Remote sensing data sources and applications

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Key collaborators

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CSA ASC

Canada

Natural Resources Canada | Ressources naturelles Canada
Canadian Forest Service | Service canadien des forêts

Conclusions / Opportunity

- Multi-source and multi-scale systems to capture change and quantify changes in carbon stocks over time
  - Optically-driven approaches for "activity" data are operational, facilitated by archival data and increasingly common open data policies

- Need an NFI
- Optical data for cover, extent, change (characterize, stratify)
  - temporally dynamic forest extent
- RS change to characterize change locations (and rates)
- RS change to target (as required) in situ measurements (TSP, REDD support, augment NFI)
- Number of plots required to provide certainty?
- Opportunity for airborne lidar to 1. emulate plots; 2. spatially extend ground measures

* Based (loosely) on discussions with M. Hansen and E. Næsset.

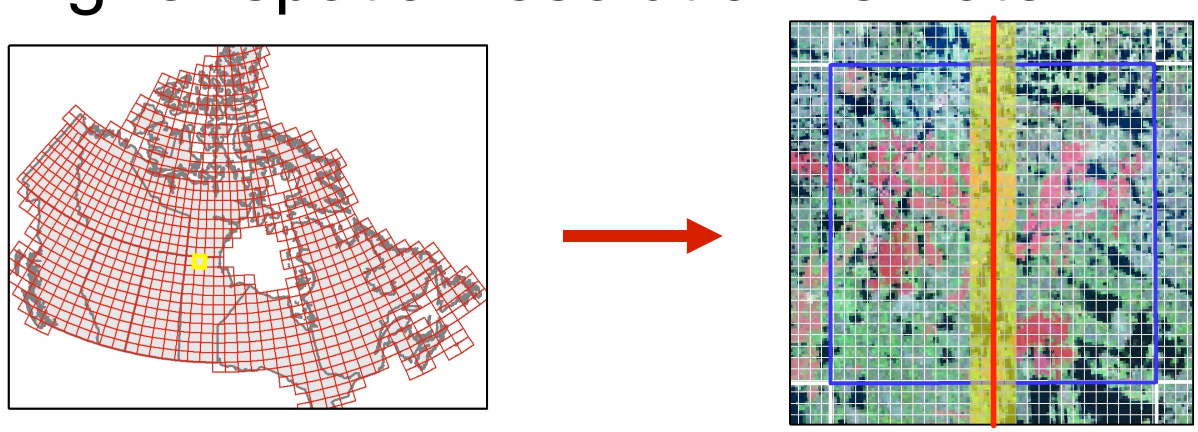
Data sources

- Plots
- Inventories
- Remote sensing
- Models

Framework notion:

Integrating multi-scale remote sensing and modeling

- Establish high spatial resolution, fine scale grid
- Populate grid through remote sensing (e.g., Landsat) and modeling
- Update the grid through satellite change detection
  - Find change, attribute change (as possible)
- Confirm / adjust modeled outcomes through sample based, higher spatial resolution remote sensing
- Repeat



RS / REDD linkages

- Disturbance
  - Landsat
- Degradation
  - High spatial resolution imagery
- Conversion
  - Landsat + interpretation (land use)
- Recovery
  - Landsat

Saturation

- Modeling: specifics of C characterization, such as dead organic matter (need for modeling)
- Remote sensing, saturation
  - Optical and Radar experience measurement saturation (empirical measures).
    - synoptic
  - Lidar does not saturate (more direct measures)
    - sample
  - Very High Spatial Resolution imagery (allometrics estimates possible)
    - sample

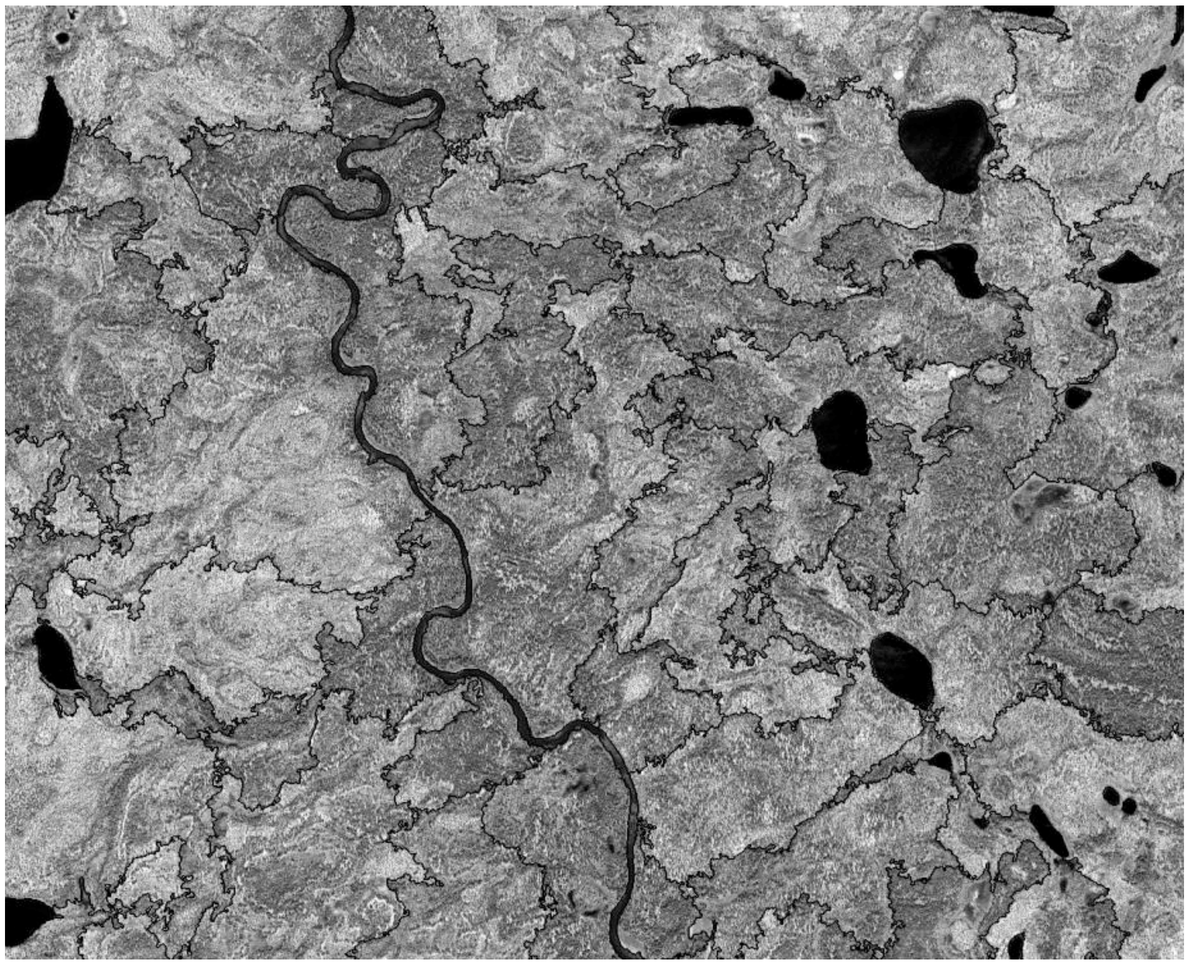
High spatial resolution imagery and analysis

- Segmentation
  - Stands
  - Trees
  - Stand-level characterizations
- Automated attribution
  - Density
  - Height
  - Species

Falkowski, M.J.; Wulder, M.A.; White, J.C.; Gillis, M.D. 2009. Supporting large-area, sample-based forest inventories with very high spatial resolution satellite imagery. Progress in Physical Geography 33(3): 403–423.

Automated Segmentation:

Goal: partition image into spatially distinct units that are homogenous and mutually distinct in terms of forest composition and structure (i.e., create stand boundaries)



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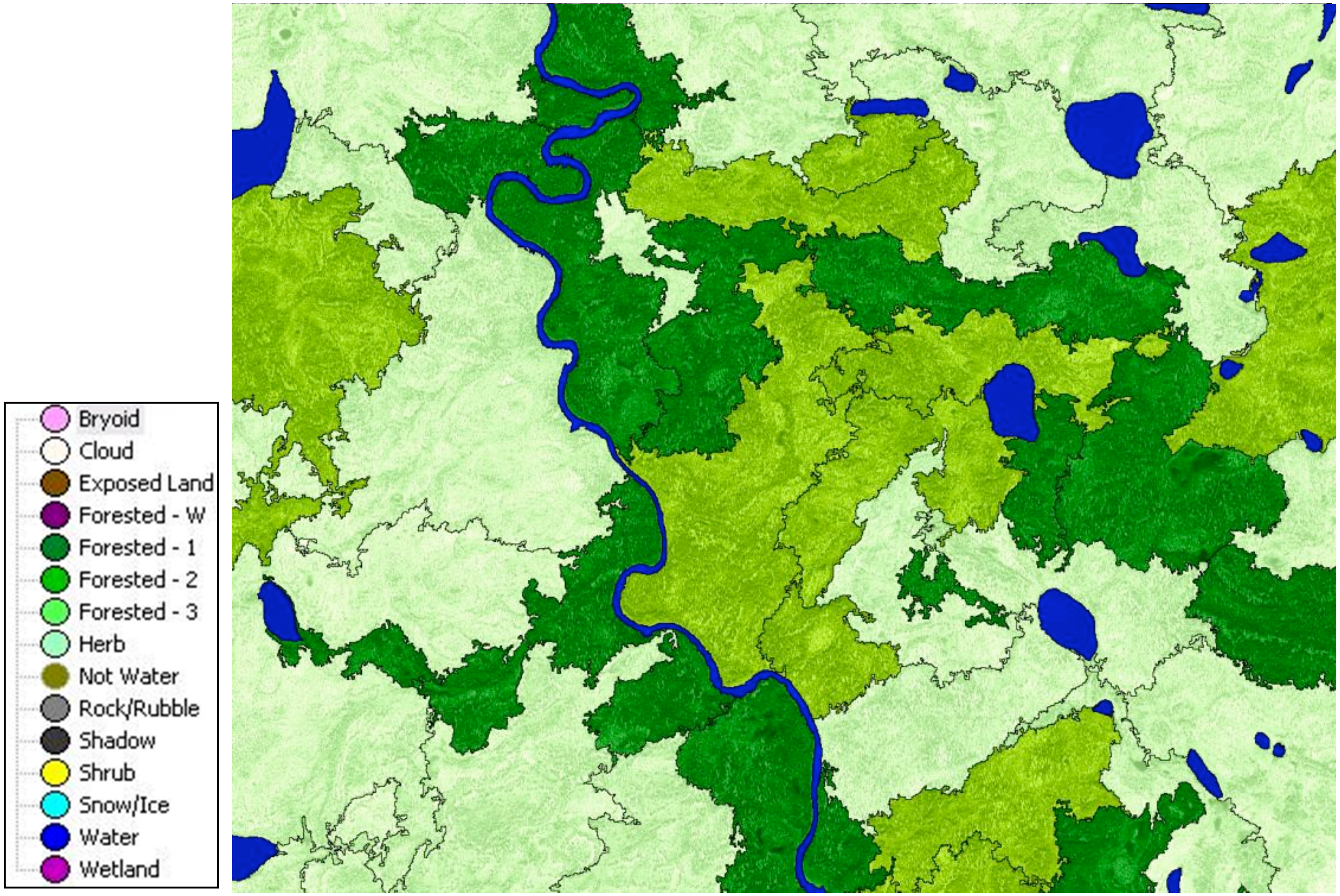
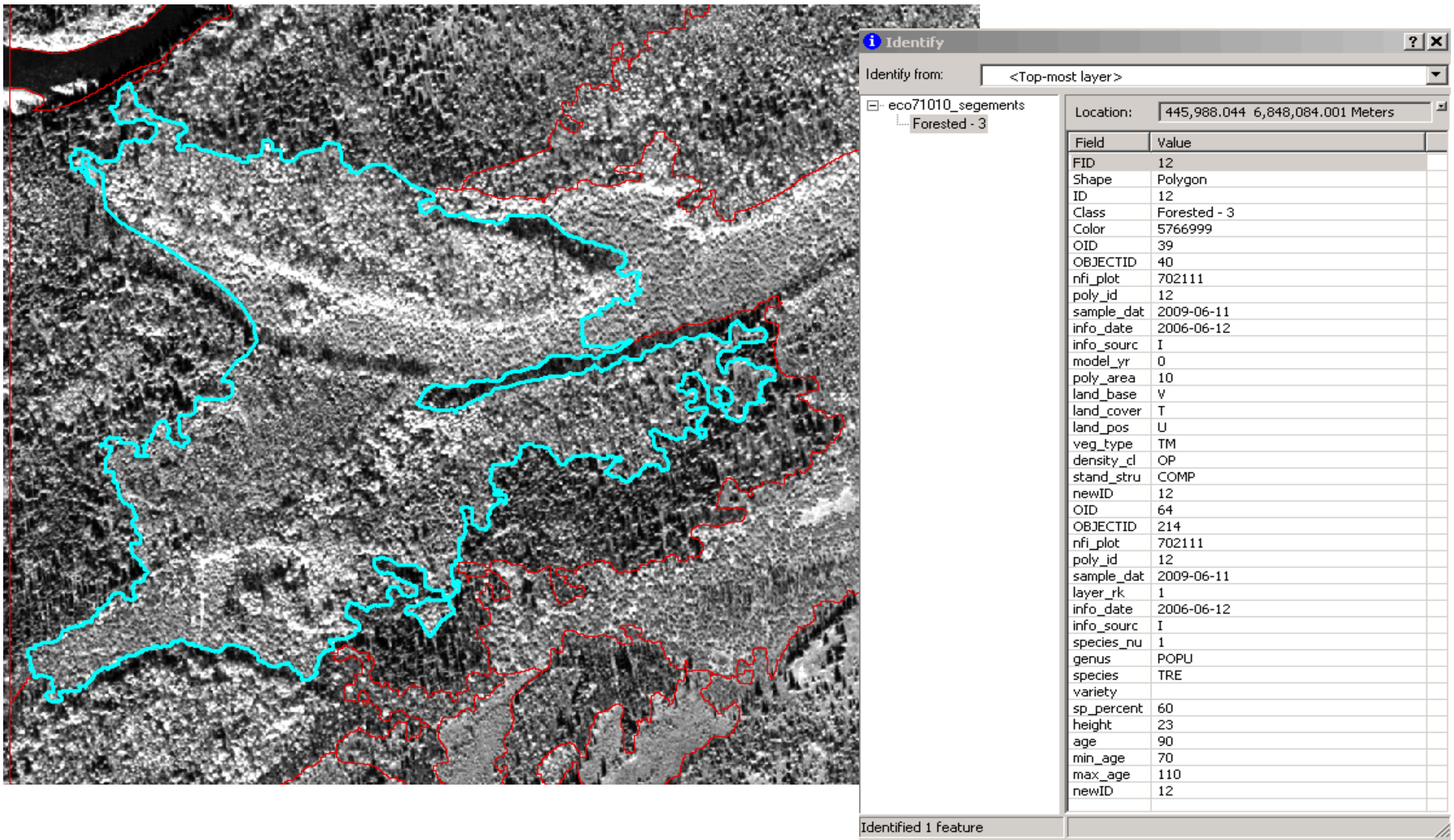
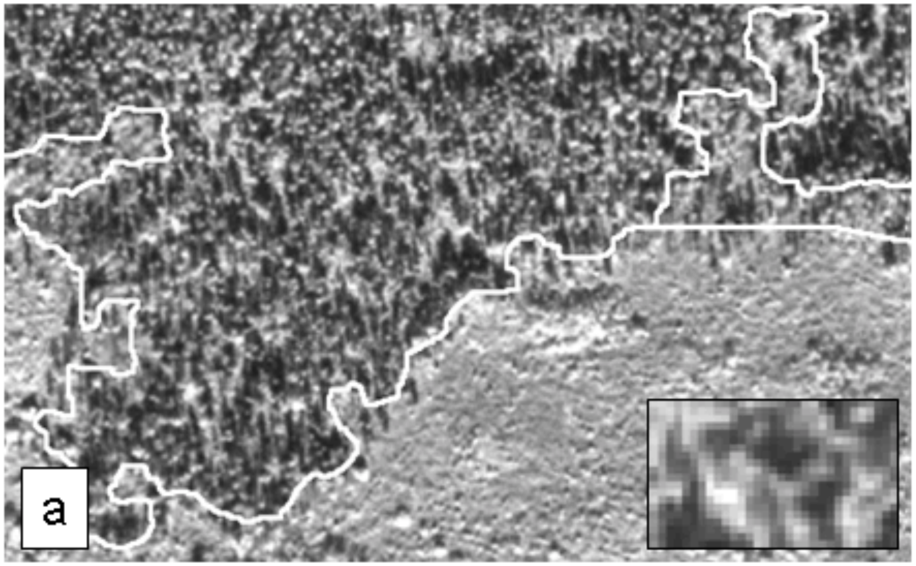
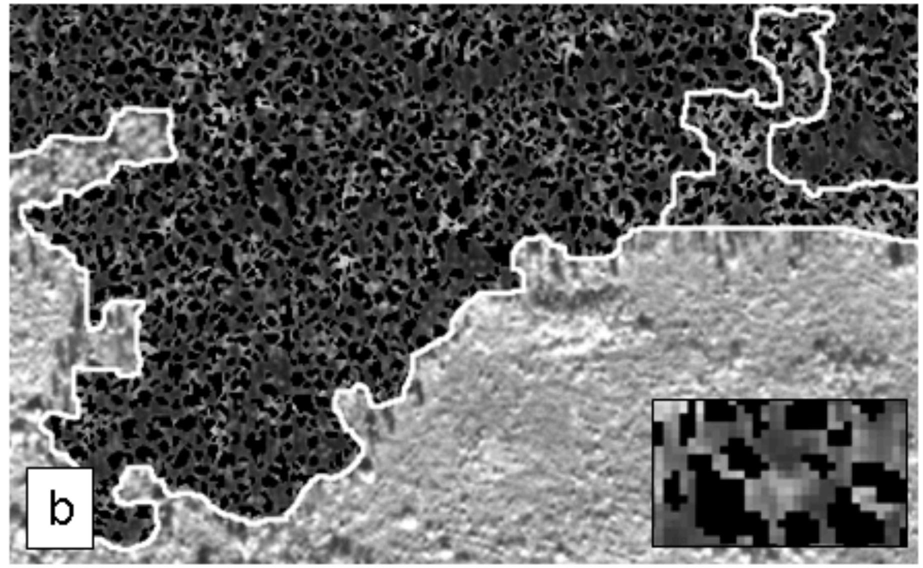


Attribution

Following segmentation, FI attributes are generated for each segment







Height estimation

- Input data
- Stand level metrics based on VHSR image, crown metrics
- Results:
  - significant *R*2 of 0.53** and an RMSE of 2.84 m

Leading species estimation

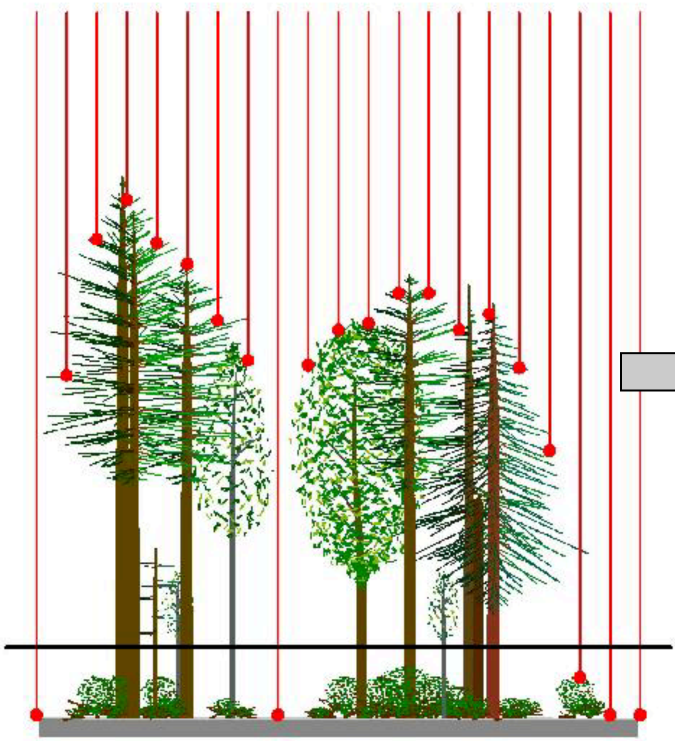
- Input data:
  - Statistics on tree crown shape metrics : *Area, Length, Roundness*
  - *Mean, Variance, 25th, 50th, 75th percentiles*
- Results:
  - Most selected metrics: *Area variance, Roundness variance, Area 50th percentile*
  - Overall accuracy of 74.5%

Mora, B., M.A. Wulder, and J.C. White (2010). Segment-constrained regression tree estimation of forest stand height from very high spatial resolution panchromatic imagery over a boreal environment. Remote Sensing of Environment. [DOI forthcoming]

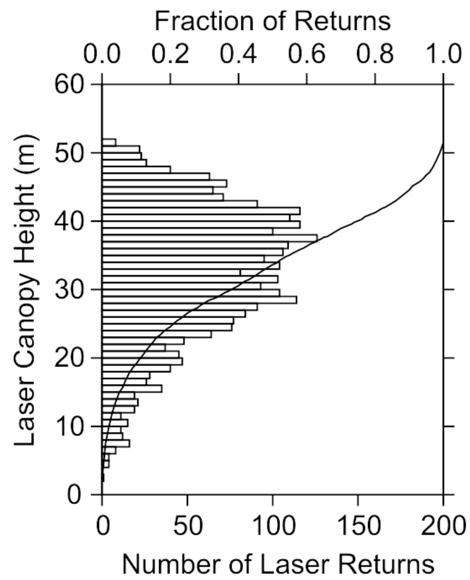
Mora, B., M.A. Wulder, and J.C. White (2010). Identifying leading species using tree crown metrics derived from very high spatial resolution imagery in a boreal forest environment. [Accepted]

Individual tree measures from the lidar are summarized to produce *critical* plot-level attributes at thousands of plot locations.

Tree-level measures

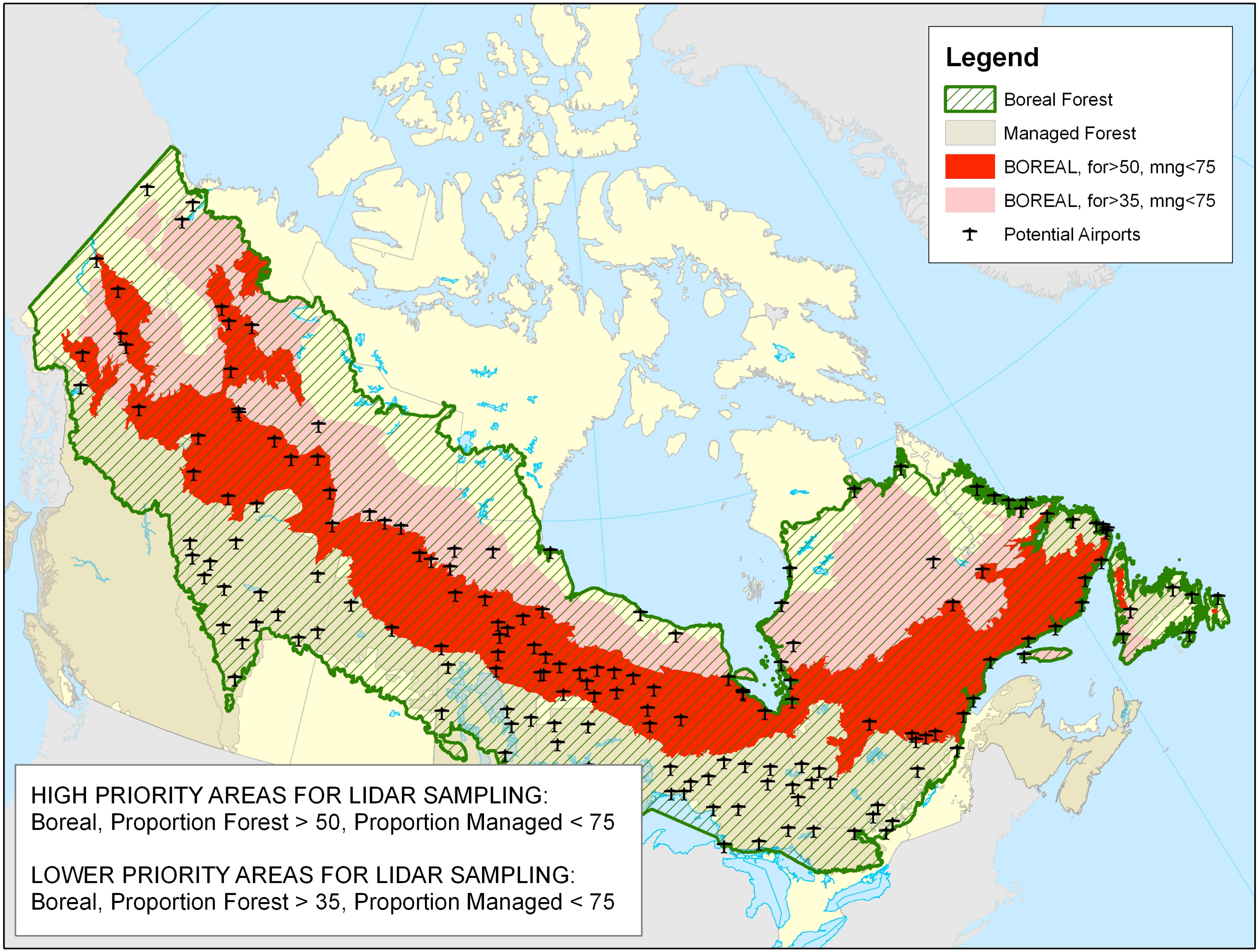


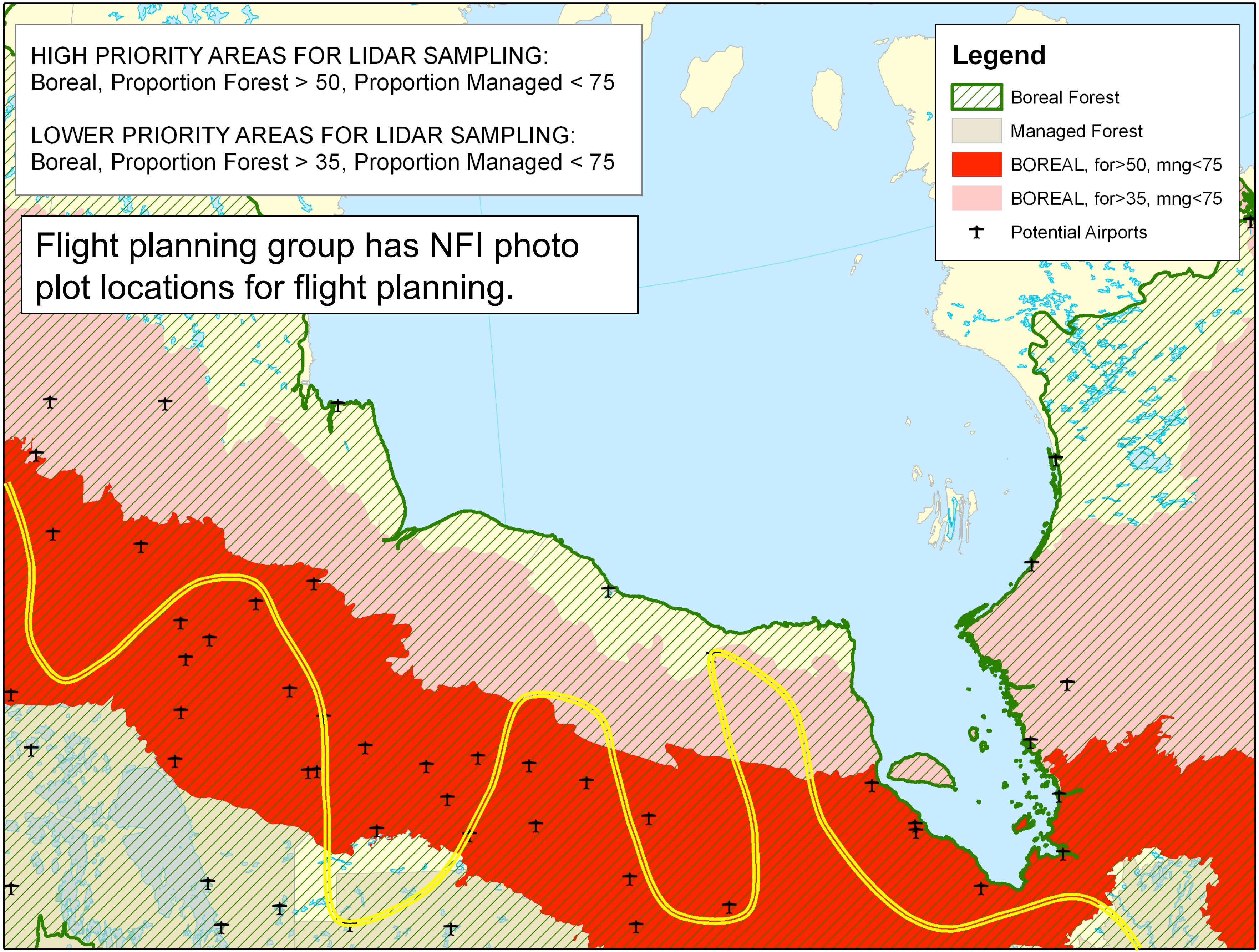
Plot



Plot-level attributes

stand structure
height (max, mean…)
crown closure
volume
biomass
gap fraction
stem density


Legend
Boreal Forest
Managed Forest
BOREAL, for>50, mng<75
BOREAL, for>35, mng<75
Potential Airports
HIGH PRIORITY AREAS FOR LIDAR SAMPLING:
Boreal, Proportion Forest > 50, Proportion Managed < 75
LOWER PRIORITY AREAS FOR LIDAR SAMPLING:
Boreal, Proportion Forest > 35, Proportion Managed < 75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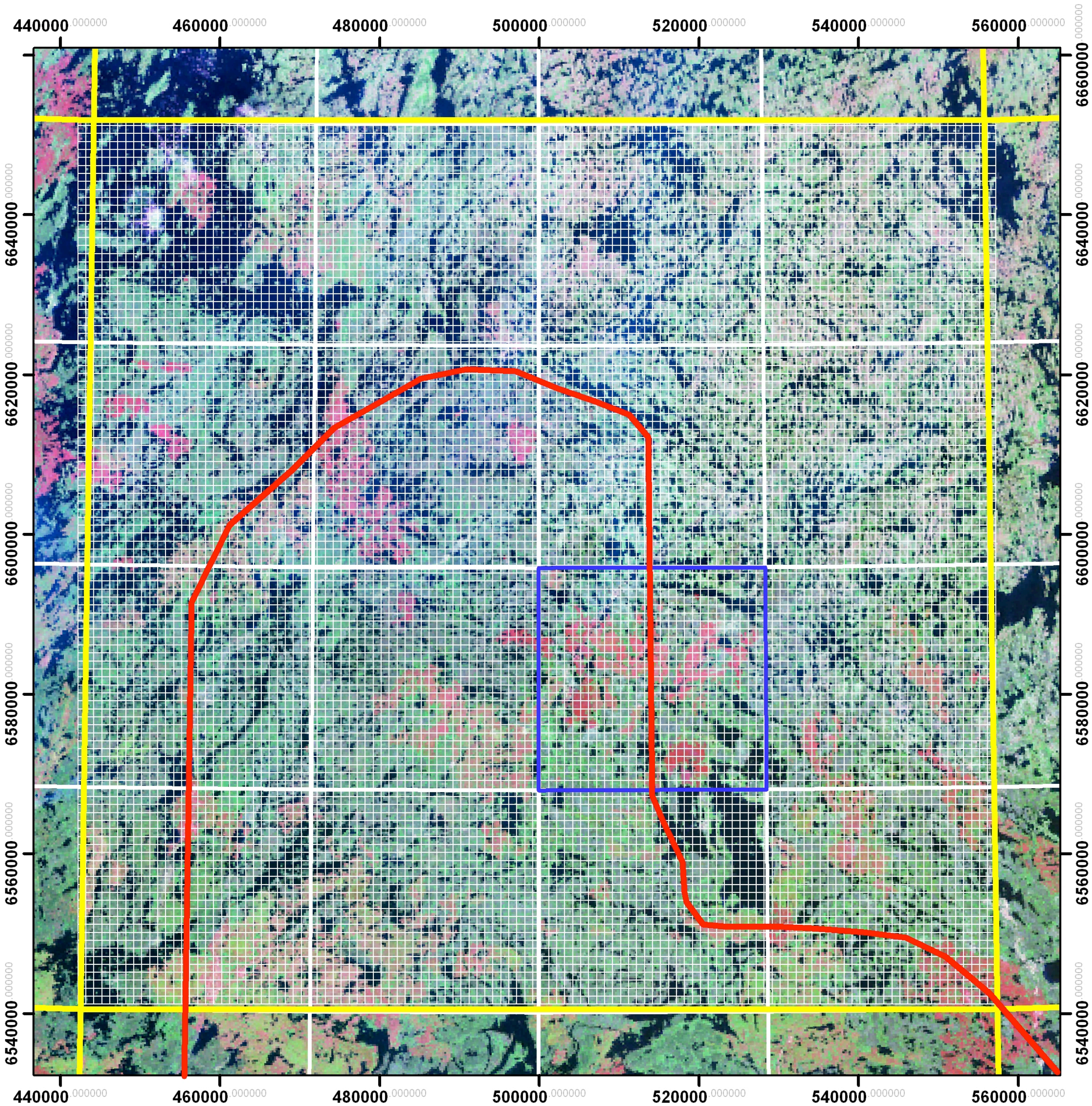
Boreal, Proportion Forest > 50, Proportion Managed < 75
LOWER PRIORITY AREAS FOR LIDAR SAMPLING:
Boreal, Proportion Forest > 35, Proportion Managed < 75
Flight planning group has NFI photo plot locations for flight planning.
Legend
Boreal Forest
Managed Forest
BOREAL, for>50, mng<75
BOREAL, for>35, mng<75
Potential Airports



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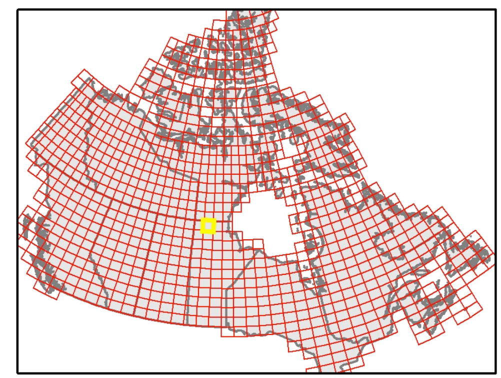
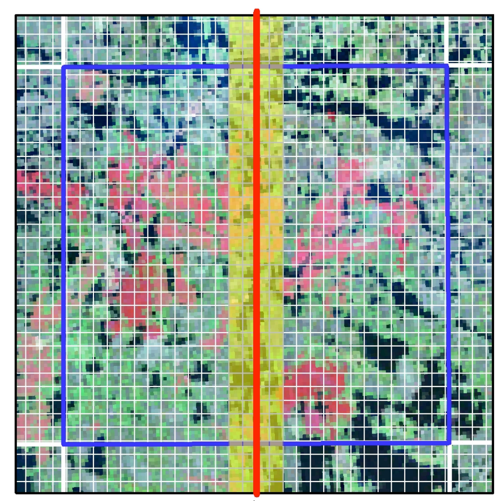
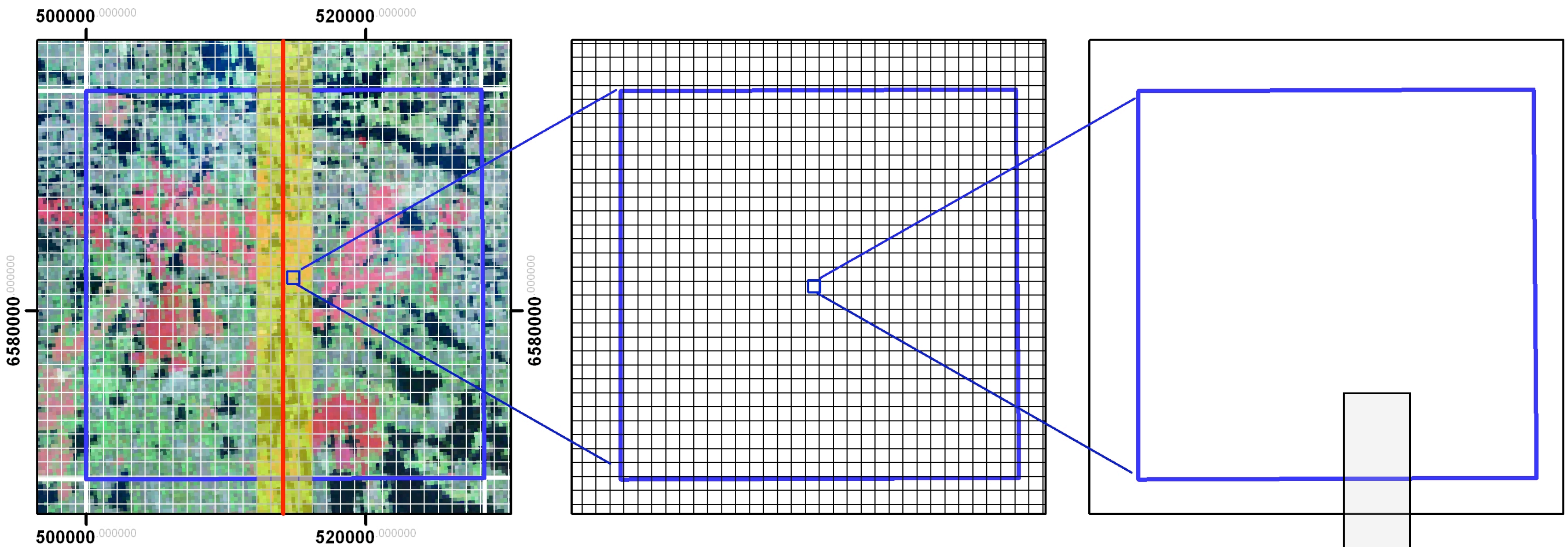


NTS 1:250K 064O



Highlighted 1km cells are populated with data from the lidar (depending on swath width).
NTS 1:50K 064O07
Lidar transect



NTS 1:50K 064O07

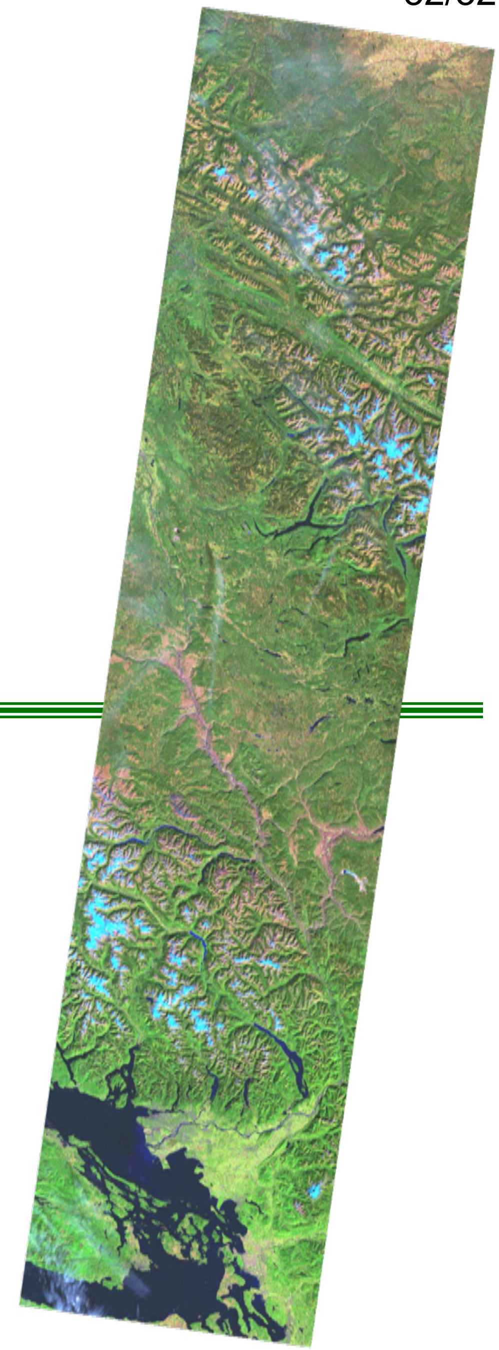
A single 1 km cell with 25 m tessellation

A single 25 m cell

ATTRIBUTES for each 25 m cell

Flight date	**Stand structure**
Number of returns	**Height**
Elev minimum	**Crown closure**
Elev maximum	**Volume**
Elev mean	**Biomass**
Elev mode	**Volume**
Elev stddev	**Gap fraction**
Elev variance	**Stem density**
…	

Thank you



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Recent Applications of Echidna® Lidar in the U.S.

A. H. Strahler[1], C. E. Woodcock[1], C. B. Schaaf[1], R. Myneni[1], J. Liu[1], G. J. Newnham[3], D. L. B. Jupp[4], D. S. Culvenor[3], J. L. Lovell[4], W. Ni-Meister[2], S. Lee[2], X. Li[1], F. Zhao[1], X. Yang[1], T. Yao[1], Q. Zhang[1], M. Schull[1], M. Roman III[1], Z. Wang[1], Y. Shuai[1]

[1]Boston University

[2]Hunter College of CUNY

[3]CSIRO Forest Biosciences

[4]CSIRO Marine and Atmospheric Research

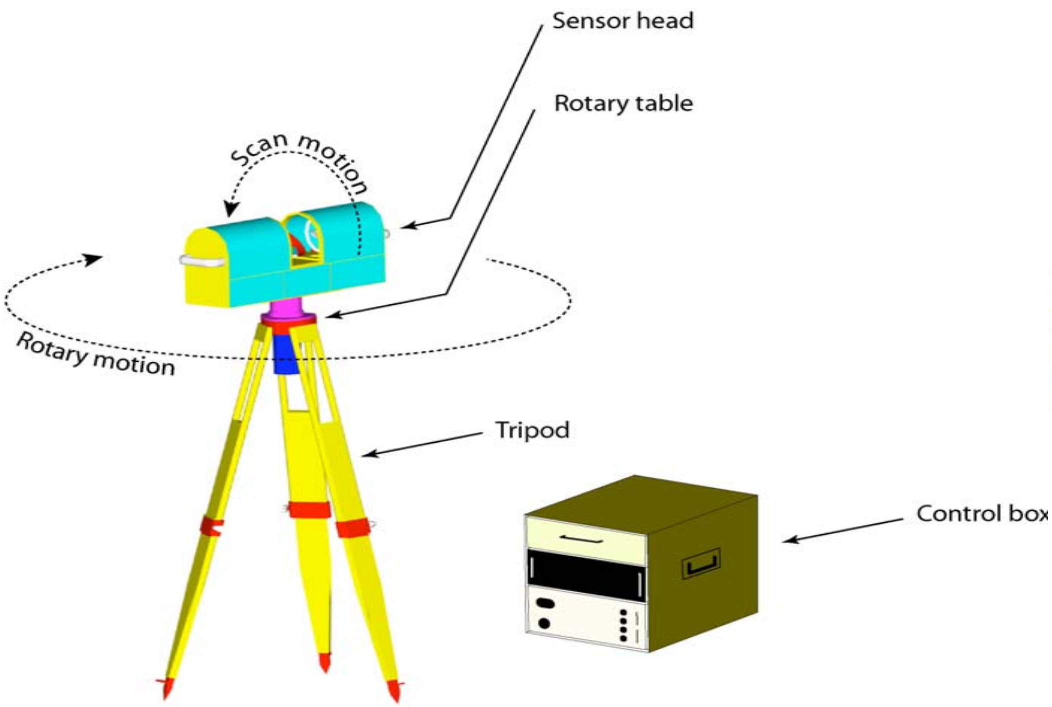
Supported by NASA Grant NNG-0GG192G
To Boston University

CSIRO

Overview

- Echidna® lidar description
- Retrieval of forest structural parameters using the Echidna® Ground-Based Lidar
  - Leaf Area Index and foliage profile
  - Canopy height
  - DBH
  - Stem count density
  - Above-ground biomass
- 3-D reconstruction of Sierra Nevada forest stands using merged point clouds from multiple Echidna® scans
  - Merging scans
  - Measuring trees in the point cloud
  - Comparison with field-measured trees
- A quick look at the new Dual Wavelength Echidna® Lidar

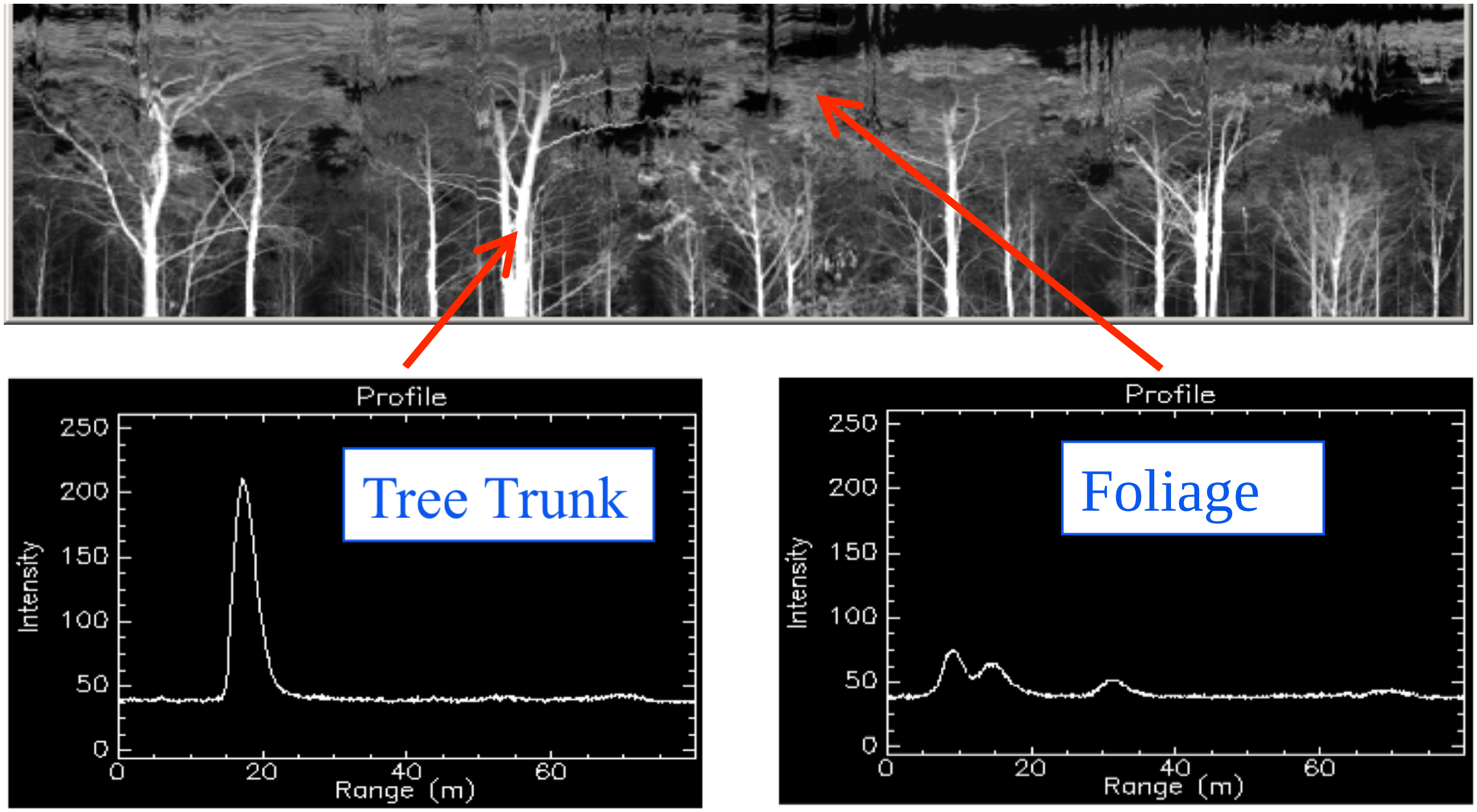
Ground-Based Lidar (Echidna®)



- Echidna® is ground-based lidar technology designed and patented by CSIRO specifically for forest and vegetation assessment
- The Echidna® and the current prototype — the Echidna® Validation Instrument (or "EVI") has key differences from scanning rangefinders
  - Digitizes the full waveform
  - Has variable beam divergence
  - Uses full hemispherical scanning and beyond
  - Linear response and calibration

Wavelength—1064 nm

Hard & Soft Returns in EVI Data

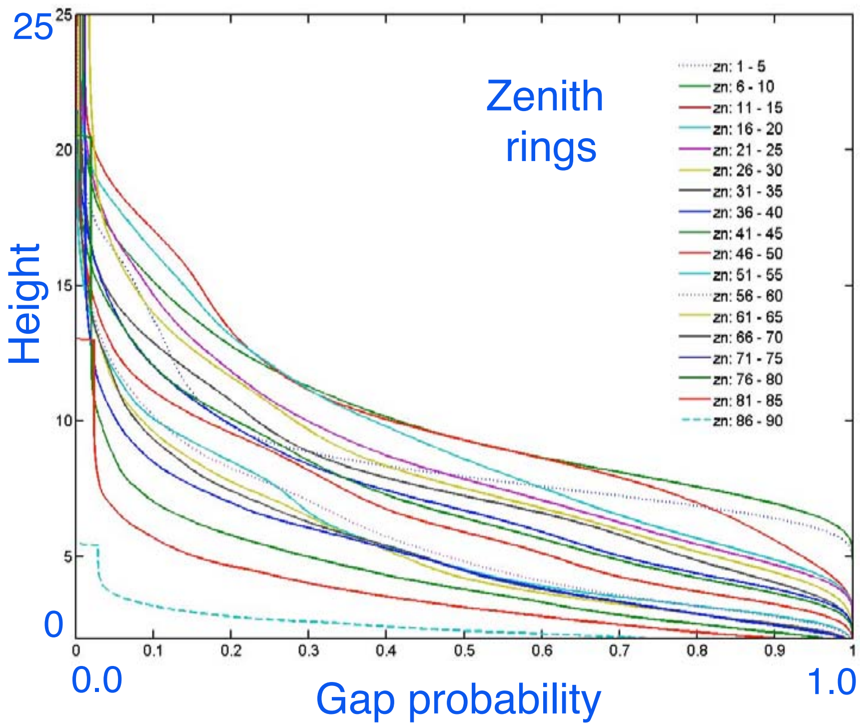


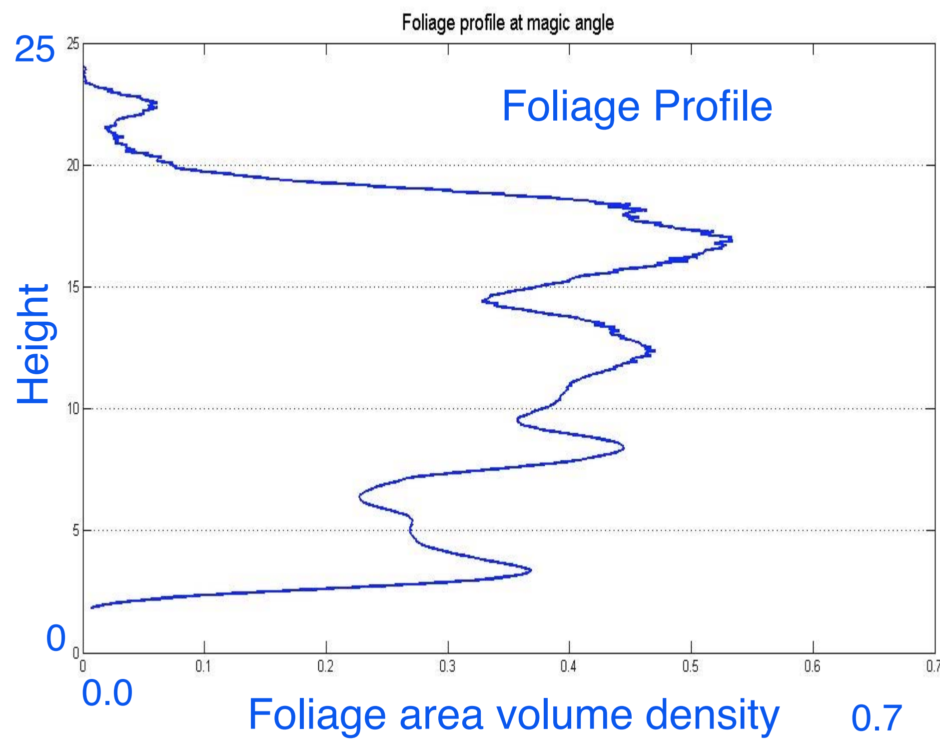
- Pulse characteristics
  - Length: 2.4 m (FWHM), strongly peaked
  - Beam divergence: 5 milliradians (standard operation)
  - Digitized every 7.5 cm on return to 140 m range

Styles of Product and Processing

- The EVI lidar provides three types of related information about forest structure:
  - Canopy: Leaf area index, foliage profile, gap probability with height as a function of direction
  - Trunk: Trunk diameters, stem counts, and stand heights
  - Bole: Stem characteristics such as bole length, form factor (taper), curvature (sweep), and defects (CSIRO)
- These parameters allow calculation of
  - Mean DBH (diameter at breast height)
  - Stem count density (stems/ha, stems/m^2)
  - Basal area (m^2/ha)
  - Above-ground biomass (kg/ha) using allometric equations
  - Foliage area volume density profile (m^2 leaf area/m^3 canopy volume)
  - Bole measurements for dimension lumber (CSIRO)
- Each one can be made easier by projecting and reformatting the data in different ways

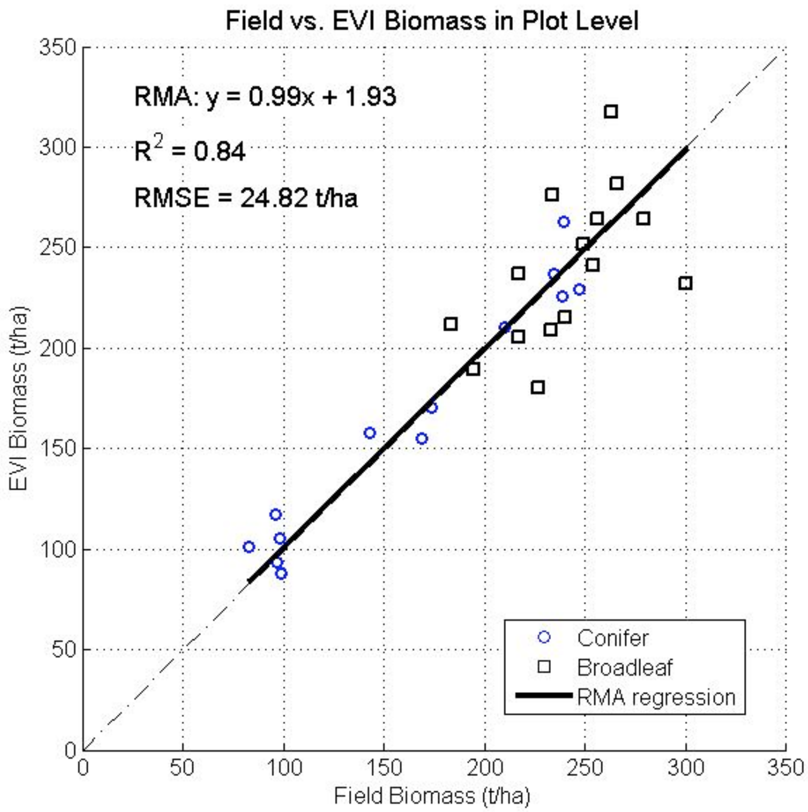
Leaf Area Index (LAI) and Foliage Profile





- LAI and foliage profile are derived from gap probability as a function of height
- Data are averaged within zenith rings at 5° increments
- Profile is derived at “hinge angle”—zenith ring 55–60° where LAI is least sensitive to leaf angle

Biomass Estimation



- With EVI-derived mean diameter and stem count density, we can estimate biomass using allometric equations
- Since EVI can't identify species, we used a pooled allometric equation for the leading one or two dominant tree species in the plot
- R^2 = 0.840 at the plot level
- R^2 = 0.975 at the site level

Conclusions

- Gap Probability-Derived Parameters
  - Pgap with Height
    - Retrieved for 5° zenith rings
    - Foliage area volume density profile is derivative of decrease of Pgap with height
  - LAI and Foliage Profile
    - Competing methods: “Hinge angle” (57.5°) and regression
    - LAIs are somewhat different for the two methods
    - Regression method uses all zenith rings (except 0–5°) so should be more accurate
    - Foliage profiles meet expectations and knowledge of stands
  - Validation of LAI
    - Good agreement with LAI-2000, hemispherical photos, literature values
    - BU LAI-2000 and hemispherical photo retrievals not always reliable
  - Stand Height
    - Retrieved from foliage profile; matches LVIS heights very well

Conclusions, Cont.

- "Find trunks" algorithm
  - Tree diameter (DBH)
    - Retrieves individual measurements well, but with variance
    - Error depends on size and distance from EVI to tree
    - Mean DBH retrieved very well using error-weighted mean
  - Stem count density (trees/m^2 or trees/ha)
    - Retrieved very well
    - Requires correction for occlusion of far stems by near stems
  - Basal area
    - Retrieved well, but with slightly more error as product of two variables (mean DBH and density) measured with error
  - Biomass
    - Uses allometric equations from leading dominant species
    - Retrieved very well using mean DBH weighted by allometric exponent