Predicting bi-decadal soil organic carbon mineralization with Rock-Eval® thermal analysis

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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 labile SOC pool such as particulate organic carbon or basal 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. Rock-Eval® 6 (RE6) 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. The objective of this study was to design a method based on RE6 indicators to assess for a given soil, the proportion of SOC that will be mineralized in the coming 20 years.

To do so, we needed samples ready to be analyzed using RE6 with a known proportion of SOC mineralized in 20 years. We used archived soil samples from 4 long-term bare fallows and 8 C3/C4 chronosequences. For each sample, the value of bi-decadal SOC mineralization was obtained from the observed SOC dynamics of its long-term bare fallow plot or the calculated C3-derived SOC decline following the conversion to C4 plants. Those values ranged from 0.3 to 14.3 gC·kg⁻¹ (concentration data), representing 8.6 to 52.6% 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: 1) HI (the amount of hydrogen-rich effluents formed during the pyrolysis phase of RE6; mgCH₉·g⁻¹ SOC), 2) O₁₀⁻₂⁻RE6 (the O recovered as CO and CO₂ during the pyrolysis phase of RE6; mgO₂·g⁻¹ SOC), 3) PC/SOC (the amount of organic C evolved during the pyrolysis phase of RE6; % of total SOC) and 4) T50 CO₂ oxidation (the temperature at which 50% of the residual organic C was oxidized to CO₂ during the RE6 oxidation
The RE6 HI parameter yielded the best predictions of bi-decadal SOC mineralization, for both concentration and proportion data. PC/SOC and T50 CO₂ oxidation parameters also yielded significant regression models. The O₁₁₀₀₆ parameter was not a good predictor of bi-decadal SOC loss, with non-significant regression models. The results showed that SOC chemical composition (HI is a proxy for SOC H/C ratio), and to a lesser degree SOC thermal stability, are related to bi-decadal SOC dynamics. The RE6 thermal analysis method can therefore provide a quantitative and accurate estimate of SOC biogeochemical stability.