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Prediction of organic carbon stability in French forest soils by near- and mid-infrared spectroscopy

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Soil organic carbon (SOC) is an essential component of food security and climate regulation. Recent international initiatives aim at increasing the size of the carbon reservoir in agricultural and forest soils globally. This requires an improved assessment of the carbon budget of soils and implies the development of reliable routine methods to monitor SOC and its biogeochemical stability.

To date, determination of SOC biogeochemical stability involves methods that are time-consuming and/or expensive (e.g. SOC basal respiration, physical SOC fractionation). Infrared spectroscopy and thermal analysis of bulk soil samples with Rock-Eval are promising proxies of SOC biogeochemical stability, infrared spectroscopy being quicker and cheaper than thermal analysis.

The objective of this work was to test the ability of near- and mid-infrared (NIR and MIR) spectroscopy to predict the biogeochemical stability of SOC in temperate forest soils, as determined by three different methods: 1/ SOC basal respiration (Respired-C = ratio of C emitted as CO_2 during a 10-week incubation at 20 °C and pF 2.5 to total SOC); 2/ SOC physical fractionation (POM-C = proportion of total SOC in the particulate organic matter fraction of size > 50 μm and density < 1.6); 3/ SOC thermal stability (T50_CO_2_PYR = the temperature at which 50% of CO_2 has evolved during the pyrolysis stage of Rock-Eval thermal analysis).

We used the archived soils of the French national survey of forest ecosystems "RENECOFOR". Our dataset included POM-C data from two soil layers (0–10 cm, 40–80 cm) from 53 sites (n = 104 samples), respired-C data from soil layers up to 1 m depth from 53 sites (n = 236 samples), and Rock-Eval T50_CO_2_PYR values from soil layers up to 1 m depth from 102 sites (n = 450 samples).

We compared the performances of three laboratory infrared spectroscopy techniques to predict SOC biogeochemical stability: diffuse reflectance NIR spectroscopy, diffuse reflectance MIR spectroscopy, and attenuated total reflectance MIR spectroscopy. Non-linear multivariate regression modeling with Random Forests was conducted to predict SOC biogeochemical stability from pre-processed infrared spectra. For each dataset, 75% of the sites were used for calibration and 25% of the sites were used for validation, ensuring a fully independent validation of the regression models.

No predictive ability of NIR or MIR spectroscopy was found for Respired-C. We observed moderate predictive performances of NIR and MIR spectroscopy for the proportion of POM-C, attenuated total reflectance MIR spectroscopy giving slightly better validation statistics (R^2val = 0.61, standard error of prediction = 0.055). Moderate to good predictive performances of NIR and MIR spectroscopy were obtained for SOC thermal stability. Diffuse reflectance MIR spectroscopy gave the best validation statistics for the T50_CO_2_PYR parameter (R^2val = 0.75, standard error of prediction = 9°C).

Our results show that NIR or MIR spectroscopy may be used as rough proxies of SOC biogeochemical stability, as assessed by SOC physical fractionation or thermal analysis. However, the moderate to good validation statistics obtained indicate that additional reference measurements are needed to assess and possibly improve the quality of prediction on new soils.