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# Student Symposium 2007

# Centre for Earth and Environmental Technologies

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Queen's University

# Application of Airborne and Ground-based Lidar Data for Forest Inventory Monitoring

Feb 8, 2007

Valerie Thomas, Postdoctoral Fellow
Laboratory for Remote Sensing of Earth and Environmental Systems (LARSEES)

Project Leader: Dr. Paul Treitz

## Partners/Collaborators:

Tembec Inc.
Forestry Research Partnership (FRP)
Ontario Ministry of Natural Resources (OMNR)
M7 Visual Intelligence (M7 VI)

## Others who have contributed:

Fluxnet-Canada
NSERC/BIOCAP
Premier's Research Excellence Awards Program (PREA)
Canadian Foundation for Climate and Atmospheric Sciences
Ontario Graduate Scholarship Program (OGS)
Queen's University

# Partners and Collaborators



**Project Leader: Paul Treitz (Queen's University)**

**HQP:**
- **Valerie Thomas (PDF) (Queen's)**
- **Laura Chasmer (PhD) (Queen's)**
- **Neal Pilger (PhD) (Queen's)**

**Other Research Participants:**
- **J. Harry McCaughey (Queen's)**
- **Benoit St. Onge (UQAM)**

**Industry and Government Partners:**
- **Ken Durst (Tembec Inc., FRP)**
- **John Pineau (Canadian Institute of Forestry)**
- **Al Stinson (Tembec, FRP)**
- **Murray Woods (OMNR)**
- **Paul Corville (FRP)**

# Original Project Goals

The objectives of this work are to:

1. develop lidar applications for estimating forest inventory and biophysical variables;
2. integrate structural estimations of forest variables with physiological measures derived from optical data; and
3. integrate airborne and ground-based lidar data for growth and yield research and the development of automated forest inventory tools.

Future work will:

Expand the airborne analysis from the mixed-wood environment to multiple locations across Ontario, testing the robustness of lidar algorithms across different ecosystems.

Continue to expand the analysis of ground-based lidar for growth-yield and inventory across multiple ecosystems (in Ontario and Saskatchewan).

Apply forest structural estimates to forest ecosite mapping and modelling.

# Milestones

| Task | Description | Start | Finish |
|---|---|---|---|
| 1. | Examine the effect of laser pulse density on the estimation of forest inventory variables. | March 1, 2005 | Jan 31, 2006 |
| 2. | Modelling of forest biomass through the relationship of lidar height metrics and allometry. | March 1, 2005 | ongoing |
| 3. | Integration of lidar and hyperspectral data to model the fraction of photosynthetically active radiation absorbed by the canopy. | March 1, 2005 | December 31, 2006 |
| 4. | Integration of lidar and hyperspectral data to examine species and canopy chlorophyll concentrations. | March 1, 2005 | January 31, 2007 |
| 5. | Integration of airborne and ground-based lidar for growth and yield and structural information. | March 1, 2005 | ongoing |

# Technology

## Airborne lidar for forest inventory mapping.

Implemented nation-wide for some small countries (Scandinavia)

Can it be implemented provincially or nationally in Canada in a more biologically diverse environment?

## Ground-based lidar for forest structural attributes

Move from airborne, stand-level estimates to individual tree estimates for growth and yield studies in permanent sample plots.

# Technology

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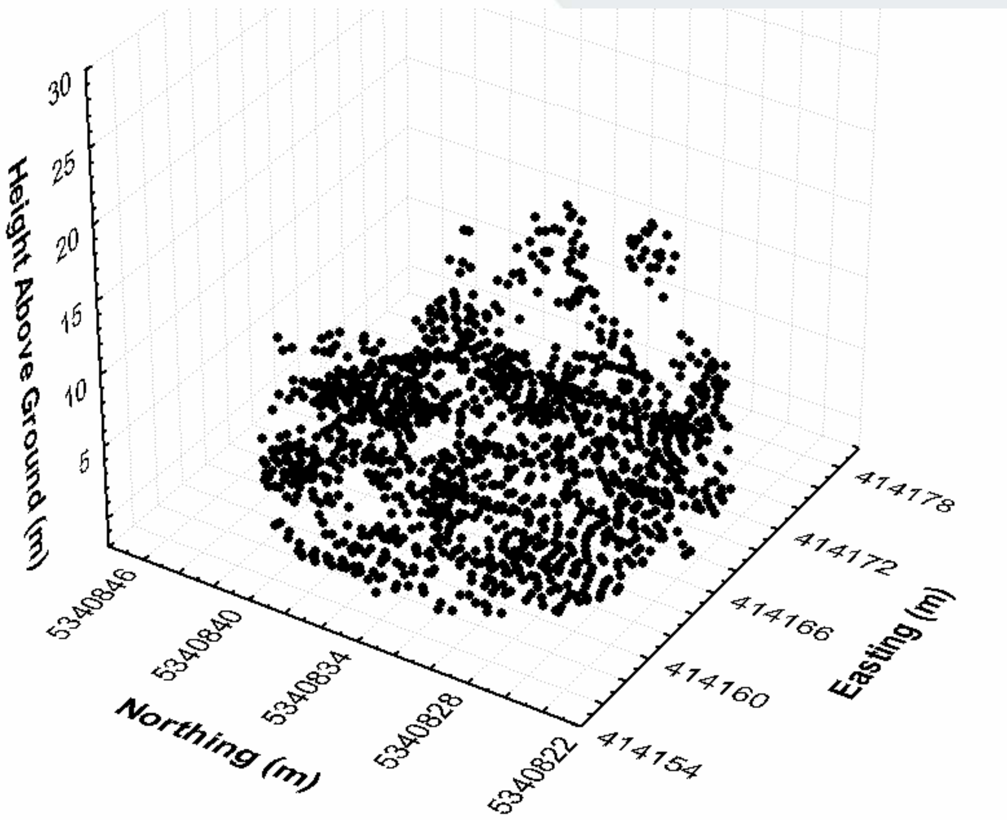


Airborne lidar: Stand level estimates of biomass, basal area, volume, etc.

Ground-based lidar: Individual tree mapping and inventory.

# Current Status

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## Current Status:

Most of the stand-based analysis is complete for the Ontario mixedwood environment. We are now expanding this analysis to other ecosystems across Ontario.

Of particular interest are:

> Development of algorithms for semi-automated biomass estimates through the integration of lidar with optical data.
>
> Quantification of above-ground-carbon for climate change modelling.

# Project Outcome



## Refereed Papers:

**Thomas, V., P. Treitz, J.H. McCaughey, T. Noland, and L. Rich, Canopy chlorophyll concentration estimation using hyperspectral and lidar data for a boreal mixedwood forest in northern Ontario, Canada. *International Journal of Remote Sensing* (accepted January 2007).**

**Thomas, V., P. Treitz, J.H. McCaughey, and I. Morrison, 2006. Mapping stand-level forest biophysical variables for a mixedwood boreal forest using lidar: an examination of scanning density. *Canadian Journal of Forest Research*, 36:34-47.**

**Chasmer, L., C. Hopkinson, and P. Treitz, 2006. Investigating laser pulse penetration through a conifer canopy by integrating airborne and terrestrial lidar, *Canadian Journal of Remote Sensing,* 32(2):116-125.**

**Thomas, V., D.A. Finch, J.H. McCaughey, T. Noland, L. Rich, and P. Treitz, 2006. Spatial modelling of the fraction of photosynthetically active radiation absorbed by a boreal mixedwood forest using a lidar-hyperspectral approach. *Agricultural and Forest Meteorology*, 140:287-307.**

**Chasmer, L., C. Hopkinson, and P. Treitz, 2006. Examining the influence of changing laser pulse repetition frequencies on conifer forest canopy returns, *Photogrammetric Engineering and Remote Sensing*, 72(12):1359-1367**

**Hopkinson, C., L. Chasmer, K. Lim, P. Treitz, and I. Creed, 2006. Towards a universal lidar canopy height indicator, *Canadian Journal of Remote Sensing,* 32(2):139-152.**

**Hopkinson, C.,L.E. Chasmer, G. Zsigovics, I. Creed, M. Sitar, W. Kalbfleisch, and P. Treitz, 2005. Vegetation class dependent errors in lidar ground elevation and canopy height estimates in a boreal wetland environment, *Canadian Journal of Remote Sensing*, 31(2):191-206.**

# Project Outcome

## In Review

Thomas, V., J.H. McCaughey, P. Treitz, D.A. Finch, T. Noland, and L. Rich, Spatial modelling of photosynthesis for a boreal mixedwood forest by integrating micrometeorological, lidar and hyperspectral remote sensing data. Submitted to Agricultural and Forest Meteorology on 17 October 2006.

## Conference Papers

Thomas, V., P. Treitz, J.H. McCaughey, D.A. Finch, T. Noland, L. Rich and I. Morrison, 2006. Integration of lidar and hyperspectral data with micrometeorological measurements to develop spatially explicit models of canopy chlorophyll, fPAR, and photosynthesis. In proceedings of Silvilaser 2006, Matsuyama, Ehime (Japan), 7-10 November 2006, Shikoku Research Center and Ehime University, pp. 145-151.

Thomas, V., P. Treitz, J.H. McCaughey, T. Noland, L. Rich and I. Morrison, 2006. Estimating forest canopy chlorophyll concentration using complementary remote sensing technologies: lidar and hyperspectral data. In proceedings of Silvilaser 2006, Matsuyama, Ehime (Japan), 7-10 November 2006, Shikoku Research Center and Ehime University, pp. 224-230.

Chasmer, L., A. Barr, A. Black, C. Hopkinson, H. McCaughey, P. Treitz, A. Shashkov, and T. Zha, 2006. Lidar derived canopy structural influences on light use efficiency at a chronosequence of Fluxnet-Canada jack pine forest sites for MODIS product validation. Proceedings of the *International Geoscience and Remote Sensing Symposium*, Denver CO. July 2006, unpaginated.

# Project Outcome

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## Selected Presentations

Thomas, V., J.H. McCaughey, P.M Treitz, D.A. Finch, and T. Noland, 2006. Spatial Variability at the Groundhog River Flux Site. Poster presentation at the Fluxnet-Canada 2006 Annual General Meeting, Victoria, British Columbia, Feb. 24-26, 2006.

McQueen, S., K. Mahoney, J.H. McCaughey, M.A. Arain, A. Cameron, R. Dexter, D.A. Finch, L. MacLean, M. Pejam, V. Thomas, and P. Treitz, 2006. 2004-2005 Carbon and Energy Exchange in the Ontario Mixedwood Forest. Poster presentation at the Fluxnet-Canada 2006 Annual General Meeting, Victoria, British Columbia, Feb. 24-26, 2006.

Thomas, V., D. Finch, J.H. McCaughey, P. Treitz, T. Noland, and L. Rich, 2005. *Modelling below-canopy PAR for a mixed-wood boreal forest environment*. Presented at the Canadian Association of Geographers Annual General Meeting, London, Ontario (May 29-June 3, 2005).

Thomas, V., J.H. McCaughey, and P. Treitz, 2005. Modelling Photosynthesis at the Groundhog River Flux Station: Preliminary Results. Poster presentation at the *Fluxnet-Canada 2005 Annual General Meeting*, February 25-27, 2005, Quebec City.

Thomas, V., J.H. McCaughey, P. Treitz, D.A. Finch, I. Morrison, T. Noland, and L. Rich, 2005. Preliminary results of the 2003-2004 sampling of canopy characteristics at the Groundhog River Flux Station. Presented at the *Fluxnet-Canada 2005 Annual General Meeting*, February 25-27, 2005, Quebec City.

McCaughey, J.H., M.A. Arain, A. Cameron, M. Khomik, L. MacLean, M. Pejam, V. Thomas, and P. Treitz, 2005. Carbon, water, and energy exchange in the Ontario mixedwood forest region. Poster presentation at the *Fluxnet-Canada 2005 Annual General Meeting*, February 25-27, 2005, Quebec City.

McCaughey, J.H., M.A. Arain, A. Cameron, L. Chasmer, D.A. Finch, M. Khomik, L. MacLean, I. Morrison, M. Pejam, V. Thomas, and P. Treitz, 2005. Progress report of the Groundhog River Flux Station (Ontario) 2004. Poster presentation at the *Fluxnet-Canada 2005 Annual General Meeting*, February 2005, Quebec City.

# Project Outcome



## Job Opportunities:

**Fluxnet-Canada Post Doctoral Fellowship, Valerie Thomas, Queen's University, Supervisor: J.H. McCaughey**

## Adaptation by collaborators:

**Tembec Inc. has contracted a commercial company to collected extensive lidar coverage for much of the Romeo-Mallette Forest. They find great utility in the bare-earth DEM and canopy height model for forest engineering applications and forest biophysical estimates.**

**Our research has also supported a significant interest in the application of lidar for forestry applications which has resulted in additional research projects being funded for our partners (e.g., Forest Futures Trust – OMNR, Tembec Inc.). This has provided additional lidar data acquisition for a range of forest ecosystems across Ontario.**

# End Users – Success Stories

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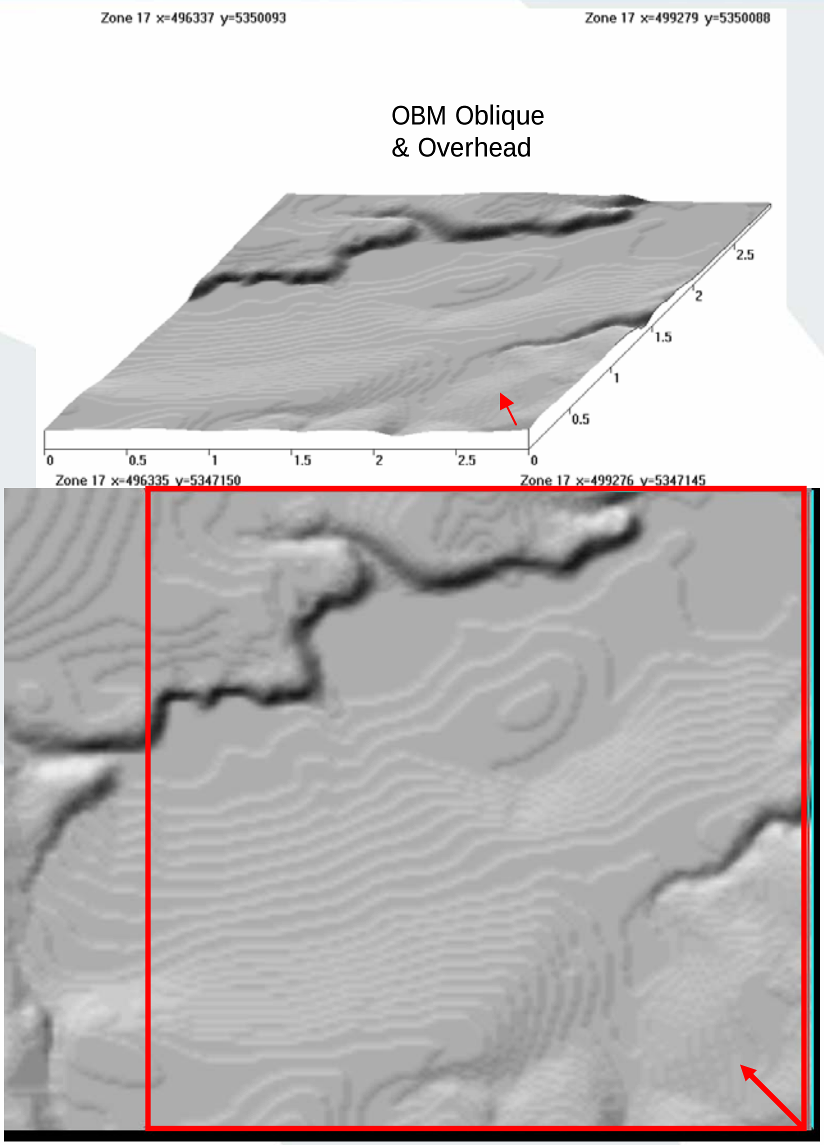
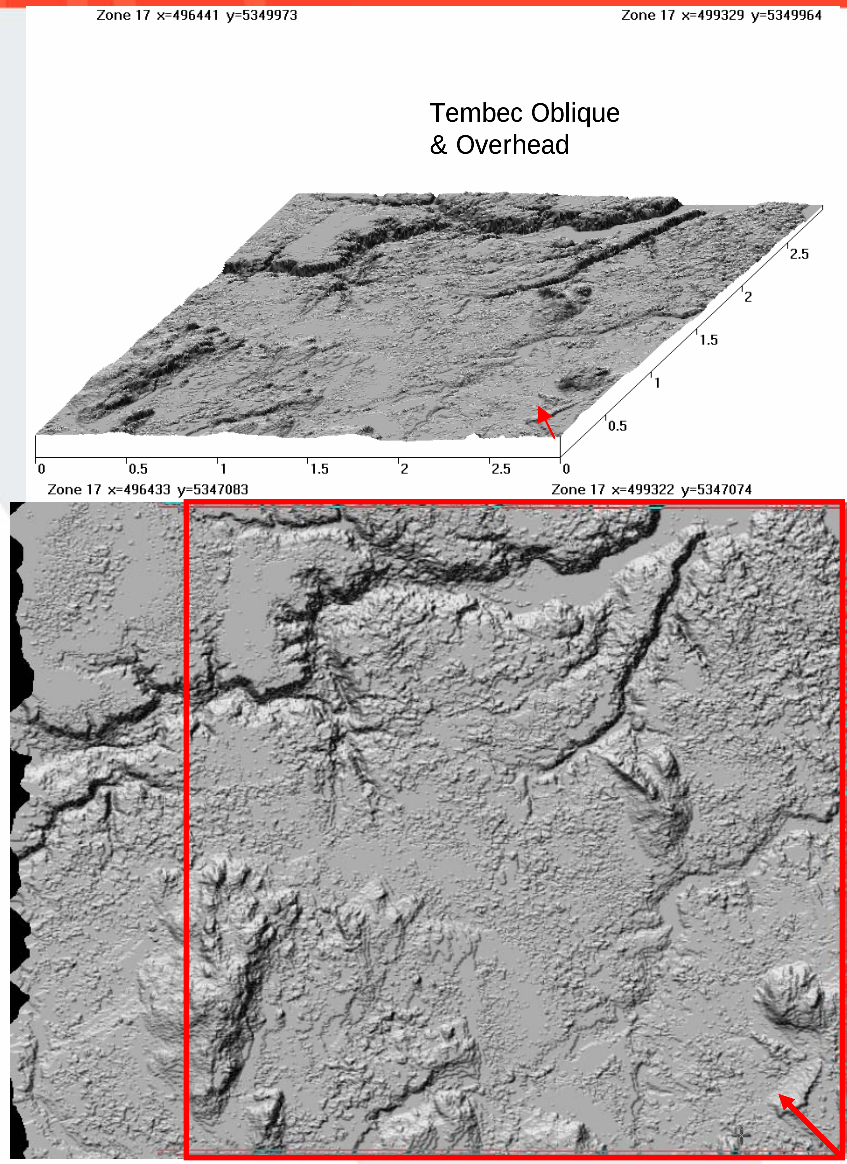
## DEM Resolution …




OBM Oblique & Overhead

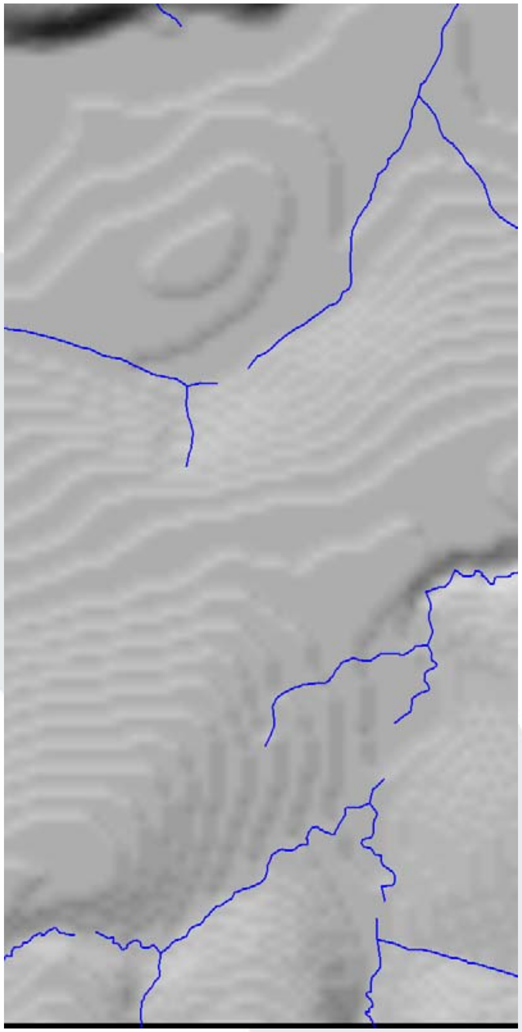



Tembec Oblique & Overhead

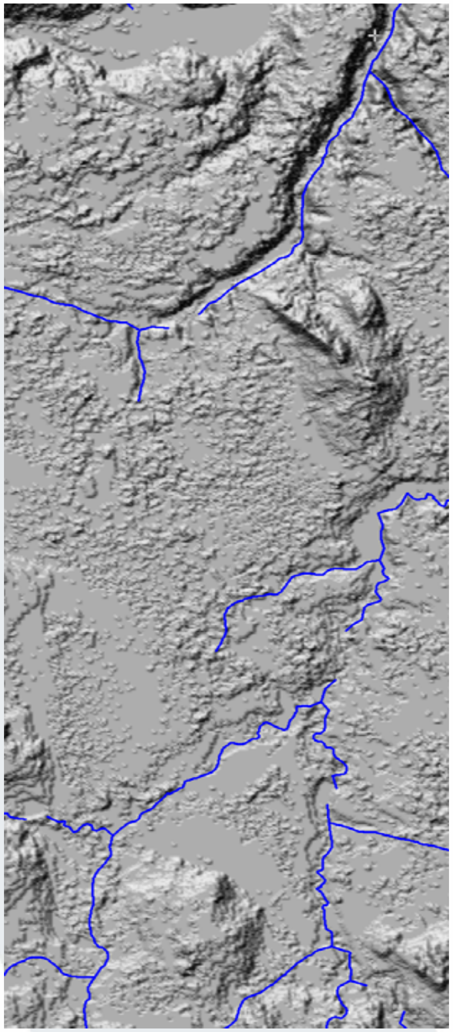
# End Users – Success Stories

Ontario Centres of Excellence

## Data Accuracy …



| OBM* | Tembec |
| --- | --- |
| Horizontal Grid = 30m | Horizontal Grid = 5m |
| Vertical Accuracy = 5 m | Vertical Accuracy = 1 m |
| Positional Accuracy = 10 m | Positional Accuracy = 1 m |

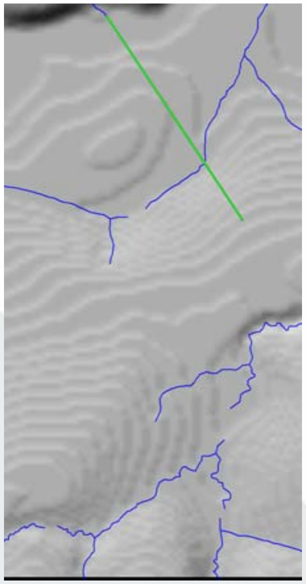


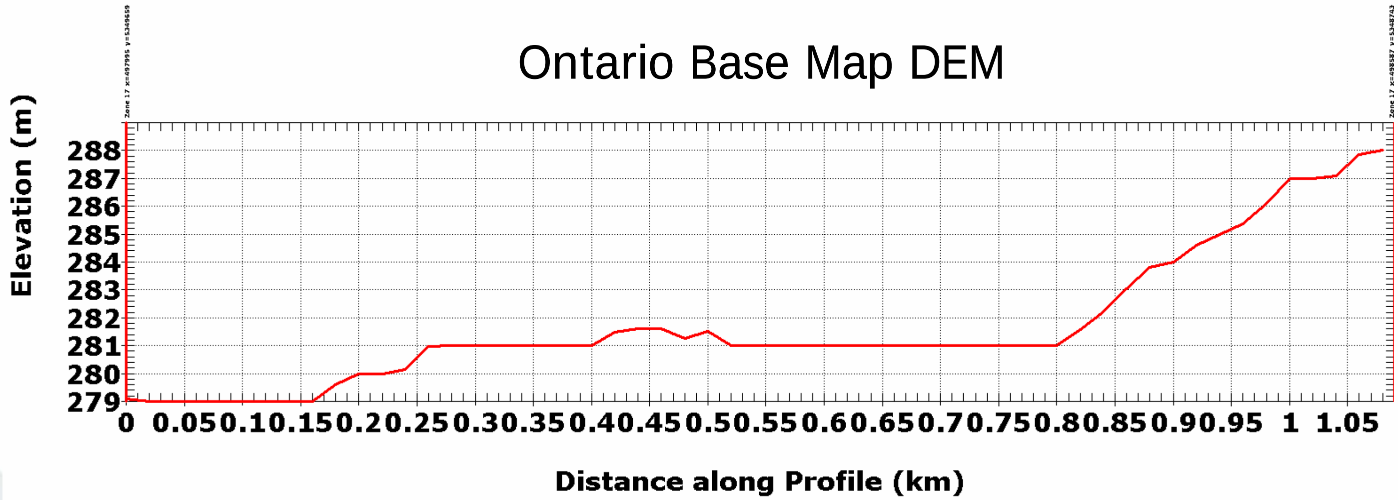
Reference:
Digital Topographic Data Base Overview, Version 2 (March 1994). OMNR, Table 2.

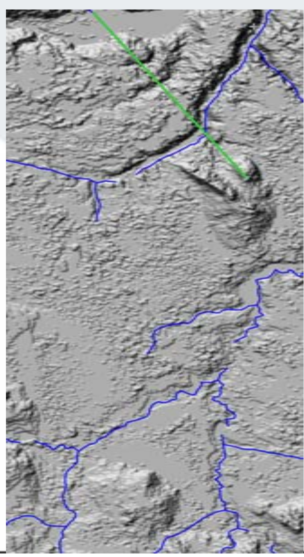
# End Users – Success Stories

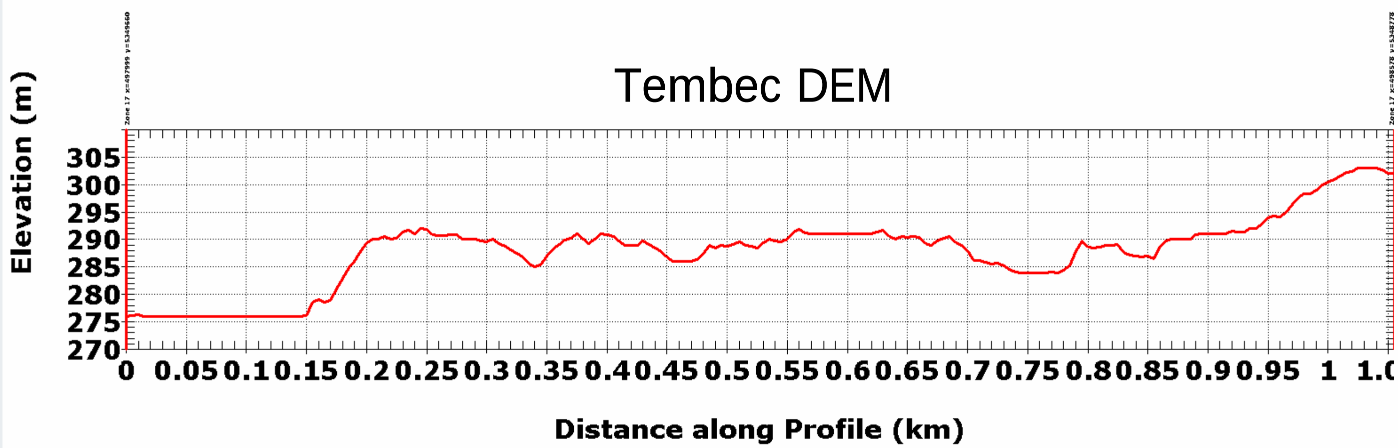


## Road Profile Comparison







# End Users – Success Stories

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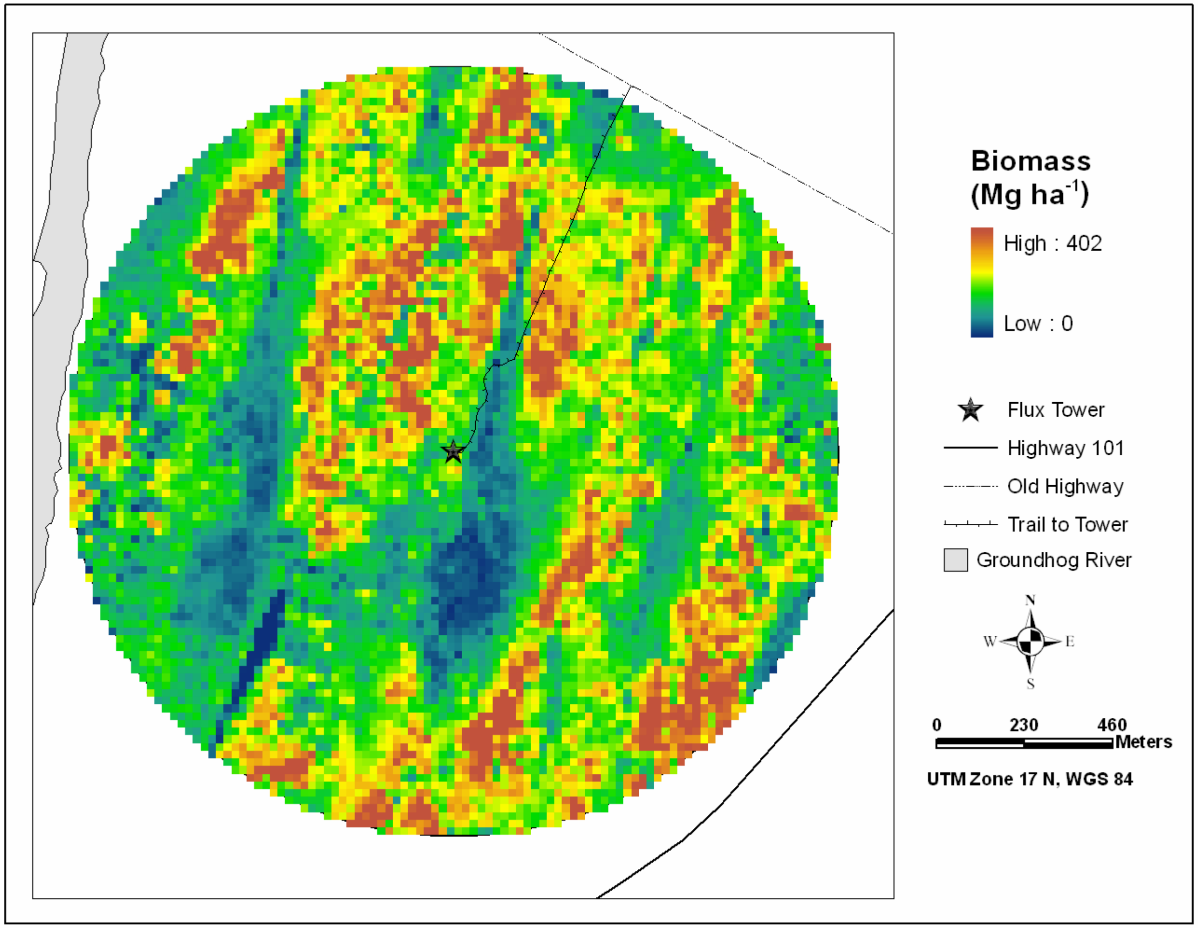
## Forest Biomass Estimation using Lidar

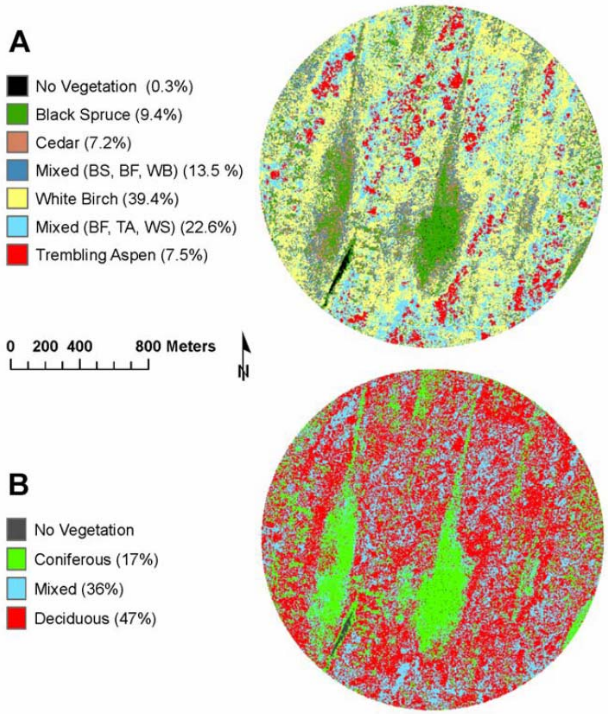
**The ability to use lower-density lidar scans to map stand-level biomass, tree heights, and basal area is crucial to implementation of lidar technology for provincial and/or national inventories for very large countries such as Canada and the United States.**



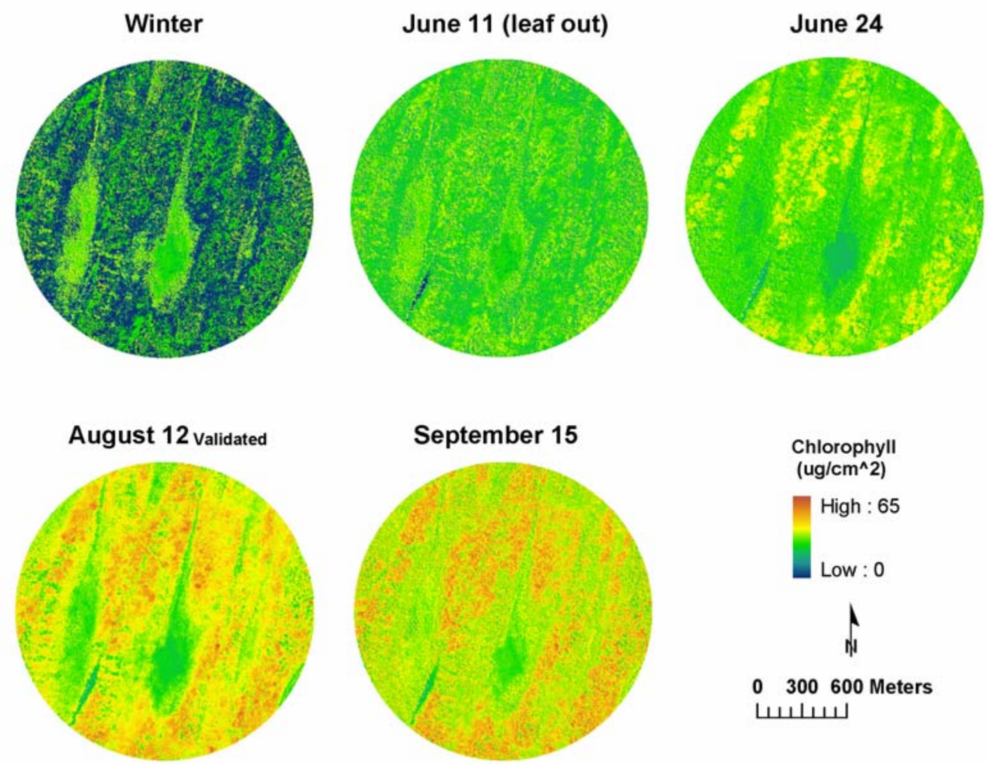
# Success Story

## Mapping canopy chlorophyll concentration throughout the seasons





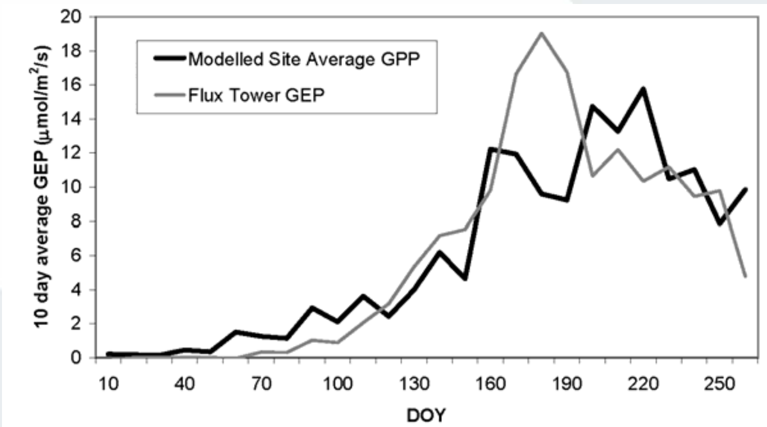

Validated canopy chlorophyll maps were classified to develop species-level (A) and coniferous-deciduous maps (B) for the Ontario Mixedwood Flux Site



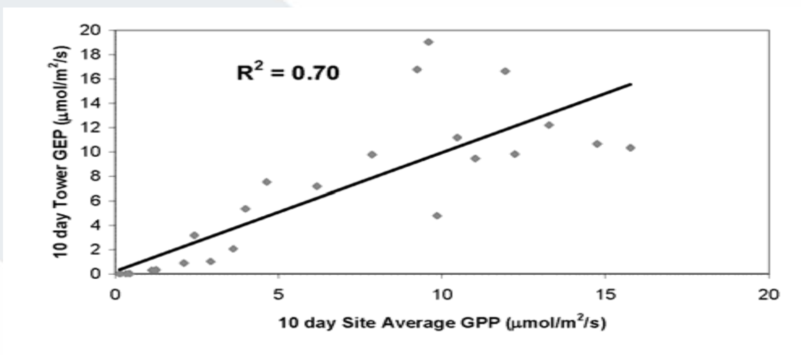

Species information combined with seasonal measurements of leaf chlorophyll were used to develop seasonal maps of total canopy chlorophyll concentration for 2004.

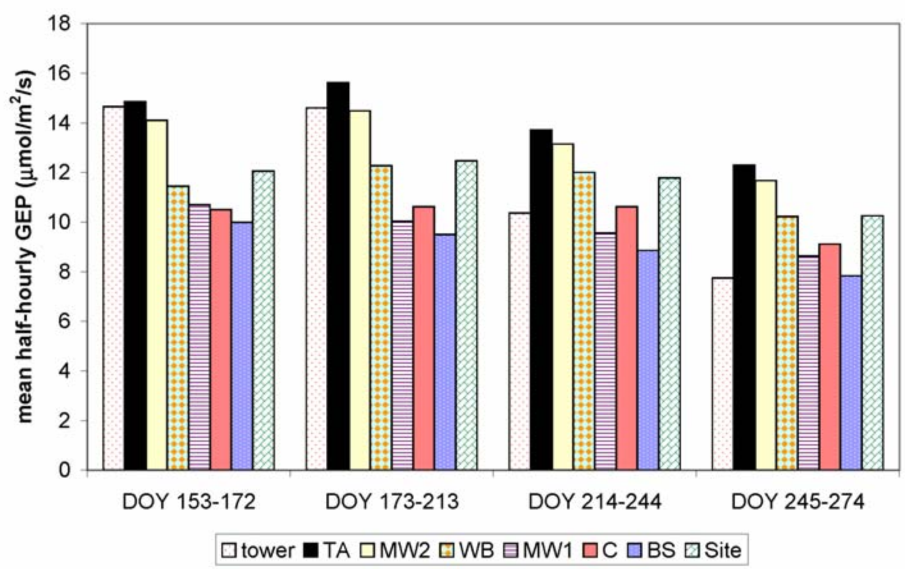
# Success Story

Integrating technologies to model photosynthesis




Ability to integrate these technologies into models of carbon exchange is key for more accurate models of carbon exchange at the regional and national scales.




Crucial inputs for climate models.

# Success Stories



**There continues to be strong collaboration with our forest industry partners on developing lidar applications in the forest sector. Tembec Inc. and OMNR have been very receptive to this technology and research direction. Dr Kevin Lim (a previous OCE funded PhD student), now Principal of Lim Geomatics has been actively involved in developing software tools for processing lidar for our forest partners.**

**Dr. Valerie Thomas – successful completion of PhD and Post Doctoral Fellowship.**

# What is Next



**Our research efforts in partnership with industry are moving towards more accurate, precise and efficient methodologies for estimating forest and terrain variables for input to the Government of Ontario's enhanced Forest Resource Inventory (eFRI). We are moving towards developing acquisition standards and products that can be incorporated into the eFRI. These standards and products are meant to provide terrain, ecological and inventory variables to serve a variety of stakeholders (e.g., forest practitioners, government regulators, etc.).**