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Beyond the Stand: A Billion-Tree: Species-Level Inventory in Mixed Northern Hardwoods

OPERATIONAL LIDAR INVENTORY

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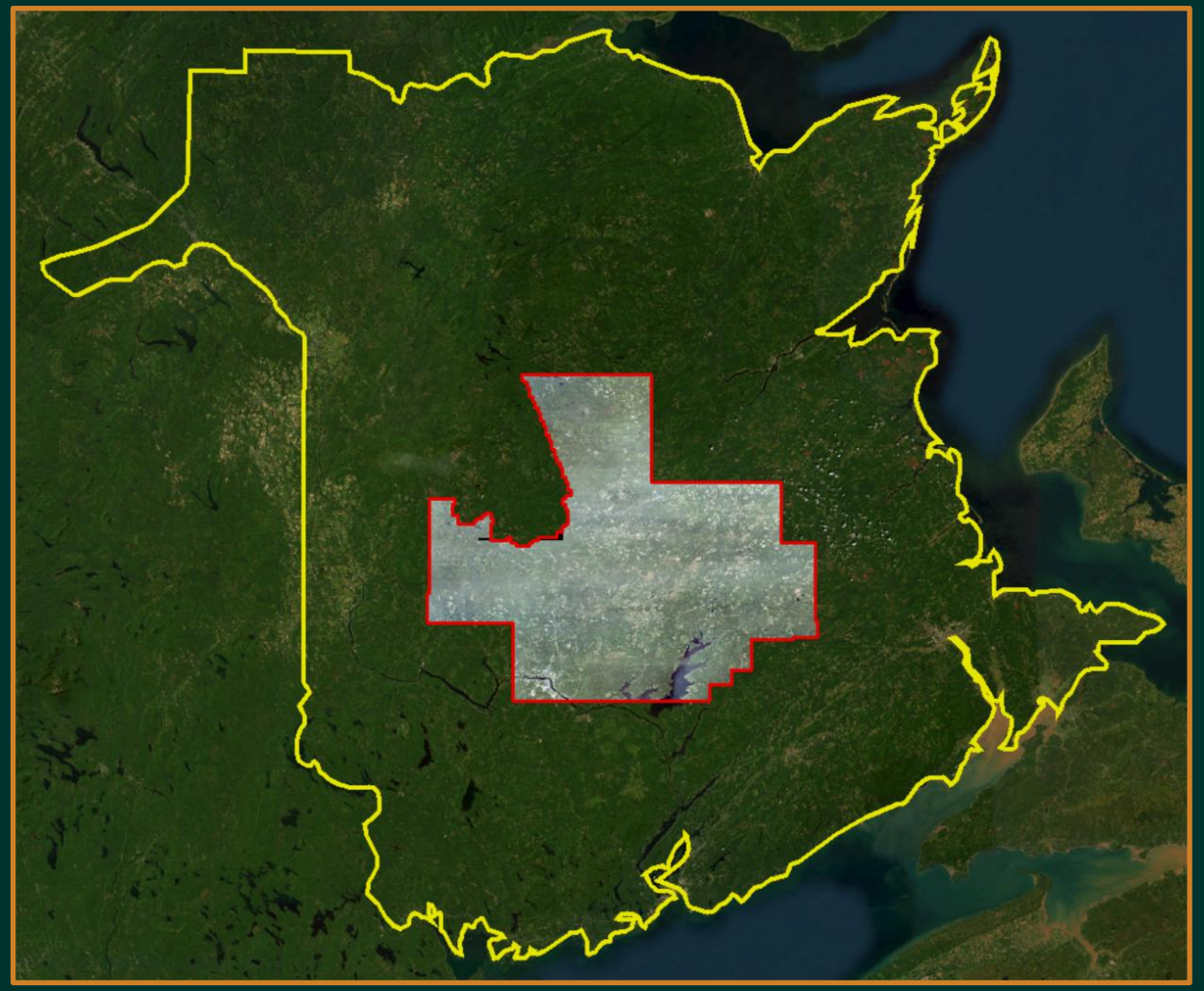
April 21, 2026

2024 New Brunswick ITI-EFI

Recent Project Completion

- 1 million hectares (2.5 M acres)
- Remote sensing data acquired in the summer of 2024
- Forest inventory analysis
  - Individual Tree Inventory (ITI)
  - Area-based Enhanced Forest Inventory (EFI)
- Project completion in March 2025



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Points of Discussion

Beyond the Stand: A Billion-Tree, Species-Level Inventory in Mixed Northern Hardwoods

- History and Context of Forest Inventories in NB
- NB's Progression Through Remote Sensing Methodologies:
  - Photo-Interpretation
  - Area-Based Enhanced Forest Inventory
  - Individual Tree Inventory Pilot in 2024
- Next Steps

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A Little Bit About New Brunswick

A Small Province But Punches Above Its Weight in Forest Management

- Population of ~800,000
- 86% of the province is forested (7.2M ha)
  - 50% is public land
  - 30% is small private owners
  - 20% is industrial freehold
- Forestry is the largest:
  - Contributor to GDB
  - Employer
- Very Progressive Department of Natural Resources

The Acadian Forest

Unique Highly Mixed Forest

- High mix of natural commercial and non-commercial species
  - Softwoods (10 commercial)
    - Balsam Fir, Red/Black/White/Norway Spruces, Jack/Red/White Pines, Hemlock, Cedar, Tamarack
  - Hardwoods (13 commercial and several non-commercial)
    - Sugar/Red Maples, Yellow/White/Grey Birches, White/Black Ash, Red Oak, Beech, Poplars, non-commercials
- Majority of prescriptions work with the natural regeneration in both even and uneven age
- Only ~20% of the forested area is in intensive softwood plantations

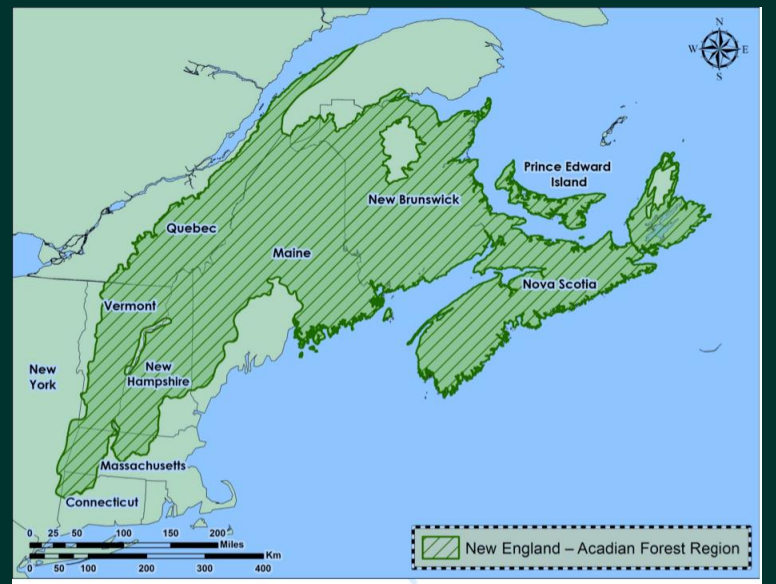
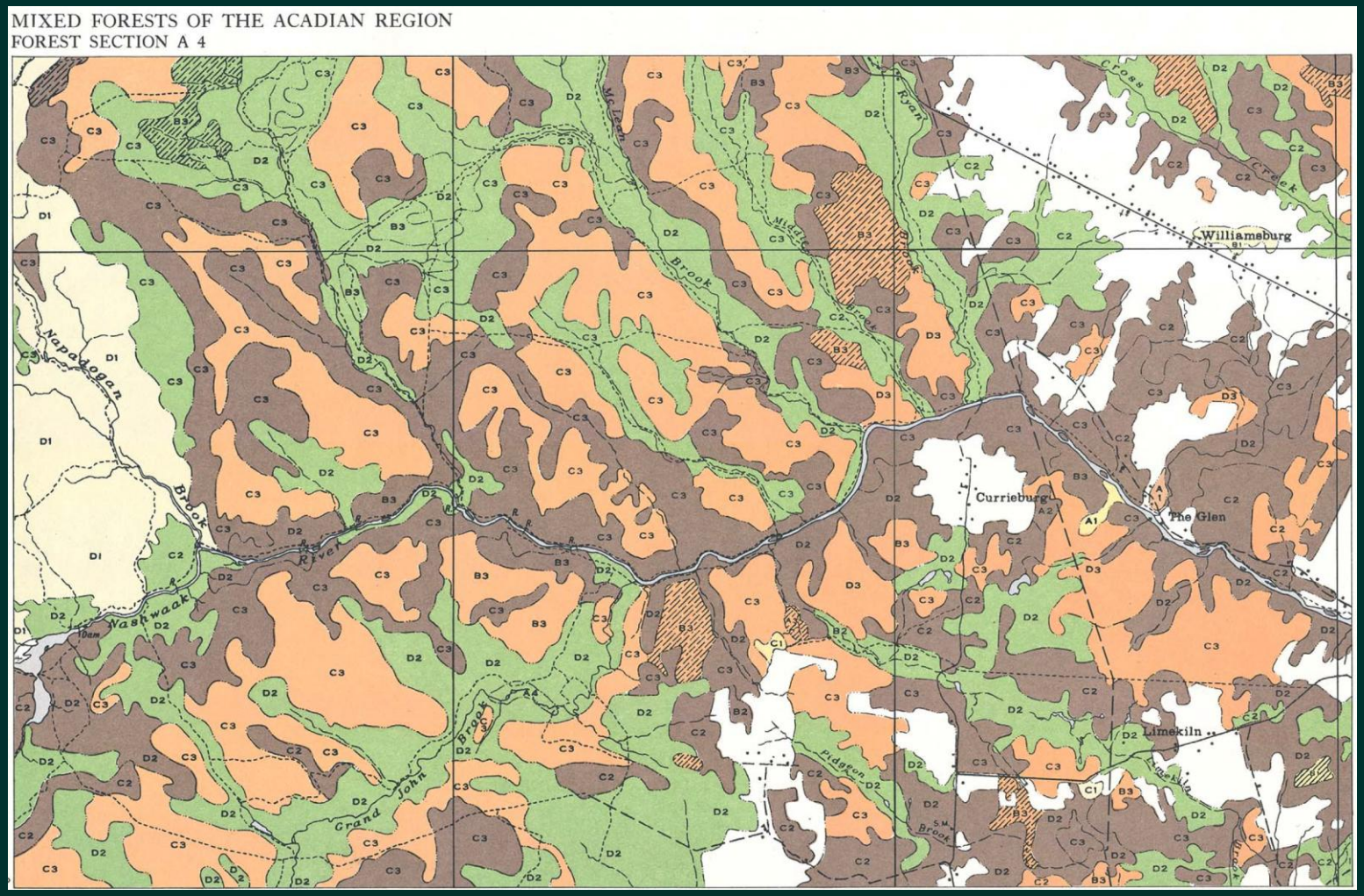


Figure 1. The New England – Acadian Forest Region; Map created by Josh Noseworthy in ArcMap

History on New Brunswick Forest Inventories

The Province's First Forest Inventory

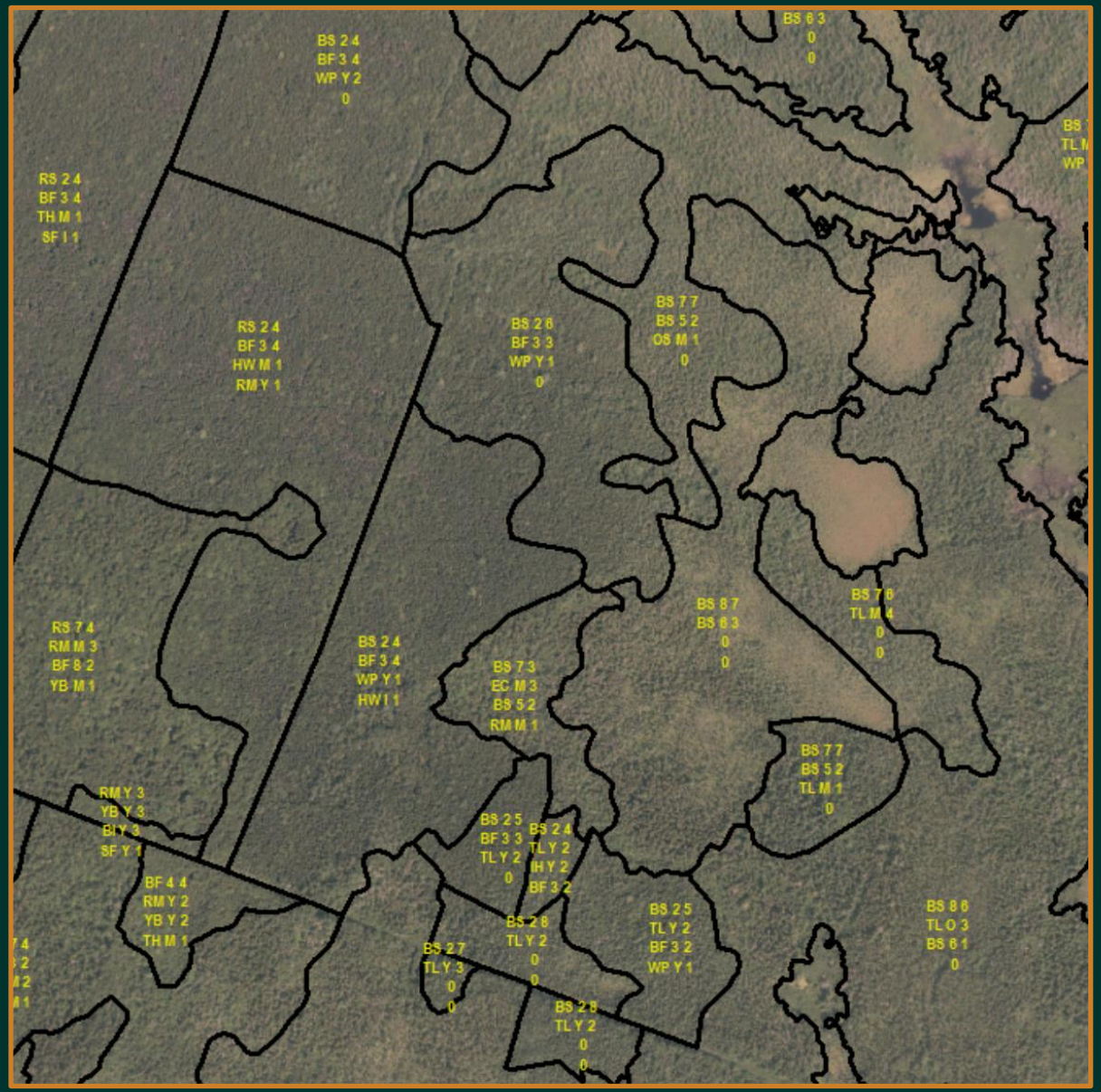
- Completed the first Province-wide capture of aerial stereo imagery in 1944-45
- A team of photo-interpreters mapped species groups of:
  - Softwood
  - Hardwood
  - Mixed
- Completed in early 1950s



History on New Brunswick Forest Inventories

Coming Into More Modern Times

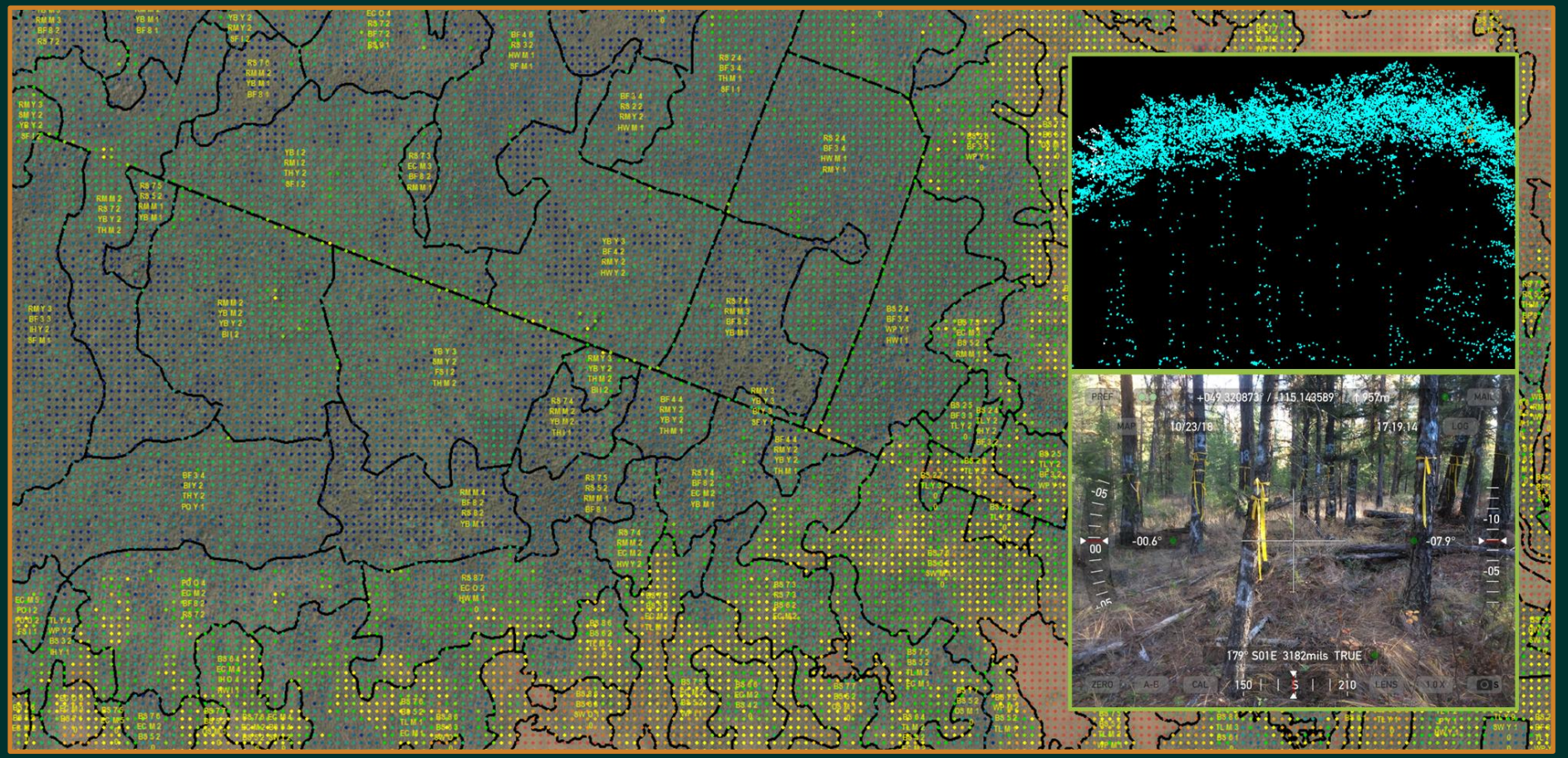
- NB purchased the first commercial ESRI Arc GIS software license in 1982
  - A digital forest inventory completed by 1985
- Completed province-wide photo-interpretated inventory on 10-year cycles until ~2014
  - Stand-based (over & under story) with:
    - Species proportions
    - Maturity stage
    - Crown closure
    - Tree heights
    - Site productivity
  - Supplemented by a strata-based ground sampling program for tree volume/size



History on New Brunswick Forest Inventories

Adopting LiDAR Early

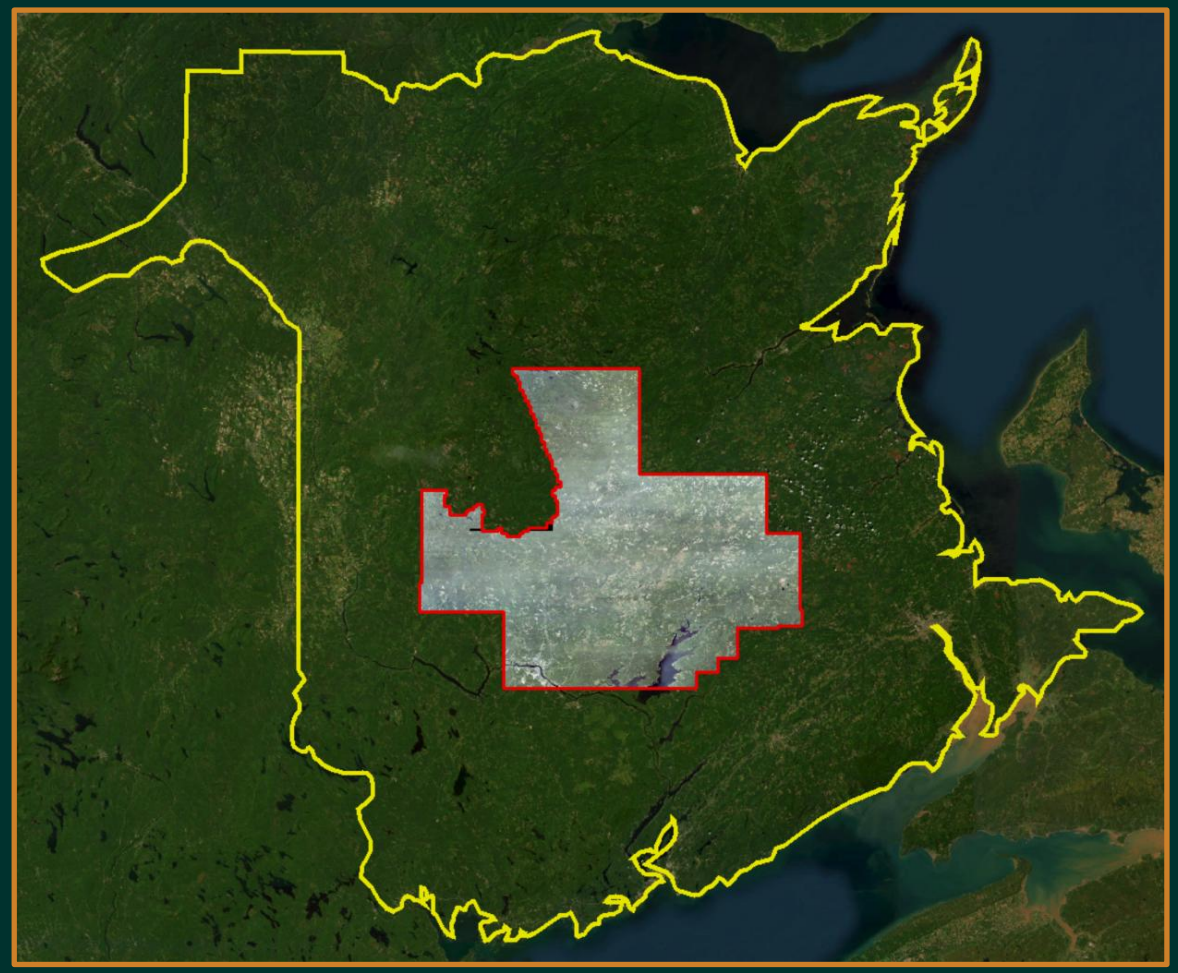
- 2014-2018 Completed the first province-wide LiDAR-based EFI on a 20m grid



Fast-Forward to 2024

NB DNR Engaged with Forsite to Complete This “Pilot” Area

- LiDAR/Imagery flown by Airborne Imaging
- LiDAR flown at 20 ppsm
  - 50% sidelap
  - Generally, 2-3x returns over treed areas
  - Some challenges with heavy canopies from shade tolerant hardwoods for ground returns
- Imagery 4-band stereo GSD 15cm



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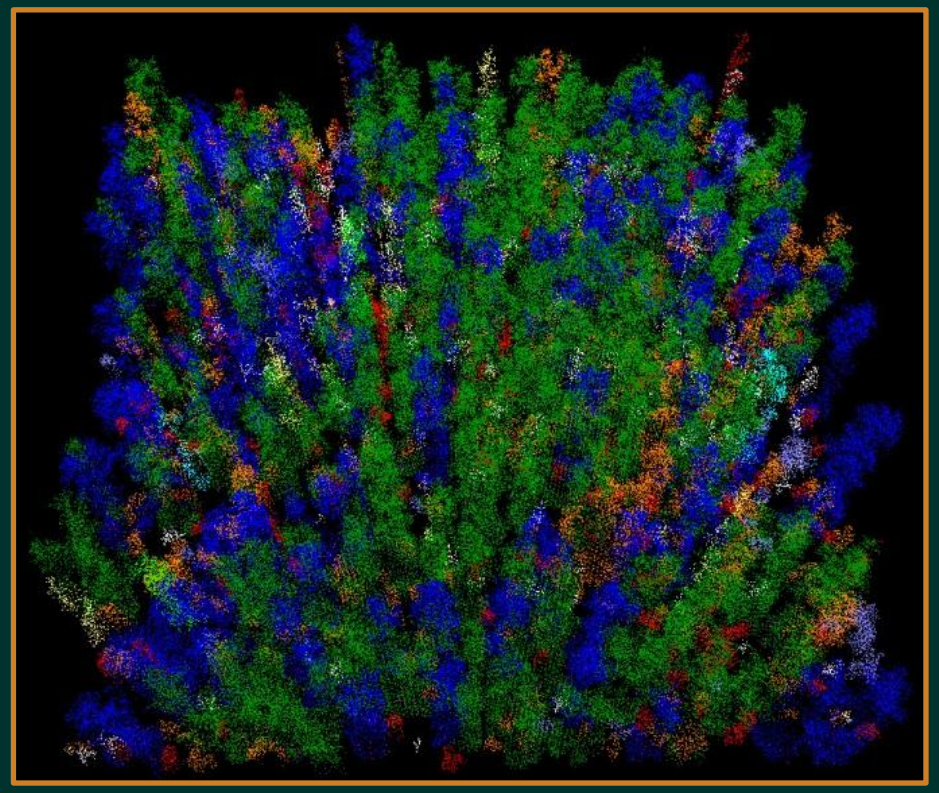
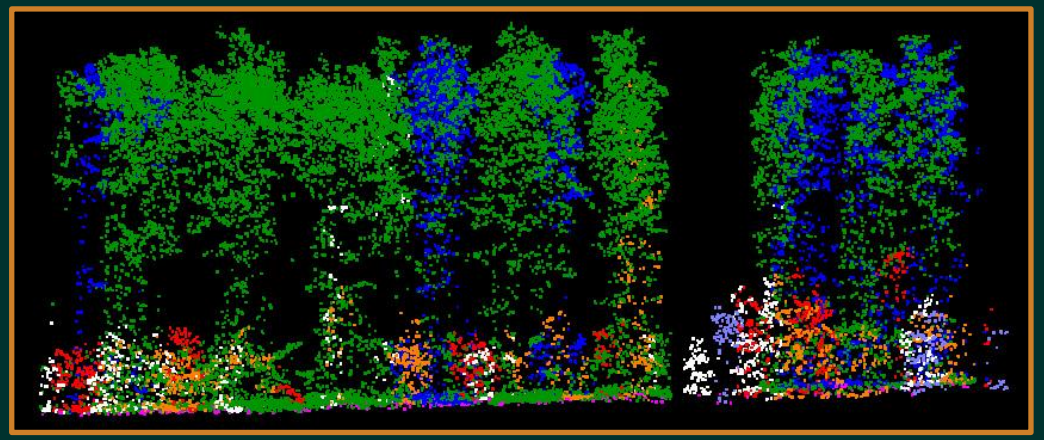
treeid

Forsite's Tree Species Identifier Software

- Framework for:
  - Organizing descriptors for each tree
  - Leveraging machine learning tools (training samples)
  - Evaluating results with tree level scorecards
  - Evaluating results with landscape scale validation areas
  - Refining the inputs to machine learning tools



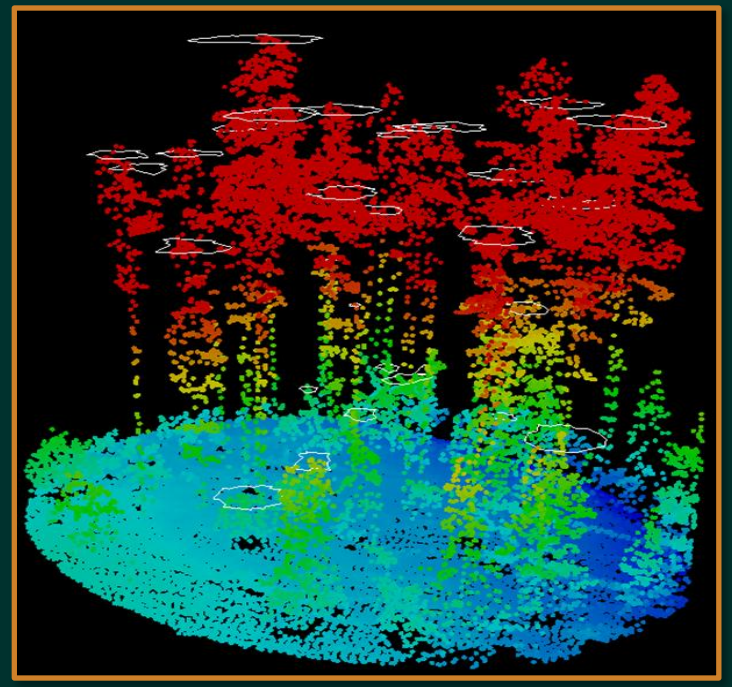
Aspen / Poplar Stand, Spruce understory



Segmentation and Training Data For Species Prediction

Leveraging the Stereo Imagery

- Stereo imagery used by our photo interpreters to collect sample trees
- Any ground plots available are used to find less common species



Over 100,000 sample stems collected!

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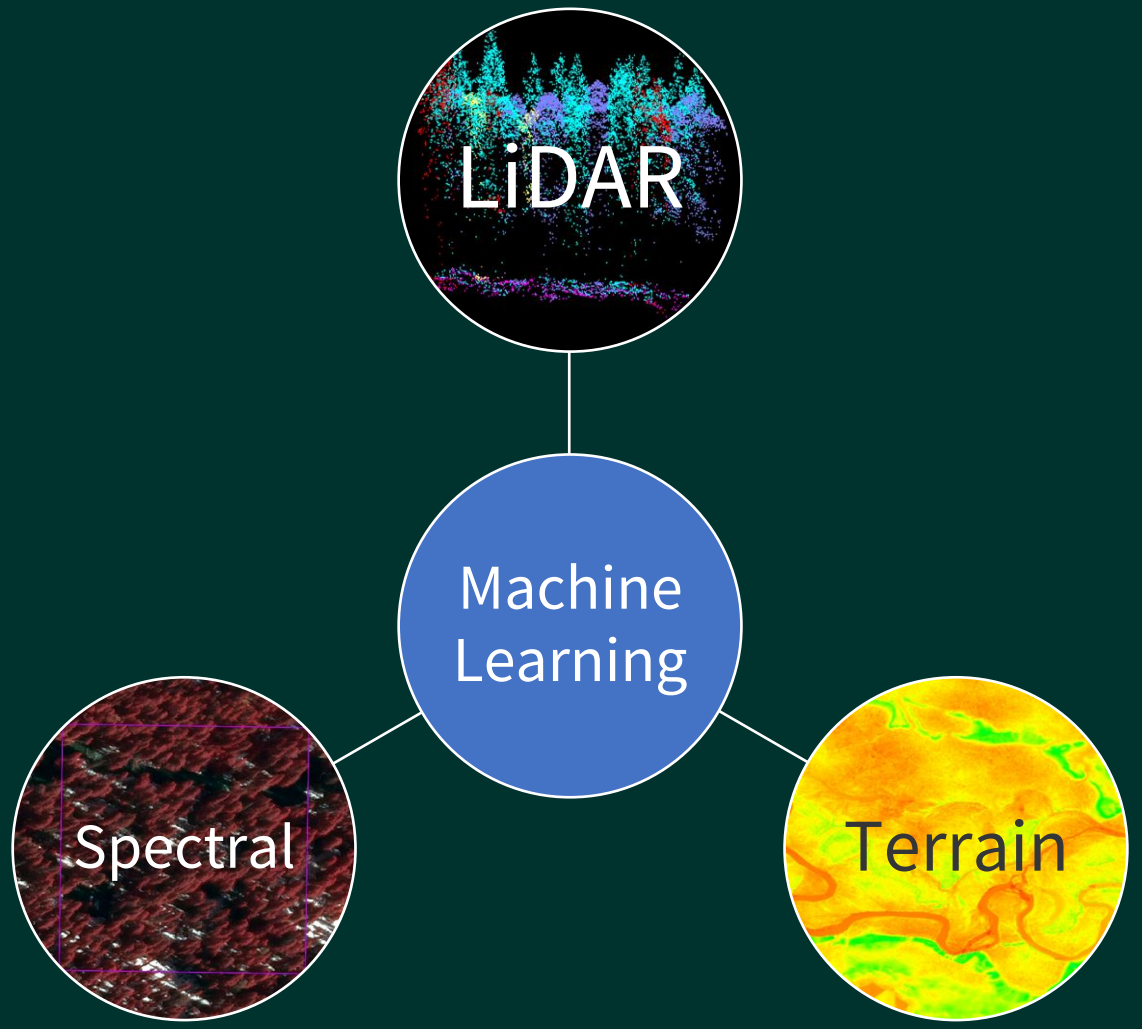
Species Prediction Models

Descriptor Variables Leverage

- LiDAR
  - Reflectivity, density, geometry
- Spectral Indices
  - Satellite & Orthos
- Terrain Data
  - Slope, Aspect, Elevation
  - Solar & Moisture Indices



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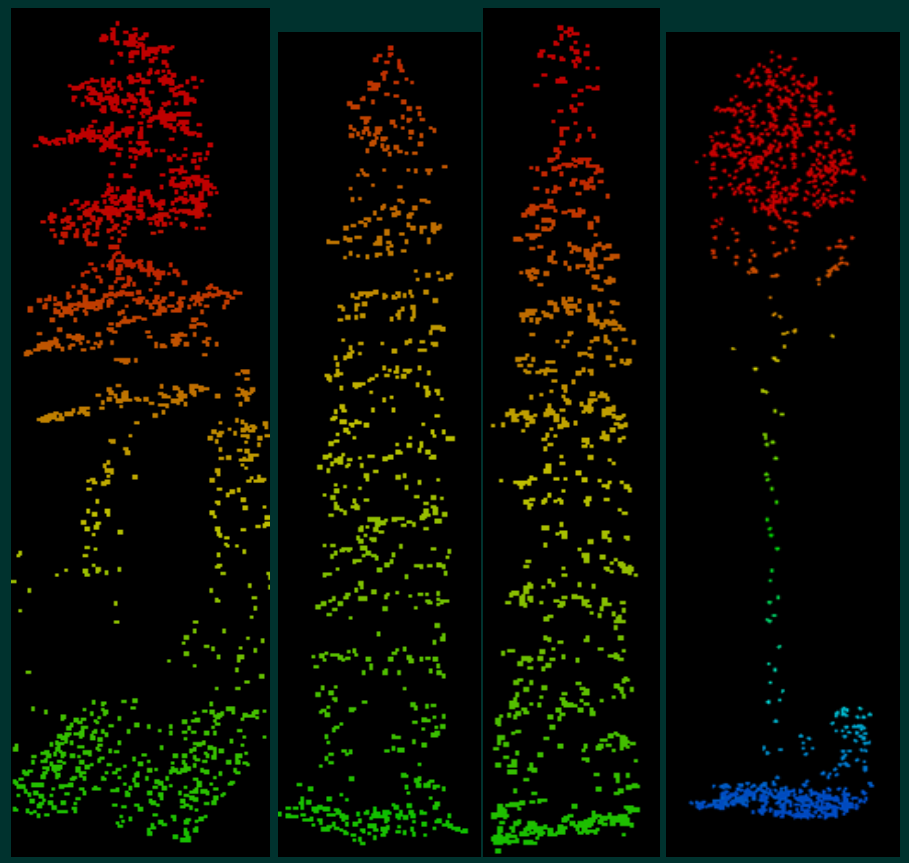
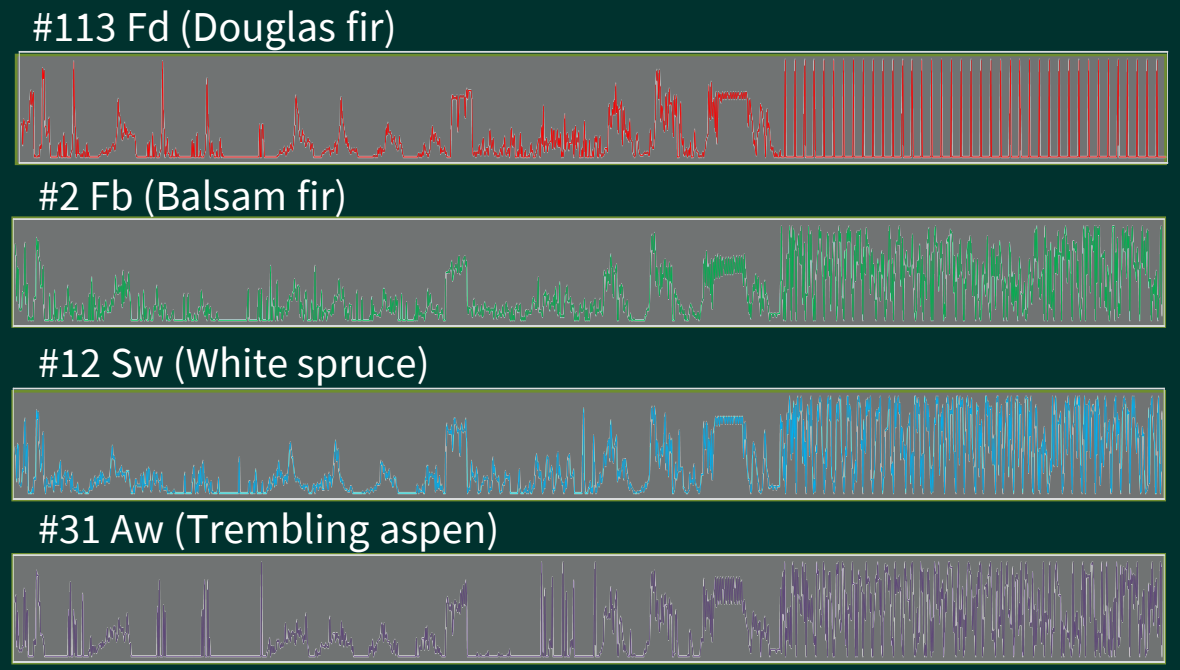
LiDAR Descriptors

Tree by Tree



- **Descriptors** are numeric representations of individual tree characteristics (e.g. density by height, geometric relationships, intensity distributions, etc.



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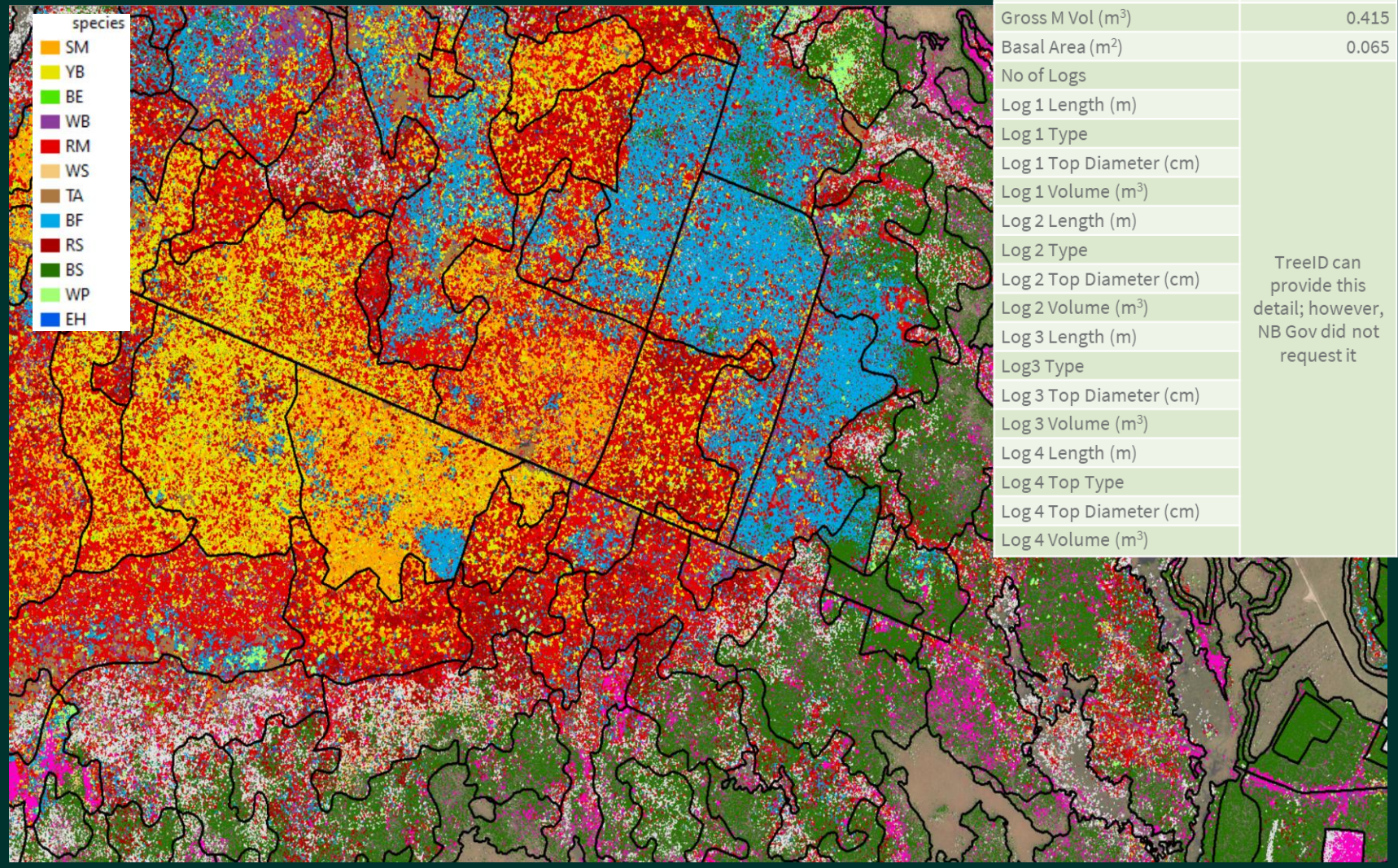
ITI Deliverable

Approximately 1 Billion Trees Segmented

- 20 species/groups
  - Balsam Fir
  - Red Spruce
  - White Spruce
  - Black Spruce
  - Norway Spruce
  - Jack Pine
  - Red Pine
  - White Pine
  - Eastern Hemlock
  - Tamarack (Larch)
  - Eastern Cedar
  - American Beech
  - Sugar (Hard) Maple
  - Red (Soft) Maple
  - Yellow Birch
  - White (Paper) Birch
  - Grey Birch
  - Poplars (trembling/largetooth aspen and balsam poplar)
  - Northern Red Oak
  - Other Hardwoods
  - Dead/Snags



Attribute	Value
Tree No	FL_193_8195571
Height (m)	18.5
DBH (cm)	28.8
Local Density (stem/ha)	854
Canopy Area (m^2)	25.6
Species	Red Spruce
Gross M Vol (m^3)	0.415
Basal Area (m^2)	0.065
No of Logs	TreeID can provide this detail; however, NB Gov did not request it
Log 1 Length (m)	
Log 1 Type	
Log 1 Top Diameter (cm)	
Log 1 Volume (m^3)	
Log 2 Length (m)	
Log 2 Type	
Log 2 Top Diameter (cm)	
Log 2 Volume (m^3)	
Log 3 Length (m)	
Log3 Type	
Log 3 Top Diameter (cm)	
Log 3 Volume (m^3)	
Log 4 Length (m)	
Log 4 Top Type	
Log 4 Top Diameter (cm)	
Log 4 Volume (m^3)	

Species Validation

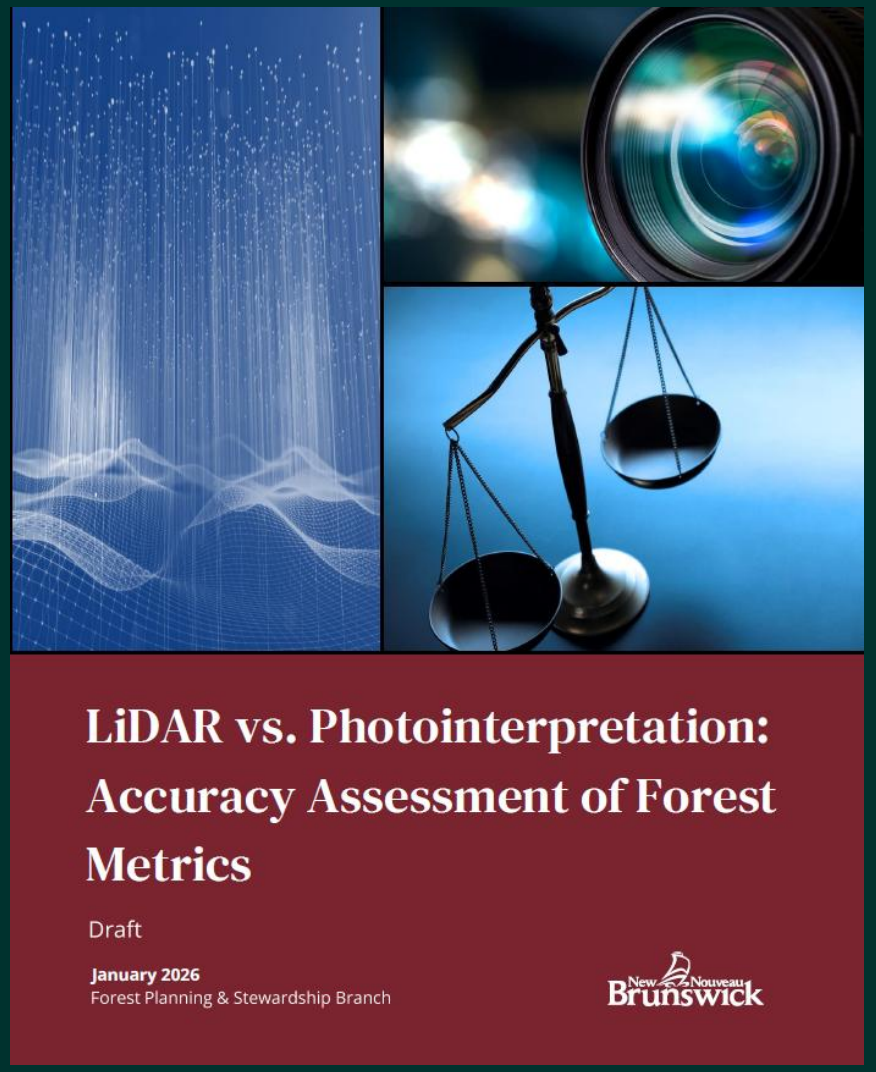
Overall species accuracy of 70%

For stems > 10m (~33') tall		TreeID Species Prediction																			
		BF	RS	WS	BS	NS	JP	WP	RP	EC	EH	TL	SM	RM	BE	YB	WB	TA	RO	GB	OH	SN
Interpreter Sample Trees	Balsam Fir	**78%**	3%	2%	4%	1%	1%	1%	0%	0%	0%	1%	1%	3%	0%	0%	2%	1%	0%	0%	0%	0%
	Red Spruce	13%	**62%**	2%	5%	0%	1%	1%	0%	2%	3%	0%	2%	4%	0%	1%	3%	1%	0%	0%	0%	1%
	White Spruce	9%	3%	**70%**	4%	4%	2%	0%	0%	2%	0%	0%	0%	2%	0%	0%	1%	1%	0%	0%	0%	1%
	Black Spruce	14%	3%	2%	**65%**	1%	3%	2%	0%	2%	1%	2%	0%	1%	0%	0%	1%	0%	0%	0%	0%	1%
	Norway Spruce	3%	0%	2%	1%	**94%**	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	Jack Pine	1%	0%	1%	2%	1%	**88%**	0%	2%	0%	0%	1%	0%	1%	0%	0%	1%	0%	0%	0%	0%	1%
	White Pine	3%	1%	1%	2%	0%	2%	**74%**	2%	0%	1%	2%	0%	6%	0%	0%	2%	1%	0%	0%	0%	0%
	Red Pine	1%	0%	0%	0%	0%	2%	1%	**93%**	0%	0%	0%	0%	1%	0%	0%	1%	0%	0%	0%	0%	0%
	Eastern White Cedar	2%	3%	1%	5%	0%	0%	0%	0%	**76%**	1%	0%	1%	3%	0%	0%	3%	1%	0%	0%	0%	2%
	Eastern Hemlock	3%	8%	1%	4%	0%	0%	3%	0%	3%	**65%**	1%	3%	4%	0%	1%	3%	2%	0%	0%	0%	0%
	Tamarack (Larch)	3%	0%	1%	6%	0%	2%	1%	0%	1%	0%	**79%**	0%	3%	0%	0%	1%	1%	0%	0%	0%	2%
	Sugar (Hard) Maple	1%	1%	0%	0%	0%	0%	0%	0%	0%	0%	0%	**64%**	13%	4%	5%	9%	2%	0%	0%	0%	0%
	Red (Soft) Maple	3%	0%	0%	1%	0%	0%	1%	0%	1%	1%	1%	7%	**63%**	1%	2%	12%	4%	0%	1%	0%	0%
	American Beech	1%	0%	0%	1%	0%	0%	0%	0%	0%	1%	0%	27%	9%	**47%**	4%	8%	1%	0%	0%	1%	1%
	Yellow Birch	1%	0%	0%	0%	0%	0%	0%	0%	0%	0%	1%	11%	9%	2%	**45%**	25%	2%	0%	0%	0%	1%
	White (Paper) Birch	4%	1%	0%	1%	0%	0%	1%	0%	1%	0%	1%	6%	14%	1%	4%	**55%**	7%	1%	3%	1%	1%
	Poplar/Aspen	2%	1%	0%	0%	0%	0%	1%	0%	0%	0%	0%	2%	10%	1%	1%	8%	**69%**	0%	2%	0%	1%
	Red Oak	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	4%	3%	1%	1%	4%	4%	**83%**	0%	0%	0%
	Grey Birch	1%	0%	0%	1%	0%	0%	0%	0%	1%	0%	1%	2%	6%	0%	1%	13%	6%	0%	**65%**	2%	0%
	Other Hardwood	1%	0%	1%	1%	0%	0%	1%	0%	2%	1%	2%	6%	13%	0%	0%	10%	4%	0%	3%	**52%**	0%
	Snags	5%	2%	2%	8%	0%	3%	1%	0%	8%	1%	2%	1%	4%	1%	0%	3%	4%	0%	0%	1%	**53%**
	Accuracy	72%	65%	71%	70%	93%	86%	76%	92%	76%	67%	79%	64%	60%	49%	49%	53%	72%	84%	68%	58%	56%	69.4%

NB DNR's Independent Evaluation

Comparing Forsite's Species Prediction to Photo-Interpretation

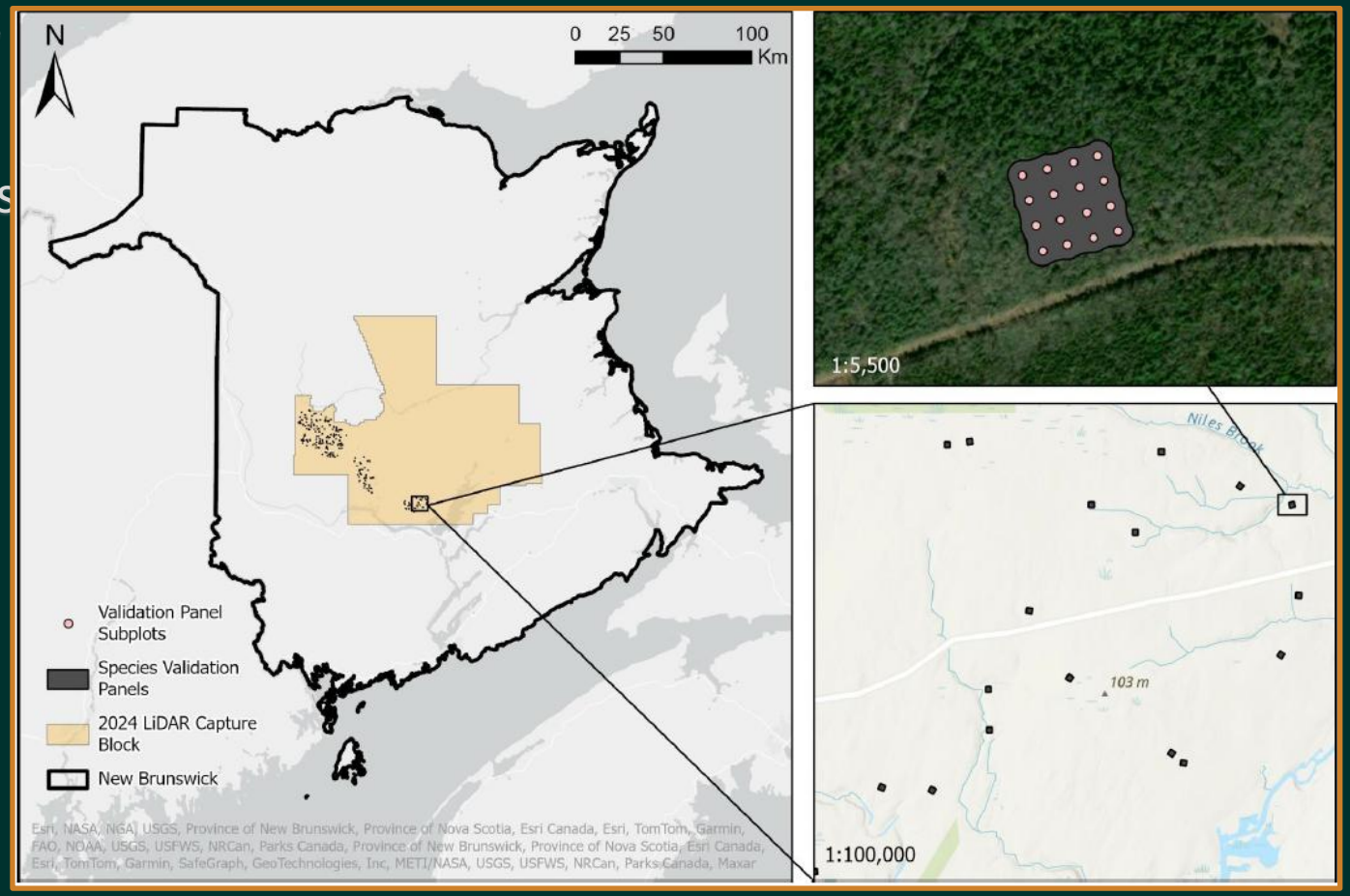
- Used two types of plots networks
  - Species "panel" plots
  - Continuous Landscape Inventory (CLI)
- Report is still in draft



NB DNR Panel Plots

Independent Ground-Based Data Withheld from Forsite

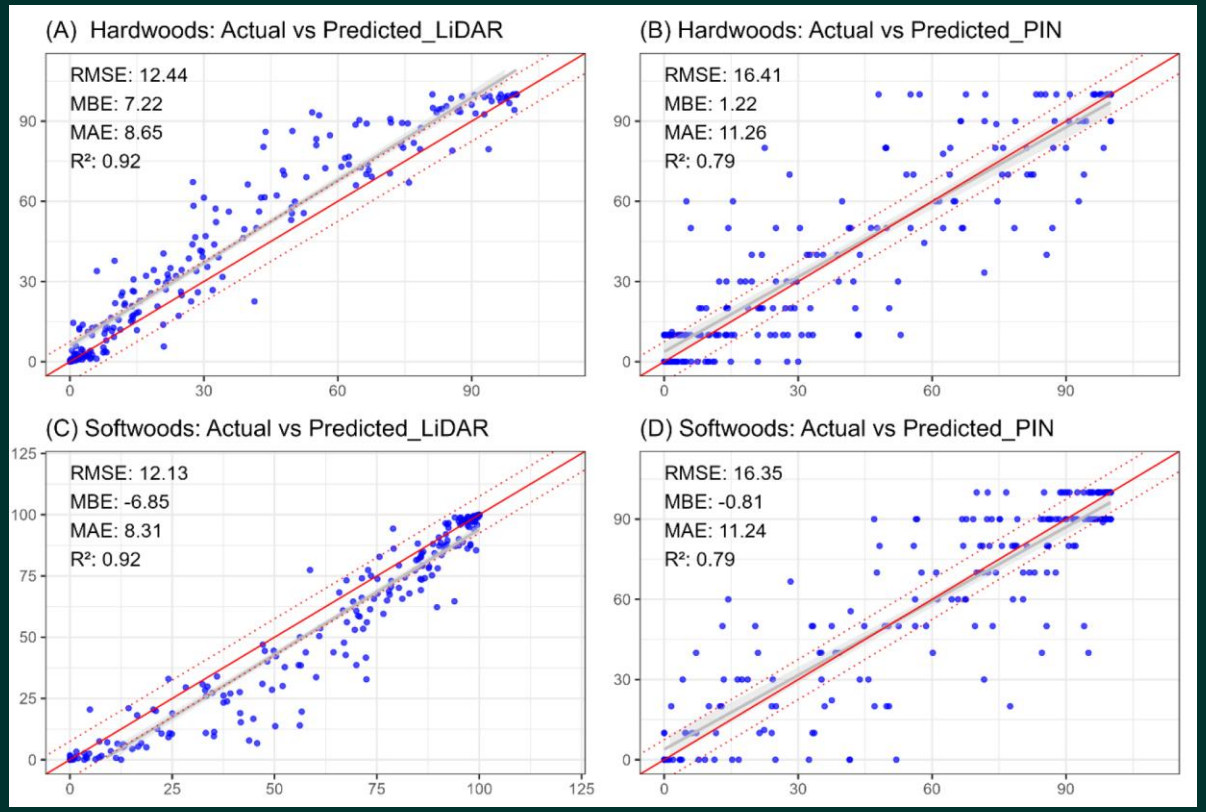
- 230 ~1 – Hectare plot spread across to capture the species diversity
  - Each comprised of 16 prism sweeps
  - Collected BA by species
  - Compared the results to:
    - Traditional stand-based photo interpretation
    - Forsite's ITI species predictions

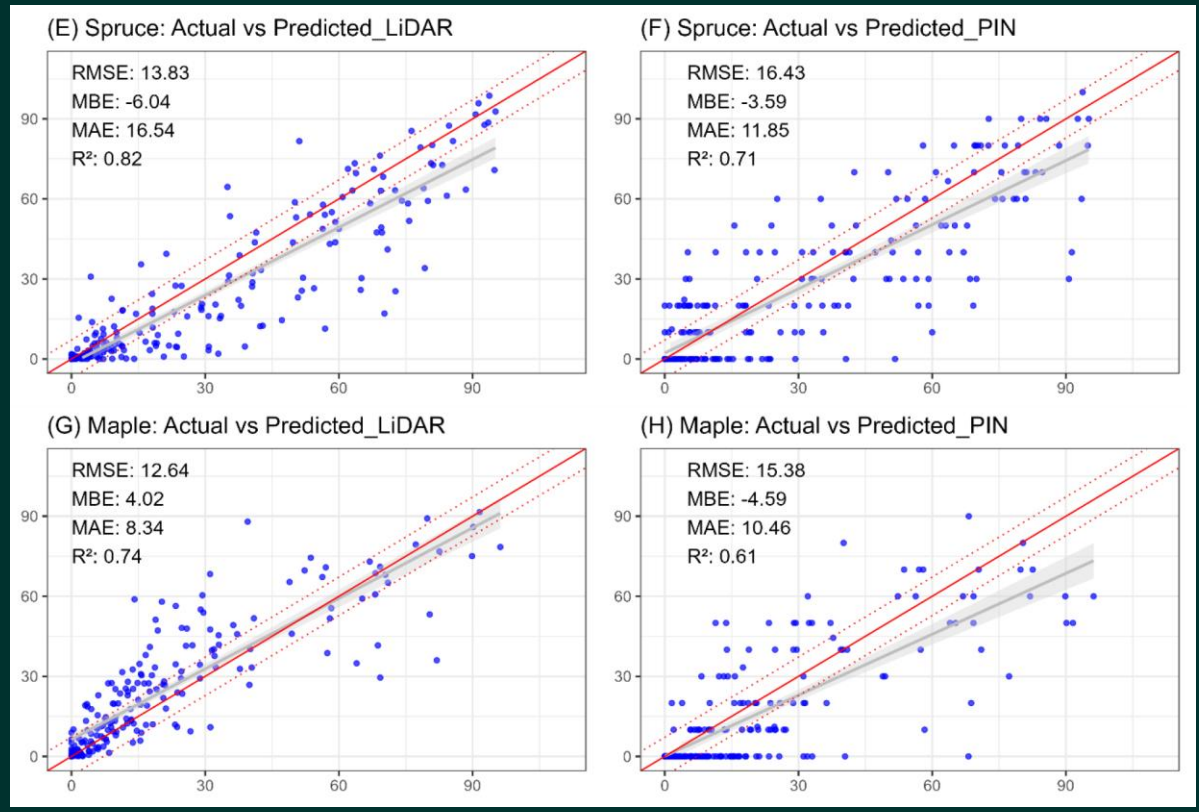


Comparing Forsite ITI and Photo-Interpretation

Assessing RMSE, MBE, MAE and R^2

Forsite ITI | Photo-Interpretation | Forsite ITI | Photo-Interpretation





Predicted Values

Panel Plot Values

DNR's Assessment on Species Accuracy

Forsite vs Photo-Interpretation

"We (NB Gov) agree that your results are better than photo interp. I'm pretty impressed with what you were able to accomplish, particularly given the timeline!"

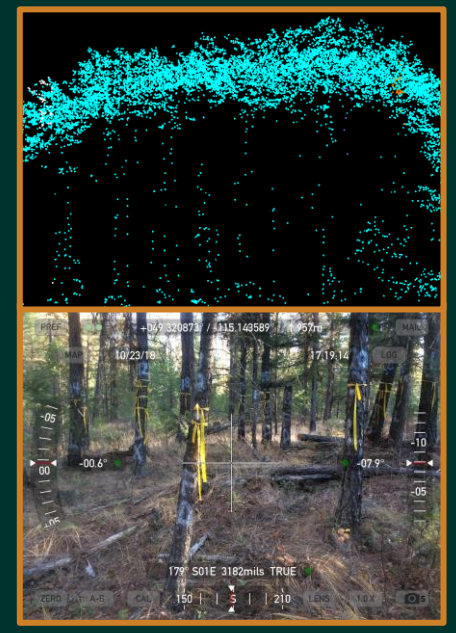
"The findings of this study clearly indicate that LiDAR-derived forest metrics provide a higher level of accuracy in characterizing forest structure and tree species composition compared to photointerpretation methods, as validated against ground-truth data."

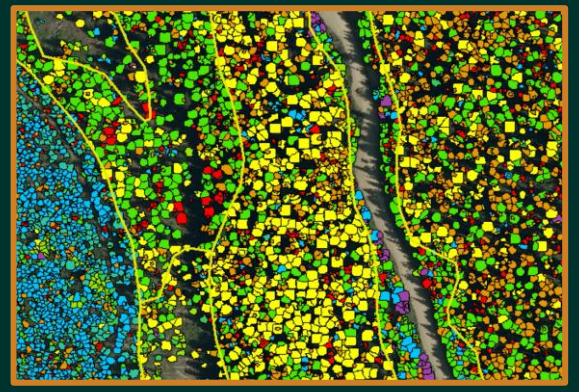
Species (or Group)	Mean Bias Error	Mean Absolute Error	Root Mean Square Error	NB Gov Judgement
Balsam Fir	Forsite	Forsite	Forsite	Forsite
Black Spruce	Forsite	Forsite	Forsite	Forsite
White Spruce	Forsite	Interpretation	Forsite	Forsite
Red Spruce	Forsite	Forsite	Forsite	Forsite
Norway Spruce	Interpretation	Interpretation	Interpretation	Interpretation
Jack Pine	Forsite	Forsite	Forsite	Forsite
White Pine	Forsite	Forsite	Forsite	Forsite
Red Pine	Interpretation	Interpretation	Interpretation	Interpretation
Eastern Hemlock	Interpretation	Forsite	Forsite	Forsite
Eastern Cedar	Interpretation	Forsite	Forsite	Forsite
Tamarack	Interpretation	Forsite	Forsite	Forsite
American Beech	Interpretation	Forsite	Forsite	Forsite
Sugar Maple	Interpretation	Forsite	Forsite	Forsite
Red Maple	Interpretation	Forsite	Forsite	Forsite
Yellow Birch	Forsite	Forsite	Forsite	Forsite
White Birch	Forsite	Interpretation	Forsite	Forsite
Grey Birch	Interpretation	Forsite	Forsite	Forsite
Red Oak	Interpretation	Interpretation	Interpretation	Interpretation
Poplars	Forsite	Forsite	Forsite	Forsite

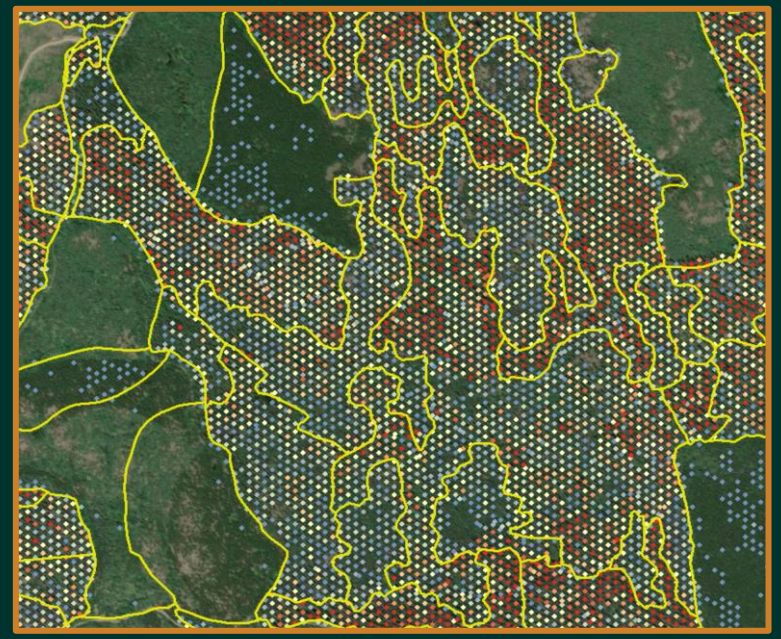
EFI/ITI - Area-Based Approach

Description

- Based on the typical areas-based approach commonly done
- ITI becomes an input to the analysis
- Preserves the species proportion and tree size







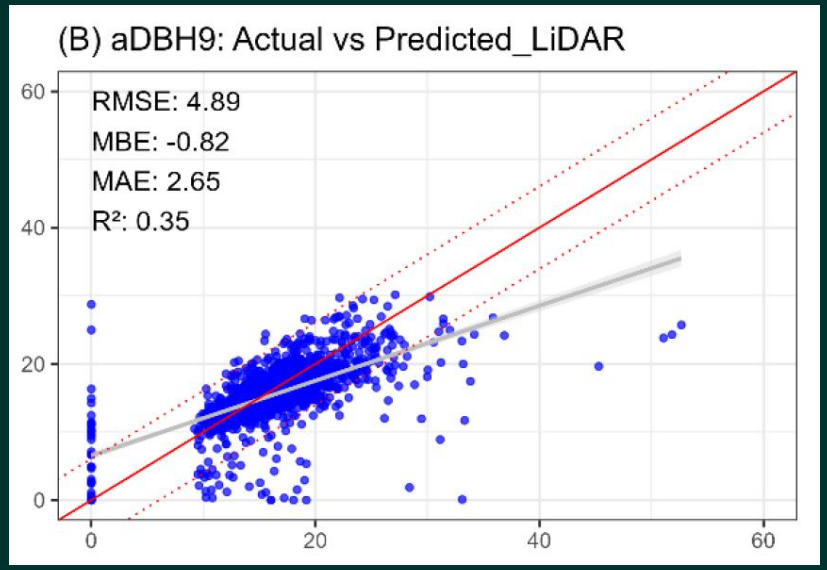
Continuous Landscape Inventory (CLI)

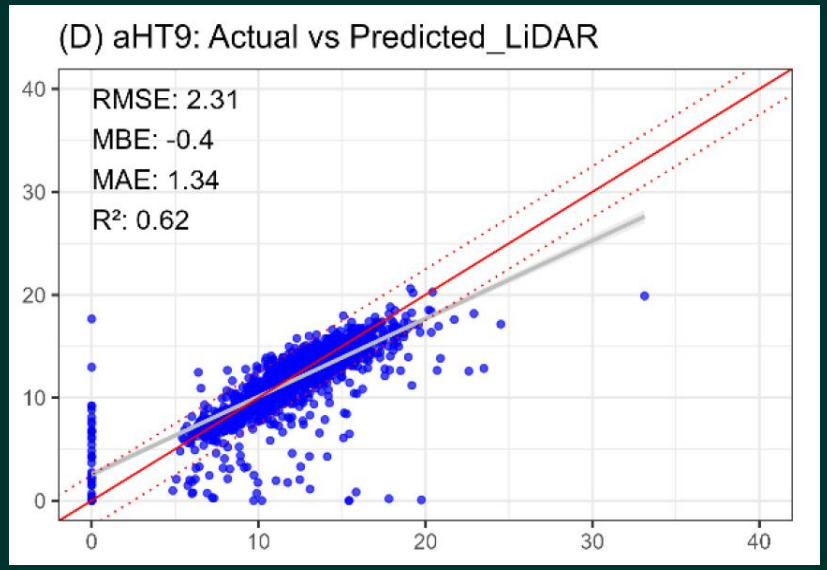
Independent forest inventory that is statically unbiased

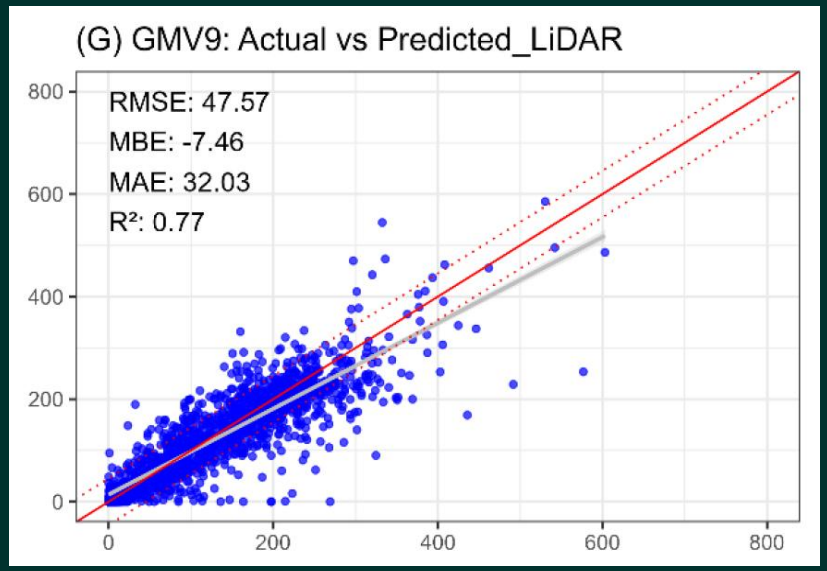
- Established in 2016
- Plots distributed on a 2km grid regardless of ownership (1 plot per ~1000 acres)
- Approximately 16,000 plots
- Remeasured on a 5-year cycle
- Plot size is 400m2 (~1/10th acre)

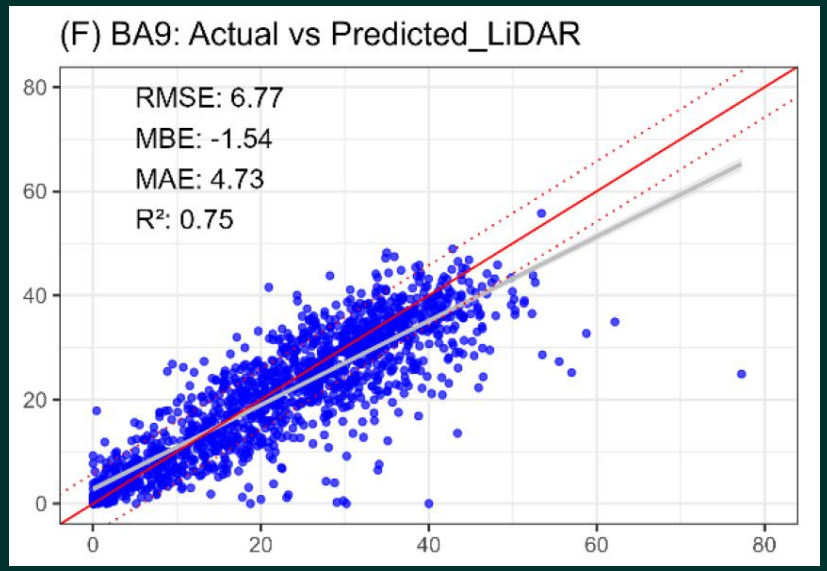
Comparison of EFI Attributes to CLI Plots

For Trees >9cm DBH







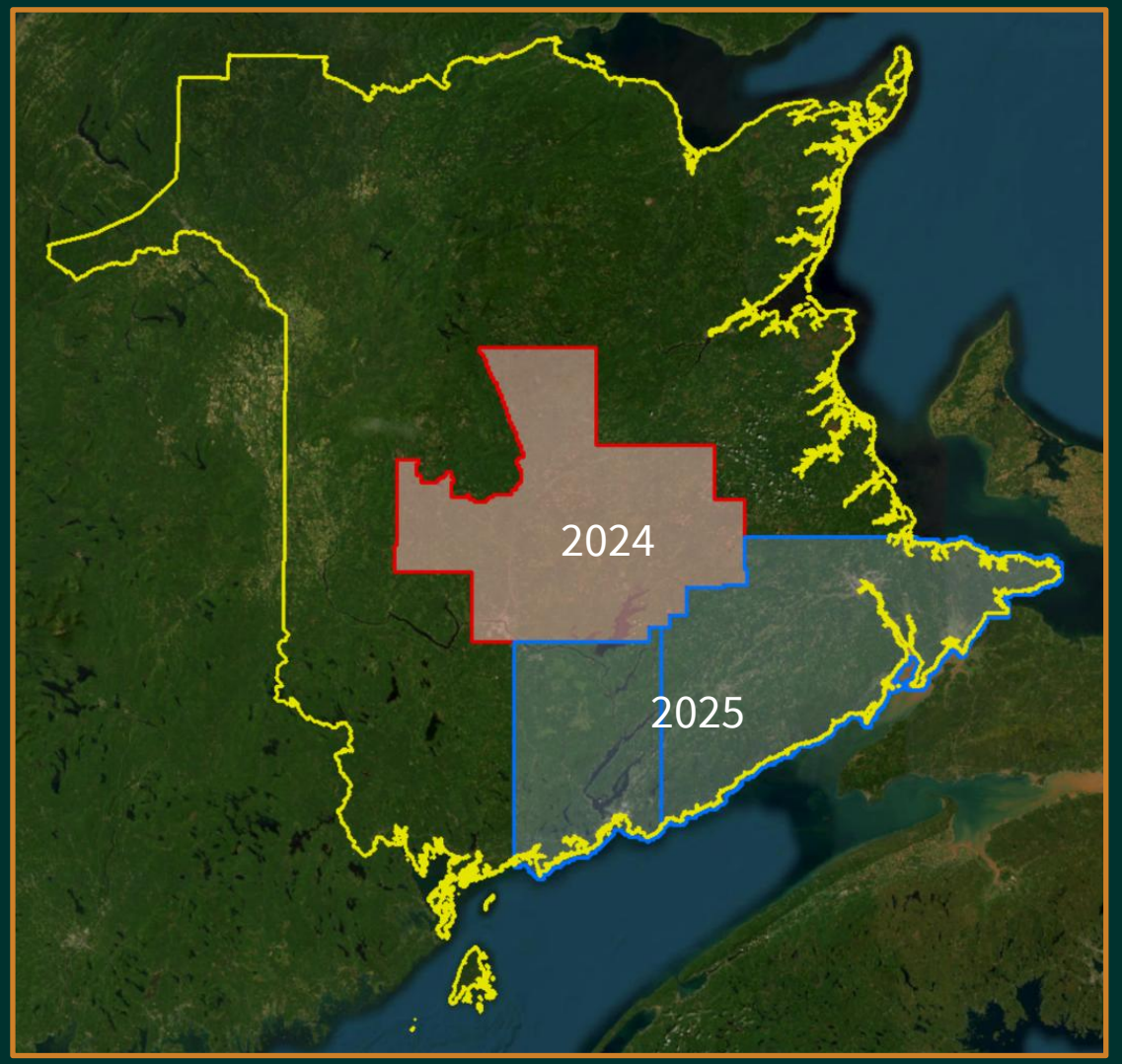


NB Moving Forward with Completing the Province

With Full ITI and EFI

- Next challenges will be how to efficiently/effectively take advantage of this fine resolution data
- Intuitive tools for mining and summarizing this data for multiple GIS skill levels

"I was able to spend a few days in the woods using the new products including the ITI and I was quite impressed, and also struck by the new challenges that it will present for our sector to effectively leverage this new rich data into improvement management and operating efficiency."



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Creating a Strategic Stand-Based Layer

Combining Various Polygons and Attributes in a Data-Driven Approach

- “Hardwire” areas lacking ITI/EFI attributes
  - Non/Sparsely forested areas
  - Recently harvested areas
- Add administrative (ownership) and policy (conservation) boundaries
- Delineate “inside” areas using a data-driven approach
  - Species classes
  - Tree size
  - Stand Volume
  - Crown Closure

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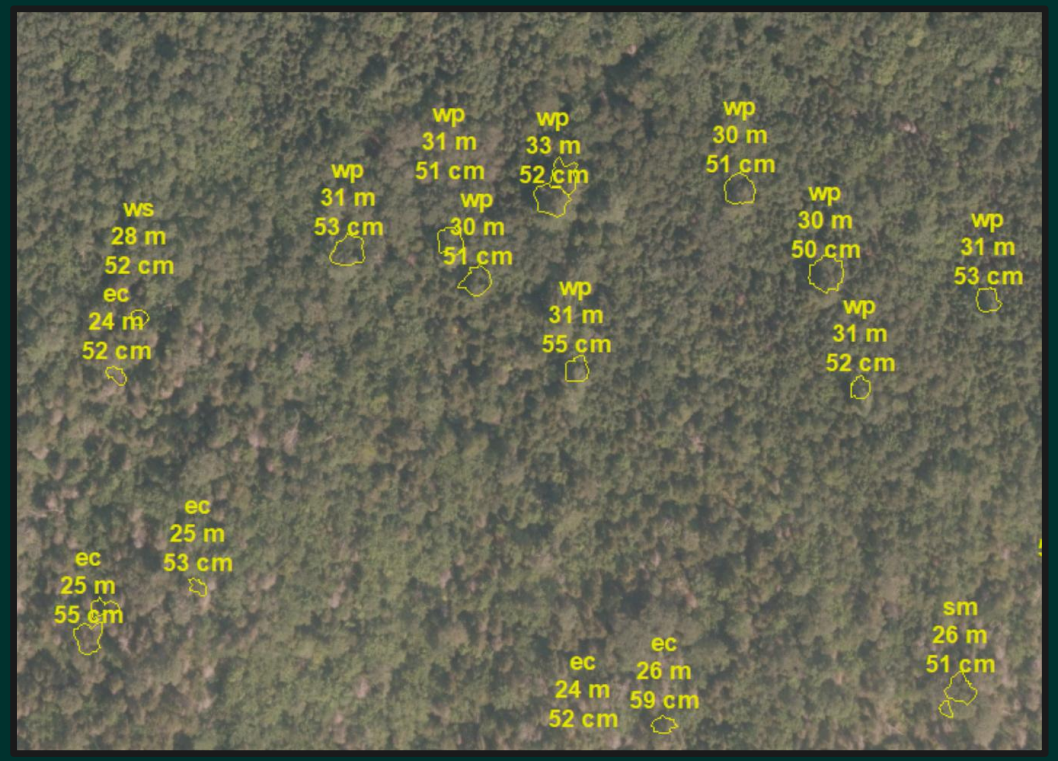
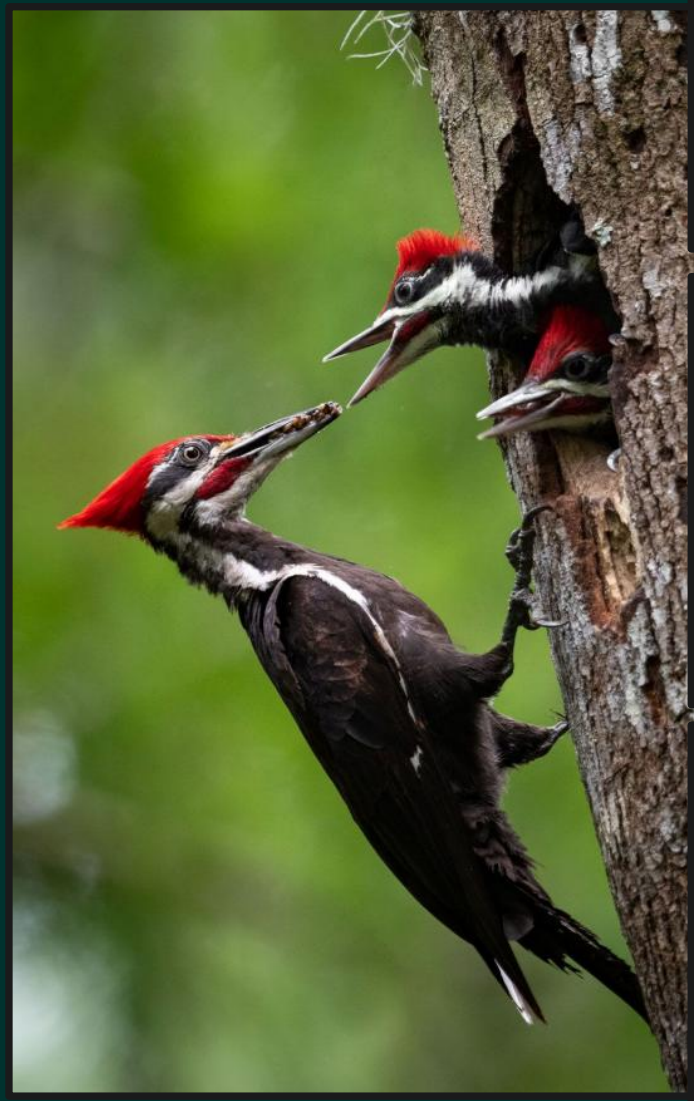
Finding Big Trees



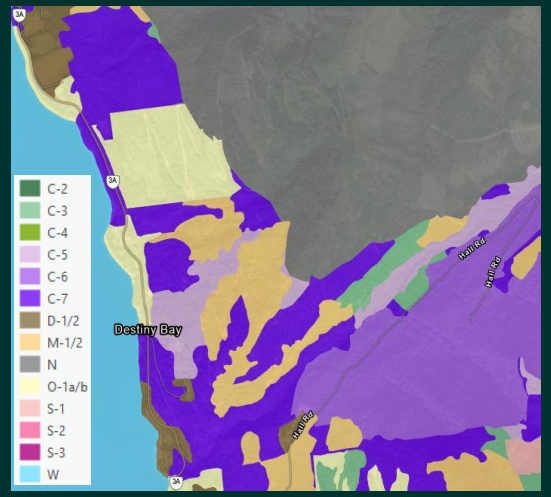


Remote Sensing Forest Fuel Mapping

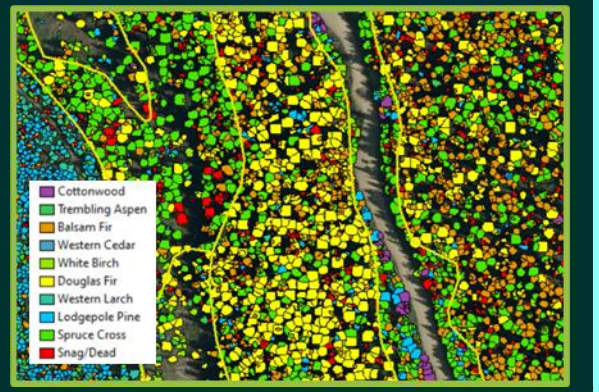
Informed decision making for fire resiliency

- Considerable increase in accuracy of forest fuel type mapping with high resolution forest fuel attributes
  - Reduces required field work
  - Accurate geo-referenced maps for staff/contractors
  - Detailed vegetation mapping for forest management (ecological and wildfire risk values)

Older Stand-Based



Adding in ITI Data



Finer Cell-Based