Mapping Tree Species Ecological Affinity in New Brunswick

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Canadian Woodlands Forum

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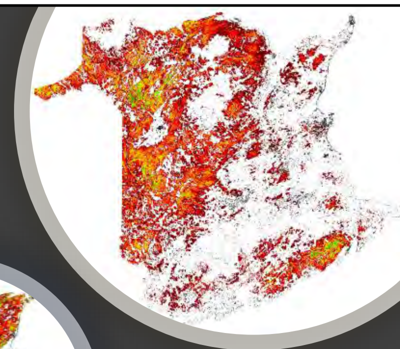
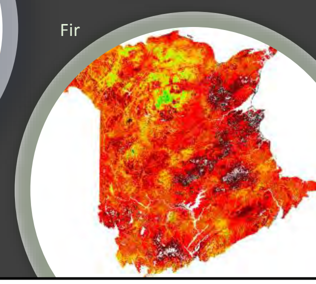
Sugar Maple

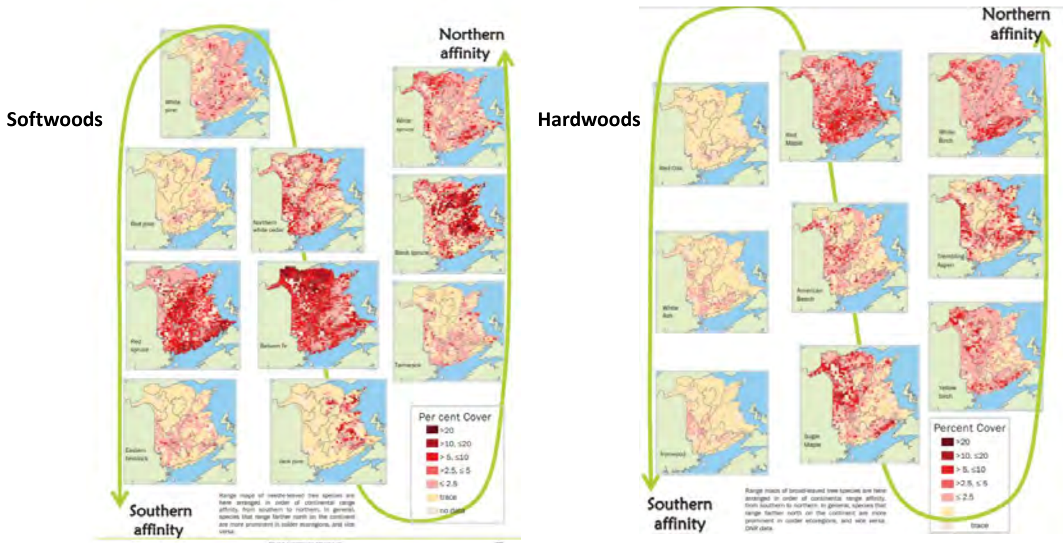


Black Spruce

Fir



V. Zelazny et al. 2007. Our landscape heritage: the story of ecological land classification in New Brunswick. Chapter 6 & Appendix 2



Important for understanding, as discussed by Zelazny:

- Site productivity
- Forest succession
- Forest management planning
- Impacts of climate change

Mapped at 10+km resolution from ground plots and not digitally available.

Increasingly difficult to determine the ecological site species across New Brunswick due to intensive management.

What would the species distribution of our forest look like today if we erased the last 100 years of disturbance?

Where would sugar maple be?

Objective

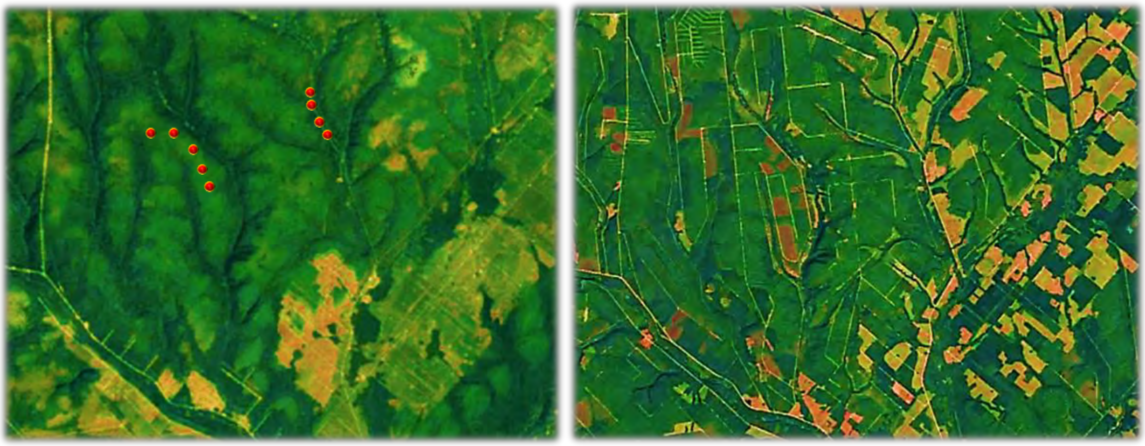
To predict ecological relative abundance (affinity) of tree species in New Brunswick as a function of location & topography from provincial ground surveys & photo-interpretation

Why?

- To consider native species affinity during silviculture planning
- To improve accuracy of forest succession predictions following harvest in NB
- To assist with ecological land classification and site-productivity prediction
- To assist with defining sources of, and barriers to, species migration under future climate

Rewind 40+ Years of
Forest Management

1984 **2018**



1:50,000 | Eco-Region Central Uplands | Eco-District Madawaska | Between Edmundston & Saint Quentin | • Ground Surveys

Photo Interpreted:

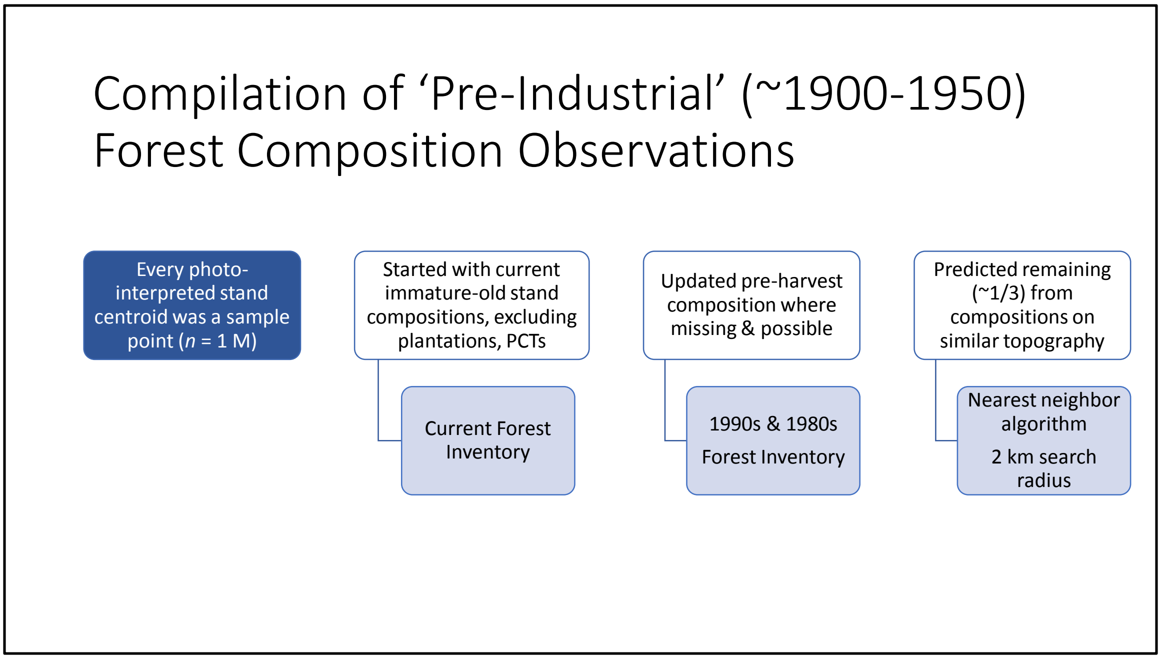
The 1980s, 1990s, and 2000s provincially photo-interpreted stands with species composition observations provide an excellent account of species composition in immature-old development stage stands.

Stand were limited to immature-mature development stages with overstory species composition. All plantations, pre-commercially thinned and recent clear-cuts were excluded (regenerating-young development stage).

Recent stand interpretations were preferred over past, except when stands were recently cutover or planted.

Ground Measured:

- 35,000 stand timber cruises from the NB Forest Development Survey (FDS) program in immature-old (age > 30) extensively managed or unharvested forest measured between 1980-2012.
- 3,000 plots from NB-Coop permanent sample plot program (1980-2015).
- 3,000 plots sampled-to-date (2018) from the NB-ERD continuous land inventory plot network on a 2 km sample grid.

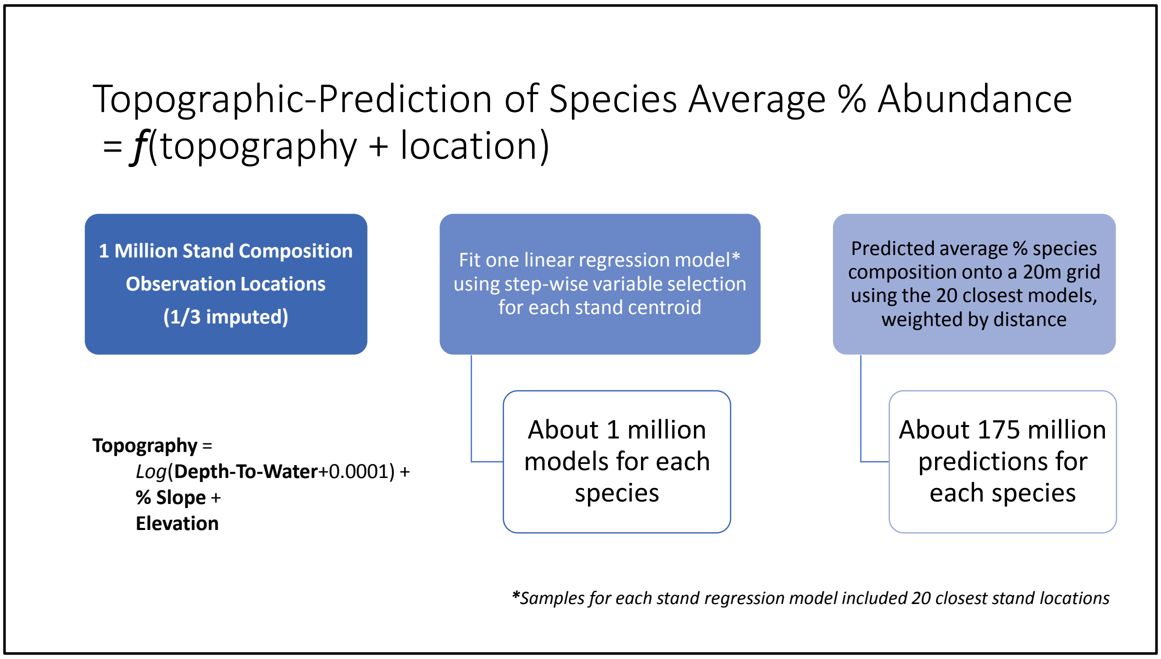


Stand polygons were converted to a point (centroid) location and each represented a species abundance observation.

Only immature-old stands with no evidence of intensive plantation management were selected as species observation points across the province; if the stand was cut, we looked back in time to the 1990s or 1980s interpretation to see if we could assign overstory to fill in as many stand point locations as possible with historic species composition. About 2/3 of stand polygons were able to be assigned an overstory composition.

Where a photo-interpreted species group was expected to contain a portion of the species of interest we multiplied the species group percentage by the expected proportion of the species of interest; e.g,

When predicting tolerant hardwood, we multiplied the interpreted tolerant-intolerant mixed group % composition value by 0.5 (50% assumed to be tolerant hardwood).



Topographic Imputation of Missing Stand Species Composition:

For each stand (polygon centroid) lacking historical overstory species (e.g., planted, recent cutovers, agriculture), species percentages were imputed from the ten most topographically similar stands locations with species, constrained to a moving 2 km search radius.

Topography is defined by Log(DWT+0.0001), Slope, and Elevation variables.

Geographically-Weighted Topographic Species Predictions

For each stand species observation from step 1, a linear regression model was fit to predict species percentages as a function of DWT, Slope, and Elevation from the 20 closest stands to the subject stand.

There are about 1 million stand polygons in NB, so we fit about 1 million regression models.

Final predictions for each 20 m grid point location were the average of predictions from a subset of 20 neighbouring stand regression models weighted by distance from the cell to the stand (local regression model).

Problem

1980s Species Photo-Interpretation is too Coarse

- Has a lot of grouped spruce, shade-tolerant, & -intolerant hardwood
  - poor resolution
- Photo-interpretation can have bias, especially in the 1980s

Solution

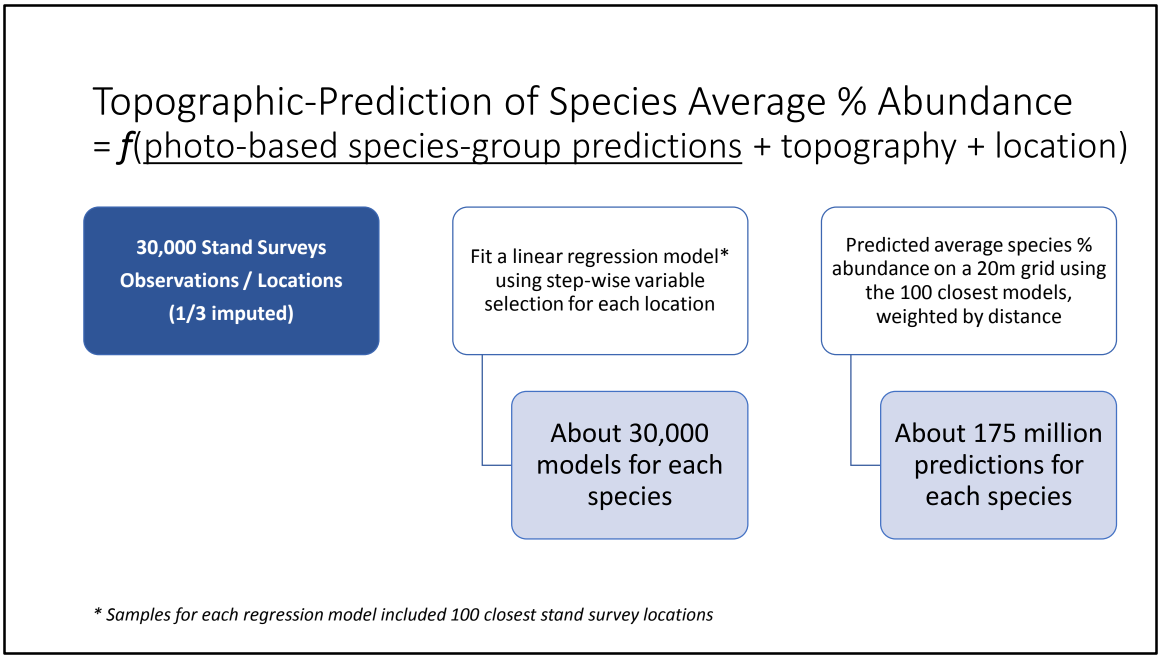
- Incorporate extensive ground survey information into modeling
  - 30,000 Timber Cruises (aka FDS) collected in the 80s and 90s

Photo-interpretation provides the most spatially-explicit and comprehensive observations of current and historical tree species distributions throughout the province; however, it is prone to interpreter error and bias.

In the 1980s, interpreters very often reported only grouped species (e.g., tolerant hardwood, spruce), and though less common, this still occurs in recent interpretations when more than five species are present and often in regenerating stands when individual species are difficult to classify. Freehold area (mostly in the northwest) has not been interpreted since the 1980s, so we have limited individual-species resolution there.

Due to these issues, photo-interpretation was only used to predict the local-topographic distribution of broad species groups (e.g., tolerant hardwood) or ‘photo-distinct’ species (e.g., cedar, white pine) as intermediary map outcomes. Photo-based species map products included: Tolerant and intolerant hardwood, Poplar, Upland & lowland conifer, Cedar, Birch, Pine. Topographic variables included depth-to-water (DTW), slope, and elevation.

These photo-informed species affinity maps were then used in addition to topographic variables to predict individual-species distributions from ground observations; e.g., photo-based predictions of tolerant hardwood abundance were used to help predict the abundance of sugar maple, beech, and yellow birch from stand survey ground plots (aka, FDS or timber cruises).



Geographically-Weighted Topographic Species Predictions
For each stand timber cruise location (FDS; 35,000), a multiple linear regression model was fit to predict species percentages as a function of:

1. Topography: Log(DWT+0.0001), Slope, and Elevation variables
2. Photo-informed species distribution maps developed in the previous step.

Photo-based topographically-dependent predictions of species-group relative abundance included:

- Pine, Lowland & Upland SW, Cedar, Poplar, Birch, Intolerant & Tolerant HW

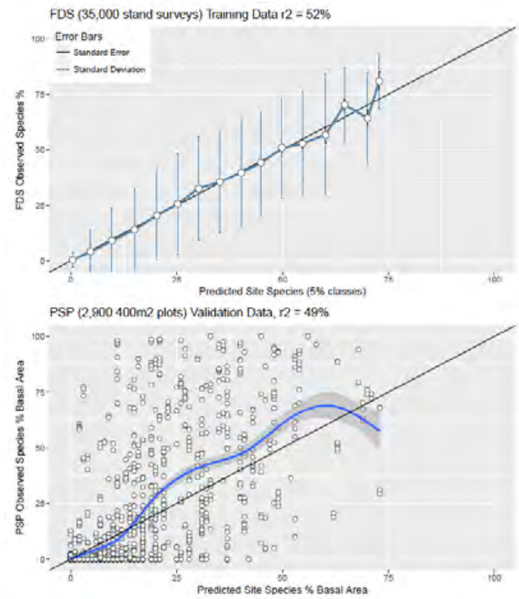
Final predictions for each 20 m grid point location were the average of predictions from a subset of 100 neighbouring stand regression models weighted by distance from the cell to the stand (local regression model).

This was done for each individual-species distribution map generated.

Accuracy (r^2)

Species	Training Data (Timber Cruises n = 35,000)	Validation Data (Permanent Sample Plots, n = 2,900)
Sugar Maple	52%	49%
Black Spruce	52%	45%
Yellow Birch	47%	27%
Cedar	47%	12%
Jack Pine	45%	43%
Beech	43%	38%
Fir	39%	42%
White Pine	38%	41%
White Birch	36%	26%
Red Maple	30%	17%
Poplar	27%	17%
Red Spruce	26%	13%
Hemlock	25%	28%
White Spruce	21%	15%
Tamarack	18%	4%

Sugar Maple



Model Training and Bias Corrections

- Ten-fold cross-validation was used to define neighborhood parameters and assess variable importance when modeling/mapping photo-based and timber-cruise (FDS) based species distributions

- As the model was fit locally, some prediction bias was detected at the provincial level when comparing all FDS observations to predictions. This bias was corrected using a 3^{rd} order polynomial equation.

- Provincial overall accuracy (r2) of individual species distribution maps (predictions) compared to FDS training observations ranged between 18-52%.

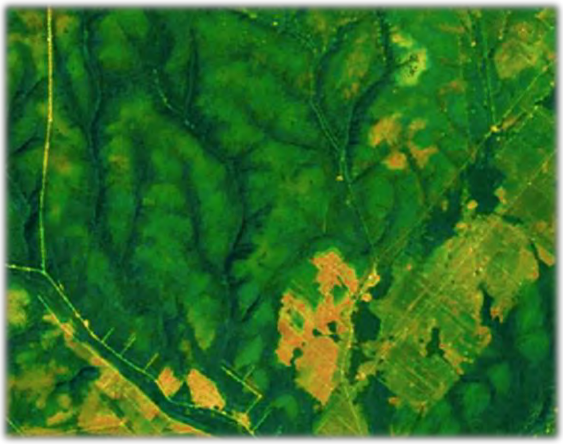
Model Validation with Permanent Sample Plots

- Predicted species distributions were intersected with immature-old forest conditions observed in independent PSP plots to see how well the predictions were performing at predicting the average abundance of individual species.

- In general, agreement between predicted and observed remained the same or dropped slightly.

- Red & white spruce, poplar, red maple, white cedar, and tamarack predictions performed poorly against validation data (r2 < 20%).

1984



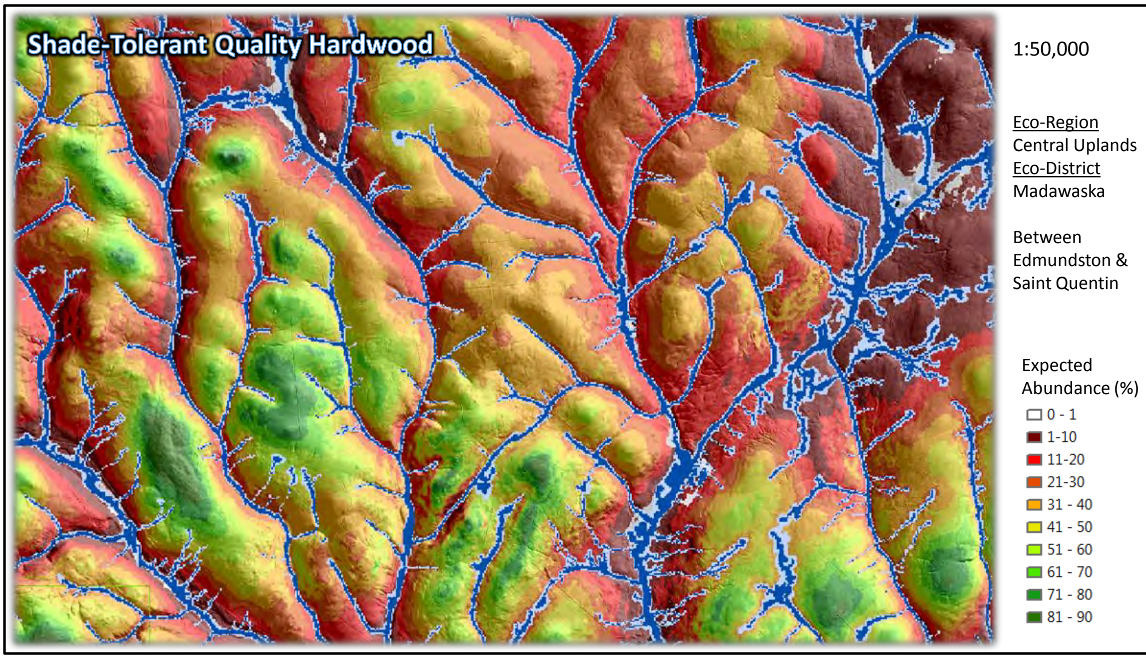
2018

1:50,000

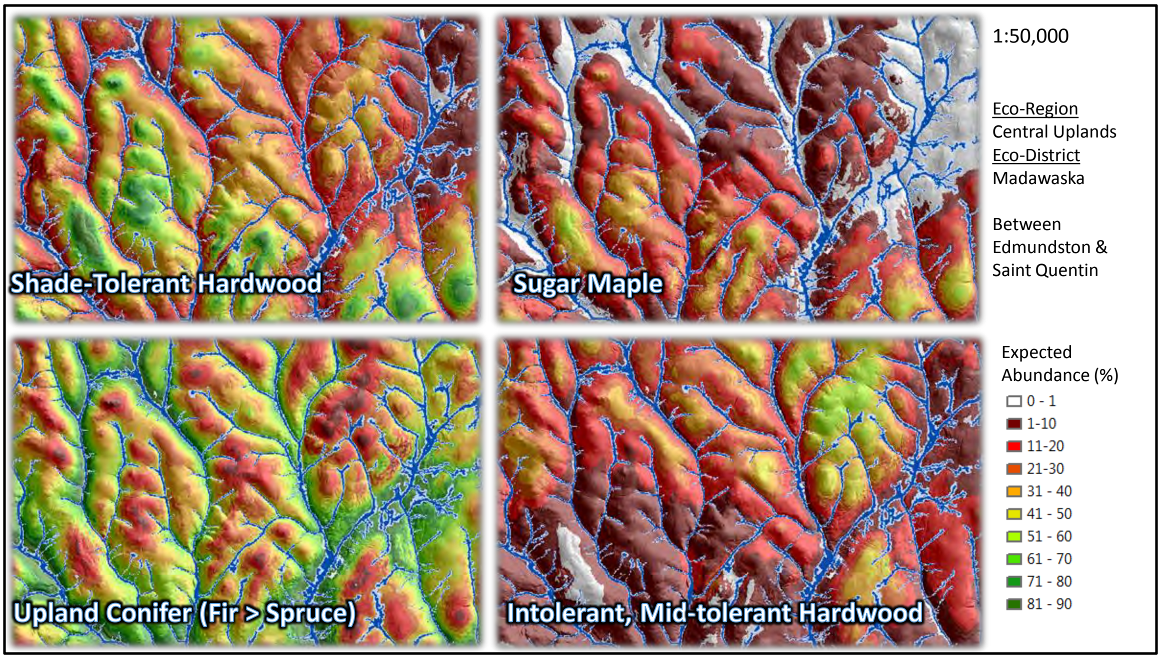
Eco-Region
Central Uplands

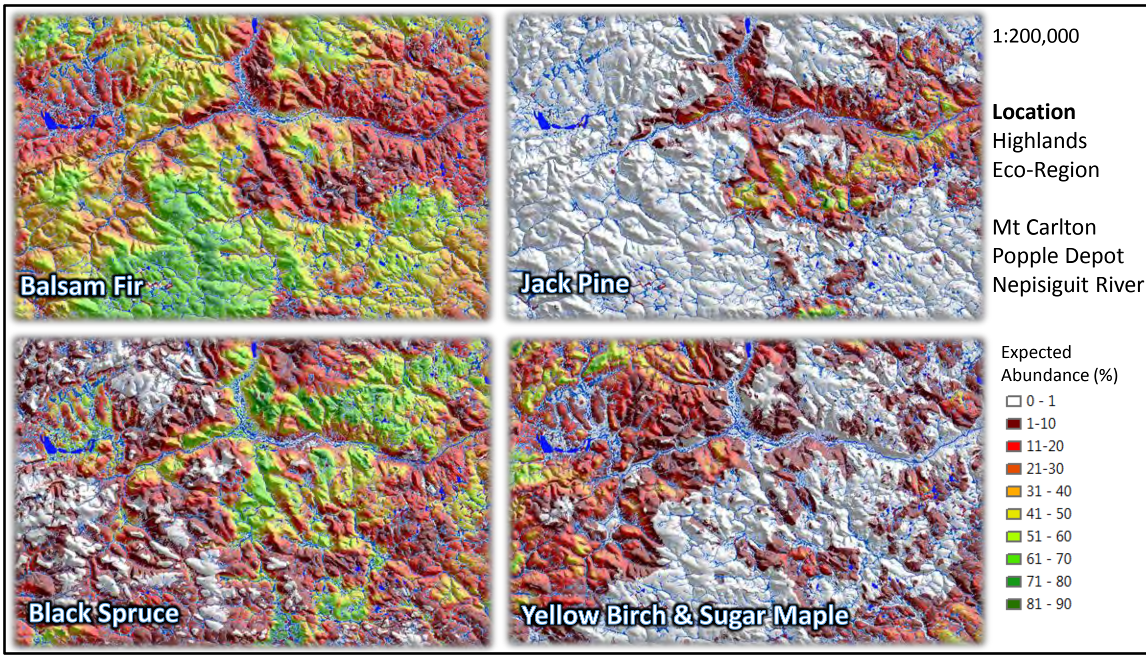
Eco-District
Madawaska

Between
Edmundston & Saint Quentin



Mostly Yellow birch and Sugar Maple


Shade-Tolerant Hardwood
Sugar Maple
Upland Conifer (Fir > Spruce)
Intolerant, Mid-tolerant Hardwood
1:50,000
Eco-Region
Central Uplands
Eco-District
Madawaska
Between
Edmundston &
Saint Quentin
Expected
Abundance (%)
0 - 1
1-10
11-20
21-30
31 - 40
41 - 50
51 - 60
61 - 70
71 - 80
81 - 90


Balsam Fir
Jack Pine
Black Spruce
Yellow Birch & Sugar Maple
1:200,000
Location
Highlands
Eco-Region
Mt Carlton
Popple Depot
Nepisiguit River
Expected
Abundance (%)
0 - 1
1-10
11-20
21-30
31 - 40
41 - 50
51 - 60
61 - 70
71 - 80
81 - 90

Final Points

- Big step toward mapping local species affinity to topography.

  "We let the species speak for themselves"

- Made possible by localizing models (moving modelling window) and allowing the relationship between species abundance and topographical variables to evolve across the landscape; e.g.,
  - Same 'Depth to Water' values will result in different predictions in the lowlands vs. the uplands.

- We hope these maps will be useful to you in many different ways.
  - GeoTIFF raster files for each species are available at www.forusresearch.com/speciesaffinity.php

Future Work

- Add, refine predictor variables:
  - Shane Furze's new NB soil attribute maps (available now):
  - Available LiDAR-derived elevation, slope, aspect (available now)
    - And possibly depth-to-water (2020?)
  - Charles Bourque's topographically-based soil water availability and drought maps (2020?)
- Try a more aggressive filtering strategy removing any stand with clearcut history
- Refine algorithm to use regression trees instead of linear models
- Pro-rate % abundance to add up to 100% and map forest-type affinity

Acknowledgments

GeoTIFF files available at:
www.forusresearch.com/speciesaffinity.php

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- **Dr. Chris Hennigar** via UNB & FORUS Research
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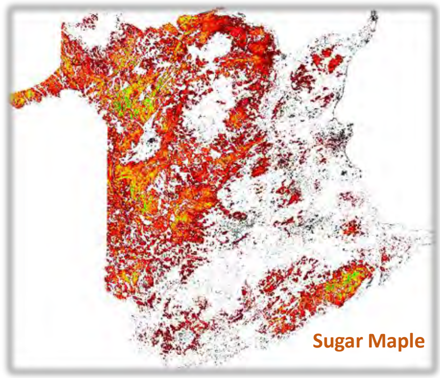
- University of New Brunswick



Funding provided by the Natural Resources Canada Climate Adaptation Platform
This work is part of a larger initiative led by the University of New Brunswick to model forest species growth and succession dynamics under climate change, and the potential range of social and economic impacts.

Photo-interpreted stand information and ground survey data were provided by the New Brunswick Department of Energy and Resource Development, JD Irving, Limited, Acadian Timber Inc., and the University of New Brunswick. Topographic variables were provided by ERD and the University of New Brunswick's Forest Watershed Research Centre