Digital Tools for Advanced Analysis and Comparison of Irregular Carbon Distributions in Cryoturbated Soil Profiles

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Cryoturbated permafrost-affected soils are often characterized by patterned ground on the surface (e.g., frost boils, stripes, or ice-wedge polygons) and by irregular and broken horizons belowground. Consequently, these soils are not well represented by typical one-dimensional soil profile descriptions that assume laterally continuous horizons for determining the distribution of soil organic carbon stocks and other soil constituents. Two-dimensional representations of soil profiles allow 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. This approach enables quantitation of soil constituents for the entire cycle of a patterned-ground pedon (generally about 1-2 m in size) or super-pedon, as typified by ice-wedge polygons (often 5-30 m across). We have generated a workflow using open-source geographic information system software (QGIS) and the R programming language/environment to digitize, scale, and rasterize two-dimensional drawings of soil profiles. Following rasterization, raster attribute tables (RATs) are built for each morphologic unit within the profile (referred to as “soil morphologic units” or SMUs). RATs can include field characterization and laboratory data for each SMU or SMU component. Analogous to soil mapping concepts, the representation of various component units within delineated SMUs is also possible. This digitization and rasterization workflow enables the quantitative analysis of two-dimensional profiles as well as their synthesis with standard one-dimensional soil profile descriptions (or observations from soil cores) via tools such as Algorithms for Quantitative Pedology (AQP; Beaudette et al., 2013, Computers & Geosciences 52:258-268). By coupling the rasterized profile images with R scripts, quantitation of carbon and nitrogen stocks or other measured soil constituents can now be easily and rapidly determined for any depth or horizontal increment and compared among multiple pedons or super-pedons. Importantly, these tools allow for improved harmonization of disparate data sources and data formats without information loss and, thereby, will enable more accurate geospatial analyses and mapping efforts, which are needed to benchmark landscape, regional, and Earth system model predictions for high latitude soils.