Enhancing Digital Elevation Models (DEMs) for Improved Soils Mapping

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PROBLEM

Although essential to terrestrial life, soils, particularly changes in soil properties, are not recognized in existing soil delineations for New Brunswick (N.B.), Canada. Instead, delineations occur as tessellated polygons depicting soil associations: individual soil types aggregated by similarities in climate, regolith, and morphology[1]. Therefore, changes in soil attributes are not recognized as topography varies. The only feasible solution is to digitally map changes in soil attributes utilizing topography since field surveys are too costly[4].

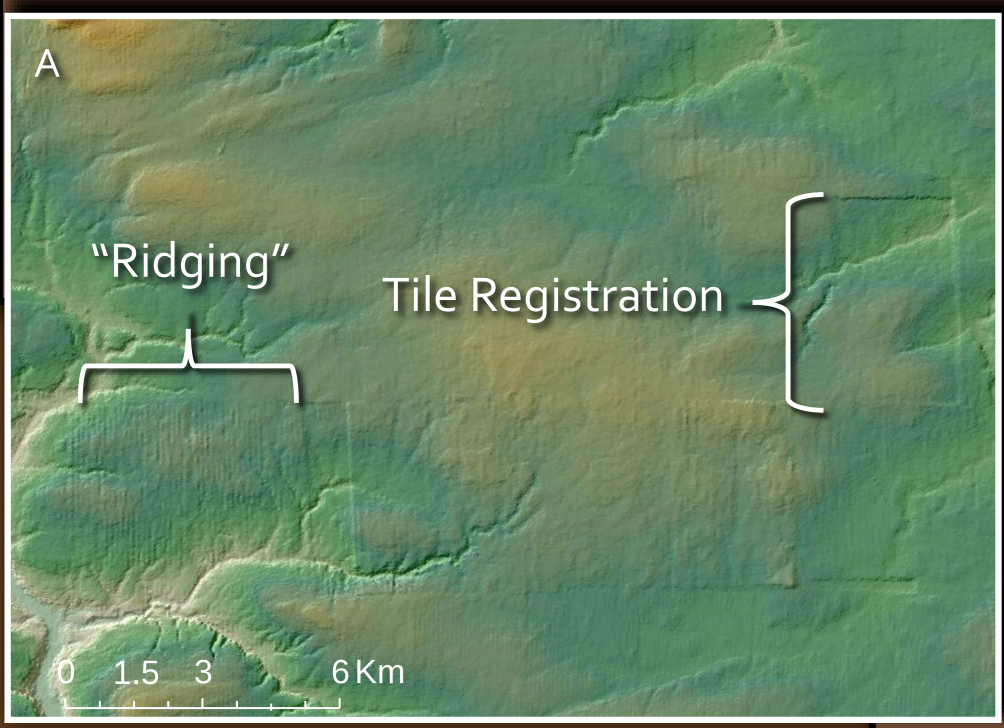


Figure 1. Representation of the two dominant sources or error, ridging and tile registration, found throughout the existing N.B. Provincial DEM.

Topography is typically mapped through Digital Elevation Models (DEMs) (Fig.2)[2], but, at 10m resolution, the N.B. DEM contains two major artifacts: "ridging" (straight lines)[9] and faulty tile registrations (rectangular depressions)[8] (Fig.1) which interfere with proper topographic and hydrographic delineations. These errors significantly limit the DEM's ability to analyze and map soil attributes.

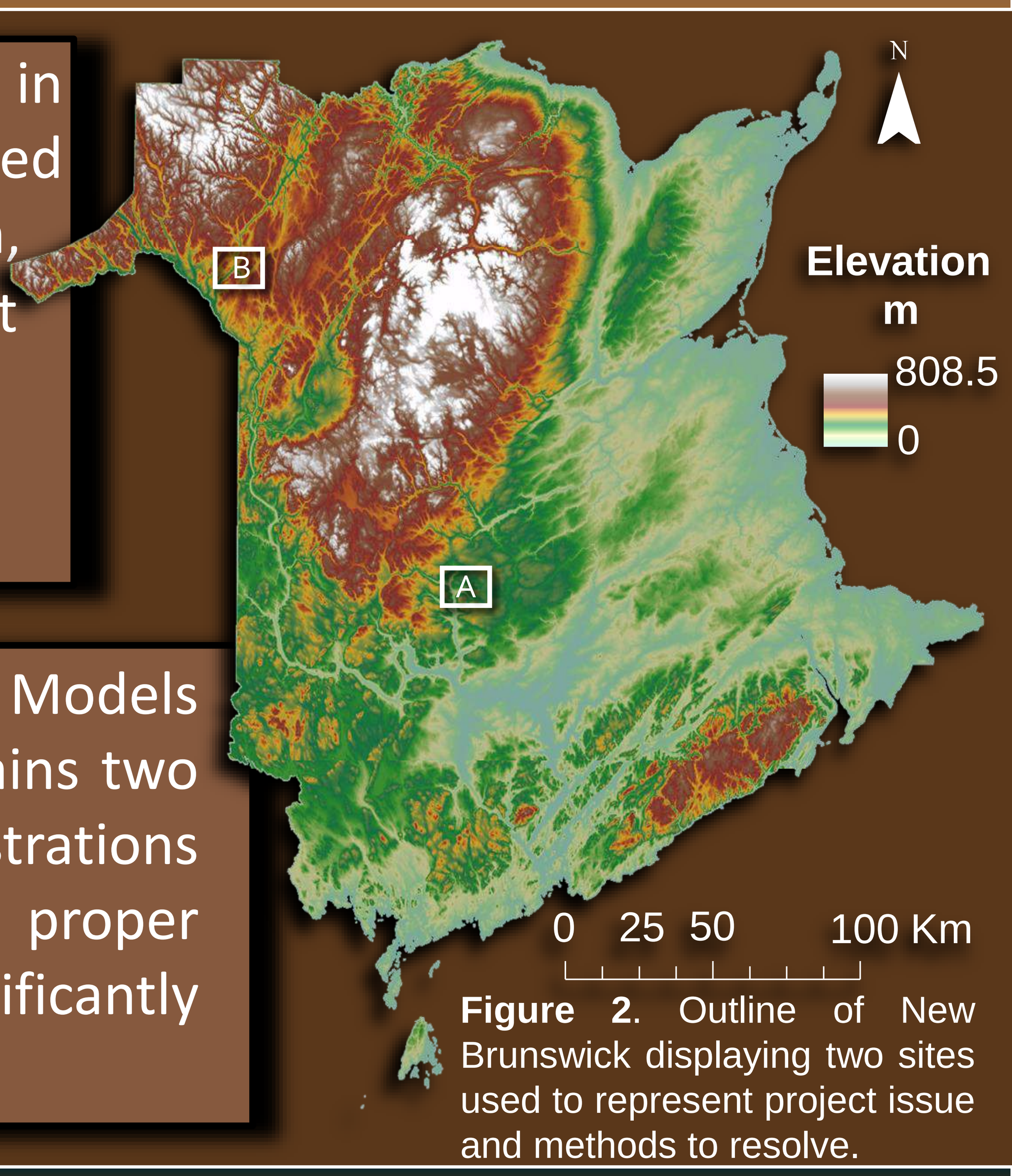


Figure 2. Outline of New Brunswick displaying two sites used to represent project issue and methods to resolve.

METHODOLOGY AND SOLUTION

The original N.B. DEM was re-examined in view of additional DEM coverages: **S**huttle **R**adar **T**opography **M**ission (SRTM) (90m), SRTM (30m), and **C**anadian **D**igital **E**levation **D**ata (CDED) (30m)[3, 5, 10]. Due to varying resolutions, projections, and derivation techniques, each DEM was recreated through projection, interpolation and sampling density algorithms (Fig.3):

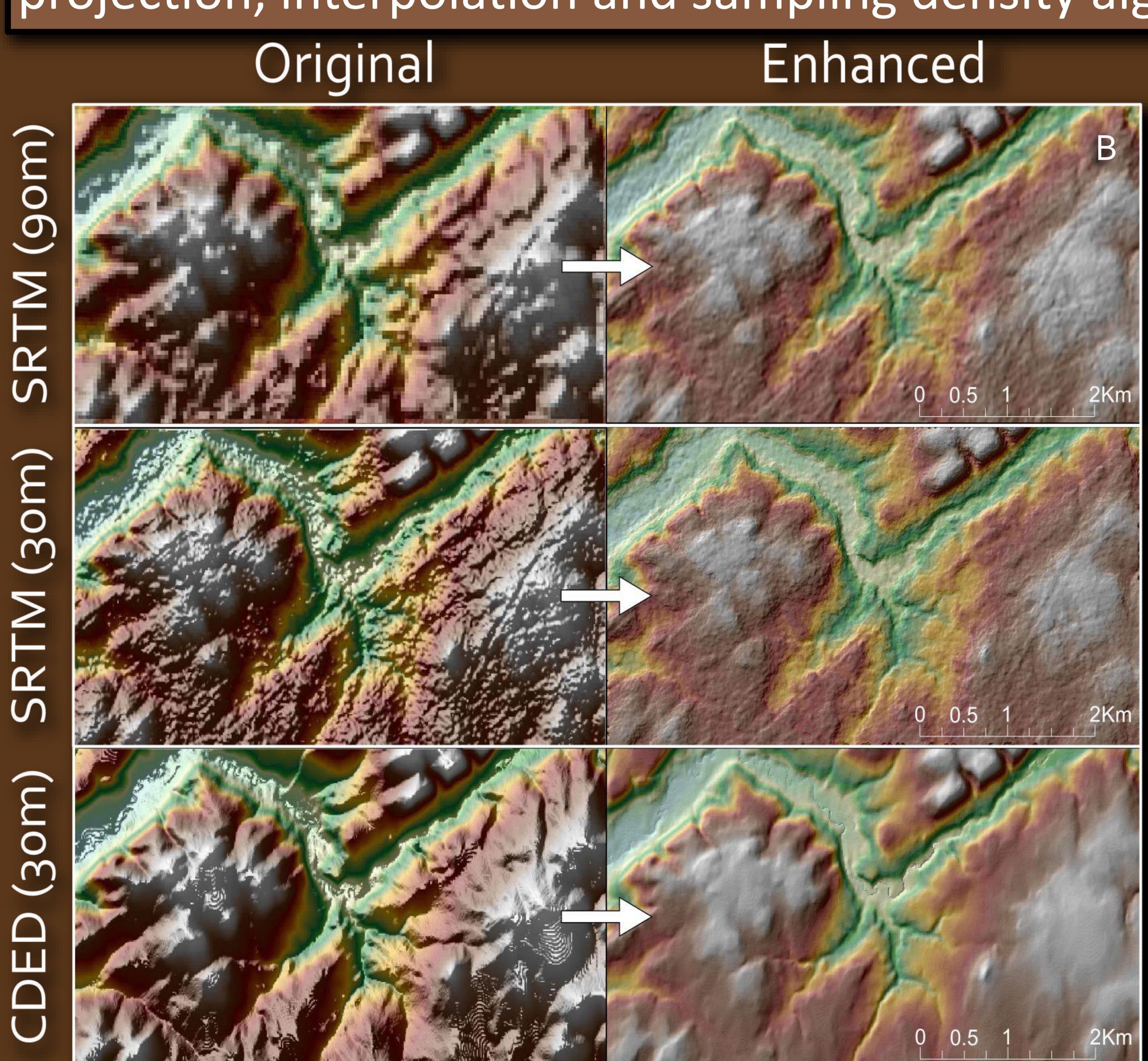
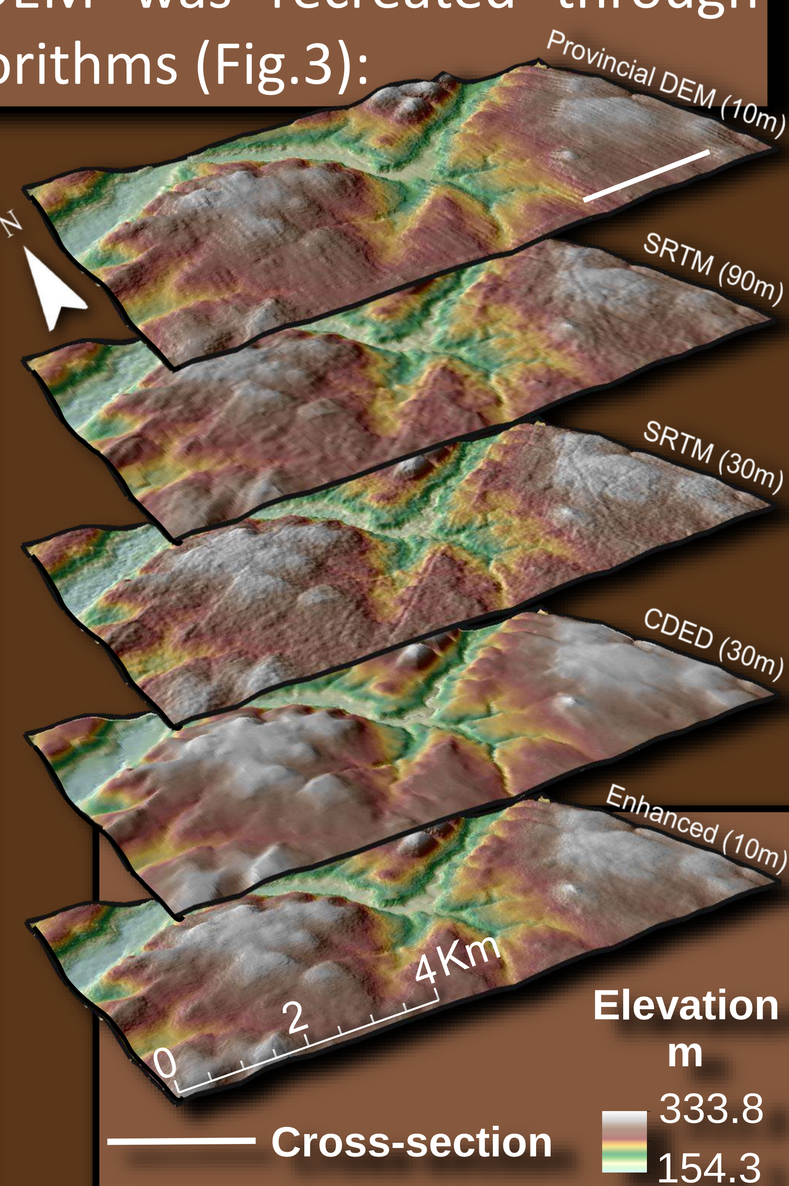


Figure 3. Visual representation of the results of the projection, interpolation and sampling density algorithms for three of the open sourced DEMs applied to the regression analyses (**top**) and visual comparison of the open sourced DEMs to the enhanced DEM derived from the regression analyses (**right**).



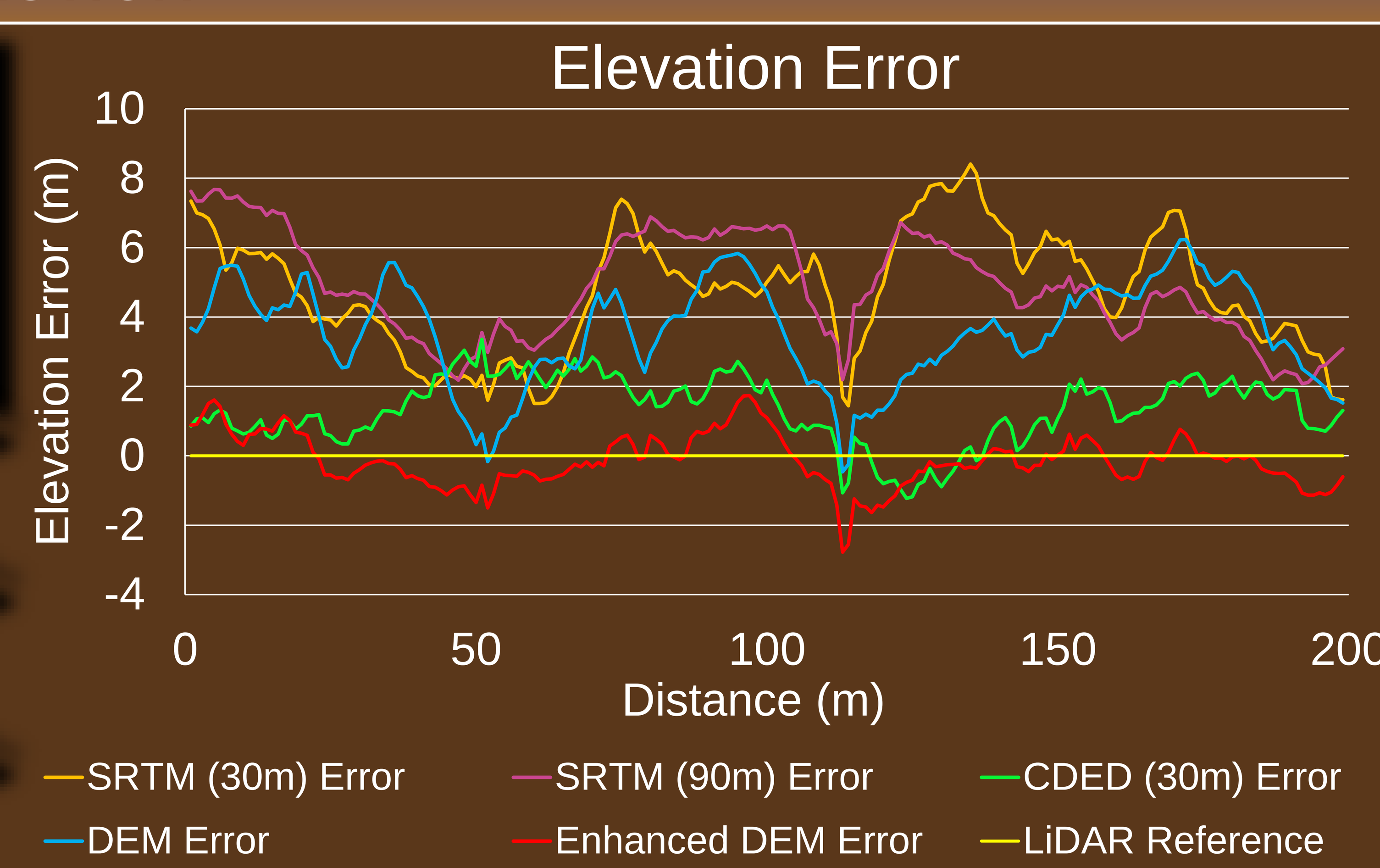


Figure 4. Cross-sectional representation of elevation errors (in meters) associated with all input and product DEMs for a location within study site B using LiDAR elevation as reference. Note the reduction in elevation error associated with the product DEM.

Multiple regression analyses were conducted on local LiDAR data sets with the aforementioned DEMs to derive an enhanced DEM for N.B.. Conformance of both original and product DEMs to LiDAR-derived elevation data sets (15cm vertical accuracy) is as follows (Table 1):

Table 1. Conformance of both original N.B. DEM and Enhanced DEM from regression analyses compared to LiDAR-derived DEMs (32 LiDAR data sets throughout N.B.) Note the 6.6m reduction in residual error.

DEM	% ± 1m	% ± 2m	Residual Error (m)
N.B. DEM	28	42	8.9
Enhanced	50	74	2.3

CONCLUSIONS AND FUTURE WORK

Delineating soils based on soil associations increases error due to the lack of accuracy within delineations (Fig.5 – comparison of soil association delineations and actual changes in soil attributes). These delineations are too crude for site-specific resource management, whether conservation strategies or policy applications, and must be improved.

To resolve: the aspatial data from existing N.B. soil surveys were extrapolated to a database resulting in both chemical and physical soil attributes for 110 soil associations and 1,100 soil horizons. Next, horizon-specific pedometric algorithms[6] will be derived, depicting attribute relationships. Through application of digital soil mapping techniques[7], the enhanced DEM, climatic data, and the derived pedotransfer functions, continuum maps of soil attributes can be derived at fine resolution and interpolated across the landscape.

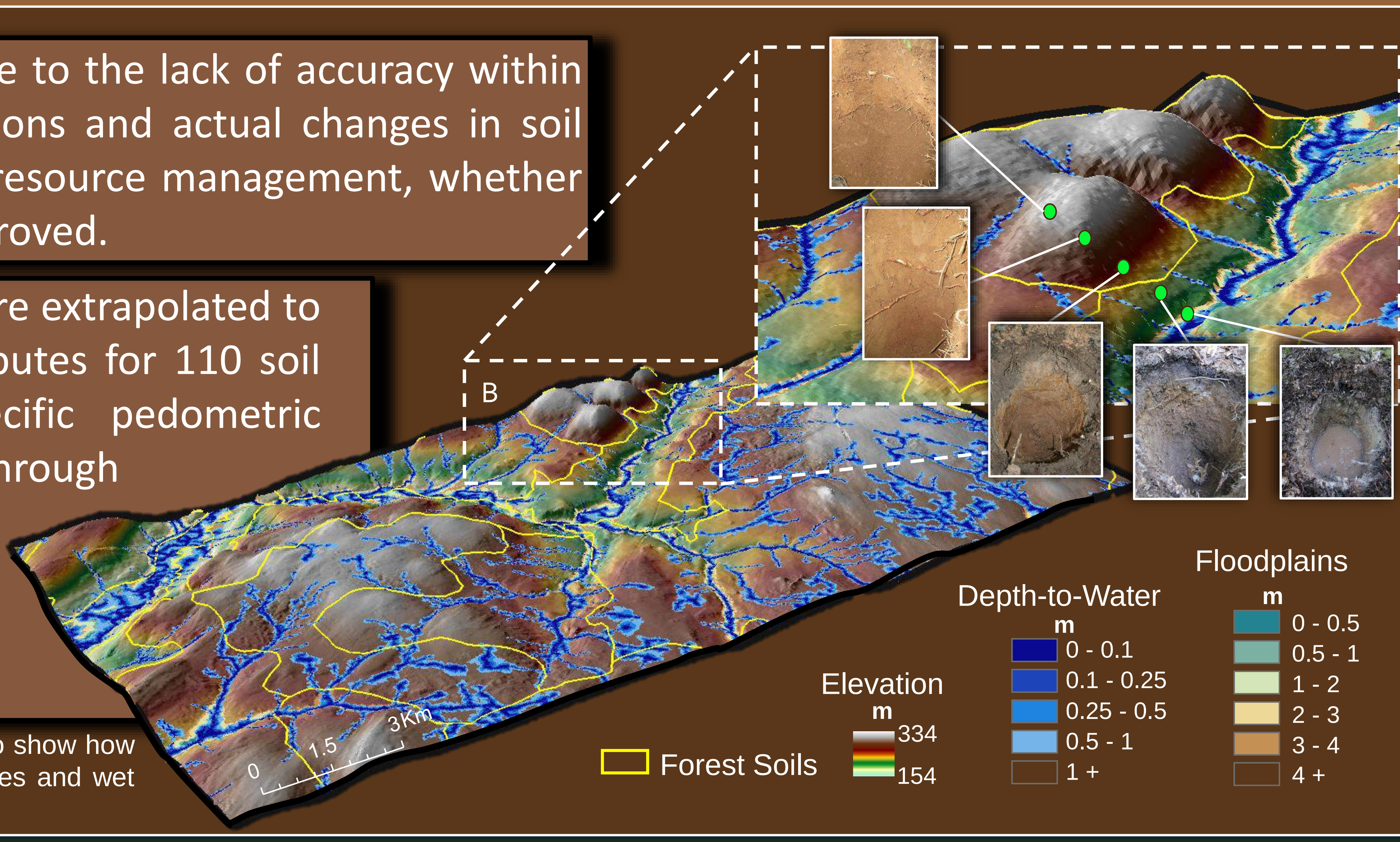


Figure 5. Visual comparison of existing, tessellated soils map for N.B. and photos of soil pits to show how soil attributes change continuously but are omitted from existing soil delineations, alluvial zones and wet areas.

LITERATURE CITED

(1) Colpitts, M. C., Macdougall, J. E., Ng, T. T. M., McInnis, B. G., & Zelazny, V. F. (1995). Forest soils of New Brunswick. Agriculture and Agri-Food Canada Research Branch, Natural Resources Canada, Canadian Forest Service (CLBRR Cont. 95-38, p. 59); **(2)** Chen, C., & Yue, T. (2010). A method of DEM construction and related error analysis. *Comput. Geosci.*, *36*(6), 717–725.; **(3)** Crippen, R. E. (2010). Global topographical exploration and analysis with the SRTM and ASTER elevation models. *Geol. Soc. London Spec. Publ.* 345(1), 5–15.; **(4)** Dobos, E., Montanarella, L., Negre, T., & Micheli, E. (2001). A regional scale soil mapping approach using integrated AVHRR and DEM data. *Int. J. Appl. Earth Obs*. *3*(1), 1–13.; **(5)** Liu, Y. (2005). An Evaluation on the data quality of SRTM DEM at the Alpine and Plateau area, North-western of China, Commission I, Technical Session: ThS-3.; **(6)** McBratney, A. B., Minasny, B., Cattle, S. R., & Vervoort, R. W. (2002). From pedotransfer functions to soil inference systems. *Geoderma*, *109*, 41–73; **(7)** McBratney, A.B., Mendonca Santos, M.L., Minasny, B. (2003). On digital soil mapping. *Geoderma,* 117, 3–52; **(8)** Mukherjee, S., Joshi, P. K., Mukherjee, S., Ghosh, A., Garg, R. D., & Mukhopadhyay, A. (2013). Evaluation of vertical accuracy of open source Digital Elevation Model (DEM). *Int. J. Appl. Earth Obs*., *21*, 205–217.; **(9)** Pegler, K., & Coleman, D. J. (1995). *TIN random densification: A process to minimize the ridging phenomenon in DTMs* (pp. 1–8). Fredericton, New Brunswick; **(10)** Sun, G., Ranson, K. ., Kharuk, V. ., & Kovacs, K. (2003). Validation of surface height from shuttle radar topography mission using shuttle laser altimeter. *Remote Sens. Environ.*, *88*(4), 401–411.