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High resolution mapping of soil organic carbon and nitrogen in two small adjacent Arctic watersheds

on Herschel Island - Yukon Territory

Key Findings

1 GeoEye images and digital elevation models (DEM) with 2x2m resolution were suitable for detecting fine scale differences in land cover classes. Highest soil organic carbon (TOC) and total nitrogen (TN) accumulation was found in recently emerged tall erect shrub areas and flat hummocky-tussocky uplands.

2 Topsoil moisture was highly correlated to TOC and the normalized difference vegetation index (NDVI) the best remote sensing approach to predict TOC contents within the active layer of ice creek watershed. Downslope carbon accumulation was high but few downstream sediment deposits were detected.


Ice Creek West, facing south. Ice Creek East is behind the ridge on the left. Picture: Jaroslav Obu, 2014.

Introduction

- Small watersheds very common across the Arctic but their cumulative contribution to the global carbon cycle has not been accounted for so far
- One of the first Arctic studies to estimate TOC and TN contents with high resolution spatial images (at the cost of having a smaller spectral range (blue - near infrared))

- The **AIM** of this study was to provide baseline information for hydrological studies in ice creek watershed, to enable comparative work between multiple Arctic watersheds and provide high resolution carbon and nitrogen estimates for future maps and models
- The **OBJECTIVES** were to 1) find an appropriate land cover classification system to map to upscale TOC and TN estimates, and 2) evaluate how terrain affects the spatial distribution of TOC and TN

Methods

Remote Sensing
- GeoEye image (1.65m) + digital elevation model (DEM, 2m)
  - slope, normalized difference vegetation index (NDVI), topographic wetness index (TWI)
  - land cover classes

Field
- 3 transects
  - active layer soil samples (23 locations, n=73)
  - vegetation plots (n=69)
- ground truthing points collected at stratified random locations across watershed

Laboratory
- soil moisture, bulk density, grain size distribution, total organic carbon (TOC) and total nitrogen (TN)

Statistical Analysis
- difference of TOC and TN between classes and transects (ANOVA + Tukey's post hoc)
- soil properties and terrain characteristics (Spearman's rank correlation, PCA)

1 Mapping Ice Creek Watershed

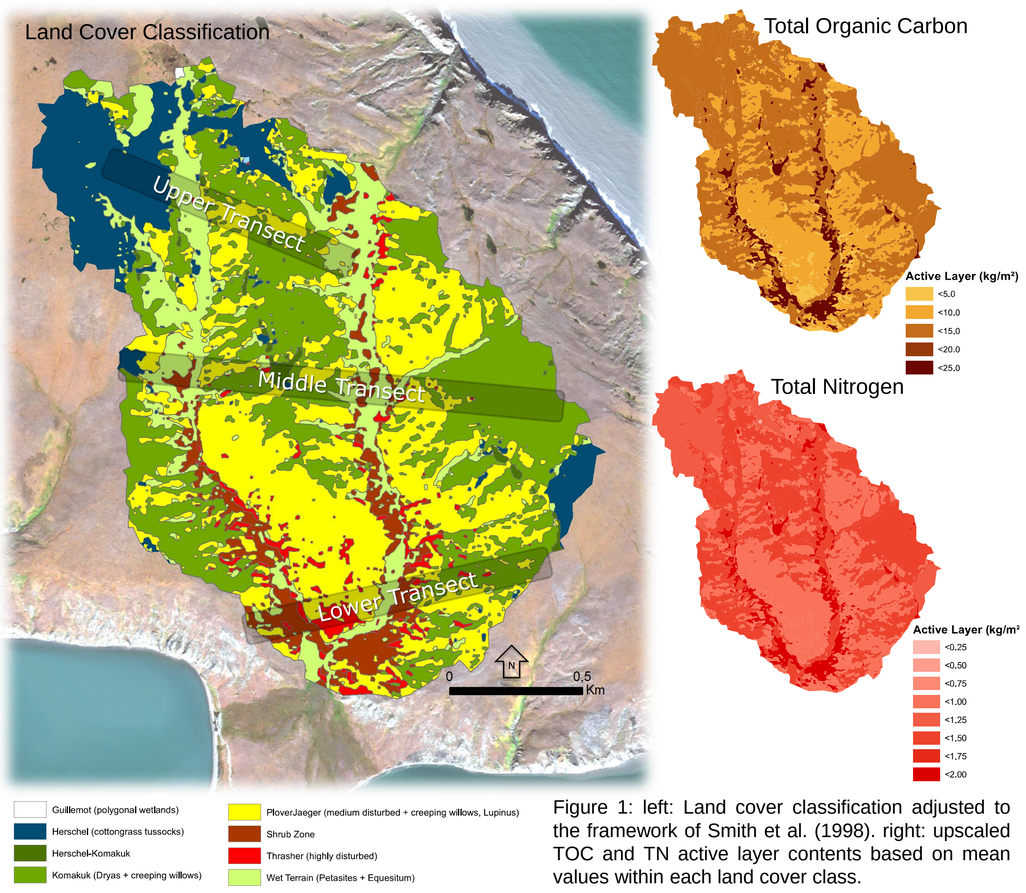

Figure 1: left: Land cover classification adjusted to the framework of Smith et al. (1998). right: upscaled TOC and TN active layer contents based on mean values within each land cover class.

The land cover classes were chosen because they represented distinct vegetation communities and were detectable using GeoEye images + DEM, the prediction accuracy was 55%. Prediction accuracy could be further optimized by excluding the mixed Herschel-Komakuk zone. The classes were useful for upscaling TOC and TN soil contents because, generally, in-class variance and redundancy between classes was low (not shown). Highest TOC and TN contents could be found in the newly emerged shrub zones and in the cottongrass uplands. Lowest TOC and TN contents were found in the steeper and/or more cryo-disturbed areas (Plover-Jaeger and Thrasher). High TOC contents in newly formed shrub zones suggest that carbon accumulation is ongoing and suggests that these areas may be affected differently by climate change than other sections of the watershed.

2 Spatial Distribution of Total Organic Carbon and Nitrogen

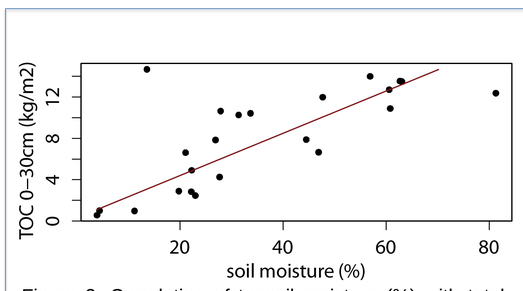

Figure 2: Correlation of topsoil moisture (%) with total organic carbon (TOC) in kg/m² in the upper 30 cm.

High correlation of topsoil moisture and TOC in uppermost 30cm of active layer (ρ =0.74, p<0.05). Normalized difference vegetation index (NDVI) was the best remote sensing approach to predict TOC contents (ρ = 0.46, p<0.05). NDVI to TOC correlations were comparable to Burnham and Sletten (2010). Low correlations for slope and topographic wetness index were found. This suggests that moisture and vegetation together play a major role in determining TOC contents in the active layer. Nitrogen, generally, was less strongly correlated to all terrain factors tested.

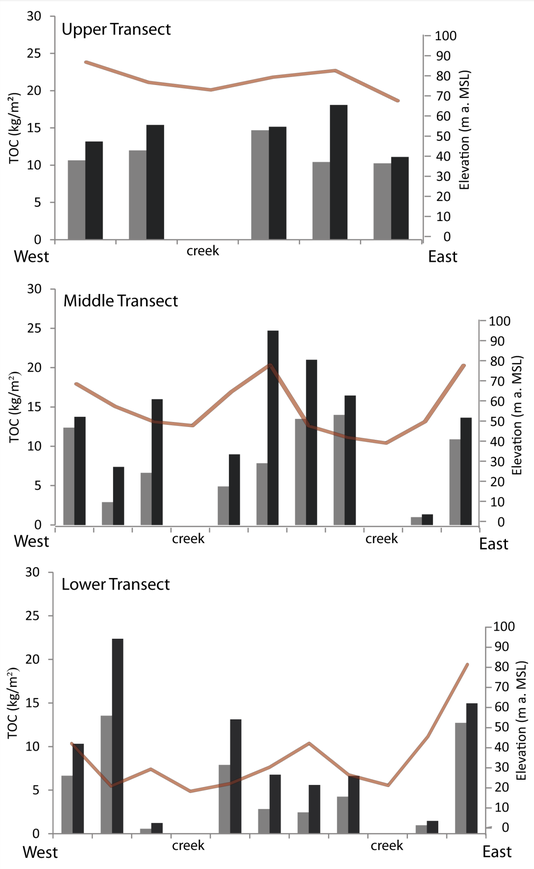

Figure 3: TOC contents of the upper 30cm (light) and active layer (dark). The brown line indicates the elevation of the sampling locations. The upper transect only passes through ice creek west.

The stream formed a small incision in the upper transect and differences in TOC contents were low. Further downstream, there was a general trend of decreasing TOC contents in the valley slopes and higher TOC contents in stream adjacent sites. Ice Creek East has fewer TOC accumulation sites than Ice Creek West. High TOC contents in accumulations sites are very variable and mainly due to variable active layer depths. Obu et *al*. (2015) confirms the high variation of TOC contents in accumulation sites. Due to their proximity to the stream these may become carbon release sites if hydrological patterns are changing.

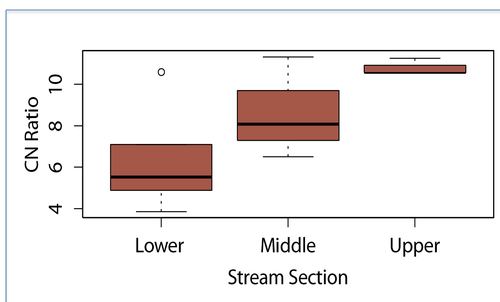

Figure 4: Boxplots comparing the CN ratios of soil to a depth of 30cm in stream adjacent sampling locations in three sections of the watershed. Statistical difference between locations was analyzed with ANVOA and Tukey's post hoc tests, df=9)

CN contents in the sampling locations furthest upstream were higher and less variable than further downstream (p=0.063). This suggest that upstream carbon rich and eroded material usually did not get moved further downstream. Warm summers with heavy rains may however change these processes in the future (Lamoureux et *al*., 2014).

Future Studies

Hydrological assessments are planned. Due to the high correlation of topsoil moisture and TOC contents we encourage the optimization of radar based moisture measurements to greatly improve Arctic carbon estimates. Future studies should assess the processes and vulnerability of sediments accumulation sites in the face of a changing climate and hydrology.

References

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COPER Coastal Permafrost Erosion, Organic Carbon and Nutrient Release to the Arctic Nearshore Zone

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