NATURAL RESOURCES CANADA - INVENTIVE BY NATURE

Digital soil mapping as a tool for Sustainable Forest Management

Kara Webster, Brandon Heung, Rob Fleming, Dave Morris, Chris Blackford… and others!

Canadian Forest Service
Dalhousie University
Ontario Ministry of Natural Resources and Forestry

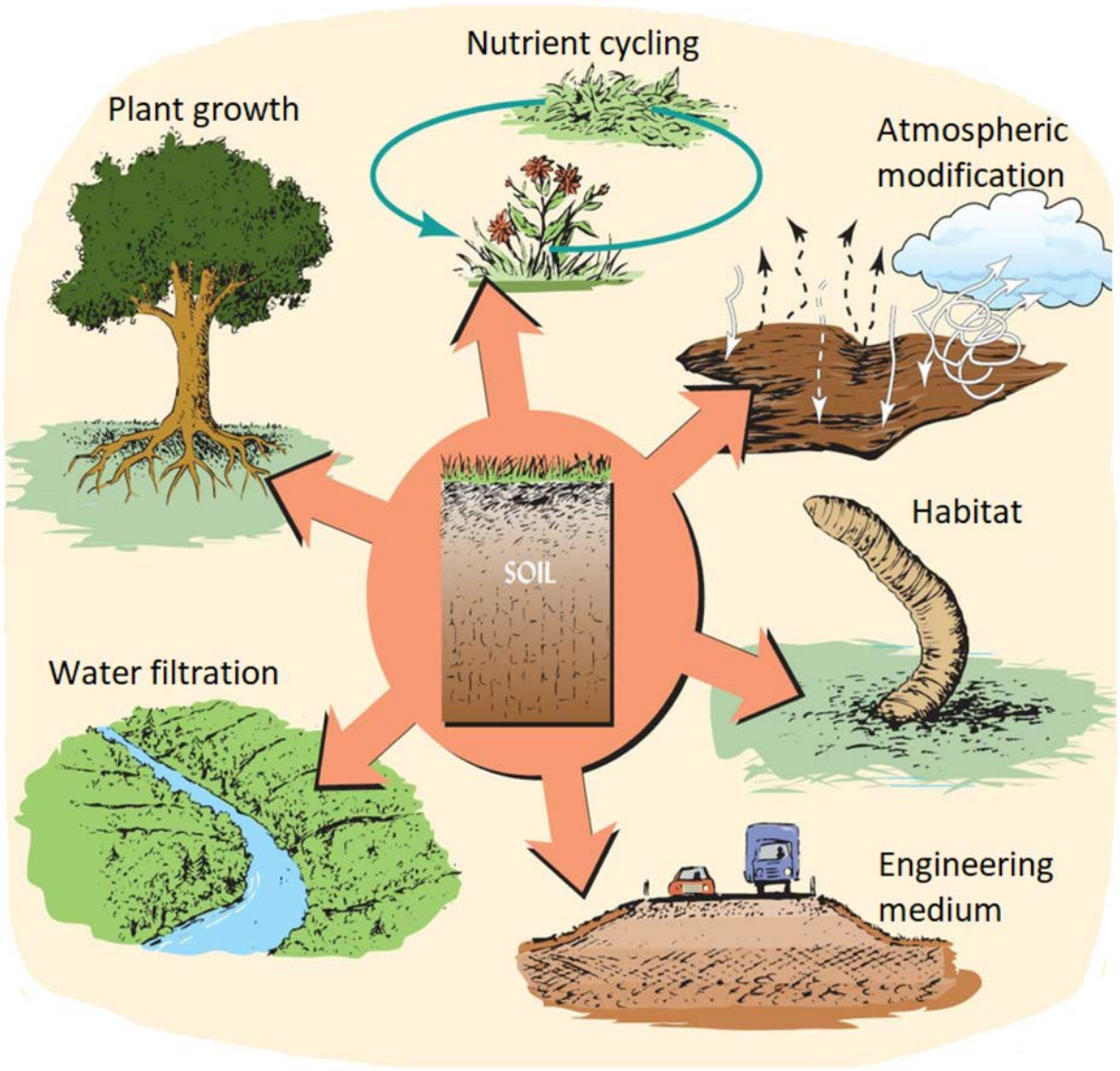
CIF-IFC Innovative Forest Solutions Forum - February 23, 2021

Soil: A foundation for healthy forests

1. Undervalued
2. Complex

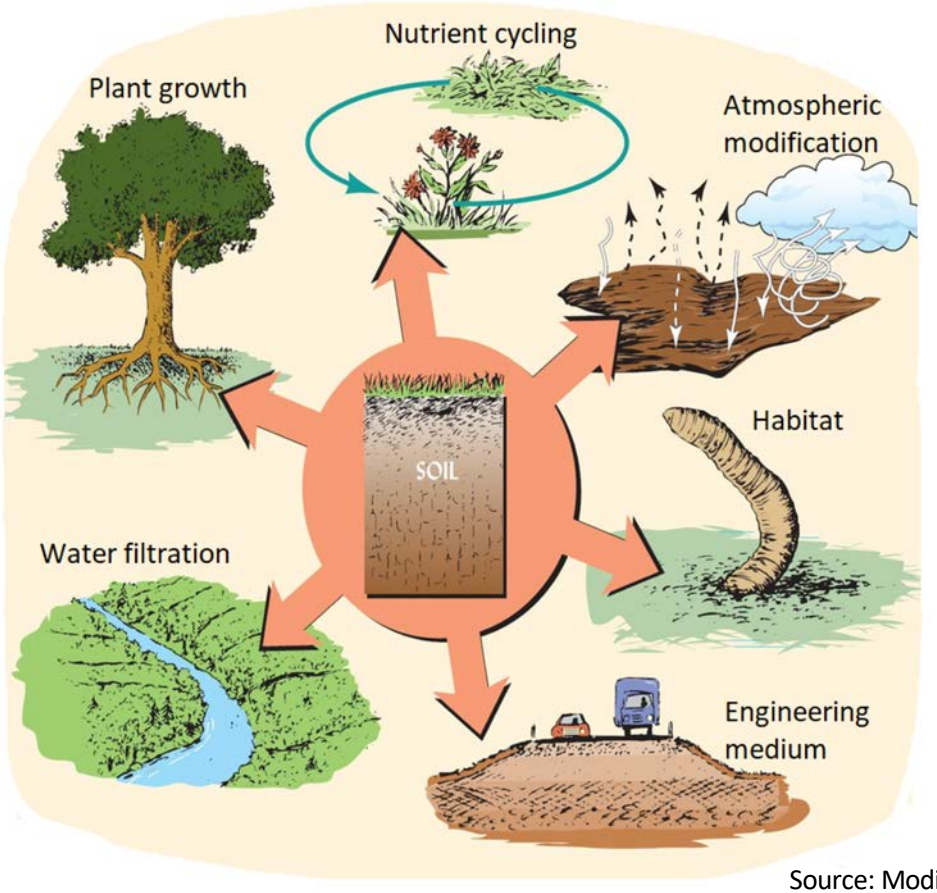
International Decade of Soils 2015-2024

Soil: A foundation for healthy forests



Source: Modified from Brady and Weil (2017)

Soil: A foundation for healthy forests

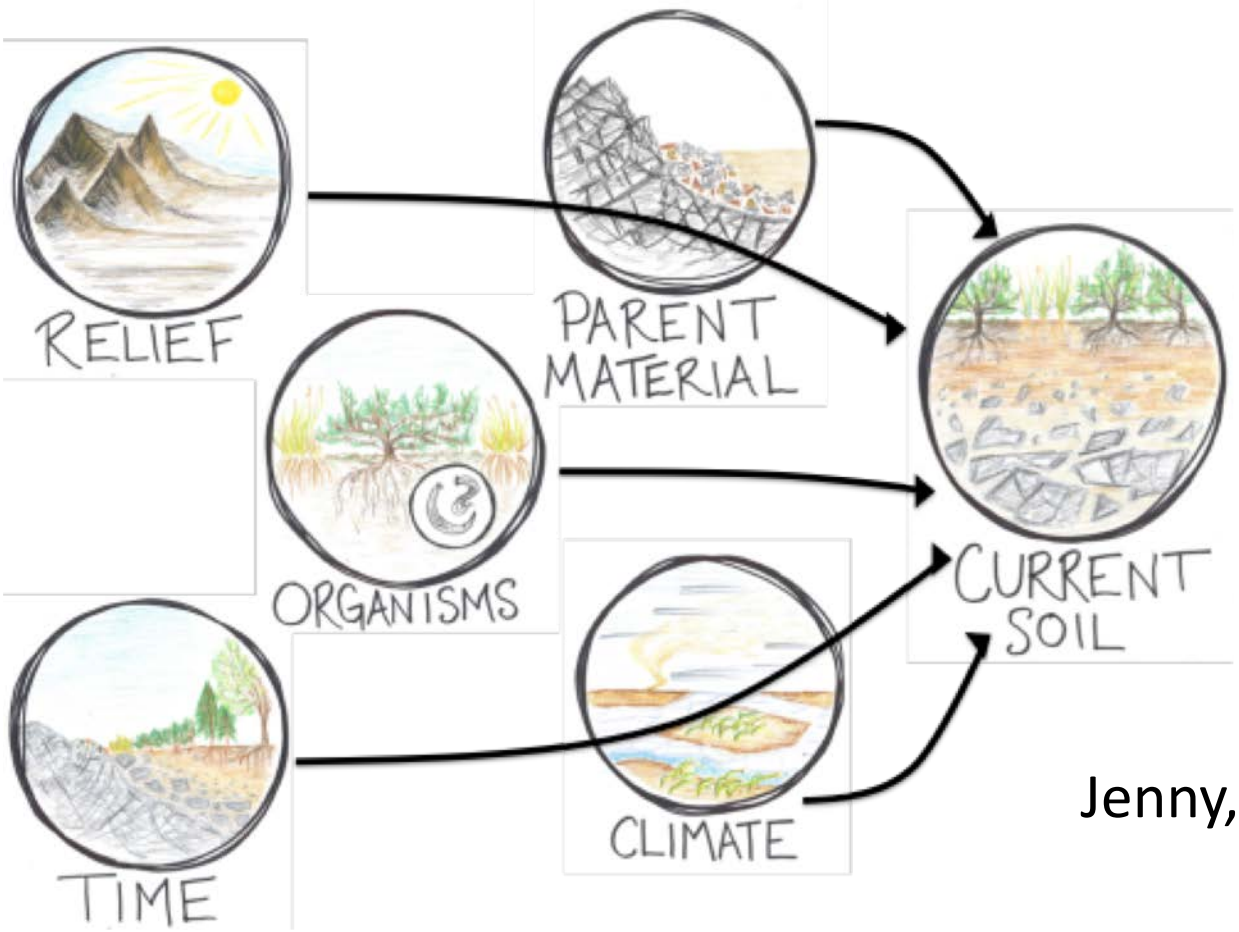


Source: Modified from Brady and Weil (2017)

Knowledge of soil variation across the landscape will improve our ability to practice Sustainable Forest Management

Why do soils vary?

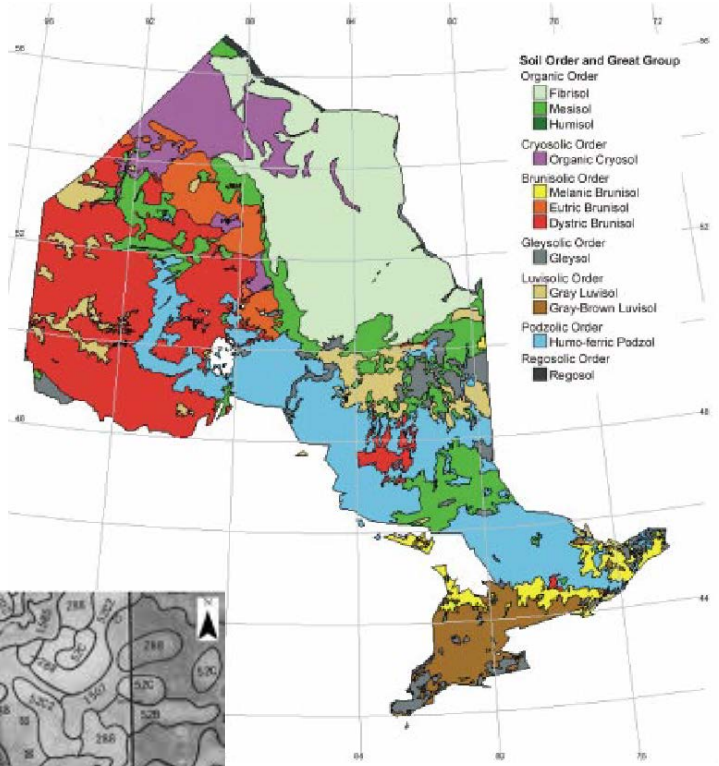
Soils are the product of many different “factors”

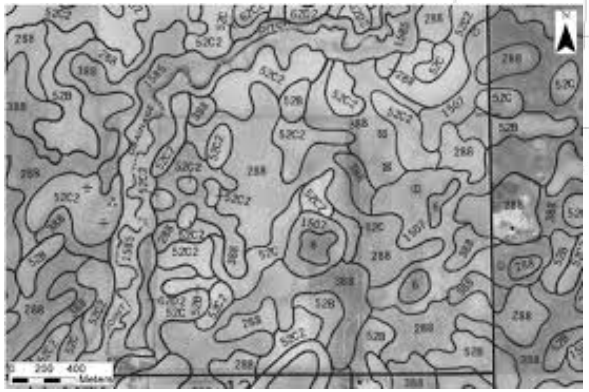


Jenny, 1941

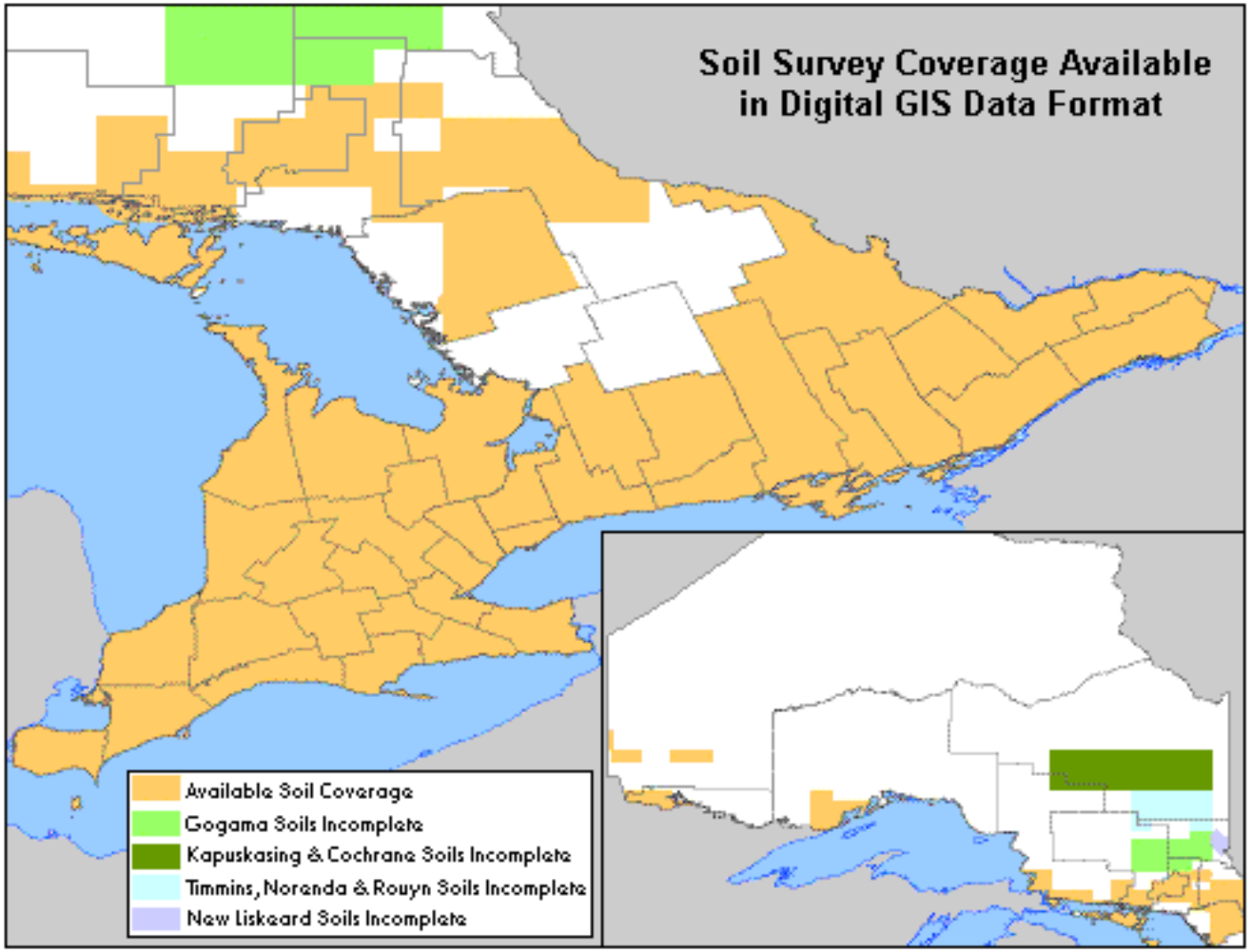
Forest soils are challenging to map!

- Existing maps are coarse
- Not easily remotely sensed
- Inferred from landscape position and vegetation associations





Soil mapping is limited… for example in northern Ontario



Work to date:

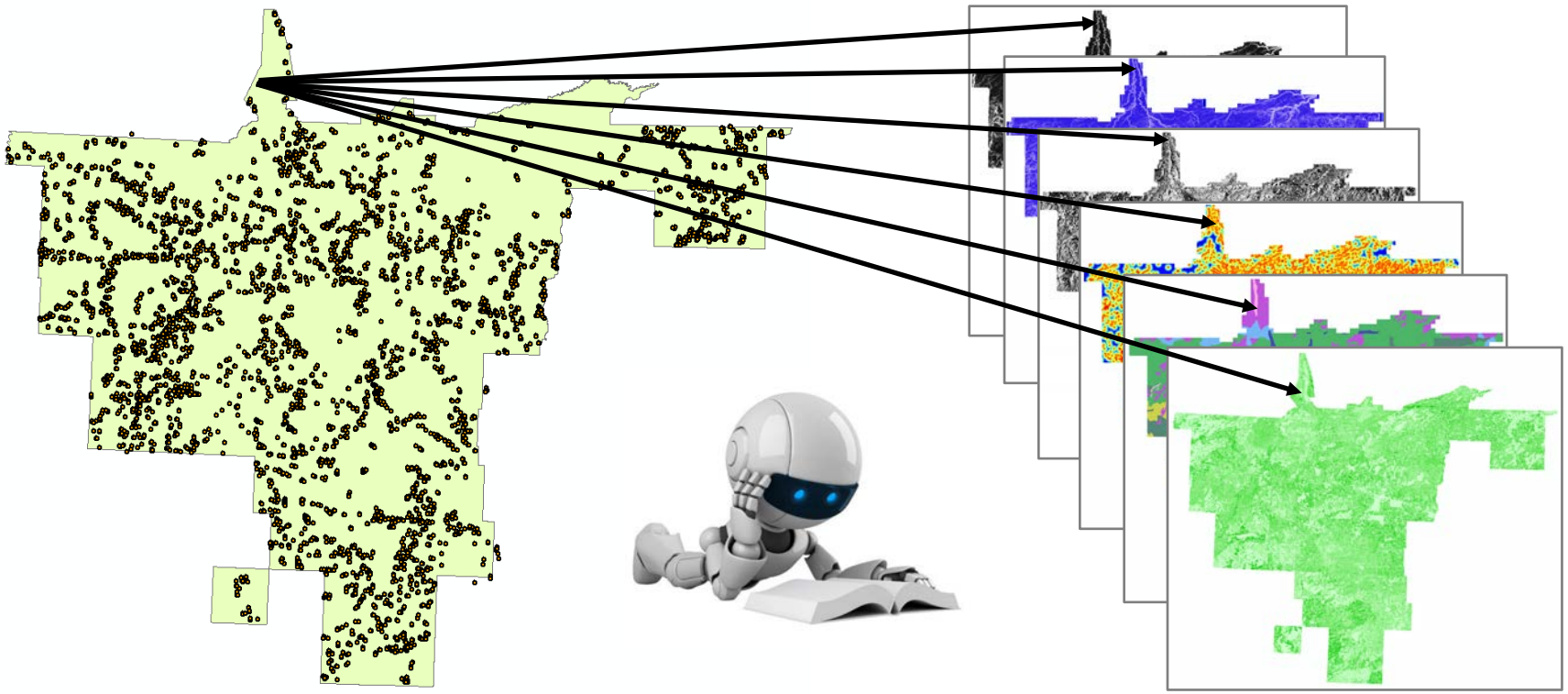
- Baseline *strategy for digital soil mapping* that can be used consistently, taking into account the diversity of "geographies"
- To initiate a *tool box* for digital soil mapping

Blackford et al. 2021. Digital soil mapping workflow for forest resource applications: a case study in the Hearst Forest, Ontario. Canadian Journal for Forest Research. 51(1): 59–77.

What is Digital Soil Mapping?

Field sampling of soil attributes

Environmental layers



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

Workflow

Predictor
Environmental data

Response
Soil property data

1

Topography data
DEM
Hydrology data
water layers, wetlands
Geology data
bedrock, surficial geology
Biota data
forest cover, other attributes/metrics

2

Plot data
Government
FEC/ELC, G&Y, FRI, NFI
Industry
forest management planning, audit
Academic
theses
Contractor

Environmental data

Soil data

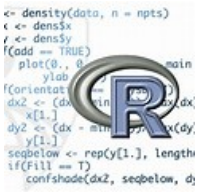
DSM dataset

Machine Learning Models
Random forest
K-Nearest Neighbour
Support Vector Machine

3

Model outputs
Model comparisons
Soil property maps
Uncertainty maps

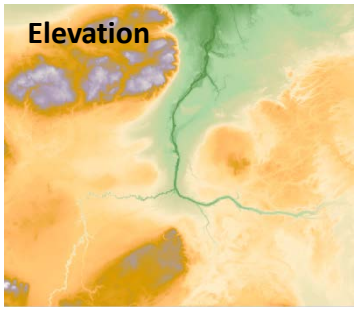
4

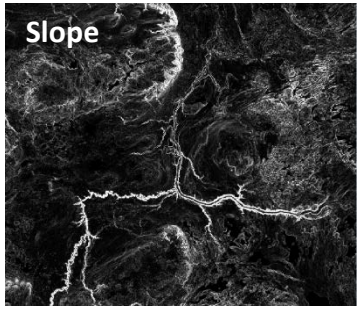


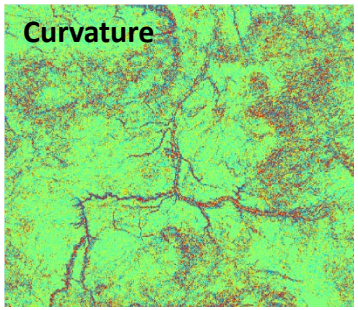
SAGA
System for Automated Geoscientific Analyses

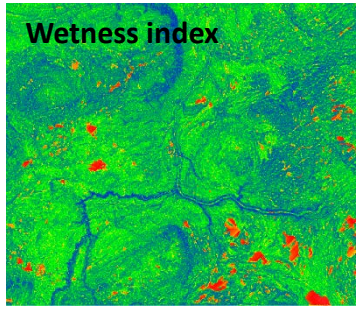
Data – Topography is a key driver

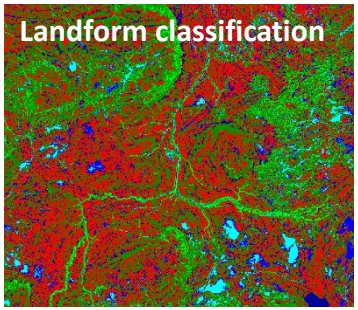
- Elevation
- Slope, Aspect, Curvature
- Wetness index, Sediment transport capacity index
- Stochastic depression analyses to delineate wetlands
- Landform classification

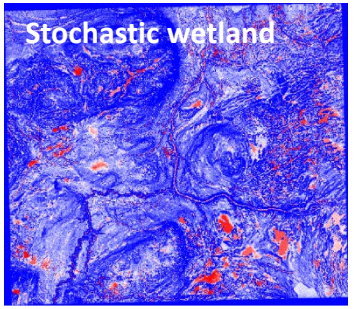






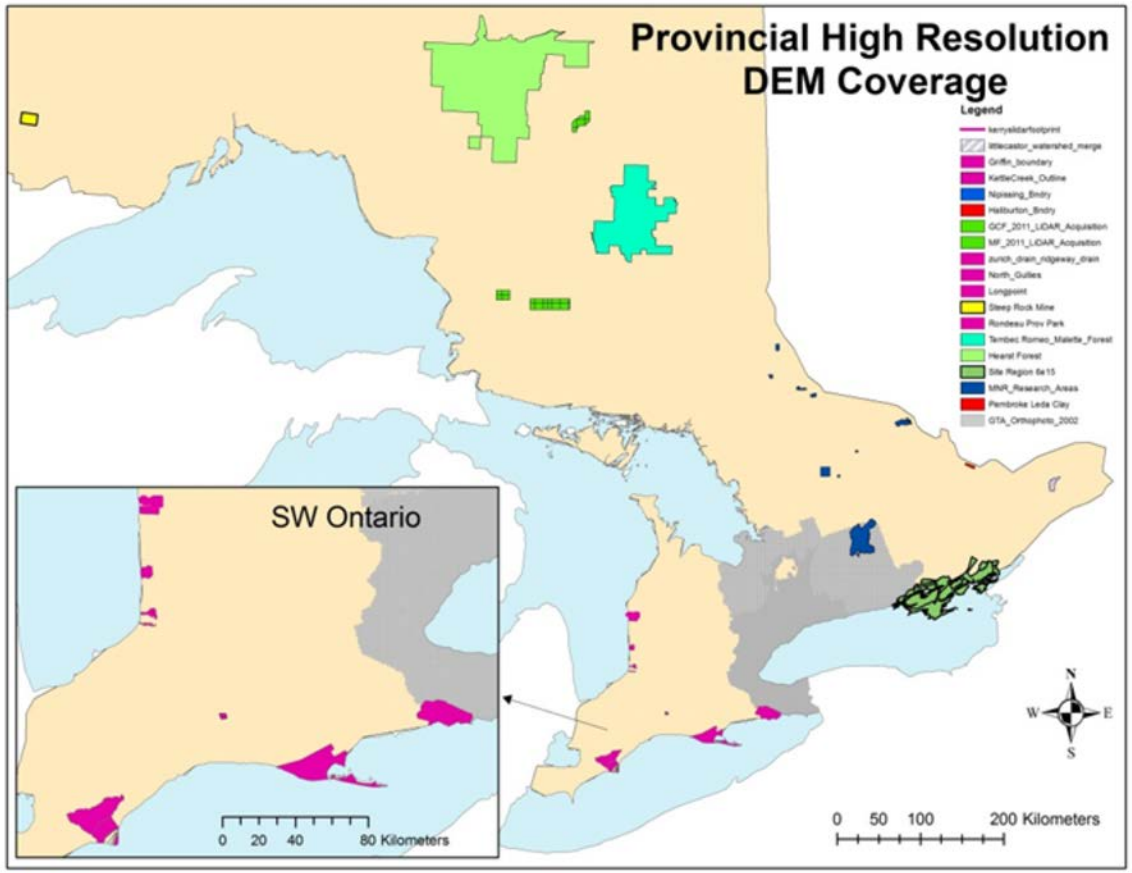




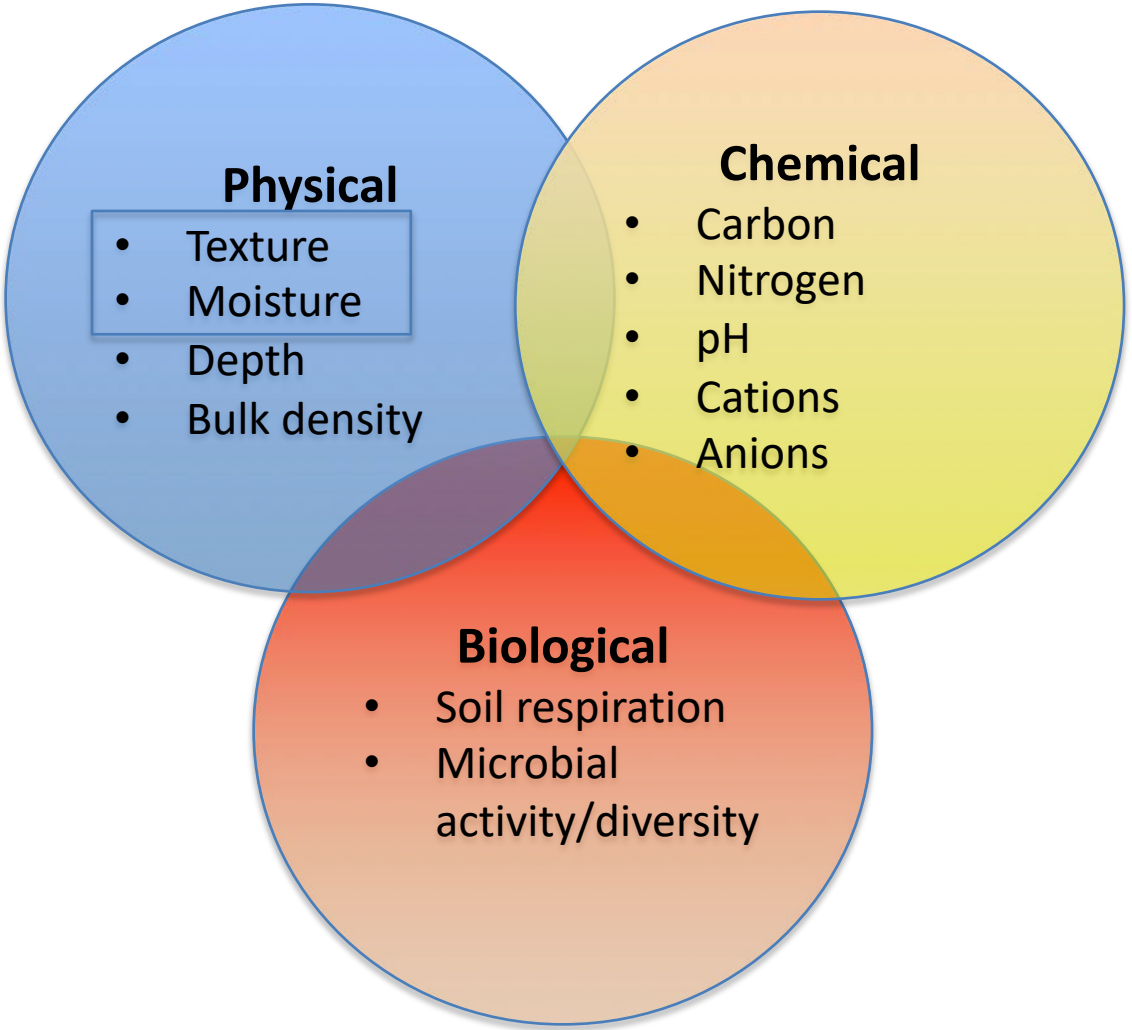


Key challenge #1:

LiDAR (Light Detection and Ranging) Digital Elevation Models = high resolution topographic maps



Data – Soil properties



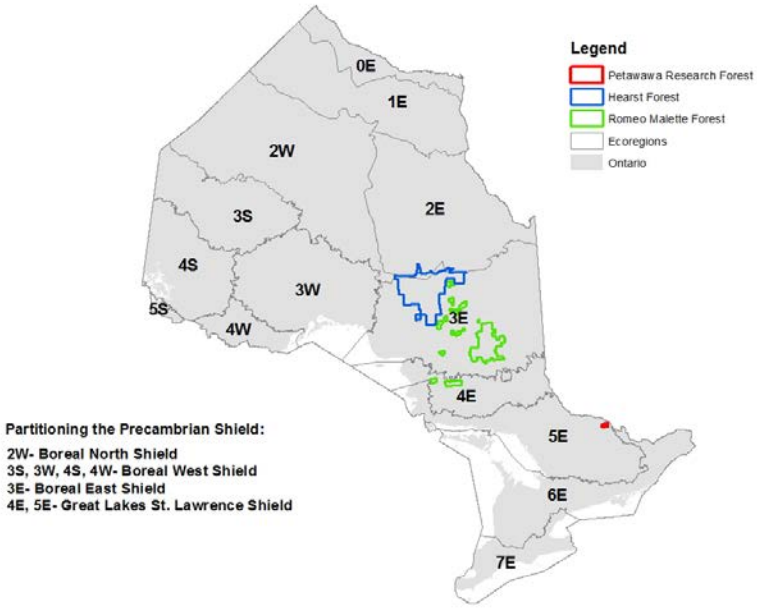
Key challenge #2:

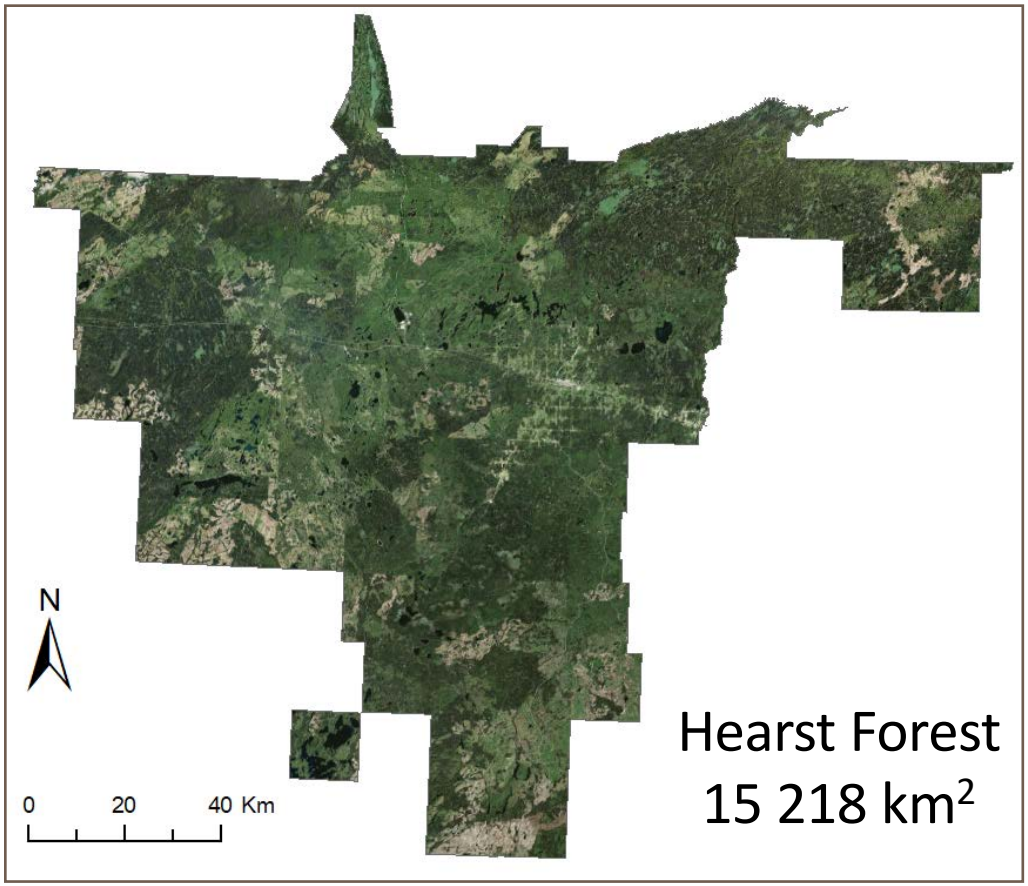
High quality and georeferenced soils information

Data source	Soil information	Coverage
Forest Resource Inventory data sets	Texture, horizons, depth, gley, moisture class, landform	Selected areas
National Forest Inventory plots	Texture, horizons, depth, moisture class, landform, chemistry	Various
Growth and Yield plots	Texture, horizons, depth, gley, moisture class, landform	Ontario AOU
Forest Ecosystem Classification/Ecological Land Classification plots	Texture, horizons, depth, gley, moisture regime, landform, topoposition, some with soil chemistry	Various
Independent research programs	Horizons, chemistry	Sporadic

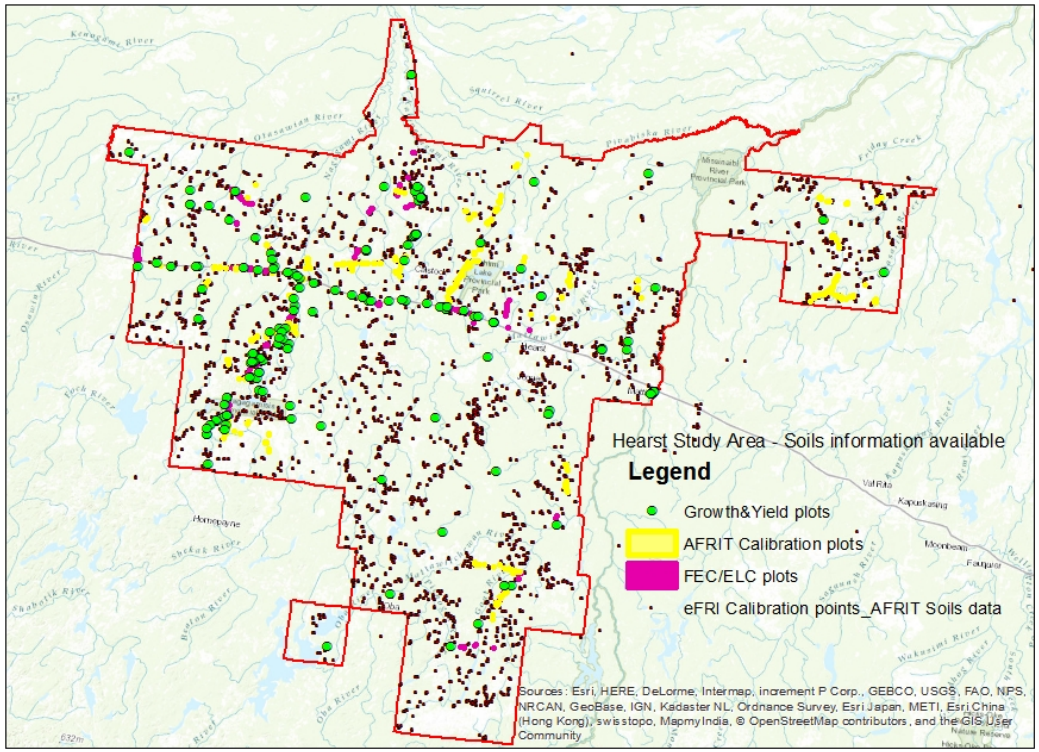
- Opportunistic collections using standardized and easy methods.

Test areas


Legend
Petawawa Research Forest
Hearst Forest
Romeo Malette Forest
Ecoregions
Ontario
0E
1E
2W
2E
3S
4S
3W
5S
4W
3E
4E
5E
6E
7E
Partitioning the Precambrian Shield:
2W- Boreal North Shield
3S, 3W, 4S, 4W- Boreal West Shield
3E- Boreal East Shield
4E, 5E- Great Lakes St. Lawrence Shield


N
0
20
40 Km
Hearst Forest
15 218 km²

Case study: Hearst Forest, Ontario

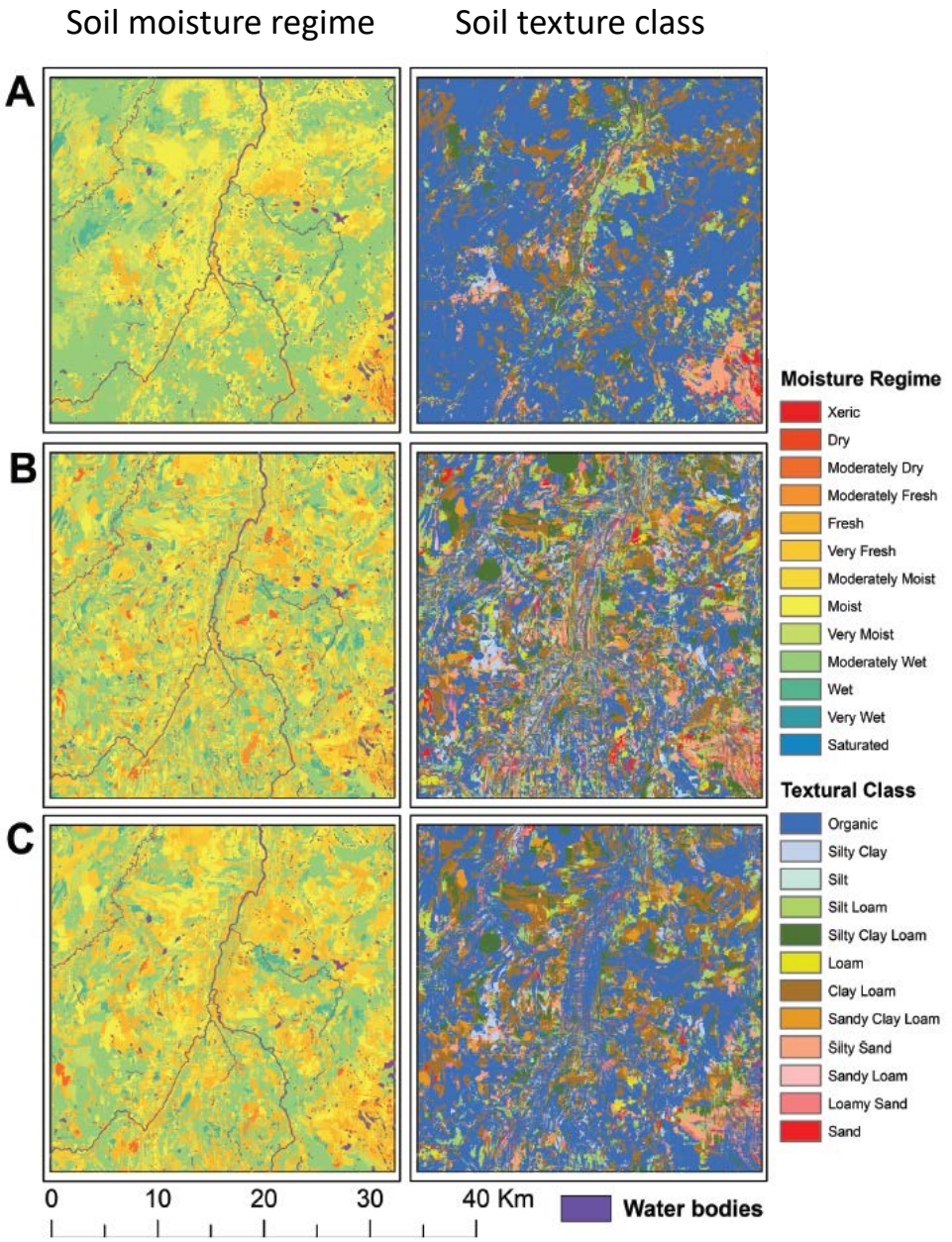


- Data collation for sites
- Data cleaning

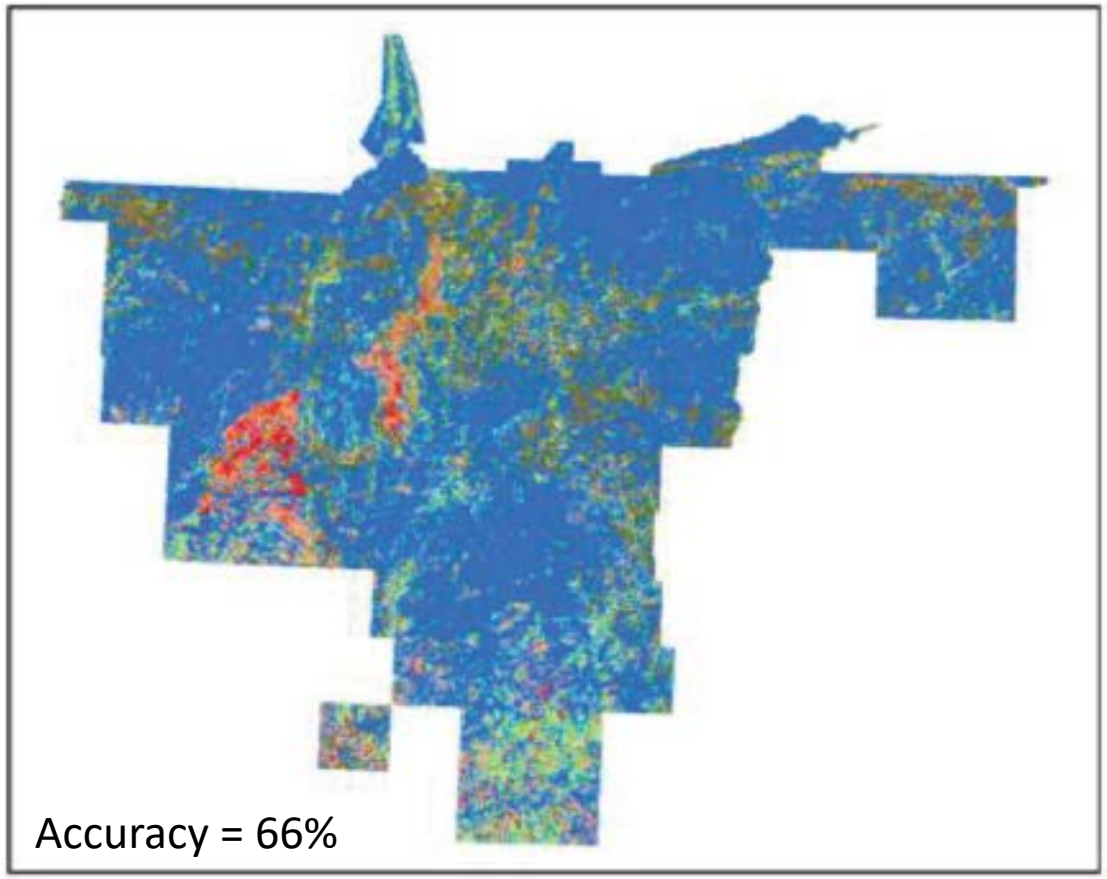
7734 moisture regime points
7213 soil texture points

Model comparisons

		Accuracy	Kappa
Random Forest			
	Moisture	0.63	0.55
	Texture	0.66	0.58
K-Nearest Neighbour			
	Moisture	0.61	0.53
	Texture	0.61	0.53
Support Vector Machine			
	Moisture	0.59	0.51
	Texture	0.60	0.51



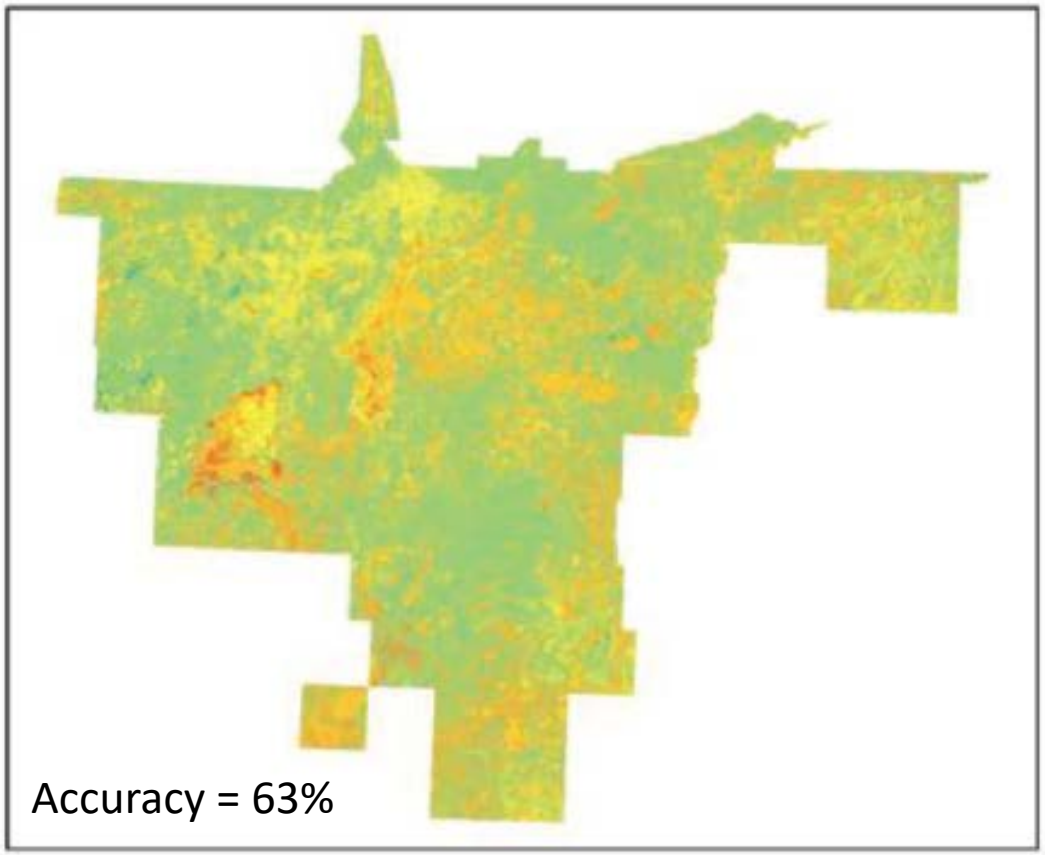
Soil texture map



Textural Class

- Organic
- Silty Clay
- Silt
- Silt Loam
- Silty Clay Loam
- Loam
- Clay Loam
- Sandy Clay Loam
- Silty Sand
- Sandy Loam
- Loamy Sand
- Sand

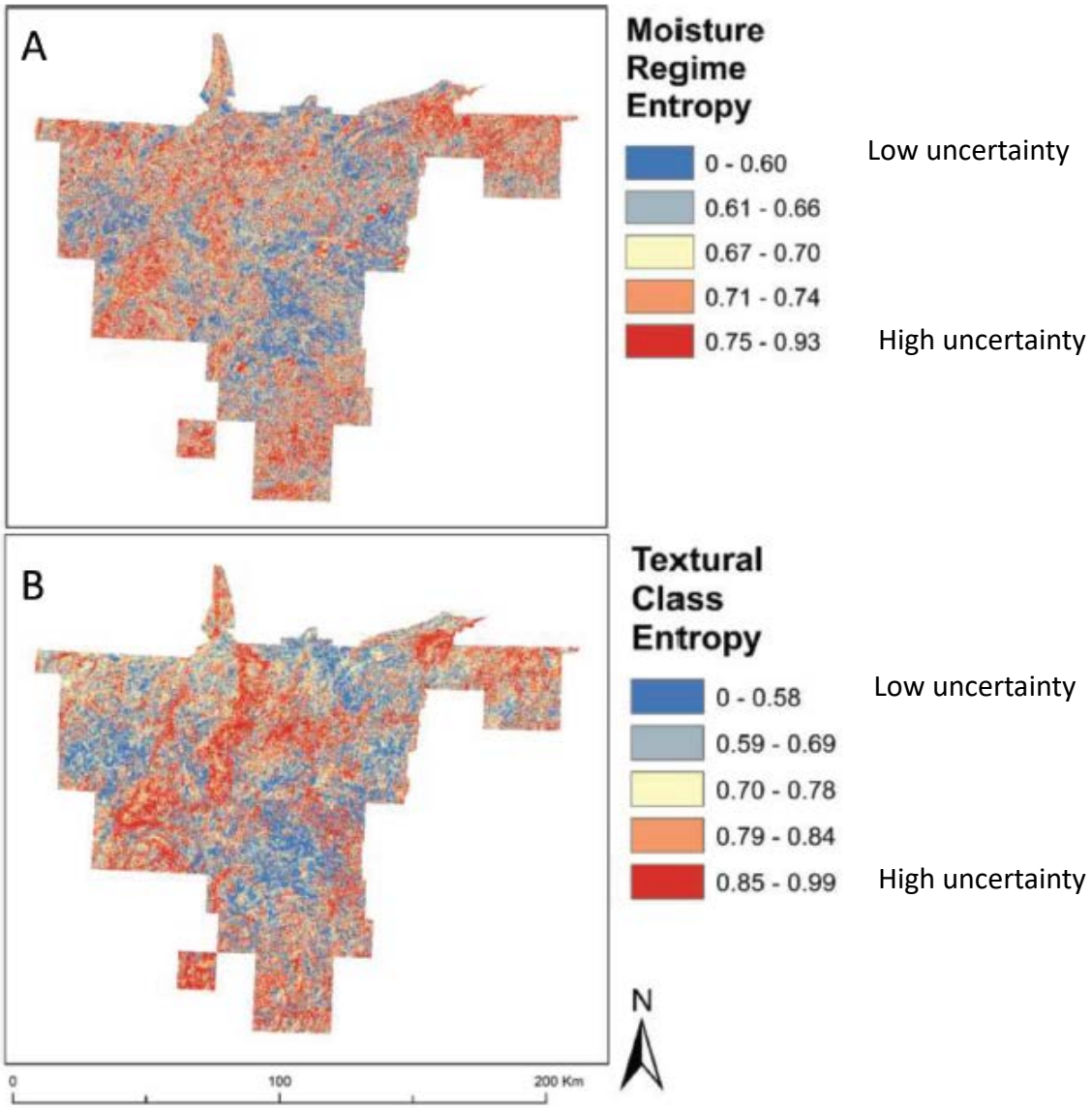
Soil moisture regime map



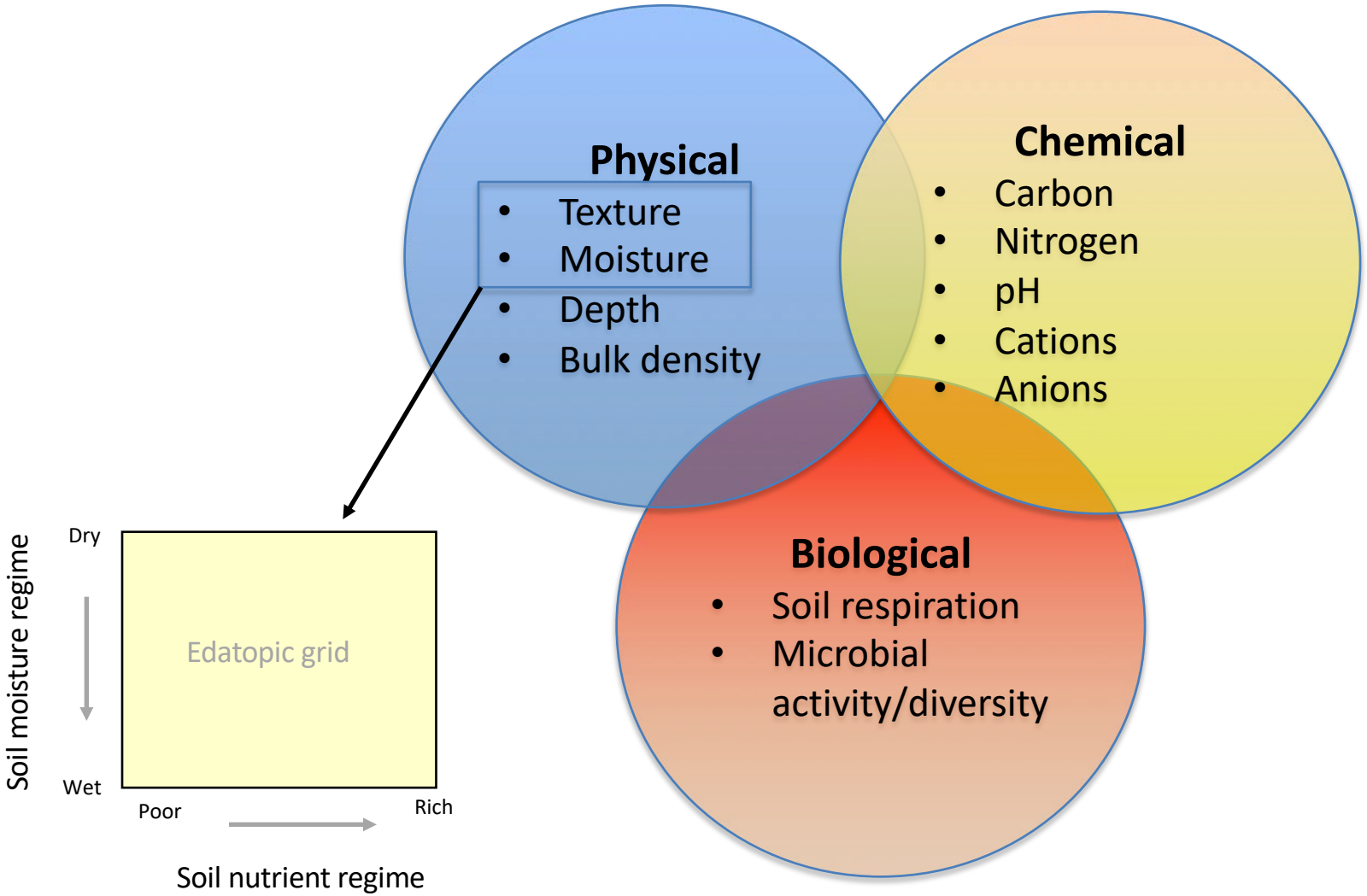
Moisture Regime

- Xeric
- Dry
- Moderately Dry
- Moderately Fresh
- Fresh
- Very Fresh
- Moderately Moist
- Moist
- Very Moist
- Moderately Wet
- Wet
- Very Wet
- Saturated

Model uncertainty

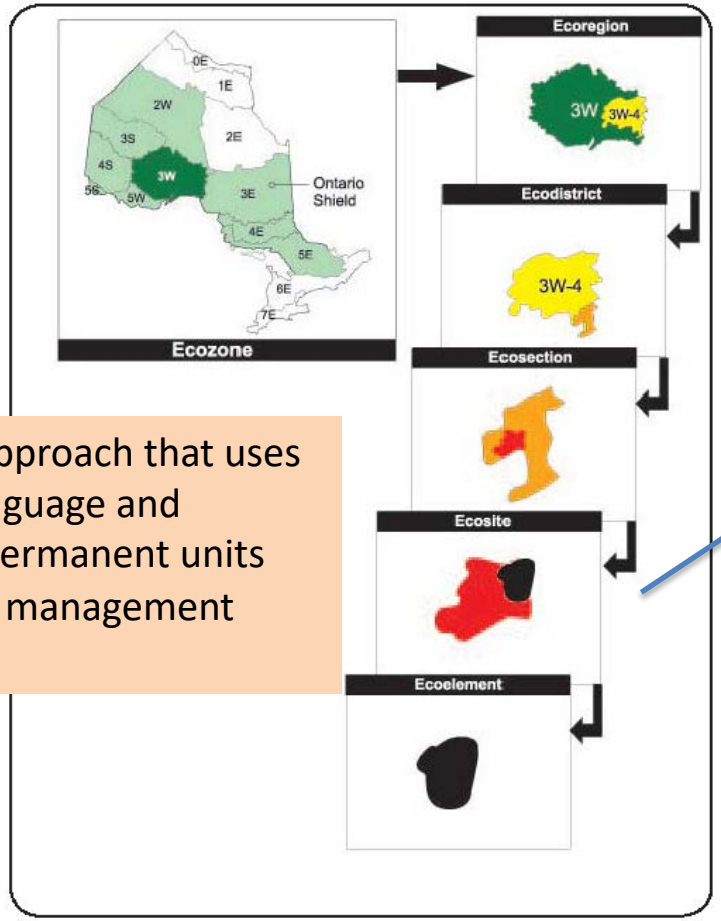


Soil properties



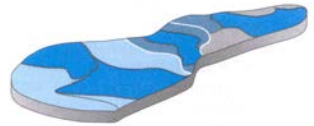
Soil property mapping informs ecosystem mapping

Classification enables development of spatial and non-spatial interpretations

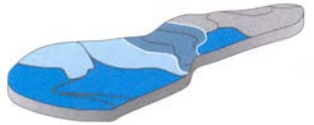


Hierarchical approach that uses a common language and inventory of permanent units for integrated management

General purpose ecosystem mapping units



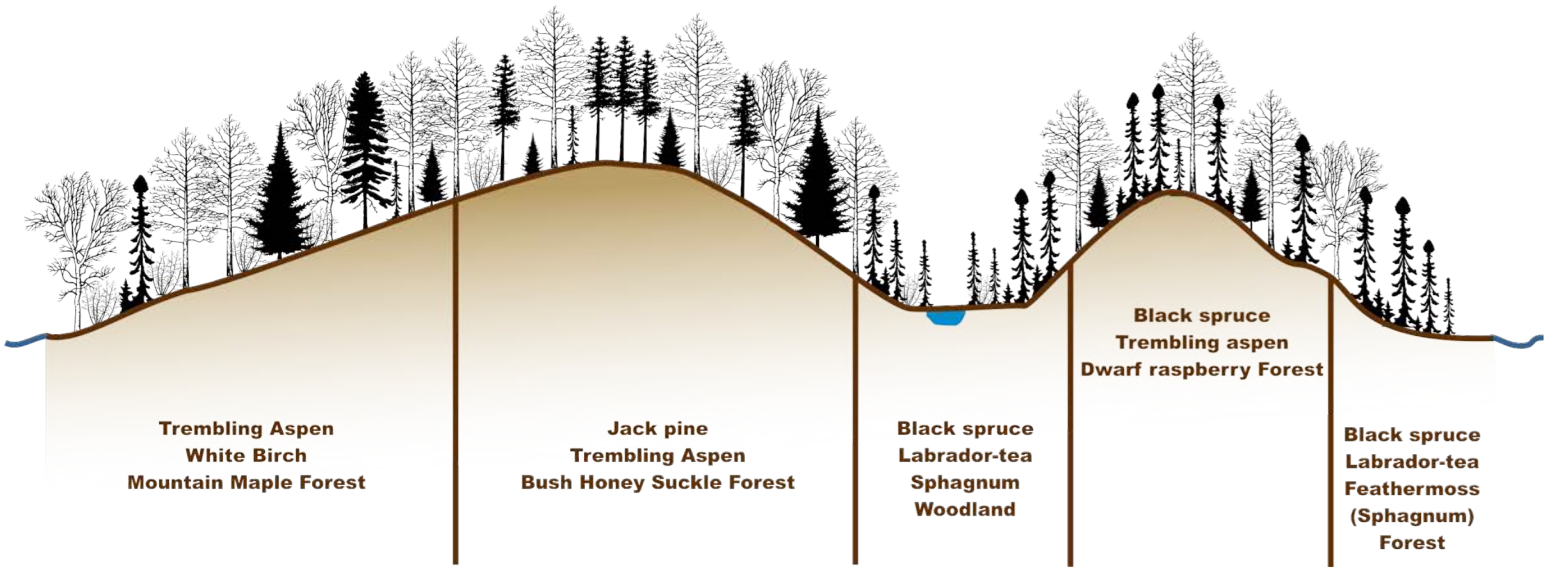
Interpreted ecosystem map for forest productivity



Interpreted ecosystem map for moose browse

Adapted from Bailey 1996

Use of Edatope to Represent Indicator Species "Niche"



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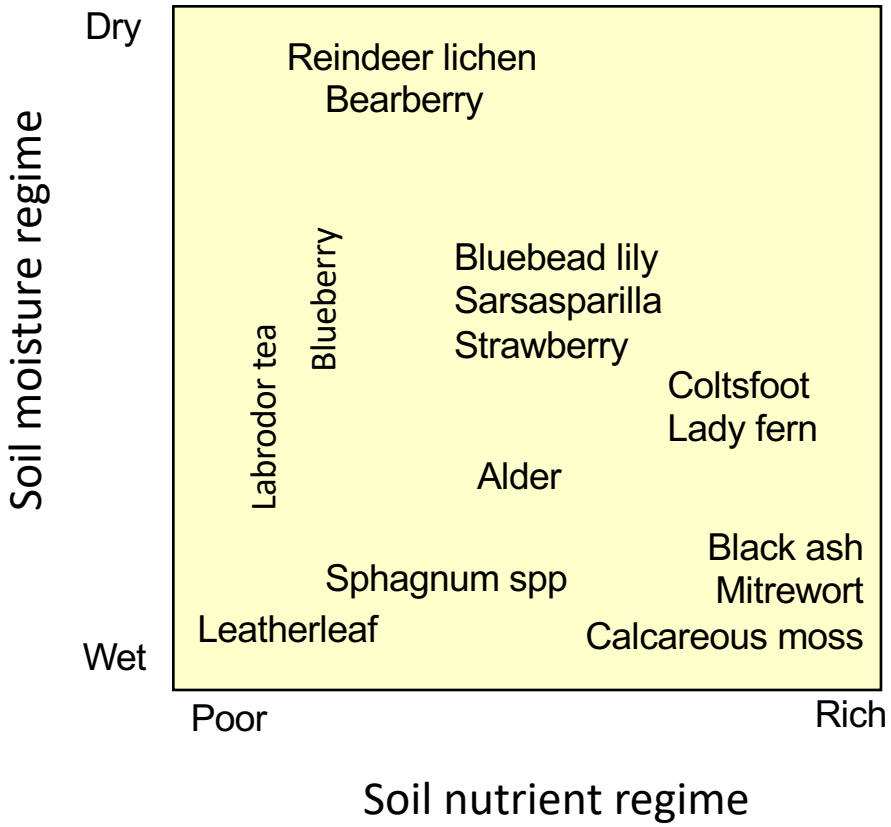
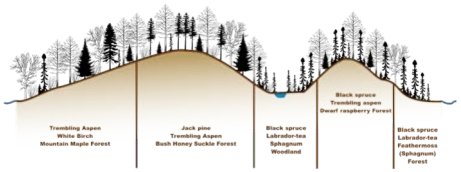
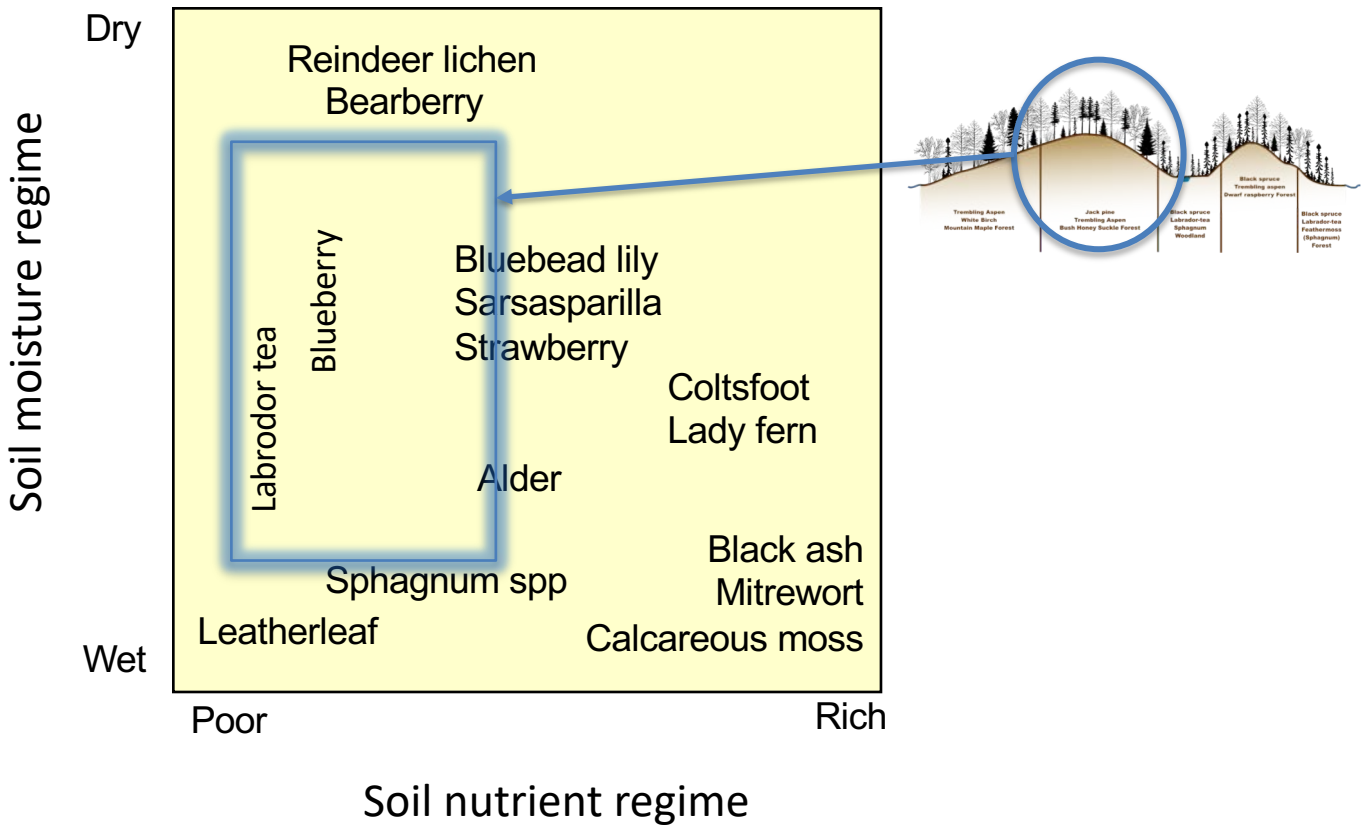


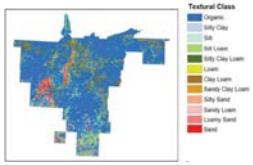


Use of Edatope to Represent Ecosite within a Forest Type

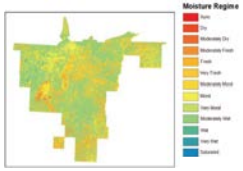


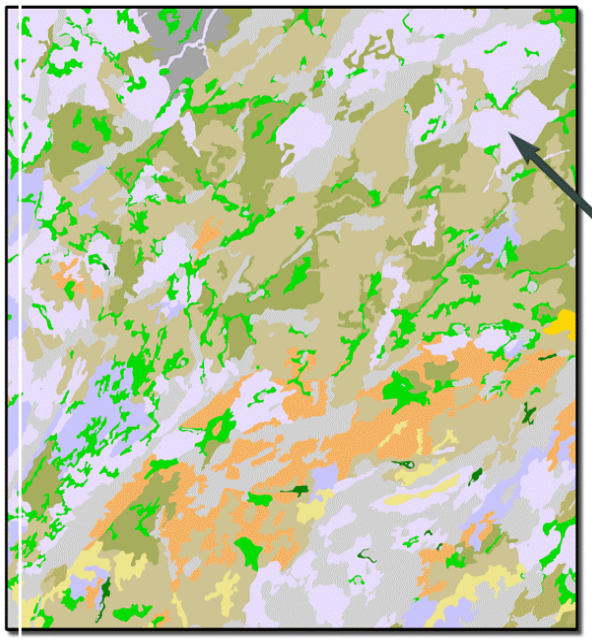
Mapping Ecosites

Texture/Nutrients regime

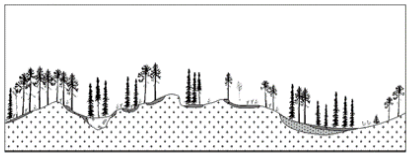


Moisture regime





Ecosite 12 - Jack Pine

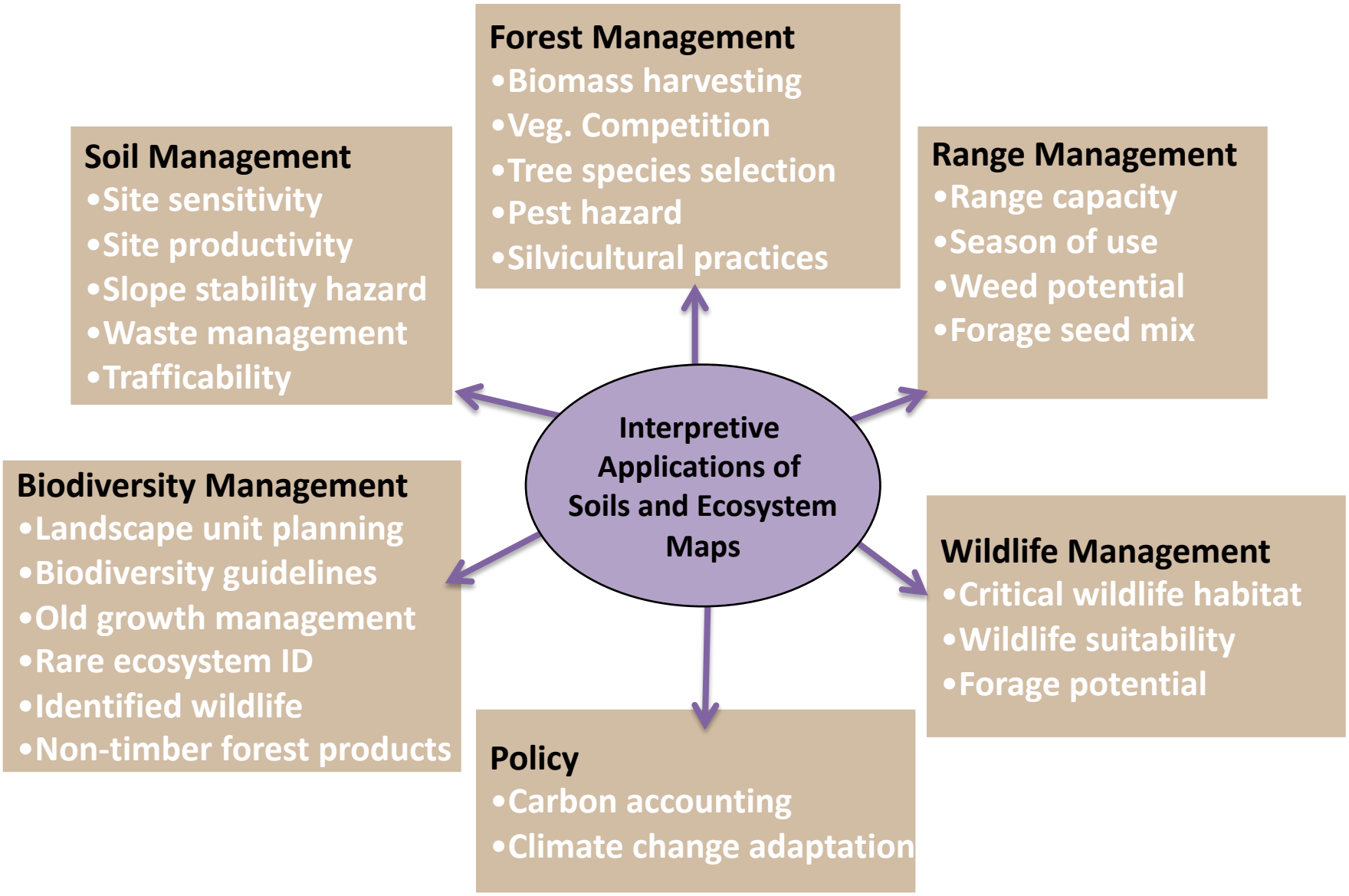


Ecosite:
12 - Black Spruce Jack Pine
Very Shallow Soil

FRI Description:
Pj 100%
Site Class 2
Barren & Scattered

Forest Unit:
PjSha - Jack Pine Shallow Soil

Moving away from “expert” interpretation from digital aerial photos at polygon scales to data-driven models at finer scales


Forest Management
•Biomass harvesting
•Veg. Competition
•Tree species selection
•Pest hazard
•Silvicultural practices
Soil Management
•Site sensitivity
•Site productivity
•Slope stability hazard
•Waste management
•Trafficability
Range Management
•Range capacity
•Season of use
•Weed potential
•Forage seed mix
Interpretive Applications of Soils and Ecosystem Maps
Biodiversity Management
•Landscape unit planning
•Biodiversity guidelines
•Old growth management
•Rare ecosystem ID
•Identified wildlife
•Non-timber forest products
Wildlife Management
•Critical wildlife habitat
•Wildlife suitability
•Forage potential
Policy
•Carbon accounting
•Climate change adaptation

Acknowledgements

- We would like to thank all of our partners for providing data including:
  - OMNRF
  - NFI
  - RYAM / Tembec
  - Hearst Forest Management
  - Petawawa Research Forest

Questions?

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International Decade of Soils 2015-2024