Mapping Belowground Carbon Pools and Potential Vulnerability in the Yukon-Kuskokwim Delta, Alaska

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Abstract

Permafrost regions store an estimated half of the global belowground organic carbon pool and twice the global atmospheric carbon level. A warming climate results in increased carbon gas emission, therefore knowing more about the amount and composition of organic carbon stored in permafrost regions is crucial for understanding feedbacks on global climate change. Using the Yukon-Kukskowim (YK) Delta, Alaska as a study site, we quantified belowground carbon pools and their potential vulnerability to release into the atmosphere as greenhouse gasses. We identified relevant landcover classes (burned and unburned upland peat plateaus, wetlands, ponds/lakes) in the YK Delta, from which we quantified total belowground carbon pools (30cm) and assessed the composition of the organic matter using Fourier-transform infrared spectroscopy. To characterize the size and distribution of soil carbon pools in the YK Delta, we built a Random Forest Machine Learning model that mapped the spatial distribution of soil carbon to a depth of 30 cm over a 1910 km2 watershed. The map product was produced in Google Earth Engine and used covariates that include, but are not limited to, Worldview2 high-resolution optical imagery (2m), ArcticDEM (5m), and Sentinel-2 level 1C multispectral imagery (10 m), including NDVI. We found substantial variation across landcover classes in soil characteristics that affect organic matter vulnerability, including gravimetric water content, thaw depth, bulk density, and percent carbon. Compared to upland areas, thaw depths were significantly deeper in wetlands and lakes, where we detected no surface permafrost (to 1m). Soil carbon content (%) was greatest in moss-dominated wetlands; however, these areas also had the lowest bulk density. Carbon pools and organic matter characteristics also varied between burned and unburned areas. Therefore, we expect that carbon vulnerability varies by landcover class and that future carbon emissions are driven by total carbon pools, thaw depths, and composition of the carbon stored in organic matter pools. These carbon pool and vulnerability maps will contribute to better understanding the impacts of subarctic warming and are critical for developing a more accurate assessment of carbon cycling feedbacks from permafrost regions on global climate change.

Mapping Potential Carbon Emissions from Soils and Sediments in the Yukon-Kuskokwim Delta

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Introduction

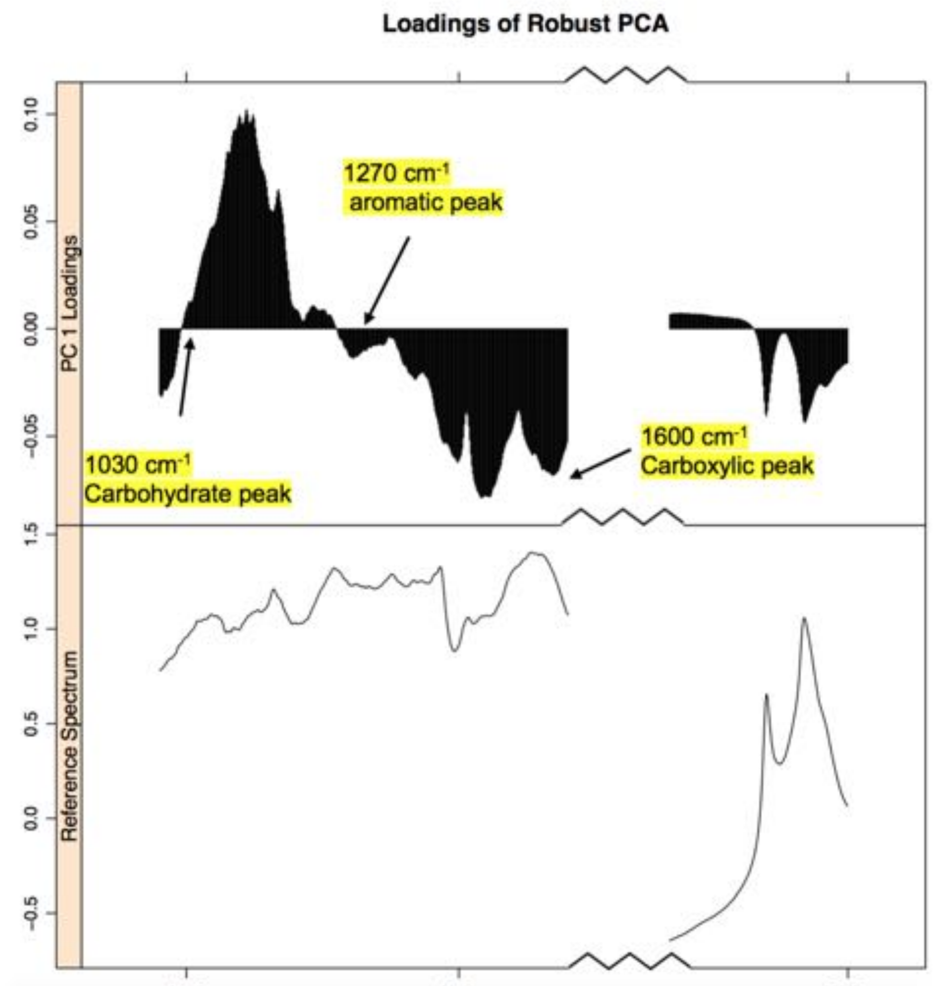
Permafrost regions store ~1300-1600 Pg of carbon, which is estimated to be half of the global belowground organic carbon pool and about two times the global atmospheric carbon level. (Zhang et al. 2003, Hugelius et al. 2014). As the climate warms, microbes become more active and more organic compounds become available, resulting in increased decomposition and carbon gas emission (Jansson & Tas, 2014). Understanding the amount and composition of organic carbon stored in permafrost regions is crucial for quantifying feedbacks from permafrost carbon on global climate change.

To address this uncertainty, we investigated carbon pools and composition across different landcover classes in burned (2015, 1972) and unburned areas of the Yukon-Kuskokwim Delta (YKD) in Alaska to determine the vulnerability of carbon across the landscape.

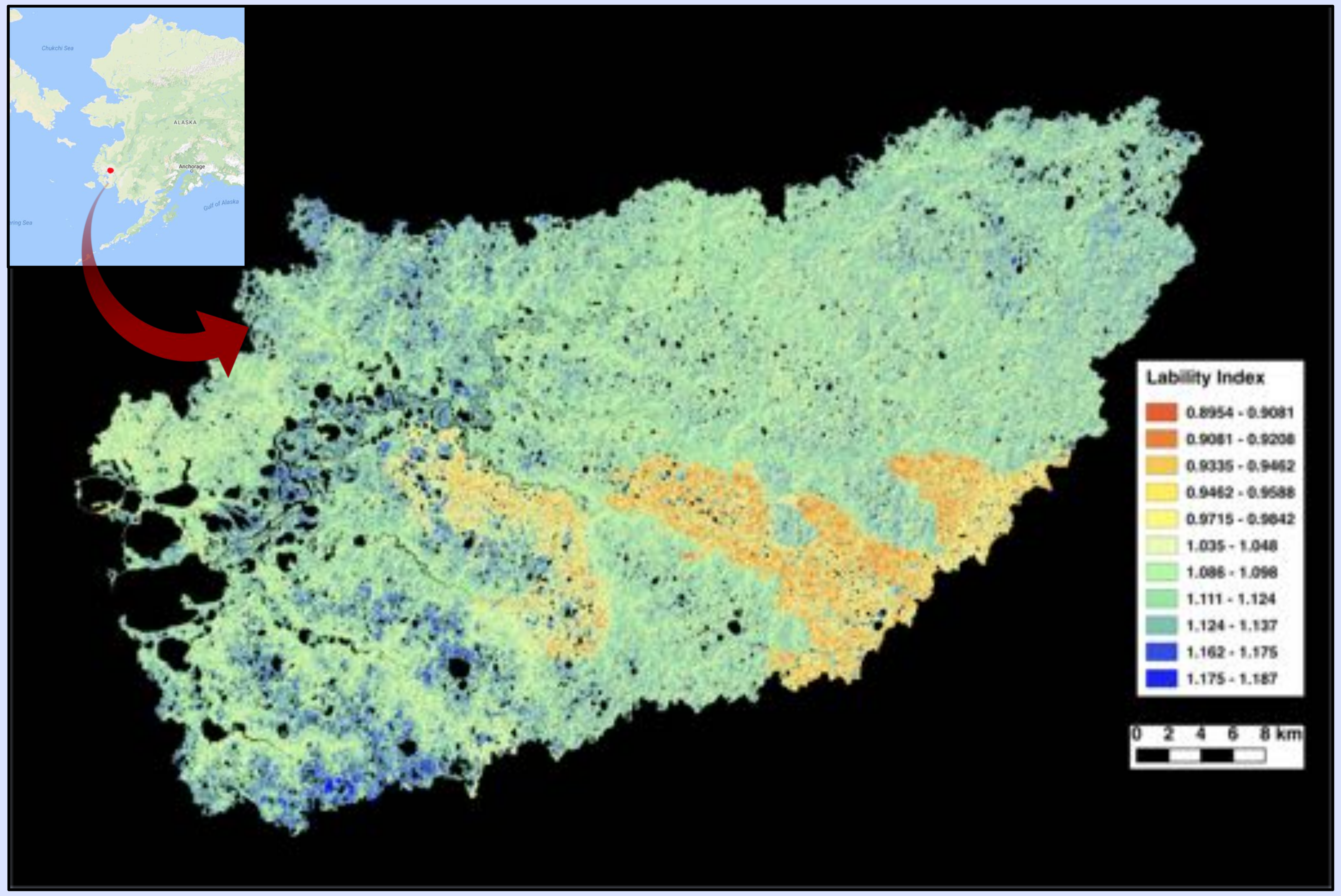
Methods

- Landcover was classified using an unsupervised classification algorithm in Google Earth Engine.
- 3 - 6 soil or sediment samples collected at 3-6 sites per class.
- Dried, ground samples were analyzed for compositional analysis using Fourier-transform infrared spectroscopy (FTIR) and for percent carbon using a LECO elemental analyzer.
- Carbon pools from each classification calculated as the product of %C, bulk density, and sample depth.
- Carbon lability calculated using a FTIR ratio of carbohydrate peaks to carboxylic peaks (1030/1060) (Ernakovich et al. 2015).
- PCA conducted to visualize differences in composition of soil organic matter among landcover classes.
- Map products are the result of a random forest predictive model implemented using Google Earth Engine. Inputs to the classification were Sentinel 2 multispectral imagery and Arctic DEM (5m). 194 sample points were used in the modeling process, with 30% withheld for model validation. Satellite imagery was filtered to 2016-2017, summer, cloud free days. Derived products included as covariates were NDVI, NDWI, and slope.

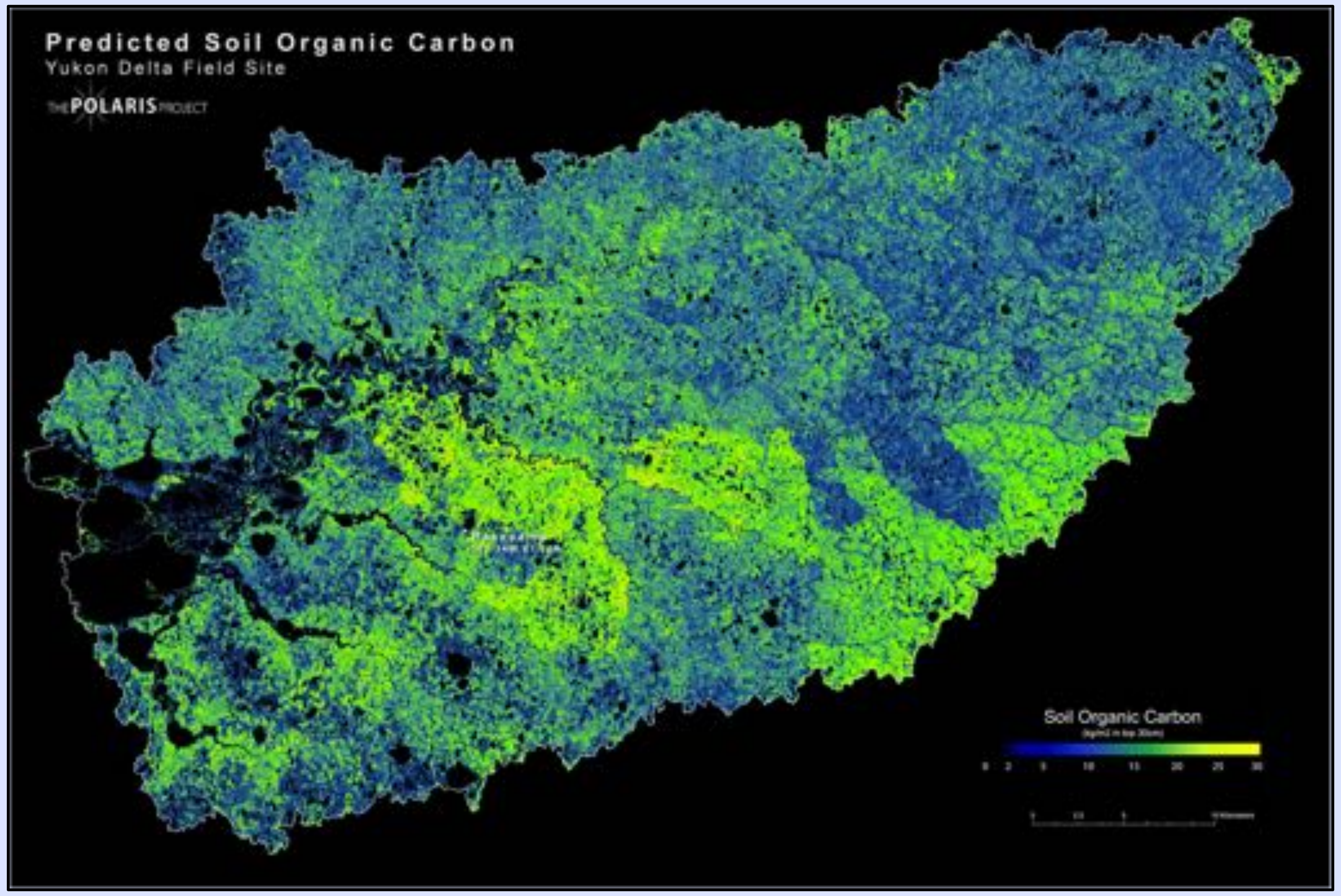
Carbon Vulnerability



We assessed carbon vulnerability using the ratio of carbohydrates (peak 1030) to carboxylates (1600), following Ernakovich et al., 2015. This ratio can be used as a proxy for the degree of decomposition in soils and therefore carbon vulnerability.

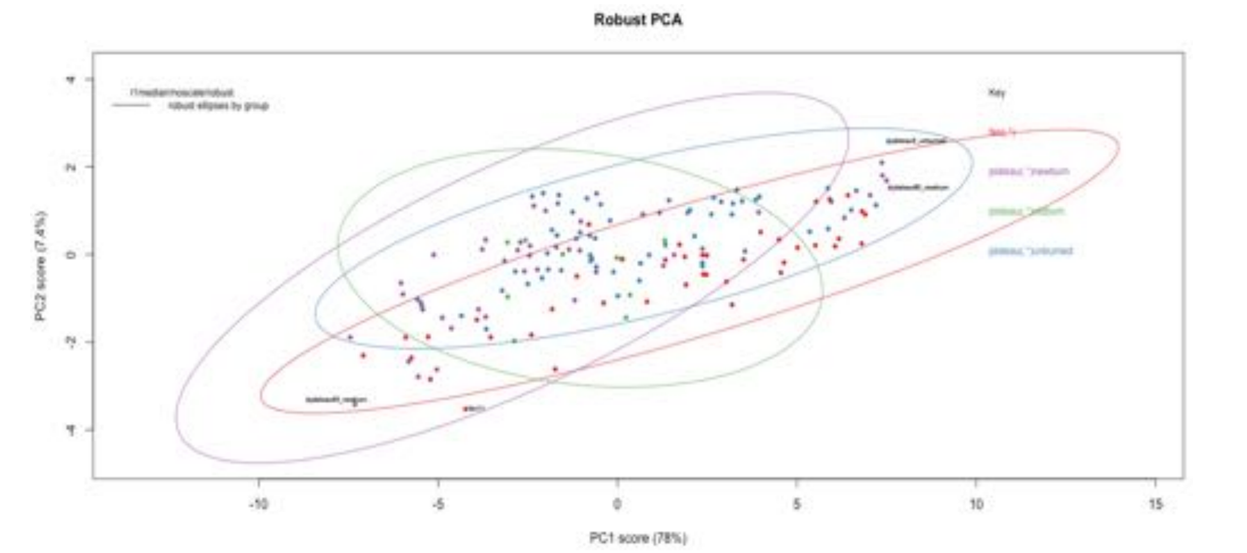


Map of soil carbon lability across the watershed where this work was conducted. Lability defined as carbohydrates/carboxylic in the soil or sediments.

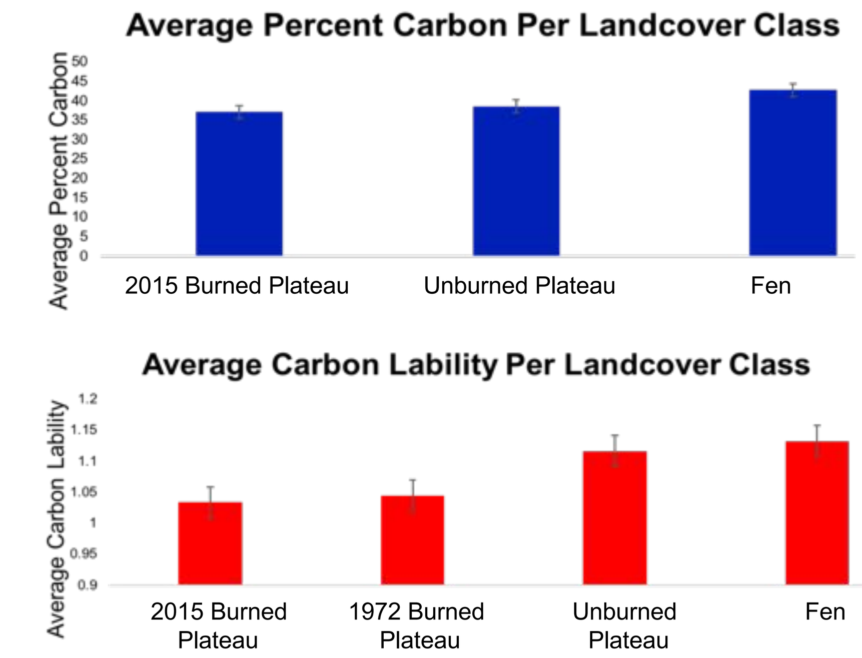


Carbon pool map made from 2016, 2017, and 2018 carbon pool data.

Robust PCA



The first two components in a principal components analysis (PCA) captured 85.4% of the variation in the soil data. Clustering in each category indicates differences in composition of soil organic matter among landcover classes.



Differences in % soil organic carbon (top panel) and carbon lability (bottom panel) by landcover class.

Top panel analysis was conducted on samples from 2018, bottom panel was on samples from 2016, 2017, and 2018.

Results & Conclusions

- The first three components in the PCA captured 96% of variation in the data, and the first component alone captured 78%.
- Wildfire presence corresponds to a decrease in carbon lability (lower values/red shading in top map).
- Wetland presence corresponds to an increase in carbon lability (blue values on top map).
- As the permafrost continues to thaw, ground collapse may increase wetland formation, leading to more labile organic matter in these soils. However, environmental conditions interact with organic matter composition to drive decomposition rates. Saturated anoxic conditions may reduce aerobic decomposition, despite potential changes in lability, but would increase anaerobic carbon processing.

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