Translating Weather Records and Forecasts into High-Resolution Soil Trafficability Maps

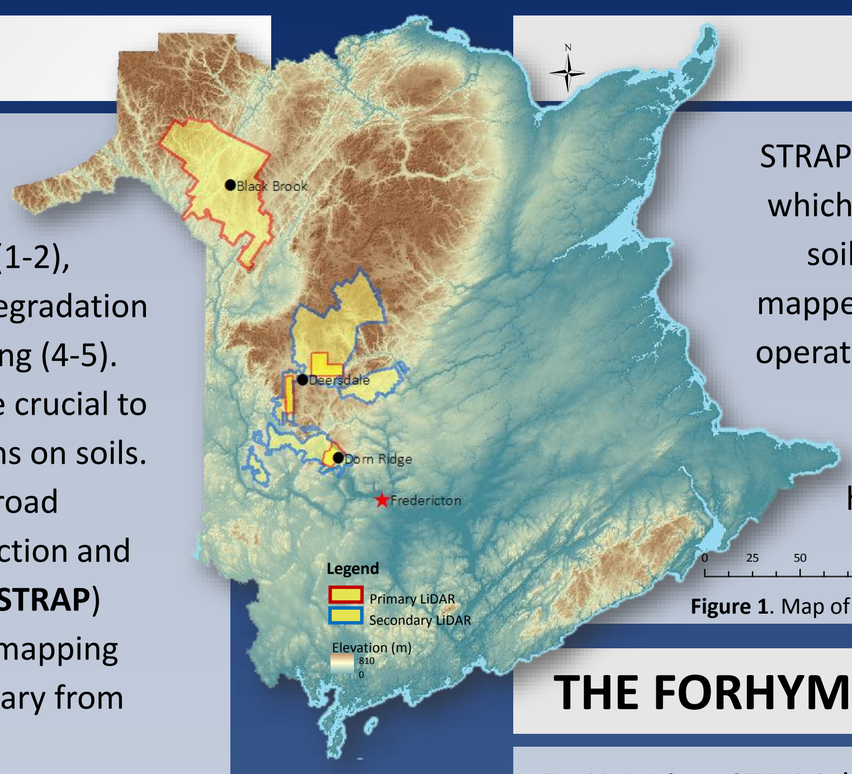
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THE PROBLEM

The increased use of heavy machinery in forest operations can lead to serious environmental problems such as decreased plant development (1-2), change in soil hydraulic properties (3), and soil degradation in the form of soil erosion, compaction, and rutting (4-5). Predicting soil trafficability has therefore become crucial to help limit the impact of heavy machine operations on soils. Doing so requires knowing **where** and **when** off-road vehicles are likely to disturb soils through compaction and rutting. The **Soil Trafficability Prediction** model (**STRAP**) responds to these questions by forecasting and mapping machine-specific rutting depths as these would vary from ridge tops to valleys.



THE STUDY AREAS



STRAP application areas (Fig. 1), for which weather-induced changes in soil trafficability are tracked and mapped as part of wood harvesting operations, at 1-m resolution, using bare-earth LiDAR DEMs. Background: provincial hydrologically corrected DEM at 10 m resolution.

Figure 1. Map of study areas in NB.





THE ARCGIS INTERFACE: WHERE?

STRAP uses ArcGIS modelling software to generate potential rut-depth surfaces (RD) from ridge tops to valleys (Fig. 3). This is done by varying the daily ForHyM RD ridge and valley outputs (i.e., RD_{valley} and RD_{ridge}) based on changes in soil type, soil penetrability, and the DEM-derived cartographic depth-to-water index (DTW). The resulting rut-depth forecasts can then be mapped at daily, weekly, and monthly time intervals.

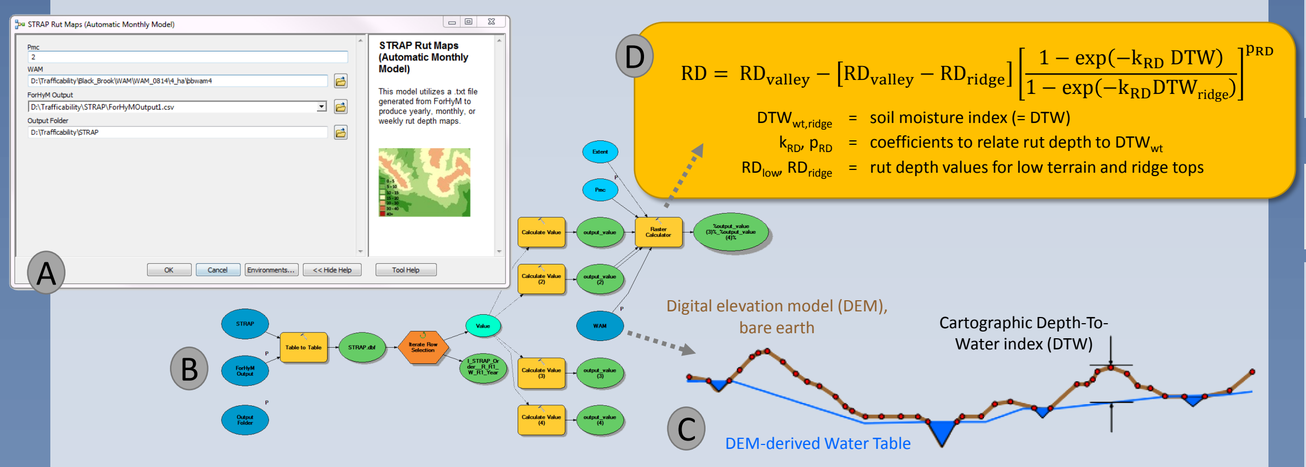


Figure 3. Strap ArcGIS user interface (A), model flowchart (B), cartographic depth-to-water mapping concept (C), and breakdown of the rut depth raster calculations (D).

For industrial purposes, daily to weekly RD forecasts are useful for deciding where and when it is best to send off-road machines without disturbing soils in a major way through compaction and rutting. Fig. 4 shows how potential rut depths incurred by wood harvesting would vary through the year, being least to zero when soils are frozen, highest during the snowmelt season, lower during summer when soils are driest, and increasing again during the fall.

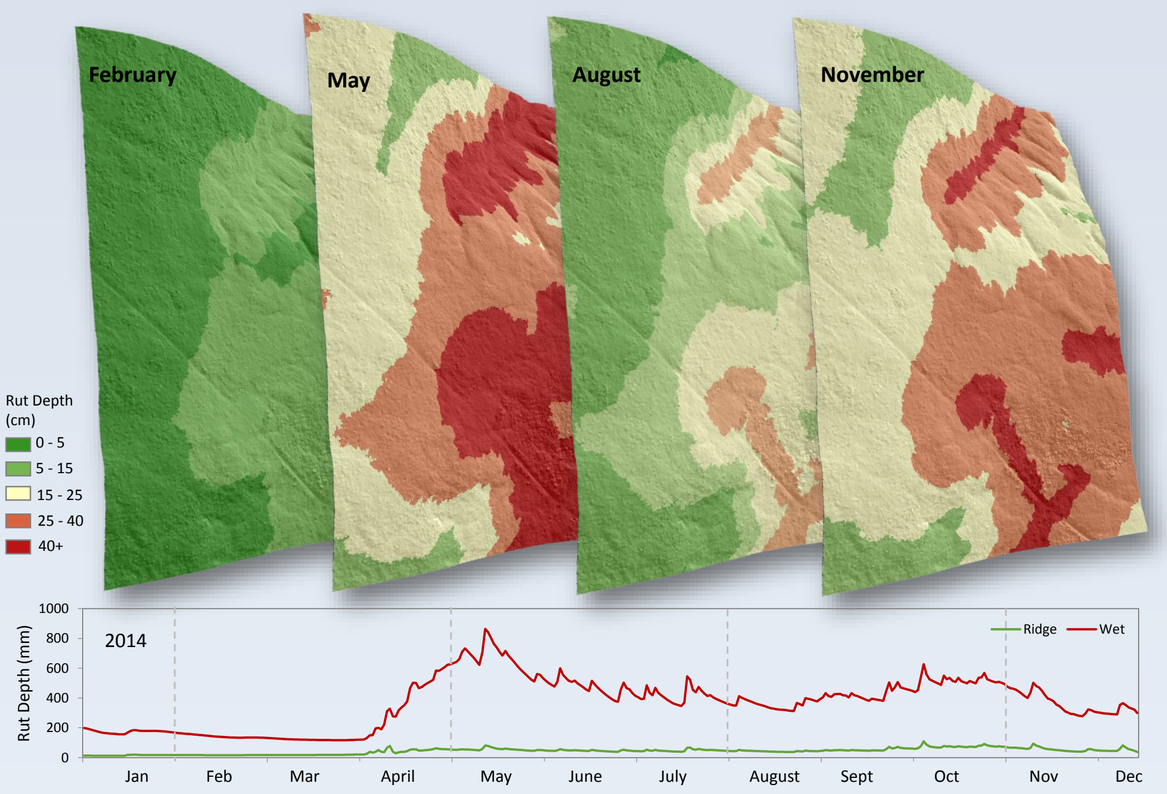


Figure 4. STRAP-generated potential winter, spring, summer and fall rut-depth maps (top); ForHyM-generated ridge-to-valley rut depths (bottom). Soils vary from regosols (ridge tops) through podsols (slopes and till plains) to gleysols (valleys).

BACKGROUND REFERENCES

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2. Grigal, D.F. 2000. Effects of extensive forest management on soil productivity. *For. Ecol. Manage.* 138: 167–185.
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THE FORHYM INTERFACE: WHEN?

ForHyM is a STELLA based model that generates temporal soil hydrology and trafficability outputs. It uses site specific weather, soil, and machine parameters to produce hydrothermal and rut depth results over time (Fig. 2). A macro-driven interface was created to produce a ForHyM-generated text file for ArcGIS interfacing. ArcGIS reads this input and generates weather and machine specific soil rut potential from ridges to streams and lakes.

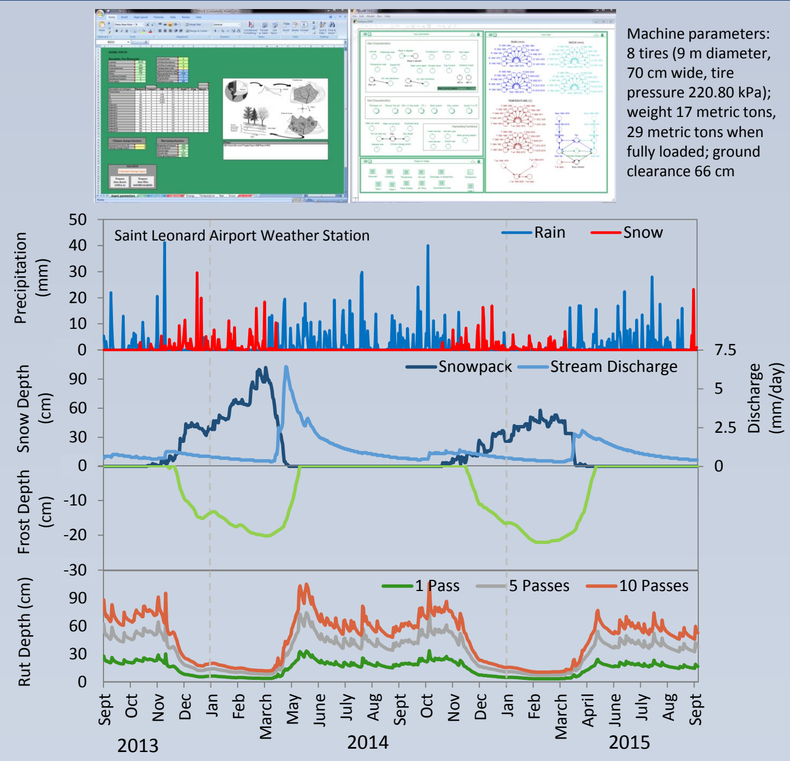


Figure 2. ForHyM Stella and Excel interfaces (top); daily rain and snow amounts, ForHyM-generated outputs for stream discharge, snow, frost and potential rut depths (bottom).

CALIBRATION WORK

STRAP-generated maps for potential machine-specific rut depths are compared with field-sampled rut depths and field-tracked ruts (Fig. 5). While there is a general map-to-actual conformance, correlation should improve with model calibration. Harvesting machine sensor data, as well as high resolution LiDAR DEMs taken before and after harvest are being used to improve model outputs.

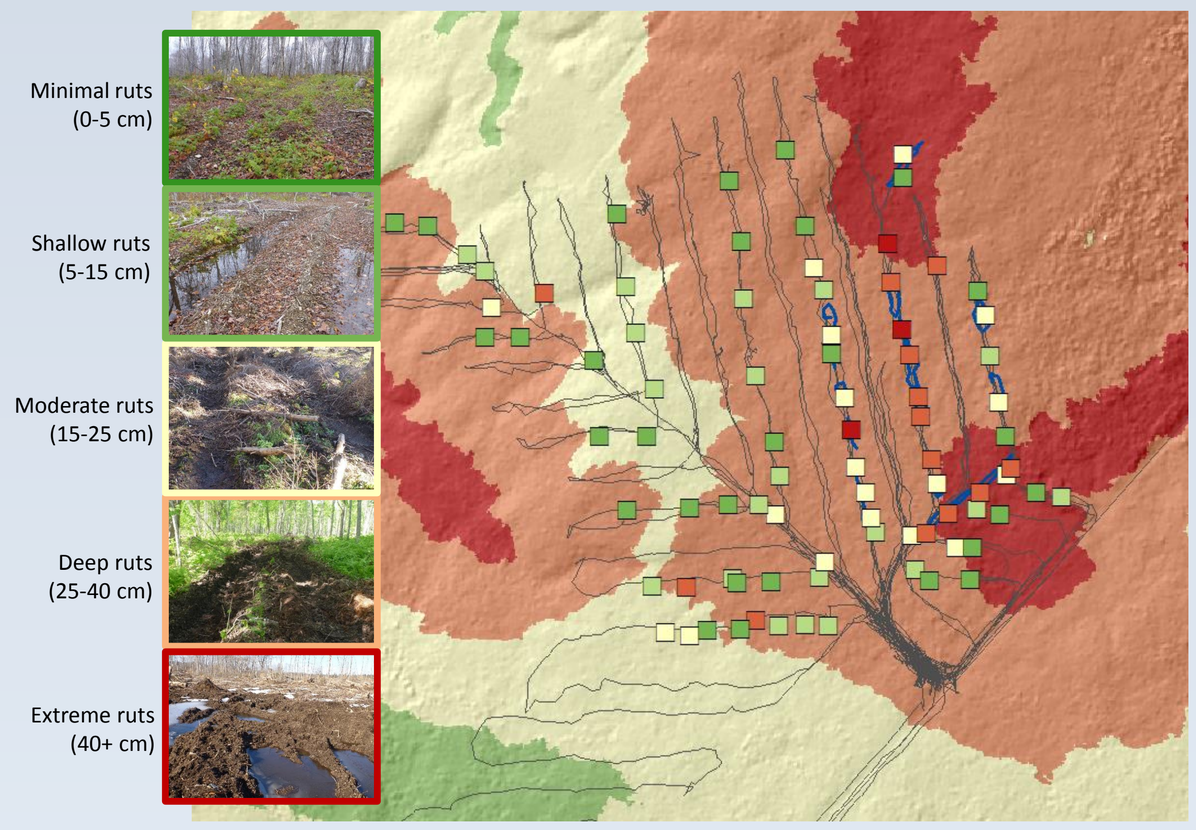


Figure 5. Typical machine tracks due to shelter-wood cutting (black lines), overlaid by: (i) STRAP-generated map for potential rut depths, (ii) field-sampled rut depths (dots) , and (iii) field-tracked ruts (blue).

OUTLOOK

Producing trafficability maps over time is becoming increasingly important as soil moisture conditions not only vary by weather and seasons, but also with climate change, with winters becoming milder, and extreme droughty to stormy weather events becoming more frequent. Therefore, knowing where and when soils change from dry to wet and remain so during planned field operations will be essential for systematically avoiding potential soil disturbance situations through weather-, soil-, and machine-informed off-road operations planning and decision making.