Quantifying and Representing Variability in Permafrost-Affected Soils across Ice Wedge Polygons for Improved Sampling Strategies, Prediction, and Modeling

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BER Program: ESS

Project: Argonne National Laboratory Soil Dynamics SFA

Project Website: https://ess.science.energy.gov/anl-sfa/ and http://tessfa.evs.anl.gov/

Project Abstract: Efforts to bridge scaling gaps when extrapolating soil properties and carbon stocks from soil profiles to sites and landscapes are significantly challenged by the highly heterogeneous nature of permafrost-affected soils. In many areas of the northern circumpolar region, this fine-scale heterogeneity is associated with patterned ground features such as ice wedge polygons (IWPs), non-sorted circles, stripes, and earth hummocks. Upscaling heterogeneous point data to the scale of individual sites or patterned ground features in permafrost regions without loss of information requires conducting data synthesis while also retaining uncertainty estimates. Efforts to overcome these challenges have ranged from generating two-dimensional representations of soils across patterned ground features to intensive, core-based one-dimensional sampling at fine scales. Two-dimensional representations of soil profiles across patterned ground features have the advantage of allowing for more accurate spatial and vertical characterization by accounting for the area of each soil horizon or layer within each incremental horizontal or vertical slice of interest within the profile. Utilizing data from soils sampled across flat-centered, low-centered, and high-centered IWPs near Utqiaġvik, Alaska, we demonstrate how exploring and synthesizing variability at multiple scales can inform sampling strategies and best practices for soil carbon stock estimation using rapid, core-based methods. Beginning with two-dimensional representations of soil variability across full IWPs, we generate populations of carbon stocks and down-profile patterns of other soil constituents (ice, total nitrogen, bulk density) across individual polygon components (such as ice wedge troughs vs. polygon centers) by pseudo-sampling these two-dimensional representations using digital workflows. The results of our analysis show how bridging these scaling gaps can lead to improved, rapid, data-driven sampling strategies for carbon stock estimation of IWPs, which can reasonably approximate mean carbon stocks of entire IWPs or carbon stocks for individual spatially scalable components of IWPs.