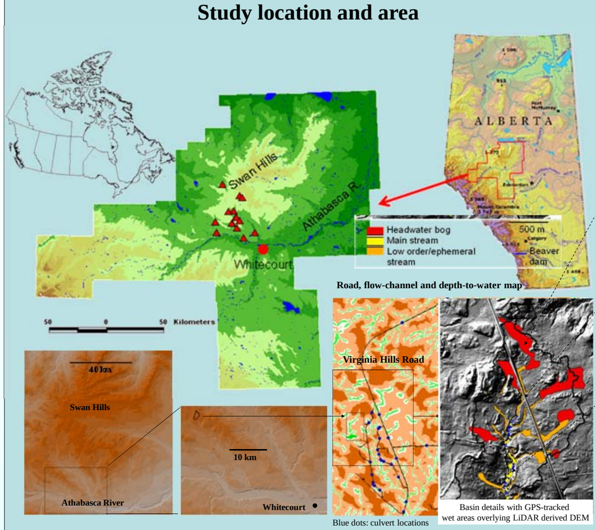
LIDAR-BASED SPATIAL MODELLING OF SOIL MOISTURE CONDITIONS AND OTHER PROPERTIES ALONG A BOREAL WETLAND-UPLAND CATENA

P. Murphy, J. Ogilvie and P.A. Arp,
Faculty of Forestry and Env. Management, University of New Brunswick, Canada

Introduction. A 1-m LiDAR-derived digital elevation model (DEM) was used to map local variations in soil moisture along flow channels from uplands to wetlands as determined by local topography and related flow orientation and accumulation calculations (Murphy et al. 2008). The resulting map was evaluated for a small watershed in the Swan Hills area of Alberta, through on-the-foot GPS-tracking of flow channels, wet-area boundaries, and soil survey transects. These evaluations dealt with small-scale variations in soil type, drainage, moisture, and other soil physical and chemical properties. Modeled soil moisture conditions showed a close match to the GPS-tracked flow channels and wet areas, and were also well correlated with soil characteristics such as drainage class, soil type, organic depth, total C, S and N, and exchangeable Mg and K. This poster presents details about (1) a comparison between the generally used DEM-derived soil moisture index (SWI) with the DEM-derived cartographic depth-to-water index (DTW, or elevational rise next to cartographically determined flow channels and shorelines), and (2) a comparison between the DTW index as derived with a the LiDAR and the coarser gridded provincial DEM data.

Note: SWI = ln(A/tan ß), where A is the upslope drainage area, and tan ß is the slope at each pixel (ß is slope in degrees).

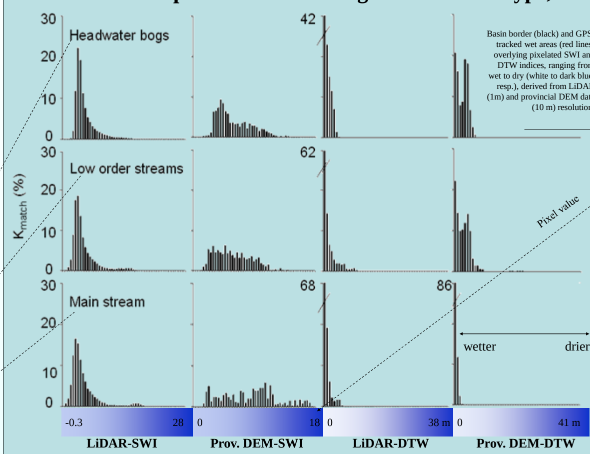
Study location and area



Blue dots: culvert locations

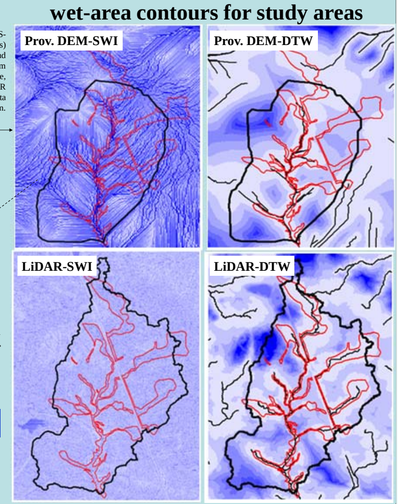
Basin details with GPS-tracked wet areas overlying LiDAR derived DEM

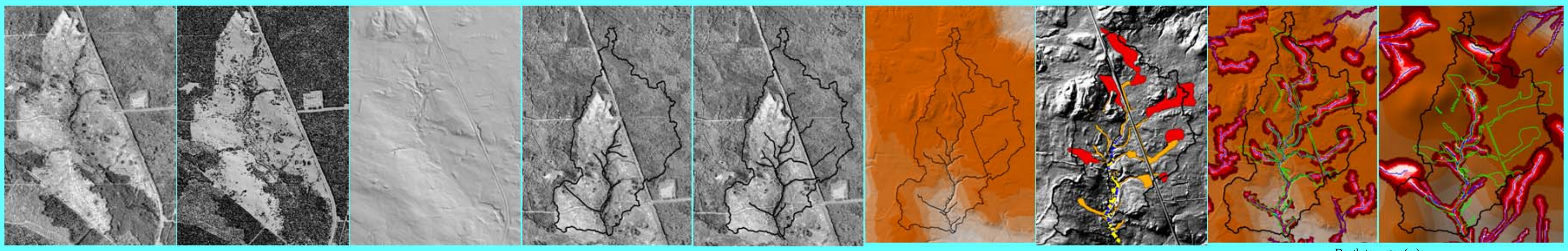
SWI and DTW pixel-value matching with wet-area type, in %



Checking conformance between wet-area features associated with headwater bogs (red), low order streams (beige) and main stream channels (yellow) with cartographic depth-to-water index (DTW, in m) and conventional soil moisture index SWI

SWI and DTW maps with wet-area contours for study areas

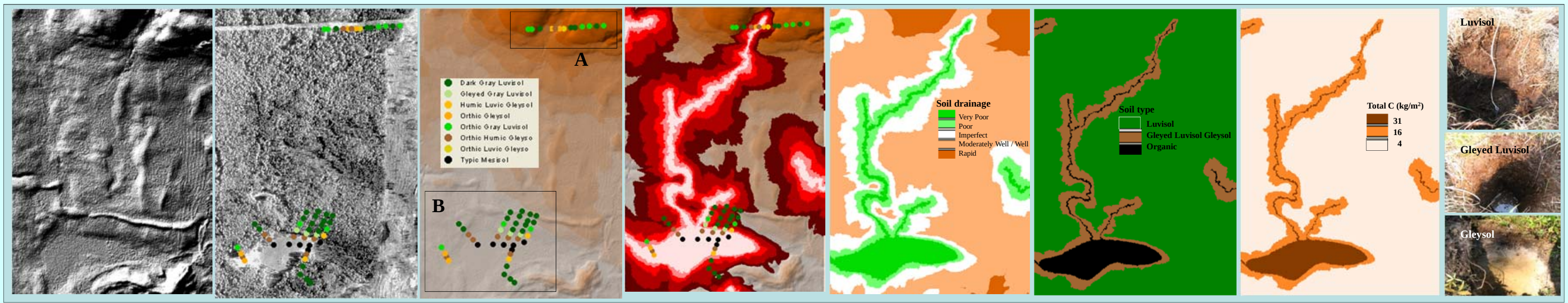




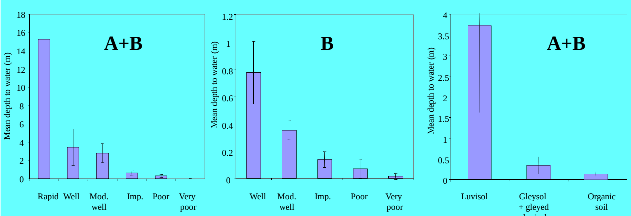
Digital ortho-rectified aerial photograph | LiDAR full feature | LiDAR bare-earth | LiDAR bare-earth + air-photo digitized flow channels | LiDAR bare-earth + GPS-tracked flow channels | LiDAR bare-earth + DEM-derived flow channels | LiDAR bare-earth + GPS-tracked wetland areas | LiDAR bare-earth + GPS-tracked wet areas + 1m DEM–derived depth-to-water classes | LiDAR bare-earth + GPS-tracked wet areas + 10m DEM –derived depth-to-water classes

Depth-to-water (m): 0 - 0.1; 0.1 - 0.25; 0.25 - 0.5; 0.5 - 1; 1 - 2

Soil catena examination, using various surface images as well as bare-ground DEMs (LiDAR, provincial data) GPS, and derivation from provincial and LiDAR DEMs **Overlaying flow-channel and wet-are features, as captured through air-photo digitization,**



Soil catena analysis. soil sampling was done at each of the above locations (coloured dots), overlain on various images: bare-ground LiDAR DEM, air photo, and cartographic DTW map (0 to 1 m, pink to red). Dot colours correspond to soil type.
The thematic maps on the far right above show soil drainage, soil type, and soil organic matter content.
The table on the right shows correlation coefficients between soil property and the cartographic depth-to-water index.
The boxes below show how the soil drainage condition at each soil within the A and B transects ranks is associated with the cartographic depth-to-water index.



Correlation coefficients between soil physical and chemical properties and the cartographic depth-to-water index

Organic layer (cm)	-0.81	Ex Zn (g/m2)	0.59
pH	0.57	Ex Al (g/m2)	-0.47
Clay (%)	0.48	Av P (g/m2)	-0.35
Sand (%)	-0.13	Av NH4 (g/m2)	0.66
% Moisture	-0.61	T P (kg/m2)	0.38
T C (kg/m2)	-0.81	T K (kg/m2)	0.60
T S (kg/m2)	-0.81	T Ca (kg/m2)	0.66
T N (kg/m2)	-0.76	T Mg (kg/m2)	0.61
Ex Ca (kg/m2)	0.39	T Fe (kg/m2)	0.51
Ex Mg (kg/m2)	0.71	T Al (kg/m2)	0.55
Ex K (kg/m2)	0.77	T Mn (g/m2)	0.93
Ex Mn (g/m2)	0.08	T Zn (g/m2)	0.58
Ex Fe (g/m2)	-0.54		

Summary. The LiDAR-DEM derived cartographic depth-to-water index (DTW) is shown to be a useful tool to map flow channels, wet areas, and soil moisture. The soil transect work further indicates that this index is also useful for mapping soil type, drainage, and a variety of soil physical and chemical properties, notably depth of organic layers, total elemental CNS (decreasing with increasing DTW), and total and exchangeable Ca, Mg, K as well as pH and total Fe, Al, Mn, and Zn (increasing with increasing DTW). These latter trends would be region specific, such that depressions would be more acidic on account of organic (humic) matter build-up. In contrast, the upland soils would be more basic on account of fine texture and dry conditions which favour luvisol rather than podsol or brunisol formation.
The flow orientation and accumulation patterns generated from the provincial DEM data also9 correspond the general on-the-ground features, but lack in detailed conformance to the GPS located and tracked surface features, i.e., flow channels and wet area borders.
The above traditional soil moisture index derivations (SWI) do not lend themselves to thematic flow channel, wet-areas and soil mapping, because the DEM-derived SWI index maps are simply too pixelated.
While the results of this study are confined to a very small study area in the Swan Hills of Alberta, general experience has shown that the methods employed are transferable to other locations within the region, the province, and elsewhere.

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Reference. Murphy et al. 2008. Hydrological Processes. 22: 1747-1754