GlobalSoilMap.net: Canada-United States digital soil mapping case

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Abstract
A consortium of pedologists has formulated a global soil mapping initiative. The GlobalSoilMap.net project currently consists of seven continental nodes that support the goal of mapping selected soil properties over 80% of the Earth's land surface. The North American Node, lead by the Natural Resources Conservation Service in Morgantown, WV has initiated a collaborative study to test the feasibility of this effort. Agri-Food and Agriculture Canada (AAFC), the Natural Resources Conservation Service (NRCS) and several universities have begun the study with specific objectives to map selected soil properties based on *detailed* (1:12,000-1:40,000) and *generalized* (1:250,000-1:1,000,000) soil survey information using digital soil mapping methods and environmental covariate data, and to compare soil property maps developed from detailed and generalized soil mapping. We also seek to advance international exchange and quality assessment of soil data and information that will improve management of agricultural and natural resources, especially those that transcend national boundaries. The study area is located in north-central North Dakota and southwestern Manitoba where glaciated landscapes support rain-fed small grains agriculture, oilseed and forage crops, and grazing lands. Major environmental concerns are water quality and quantity, accelerated soil erosion, soil salinization, aggregate stability, and organic matter and soil productivity maintenance. To date, the team of soil scientists have assembled spatial data, developed a work plan and have implemented appropriate DSM methods and begun to evaluate mapping outcomes for addressing local and transnational resource management needs.

Key Words
GlobalSoilMap.net. digital soil mapping, soil survey information.

Introduction
We have adopted a case studies approach to digital soil mapping for land areas of mutual interest to collaborating organizations. Mapping will be conducted at spatial resolutions less than 100 m cell size (<= 1 hectare) and for a set of soil properties being considered by the global soil mapping community and relevant to our intra-continental, trans-national collaborators and users. Soil properties are being estimated and mapped from existing soil geographic databases or from model predictions based on judicious use of environmental covariates and pedo-transfer functions.
The objectives for this case study are:
1. Map selected soil properties based on *detailed* soil mapping in Canada and USA using digital soil mapping methods and spatial data of high spatial resolution.
2. Map selected soil properties based on *generalized* soil mapping in Canada and USA, and compare to soil property maps developed from spatial data of high spatial resolution.
3. 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 (>= 90m).

Methods
Study area
The spatial extent of our case study area occupies a rectangular land area of approximately 6,224 km^2, or 622,400 hectares (~1,538,000 acres). The extent encompasses parts of the Northern Black Glaciated Plains Major Land Resource Area (MLRA 55A) and Aspen Parkland and Southwest Manitoba Uplands Ecoregions

1 – 6 August 2010, Brisbane, Australia. Published on DVD.

in the Prairies Ecozone of Canada. The area includes portions of north central North Dakota and southwestern Manitoba bisecting the Turtle Mountains to the east and major portions of the trans-national Souris River watershed to the west (Figure 1). Landscapes in the case study area are described generally as level to undulating and hummocky glacial till plains, glacio-lacustrine deposits, sandy eolian materials, kettle holes, kames, moraines, and glacial lake plains. Soils are dominated by Mollisols with frigid soil temperature regimes and udic or aquic soil moisture regimes (Soil Classification Working Group 1998; Soil Survey Staff 2006) and by Chernozems and Gleysols (Canadian System of Soil Classification, 3rd edition)

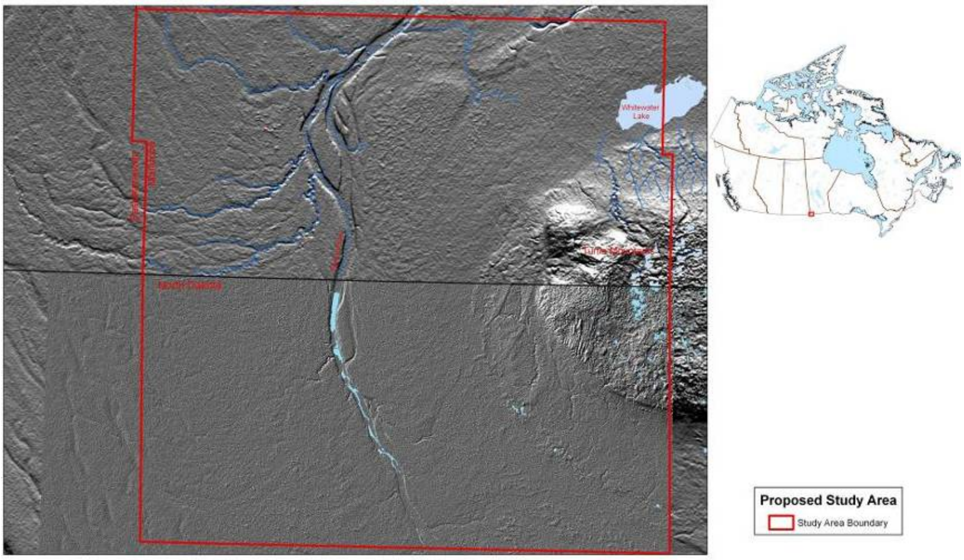

Figure 1. Study area location in southwestern Manitoba and north-central North Dakota within the northern glaciated plains region of North America (courtesy Soil Resources Group, AAFC).

Digital and field data

Data for Canada include Canadian detailed soil survey data at 1:20,000 – 1:40,000 scale in addition to generalized soil survey data at 1:1,000,000 scale (Soil Landscapes of Canada, SLC), numerous pedon observations (n ~ 500), and other geo-referenced soil inspection points are available in southern Manitoba. Data for the United States include detailed soil survey data at 1:12,000 - 1:24,000 scale (SSURGO) in addition to generalized soil survey data at 1:250,000 scale (US GSM, or STATSGO2), pedon descriptions and laboratory data, and field transects. Numbers and locations of pedon descriptions and field transects in the study area are being compiled. Shuttle Radar Topographic Mission (SRTM) digital elevation models (DEM) at 90 m spatial resolution are the only elevation data available for the entire proposed study area. DEM data at finer spatial resolution (<= 30 m) are available in North Dakota. In addition, SRTM data are not available for land areas more northerly than 60^{o} N latitude. This excludes all of northern Canada and nearly all of the State of Alaska in the North American continent.

Estimating and mapping soil properties

We propose and prioritize the following minimum set of soil properties which follows the GlobalSoilMap.net consortium specifications (McMillan *et al.* 2009) for estimated properties for the case study area using digital soil mapping methods:

1. Organic Carbon (g/kg)
2. Clay (%)
3. Bulk Density (kg/m^3)

From these attributes, the following two properties can also be predicted using pedo-transfer functions:

4. Carbon Density (computed from Carbon % and Bulk Density; given in kg/m^3)
5. Available Water Capacity (given in mm/m)

The project has also identified the following “secondary” variables that are considered to be desirable and feasible to predict but which are still considered optional for delivery by nodes.

6. pH (specify method, H_20, $CaCl_2$, KCl)
7. CEC (Cations plus exchangeable acidity cmols/kg)
8. EC (Electrical conductivity dS/m)

For each soil property, we will determine values both horizontally across the landscape as well as vertically through the soil profile to a soil depth of at least one meter, or soil depth to restrictive layer, by taxonomic horizon. In some cases, vertical variation can be integrated with horizontal variation for some soil functions (e.g., Root Zone Available Water Holding Capacity). In other cases, modeling soil property variation at multiple depth increments, or layers, may be more appropriate (e.g., particle size distribution, pH). Digital soil mapping will be based upon detailed soil surveys in Canada and detailed soil surveys (SSURGO) in the USA for Objectives 1 and 3. Soil Landscapes of Canada (at 1:1,000,000 scale) and STATSGO2 (at 1:250,000 scale) soil geographic databases will be used for DSM applications under Objective 2.

Inference models
In general, the DSM methodology for the case study within the North American continental node will be related explicitly to, and incorporate to the degree possible, legacy soil survey data within each survey area including their description, location and extent, quality and relevance to soil properties being mapped. Other modeling approaches for this particular case study will follow standards as documented and recently applied by others in the digital soil mapping consortium and community (e.g., Bui *et al.* 1996). We will also build upon and complement methodologies implemented by the North American Soil Characteristics Database for Hydrological and Meteorological Modeling (NOAM-Soil) project building on the work of Miller and White (1998) and Padbury *et al.* (2002).

Results
The following are expected results from this project:

- Literature review of selected soil properties and appropriate DSM methods to meet land management needs in case study region.
- Development of a collaborative, intra-continental, trans-national approach to digital soil mapping over a range of spatial scales.
- An approach for predicting and mapping relevant soil properties for the region using advanced digital soil mapping (DSM) methodologies..
- Trans-national geo-spatial database development, application, and assessment for mapping selected soil properties using soil, climate, land cover, and terrain variables.
- Development of predictive soil property maps, prioritized by user application need.
- Recommendations on future trans-national collaboration for North America GSM node.

Collaborators note that both coarse (90 m) and fine (30 m) spatial resolution DEM are unlikely to adequately resolve subtle soil landscape patterns and processes in our study area (see figure 2). To meet the 90 m resolution digital soil property map standard as proposed by the GlobalSoilMap.net consortium, we plan to employ DSM methods that are less reliant on terrain model derivatives for similar landscapes throughout the North American continent. In the final analysis for this case study, however, soil property maps will be produced at 90 m resolution, which will result in very fine scale soil variation mapped at finer spatial resolutions being aggregated, or integrated, over the range of the coarser resolution data.

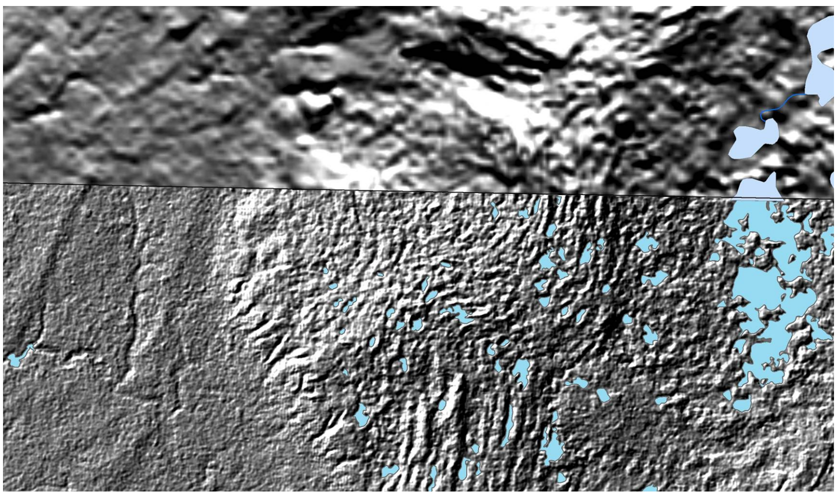

Figure 2. Comparison of SRTM-derived hillshade maps for Manitoba at 90 m resolution (top) and for North Dakota at 30 m resolution (bottom) for a portion of the northern glaciated plains study area (courtesy Soil Resource Group, AAFC).

Conclusion

The outcomes anticipated from this case study will include a set of mapped soil properties of continental rather than regional importance and those that relate to the soil properties (and soil functions) defined by the global soil map consortium (i.e., carbon density, infiltration, permeability, drainage, nutrient supplying capacity, and plant available water capacity). In addition, we need to focus on land degradation and land management needs relevant to our case study area and operational work plans and policies of associated collaborating institutions

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