The AWARE Project:

Overview and Outcomes

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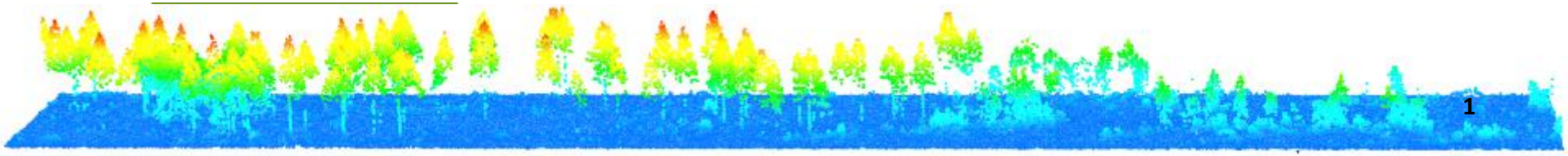
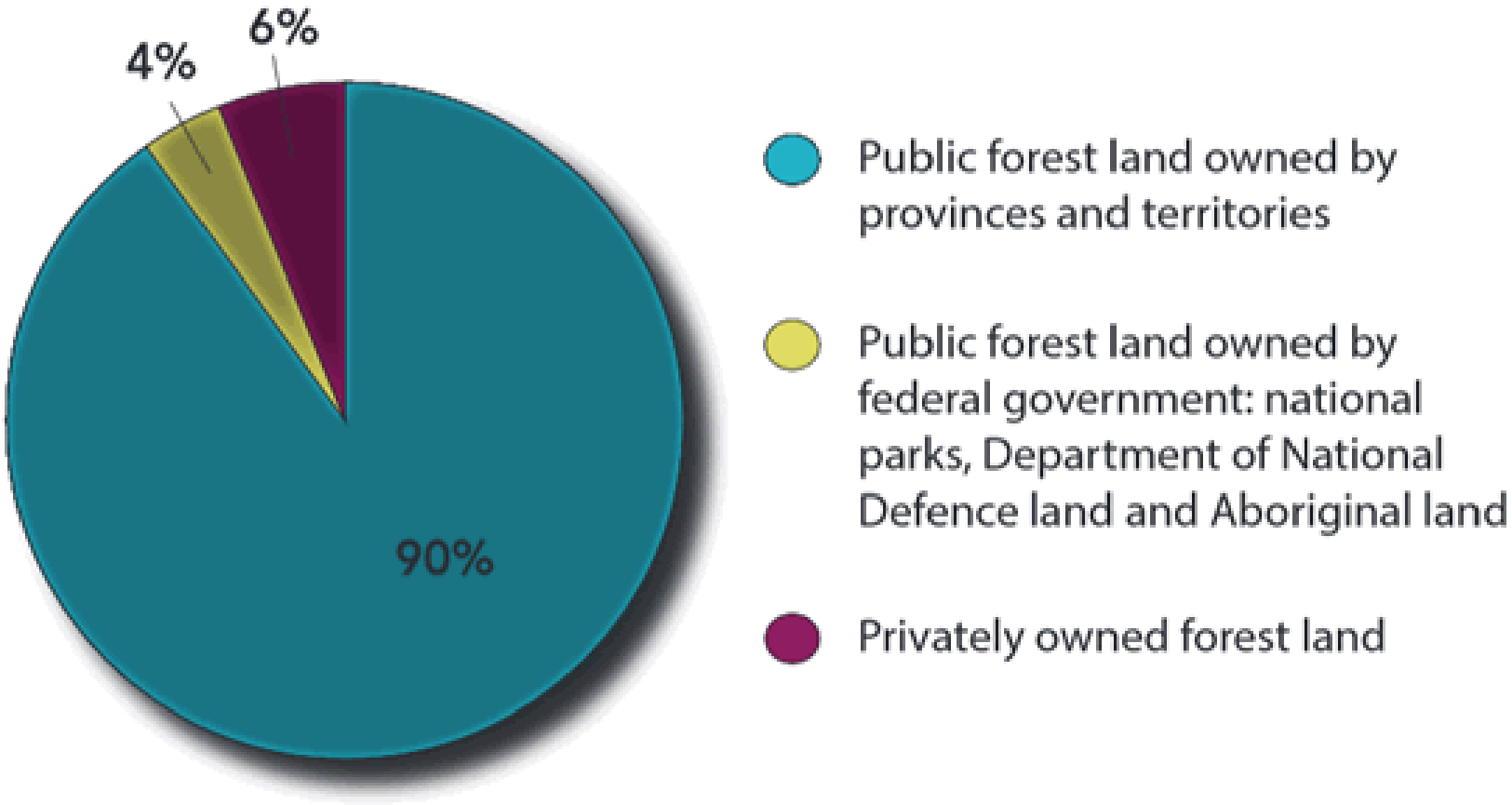
University of British Columbia

CiF eLecture Series September / October 2019



Canada's Forest Sector

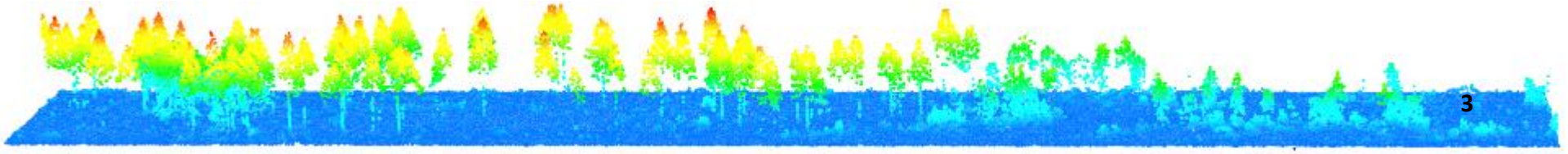


http://www.nrcan.gc.ca/forests/canada/ownership/17495

Canadian Forest Sector

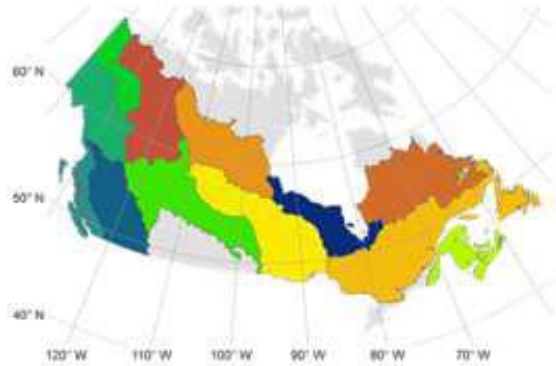
- Industrial Forest Companies and both Provincial and Federal forestry agencies also key roles in forest management decisions under legislation and for public oversight

- As a result industrial companies, provincial and federal agencies have a history of working together to improve forest inventory and Canadian competitiveness

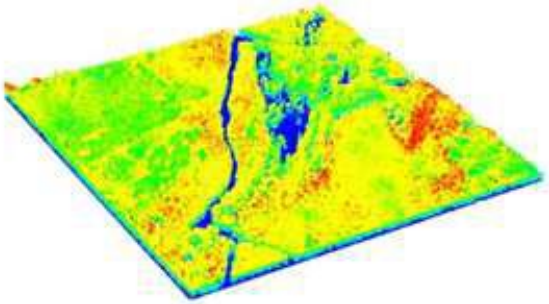


Forest Inventory in Canada occurs at a range of scales from strategic broad scale assessments to operational inventories driving daily decisions

Stratification, Trends and Reporting, Sampling, Hypothesis Generation



National - Regional



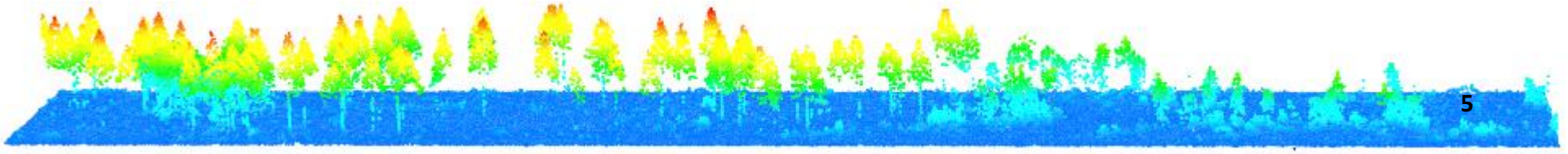
Stand – Landscape

Plot - Tree

Model Validation, Extrapolation and Scaling Up

The Use of Remote Sensing in Forestry Inventory

- Has a long and well established theory in which Canada is recognized as a leader
- Conventionally, 2 or 3 stage sampling approaches has relied on aerial photography as the spatial base however has some issues:
  - Manually intensive
  - Difficult to scale
  - Static representation of the forest resource
- Which is being pulled way beyond its original intent



Appendix 1

Table A-1. VegCAP Contents and Relationships to Oracle Tables

Fields are listed alphabetically

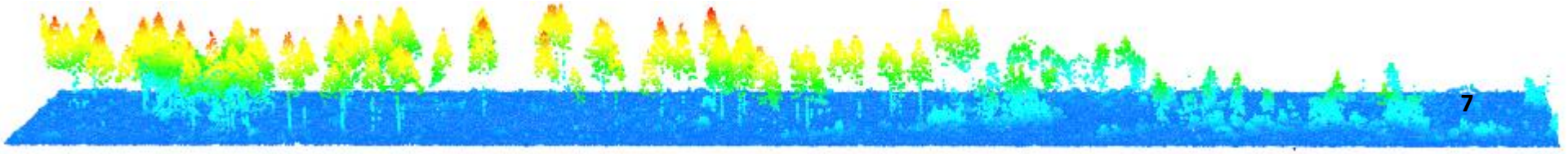
VegCAP Field	VegCAP Table	SDE Oracle Attribute (Field)	Notes	SDE Oracle Sub-Type (Table)
accuracy_cd	Feature_Link	n/a	specific to VegCAP	n/a
ACTIVITY_END_DATE	HISTORY	activity_end_date		resource_inventory_history
ACTIVITY_START_DATE	HISTORY	activity_start_date		resource_inventory_history
ADJOINING_NTS_MAP_NUMBER	HISTORY	adjoining_nts_map_num		vegrpt_polylayer
Adjusted_AGE_Site_Height	LEADING_SPECIES	n/a	not used	n/a
Adjusted_AGE_Site_Height	SECONDARY_SPECIES	n/a	not used	n/a
Adjusted_AGE_Top_Height	LEADING_SPECIES	n/a	not used	n/a
Adjusted_AGE_Top_Height	SECONDARY_SPECIES	n/a	not used	n/a
Adjusted_ALPINE_DESIGNATION	POLYGON	adj_alpine_designation	not used	veg_vegetation_cover_polygon
Adjusted_BASAL_AREA	LAYER	adj_basal_area	not used	tree_cover_layer
Adjusted_BRYOID_COVER_PERCENT	NON_TREE	n/a	not used	n/a
Adjusted_COMP1	LAND_COVER_COMPONENTS	n/a	not used	n/a
Adjusted_COMP2	LAND_COVER_COMPONENTS	n/a	not used	n/a
Adjusted_COMP3	LAND_COVER_COMPONENTS	n/a	not used	n/a
Adjusted_CROWN_CLOSURE	LAYER	n/a	not used	n/a
Adjusted_Density_VRI_LIVE_STEMS_PER_HA	LAYER	adj_vri_live_stem_ha	not used	tree_cover_layer
Adjusted_ESTIMATED_SITE_INDEX	LAYER	n/a	not used	n/a
Adjusted_Gross_Volume	SPECIES	n/a	not used	n/a
Adjusted_HERB_COVER_PERCENT	NON_TREE	n/a	not used	n/a
Adjusted_HERB_COVER_TYPE	NON_TREE	n/a	not used	n/a
Adjusted_Lorey_HEIGHT	LEADING_SPECIES	n/a	not used	n/a
Adjusted_Lorey_HEIGHT	SECONDARY_SPECIES	n/a	not used	n/a
Adjusted_MEAN_QUADRATIC_DIAM_PRI_UTIL_LVL	LAYER	n/a	not used	n/a
Adjusted_MEAN_QUADRATIC_DIAM_SEC_UTIL_LVL	LAYER	n/a	not used	n/a
Adjusted_Net_Volume	SPECIES	n/a	not used	n/a
Adjusted_NON_VEG_COVER_TYPE	NON_VEG	n/a	not used	n/a
Adjusted_PERCENT1	LAND_COVER_COMPONENTS	n/a	not used	n/a
Adjusted_PERCENT2	LAND_COVER_COMPONENTS	n/a	not used	n/a
Adjusted_PERCENT3	LAND_COVER_COMPONENTS	n/a	not used	n/a
Adjusted_Random_Tree_AGE	LEADING_SPECIES	n/a	not used	n/a
Adjusted_Random_Tree_AGE	SECONDARY_SPECIES	n/a	not used	n/a
Adjusted_Random_Tree_HEIGHT	LEADING_SPECIES	n/a	not used	n/a
Adjusted_Random_Tree_HEIGHT	SECONDARY_SPECIES	n/a	not used	n/a
Adjusted_SHRUB_CROWN_CLOSURE	NON_TREE	n/a	not used	n/a
Adjusted_SHRUB_HEIGHT	NON_TREE	adj_shrub_height	not used	vegetative_cover
Adjusted_Site_HEIGHT	LEADING_SPECIES	adj_height	not used	tree_species
Adjusted_Site_HEIGHT	SECONDARY_SPECIES	adj_height	not used	tree_species
Adjusted_SITE_POSITION_MESO	POLYGON	adj_site_position_meso	not used	veg_vegetation_cover_polygon
Adjusted_SNAG_Freq_VRI_DEAD_STEMS_PER_HA	LAYER	adj_dead_stem_ha	not used	tree_cover_layer
Adjusted_SOIL_MOIST1	LAND_COVER_COMPONENTS	n/a	not used	n/a
Adjusted_SOIL_MOIST1	LAND_COVER_COMPONENTS	n/a	not used	n/a
Adjusted_SOIL_MOIST2	LAND_COVER_COMPONENTS	n/a	not used	n/a
Adjusted_SOIL_MOIST2	LAND_COVER_COMPONENTS	n/a	not used	n/a
Adjusted_SOIL_MOIST3	LAND_COVER_COMPONENTS	n/a	not used	n/a
Adjusted_SOIL_MOIST3	LAND_COVER_COMPONENTS	n/a	not used	n/a
Adjusted_SOIL_NUTRIENT_REGIME	POLYGON	adj_soil_nutrient_regime	not used	veg_vegetation_cover_polygon
Adjusted_SPECIES_CD	SPECIES	n/a	not used	n/a
Adjusted_SPECIES_PERCENT	SPECIES	n/a	not used	n/a
Adjusted_Top_HEIGHT	LEADING_SPECIES	n/a	not used	n/a
Adjusted_Top_HEIGHT	SECONDARY_SPECIES	n/a	not used	n/a
Adjusted_VERTICAL_COMPLEXITY	LAYER	n/a	not used	n/a

Advanced Remote Sensing

- Light Detection and Ranging (LiDAR) is a relatively new technology which is being actively adopted by forest companies / agencies globally

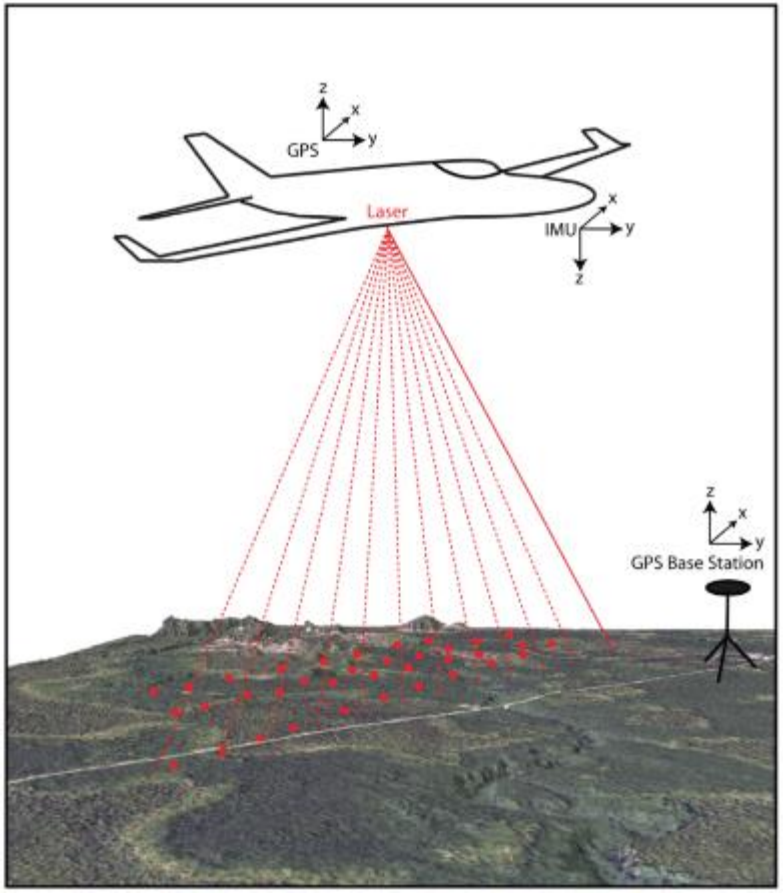
- Can we acquired from the ground, plane or satellite. Aircraft most common – known as Airborne laser scanning (ALS)

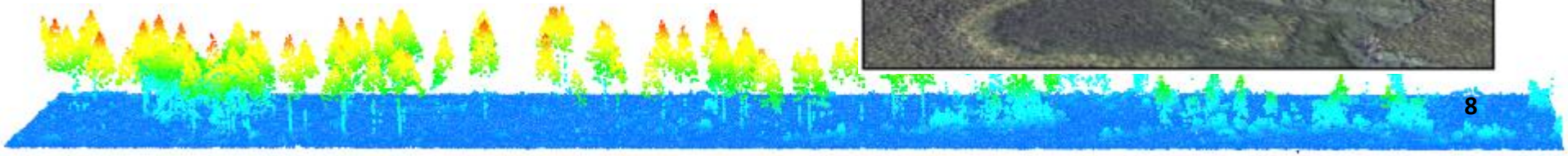
- In addition, high spatial resolution imagery, acquired from satellite, aircraft, or drones is also being processed in such a way as to allow 3D representation of forest information.



LIDAR / ALS

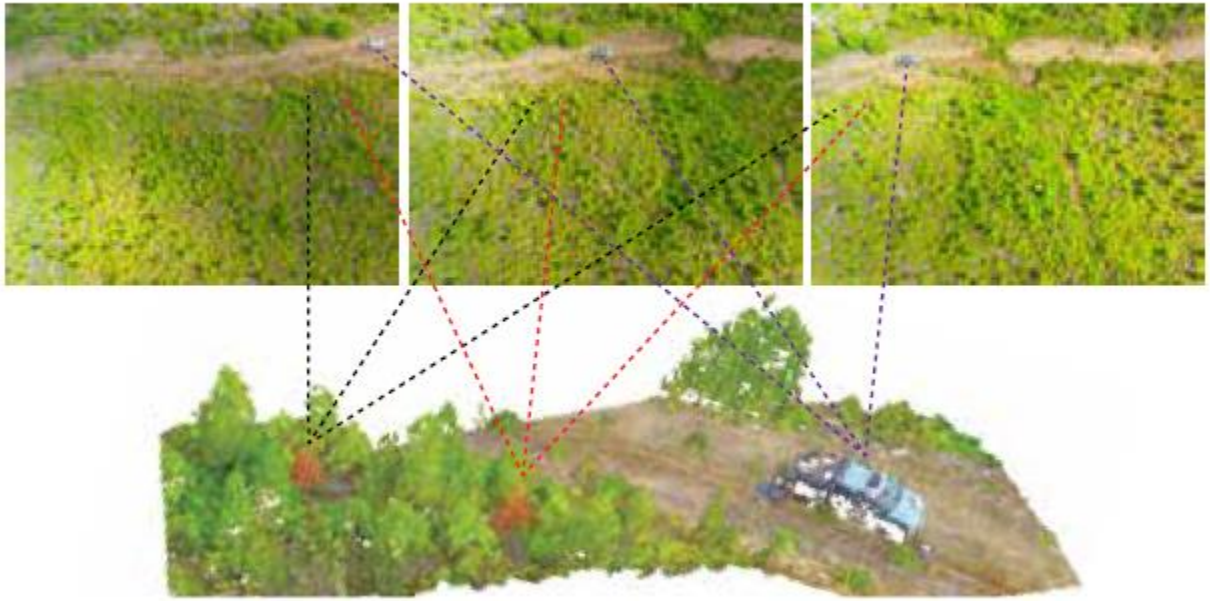
- Precise GPS location of aircraft required (x_p, y_p, z_p)
- Precise inertial measurement unit (IMU) of aircraft required (pitch, roll , and yaw)

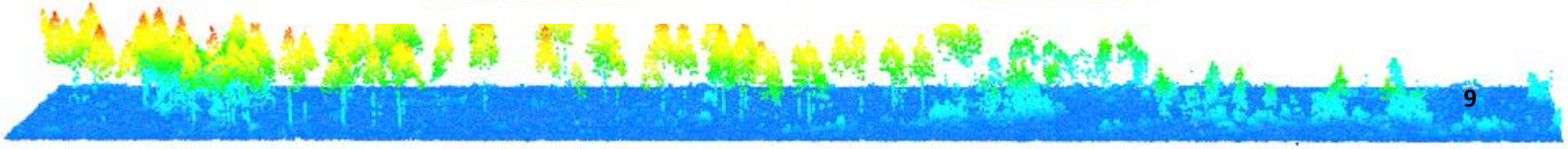




Digital Aerial Photogrammetry

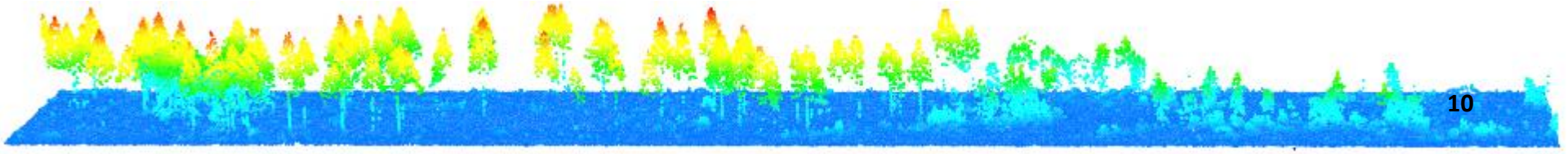
- Digital manipulation of many aerial imagers with high degree of overlap to produce a 3D point cloud
- Images can be from existing aerial campaigns or drones



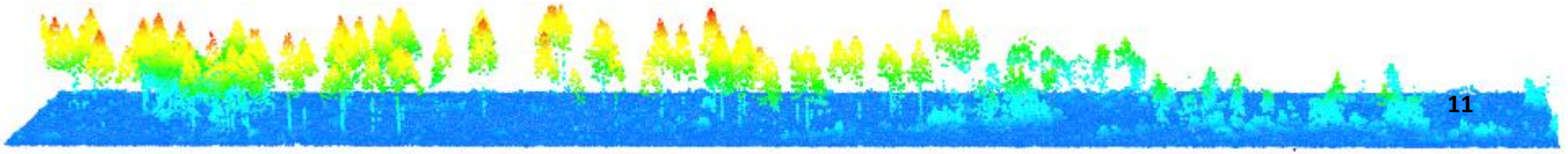


Some Early Canadian Successes

- Demonstration of LIDAR Applications for forestry with the forest industry in Ontario and Alberta amongst others
- Wet Area Mapping initiative using large areas of LIDAR coverage in Alberta



- In 2010/11 the Federal Government Research agency (NSERC) with advice from the Canadian Wood Fiber Centre / Canadian Forest Service and FP-Innovations indicted advanced remote sensing of wood properties a research priority



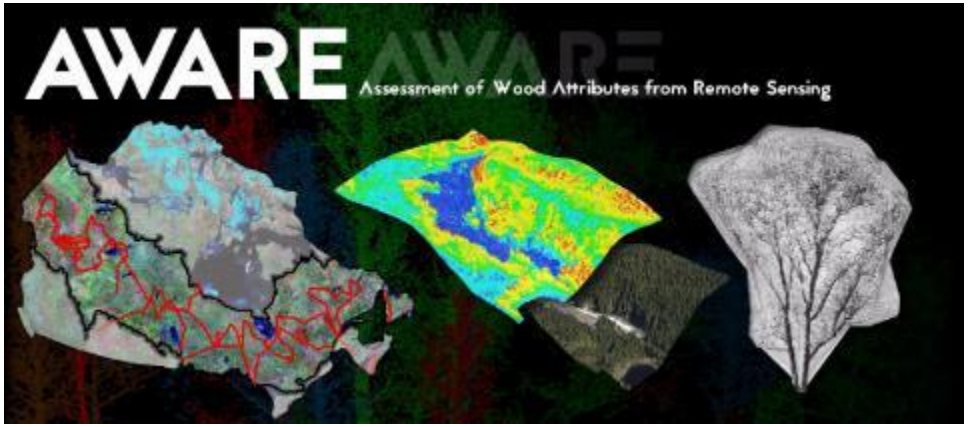
AWARE

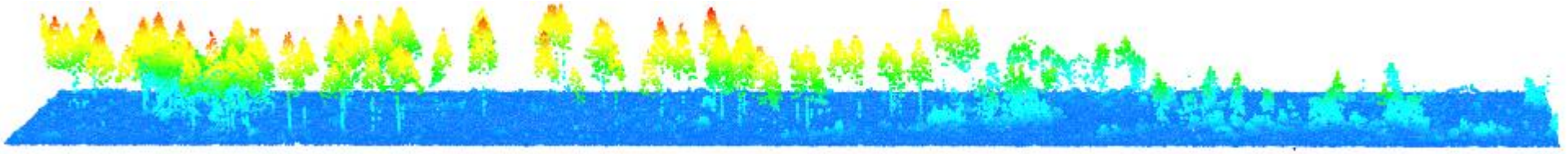
AWARE = **A**ssessment of **W**ood **A**ttributes from **RE**mote Sensing

NSERC Collaborative Research and Development 5 year project

Collaboration between Industry and Universities with Provincial / Federal support

In 5th year.





FPInnovations

West Fraser

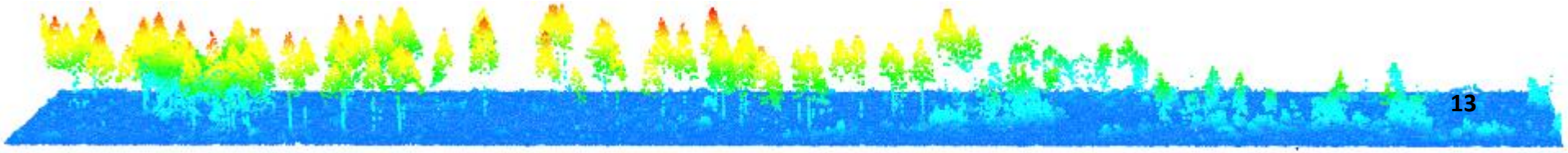
Kruger
Publication
Papers

RYAM
Forest
Management

IRVING
WOODLANDS DIVISION

LECOURS LUMBER
CO. LIMITED

columbia
FOREST PRODUCTS
Innovating Responsibly



a place of mind
THE UNIVERSITY OF BRITISH COLUMBIA

UNIVERSITÉ DE SHERBROOKE

UNB
EST. 1785
FREDERICTON • SAINT JOHN

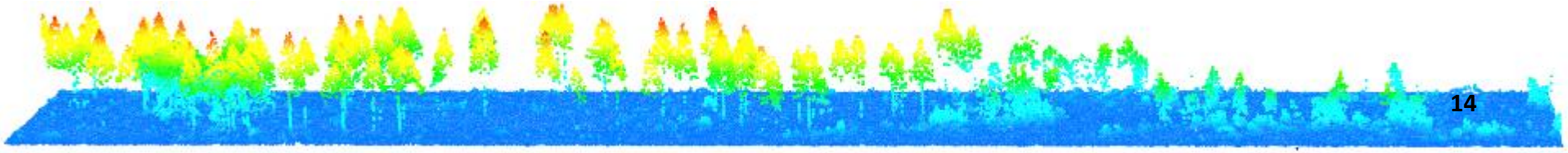
UQÀM | Université du Québec à Montréal

Queen's UNIVERSITY

NIPISSING UNIVERSITY

UNIVERSITY OF TORONTO

UNIVERSITÉ LAVAL



Ontario

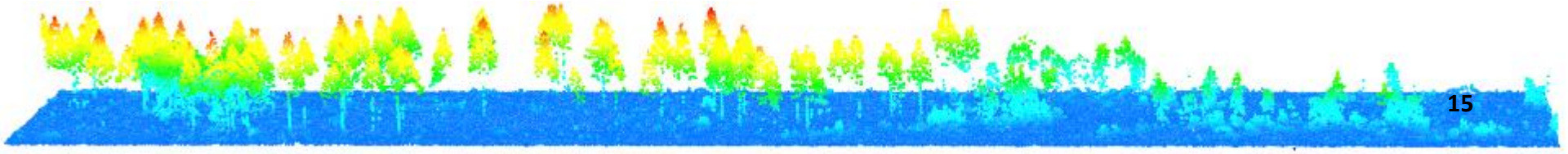
Alberta
Environment and Sustainable Resource Development

British Columbia

New Nouveau Brunswick
CANADA

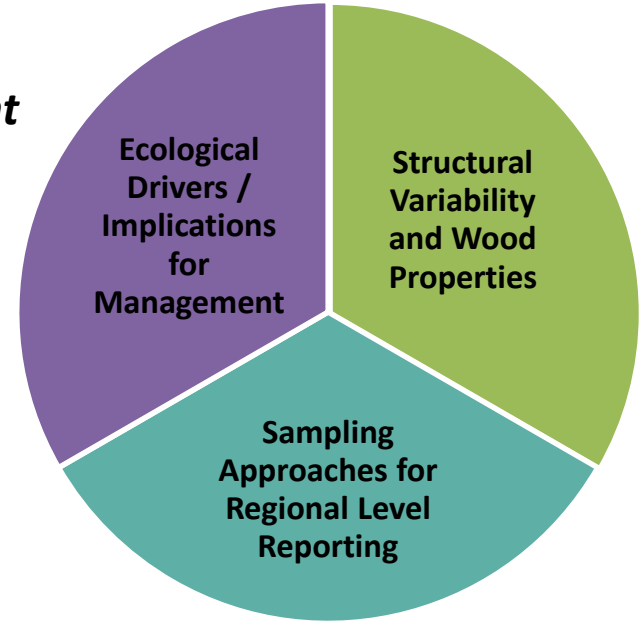
Ministère des Ressources naturelles et de la Faune
Québec
Direction des inventaires forestiers

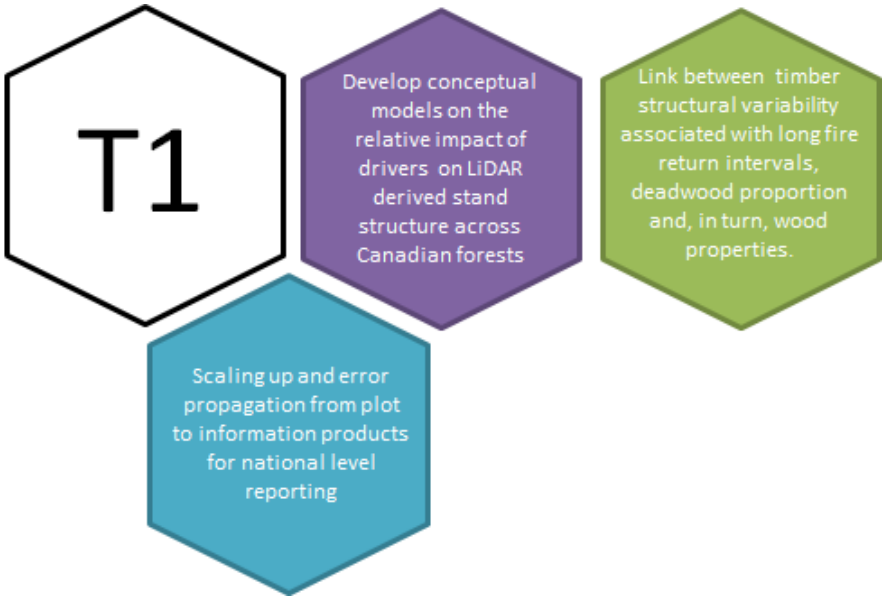
Newfoundland Labrador
CANADA

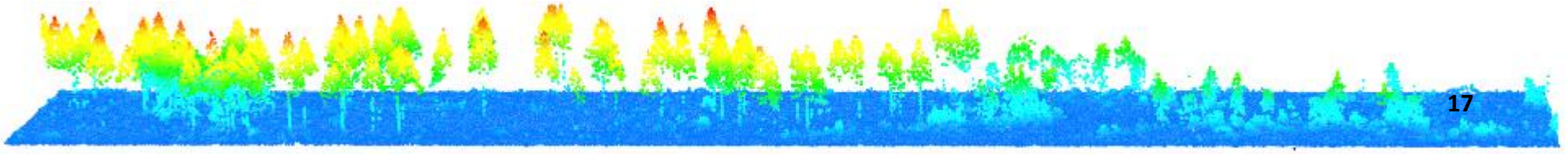



Slave Lake
Corner Brook
Hearst
Gordon Cosens
Black Brook
Petawawa

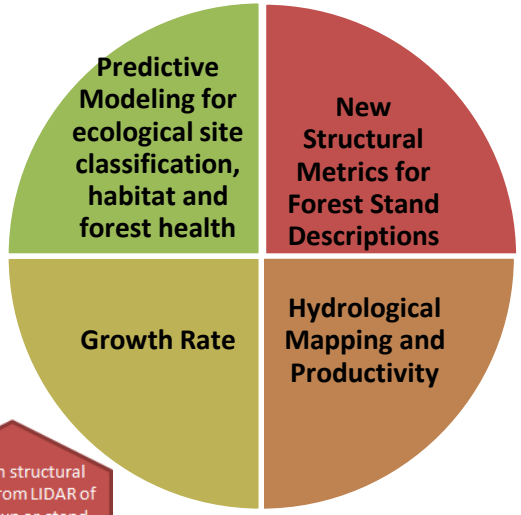
Theme 1: What is the relative impact of ecological drivers such as disturbance, productivity, management practices, and species composition on broad-scale variations in stand structure and wood properties across Canadian forests and how can these be scaled up regionally ?





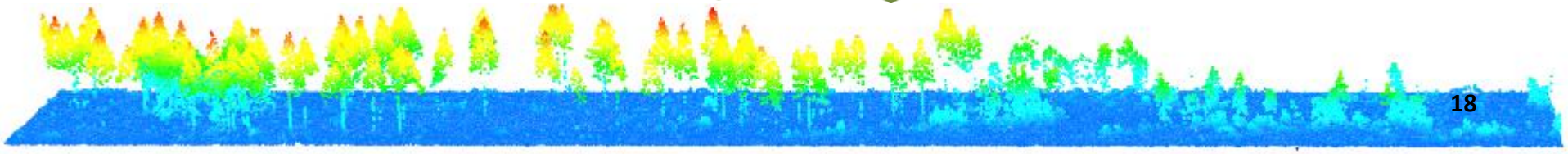


Theme 2: How can advanced remote sensing technologies improve stand-level attribute estimation for strategic forest management?

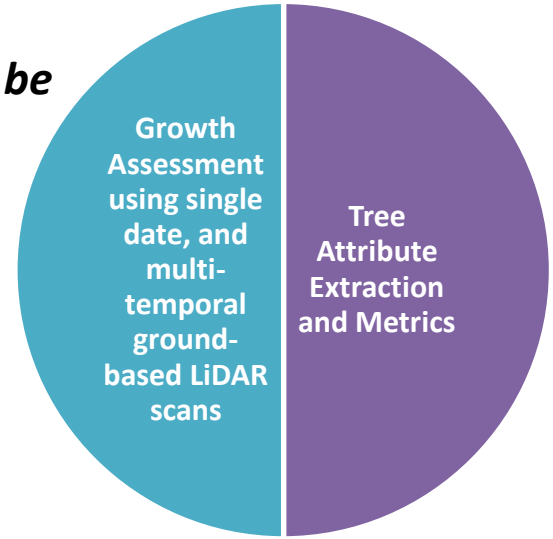


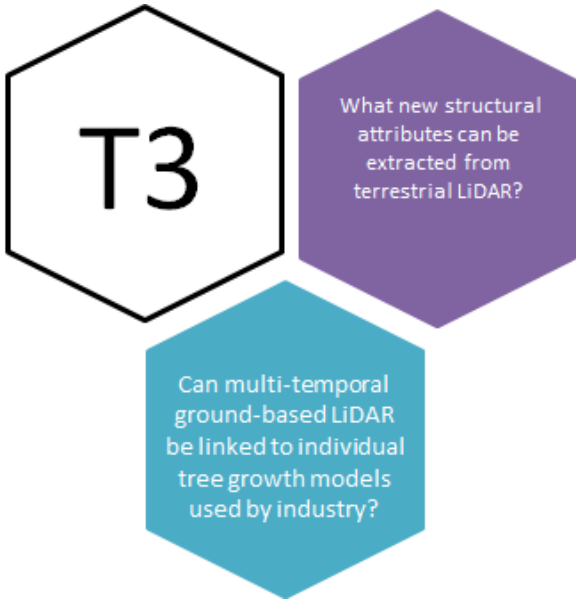
T2

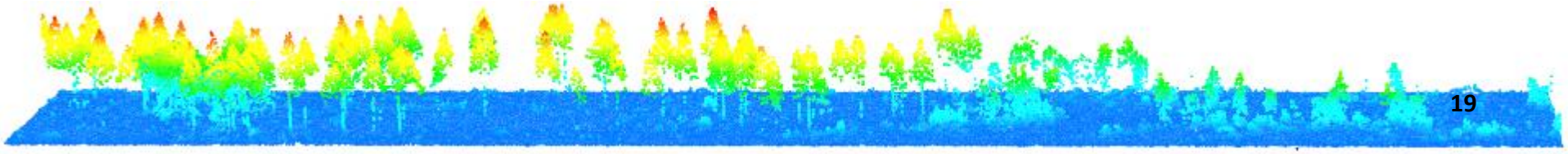
- What new LiDAR stand structure metrics can be linked to stem characteristics such as lumber grade and log size class ?
- How well do LIDAR metrics developed in the Eastern mixedwood Boreal forests transfer to Western Boreal forest types ?
- What LiDAR metrics can be derived from full waveform and discrete airborne data and what is their transferability across sites ?
- How can LIDAR be used to improve pre-harvest ground verification approaches and assess optimum year of thinning ?
- How can ALS LiDAR be used to assess product mix based on stem class distribution in pine dominated stands ?
- How can structural metrics from LIDAR of tree crown or stand canopies be used to predict wood fibre properties ?
- What hydrologic indicators can be derived from a LiDAR-DEM to support land classification schemes relevant for forest management ?
- How can LiDAR terrain indices be combined with structural and climate data to derive new productivity / site classification schemes?
- How can SGM techniques be used, when paired with existing LiDAR terrain models, to predict forest stand growth ?
- How can multi-temporal LiDAR be used to predict height growth and linked into growth and yield models?
- Can we improve forest growth projections with LiDAR-enhanced forest inventory data?
- What is the impact of changing site conditions on timber and wood fibre quality over time?
- How can airborne LIDAR and optical imagery be used to augment conventional forest health surveys?
- What is the best approach to map new "value-based" forest attributes combining conventional forest inventory and LiDAR data?
- What landscape level ecosystem goods and service values can be developed with airborne LiDAR data?
- How can forest attributes derived from multi-resolution remote sensing data be used to conduct habitat assessment?



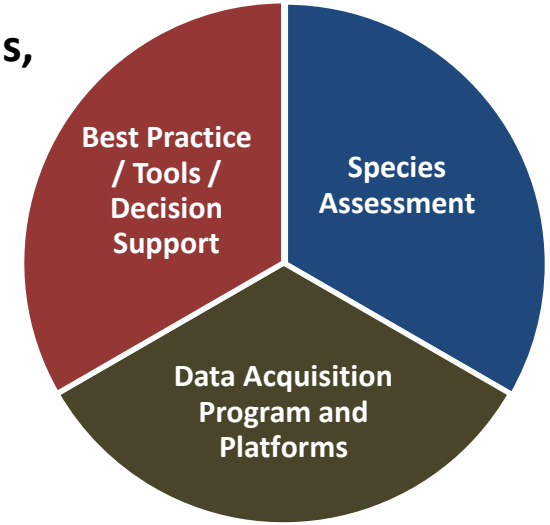
Theme 3: What individual tree attributes can be accurately measured from ground-based LiDAR and how can this data be used to scale-up and validate stand level assessments?







Cross-Cutting Theme: Data Acquisition, Modelling, Standards, and Development of Generic Transferable Tools



CC

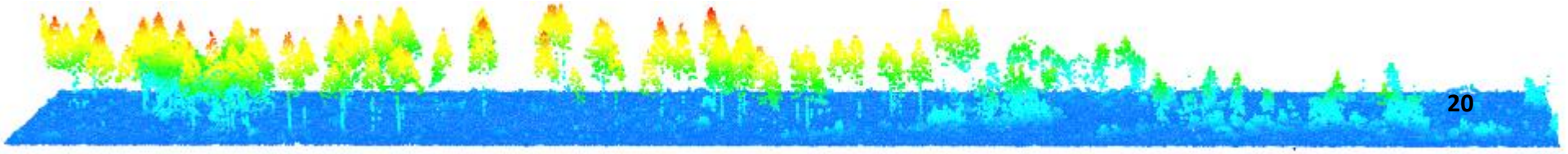
How can LIDAR be used in combination with imagery to predict species groups and / or individual species?

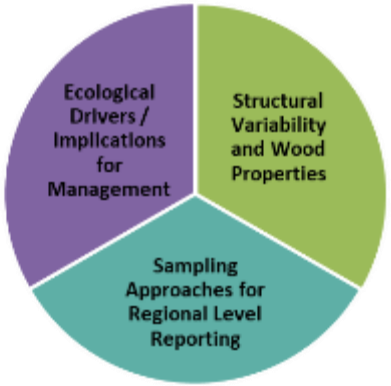
Does contextual data provide additional predictive power to species models ?

How generalizable are methods of species prediction across additional core sites

Can UAV technologies provide consistent and accurate remote sensing data for Enhanced Forest Inventory?

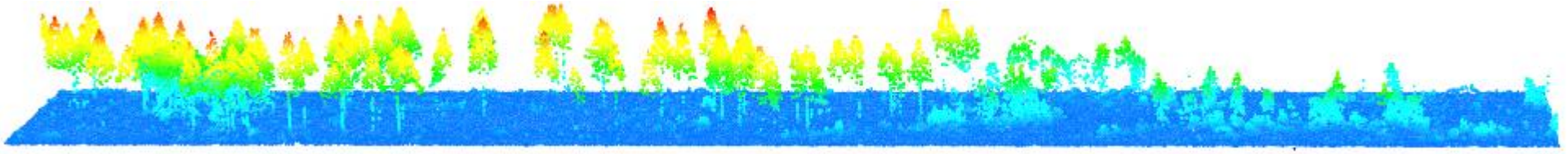
What demonstration datasets, and best practice guidelines can be developed to ensure results from AWARE are well communicated to the industry?



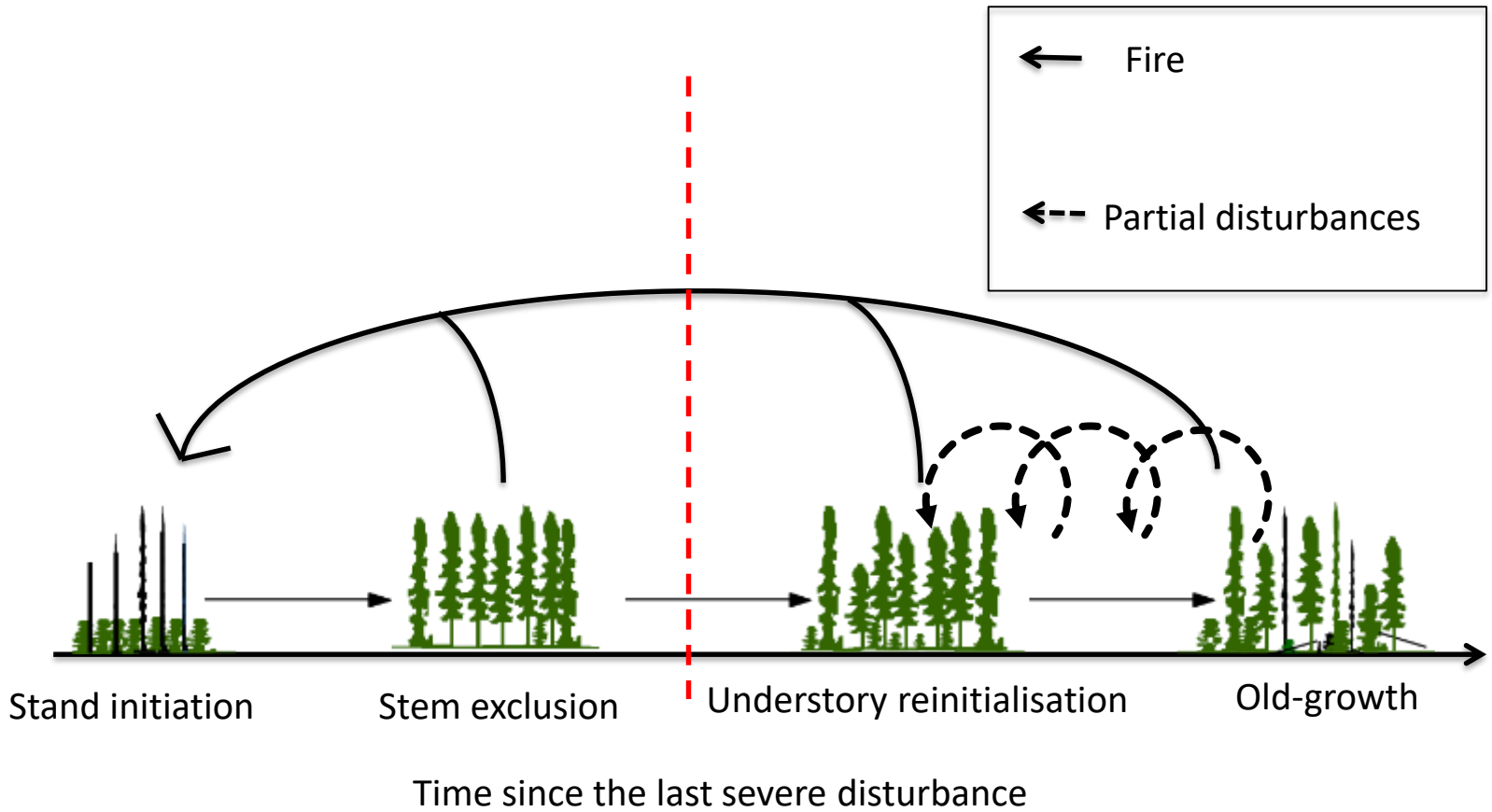


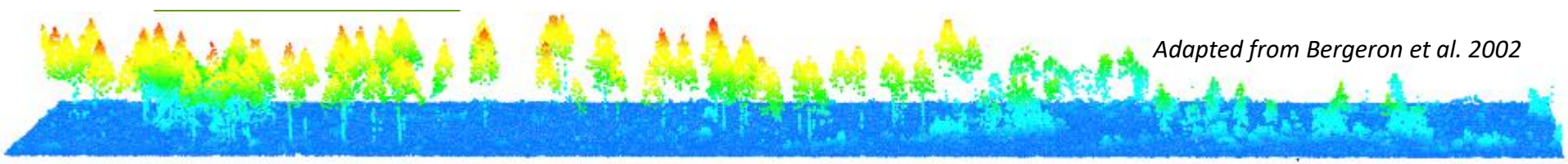
Kaysandra Waldron (Laval)

STRUCTURE AS A DRIVER OF WOOD PROPERTIES

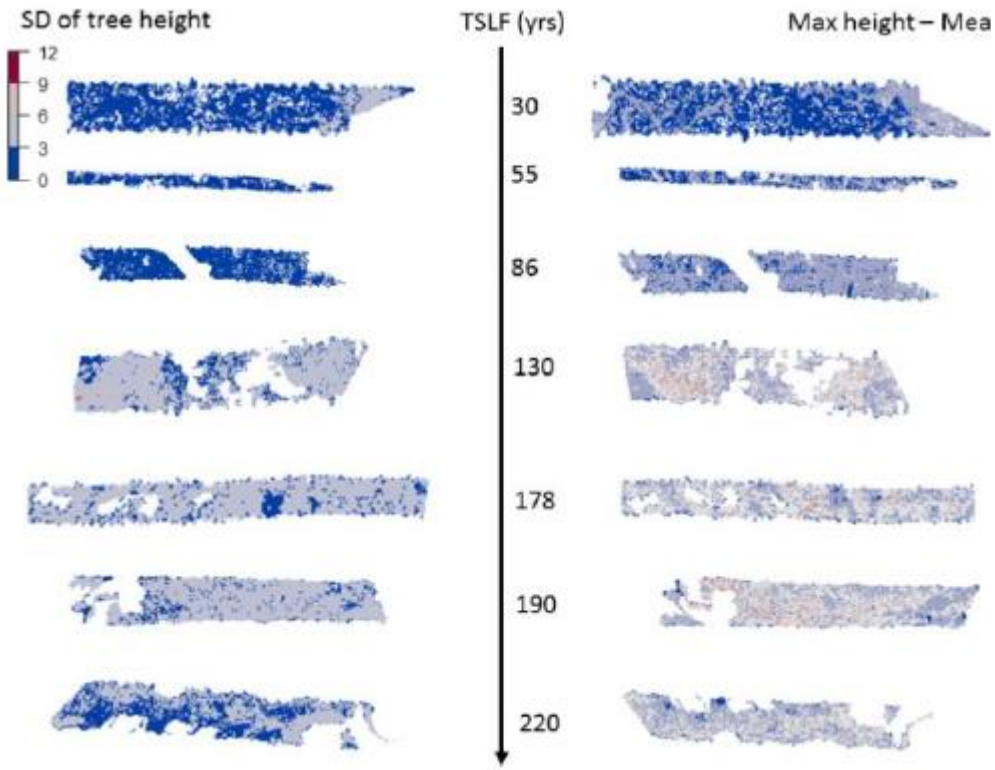


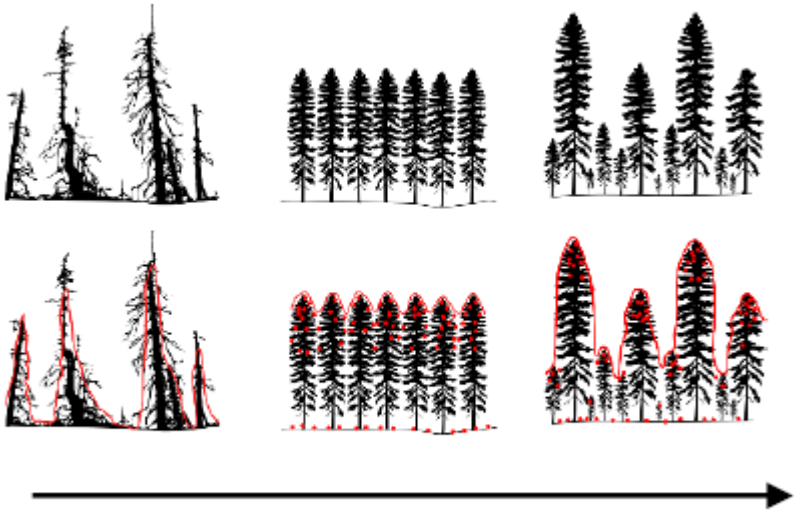
Fire as a driver of stand structure

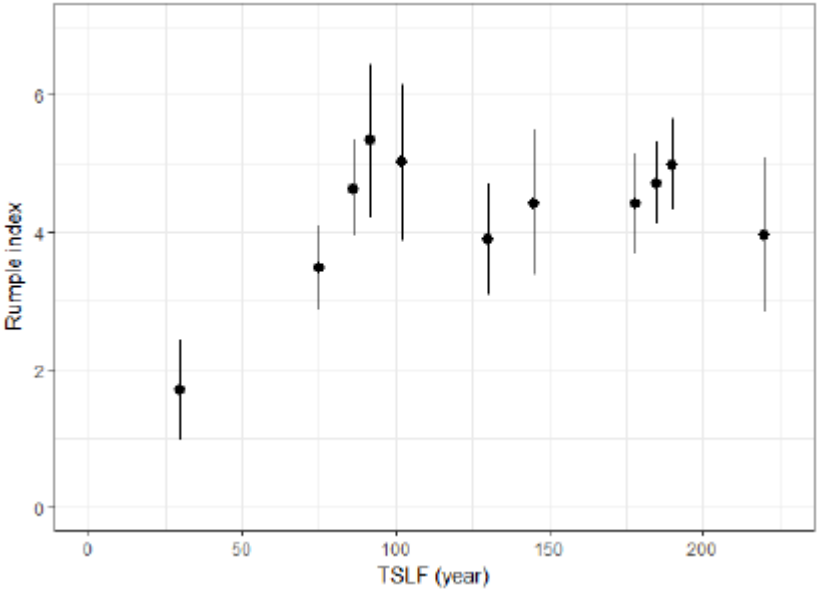


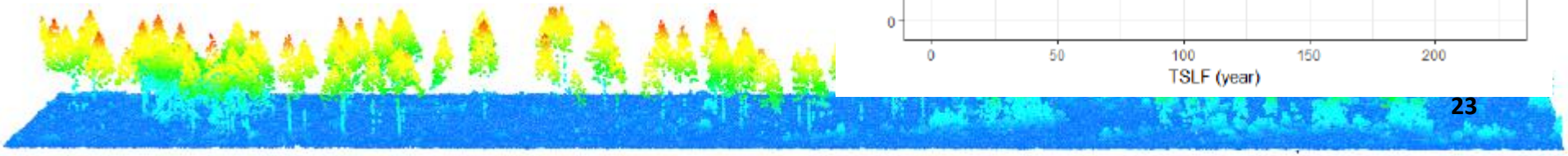


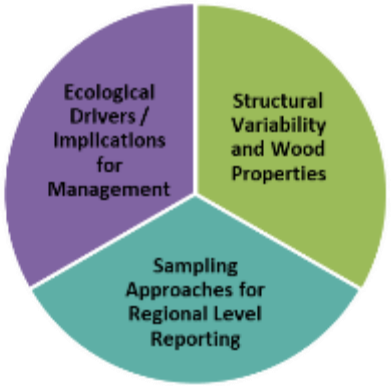
Adapted from Bergeron et al. 2002


SD of tree height
12
9
6
3
0
TSLF (yrs)
30
55
86
130
178
190
220
Max height – Mea



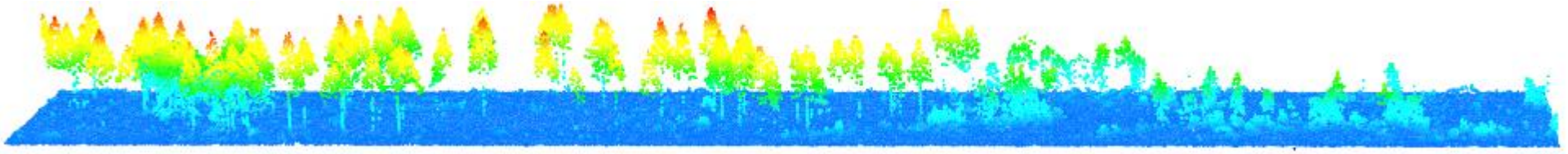

Rumple index
0
2
4
6
0
50
100
150
200
TSLF (year)

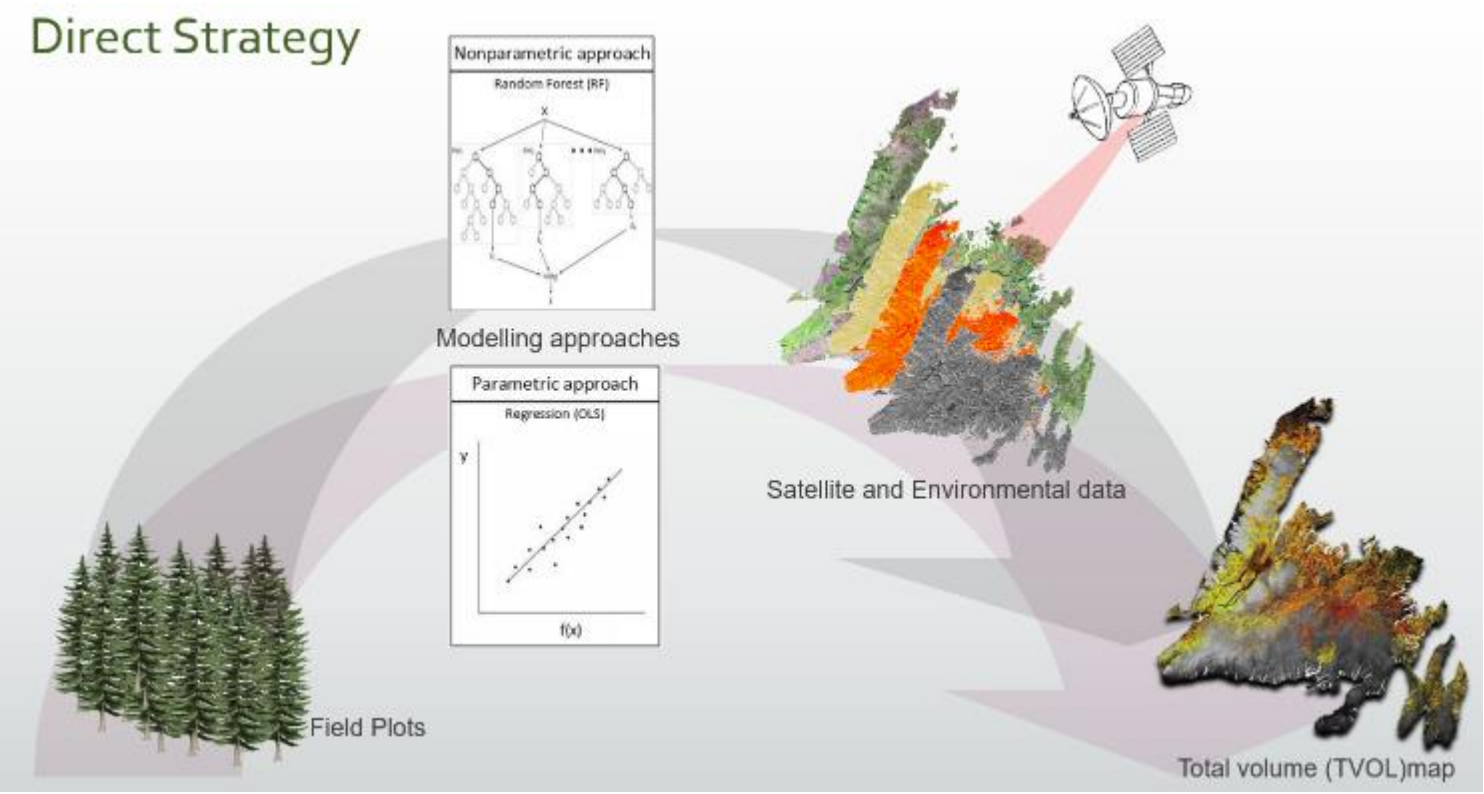


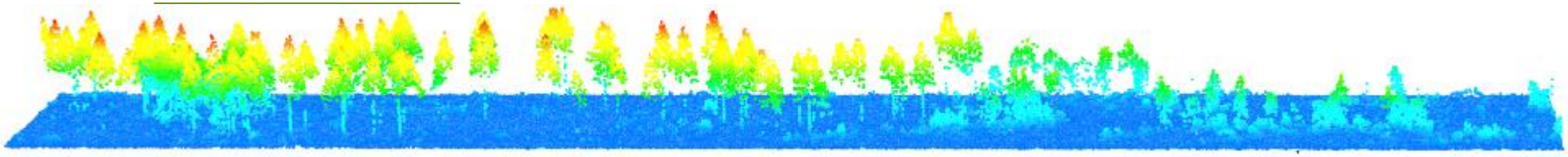


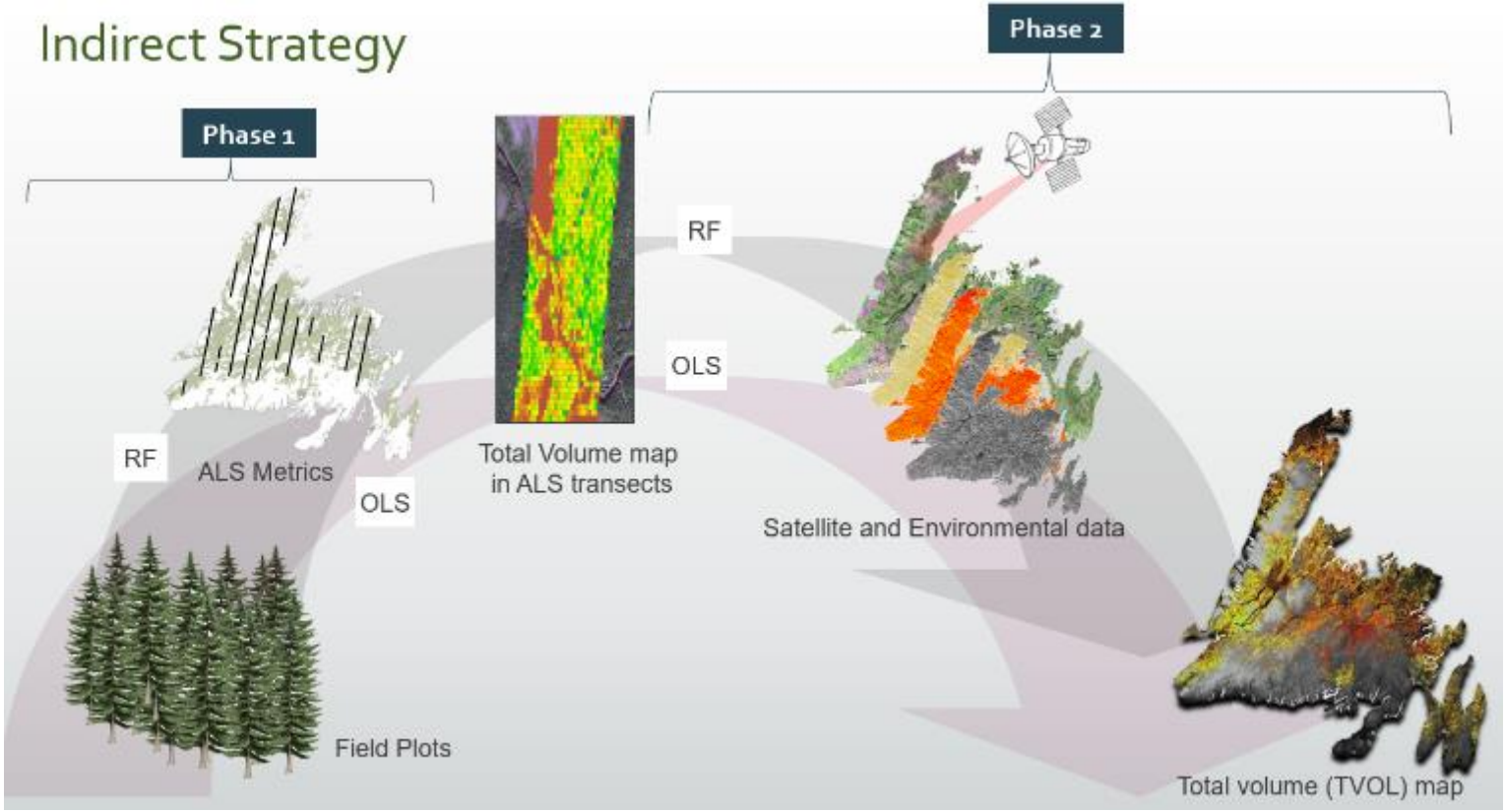
Mélodie Bujold (Sherbrooke)

SAMPLING STRATEGIES FROM LIDAR TO BROADER AREAS

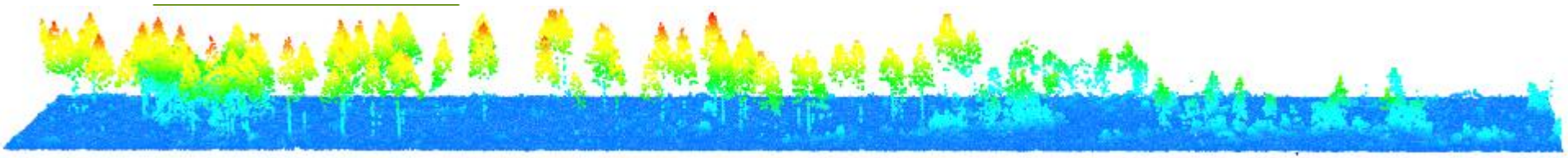



Direct Strategy
Nonparametric approach
Random Forest (RF)
Modelling approaches
Parametric approach
Regression (OLS)
y
f(x)
Satellite and Environmental data
Field Plots
Total volume (TVOL)map





RF: Random forest **OLS: Ordinary least square regression**



Indirect approach more accurate for prediction of key attributes

Luther, J.E.; Fournier, R.A.; van Lier, O.R.; Bujold, M. Extending ALS-Based Mapping of Forest Attributes with Medium Resolution Satellite and Environmental Data. *Remote Sens.* **2019**, *11*, 1092.

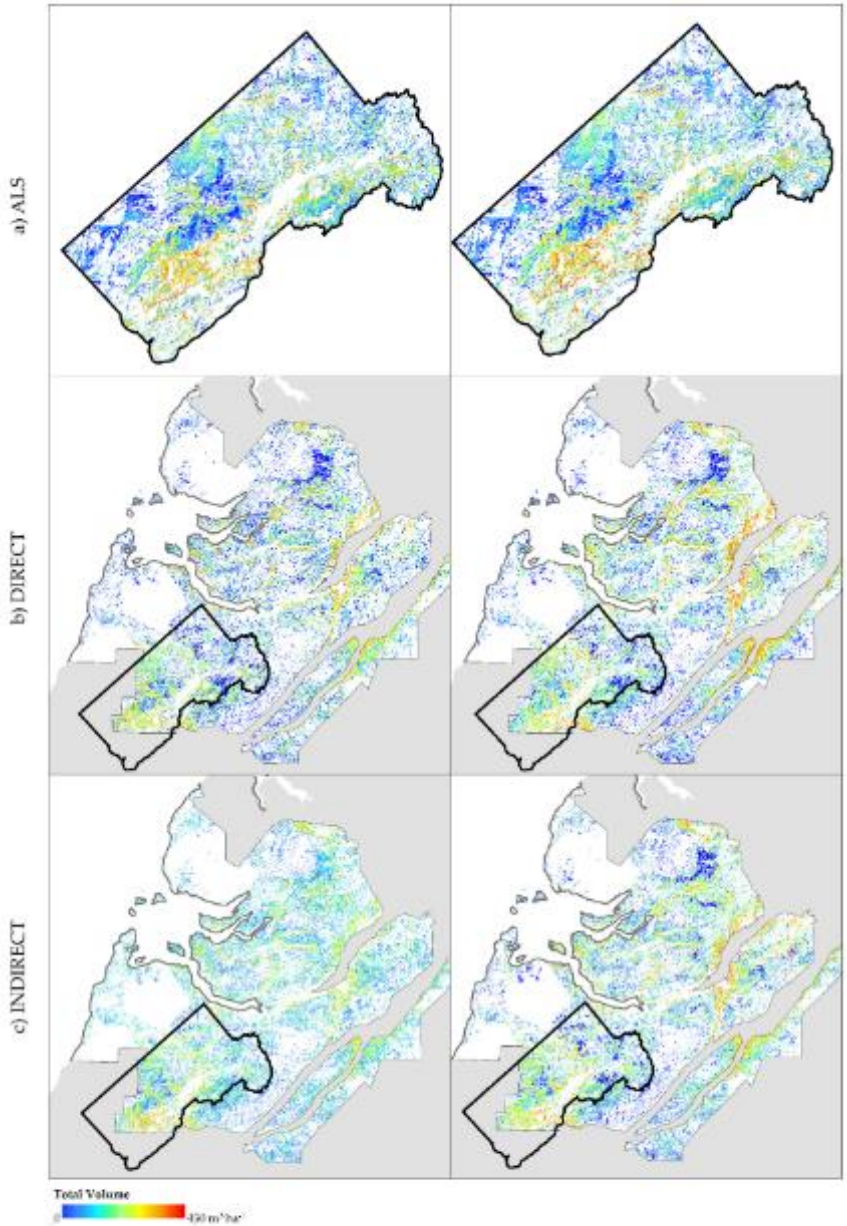
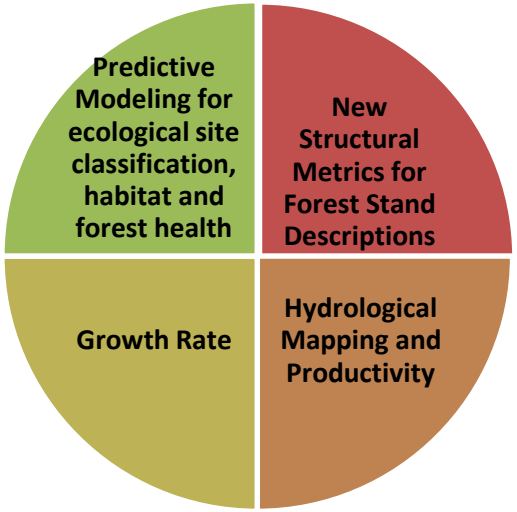
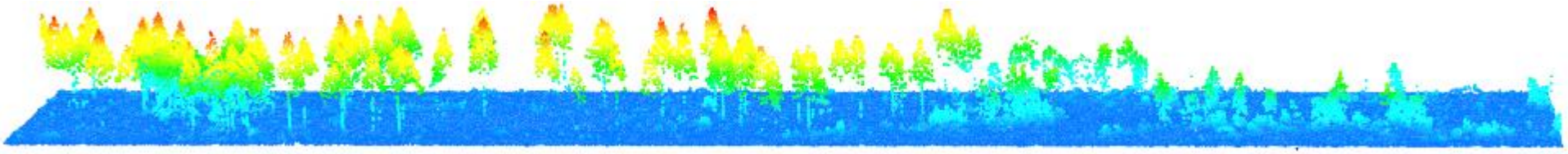


Figure 4. Illustrative maps of total volume (m^3 ha^{-1}) predicted with (**a**) ALS, (**b**) direct and (**c**) indirect modeling approaches. The corresponding ALS area is outlined in black.



Karin van Ewijk (Queens)

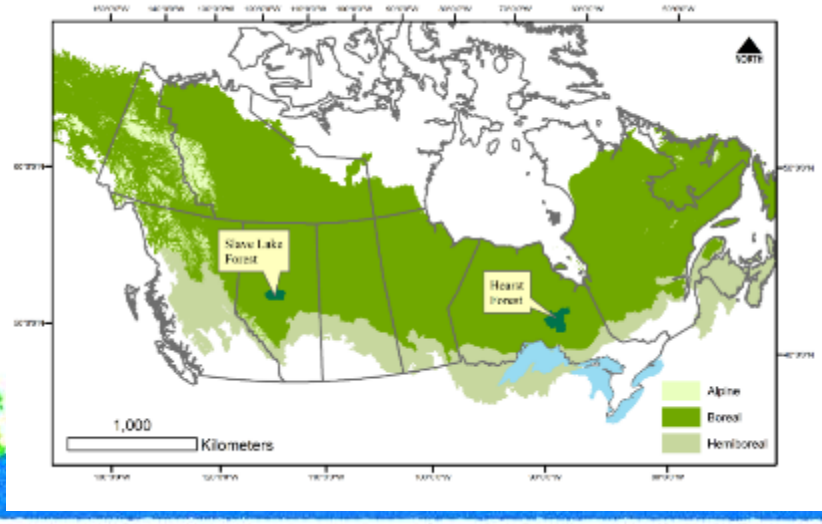
MODEL TRANSFERABILITY

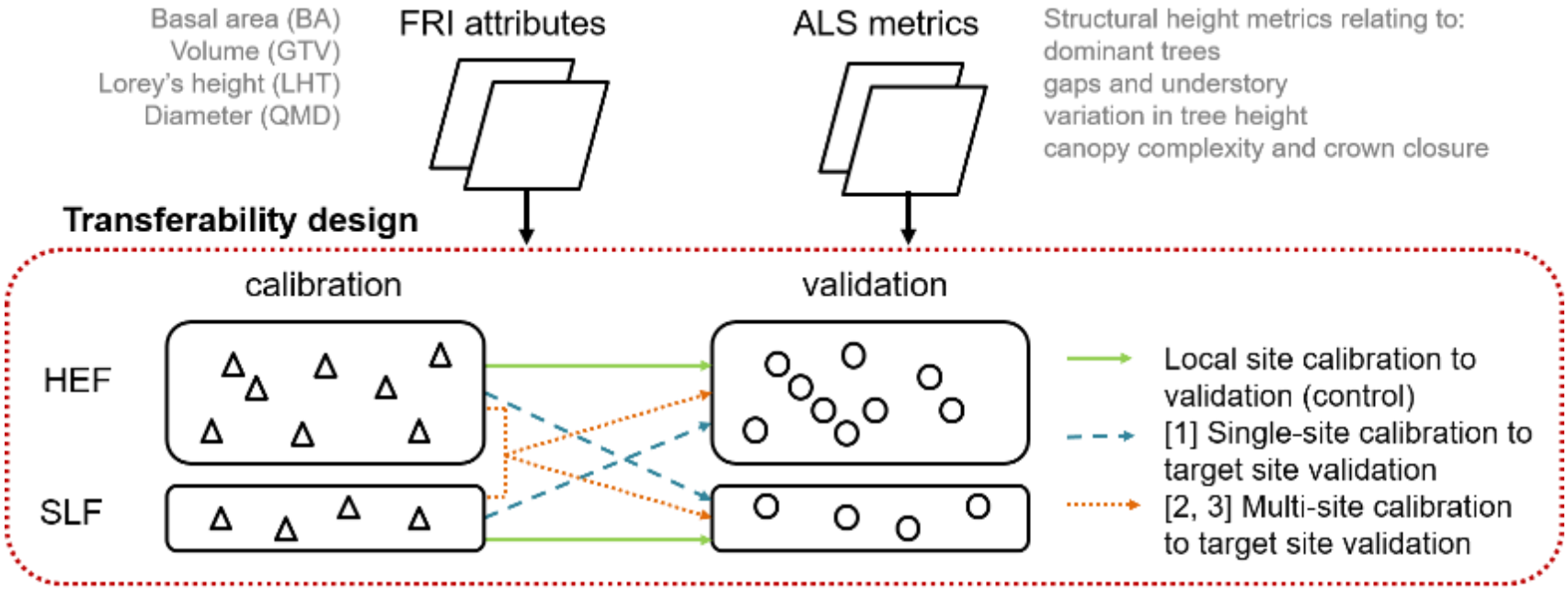


Transferability of LIDAR models

Photo credit: CWFC, 2010

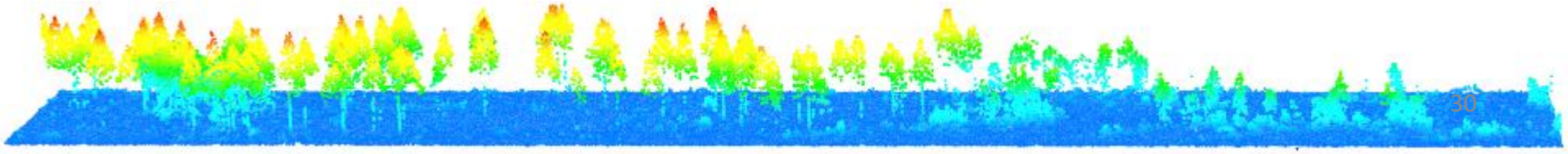
Photo credit: SLF field crew, 2016





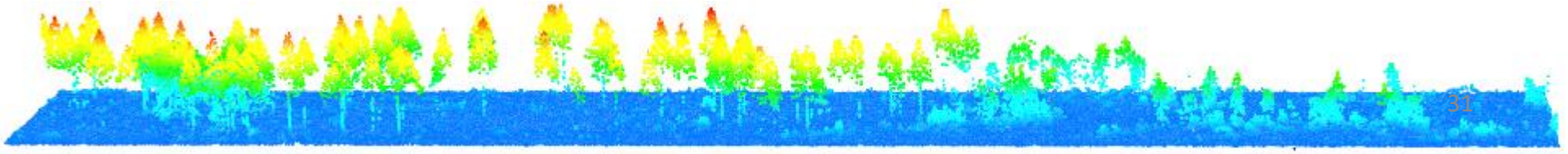
Modeling approaches
Parametric (OLS)
Non-parametric (RF)

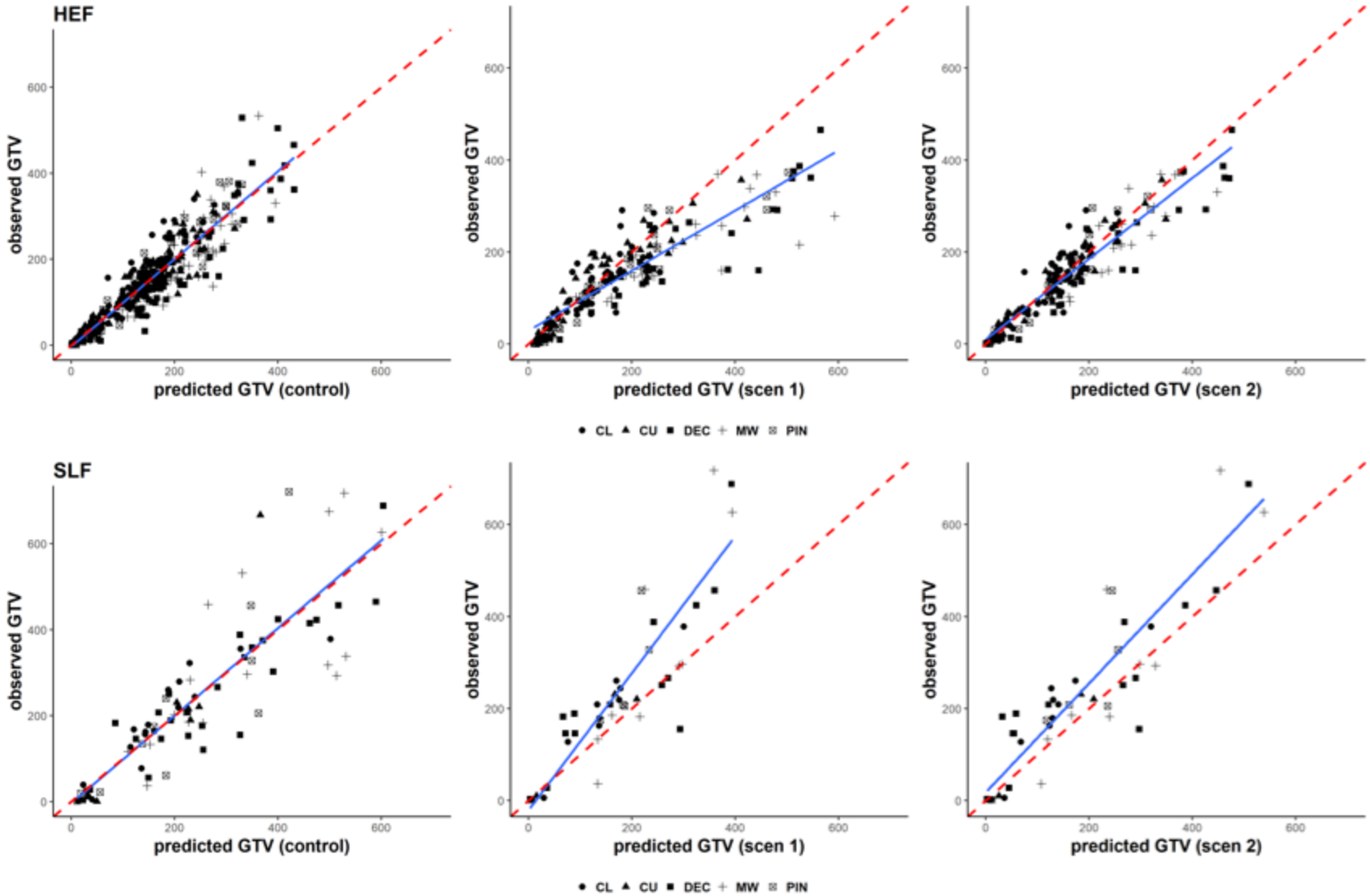
Evaluation criteria
Model output: RMSE (%), Bias (%), R^2; Equivalence test

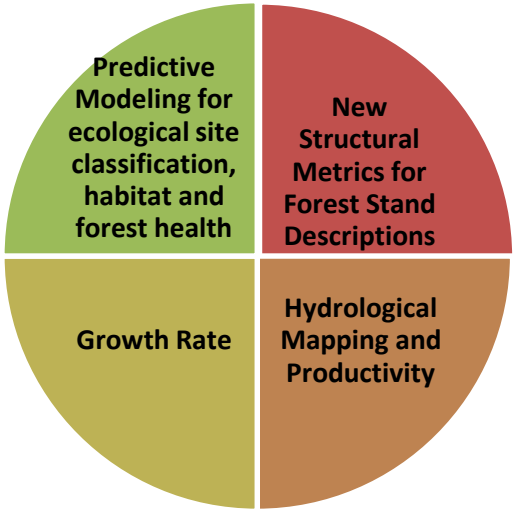


- The best transferability scenarios were within ± 5% relative error and an increase 10% in relative bias.
- The worse were a 23% increase in error and 29% increase in bias
- The worse thing to do is a straight transfer; combining plots from both models was more successful.

- Overall models of height (such as Lorey's height) were the most accurately transferred, whereas volume and diameter were the poorest.

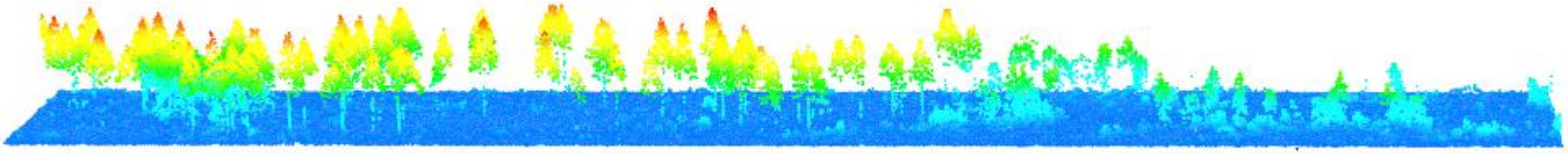



HEF
observed GTV
predicted GTV (control)
predicted GTV (scen 1)
predicted GTV (scen 2)
CL CU DEC MW PIN
SLF
observed GTV
predicted GTV (control)
predicted GTV (scen 1)
predicted GTV (scen 2)
CL CU DEC MW PIN



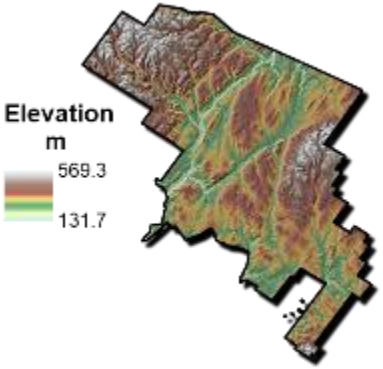
Shane Furze (UNB)

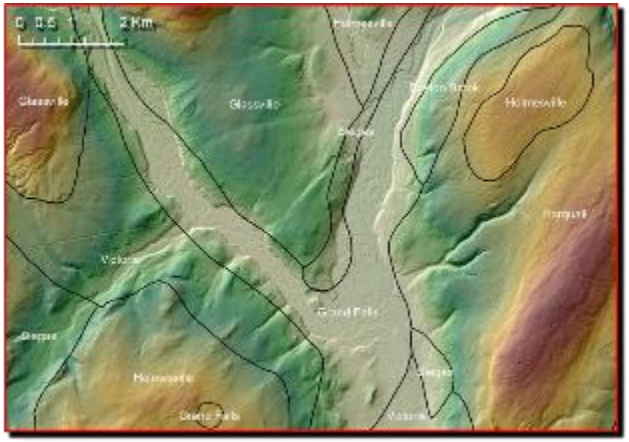
SOIL PRODUCTIVITY MAPPING



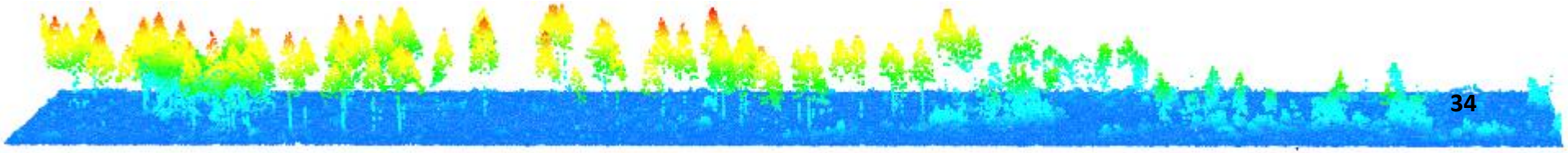
Soil Mapping Limitations

- In the past, soils delineated by broad polygons
  - ‘soil associations’

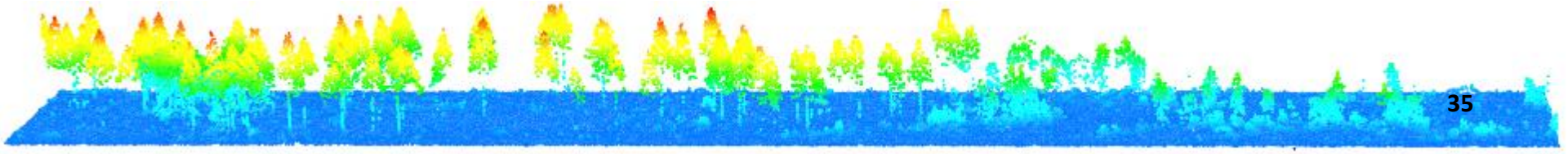




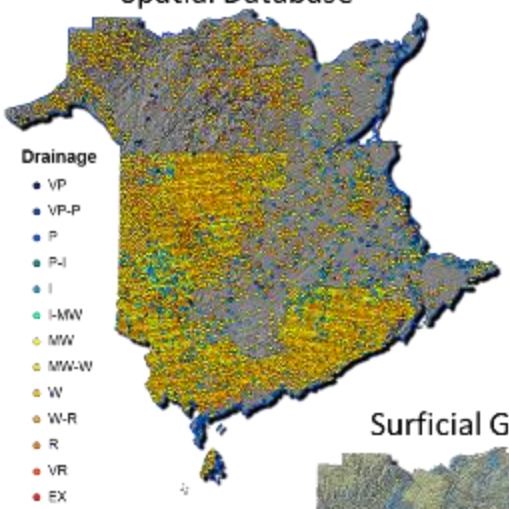
- LIDAR DEM and Terrain Attributes
  - Paradigm shift
    - Map soil properties continuously based on soil-forming factors
    - Models to compare soil properties to climate, geology, and topography
    - Requires “accurate” representations of soil-forming factors



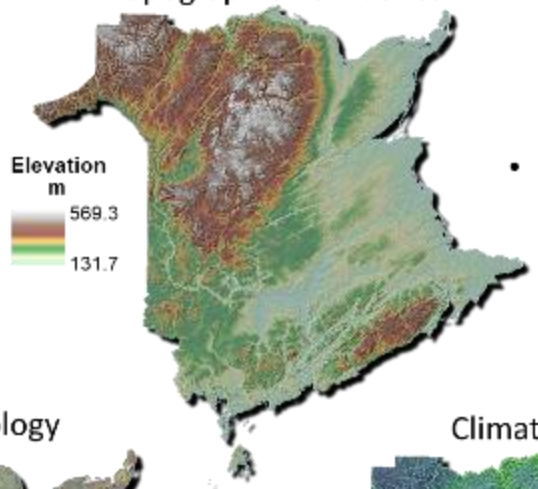
- Numerical prediction of key soil attributes using soil plot information and spatial coverages including LiDAR.
- Roll out predictions across the entire forest estate
- Link these fine scale models with individual tree responses



Spatial Database



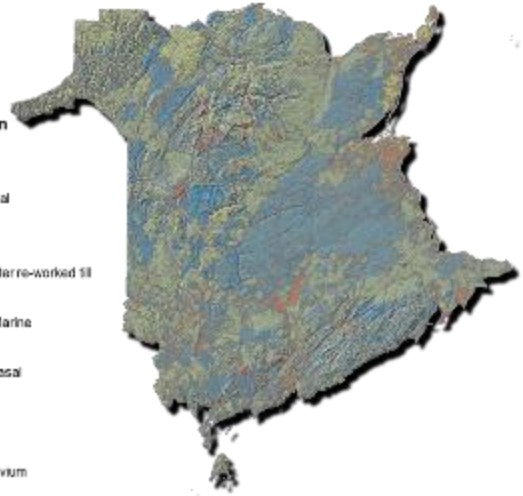
Topographic Derivatives



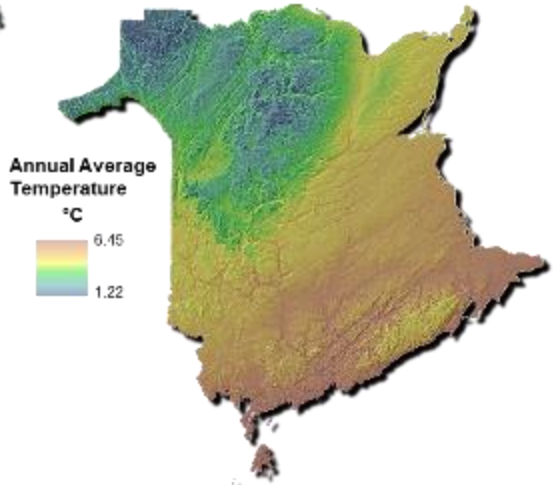
Total:
50+ Data sets

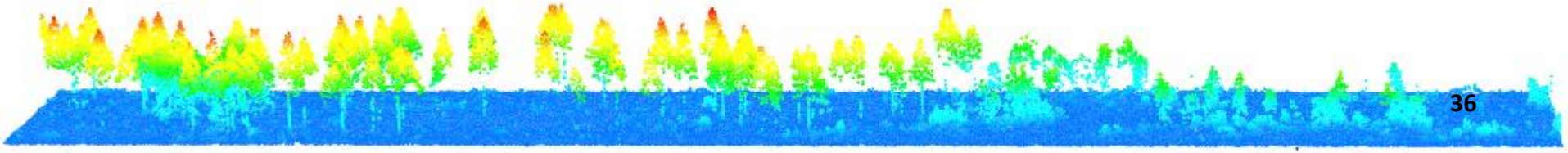
- Topographic and climate based on DEM

Surficial Geology

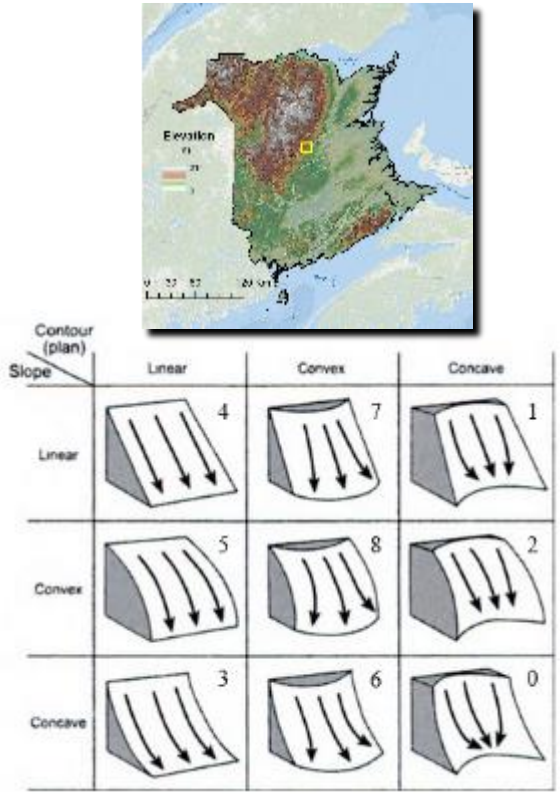


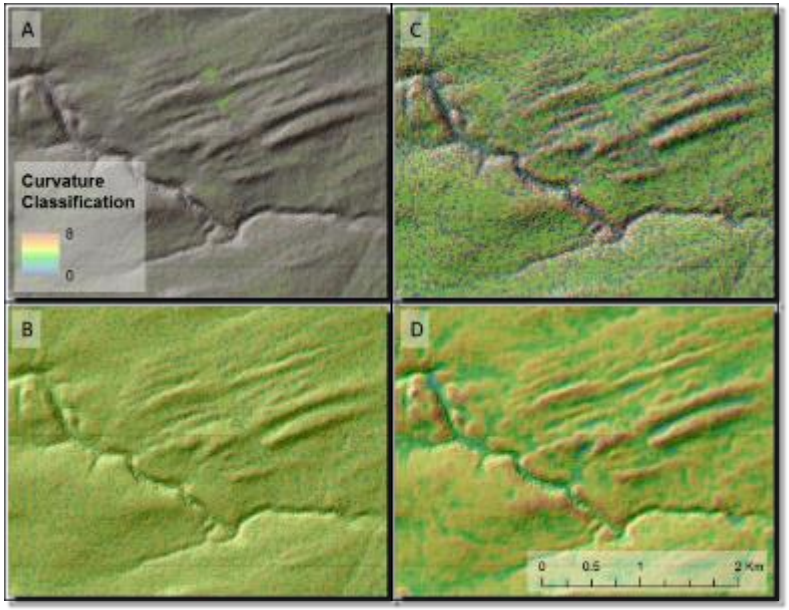
Climate Data



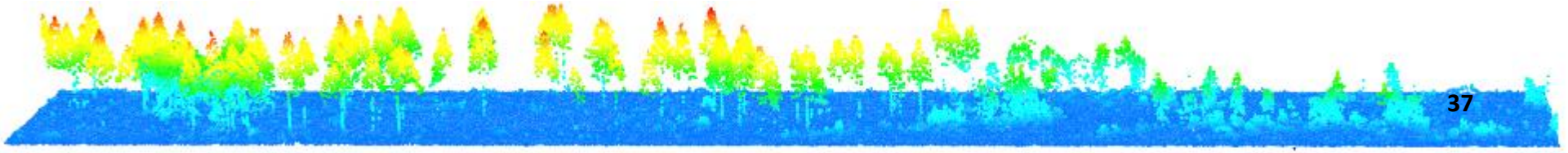


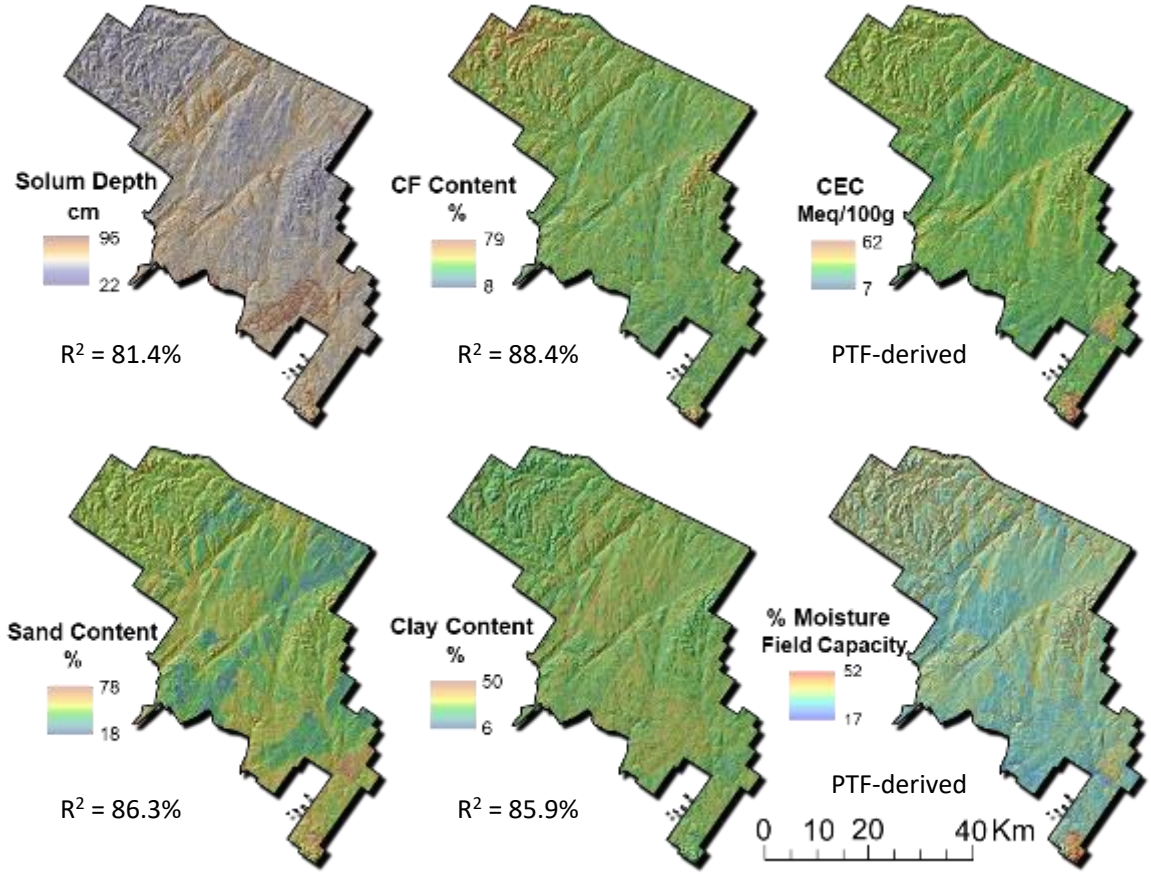
LIDAR Curvature Classification

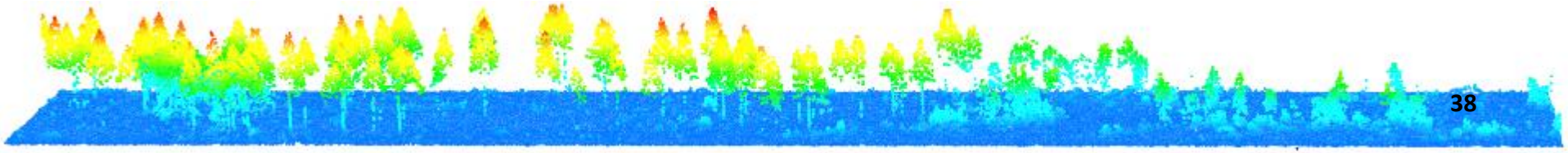


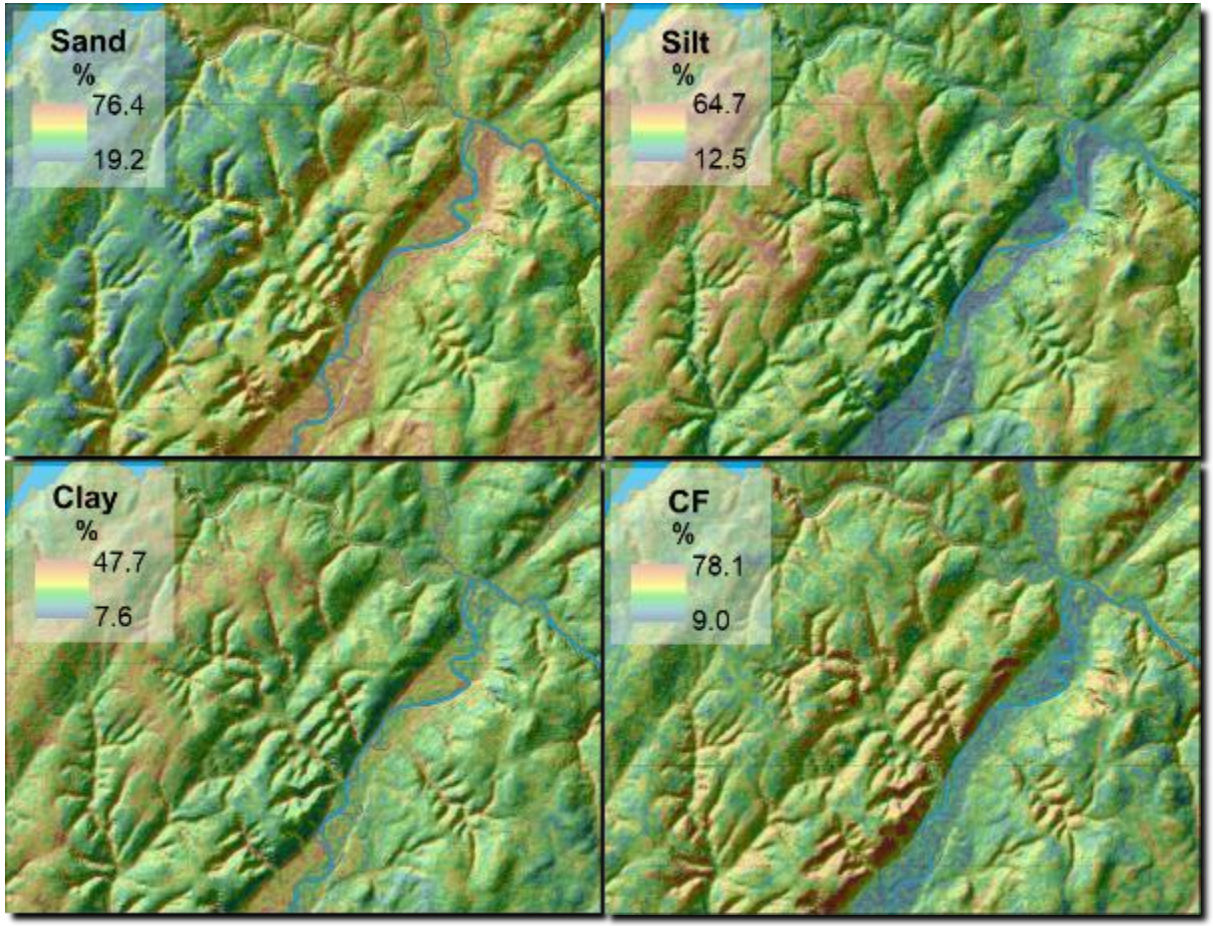


A – 10m resolution, B – 50m resolution, C – 10m resolution with 50m^2 smoothed, D – 50m resolution with 250m^2 smoothed.




Solum Depth
cm
95
22
R^2 = 81.4%
CF Content
%
79
8
R^2 = 88.4%
CEC
Meq/100g
62
7
PTF-derived
Sand Content
%
78
18
R^2 = 86.3%
Clay Content
%
50
6
R^2 = 85.9%
% Moisture
Field Capacity
52
17
PTF-derived
0 10 20 40 Km



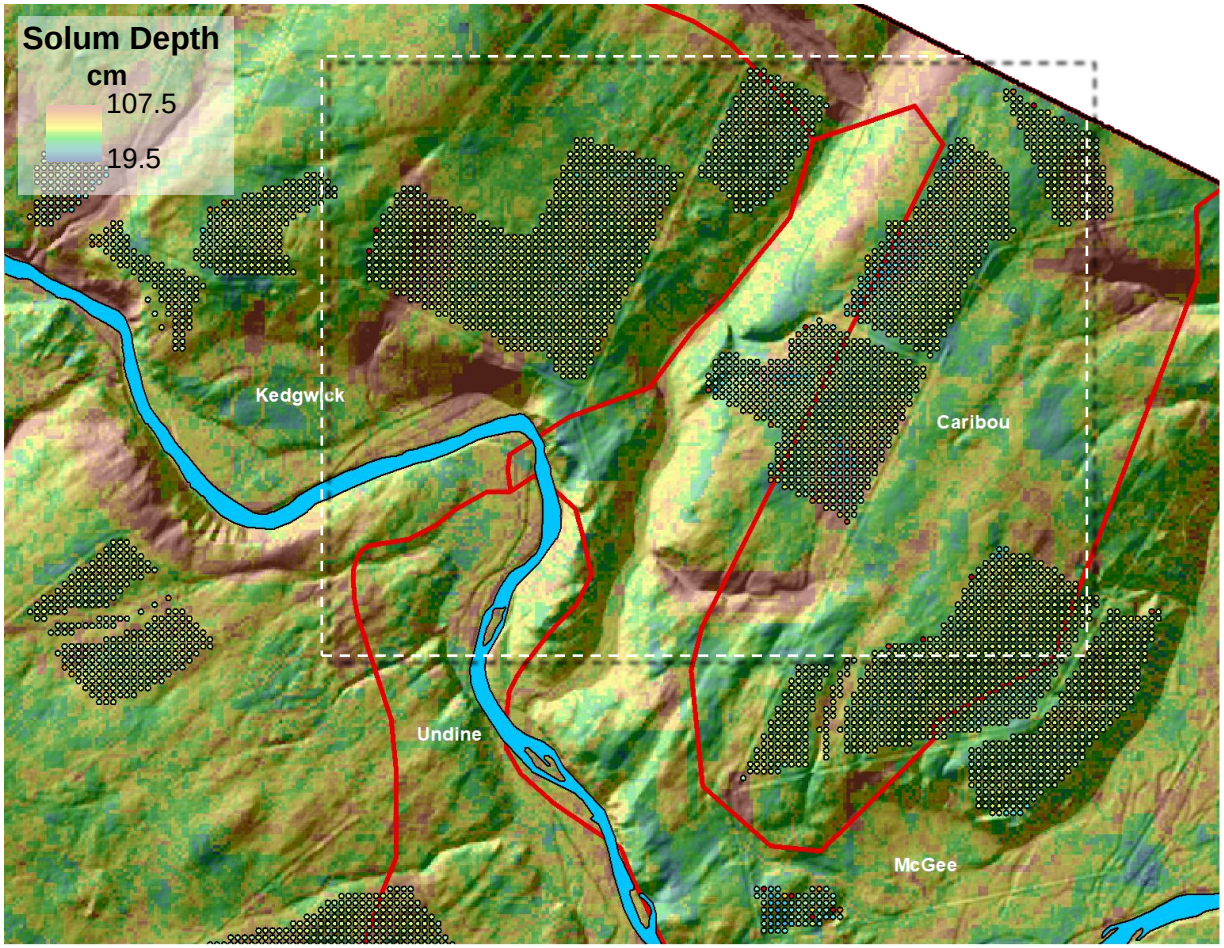


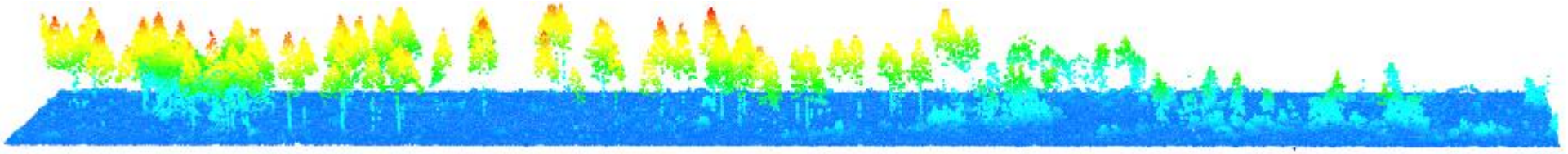
Furze, S., Castonguay, M., Ogilvie, J., Nasr, M., Cormier, P., Gagnon, R., Adams, G., & Arp, P. A. (2017). Assessing Soil-Related Black Spruce and White Spruce Plantation Productivity. Open Journal of Forestry, 7, 209- 227.

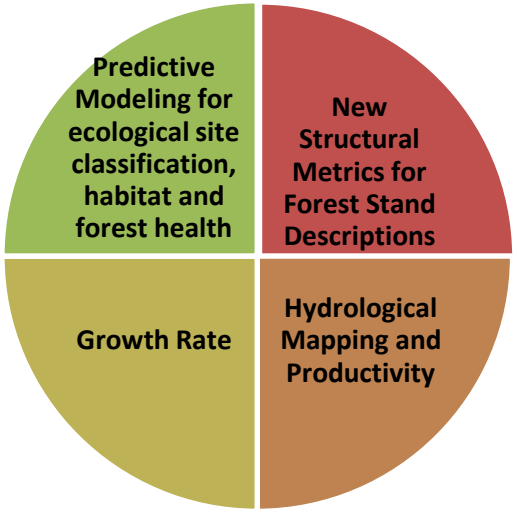
WS Plantations

Avg. Height/ Age

- 0.002 – 0.1
- 0.1 – 0.15
- 0.15 – 0.2
- 0.2 – 0.25
- 0.25 – 0.3
- 0.3 – 0.35
- 0.35 – 0.4
- 0.4 – 0.45
- 0.45 – 0.5
- 0.5 – 0.55
- 0.55 – 0.6
- 0.6 – 0.65
- 0.65 – 0.7
- 0.7 – 0.75
- 0.75+
- Waterbodies
- Soil Associations

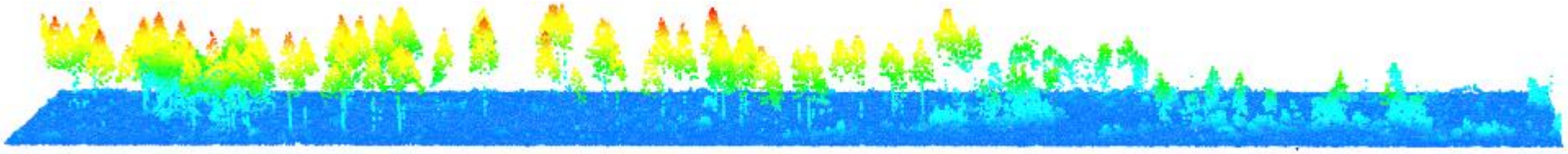




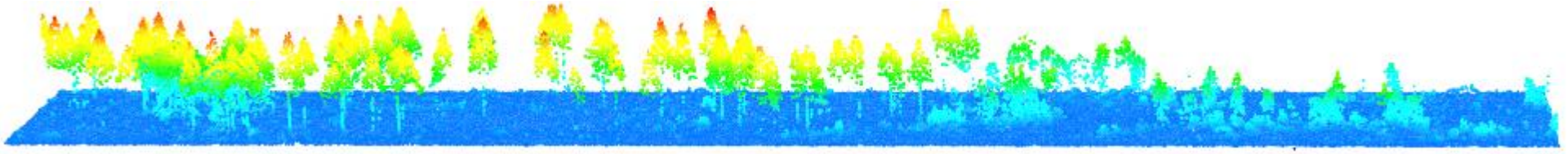


Sean M. Lamb (UNB), Piotr Tompalski (UBC), Joseph Rakofsky (UBC)

STAND GROWTH



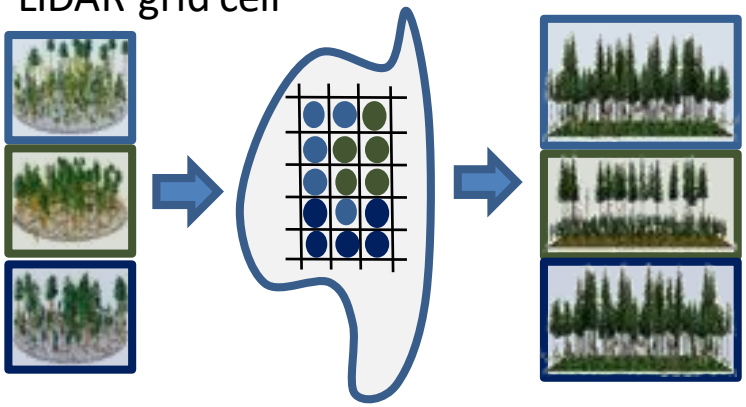
- How can we predict growth with LIDAR data ?
  - ✓Linking LIDAR plot attributes with measured plot attributes and then interpolating
  - ✓Linking LIDAR to growth modelling
  - ✓Using two sets of remote sensing data



Spruce Plantations in New Brunswick

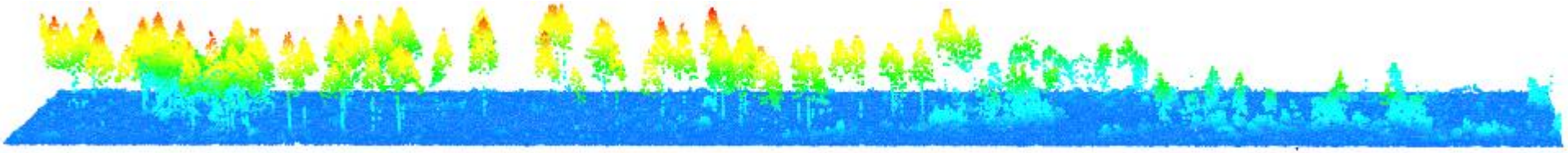
1. Impute tree-level inventory for LiDAR grid cells in spruce (*Picea* sp.) plantations

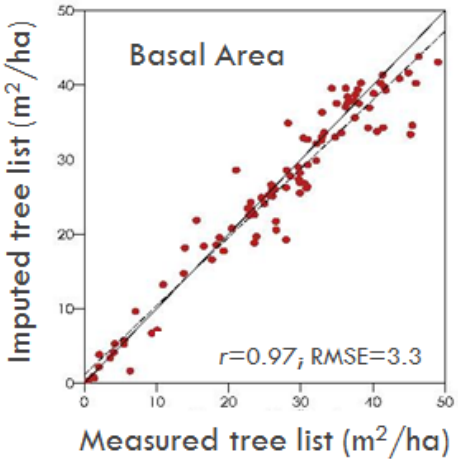
- Match plot measurements with LiDAR grid cells based on planted species and 6 inventory variables
- Use tree-level inventory from matched plot as a surrogate for each LIDAR grid cell

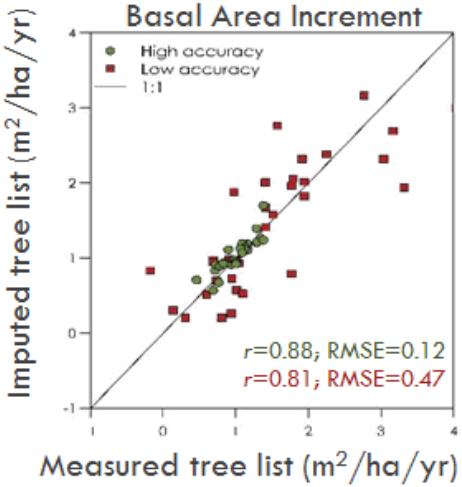


2. Forecast forest inventory using imputed tree lists and a locally calibrated tree-list growth model

- Input imputed tree lists into tree-list growth model (Open Stand Model) to forecast inventory
- Compare predicted annual increment from tree lists imputed by plot matching with measured tree lists







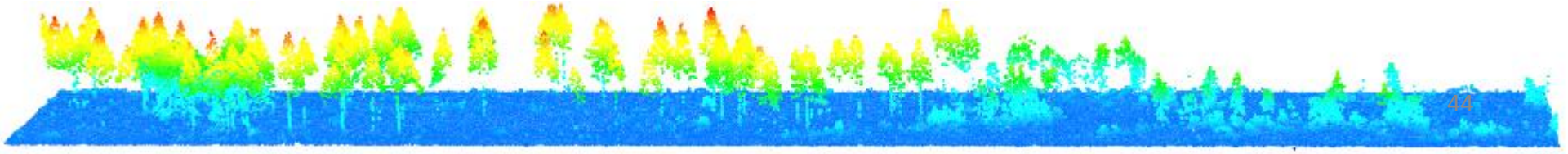
Variables generated from imputed tree lists highly correlated with those from measured trees

Imputed and measured tree lists had statistically equivalent basal area distribution by species

Modelled inventory increments from imputed tree lists highly correlated with those from measured plots

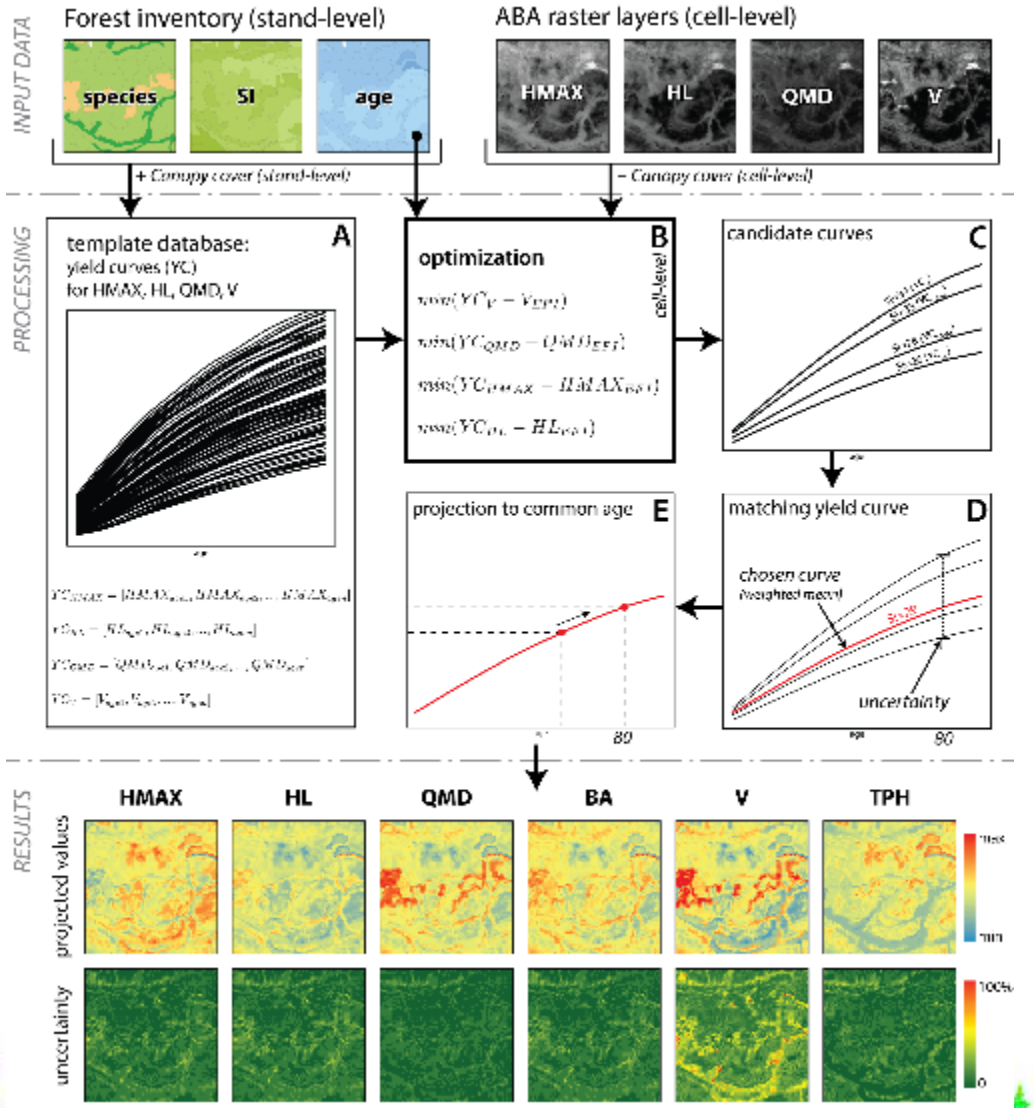
Volumes forecasted 3-5 years for 15 test plantations using imputed tree lists statistically equivalent to actual harvest

Lamb, S.M., MacLean, D.A., Hennigar, C.R., and Pitt, D.G. 2018. Forecasting forest inventory using imputed tree lists for LiDAR grid cells and a tree-list growth model. Forests 9(4): 167.

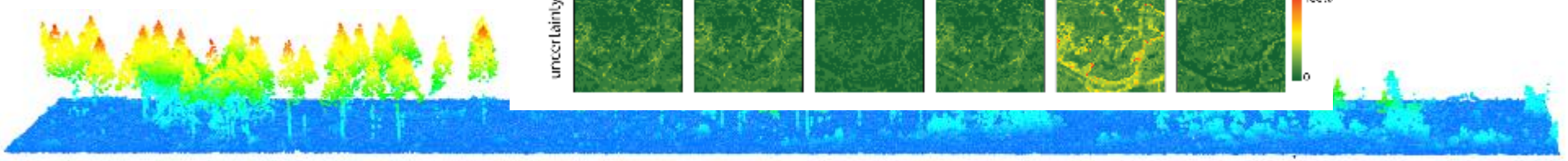


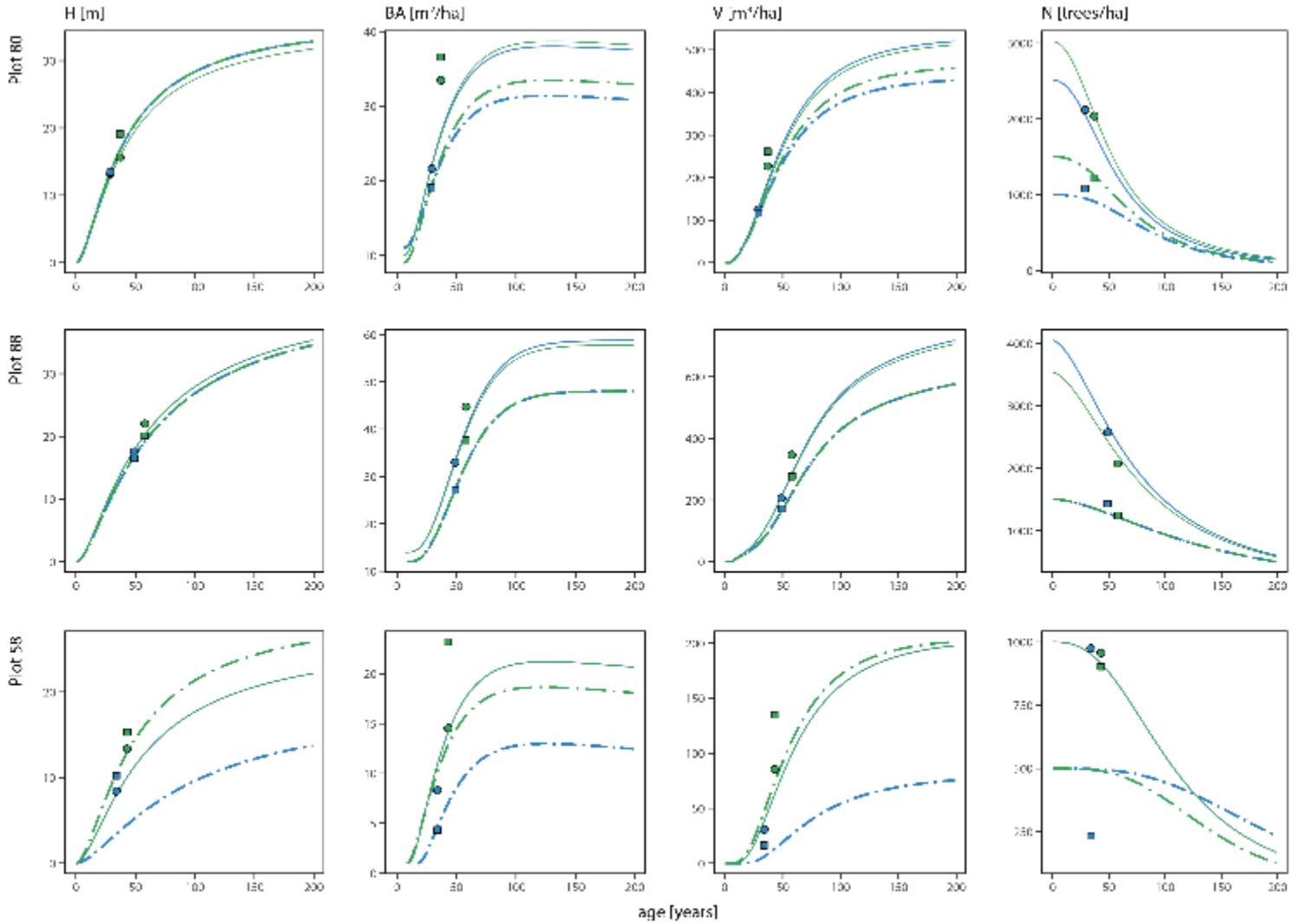
Linking LIDAR with existing growth models in Alberta (GYPSY)

Slave Lake; mixed wood boreal species



Tompalski, P., Coops, N., White, J., & Wulder, M. (2016). Enhancing Forest Growth and Yield Predictions with Airborne Laser Scanning Data: Increasing Spatial Detail and Optimizing Yield Curve Selection through Template Matching. *Forests*, *7*(12), 255. doi:10.3390/f7110255



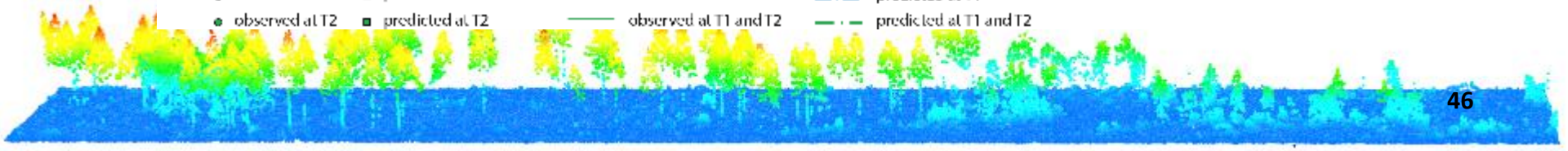


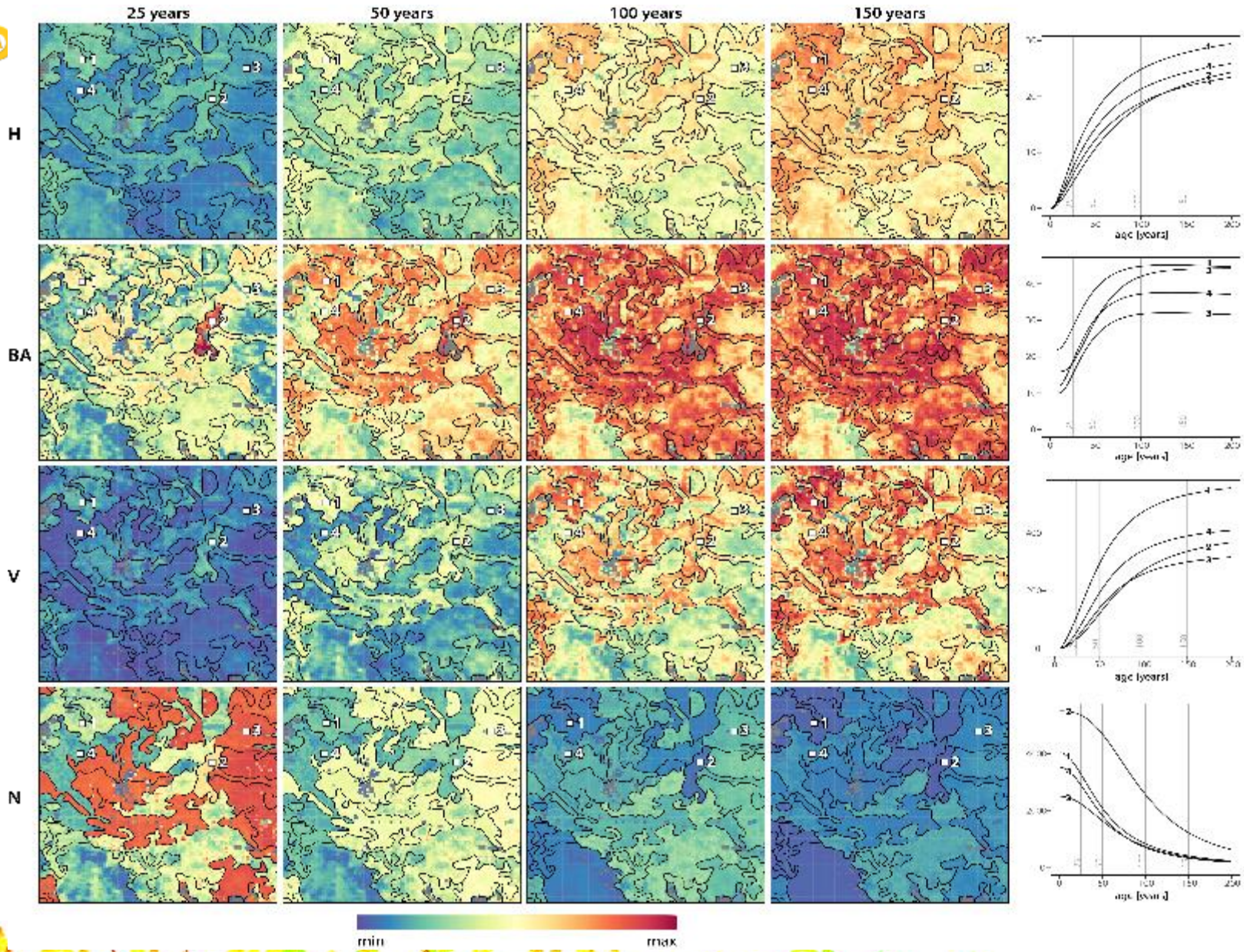
Plot-level stand attributes:

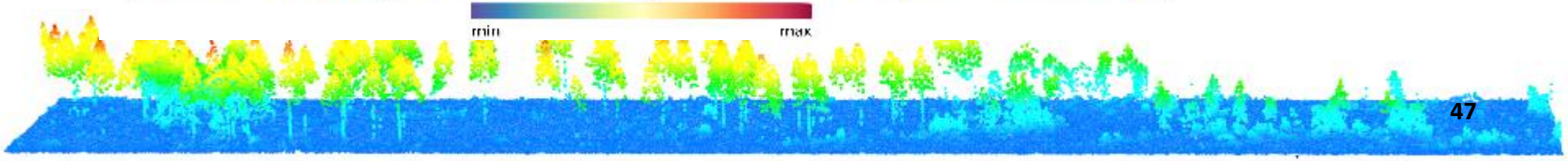
- observed at T1
- predicted at T1
- observed at T2
- predicted at T2

Yield curves matched based on:

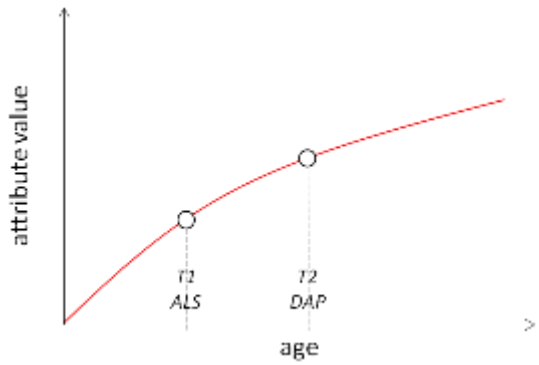
- observed at T1
- predicted at T1
- observed at T1 and T2
- predicted at T1 and T2



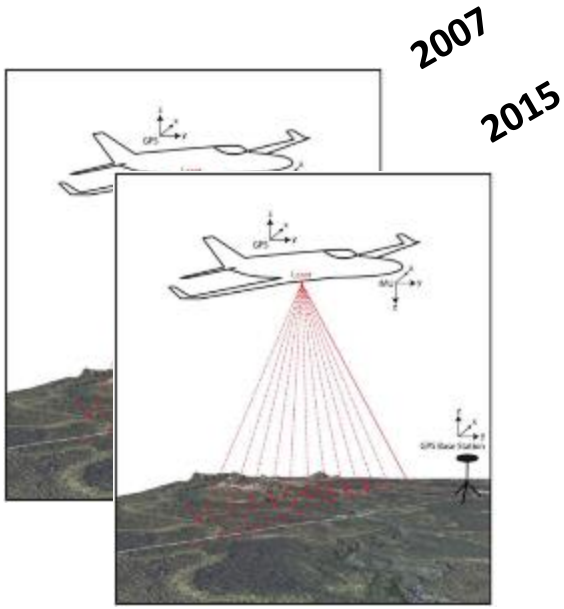

25 years
50 years
100 years
150 years
H
BA
V
N
age [years]
min
max



Using two sets of remote sensing data

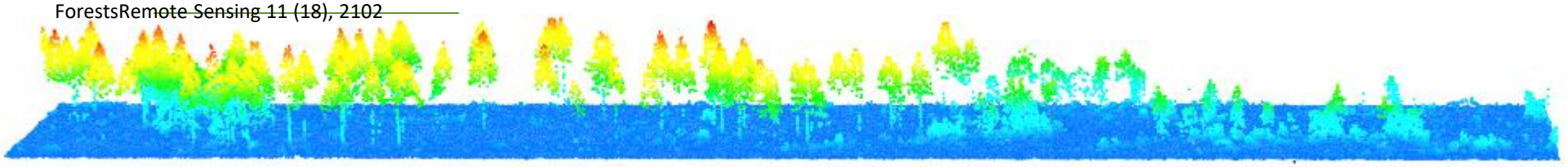


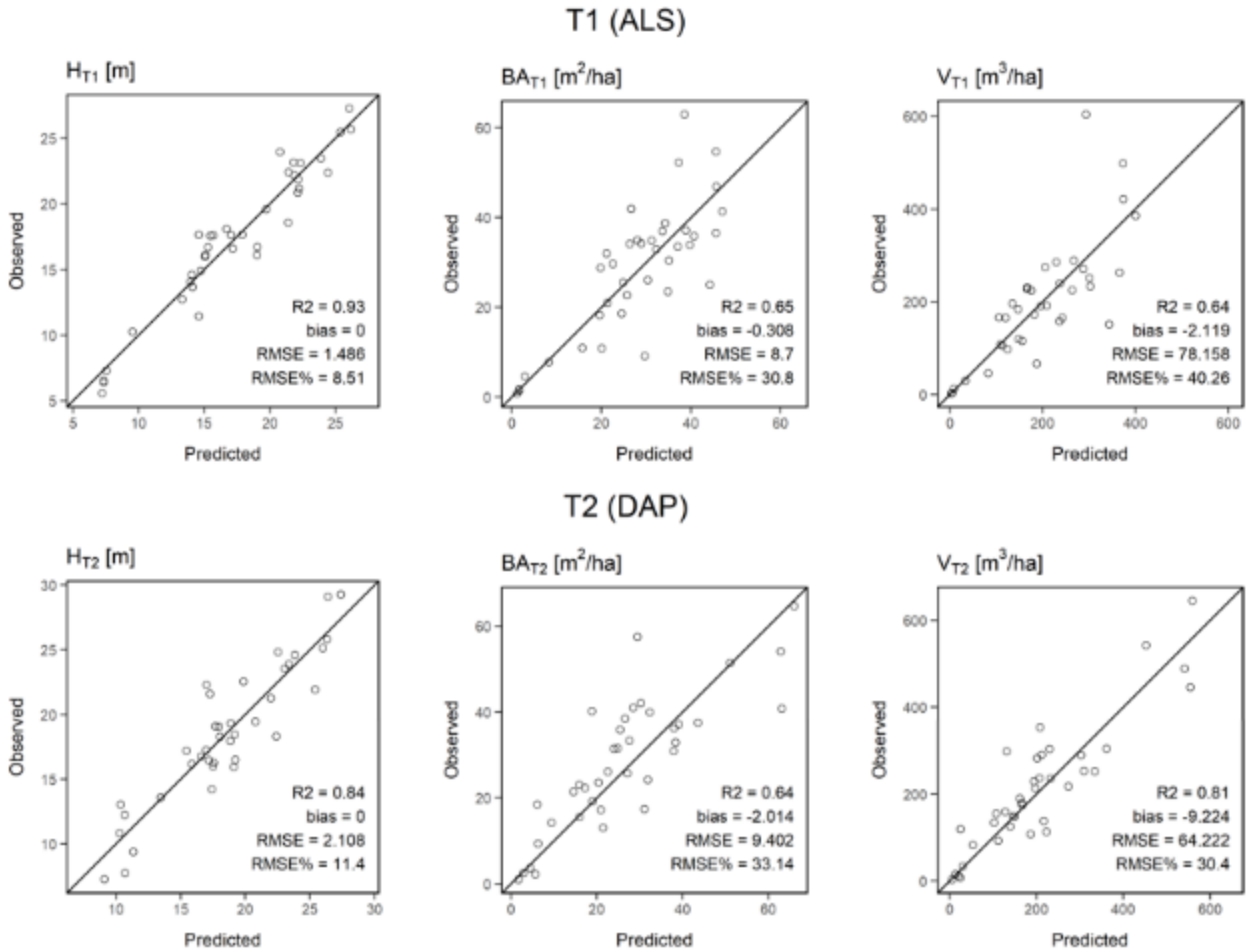
Yield
Projection



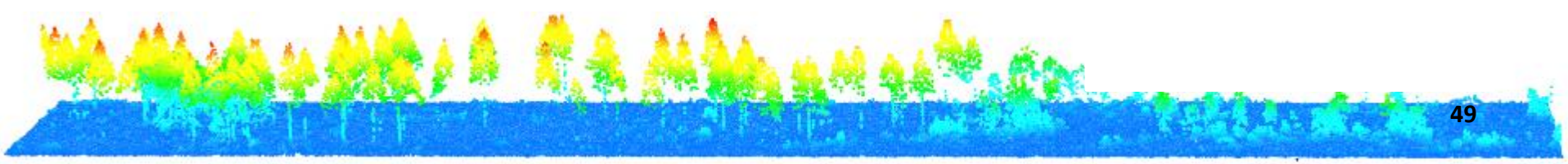
Multi-
Temporal
Point Clouds

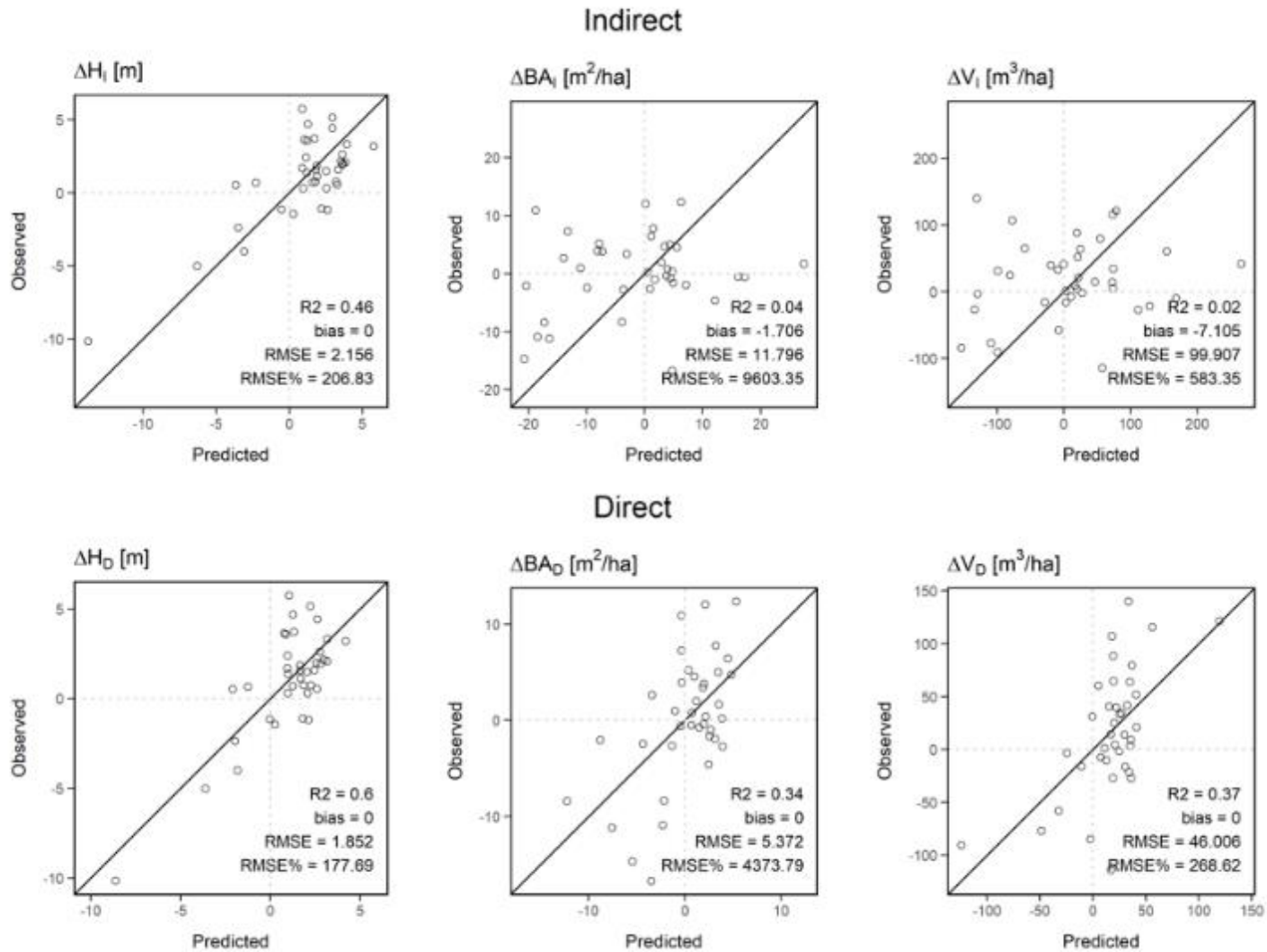
Tompalski, P., Radofsky, J., Coops, N., White, J., Graham, A., Rosychuk (2019) Challenges of Multi-Temporal and Multi-Sensor Forest Growth Analyses in a Highly Disturbed Boreal Mixedwood ForestsRemote Sensing 11 (18), 2102



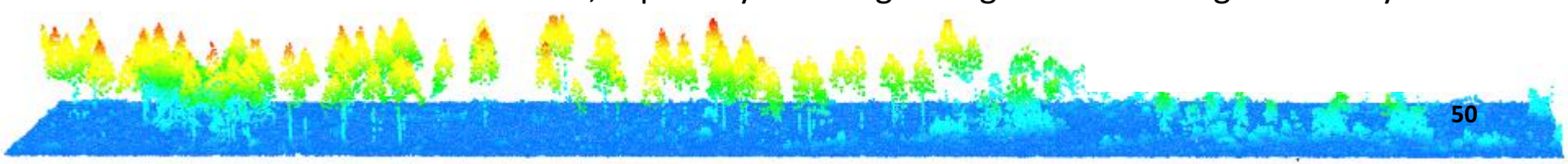


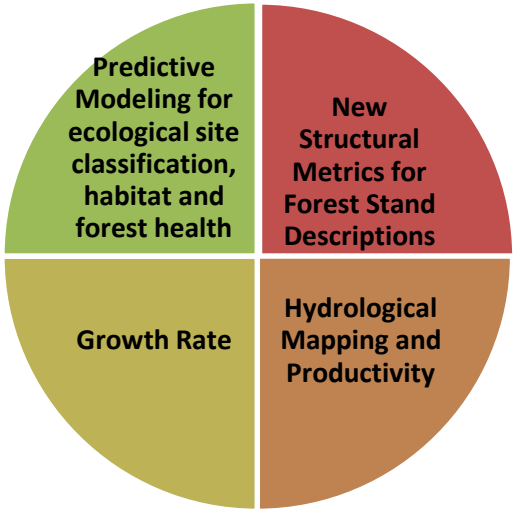
T1 = 2007; T2 = 2017: even if models for two points in time are significant





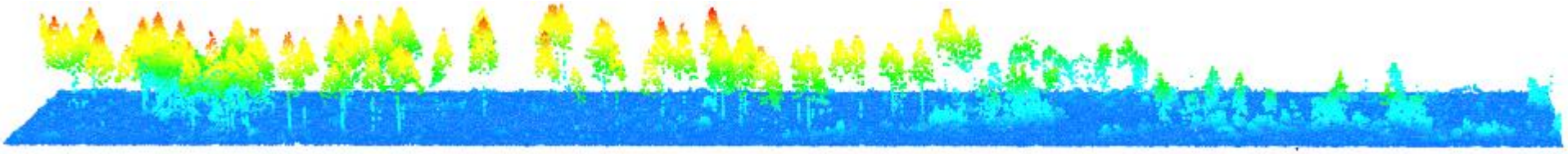
Growth can be difficult to assess; especially in slow growing stands with high mortality





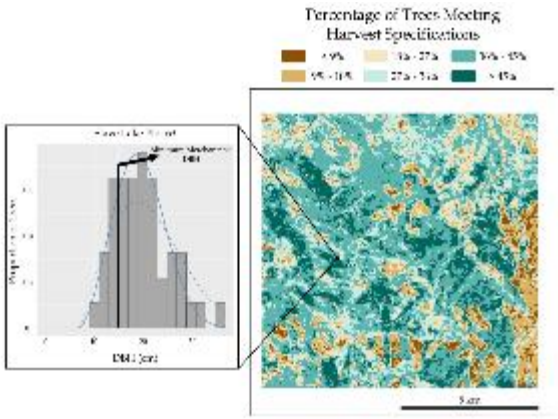
Chris Mulverhill (UBC), PiotrTompalski (UBC)

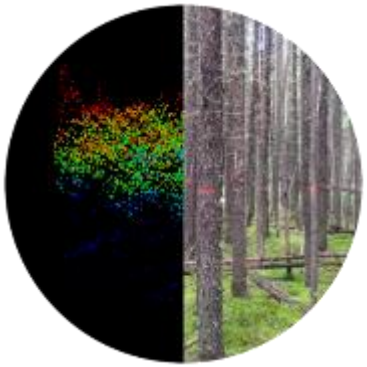
PRODUCT MIX



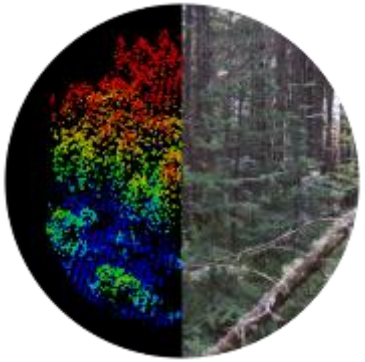
Stem diameter distributions in boreal mixedwoods

Testing different ground-based and ALS-based techniques for separating structurally simple and complex areas and then predicting structurally appropriate models.

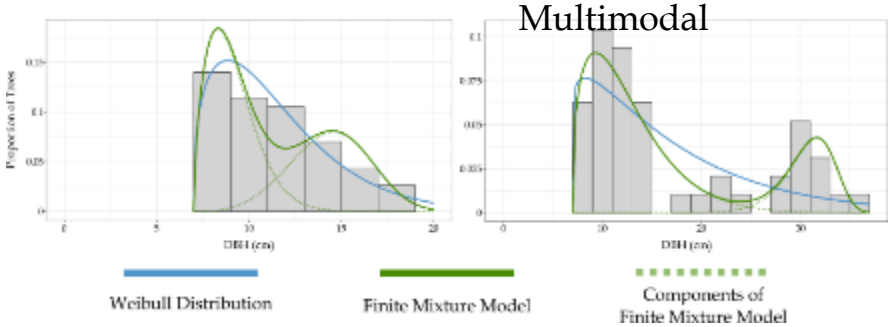


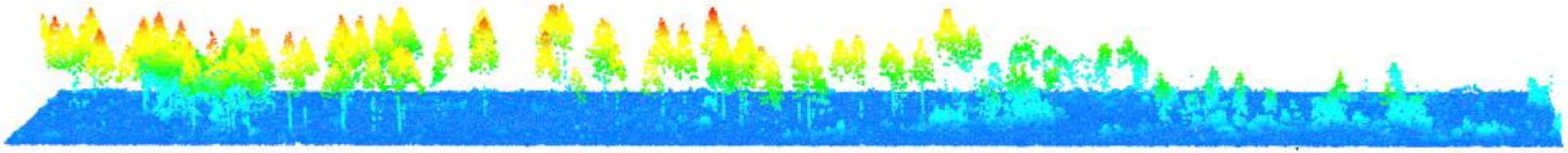


Simple - Unimodal

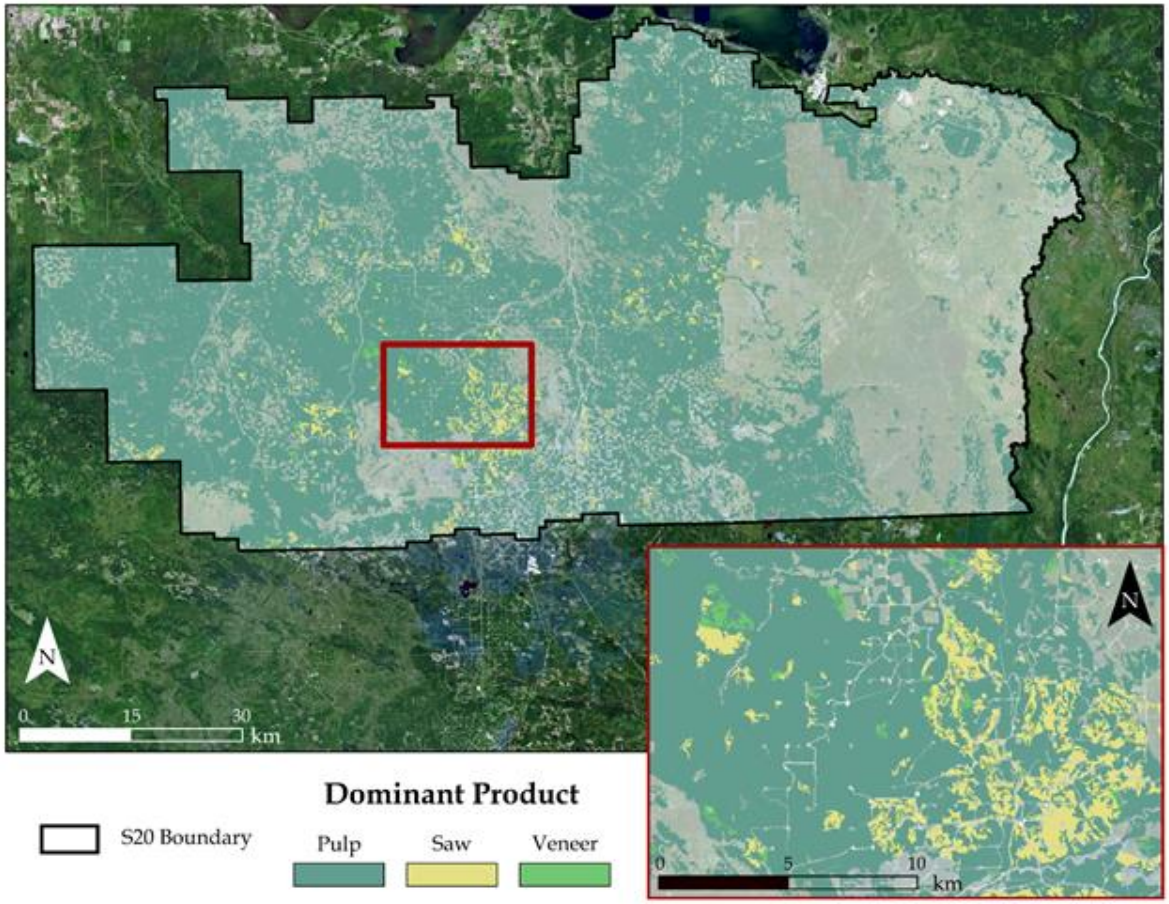


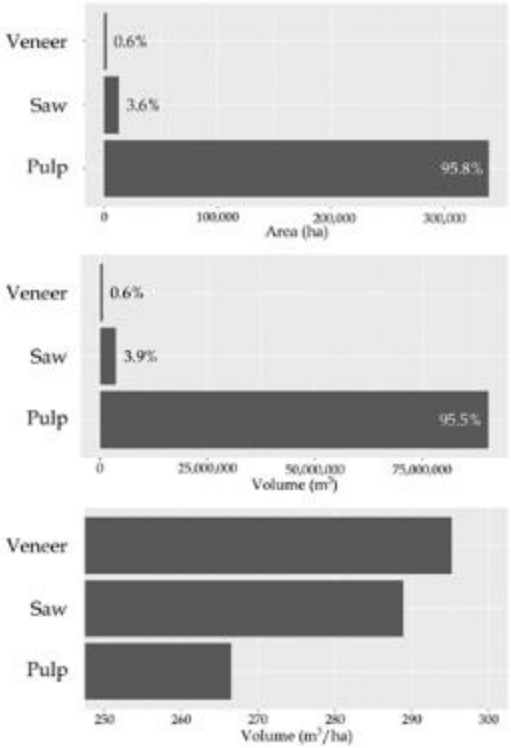
Complex - Multimodal



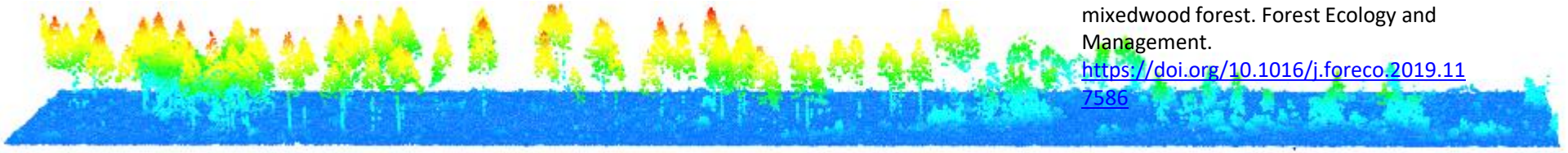


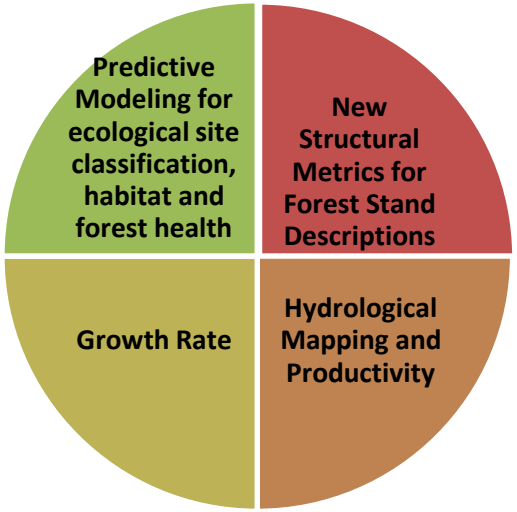
Application





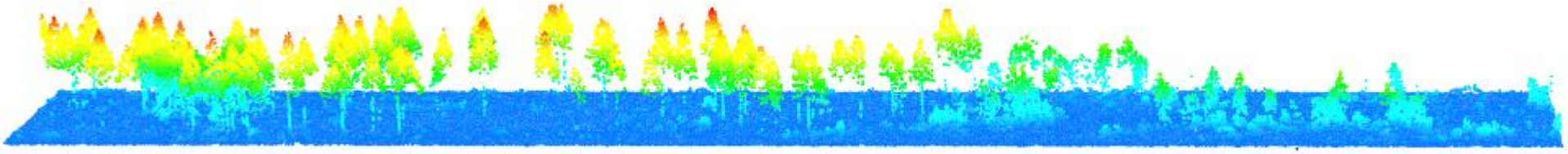
Mulverhill, C., Coops, N. White, J., Tompalski, P., Marshall, P (2019) Structural development following stand-replacing disturbance in a boreal mixedwood forest. Forest Ecology and Management. https://doi.org/10.1016/j.foreco.2019.117586

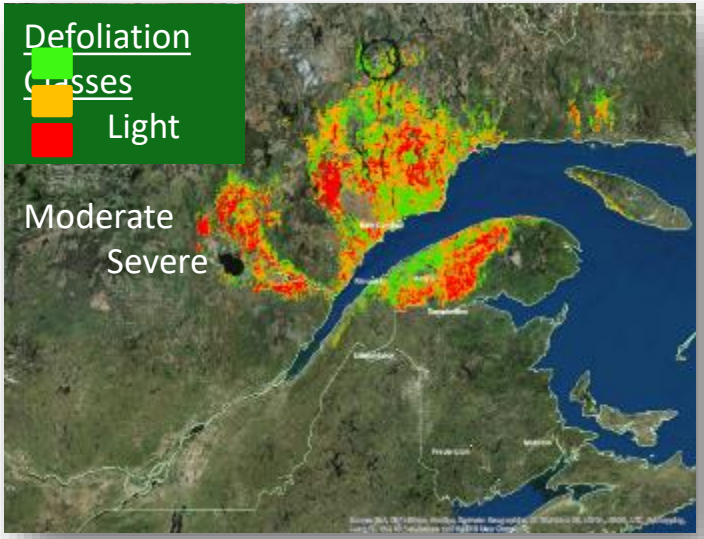


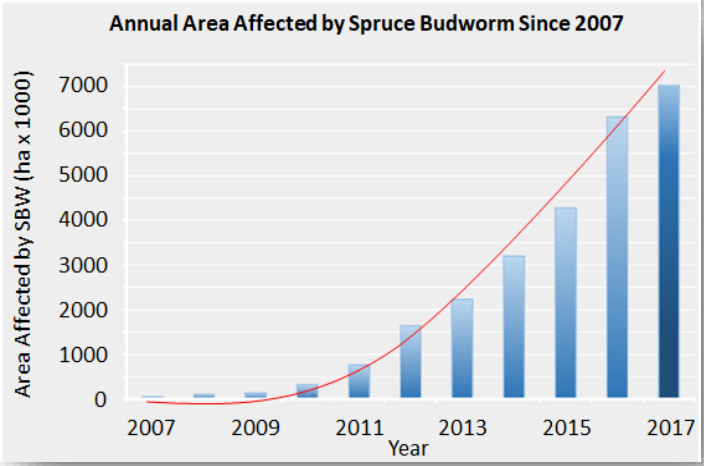


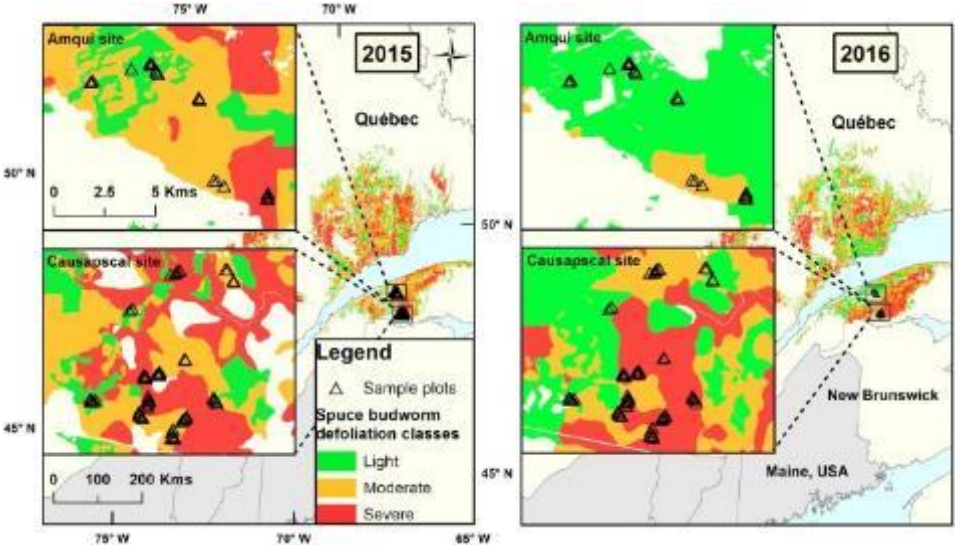
Shane Donavan (UNB), Tristan Goodbody (UBC)

FOREST HEALTH

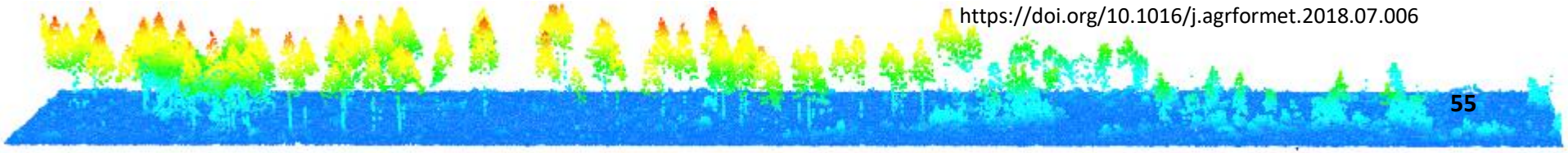




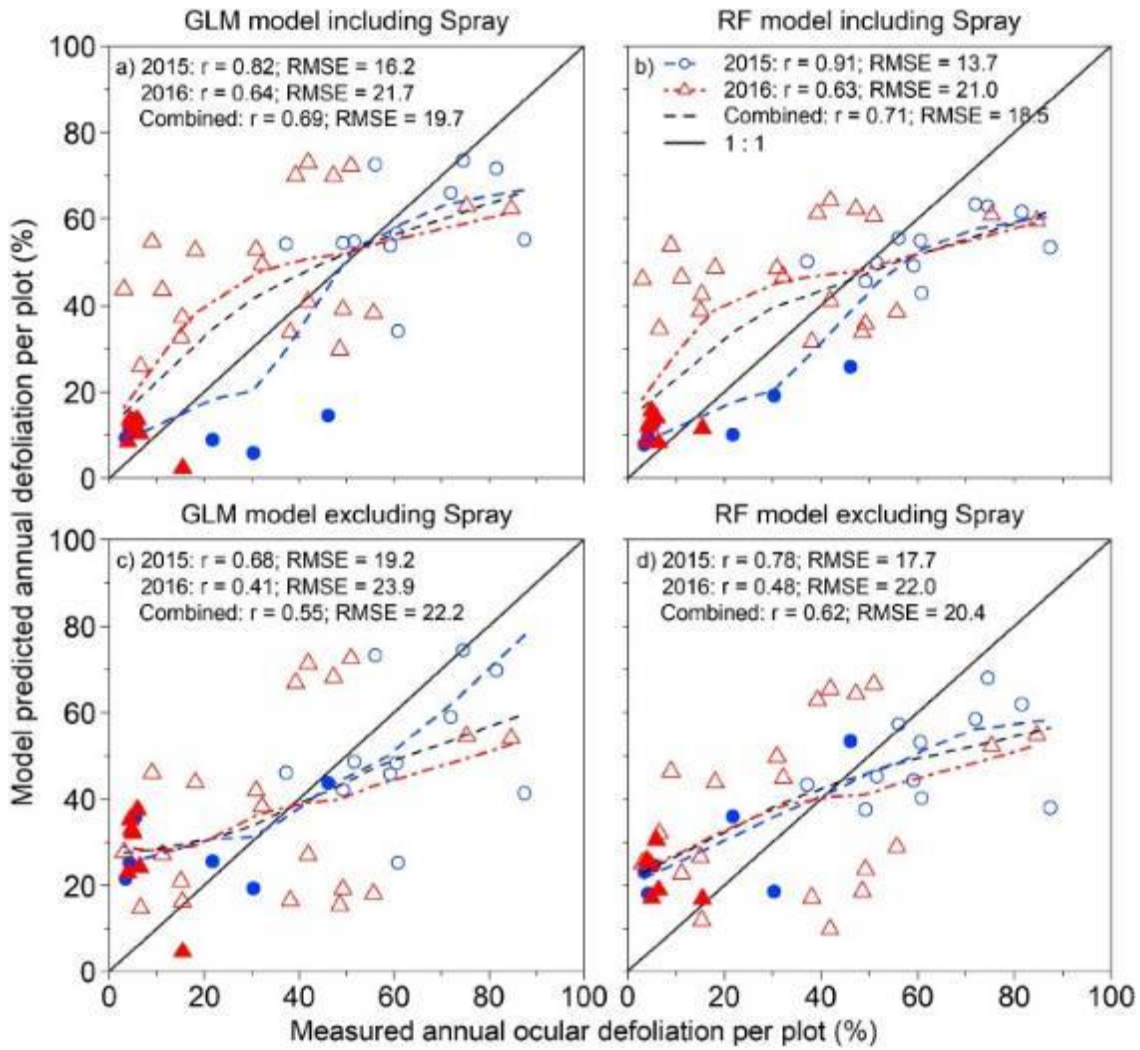


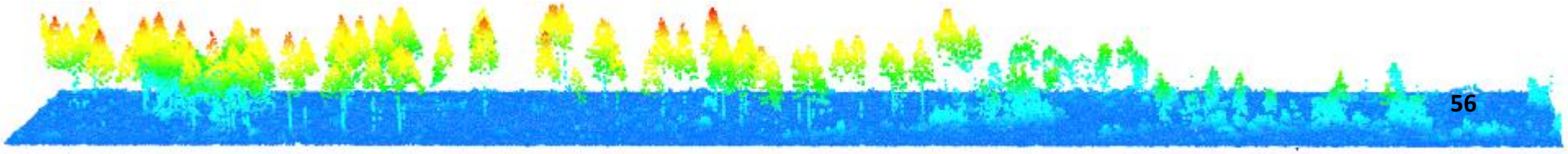


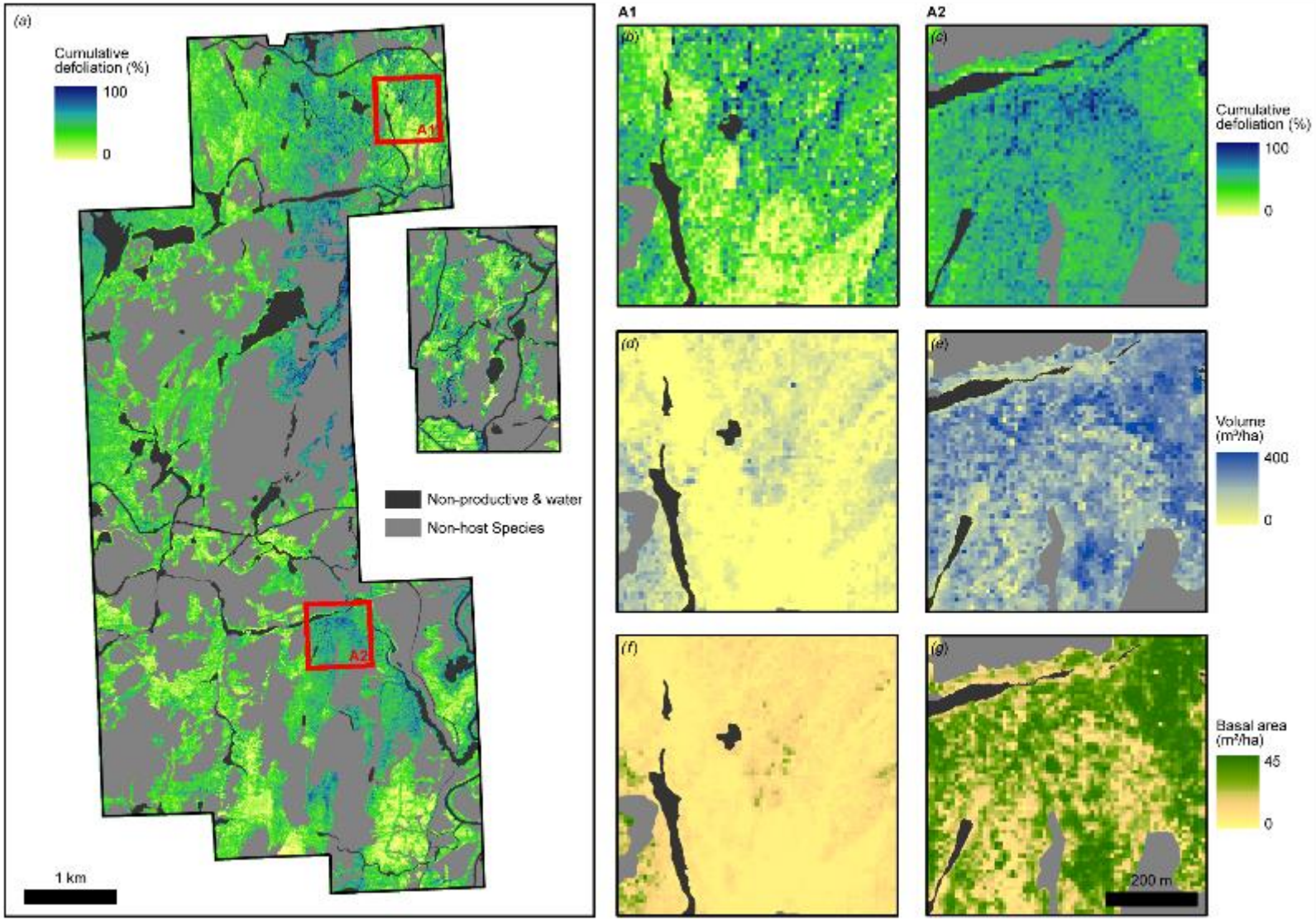
Donovan, S., MacLean, D., Kershaw, J., Mavigne, M (2018) Quantification of forest canopy changes caused by spruce budworm defoliation using digital hemispherical imagery. Agriculture and Forest Meteorology. https://doi.org/10.1016/j.agrformet.2018.07.006

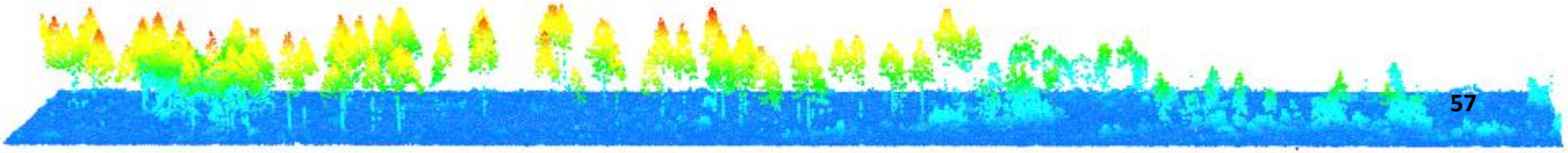


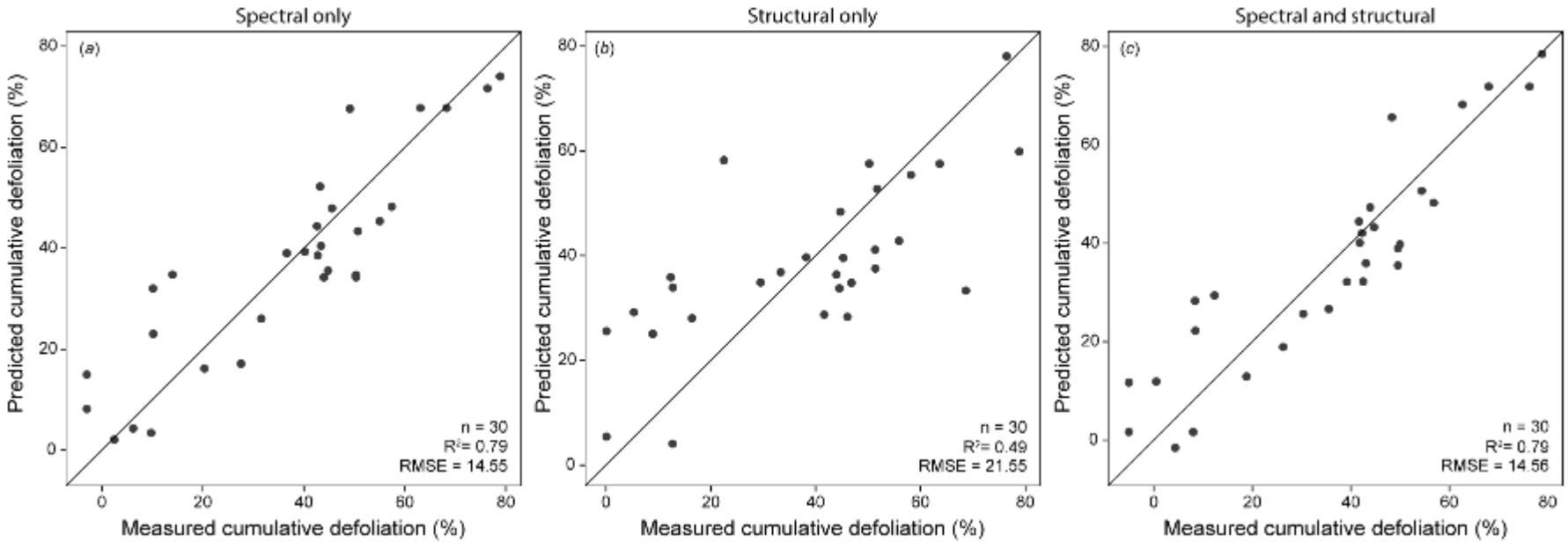

a) Raw Image
b) Processed


GLM model including Spray
a) 2015: r = 0.82; RMSE = 16.2
2016: r = 0.64; RMSE = 21.7
Combined: r = 0.69; RMSE = 19.7
RF model including Spray
b) 2015: r = 0.91; RMSE = 13.7
2016: r = 0.63; RMSE = 21.0
Combined: r = 0.71; RMSE = 18.5
1 : 1
GLM model excluding Spray
c) 2015: r = 0.68; RMSE = 19.2
2016: r = 0.41; RMSE = 23.9
Combined: r = 0.55; RMSE = 22.2
RF model excluding Spray
d) 2015: r = 0.78; RMSE = 17.7
2016: r = 0.48; RMSE = 22.0
Combined: r = 0.62; RMSE = 20.4
Model predicted annual defoliation per plot (%)
Measured annual ocular defoliation per plot (%)
0
20
40
60
80
100

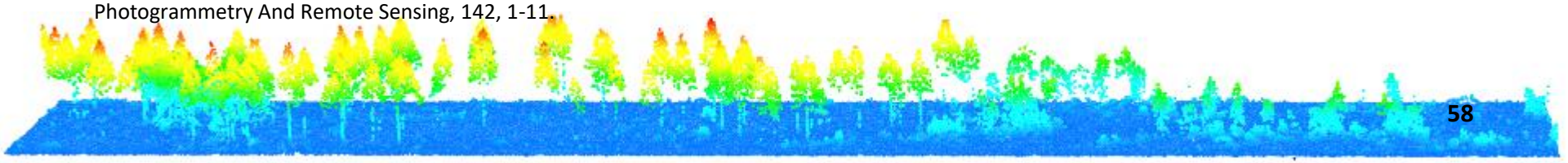


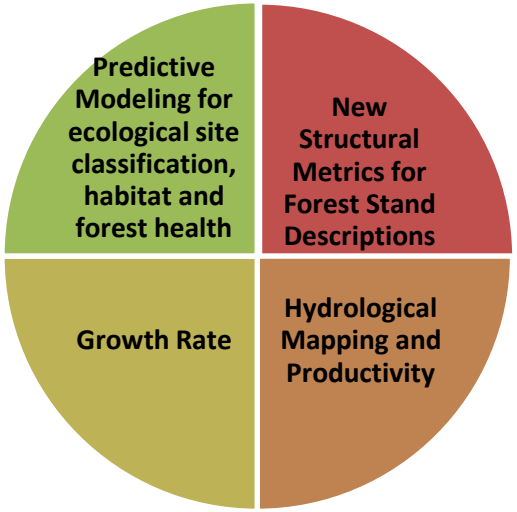

(a)
Cumulative defoliation (%)
100
0
A1
A2
Non-productive & water
Non-host Species
1 km
A1
A2
(b)
(c)
(d)
(e)
(f)
(g)
Cumulative defoliation (%)
100
0
Volume (m³/ha)
400
0
Basal area (m²/ha)
45
0
200 m





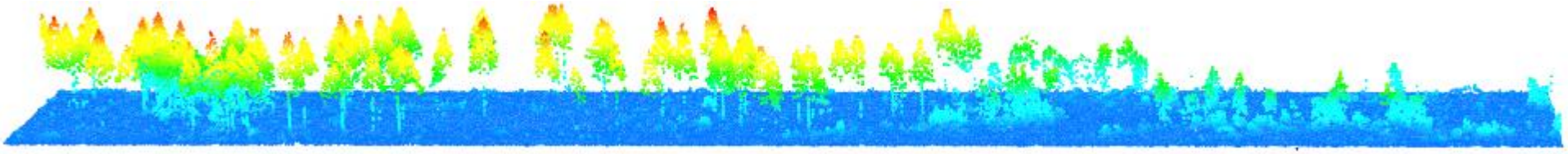
Goodbody, T. R.H., Coops, N. C., Hermosilla, T., Tompalski, P., Mccartney, G., & Maclean, D. A. 2018. Digital Aerial Photogrammetry For Assessing Cumulative Spruce Budworm Defoliation And Enhancing Forest Inventories At A Landscape Level. ISPRS Journal Of Photogrammetry And Remote Sensing, 142, 1-11.





Rebecca Wylie

WOOD DENSITY AND STAND AGE



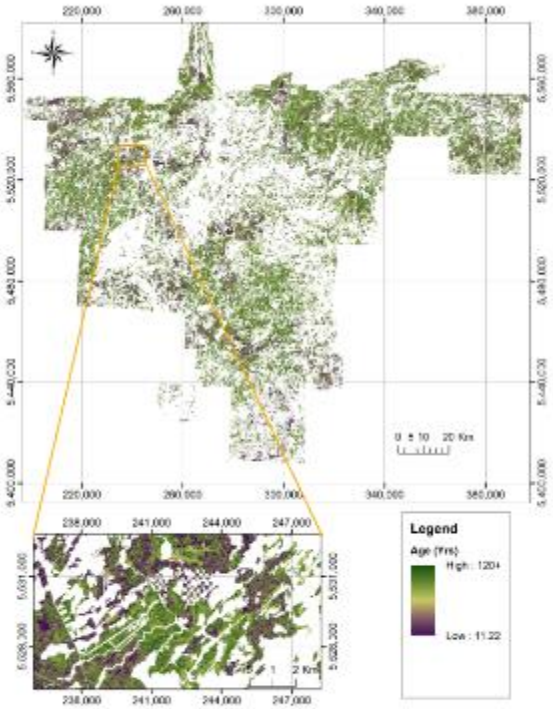
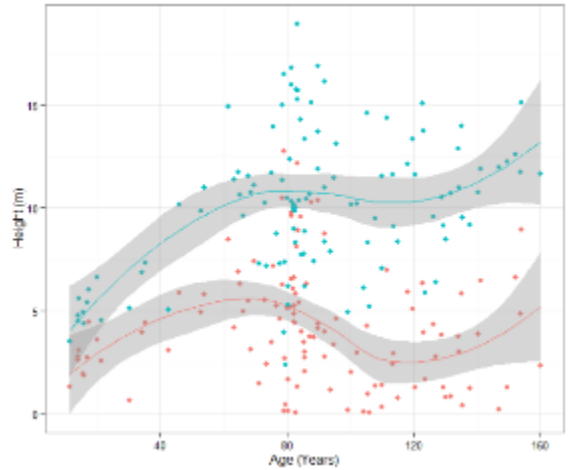


Figure 7. Mean age (years) imputation for FRI polygons that met rf kNN model requirements, using ALS structural metrics (MAX, cc4, cc10, cc16, P90, COVAR, Elevation and TWI) Hearst Forest in Northeastern Ontario.



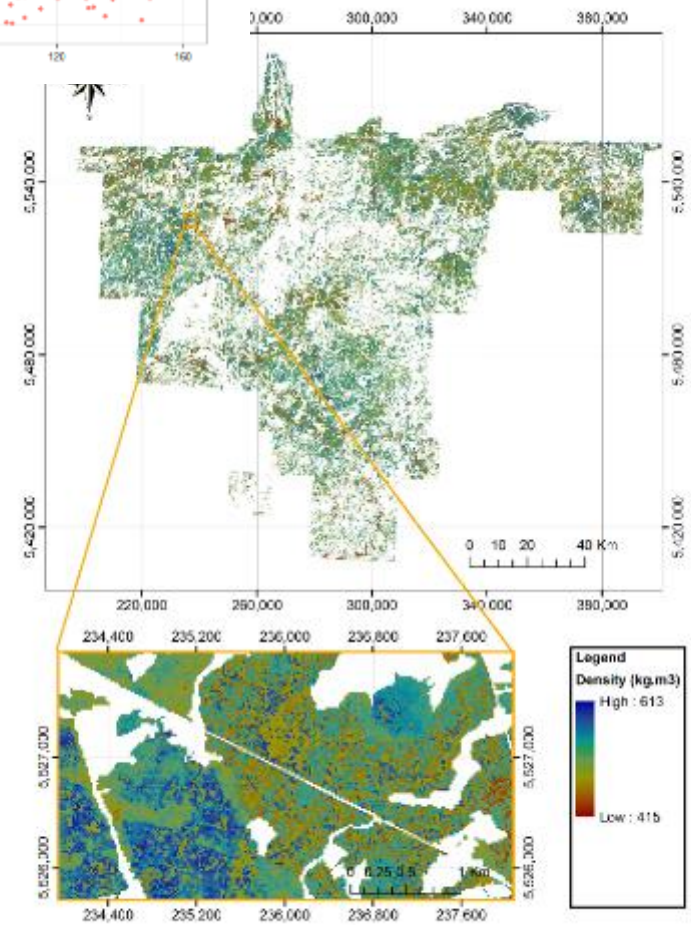
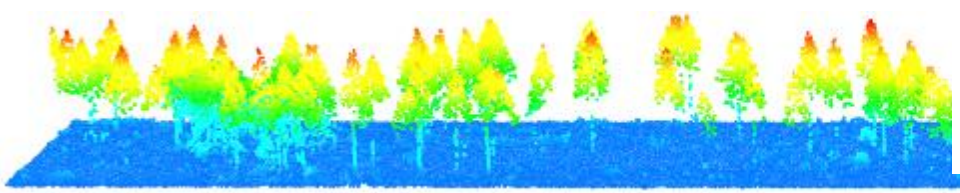
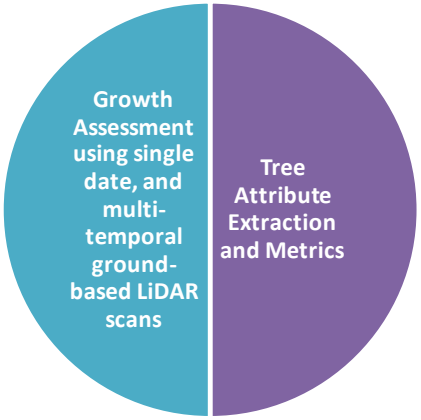


Figure 11. Mean stem level wood density (kg m^{-3}) 20 x 20 m pixel, Hearst Forest Northeastern Ontario.

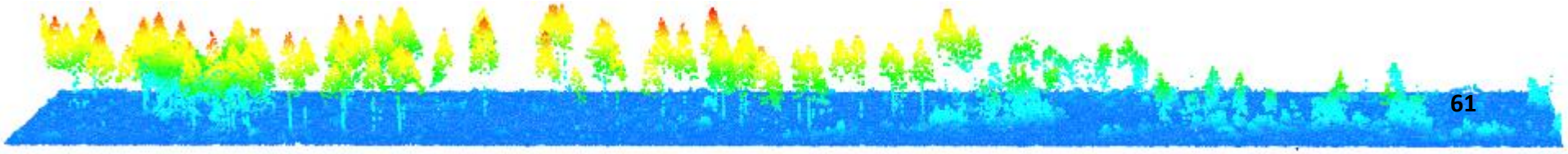
Wylie, R., Woods, M., Dech, J (2019). Estimating Stand Age from Airborne Laser Scanning Data to Improve Models of Black Spruce Wood Density in the Boreal Forest of Ontario. Remote Sensing DOI: 10.3390/rs11172022



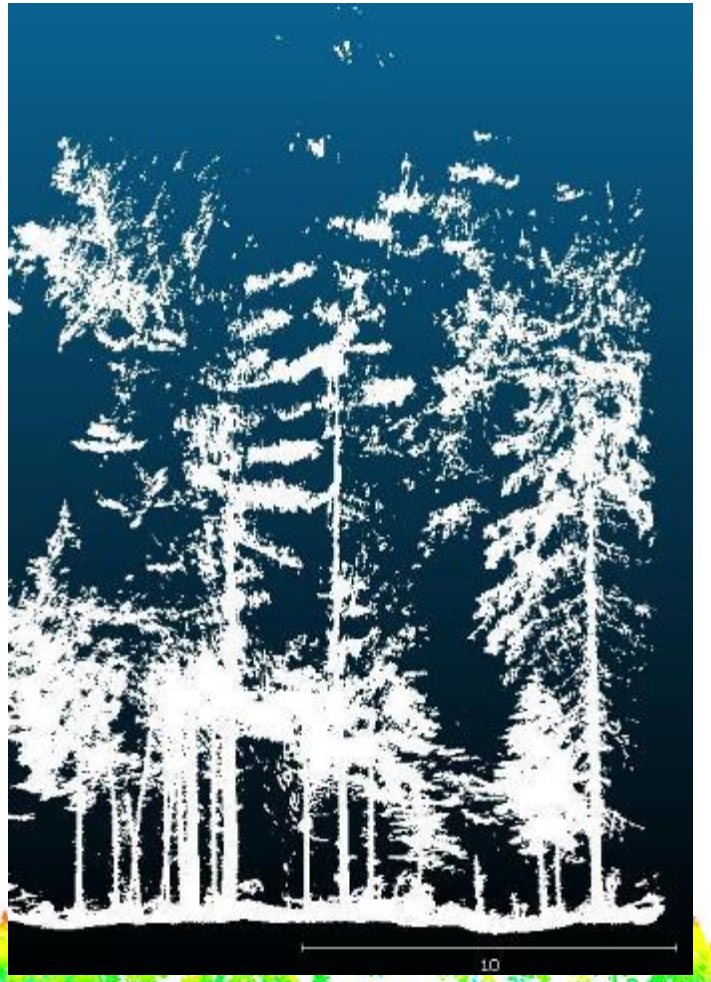


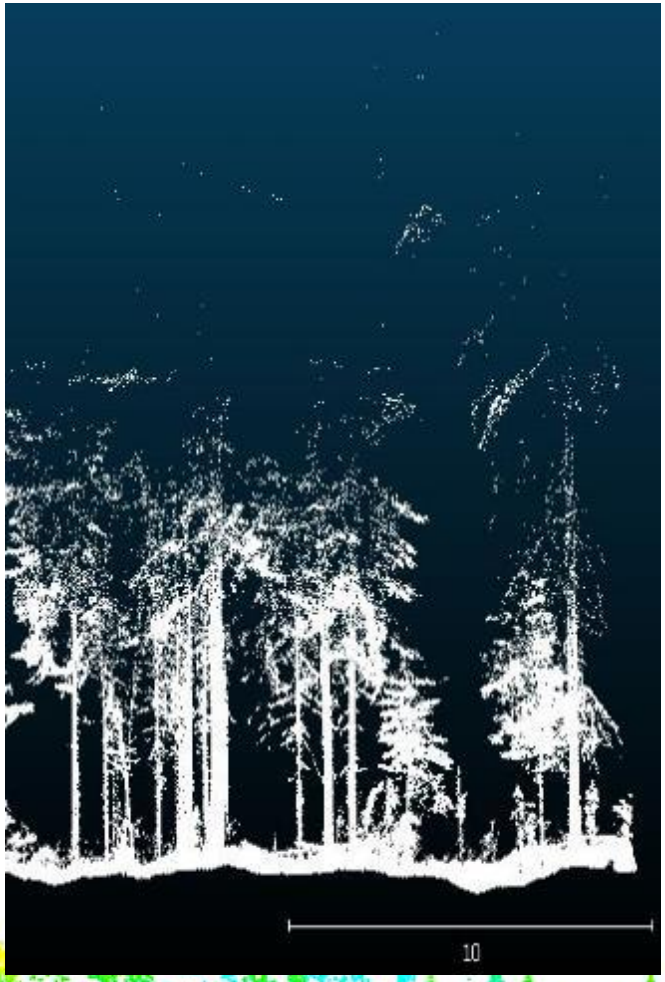
Abdelmounaime Safia , Van Tho (UQAM)

STRUCTURAL ATTRIBUTES FROM GROUND BASED LIDAR

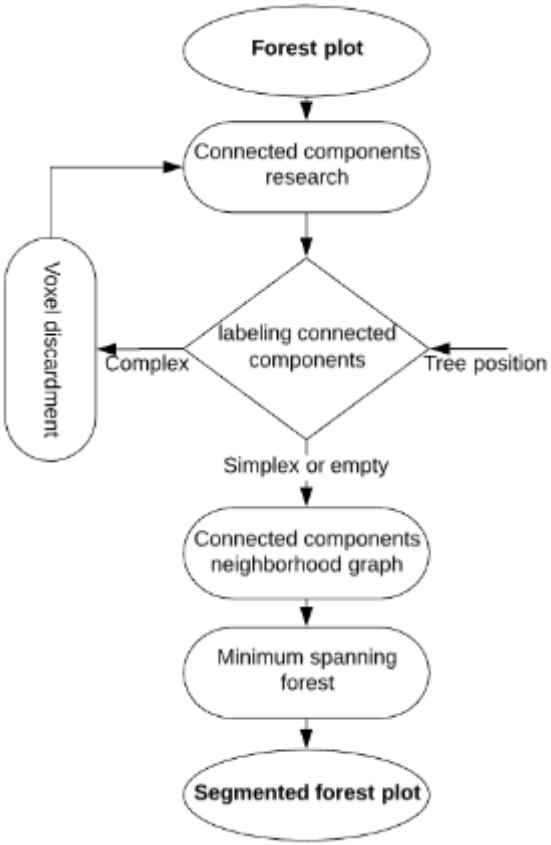


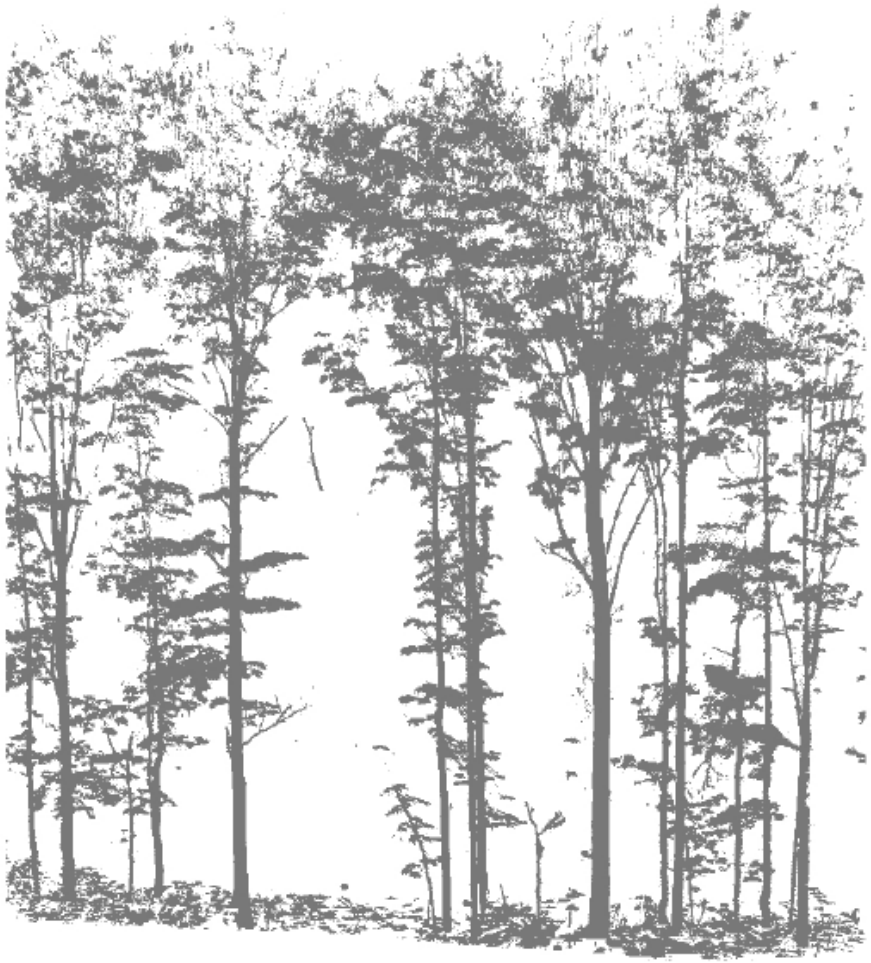
Ground Based and Mobile LIDAR Systems

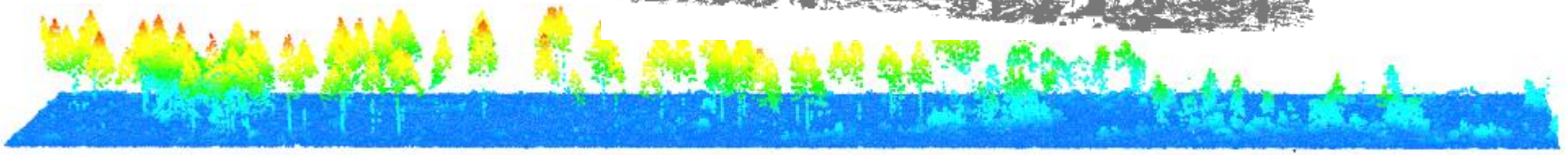




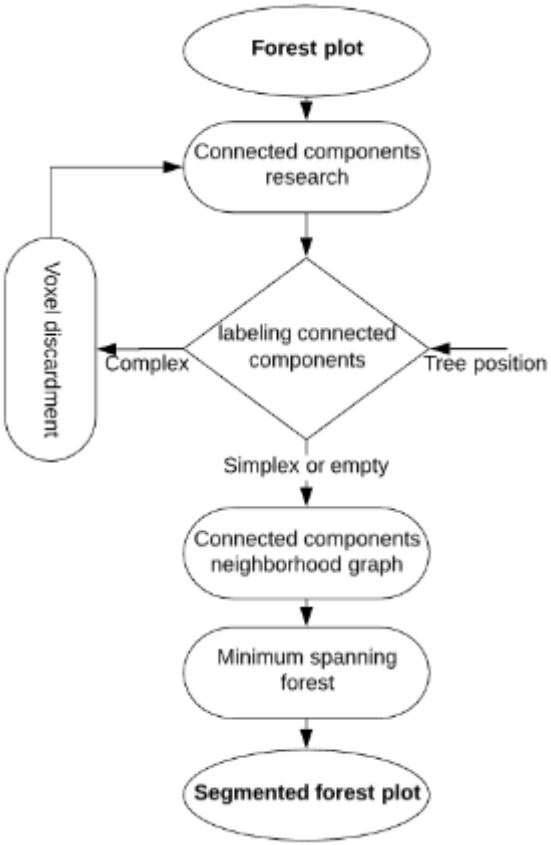
Identification of individual trees in the point cloud

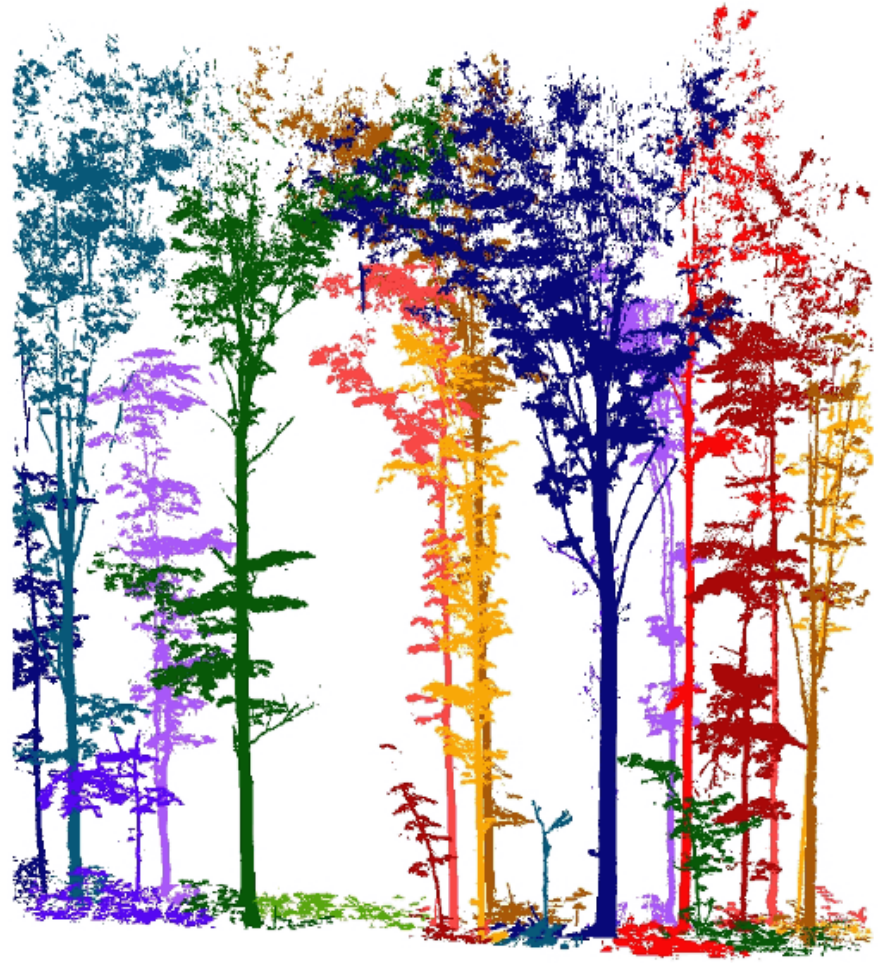


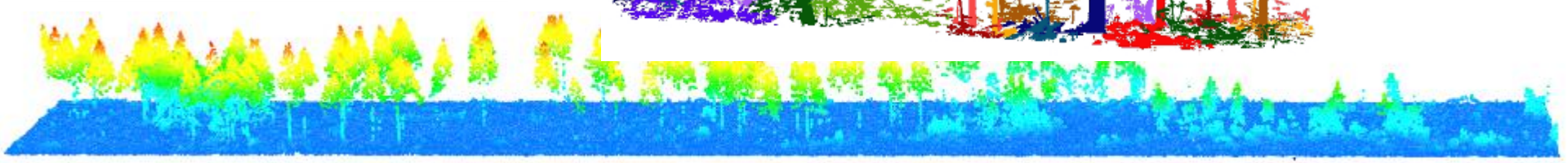




Identification of individual trees in the point cloud

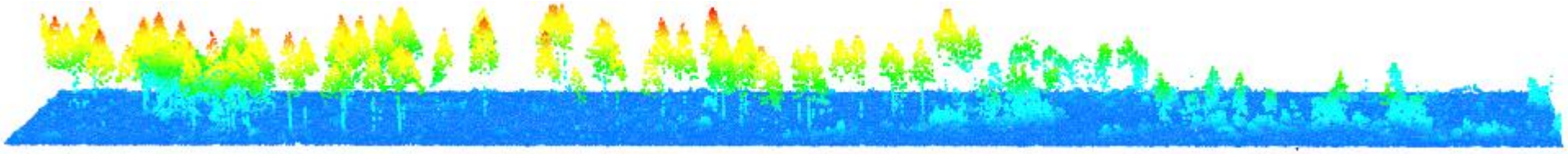




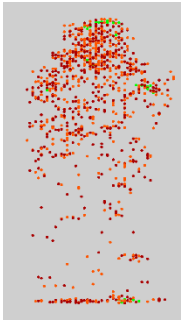


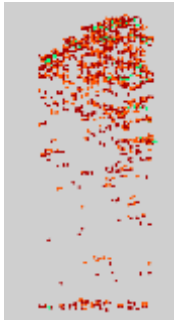
Rachel Perron, Jean-Francois Prieur (UQAM/ Sherbrooke)

IDENTIFYING SPECIES

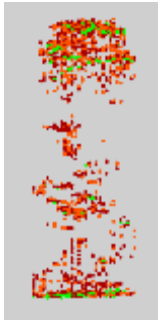


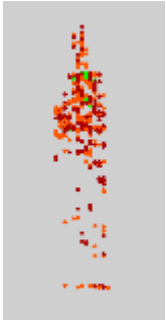
SPECIES ID

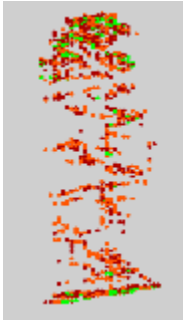

Fraxinus nigra

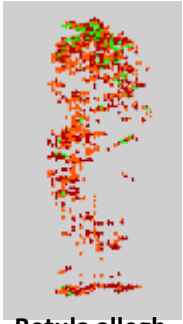

Fraxinus amer.

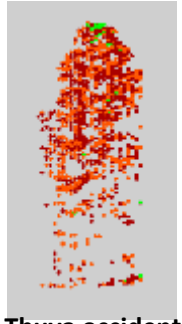

Tilia americana

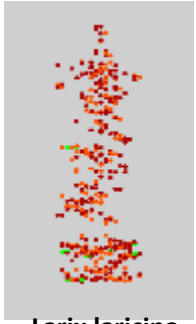

Fagus grandi.

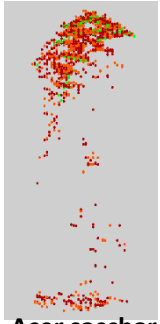

Abies balsamea

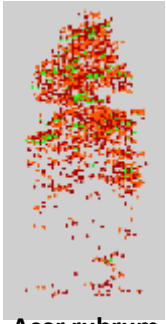

Betula papyrifera

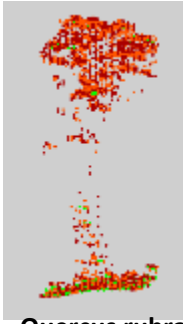

Betula allegh.

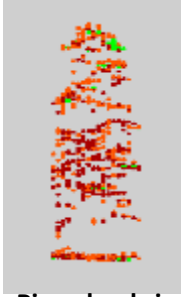

Thuya occident.

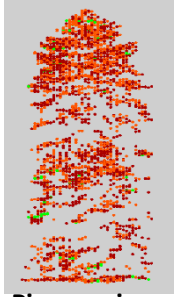

Larix laricina

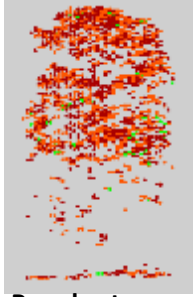

Acer sacchar.

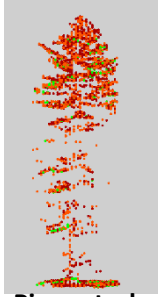

Acer rubrum

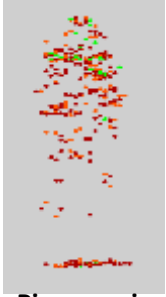

Quercus rubra

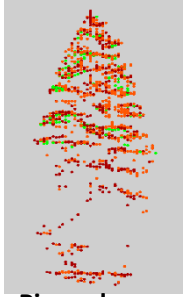

Pinus banksia.

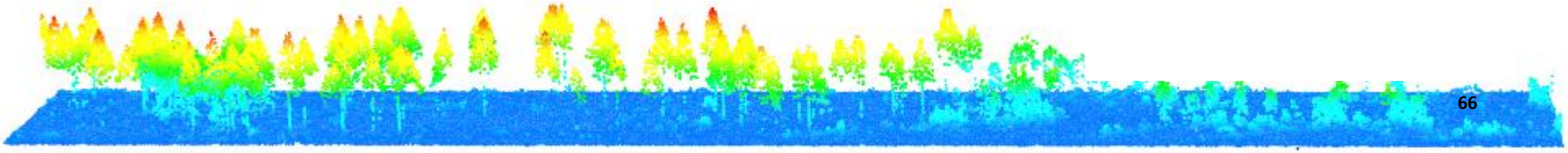

Pinus resinosa

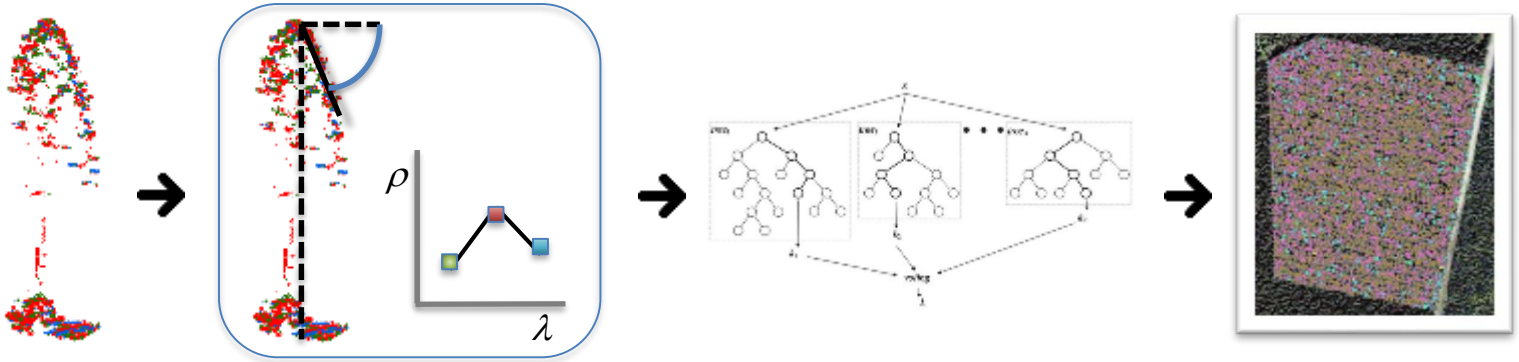

Populus tremu.

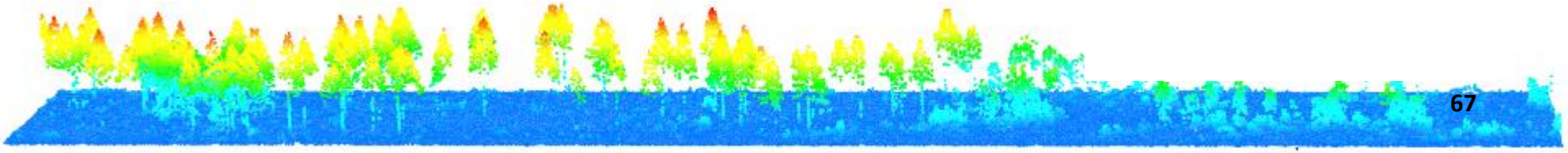

Pinus strobus


Picea mariana

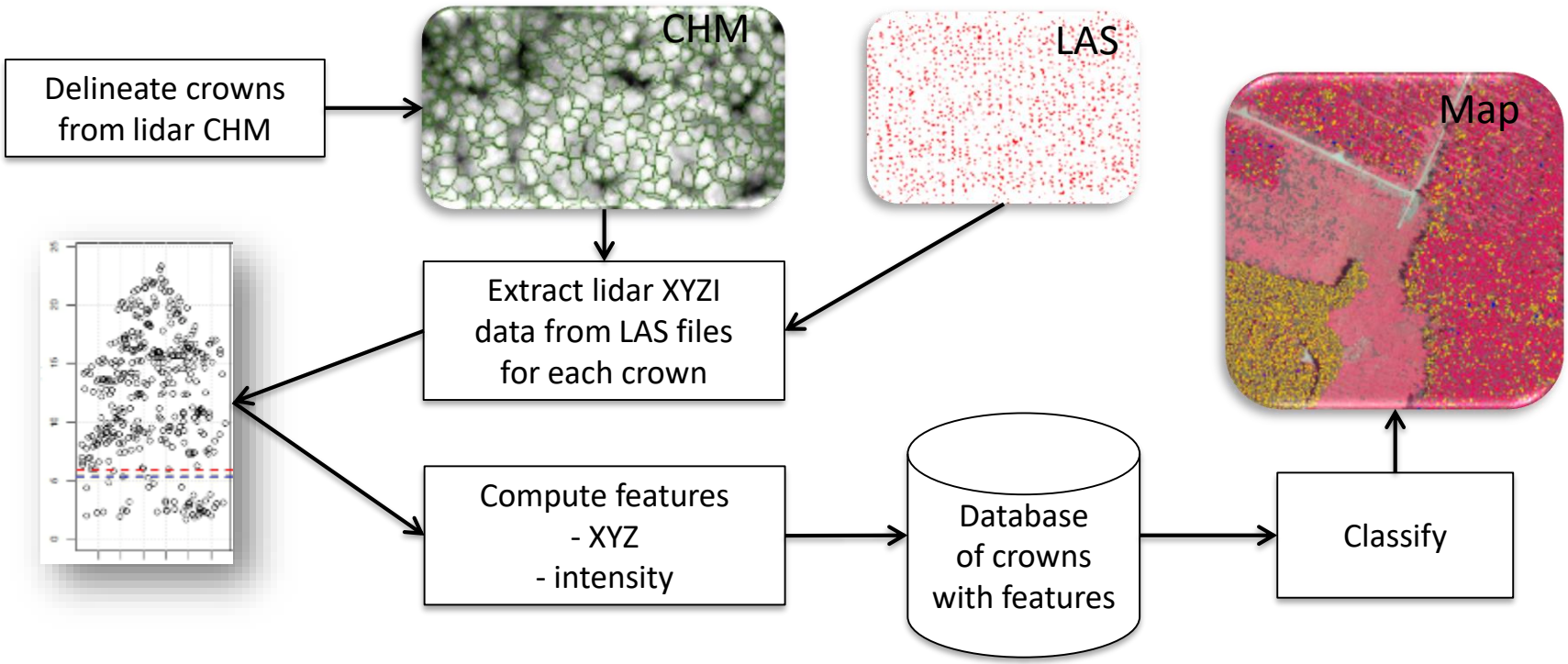

Picea glauca

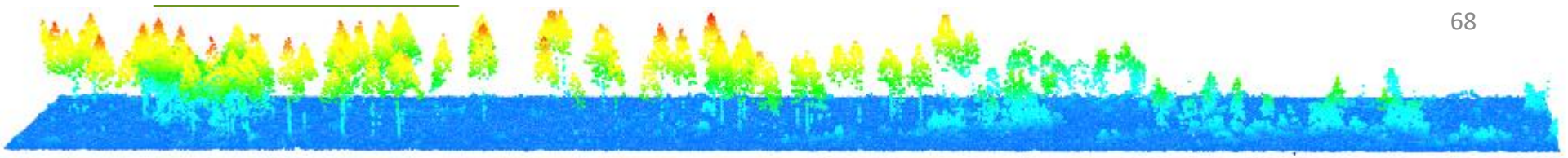



ρ
λ



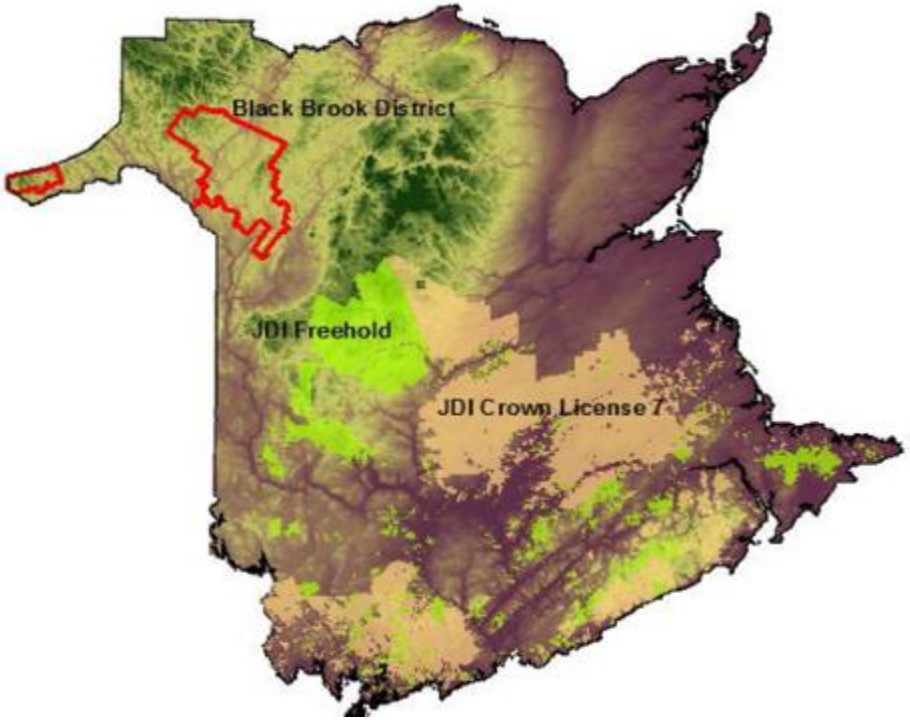
Species Mapping Workflow

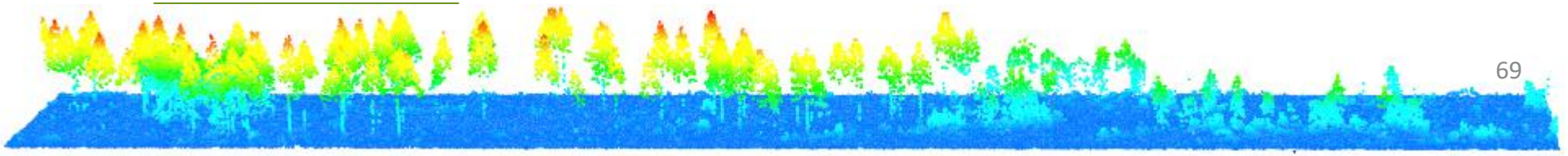




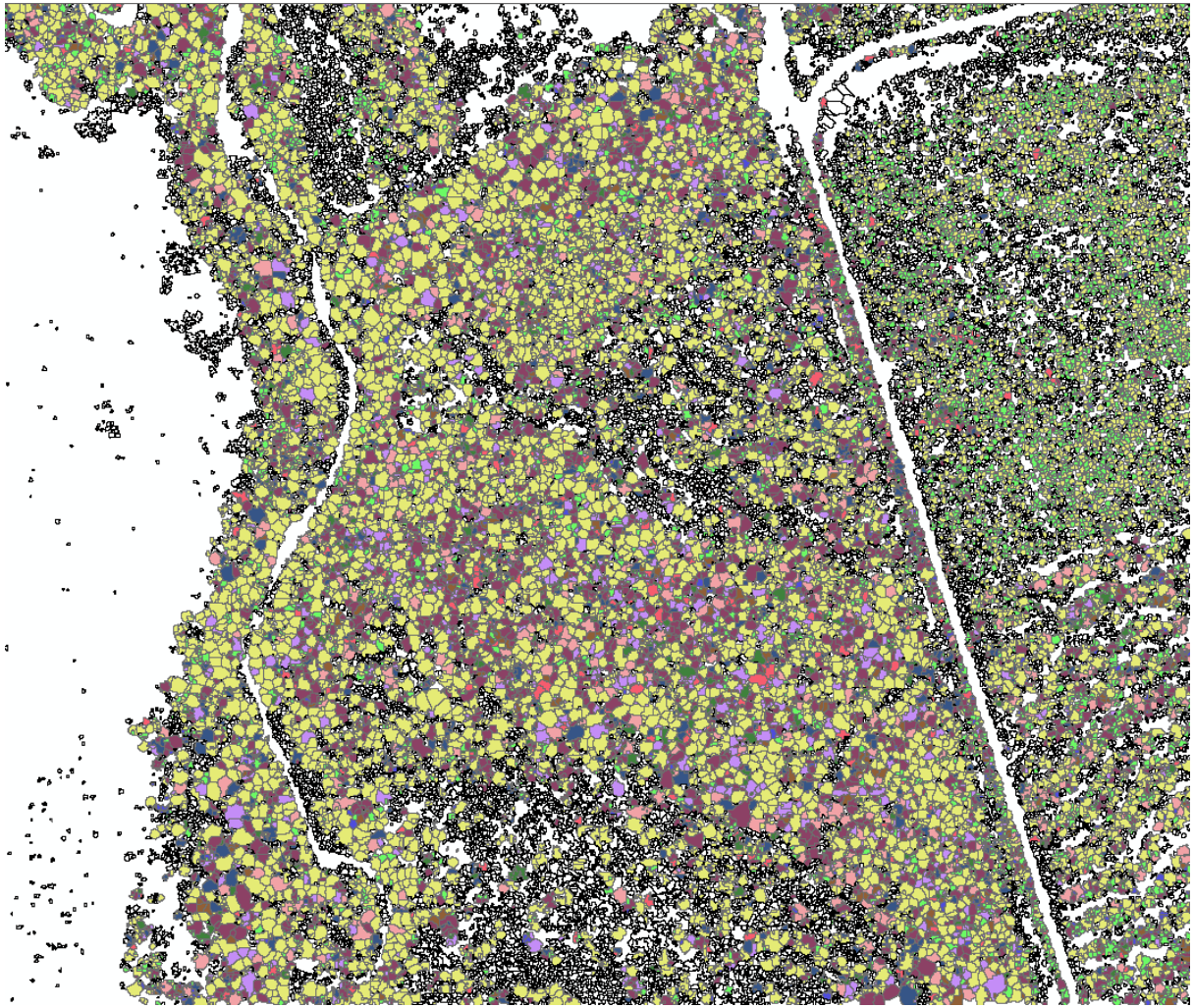
Species Mapping at BlackBrook Forest, NB

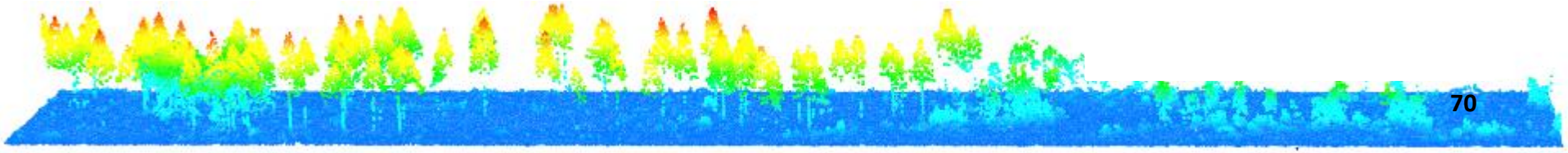
- **209 000 ha**
- White, red, black and Norway spruce planted stands total more than 40% of the landbase
- Tolerant hardwood stands make up 28%





BlackBrook






Species
BE
BF
EC
NS
RM
SM
TA
TL
WB
WBS
YB
0
25
50
100 m

Table 5. Classification levels.

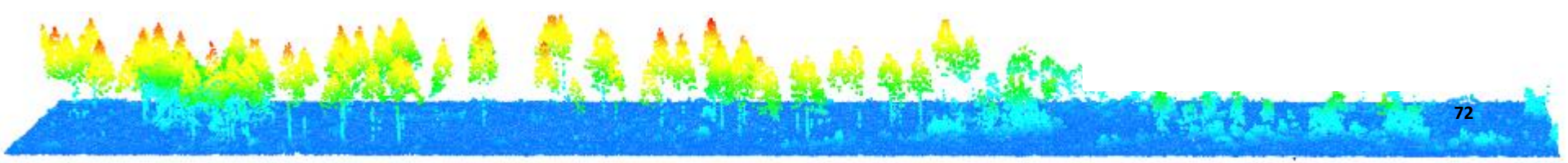
Deciduous/ Coniferous	Functional group	Species
Deciduous (D)	Tolerant deciduous (TH)	Beech (BE) Red maple (RM) Sugar maple (SM)
	Birch (BI)	White birch (WB) Yellow birch (YB)
	Trembling aspen (PO)	Trembling aspen (PO)
Coniferous (C)	Spruce-Fir (SF)	Spruce (black/white, SP) Norway spruce (NS) Balsam fir (BF)
	Pine (PI)	Jack pine (JP) Red pine (RP)
	Eastern white cedar (EC)	Eastern white cedar (EC)
	Eastern larch (TL)	Eastern larch (TL)

	Deciduous	Coniferous	*UA*
Deciduous	1273 (1401)	113 (129)	92 (92)
Coniferous	246 (118)	2429 (1229)	91 (91)
PA	84 (92)	96 (91)	91 (91)

Global model, both sectors

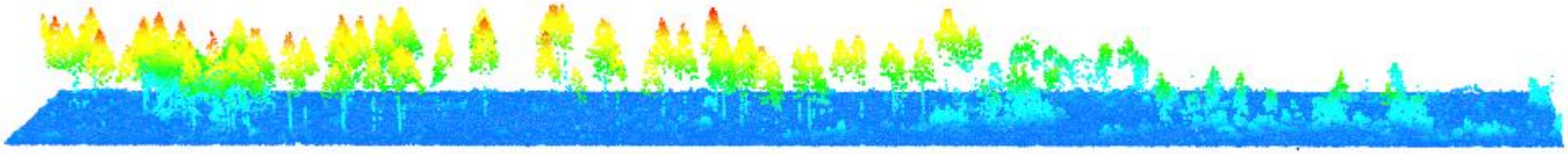
Table 9. Confusion matrix for the functional groups using the global model for the entire AOI. Numbers in parentheses are for the 10 species case, the others for the 13 species case.

	BI	EC	PI	PO	SF	TH	TL	*UA*
BI	207 (247)	7 (16)	1 (-)	23 (36)	15 (33)	119 (136)	19 (-)	53 (53)
EC	25 (6)	54 (22)	2 (-)	11 (2)	61 (10)	27 (5)	16 (-)	27 (49)
PI	13 (-)	1 (-)	941 (-)	23 (-)	115 (-)	17 (-)	12 (-)	84 (-)
PO	57 (72)	1 (6)	8 (-)	143 (16)	18 (39)	55 (61)	14 (-)	48 (48)
SF	22 (46)	9 (37)	26 (-)	12 (24)	951 (1160)	27 (36)	33 (-)	88 (89)
TH	167 (161)	8 (15)	3 (-)	23 (25)	13 (21)	478 (50)	5 (-)	69 (69)
TL	40 (-)	14 (-)	4 (-)	14 (-)	89 (-)	16 (-)	100 (-)	36 (-)
PA	39 (46)	57 (23)	96 (-)	57 (65)	75 (92)	65 (68)	50 (-)	71 (73)



Jean-Francois Prieur (UQAM/ Sherbrooke), Bastian Vandendaele (Sherbrooke) Chris Mulverhill (UBC)

NEW DATA AND APPROACHES



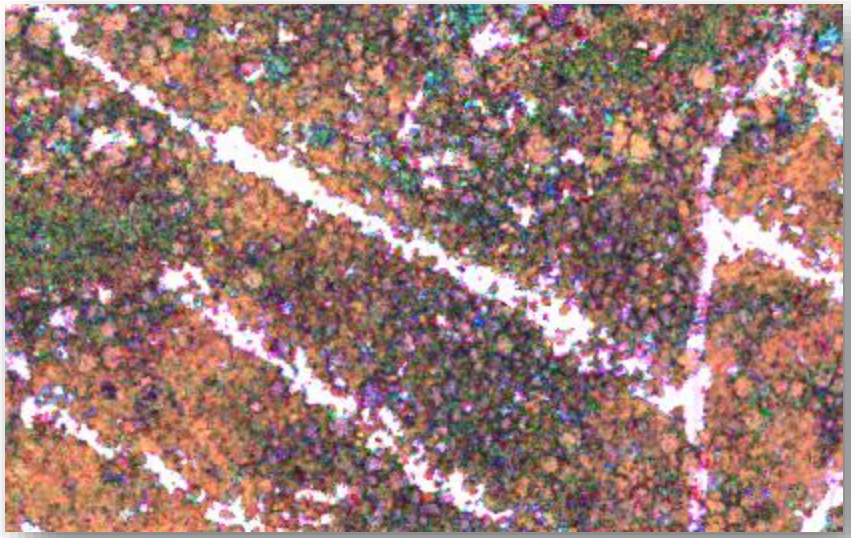
Multispectral lidar

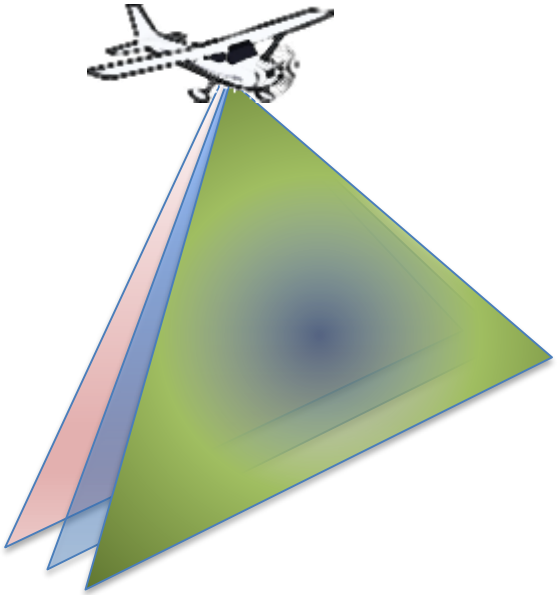
The Titan system from Teledyne Optech scans in 3 λ

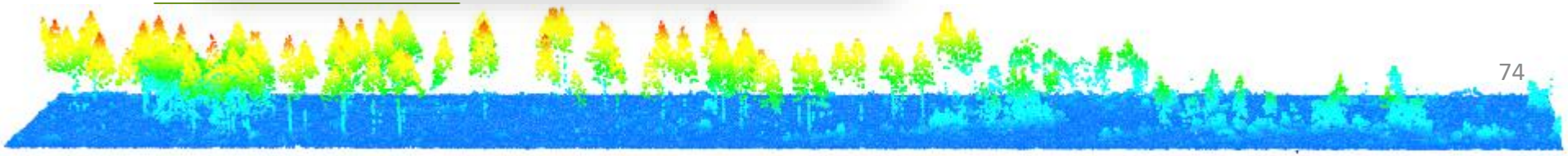
1064 nm (NIR = C2) @ 0.0°

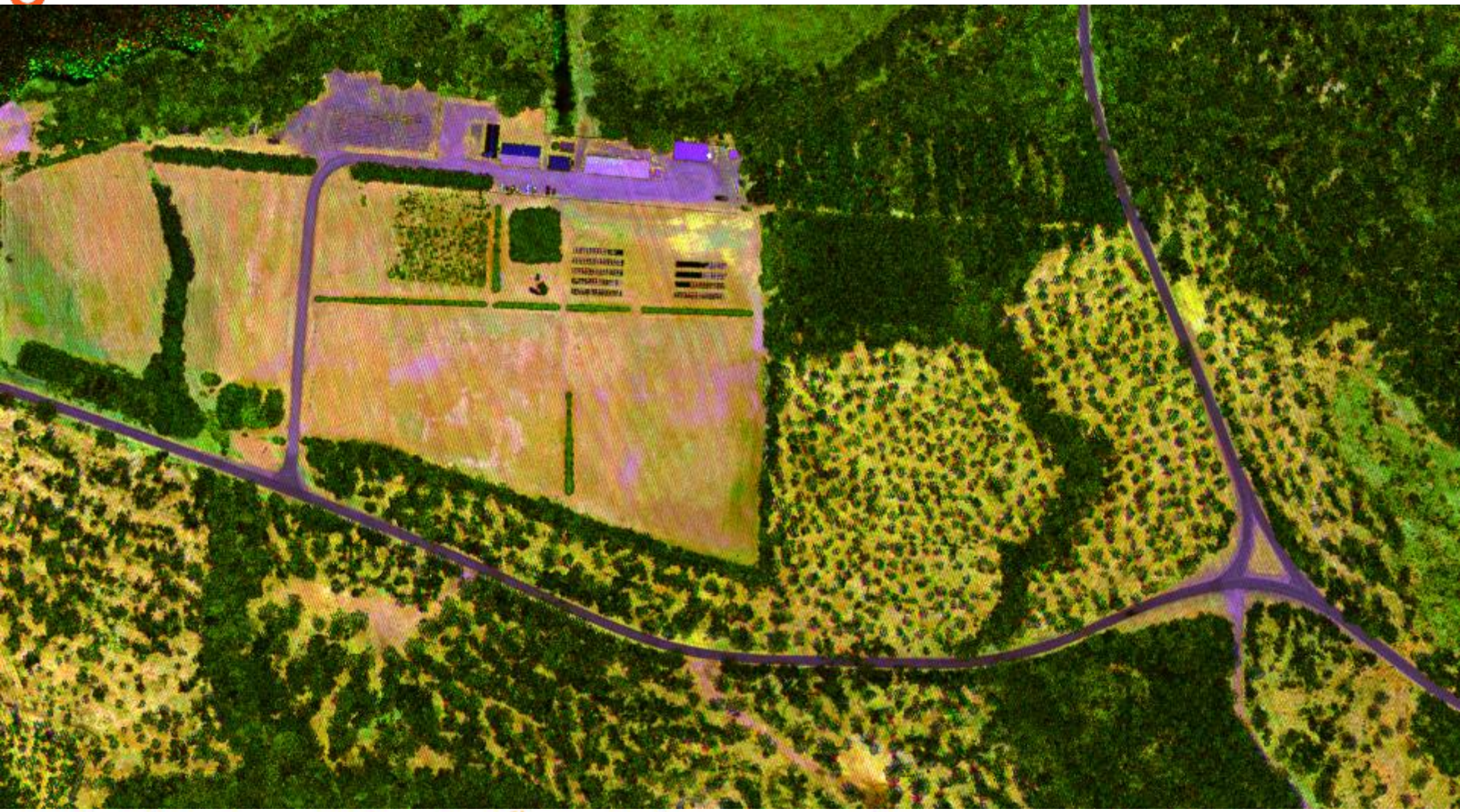
1550 nm (SWIR = C1) @ 3.5°

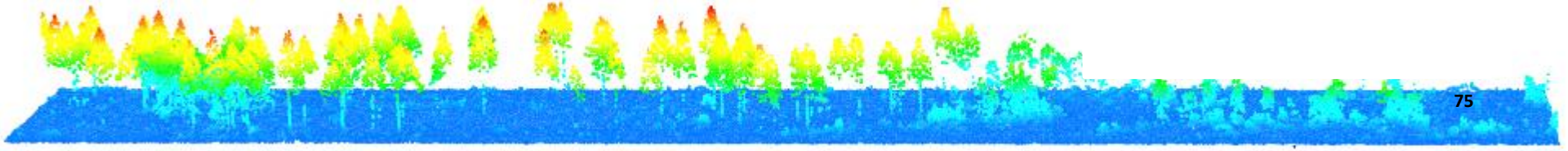
532 nm (green = C3) @ 7.0°





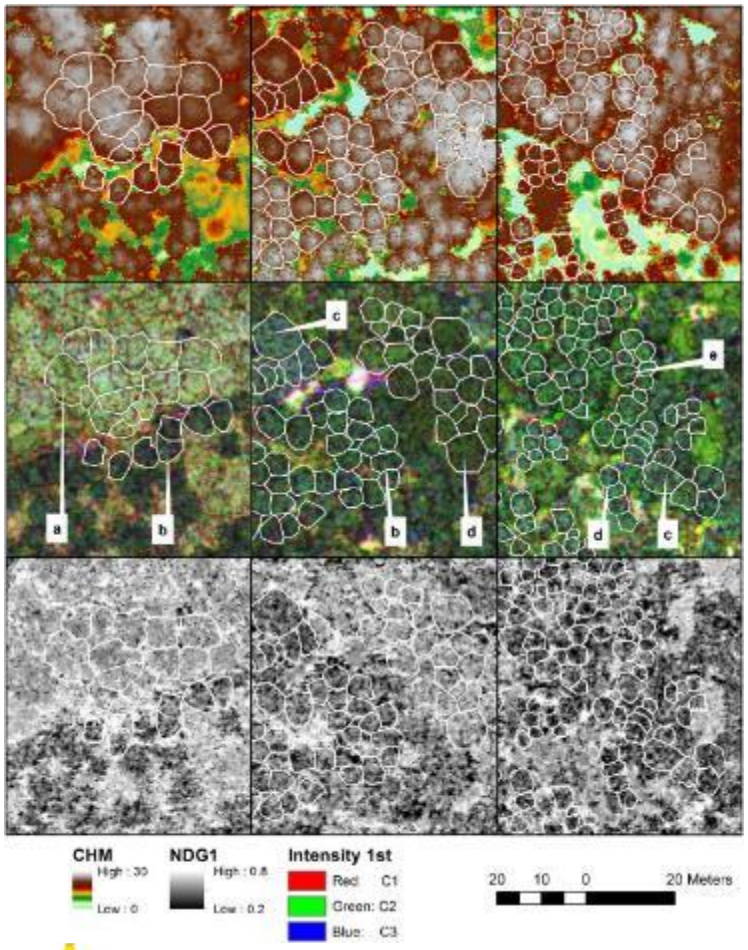




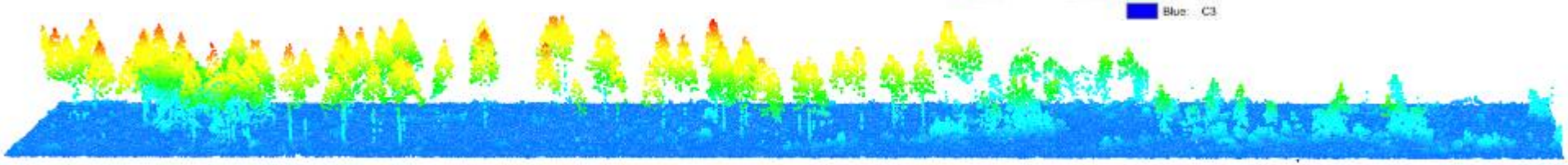


Classifying species with multispectral ALS

- Optech Titan 3D and intensity data
- 10 tree species – accuracy 75%
- 1550 nm channel and green normalized difference spectral index were most useful

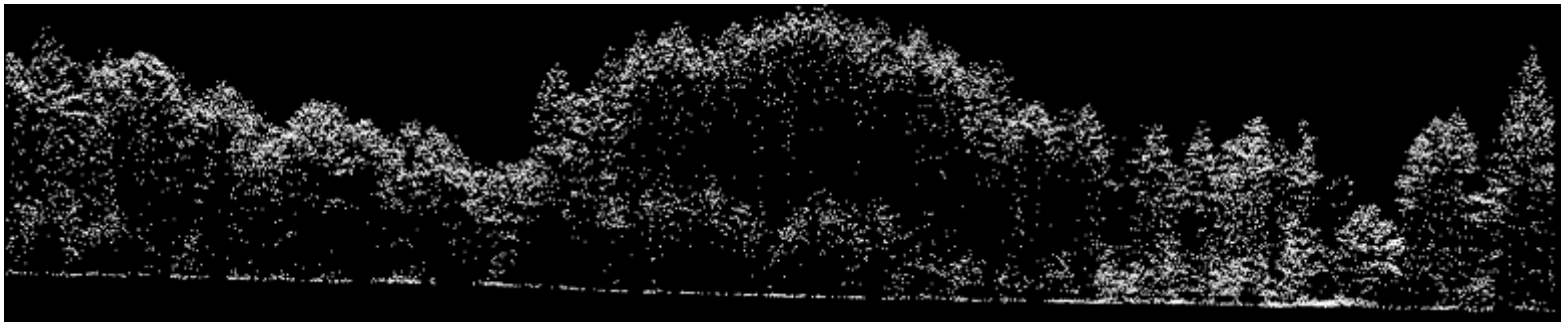


Budei, B. C., St-Onge, B., Hopkinson, C. et Audet, F.-A. (2018). Identifying the genus or species of individual trees using a three-wavelength airborne lidar system. *Remote Sensing of Environment*, *204*, 632-647. doi:10.1016/j.rse.2017.09.037

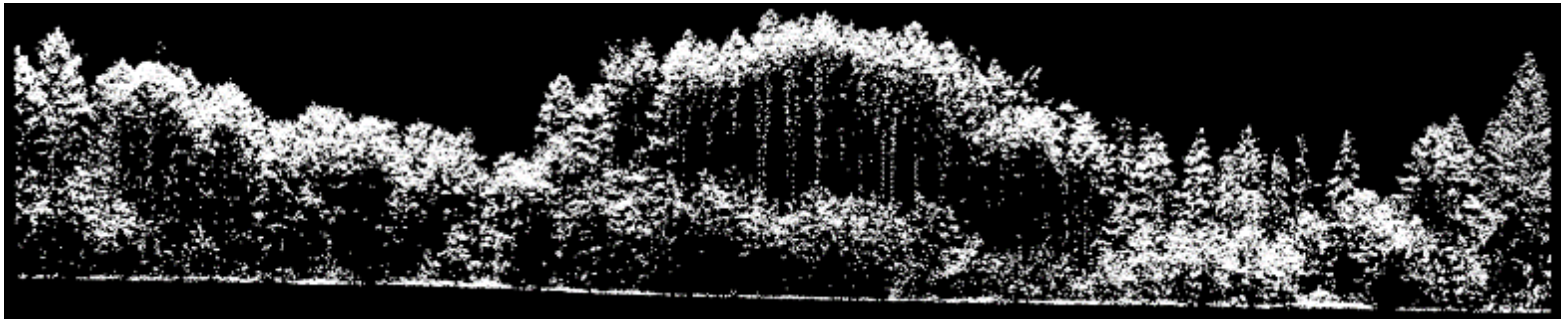


Petawawa

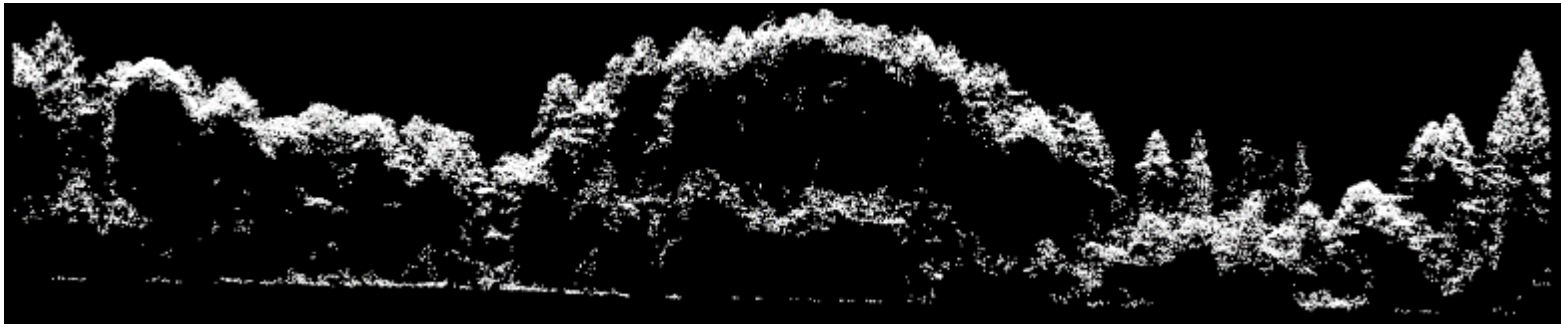
Standard ALS

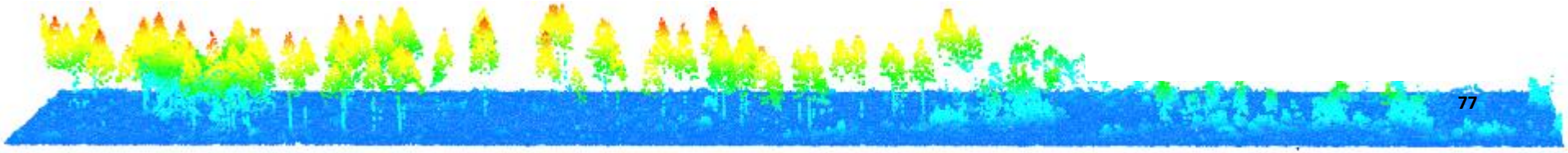


Multi-spectral ALS

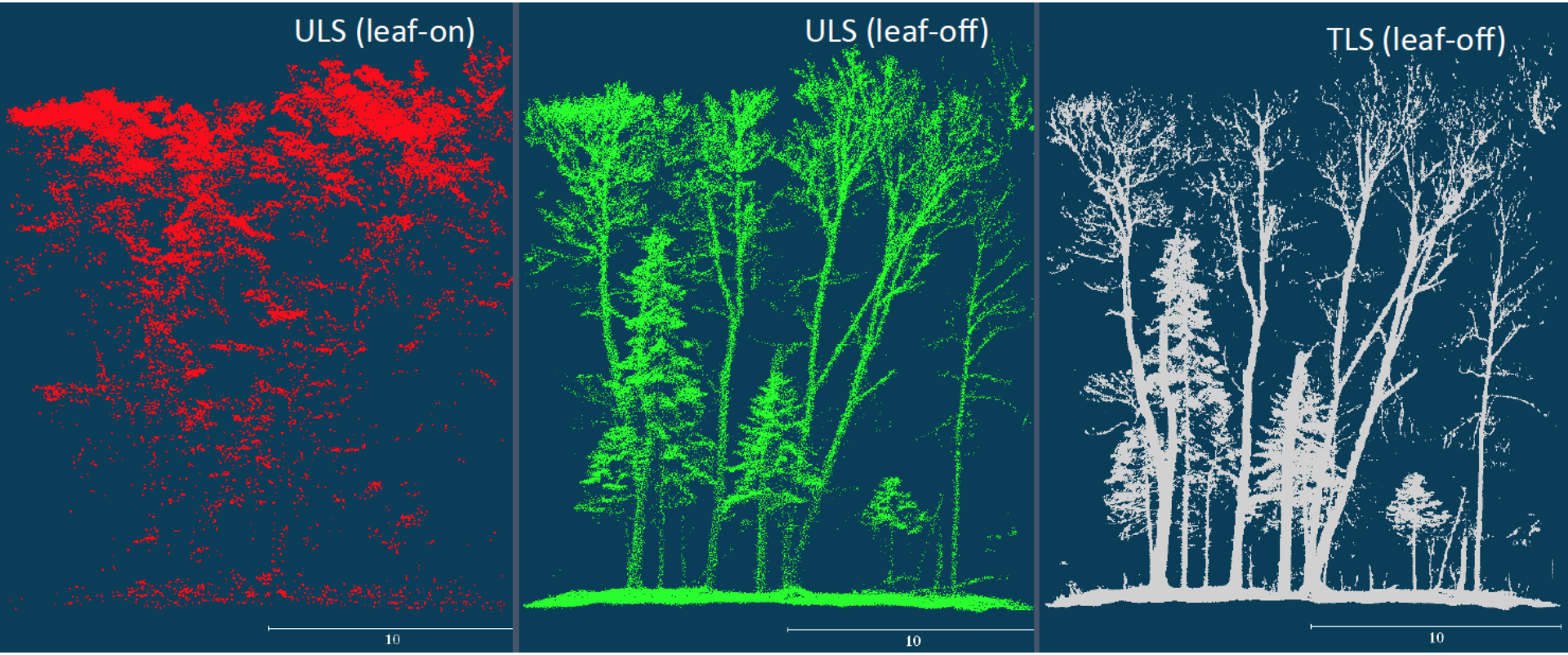


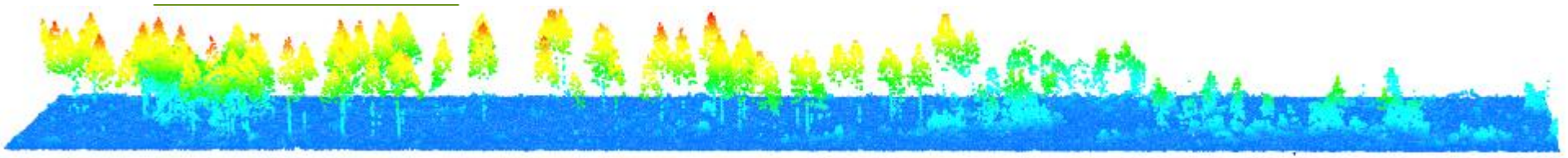
Single Photon





UAV LIDAR for forest inventory





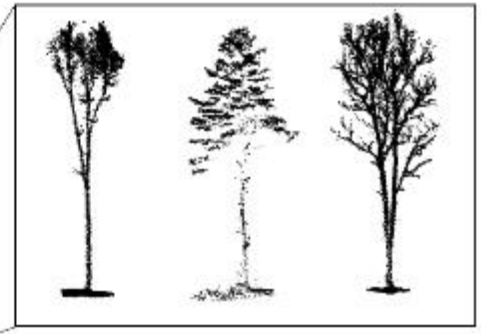
Tree Segmentation

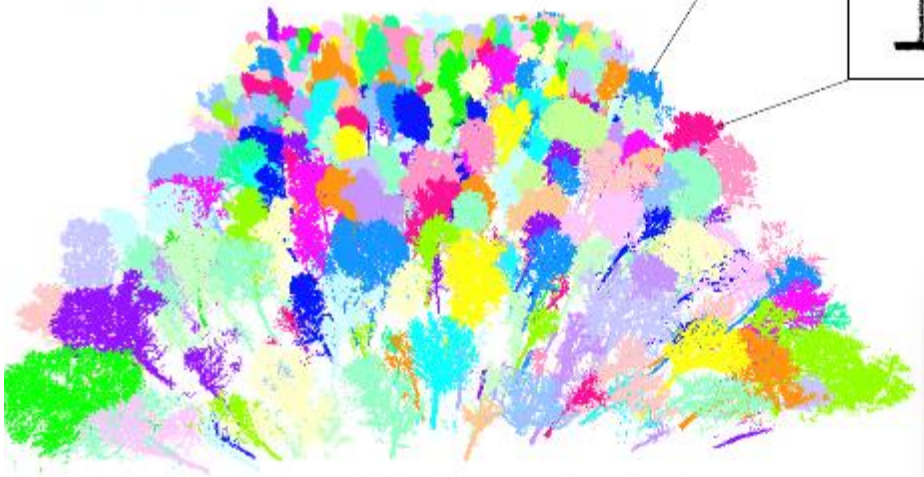
N° Tree: 532

Correctly segmented: **78%**

Oversegmented: **5%**

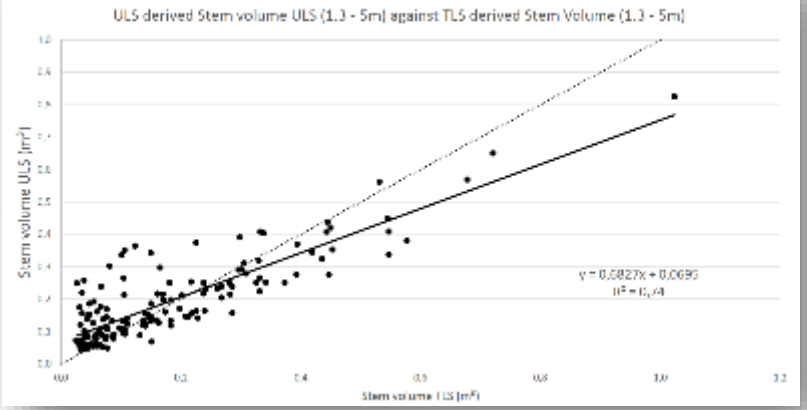
Undersegmented: **17%**

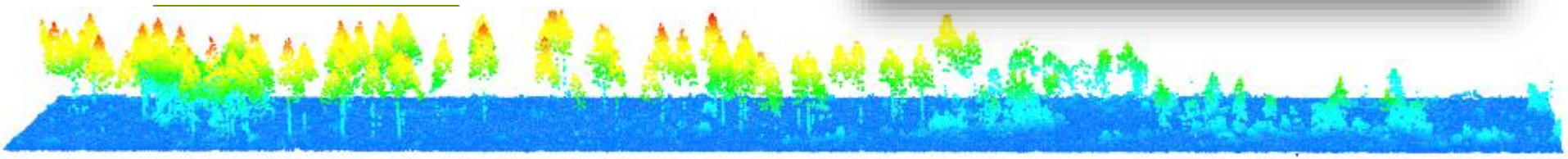


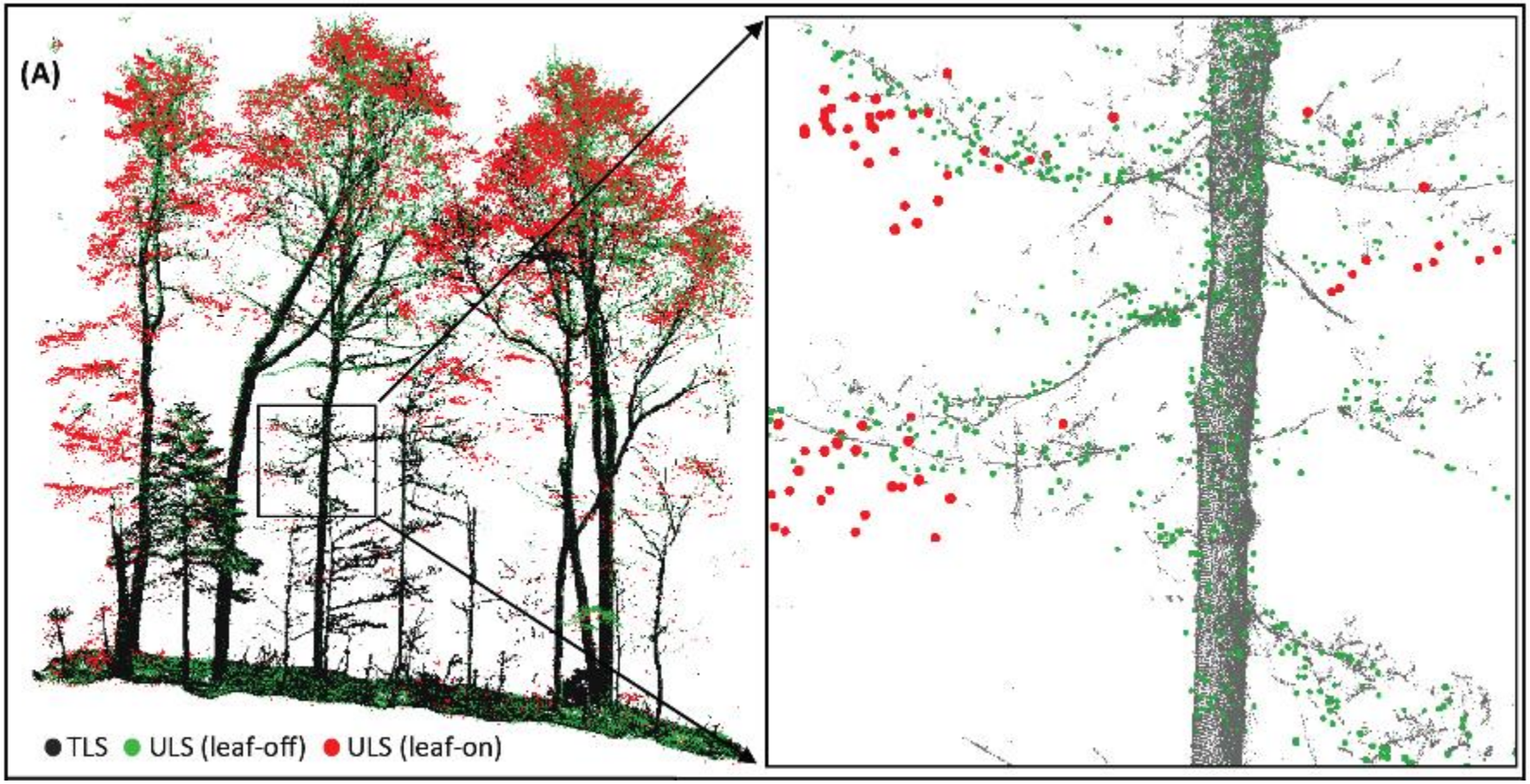


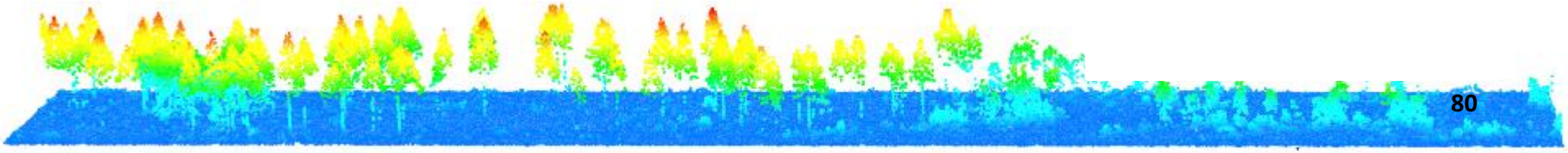
Mc Coy Brook deciduous site (NHRI) – 1ha

Stem Volume (1.3 m – 5m)

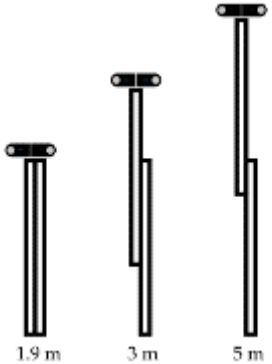





(A)
TLS
ULS (leaf-off)
ULS (leaf-on)



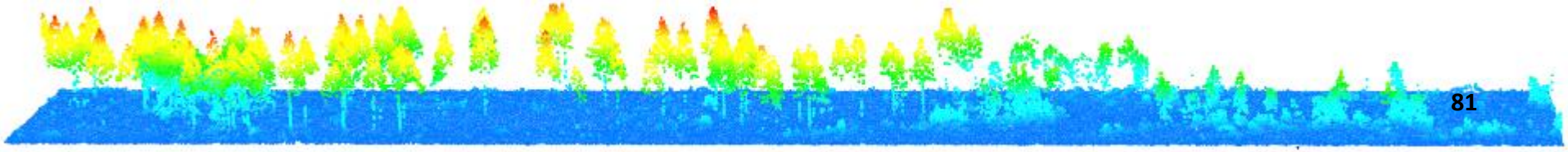
DAP on the ground

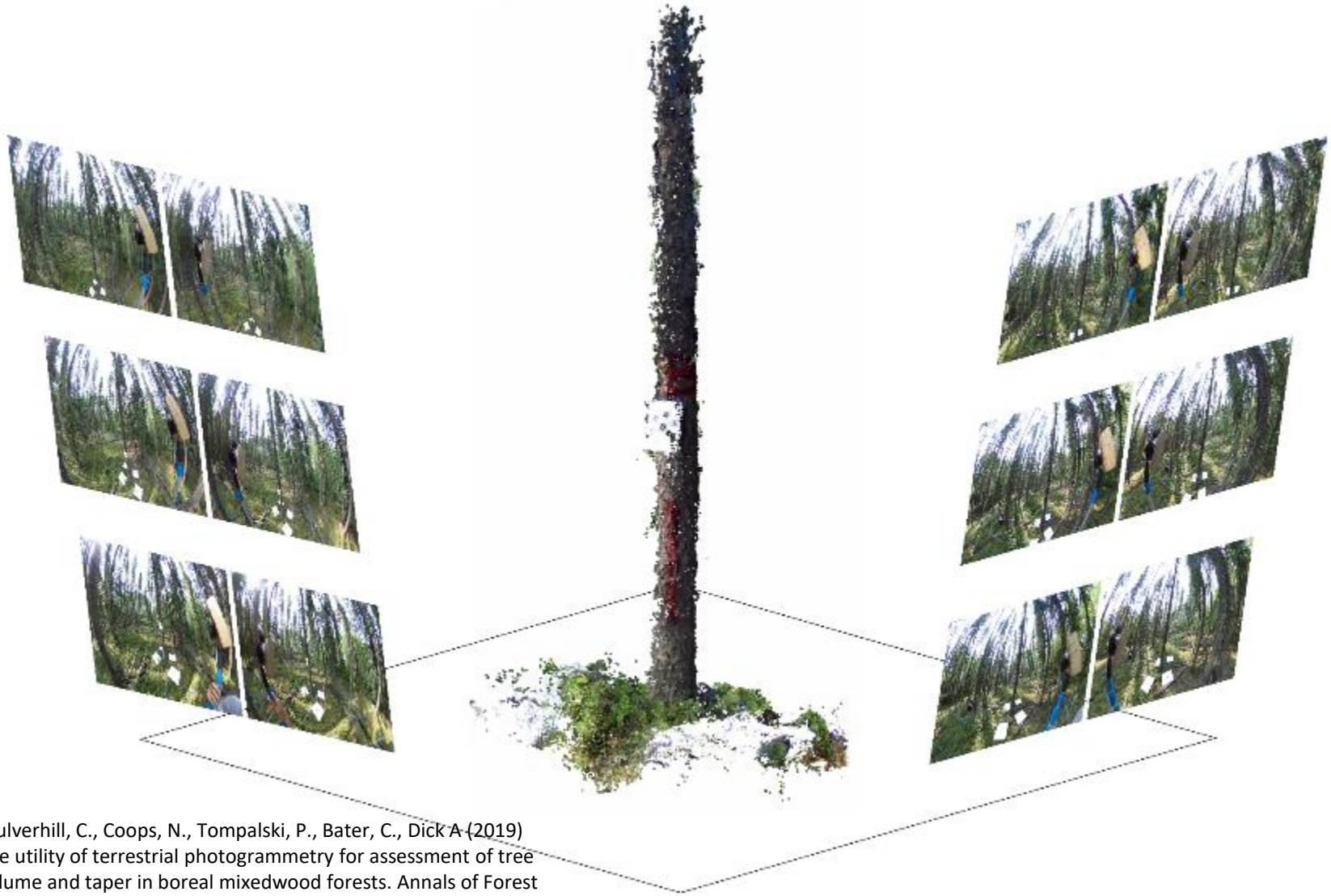


- Two Ricoh THETA S 360˚ cameras
- 3 different heights:

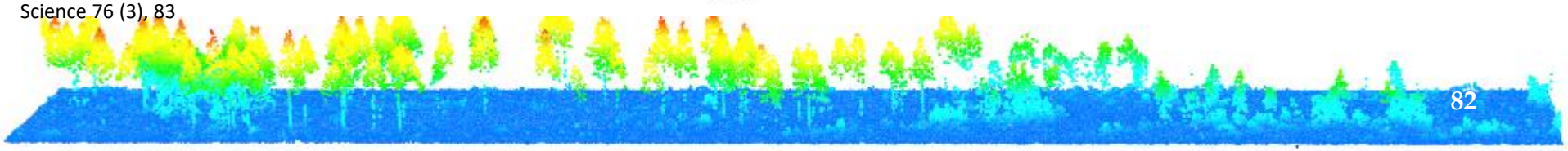
  1.9m, 3m, 5m
- Different locations around individual trees and plots

- 30 individual trees photographed, felled, and measured



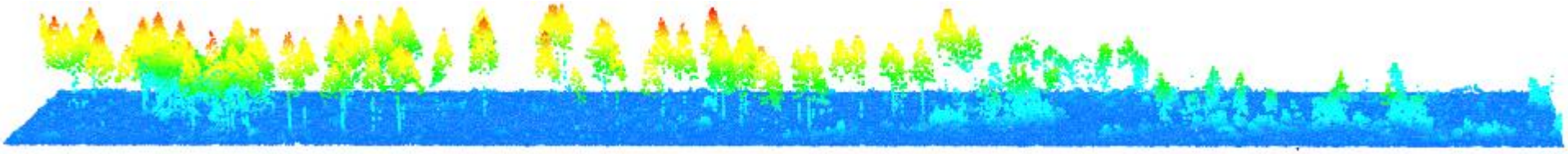


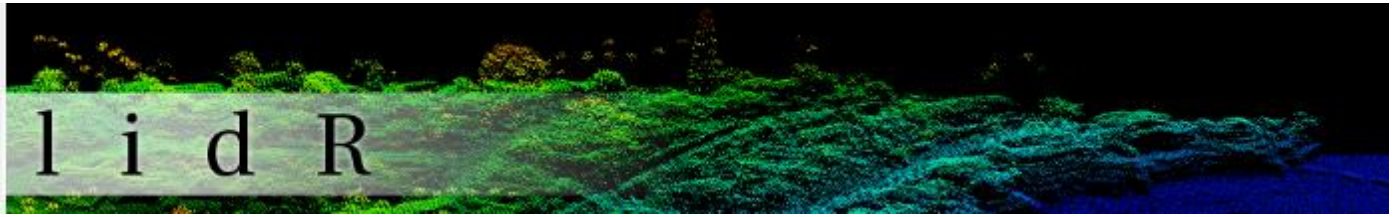
Mulverhill, C., Coops, N., Tompalski, P., Bater, C., Dick A (2019) The utility of terrestrial photogrammetry for assessment of tree volume and taper in boreal mixedwood forests. Annals of Forest Science 76 (3), 83



Jean-Romain Roussel

ACCESSIBLE, FREE CODE





Jean-Romain Roussel

jean-romain.roussel.1@ulaval.ca

https://github.com/Jean-Romain/lidR

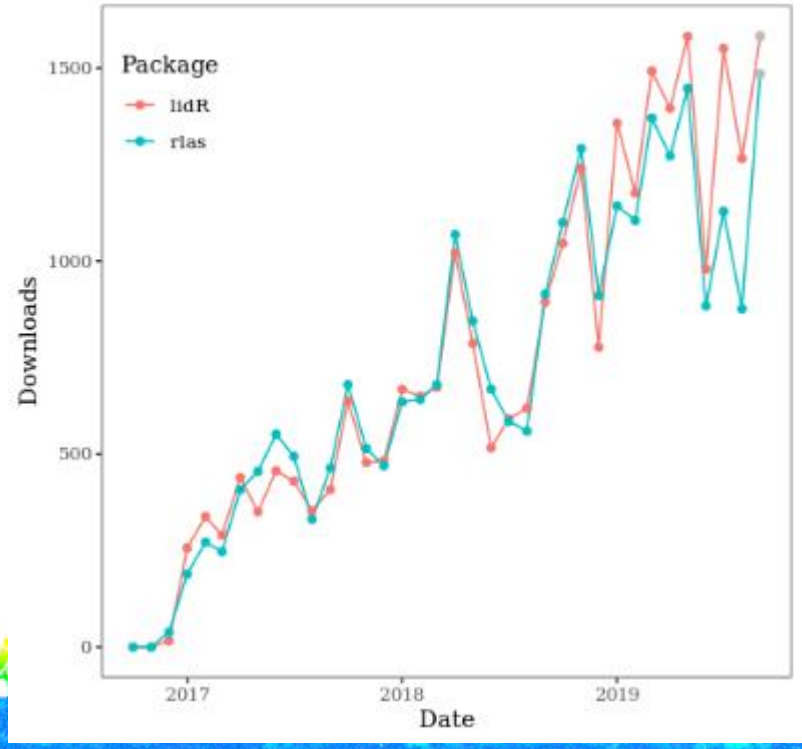
lidR does not aim to provide predefined processes, it is designed to enable users to build their own.

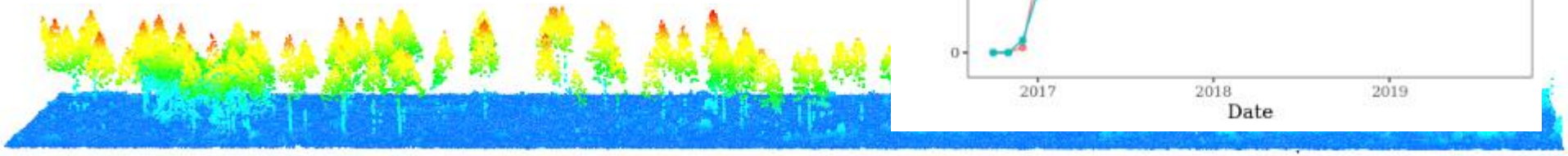
Support for multi-core processing

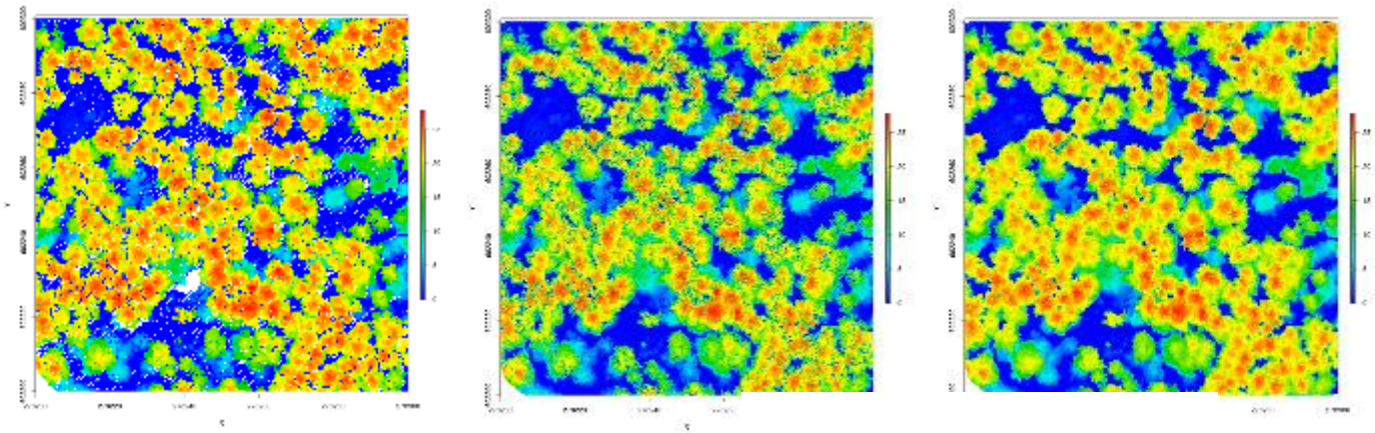
Processing of Large Datasets

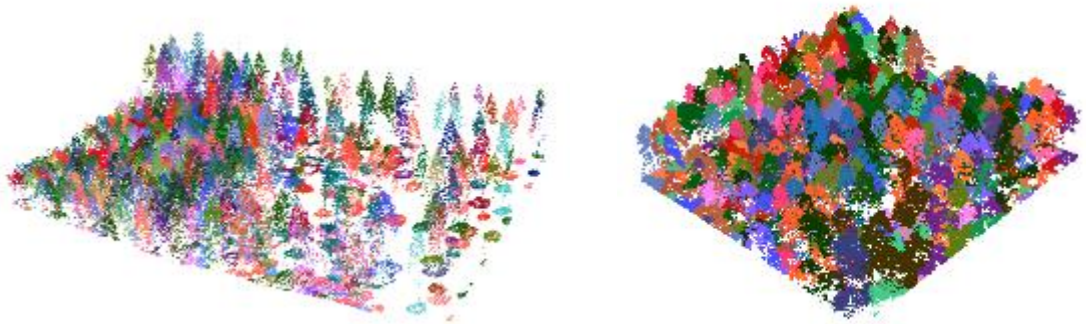
Examples:

- Multiple algorithms to create CHM
- Multiple algorithms to segment crowns
- Custom metrics







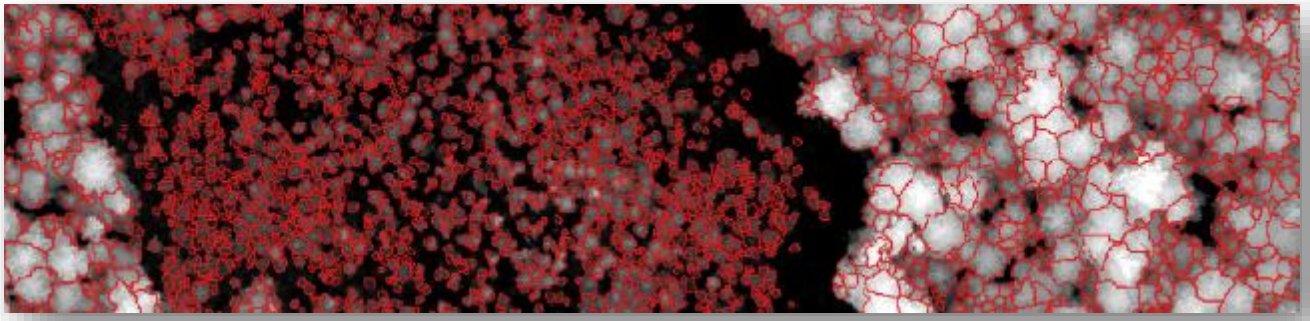


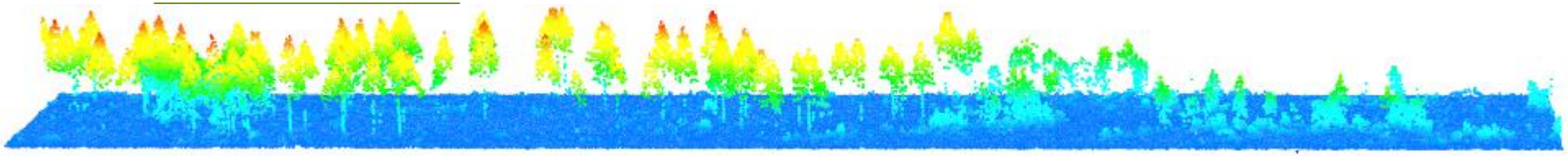
- https://github.com/Jean-Romain/lidR/
- https://github.com/Jean-Romain/lidR/wiki
- https://CRAN.R-project.org/package=lidR

SEGMA

Tree crown delineation software for airborne lidar CHMs

- Free, open source, cross-platform, and fast solution for delineating individual trees from lidar CHMs.
- Direct batch production of shapefiles where each polygon represents a tree crown.
- Computes attributes for each crown.
- Provides a key input for tree species ID.

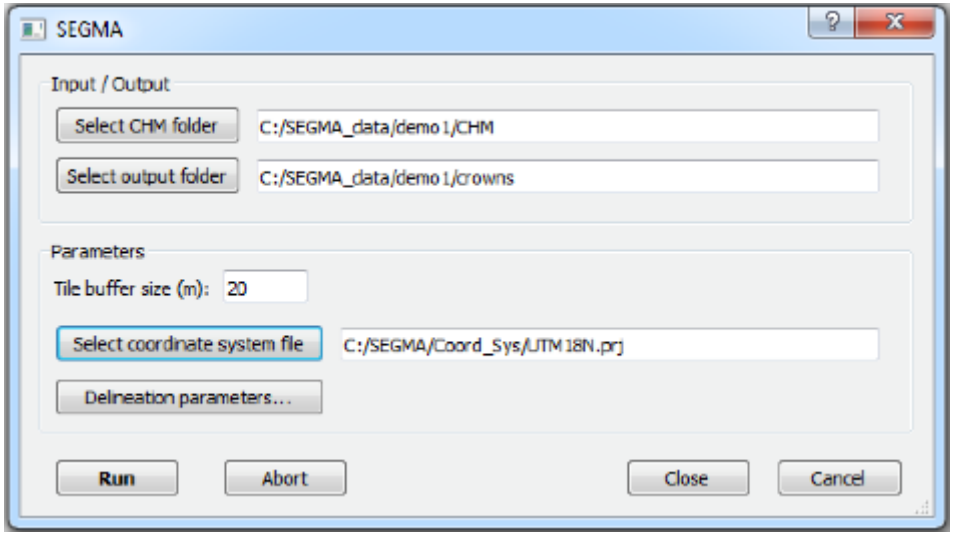


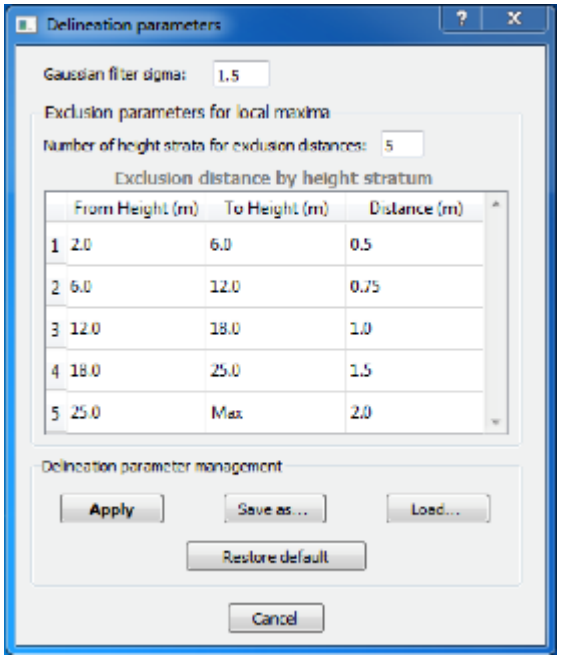


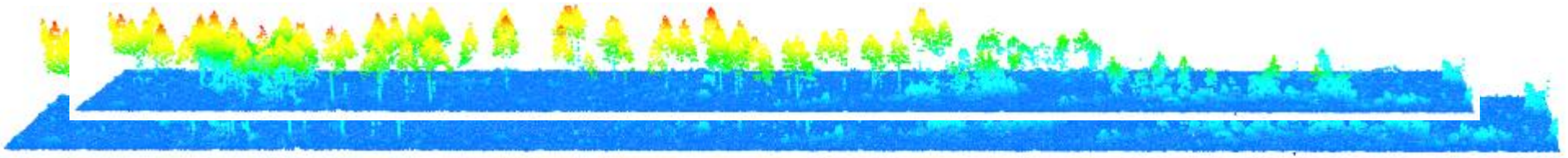
SEGMA

Tree crown delineation software for airborne lidar CHMs

Comes with a graphical user interface.

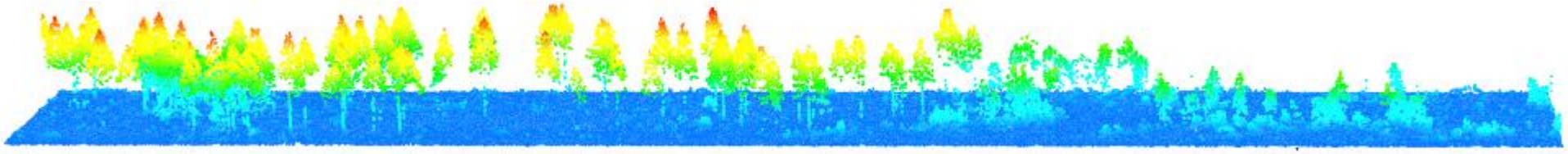




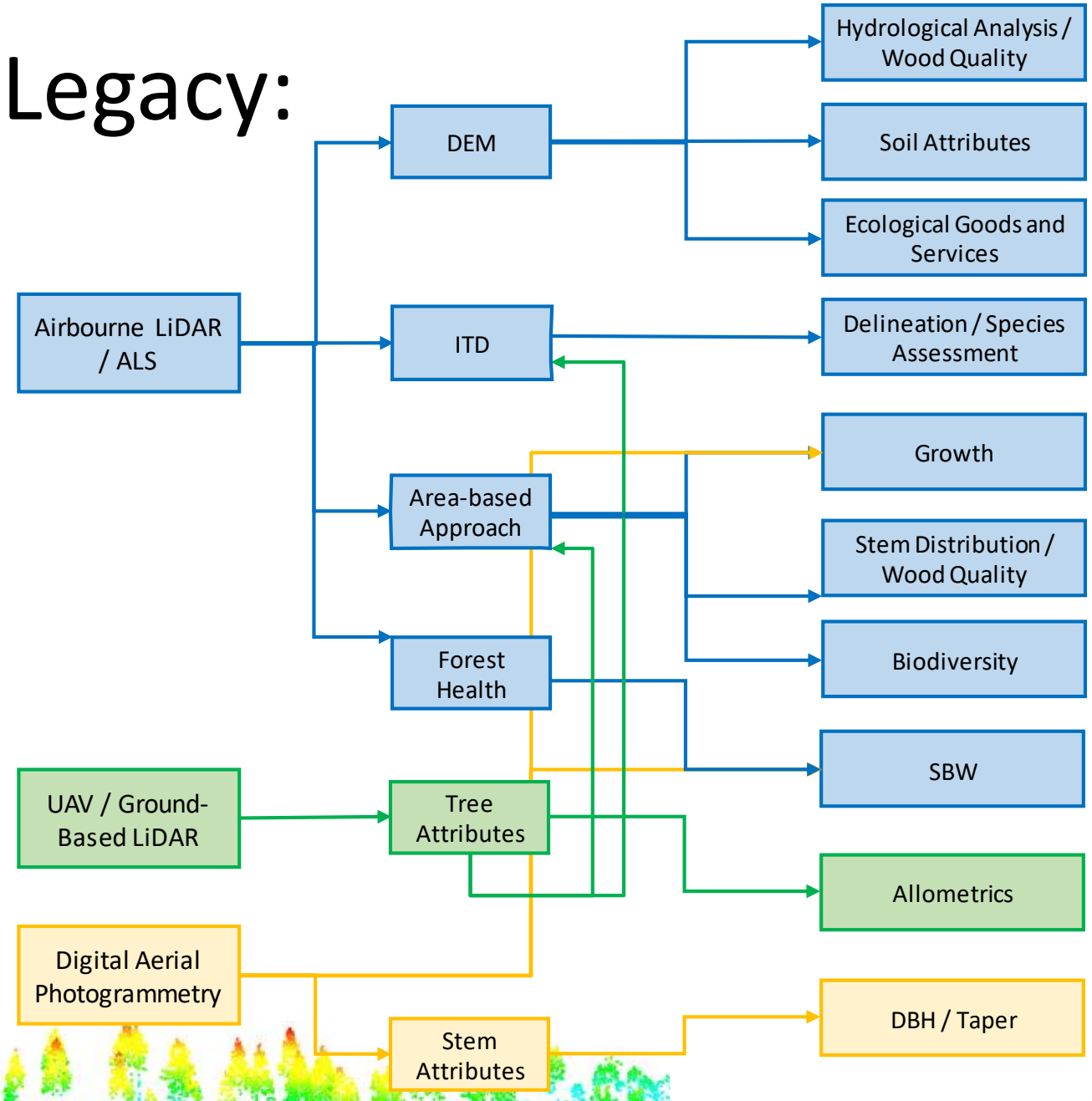



Best Practice / Tools / Decision Support
Species Assessment
Data Acquisition Program and Platforms

WRAP-UP



AWARE Legacy:



AWARE Legacy:

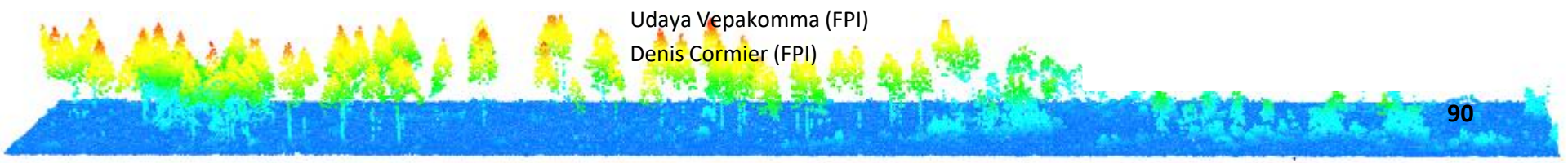
- Provided funds for 25 Graduate Students, Postdocs and Research Associates
- 9 students have graduated to date, with more completing
- 18 journal review papers to date; 8 in review and more to come
- 25 posters, conference proceedings, reports
- Quarterly newsletter
- Industry – Government – University Collaborations
- Long Term Website for Data / papers / reports being developed

AWARE.FORESTRY.UBC.CA

University Investigators:
Nicholas Coops; Peter Marshall (UBC)
Alexis Achim (Laval)
Paul Treitz (Queens)
Benoit St-Onge (UQAM)
Richard Fournier (Sherbrooke)
Paul Arp, Chris Hennigar (UNB)
Jeff Deck (Nipissing)
John Caspersen (Toronto)

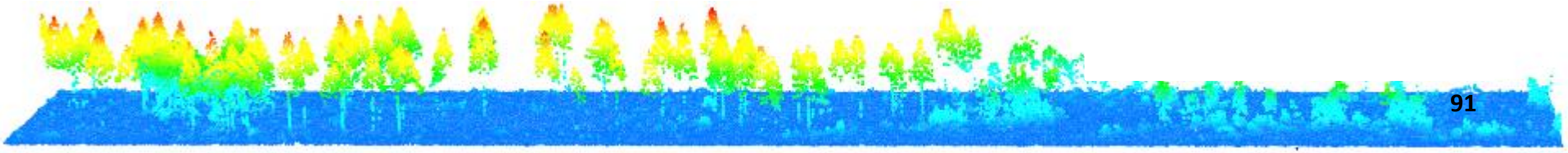
Government Investigators:
Joan Luther (CFS)
Oliver van Lier (CFS)
Adam Dick (CFS)
Jean-François Côté (CWFC)
Doug Pitt (CWFC)
Murray Woods (Govt Ontario / CWFC)
Chris Bater (Govt. Alberta)
Joanne White (CFS)
Udaya Vepakomma (FPI)
Denis Cormier (FPI)

International Reviewers:
Ross Nelson (Retired / NASA)
Sorin Popescu (Texas A and M University)



Final Annual General Meeting with Open Showcase Day will be held in

Toronto February 19 – 20th 2020



E-LECTURE SERIES: An Update on Canadian Forestry Applications of LIDAR and Digital Photogrammetry. The AWARE Experience.

In collaboration with:

NSERC CRSNG

AWARE

Assessment of Wood Attributes using Remote sEnsing

September 25, 2019

The AWARE Project: Results and Outcomes

Nicholas Coops
Professor, UBC
Canada Research Chair in Remote Sensing
Principal Investigator: Assessment of Wood Attributes from Remote Sensing (AWARE)

October 2, 2019

Digital Soil Mapping in New Brunswick

Paul Arp
Professor in the Faculty of Forestry and Environmental Management
UNB

Shane Furze
Research Scientist
Forest Watershed Research Center UNB

Greg Adams
Advisor, Tree Improvement and Research and Development
J.D. Irving

October 16, 2019

New LIDAR Technologies on the Horizon - SPL and Multi-Spectral LIDAR

Jean-Francois Prieur
Graduate Student
UQAM

Martin Queinnec
Graduate Student UBC

Grant McCartney
Forest Information Systems Coordinator, Chief Foresters Group (Ontario)
Ryam Forest Management Rayonier Advanced Materials Inc.

Joanne White
Research Scientist
Canadian Forest Service
Natural Resources Canada

Ian Sinclair
Senior Analyst
Ministry of Natural Resources and Forestry
Govt. of Ontario

October 23, 2019

Assessing Non-Timber Values Using LIDAR and Advanced Remote Sensing Data

Richard Fournier
Professor
Department of Applied Geomatics Universite de Sherbrooke

Alexis Achim
Professor
Department of Geography and Geomatics
Laval University

Chris Mulverhill
Graduate Student
UBC

Christopher Bater
Forest Management Specialist
Forestry Division
Alberta Agriculture and Forestry
Govt. of Alberta

Sam Herniman
Graduate Student
UBC

Catherine Frizzle
Graduate Student
Universite de Sherbrooke

October 30, 2019

Digital Photogrammetric Applications to Enhanced Forest Inventory

Tristan Goodbody
Postdoctoral Research Fellow
UBC

Adam Dick
Forest Research Project Leader
Canadian Wood Fibre Centre
Canadian Forest Service
Natural Resources Canada

Co-presenters:
Chris Mulverhill & Joanne White

Thank you!

aware.forestry.ubc.ca

www.researchgate.net/project/
AWARE-Assessment-of-Wood-Attributes-from-Remote-Sensing

irsslab.forestry.ubc.ca

IRSS_UBC

nicholas.coops@ubc.ca