



Agriculture and
Agri-Food Canada

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Canada – USA Digital Soil Mapping Case Study

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Canada

Canada – USA Digital Soil Mapping Case Study

Outline

The Global Soil Map Project

- rationale, time frame, theory

Canada's Contribution to GSM

- rationale, time frame, constraints, proposed methods

Canada – USA Pilot Study

- location, objectives, initial results...

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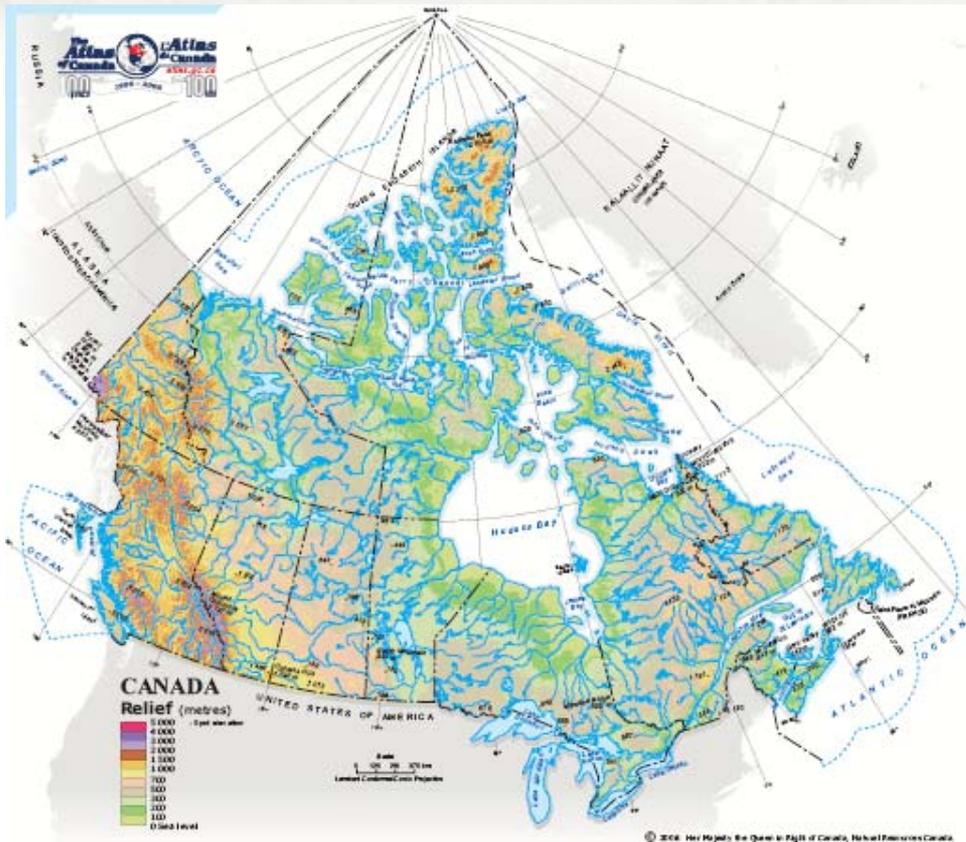
Digital Soil Map - North American Node

- Support the Global Consortium approach to producing raster soil property maps
- Digital Elevation Models primarily based on Shuttle Radar imagery (SRTM)
- Information to be built using “legacy” data (existing information)
- North America has a large inventory of soil survey data
 - Point data (useful for validation)
 - Detailed soil map coverages (where available)
 - Generalized soil map coverage
 - Polygon disaggregation information and techniques
 - Ancillary data (satellite imagery, surficial geology maps, etc.)

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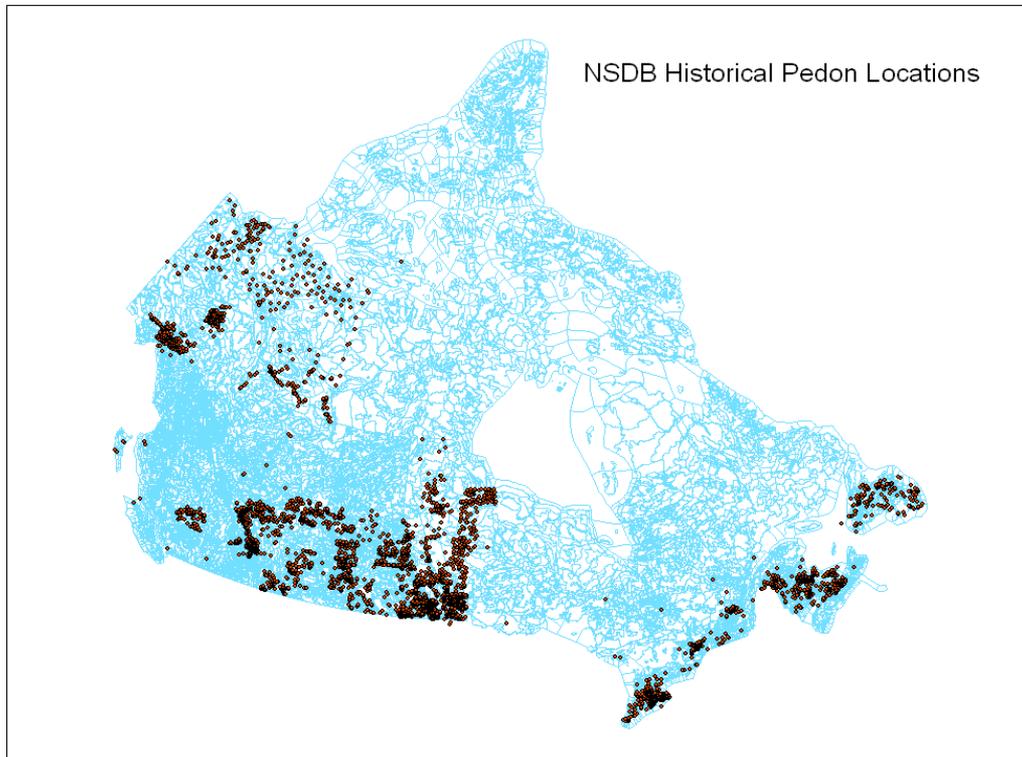
Canada's Land Area

- 9,093,507km² (~6% of the world land area; ~40% NA; NA ~16%).
- Approx. 40% of Canada is north of 60°N (the SRTM limit) – an alternative, compatible 90m raster DEM is needed for northern Canada.
- Approx. 1 billion 90m by 90m grid cells in the Canadian portion of the Global Soil Map



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Pedon Samples in the Canadian Soil Data Base



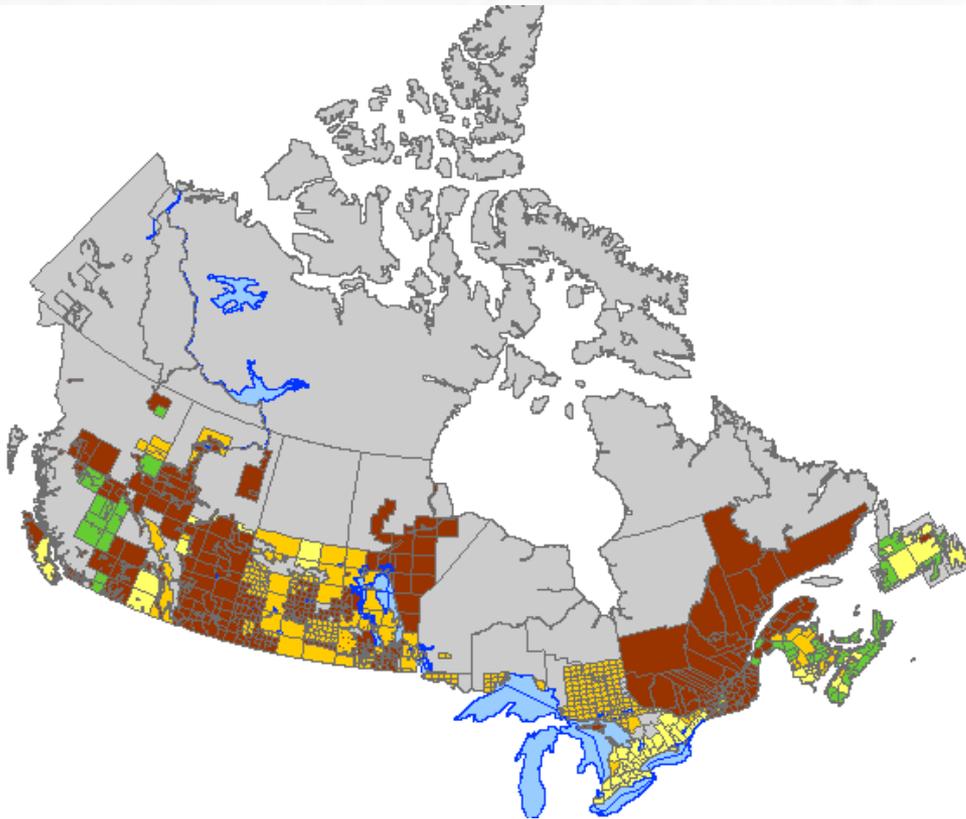
- Approx. 6500 pedons in the NSDB (1 pedon/1400 km²).
- Additional soil inspection data in provincial data bases.
- Pedons sampled during soil inventory projects (non random).
- North American Geochemical sampling will provide additional Pedon data on a geostatistically valid basis (1 site/1600 km²).
- **low density limits use for DSM applications.**

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Detailed Canadian Soil Maps

Approximately 20% of Canada (mainly in agricultural areas).

- Over 3,000 separate maps, at scales from 1:20,000 to 1:250,000, in different historical formats.
- long term national plan to compile them as consistent provincial GIS soil map coverages within the Canadian Soil Data Base.
- No standard landform model.



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Soil Landscapes of Canada (SLC) – Version 3



- Digital Maps at 1:1,000,000, with separate soil and base map layers.
- Modern relational data base format, with soil components linked to attribute models, supports many national modeling applications.
- SLC Version 3.2 will include a soil - land form model.
- **Coverage currently limited to agricultural areas of Canada**

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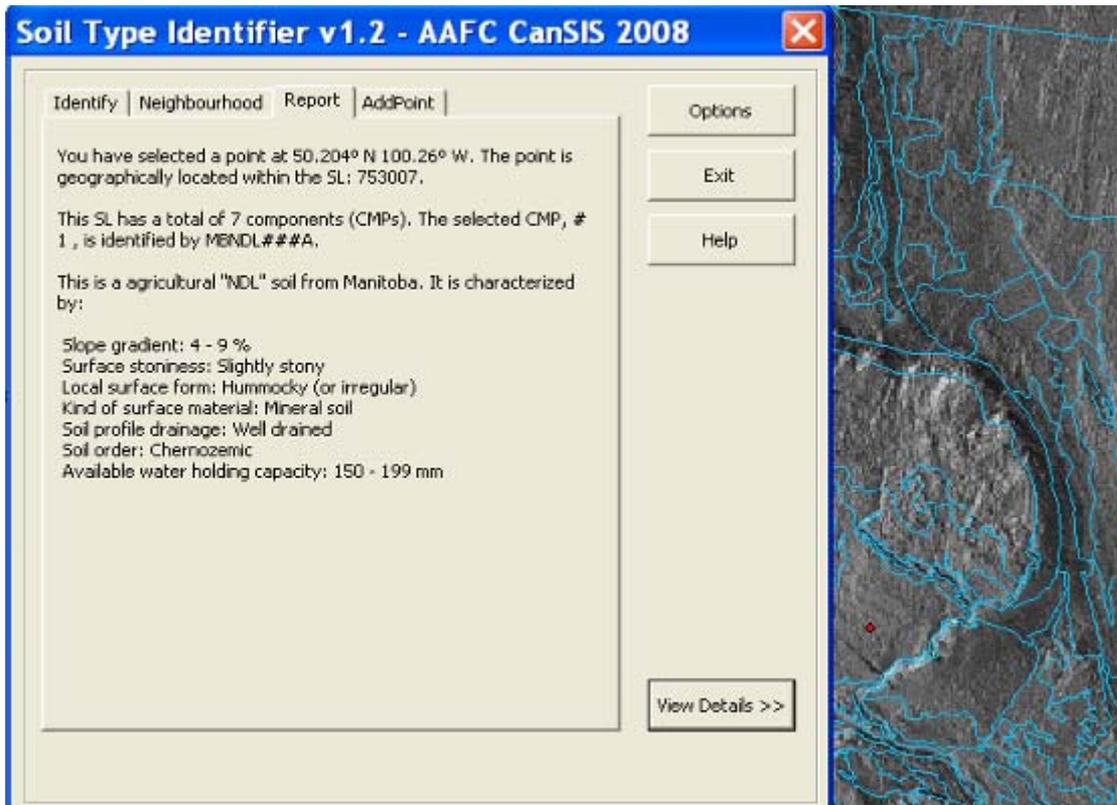


Older Soil Landscapes of Canada (SLC) maps, such as SLC version 2.2, provide national coverage, but

- no explicit soil - landform model.
- many soil components are not linked to modern soil name and soil layer file attribute models.
- many soil attributes are generalized (dominant and subdominant values for each polygon).

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Soil Survey Knowledge Data Mining Tool



- **ArcGIS Tool developed by AAFC to populate DSM raster cell data from “Legacy” soil polygon attribute files.**
- **Can be used with variable size raster cells, and variable soil layer depths.**
- **Will be tested on Canada – USA DSM Pilot Study area.**

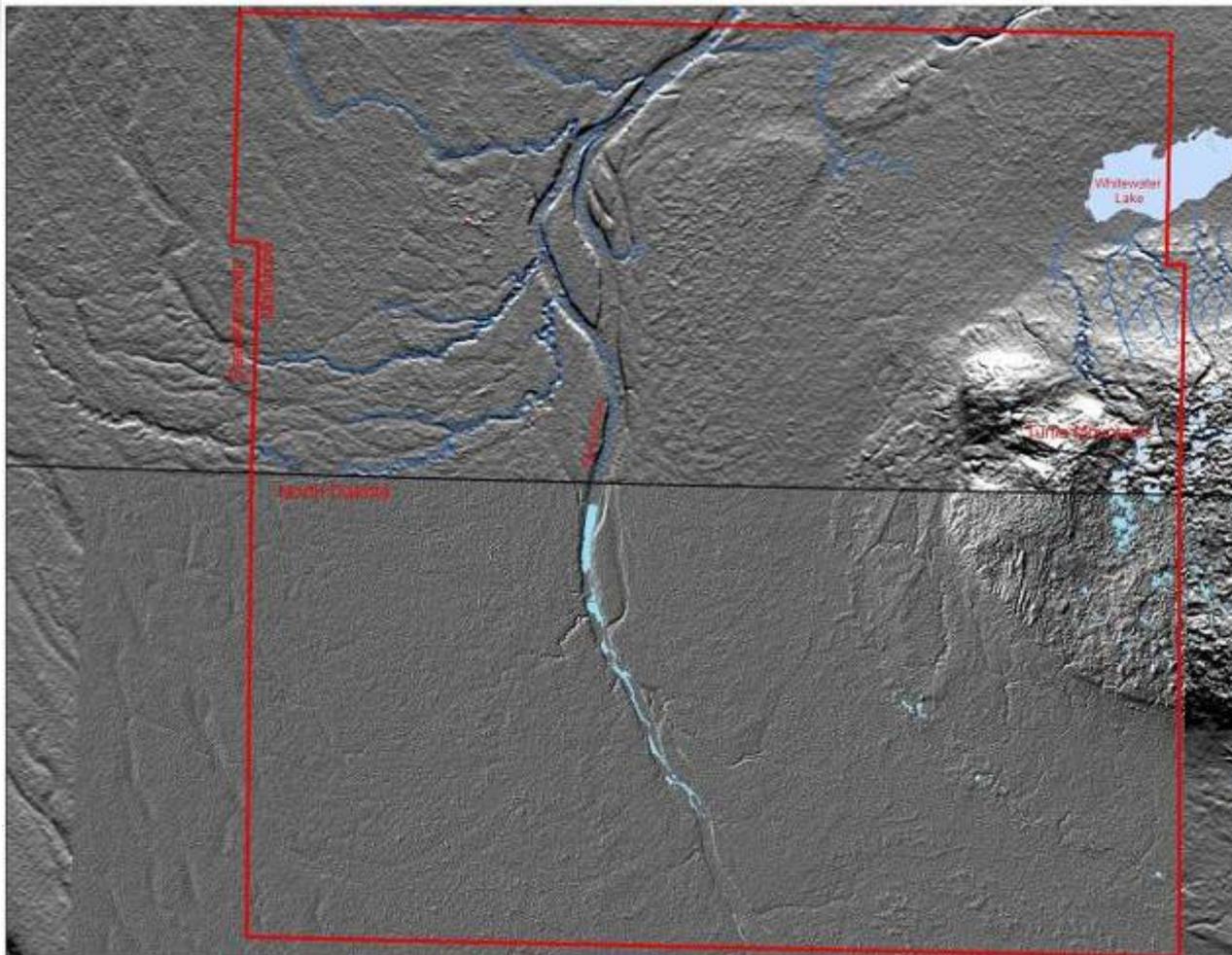
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Canada - USA Pilot Study Area Selection Criteria:

- Contiguous map area across Canada – USA border
- Primarily agricultural land, with a variety of landforms
- Must have pedon data, and detailed and generalized soil map coverages, in digital GIS format
- SRTM DEM data, as well as remote sensing imagery and other data sources
- Regional soil expertise available to advise and test DSM interpretive map products

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Northern Glaciated Plains Digital Soil Map Test Area



Canada - Aspen Parkland and Southwest Manitoba Uplands Ecoregions

USA - Northern Black Glaciated Plains Major Land Resource Area (MLRA 55A)

Area: approx. 6,225 km²
(622,400 hectares)

Proposed Study Area

 Study Area Boundary

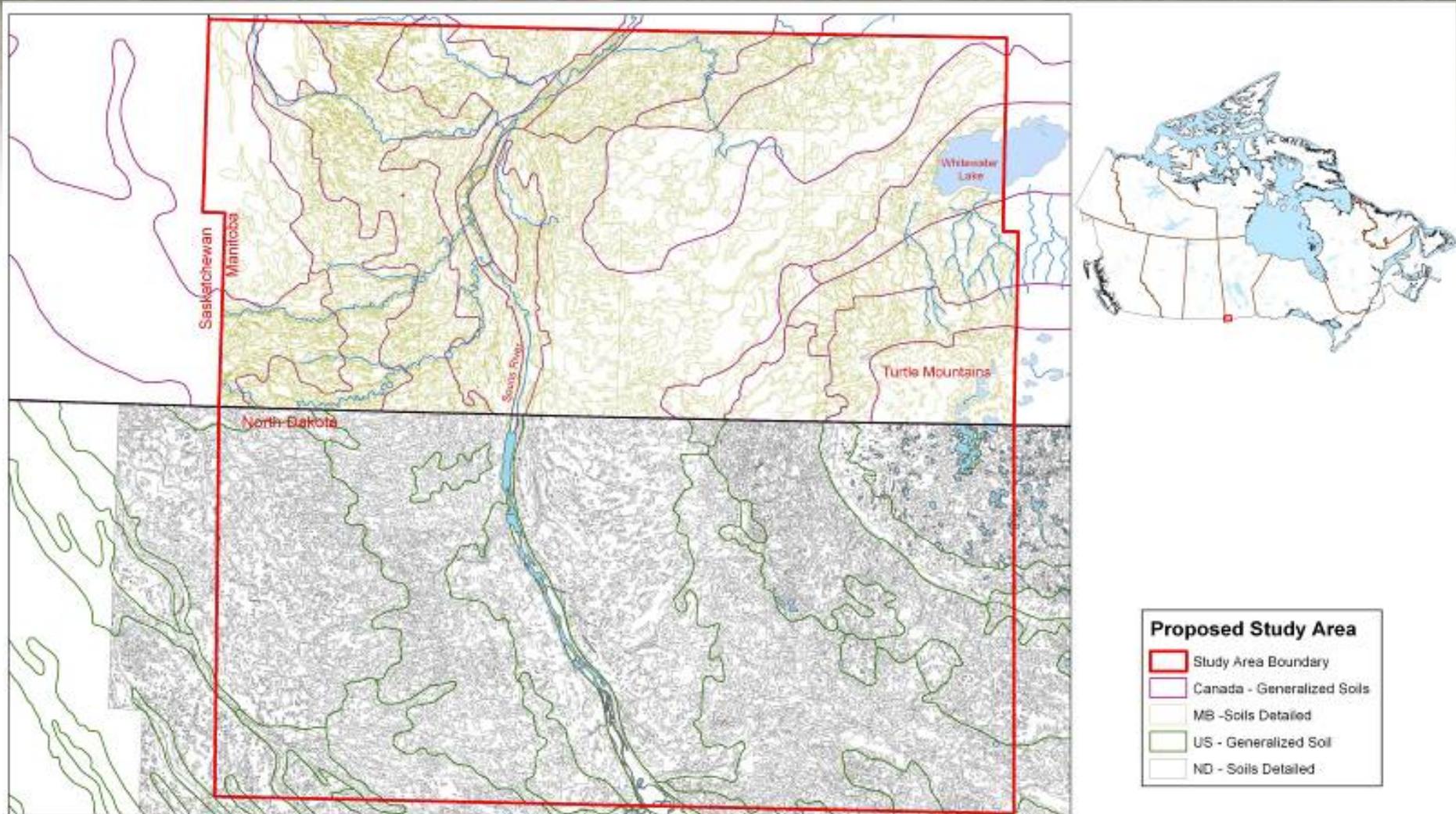
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Northern Glaciated Plains Case Study - Objectives:

- Use Global Consortium DSM methodology to produce raster based soil property maps using existing (“legacy”) US and Canadian **detailed** soil maps and high resolution spatial data.
- Map selected soil properties based on existing US and Canadian **generalized** soil maps, and compare to DSM soil property maps developed from detailed soil maps. Point data may also be useful for calibrations and validation purposes
- Map selected soil properties based on detailed mapping using spatial data at highest spatial resolution available (≤ 30 m), and compare to soil property maps based on spatial data of lower spatial resolution (≥ 90 m).
- Investigate various DSM techniques, ancillary data sources and data gaps, and develop the methodology and expertise to complete the Canadian and USA portions of the world DSM.

Northern Glaciated Plains Digital Soil Map Test Area

Canada and USA Generalized and detailed soil maps



Generalized coverages extracted from the Soil Landscapes of Canada SLCv3.1.1 at 1:1.000,00 scale and US STATSGO at 1:250,000 scale.

Detailed soil surveys of the Manitoba RMs of Edward, Arthur, Brenda and Winchester at 1:20,000 and 1:40,000 scale from the Manitoba Rural Municipality Soil Information Database (RMSID), and SSURGO at 1:12,000 and 1:24,000 scale extracted from the Soil Survey of Bottineau County (North Dakota).

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Northern Glaciated Plains - Proposed DSM Map Layers

Primary Soil Attributes (from US / Canadian soil data files)

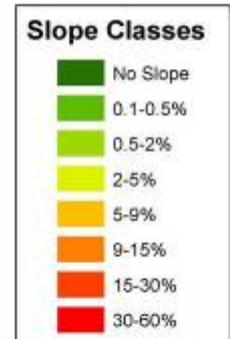
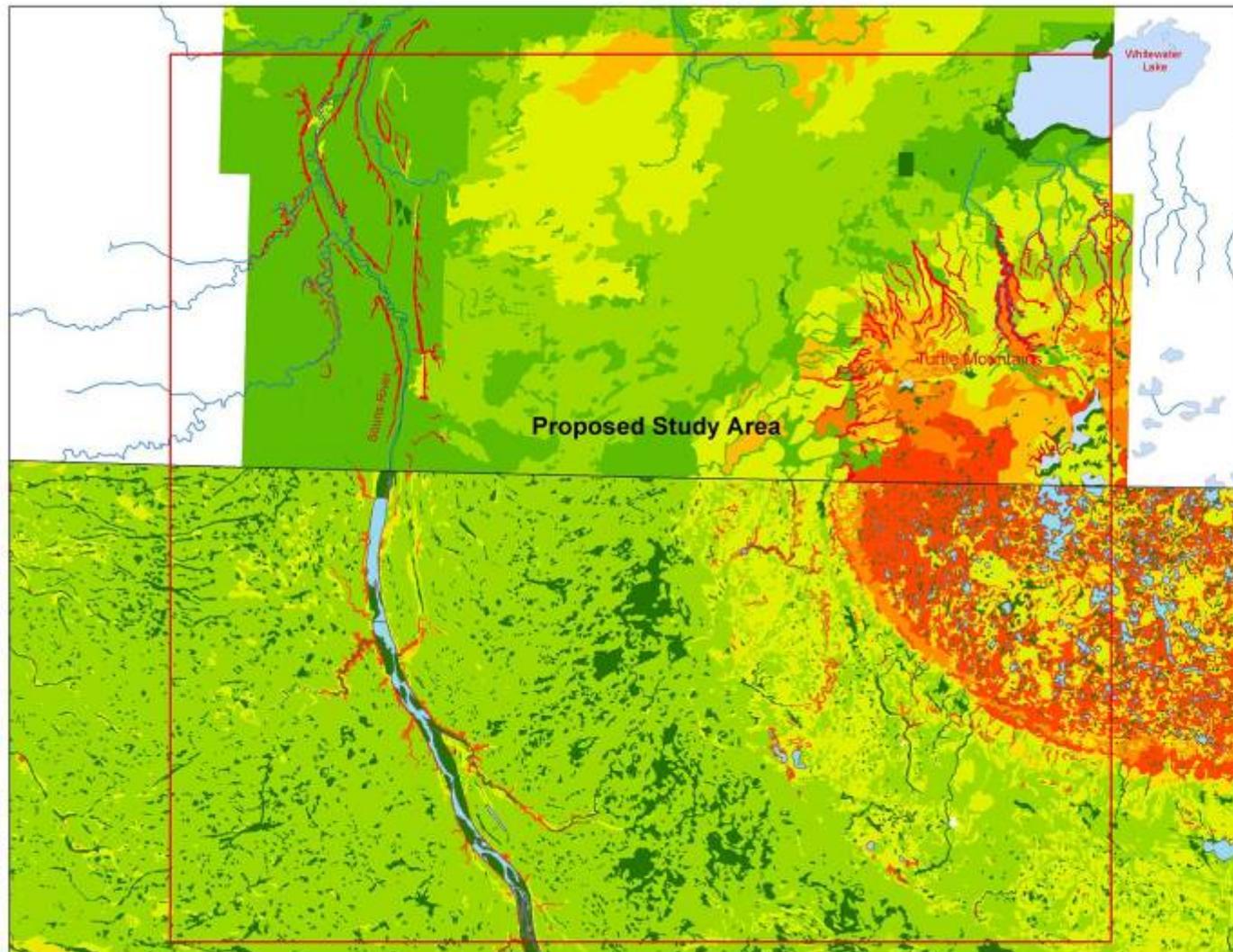
- Texture
- Depth (soil horizons, solum, restrictive layers)
- Soil Carbon
- Drainage class
- Coarse fragments
- Bulk density

Inferred Soil Attributes (from pedo-transfer functions)

- Plant available water capacity
- Nutrient supply capacity (CEC, exchangeable bases, available P)
- Infiltration / Permeability
- Salinity/ risk of salinization

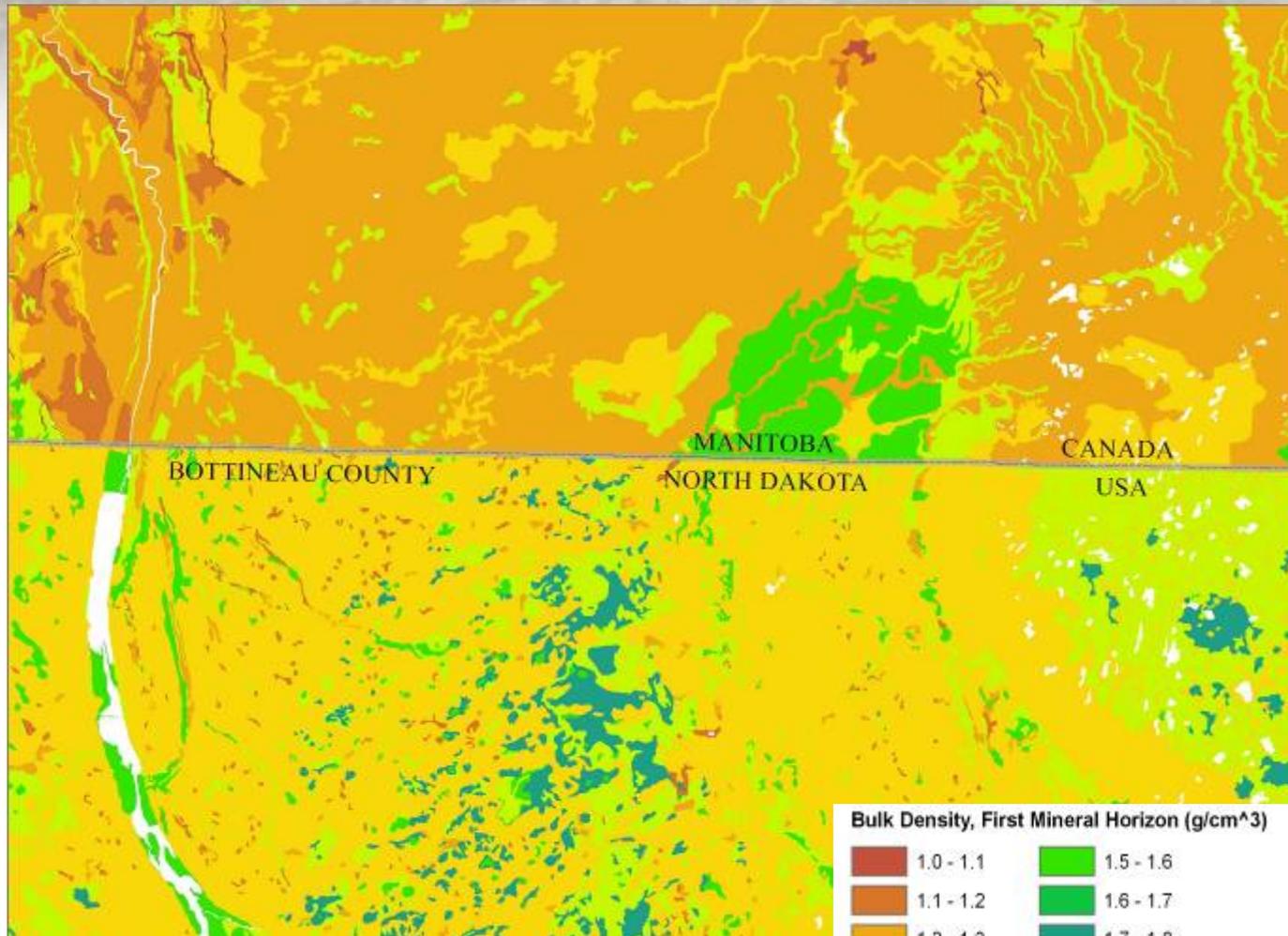
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Soil Map Slope Manitoba (1:20,000 / 1:40,000) and North Dakota (1:12,000)



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Soil bulk density derived from detailed soil map data



Bulk Density:
First mineral horizon, weighted by map unit composition

Source:
1:12,000-1:40,000 scale digital soil map data

Resolution:
10 meters

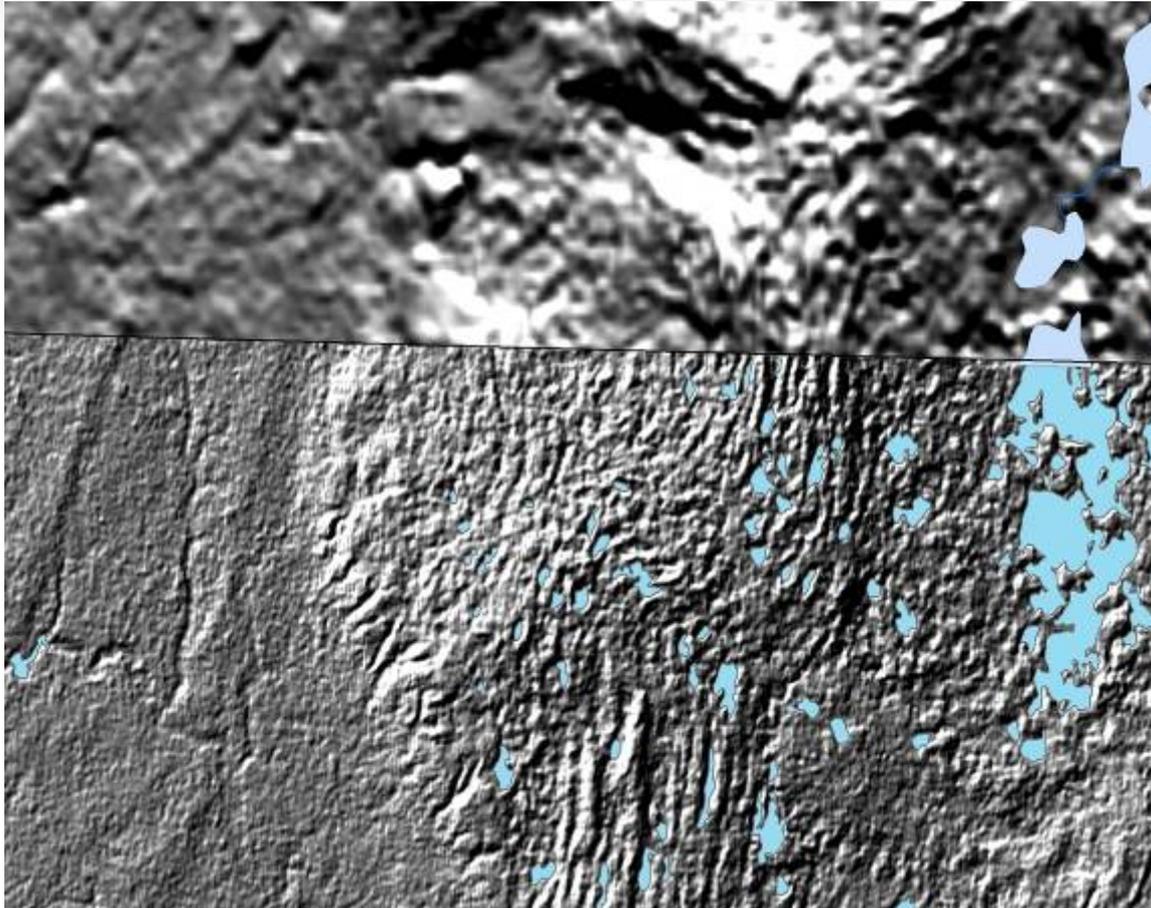
0 4.5 9 18 Km





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Northern Glaciated Plains Study Area – Enhancements to the 90m SRTM coverage

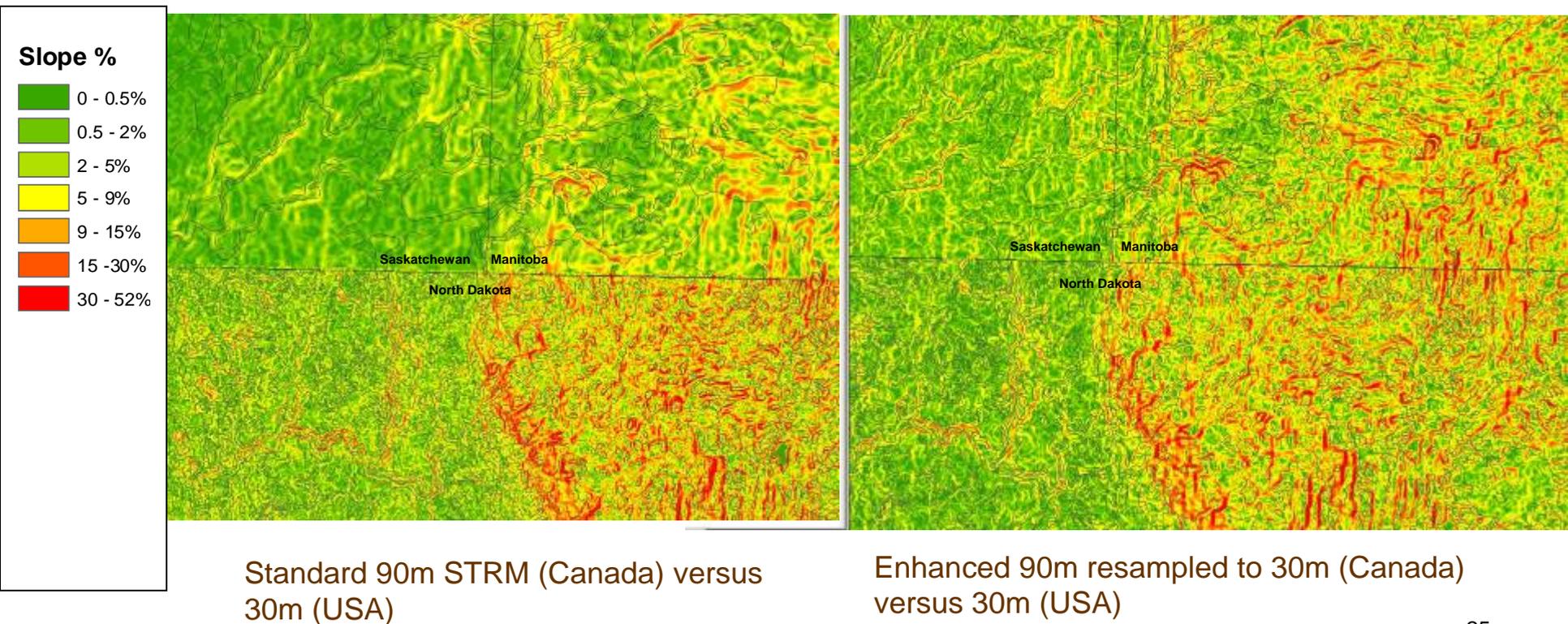


SRTM data is available for the USA at 30m resolution, but limited to 90m for the rest of the world. 30m data has 9 times the number of digital elevation values.

Canadian researchers are investigating methods of enhancing the 90m raster product for predictive Digital Soil Mapping applications

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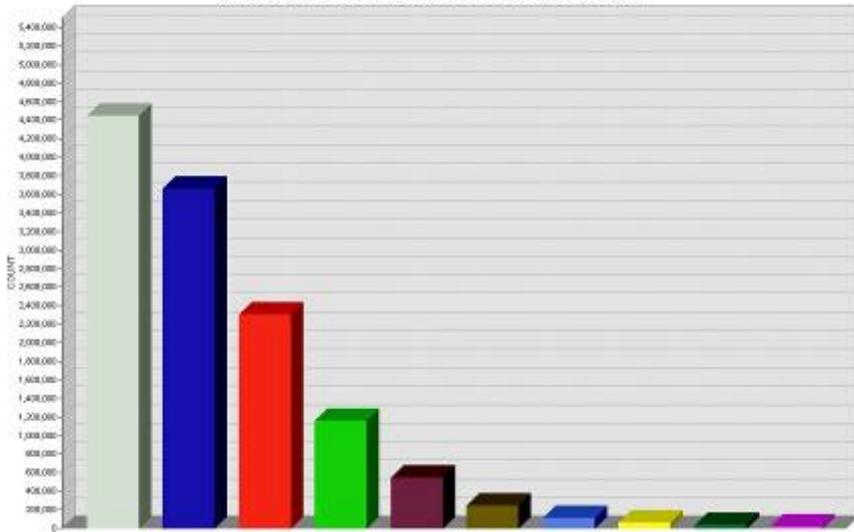
Several methods are being investigated to “up sample” the standard 90m global SRTM data to produce higher resolution 30m DEM products for Canada. A slope map of the Canada-USA study area derived from the standard 90m SRTM (Canada) versus 30m (USA) is shown on the left. The same area, with the Canadian portion resampled by cubic convolution to 30m, is shown on the right. Cubic convolution is a raster based interpolation algorithm that calculates the weighted average of 16 of the nearest input cell centres.



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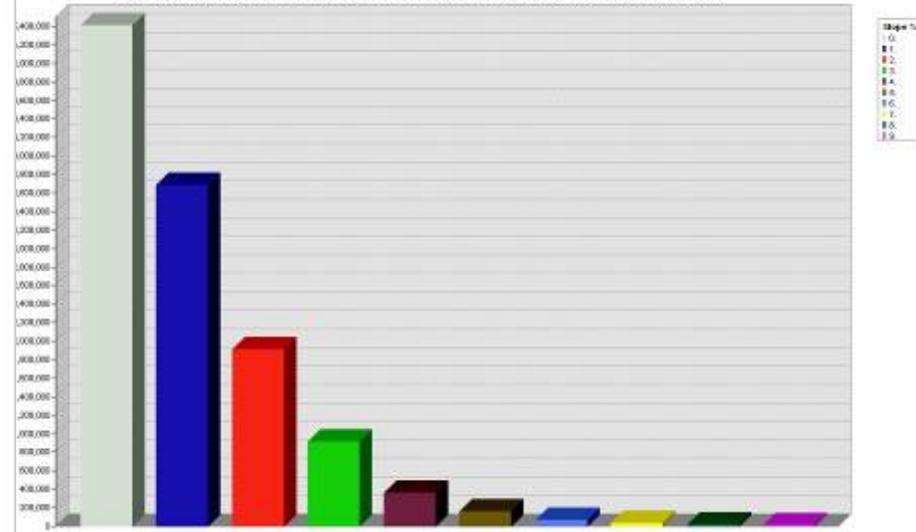
Statistical comparisons can also be used to evaluate DEM attributes derived from standard 90m global SRTM data versus results from “up sampling” methods. The histograms below show the range in slope values based on a 30m pixel to pixel comparison between the SRTM 30m and SRTM 90m (graph on the left) and the SRTM 30m and SRTM 90m resampled to 30m (graph on the right). As illustrated, there is a significant improvement in the resampled SRTM 90m data since the differences in slope values primarily occur in the 0-1% slope class, while the same values in the SRTM 90m occur in the steeper classes.

Range of Slope Values by Pixel Count of SRTM 90 Metre vs SRTM 30 Metre



Standard 90m STRM (Canada) versus 30m (USA)

Range of Slope Values by Pixel Count of SRTM 90 Metre Resampled by Cubic Convolution vs SRTM 30 Metre



Enhanced 90m resampled to 30m (Canada) versus 30m (USA)

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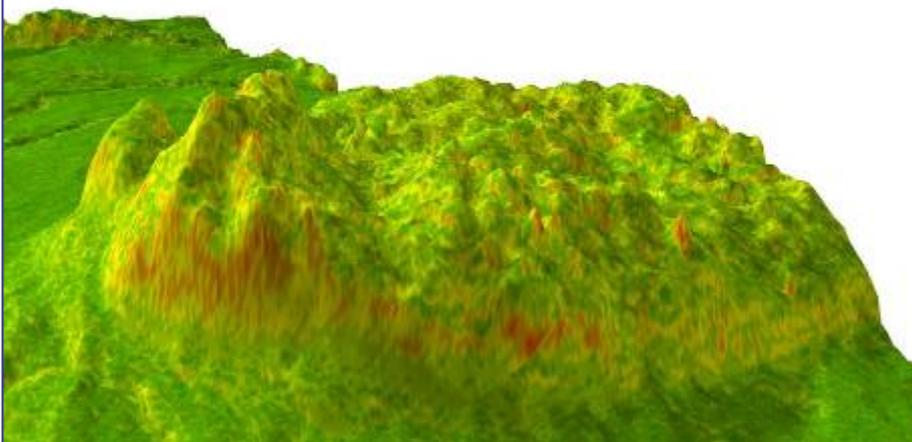
Three dimensional views can also be generated to compare digital elevation model results. These examples both show the Turtle Mountain Upland portion of the Canada - USA study area with slope classes for each pixel draped over the DEM.

The 30m derived slope map (right) has significantly more pixels with <5% slope, and provides a better representation of the slopes in the study area.

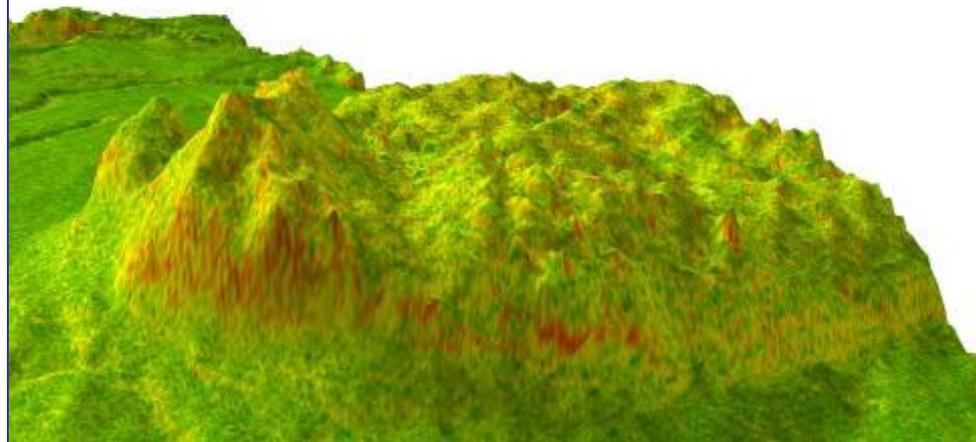
Slope %



SRTM 90m Slope map draped over the DEM



SRTM 90m (Resampled to 30m) Slope map draped over the DEM



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Conclusions

- The AAFC Soil Resource Group is cooperating with the US National Geospatial Development Center to complete the Canadian and US portions of the Digital Soil Map (DSM) of the world.
- Further research is needed to identify the most appropriate DSM methods to use in particular soil landscapes, and to understand the effects of DEM resolution, soil map scale and additional data sources.
- A hierarchy of existing Canadian soil map information will be used, from detailed soil map coverages (where available) to newer (SLCv3.x) and older (SLCv2.2) Soil Landscapes of Canada maps in the remaining areas.
- The raster based DSM will essentially become a new “product line” of soil map information, with first release planned for 2014 (“Version 1”).
- Building new interpretive products also identifies gaps and correlation issues in our existing soil map information. These must also be addressed so that we can provide higher quality conventional and DSM products.

Digital map of soil organic carbon (g m⁻²) derived from legacy data

SSURGO:

$$\text{SOC}_{0-20} = \text{Organic Matter (g/100 g soil)} * 0.58^{\dagger} * 0.01^{\ddagger} * 1/3 \text{ bar Bulk Density (g cm}^{-3}\text{)} * 1,000,000^{\S} * \text{Horizon Thickness (m)} * \text{Rock Fragment Conversion Factor}^{\ell}$$

DSS:

$$\text{SOC}_{0-20} = \text{Organic Carbon (g/100 g soil)} * 0.01^{\ddagger} * \text{Bulk Density (g cm}^{-3}\text{)} * 1,000,000^{\S} * \text{Horizon Thickness (m)} * (1 - [\text{Vol}_{\text{coarse fragments}}/100])$$

[†] Conversion factor between organic matter and organic carbon

[‡] Conversion factor from g SOC/100 g soil to g SOC/g soil

[§] Conversion factor from g SOC cm⁻³ soil to g SOC m⁻³

^ℓ RFCF is used to adjust for the volume of rocks in a soil sample.

$$\text{RFCF} = (\text{Mass} < 2\text{mm fraction} * 1/3 \text{ bar } Pb) / [(\text{Mass} < 2\text{mm fraction} * 1/3 \text{ bar } Pb) + (1 - \text{Mass} < 2\text{mm fraction})/2.65 \text{ g cm}^{-3}]$$

Bliss, N.B., S.W. Waltman, and G.W. Peterson. 1995. Preparing a soil carbon inventory of the United States using geographic information systems.p. 275-295. In R. Lal, J. Kimble, E. Levine, and B.A. Stewart (Eds) Soils and Global Change. CRC Press, Boca Raton, Florida, USA.

Issues

- SRTM data availability and alternatives
- DSM methods less reliant on terrain model derivatives
- Data harmonization
 - Cartographic and taxonomic
- Mapping inconsistencies
 - Within country and between countries
- Soil properties with depth
 - Taxonomic horizons vs. layers
- Consistency of node DSM methodologies
- Future trans-national collaborations of NA GSM node:
 - Mexico, Central America, Caribbean
- Consortium-wide DSM training and mapping activities