Operational Implementation of LiDAR Inventories in Boreal Ontario

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Southern Science & Information
OMNR – North Bay
Advanced Forest Resource Inventory Technologies
Outline

- Ontario’s Enhanced Inventory Program
- LiDAR Derived Inventory Primer
- Current LiDAR Inventory Success Stories
- Operational Economics
- Ongoing Enhancements
- Emerging Technologies
Ontario’s Enhanced Inventory Program

- Move to a 10-year cycle
- Evolve from a periodic inventory to a continuous inventory update
- Inventory will be ecologically based
- Move to a higher quality information through the implementation of new technologies
- Enhancement of the “field” component

Credit: Ontario’s eFRI Program
Ontario’s Enhanced Inventory Program – Digital Imagery

- **FRI specifications of:**
  - 35 cm resolution for RGB and colour infrared
  - 20 cm resolution panchromatic
- **Level 1, stereo imagery**
  - Continuous strip of imagery viewed in a softcopy environment for interpretation in FRI
- **Level 2, orthophoto**
  - 5x5km tiles photos with uniform scale
- **Digital Surface Model (DSM), an elevational map of the tops of vegetation on the landbase**
- **Leica ADS40/80 Push-Broom Sensor**

Credit: Ontario’s eFRI Program
Ontario’s Enhanced Inventory Program – New Attributes

- Source of information
- Management consideration
- Horizontal structure
- Incidental species
- Vertical structure
- Stage of development
- Depletion type
- Depletion year
- Access
- Crown Closure and Stocking

- Opportunity for SFL holders to acquire additional Remote Sensing information

Credit: Ontario’s eFRI Program
● "Active" remote sensing technology; transmit & receive ~35,000-500,000 pulses of NIR laser light per second

● Discrete System - Each pulse can produce multiple returns (up to 4)

● GPS provides the exact X-Y-Z position of each return
Study Sites – Northeastern Ontario ~ 2M ha

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<th>Romeo Malette</th>
<th>Hearst</th>
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<td>1,000 m</td>
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<td>&lt; 50 cm</td>
<td>&lt; 30 cm</td>
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<tr>
<td><strong>Pulse density</strong></td>
<td>~0.5 /m²</td>
<td>~1.0 /m²</td>
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Field Sampling vs. 100% Enumeration

- 100% enumeration of the landbase with LiDAR measurements of vertical structure
- permits the use of regression estimators to scale predicts from Prediction Units to: groups, stands, forest
LiDAR offers more than a DTM

Additional forest inventory information contained in point cloud data

Focus of AFRIT is “Area” based modeling NOT “Individual Tree”

Prediction Unit = 20m X 20m (400m²)
LiDAR Derived Inventory – Pairing with Ground Data

Field Plot Measurement
LiDAR Derived Inventory

LiDAR predictive Models for:

- Height (AVG, Top)
- QMDBH
- Volume (GTV, GMV)
- Basal area
- Biomass
- Density*
- Sawlog Volume
- Close Utilization Volume
- Dom/Codom Ht
- Mean Tree GMV
- Size Class Distributions

* Derived from DBHq & BA
LiDAR Derived Inventory – 400m² Surfaces

Top Height

Average Height

Basal Area

QMDBH

Gross Total Volume

Gross Merchantable Volume

Biomass

Density

$TOPHT = 17.2 \pm 0.2 \text{ m}$

$AVGHT = 12.8 \pm 0.3 \text{ m}$

$SUMBA = 20.2 \pm 1.0 \text{ m}^2 \text{ ha}^{-1}$

$QMDBH = 14.8 \pm 0.3 \text{ cm}$

$SUMGTV = 144.3 \pm 8.1 \text{ m}^3 \text{ ha}^{-1}$

$SUMGMV = 102.1 \pm 6.3 \text{ m}^3 \text{ ha}^{-1}$

$BIOMASS = 85087.3 \pm 4374.0 \text{ Kg ha}^{-1}$

$DENSITY^{1} = 1187 \text{ stems ha}^{-1}$

$^{1}$ Density was calculated from Basal Area and QMDBH and confidence intervals were not calculated.
LiDAR Information can add more value to our rich image and inventory interpretation.
Enhanced Modeling Approaches

Regression

\[ y = b_0 + b_1 x_1 + b_2 x_2 \]

\[ y_1 = b_0 + b_1 x_1 + b_2 x_2 \]
\[ y_2 = b_0 + b_1 x_1 + b_2 x_3 \]
\[ \vdots \]
\[ y_p = b_0 + b_1 x_2 + b_2 x_3 \]

\[ y = e^{b_0} \cdot x_1^{b_1} \cdot x_2^{b_2} \cdot \ldots \cdot x_5^{b_5} \]
Enhanced Modeling Approaches

Regression

\[ y = b_0 + b_1 x_1 + b_2 x_2 \]

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\[ y = e^{b_0} \cdot x_1^{b_1} \cdot x_2^{b_2} \cdots x_5^{b_5} \]

RandomForest

Option for hundreds to thousands of trees
SUR vs. RandomForest - Predicted vs. Observed

SUR Regression Model

RandomForest
LiDAR Derived Inventory – Size-Class Distributions

Density and Volume by 2cm Diameter Classes

Black Spruce Validation Data – Aggregated by VCI class
LiDAR Derived Inventory – Size-Class Distributions

Density and Volume by 2cm Diameter Classes

Mixedwood Validation Data – Aggregated by VCI class
Improving planning decisions by using Enhanced Forest Inventory (EFI)

Sébastien Lacroix, FPInnovations
Murray Woods, OMNR
Chad St-Amand, Tembec
Lino Morandin, Tembec
Pierre Bédard, FPInnovations
Joseph Nader, FPInnovations
Doug Pitt, CWFC

4/2/2012   www.fpinnovations.ca
Objectives

- Are LiDAR-enhanced inventories leading to *better* forest management decisions?
- What are the cost savings associated with enhanced decision making?
Approach – Volume Comparison

- LiDAR provides better volume prediction (statistically tested)
  - Yield Curve: 14.5%
  - LIDAR: 5.4%

### Difference from harvested volume (scaled)

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10 % & under

greater than 10 %
Comparison of 2 scenarios

1. **Actual cut over – ACTUAL**
   - Area harvested within approved plan

2. **Redesign blocks within proposed plan – LIDAR**
   - New harvest planning using LiDAR for area similar to initial plan
   - Validated by Tembec FRM
   - Stay within approved 5 year harvest blocks
Approach – Cost Analysis: Scenarios

Actual harvested area, obtained using digital imagery - **ACTUAL**

![Map of Actual Harvest and DBHq](image-url)
Approach – Cost Analysis: Scenarios

Redesign plan, based on full suite of LiDAR data products – LIDAR

* As a result – less roads need to be constructed and maintained $$$
# Results: Actual vs. LiDAR Scenario

Three groups of cost items:

A. **Inventory acquisition and processing** - 6 items $ - 0.10 m$^3$

B. **Forest operations** – 20 items $1.40 m$^3$

C. **Mill** - 4 items $0.30 m$^3$

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|        |                | Savings $1.60 m$^3$

\[ X \ 500,000 \ m^3 / \text{year} = \$800,000 / \text{year} \]

**Payback = 1.3 years**
Ongoing Enhancements

- ITC – Individual Tree Classification
Ongoing Enhancements

• Site Productivity - Predicted Texture

Clement Akumu, John Johnson, Peter Uhlig, Sean McMurray, Dave Etheridge

Environmental input variables:
• Elevation (10m)
• Slope (%)
• Surface shape (Curvature)
• Mode of deposition (NOEGTS)
• Landcover
• Slope Position from TPI
  • (macro window = 1km)
  • (medium window = 500m)
  • (micro window = 20m)
• Wetness Index
Ongoing Enhancements

- Site Productivity - Wet Areas Mapping
  Paul Arp, Jae Ogilvie - UNB
Ongoing Enhancements

• Fibre Analysis – Jeff Dech, Bharat Pokharel, Megan Smith, Art Groot

Comparative analysis of wood fibre attributes and transition years among four contrasting ecosite groups
Ongoing Enhancements

- LiDAR Species Classification...from Low Density LiDAR

$n = 346$ plots; 86 used for validation:

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<tr>
<td>CON</td>
<td>4</td>
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<td>96</td>
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Actual %

Prediction for each 400m²
Emerging Technologies

• Rapid Technology Evolution
  – Discrete LiDAR ➔ Full Waveform ➔ Image Pixel Correlation

Area-Based ➔ Individual Tree (crown attributes – tree quality – fibre properties)

Petawawa Research Forest Plot nPW12

LiDAR 2005

LiDAR 2012

SGM 2009
Future Opportunities

- LiDAR Species Classification…from High Density LiDAR

Error matrix of classification

Baoxin Hu
Dept. of Earth and Space Science and Engineering
York University, Toronto, Canada
LiDAR has the ability to complement eFRI information
- add spatial resolution of metrics - additional values

Opportunity to develop scalable inventory information to ensure:
- forest sustainability
- spatial habitat modeling, product quality, etc.
- linkage between strategic & operational planning
- maximizing value – “right wood to the right mill at the cheapest cost”

Software tools are available and expanding

Economics of acquiring LiDAR datasets are being realized by industry and Gov’t

Existing and Emerging technologies offer exciting future opportunities
Thank you - Questions?


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