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Alternative modelling approaches for estimating pyrogenic carbon, soil organic carbon and total nitrogen in contrasting ecoregions within the United States

Verena Jauss (1), Patrick Sullivan (2), Johannes Lehmann (1), Jonathan Sanderman (3), and Markus Daub (4)

(1) Department of Soil and Crop Sciences, Cornell University, Ithaca 14853, NY, USA, (2) Department of Natural Resources, Cornell University, Ithaca, NY 14853, USA, (3) CSIRO Land and Water, Glen Osmond, Australia, (4) Institute for Analysis, Dynamics and Modelling, University of Stuttgart, 70569 Stuttgart, Germany

Given that turnover rates of pyrogenic carbon (PyC) in soil are substantially slower than those of other organic carbon input, it is considered an important carbon pool and its function and fate are relevant to global environmental change processes. Research on PyC has expanded greatly over recent years, but the analytical challenges of determining environmental core factors influencing its production, accumulation and dispersion still require elucidation across different scales.

Mid-infrared spectroscopy and partial least-squares analysis were used in conjunction with ultraviolet photo-oxidation followed by nuclear magnetic resonance spectroscopy techniques, to quantify PyC, soil organic carbon (SOC) and total nitrogen (total N) amounts for samples we collected of surface and subsurface soils across the United States at National Science Foundation supported Long Term Ecological Research (LTER) sites as well as samples from a national soil sampling effort by the U.S. Geological Survey.

In our study, we illustrate the impact of the aforementioned natural factors by examining their correlation with PyC content in soils under contrasting environmental conditions thus identifying the factors affecting PyC accumulation.

Our central findings revealed a statistically significant relationship of PyC with environmental variables soil drainage, lignin content of the vegetation, mean annual temperature and mean annual precipitation as well as for the USGS sites total soil sulphur.

During our investigations we evaluated PyC on different spatial scales. On a geographically smaller scale we examined samples from New England and New York. We developed a new and innovative Bayesian framework and applied three spatial models to the data in order to relate critical environmental covariates to changes in spatial density of PyC over the landscape. Akaike Information Criterion demonstrated that the Bayesian Multivariate Linear Regression model performed best (r2=0.6; p«0.0001) in our analysis, giving global mean density estimates for PyC of 25.8 g kg-1 (12.2 Gg km-2) as opposed to the Ordinary Kriging model, which performed worst (r2=0.0; p»0.05) with estimates of 11.0 g kg-1 (0.84 Gg km-2).

On a larger scale, we looked at selected profiles at five diverse LTER sites as well as sites along a vegetation gradient in Oregon. At the LTER sites PyC content ranged from 9.8 mg g-1 (Coweeta, NC) to 56.4 mg g-1 (Bonanza, AK). Furthermore, we examined the multivariate relationships between environmental factors and our measurements of PyC, SOC and total N at the LTER sites through the application of a canonical correspondence analysis. Using our Oregon samples, we expanded on a previously established method to predict soil properties vertically in the soil profile using equal-area quadratic splines in order to calculate PyC stocks as well as to infer and visualize PyC contents, which were most prevalent in the first 0.2 m with 7–24% of SOC, and could be found in the subsoil of all locations. However, PyC contents did not change consistently with soil depth.