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Predicting bi-decadal organic carbon mineralization in northwestern European soils with Rock-Eval pyrolysis

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The organic carbon reservoir of soils is a key component of climate change, calling for an accurate knowledge of the residence time of soil organic carbon (SOC). Existing proxies of the size of SOC labile pool such as SOC fractionation or respiration tests are time consuming and unable to consistently predict SOC mineralization over years to decades. Similarly, models of SOC dynamics often yield unrealistic values of the size of SOC kinetic pools. Thermal analysis of bulk soil samples has recently been shown to provide useful and cost-effective information regarding the long-term in-situ decomposition of SOC. Barré et al. (2016) analyzed soil samples from long-term bare fallow sites in northwestern Europe using Rock-Eval 6 pyrolysis (RE6), and demonstrated that persistent SOC is thermally more stable and has less hydrogen-rich compounds (low RE6 HI parameter) than labile SOC.

The objective of this study was to predict SOC loss over a 20-year period (i.e. the size of the SOC pool with a residence time lower than 20 years) using RE6 indicators.

Thirty-six archive soil samples coming from 4 long-term bare fallow chronosequences (Grignon, France; Rothamsted, Great Britain; Ultuna, Sweden; Versailles, France) were used in this study. For each sample, the value of bi-decadal SOC mineralization was obtained from the observed SOC dynamics of its long-term bare fallow plot (approximated by a spline function). Those values ranged from 0.8 to 14.3 $gC{\cdot}kg^{-1}$ (concentration data), representing 8.6 to 50.6% of total SOC (proportion data). All samples were analyzed using RE6 and simple linear regression models were used to predict bi-decadal SOC loss (concentration and proportion data) from 4 RE6 parameters: HI, OI, PC/SOC and T50 CO_2 oxidation. HI (the amount of hydrogen-rich effluents formed during the pyrolysis phase of RE6; mgCH.g-1SOC) and OI (the CO_2 yield during the pyrolysis phase of RE6; $mgCO_2$.g-1SOC) parameters describe SOC bulk chemistry. PC/SOC (the amount of organic C evolved during the pyrolysis phase of RE6; % of total SOC) and T50 CO_2 oxidation (the temperature at which 50% of the residual organic C was oxidized to CO_2 during the RE6 oxidation phase; °C) parameters represent SOC thermal stability.

The RE6 HI parameter yielded the best predictions of bi-decadal SOC mineralization, for both concentration (R^2 = 0.75) and proportion (R^2 = 0.66) data. PC/SOC and T50 CO_2 oxidation parameters also yielded significant regression models with R^2 = 0.68 and 0.42 for concentration data and R^2 = 0.59 and 0.26 for proportion data, respectively. The OI parameter was not a good predictor of bi-decadal SOC loss, with non-significant regression models.

The RE6 thermal analysis method can predict in-situ SOC biogeochemical stability. SOC chemical composition, and to a lesser SOC thermal stability, are related to its bi-decadal dynamics. RE6 appears to be a more accurate and convenient proxy of the size of the bi-decadal labile SOC pool than other existing methodologies. Future developments include the validation of these RE6 models of bi-decadal SOC loss on soils from contrasted pedoclimatic conditions.

Reference: Barré et al., 2016. Biogeochemistry 130, 1-12