Ressources naturelles Canada | Natural Resources Canada

Advancing Digital Soil Mapping tools in support of forest resource inventory, planning and decision-making

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Grant McCartney, Jeremy Arkin (Forsite)




Canada

Land Acknowledgement

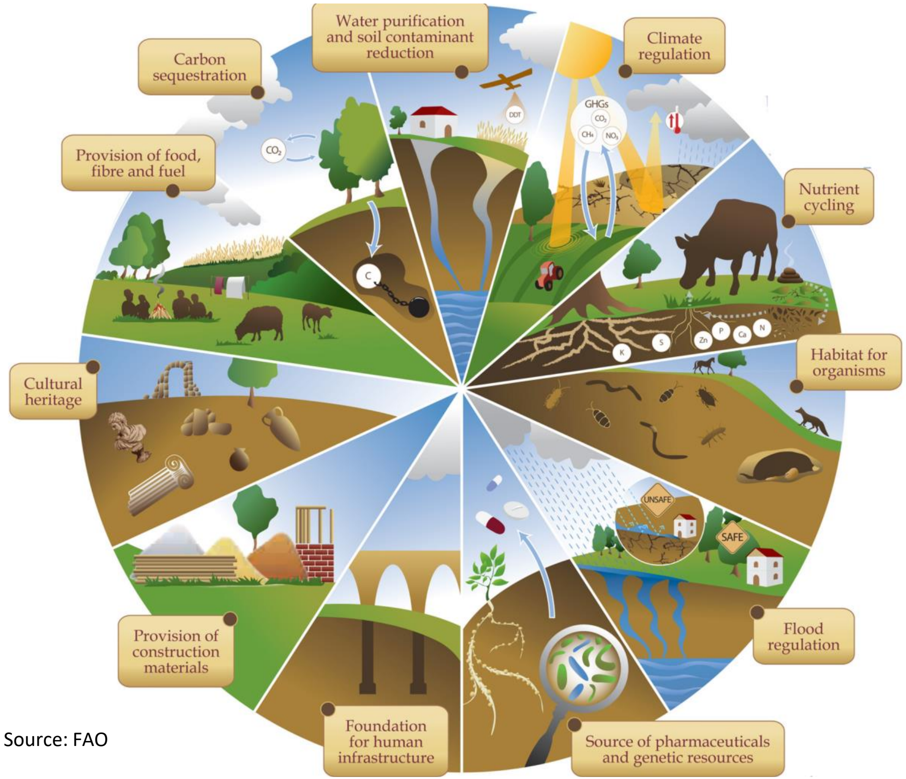
I’d like to respectfully acknowledge that the areas covered by the work I am presenting today are on the inherent and treaty lands of First Nations and within the traditional lands of Indigenous peoples. For thousands of years, Indigenous peoples inhabited and cared for this land, and continue to do so today.

My office at GLFC is located in Robinson-Huron Treaty territory, this land is the traditional territory of the Anishinaabek, specifically the Garden River and Batchewana First Nations, as well as Métis People.

Soil: A foundation for healthy forests

International Decade of Soils 2015-2024

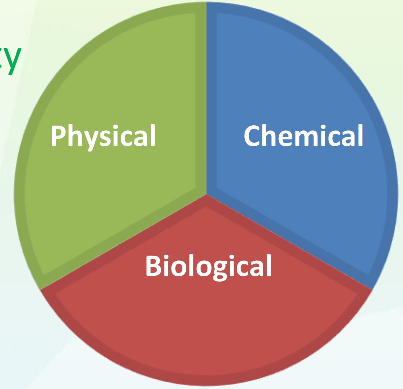
Senate committee on Agriculture and Forestry report on status of soil health in Canada (due by the end of this year)



Source: FAO

Soil: A foundation for healthy forests

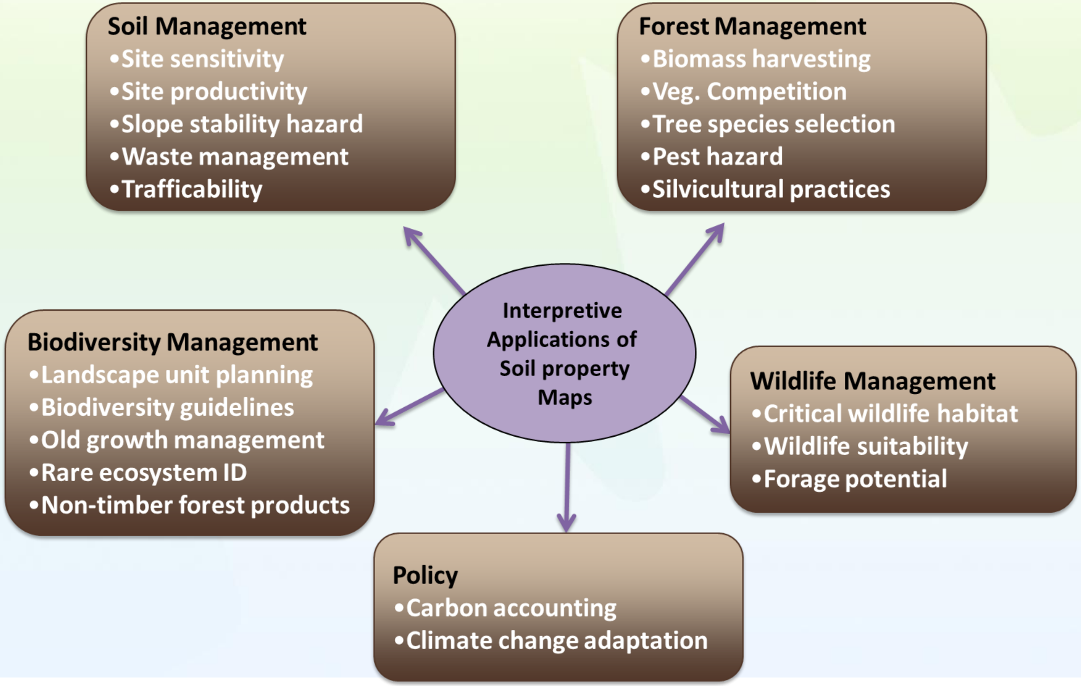
- Texture
- Moisture
- Depth
- Bulk density



- Carbon
- Nitrogen
- pH
- Cations
- Anions

- Decomposition/respiration
- Microbial activity/diversity
- Soil fauna

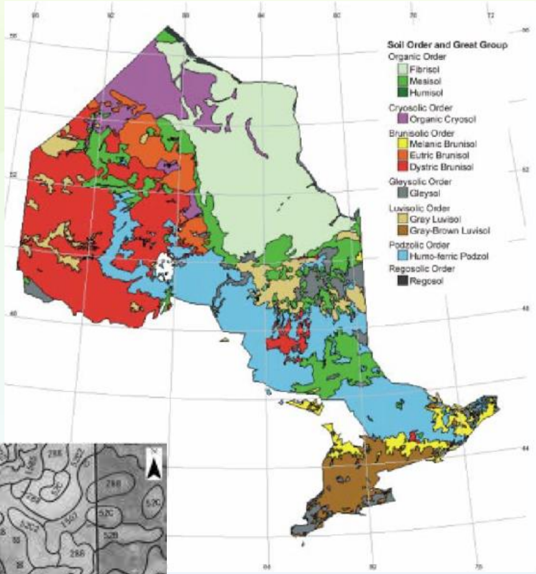
Soil information is essential for many different applications



- The type of soil information (i.e., specific properties) might be different for different applications.
- Understanding how these properties vary across the landscape will improve our ability to practice Sustainable Forest Management

But... soils are not easy to map

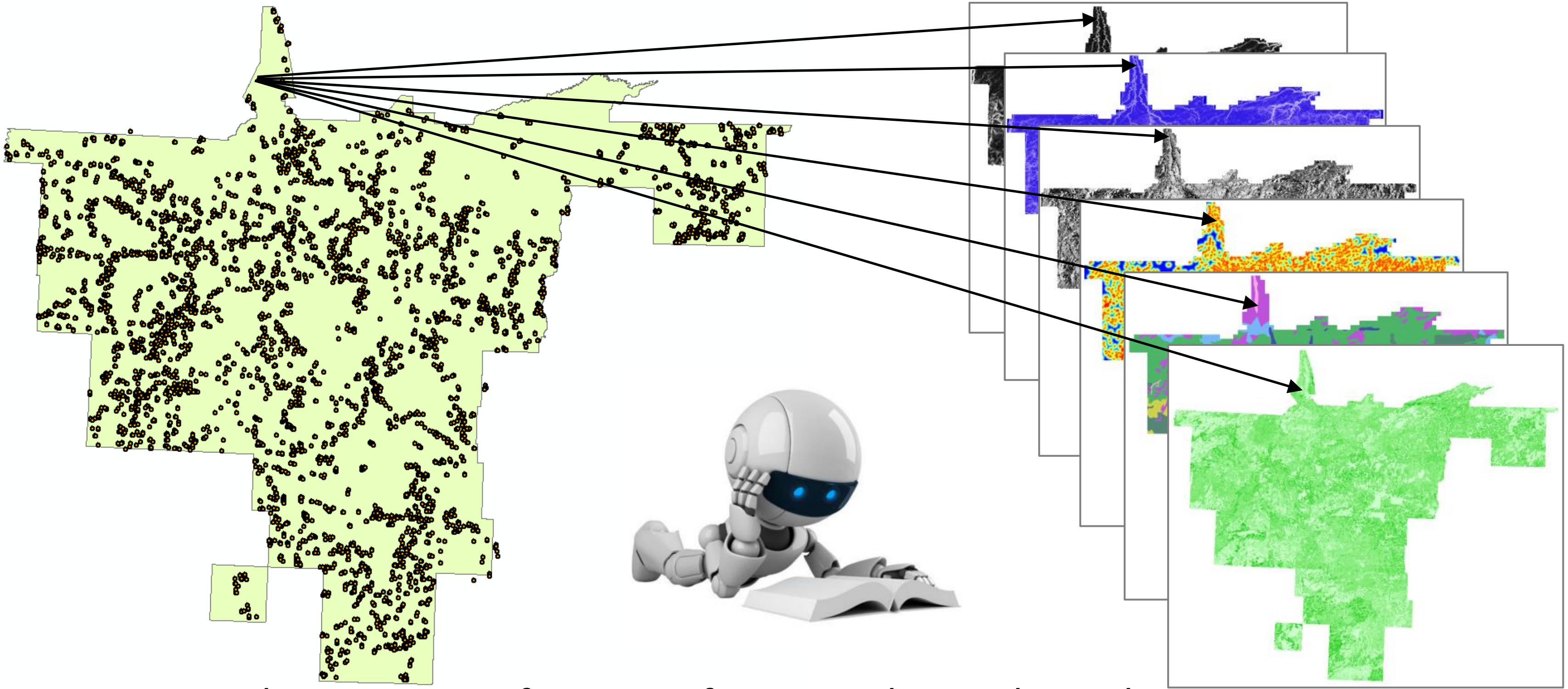
- Existing maps are coarse
- Not easily remotely sensed
- Inferred from landscape position and vegetation associations
- Forest soils offer additional challenges (e.g., tree canopy, forest floor, complex terrain)



Digital soil mapping

Field sampling of soil attributes

Environmental layers



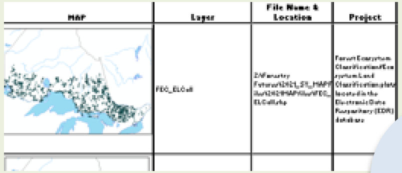
Soil property is a function of topography, geology, climate, …

How do we improve on our **forest** soil mapping?

- Adapting digital soil mapping to forest systems by mapping at relevant scales for forest management
  - Data, data, data
  - What are the key properties (or proxies for the key properties)
  - Workflow
- Mapping soil properties for different applications

Project Goals

1. Compiling legacy **data** and facilitating soil data acquisition.

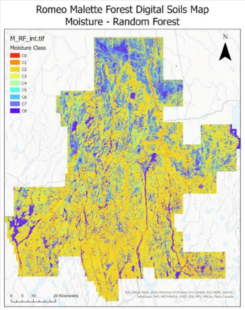


MAP	Layer	File Name & Location	Project

2. Summarizing key **indicators or metrics** of soil properties.

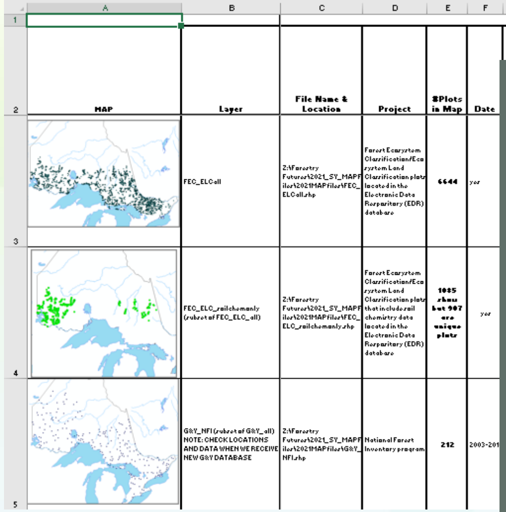
$$D_B = f(\text{Depth, SOC, CF, pH,})$$

3. Expanding soil property **map products** and their applications.



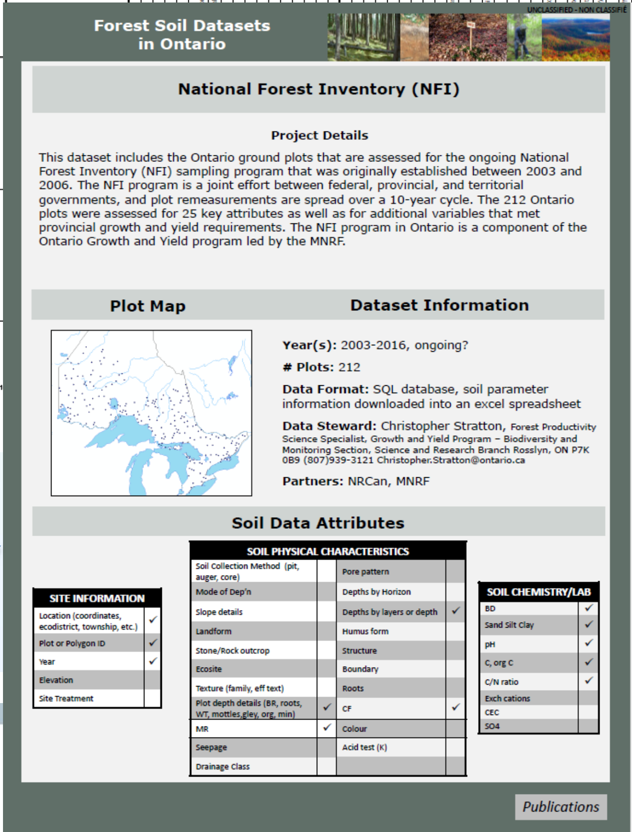
Compiling legacy soil data

- Large datasets (NFI, FEC/ELC, G&Y, FRI, VSN)
- Regional datasets (ARNEWS)
- Project datasets (LTSP, TLW, PRF, AFRIT, university)
- Field-determined soil properties vs. lab-determined soil properties



MAP	Layer	File Name & Location	Project	#Plots in Map	Date
	FEC_ELCall	Z:\Forestry Futures\2021_SY_MAPFiles\2021MAPfiles\FEC_ELCall.shp	Forest Ecosystem Classification/Ecosystem Land Classification plots located in the Electronic Data Respository (EDR) database	6644	yes
	FEC_ELC_soilchemonly (subset of FEC_ELC_all)	Z:\Forestry Futures\2021_SY_MAPFiles\2021MAPfiles\FEC_ELC_soilchemonly.shp	Forest Ecosystem Classification/Ecosystem Land Classification plots that include soil chemistry data located in the Electronic Data Respository (EDR) database	1085 shown but 907 are unique plots	yes
	G&Y_NFI (subset of G&Y_all) NOTE: CHECK LOCATIONS AND DATA WHEN WE RECEIVE NEW G&Y DATABASE	Z:\Forestry Futures\2021_SY_MAPFiles\2021MAPfiles\G&Y_NFI.shp	National Forest Inventory program	212	2003-201

Data, metadata



UNCLASSIFIED - NON CLASSIFIÉ

Forest Soil Datasets in Ontario

National Forest Inventory (NFI)

Project Details

This dataset includes the Ontario ground plots that are assessed for the ongoing National Forest Inventory (NFI) sampling program that was originally established between 2003 and 2006. The NFI program is a joint effort between federal, provincial, and territorial governments, and plot remeasurements are spread over a 10-year cycle. The 212 Ontario plots were assessed for 25 key attributes as well as for additional variables that met provincial growth and yield requirements. The NFI program in Ontario is a component of the Ontario Growth and Yield program led by the MNRF.

Plot Map | **Dataset Information**

Year(s): 2003-2016, ongoing?

 # Plots: 212

Data Format: SQL database, soil parameter information downloaded into an excel spreadsheet

Data Steward: Christopher Stratton, Forest Productivity Science Specialist, Growth and Yield Program – Biodiversity and Monitoring Section, Science and Research Branch Rosslyn, ON P7K 0B9 (807)939-3121 Christopher.Stratton@ontario.ca

Partners: NRCan, MNRF

Soil Data Attributes

SITE INFORMATION	
Location (coordinates, ecodistrict, township, etc.)	✓
Plot or Polygon ID	✓
Year	✓
Elevation	
Site Treatment	

SOIL PHYSICAL CHARACTERISTICS			
Soil Collection Method (pit, auger, core)		Pore pattern	
Mode of Dep'n		Depths by Horizon	
Slope details		Depths by layers or depth	✓
Landform		Humus form	
Stone/Rock outcrop		Structure	
Ecosite		Boundary	
Texture (family, eff text)		Roots	
Plot depth details (BR, roots, WT, mottles,gley, org, min)	✓	CF	✓
MR	✓	Colour	
Seepage		Acid test (K)	
Drainage Class			

SOIL CHEMISTRY/LAB	
BD	✓
Sand Silt Clay	✓
pH	✓
C, org C	✓
C/N ratio	✓
Exch cations	
CEC	
SO4	

Publications

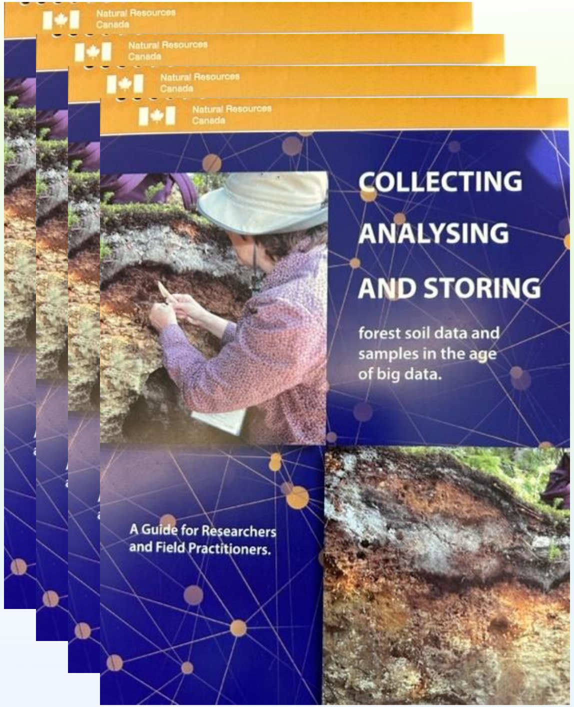
Fact sheets

Shelagh Yanni

Facilitating soil data acquisition

- Encouraging soil collections as part of other studies, community-based monitoring
- Flexible sampling protocols and guidance documents
  - ☑ Overview
  - ☐ Planning
  - ☐ Field collection
  - ☐ Processing soils
  - ☐ Laboratory analyses
  - ☐ Data management

Quick reference booklets



David Paré, Charlotte Norris, Shelagh Yanni, Stephanie Nelson, Dave Morris, Kim Chapman

Compiling legacy data and facilitating soil data acquisition

- Key challenges
  - Locational accuracy
  - Subjective/qualitative measures
  - Non-standard methods
  - Expense of field collection of samples and processing and analyses.

- Opportunities
  - Linking soil databases
  - Rapid assessment methods
  - In-situ quantitative sensors
  - Rapid laboratory methods

Summarizing key indicators or metrics of soil properties

- Some properties are critical but may be difficult to measure.
- Can more easily measured properties serve as a proxy?
- Can we build “Pedo-transfer functions” from these proxies?

Example of Bulk Density

$$D_B = f(\text{Depth, SOC, CF, pH, Silt, Sand, Clay})$$

$$D_B = f(\text{Depth, SOC, CF, pH,})$$

$$D_B = f(\text{Depth, SOC, CF})$$

$$D_B = f(\text{Depth, SOC})$$

$$D_B = f(\text{SOC})$$

$$D_B = f(\text{Depth})$$

Summarizing key indicators or metrics of soil properties

Canadian Journal of Forest Research

Article

A quantitative approach to defining soil nutrient regimes within ecosystem classifications for Northwestern Ontario

R.L. Fleming[a], P.W. Uhlig[b], D.M. Morris[c], M. Kwiaton[c], K.A. Baldwin[a], P.W. Hazlett[a], K.I. Webster[a], and K.A. Chapman[a]

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Abstract

Soil nutrient regimes (SNRs) are often incorporated in ecosystem classifications. Evaluation of actual nutrient levels associated with these SNRs and the development of complementary soil chemistry regimes (SCRs) could broaden their utility. Using data from 618 forest stands in northwestern Ontario, we developed five-category SCRs using *K*-means clustering and examined relationships among individual nutrients, SCRs, and the SNRs of the Canadian National Vegetation Classification Associations and the Ontario Ecological Land Classification Ecosites. F, A, and B horizon samples were analyzed for organic C (OrgC), total N (TotN), C:N ratio (C:N), cation exchange capacity (CEC), exchangeable bases, base saturation (BaSat), and pH. CEC, pH, and BaSat showed good correspondence across horizons, and together with C:N accounted for much of the variation in chemical properties. There was broad agreement between Association and Ecosite SNRs and B horizon (BHorz) and All horizon (AllHorz) SCRs. C:N decreased while pH and cation metrics increased with increasing SNR and SCR richness. User's accuracies (SNRs vs. SCRs) for the classifications ranged from 31%–39% but increased to 80%–86% for SNR values within ±1 SCR class. Classification trees identified pH class, soil texture, and overstory composition as the principal field-measured factors related to BHorz SCRs.

Key words: ecosystem classification, nutrient regime, soil chemistry, soil properties, Ontario

Building pedotransfer functions for soil nutrient regime

J. Zhang[1], B. Heung[1], Shelagh Yanni[2], Kara Webster[2]

Natural Resources Canada / Ressources naturelles Canada
Canadian Forest Service / Service canadien des forêts
DALHOUSIE UNIVERSITY

Texture and pH are important to nutrient regime

Rob Fleming, Jin Zhang

Expanding soil property map products and their applications – Step 1: Workflow

- Workflow
  - Plot data
  - Spatial layers and covariates (LiDAR DEM acquisition)
  - Model choice (kNN, RF, SVM)
  - Variable Inflation Factor, Recursive Feature Elimination to remove multi-collinearity
  - Resampling to improve balance across categories
  - Variable importance

"Tips and Tricks" report of DSM workflow best practices

Jeremy Arkin, Grant McCartney, Brandon Heung, Ian Sinclair

Test area – Romeo Malette Forest

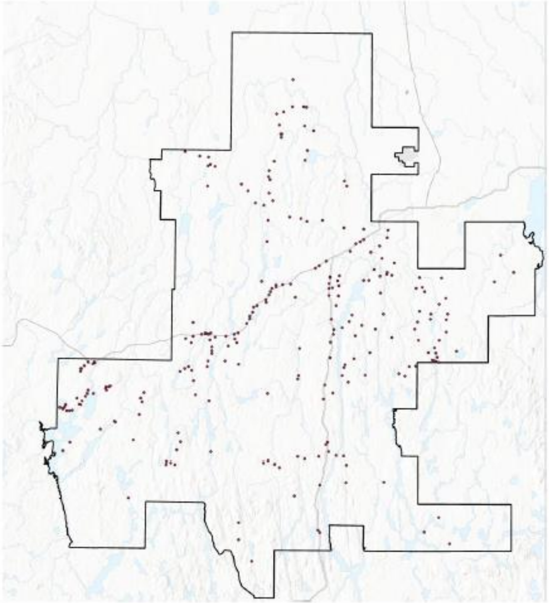
RMF VSN Plots

FORSITE
Forest Management Specialists

- Plot Data
  - 258 Plots

Moisture	
Class	# of points
C0	9
C1	39
C2	97
C3	56
C4	19
C5	17
C6	5
C7	7
C8	9

Texture	
Class	# of points
Clayey	11
Coarse loamy	128
Fine loamy	12
Folic	25
Organic Peat	15
Sandy	51
Silty	16



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Covariates

- Topography (25 variables)
- Geology (surficial and bedrock)
- Hydrology (2018 LiDAR derived water bodies and stream network)
- Biology data (forest type)

Expanding soil property map products and their applications – Step 2: Outputs

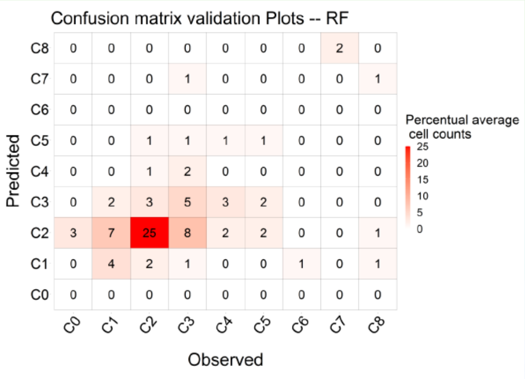
- Outputs
  - How good was the model? Accuracy and Kappa with confusion matrices
  - What are the most important covariates? Variable importance
  - What is the distribution of the property? Maps of soil property
  - How confident are we in the prediction? Certainty/entropy maps

Jeremy Arkin, Grant McCartney, Brandon Heung

Accuracy, Kappa and Confusion Matrices

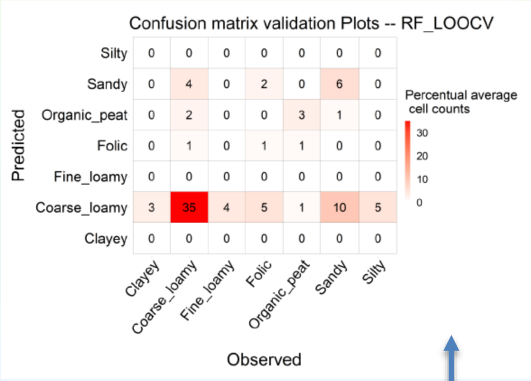
Moisture Regime

Accuracy	Kappa
0.42	0.19



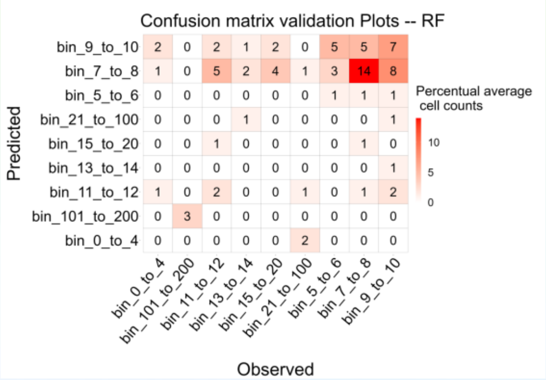
Texture

Accuracy	Kappa
0.46	0.12



Depth of AB

Accuracy	Kappa
0.36	0.15

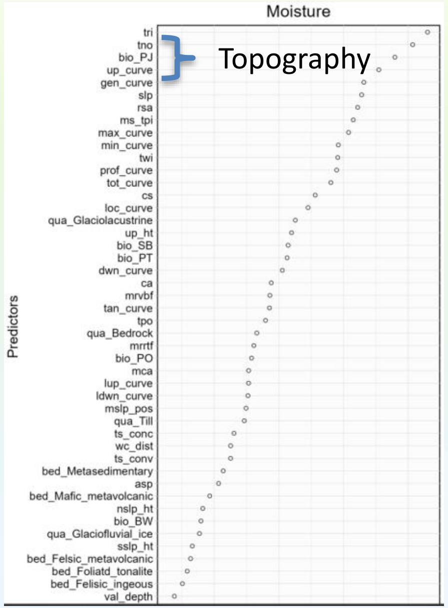


Overpredicting coarse-loamy category

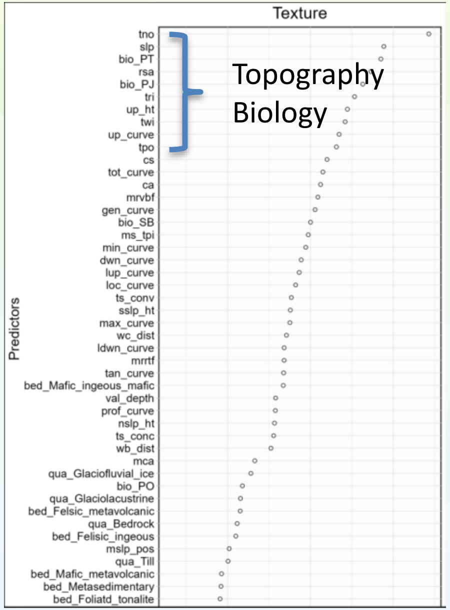
Jeremy Arkin, Grant McCartney

Variable Importance

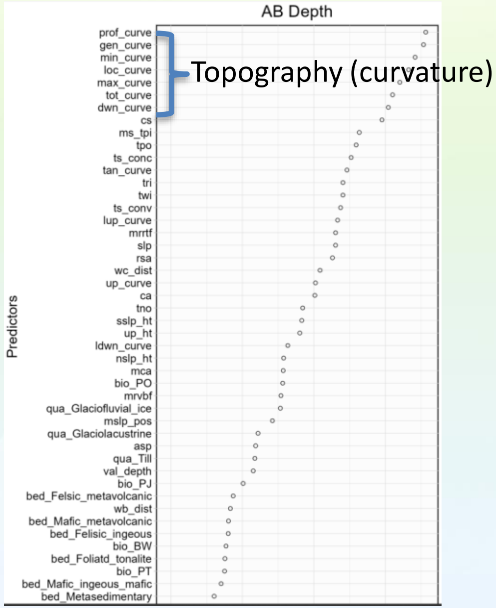
Moisture Regime



Texture



Depth



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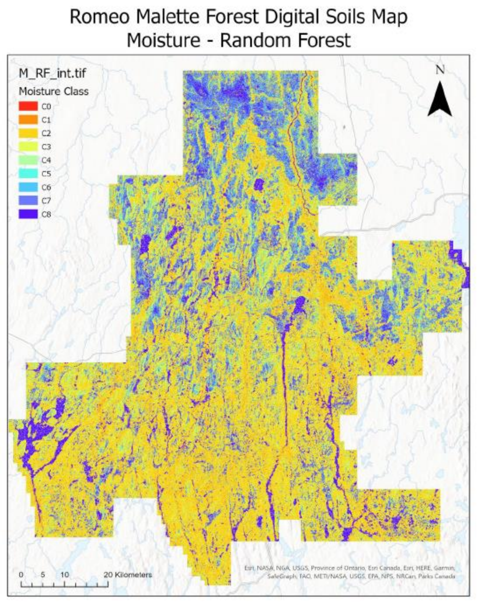
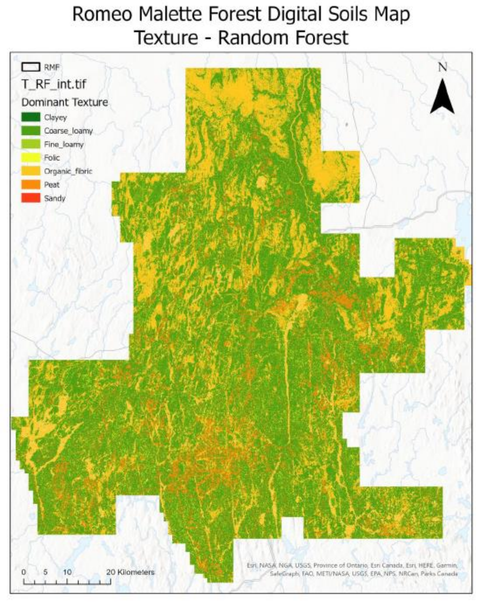
Increasing importance →

Raster Maps

Moisture Regime



Texture



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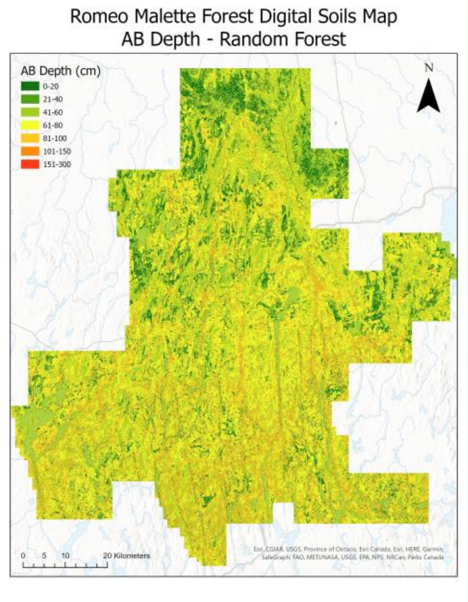

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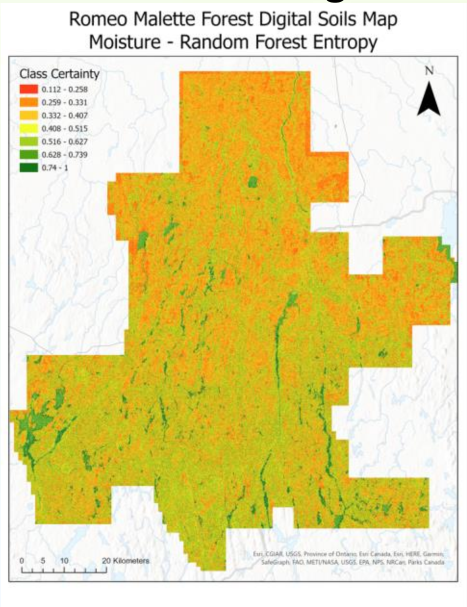
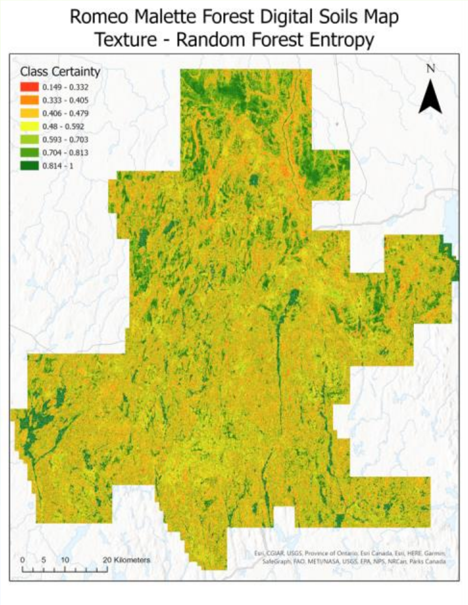
Certainty/Entropy

Moisture Regime



Texture



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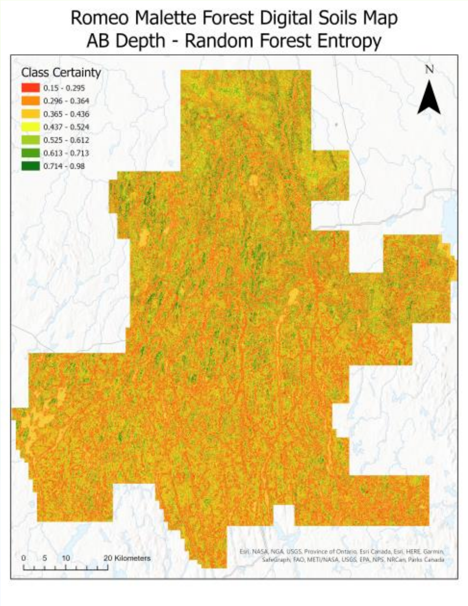

Jeremy Arkin, Grant McCartney

Expanding soil property map products and their applications

- Key challenges
  - Covariate layers
    - What are the quality of the covariate layers?
    - Which are most important?
    - Are more covariates better?
  - Combining different data sources

- Opportunities
  - LiDAR acquisition for topography and biota/inventory data
  - Scripts that streamline the process
    - Options for different model types
    - Consistency in the workflow and outputs

Recommendations and Next Steps

- Encourage opportunistic sampling of soils
- Rapid, easy and standardized field methods
- Testing new technology and funding for lab analyses
- Sample archives (additional soil properties or new technologies)
- Data repositories
- Best practices, scripts, and training (test data)
- Continued testing and application at FMU scales.

Thank you!

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