detectable tree. Species was classified at three different levels: coniferous vs. deciduous (C/D), genus (8 classes), and species (11 classes) based on the lidar data. Additionally, we wanted to detect balsam fir regeneration within spruce plantations. Using more than 1500 calibration crowns, we have trained a balanced random forest for each classification level, and applied it to all crowns (approx. 145 000 000 crowns). The accuracy was evaluated for each level, based on the training crowns. The random forest accuracies (1.0 - OOB error) for the C/D, genus, and species level were respectively 93%, 58%, and 49%. The confusion matrix reveals that in many cases, when a tree is not well classified, it is attributed to a species that is similar in terms of sylvicultural treatment and use. In the case of fir/spruce discrimination, the accuracy in the training set was 77%. The species predictions at each level are written to separate fields of the attribute table of the crown shapefiles. The stand map of Black Brook forest can then be used to decide which field to use for any given tree. For example, within a spruce plantation stand polygon, the fir/spruce prediction will be employed. Finally, additional remote sensing data (airborne imagery), and ancillary data (wetness, site quality) are being analysed to improve the species predictions.

Question 24: Assessing the Capacity of UAV-based LiDAR to Support Operational-level Forest Inventory in Different Forest Environments

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Forest inventories have been designed to provide the essential data used for long-term strategic management planning and decision making. Recently, Enhanced Forest Inventories derived from Airborne Laser Scanning or stereo Image Point Clouds have been extensively used to produce area-based estimates of growing stock (basal area, volume) and average tree size (diameter, height, volume). Although this development enables precision forest management on large scale and represents a prerequisite for the sustainable use of wood resources, there is a growing interest in adding information on wood attributes at the tree level for supporting Operational-level Forest Inventory (OFI). With increased LiDAR accessibility and advancement in small-scale technologies over the last few years, it is now possible to support a light weight LiDAR instrument (UAVL) on Unmanned Aerial Vehicles (UAVs). The operational flexibility, high spatial and temporal resolution of UAVs combined with the LiDAR signal's capacity to break through forest canopy makes this technology promising tool for characterization of forest structure at a finer scale. This project aims to investigate how UAVL can be used to identify and estimate a core set of tree structural attributes that can support OFI (i.e. individual tree delineation, stem diameter distribution, volume) conducive to different forest ecosystems. Specifically, we consider test sites in the boreal deciduous forest (northwestern New-Brunswick), in the boreal coniferous forest (western Newfoundland), and in the tropical evergreen forest (Democratic Republic of Congo). Structural attributes will be derived from high density point clouds and correlated with field measurement to estimate the potential use of this technology for forest management.