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Complementarity and drivers of thermal and physical soil organic carbon fractions at the scale of mainland France

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Introduction

Context

- Thermal and simple physical fractionations allow to measure SOC pools on large sample sets (~1000 samples).
- Rock-Eval® thermal analyses coupled to the use of the PARTYsoc machine learning model allow fractionating SOC into **active SOC** (mean residence time (MRT) ~ 30 years) and **centennially stable SOC** (Cécillon et al., 2021).
- Simple physical fractionation schemes allow distinguishing the more **labile POC** fraction (MRT ~ 10 years) from the more **stable MaOC** fraction (MRT ~ 50 years) (Balesdent et al., 1996).

Objectives

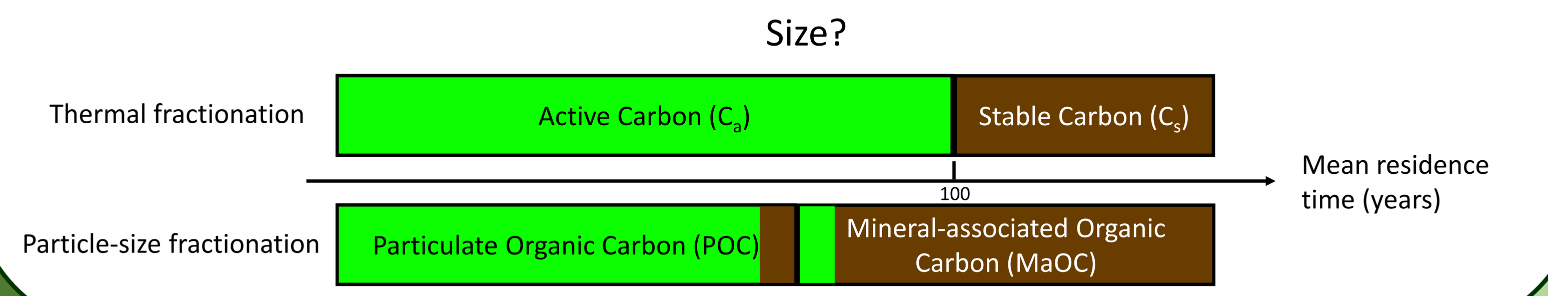
- **We evaluate for the first time the redundancy or complementarity of the active (C_a) vs POC and stable (C_s) vs MaOC fractions. For this purpose, we compared the amounts and drivers of these fractions on a large data set from mainland France with the following hypotheses:**

(1) as they do not target the same kinetic pools, POC and C_a as well as MaOC and C_s will have different sizes;

(2) proportions of fractions are influenced by land cover with higher proportion of POC and C_a in grassland and forest soils;

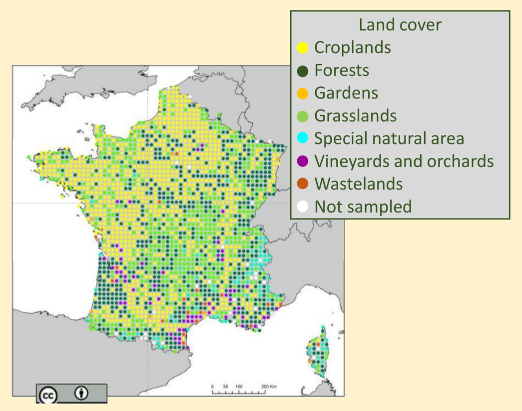
(3) the importance of pedological drivers on pool sizes will increase with MRT, whereas the importance of land cover will decrease with MRT;

(4) the quantity of MaOC and C_s will saturate at a certain TOC level.



Material & methods

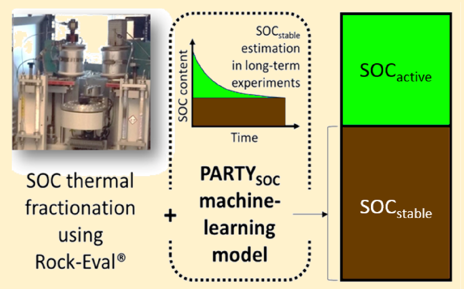
The French Soil Quality Monitoring Network: RMQS (Jolivet et al., 2006)



- 2038 topsoil samples.
- Rock-Eval® thermal analyses and physical fractionation on significant subsets.
- Land cover (cropland, grassland, forest and vineyard), climatic and main soil properties for each site.

The $PARTY_{SOC}$ model (Cécillon et al., 2018; 2021) (n=1621)

- $PARTY_{SOC}$ is a **machine-learning model** (Random Forest) using the Rock-Eval® data to quantify the proportion of carbon which is stable **over a century**.



The POC/MaOC fractionation (n=954)

- Dispersion of the soil in $Na_6[(PO_3)_6]$.
- Sieving to 3 fractions (>0.2 mm; 0.05–0.2 mm, <0.05 mm), grinding.
- C and N measurements by elemental analysis.

A Random Forest model to determine the drivers of C_a, C_s, POC and MaOC fractions

- The drivers were separated into 3 categories:

Land cover: Croplands, Forests, Grasslands, Vineyards
Climate: Mean annual rainfall, Mean annual temperature
Pedology: Clay, Sand, pH, Inorganic carbon, Amorphous & crystalline iron oxyhydroxides, Exchangeable calcium

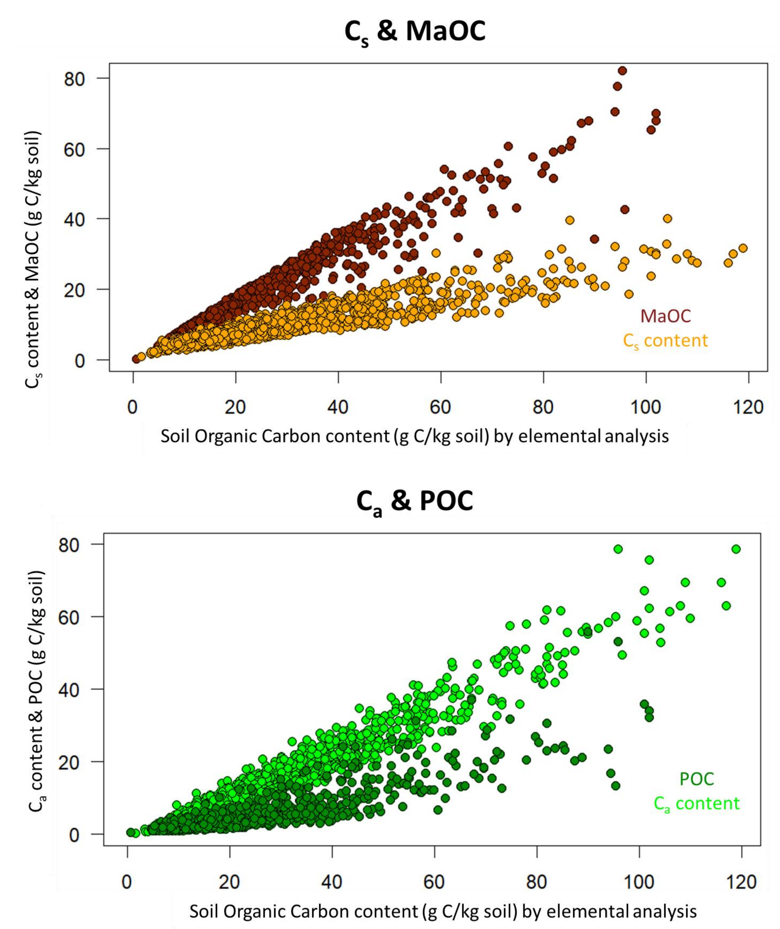
- We estimated the relative role of each category for the 4 fractions by two kinds of calculations: the Mean Decrease in Impurity (MDI), which estimates the importance ranks of the features, and the permutation-based score variation, which calculates the decrease in a model score when a feature value is randomly modified.

Results

I) Fractions are of different size

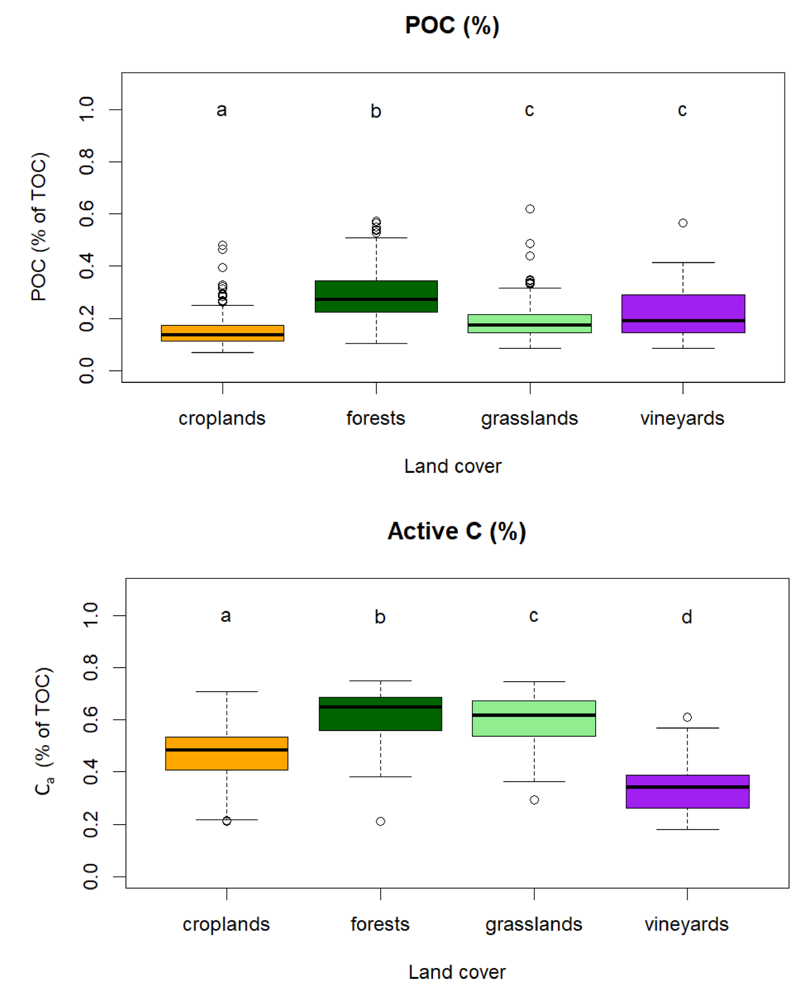
We limited our results to samples with a soil organic carbon content < 120 g/kg soil to exclude organic soils (e.g. peatlands).

MaOC ~ 2.2 × C_s
POC ~ 0.45 × C_a
C_s/MaOC standard deviation: 0.13
POC/C_a standard deviation: 0.23



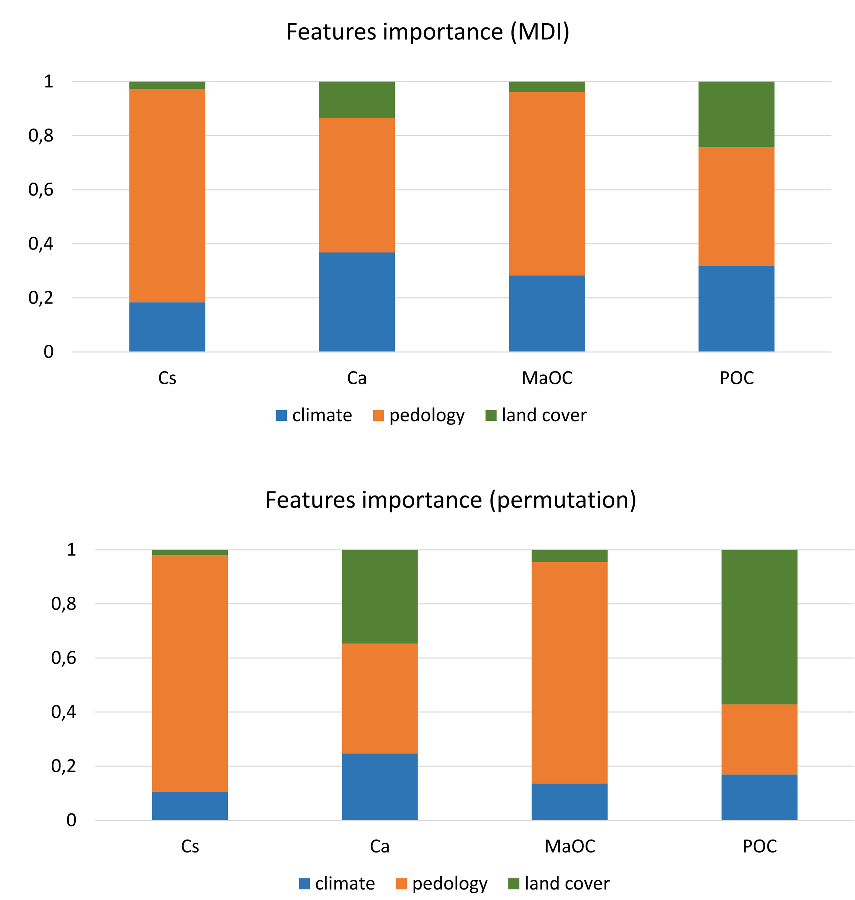
II) C_a and POC proportions are smaller in croplands than in forests and grasslands

- C_a and POC as percentage of TOC are smaller in cropland compared to grassland and forest soils.
- The proportion of C_a is the smallest in vineyards.
- Contrary to our hypothesis the proportion of POC is similar in vineyards and grasslands.



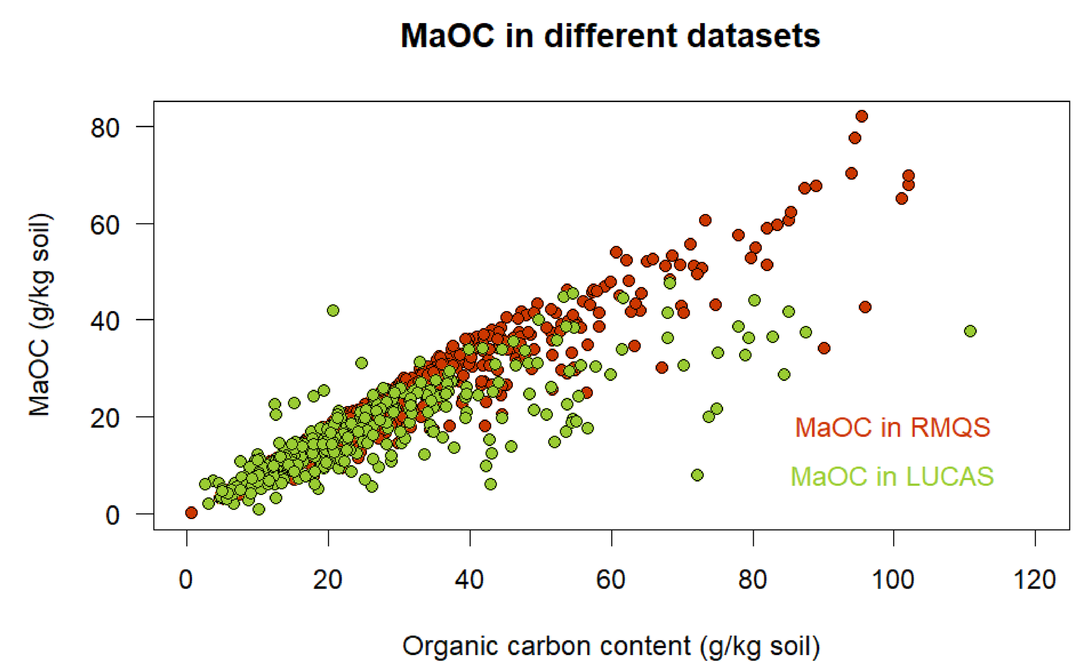
III) Pedology drives the stable fractions, land cover and climate drive the labile fractions

C_s and MaOC show similar drivers, as well as C_a and POC.
Climate and land cover parameters have an important influence on POC and to a lesser extent on C_a; their effect is weaker on MaOC and even smaller on C_s.



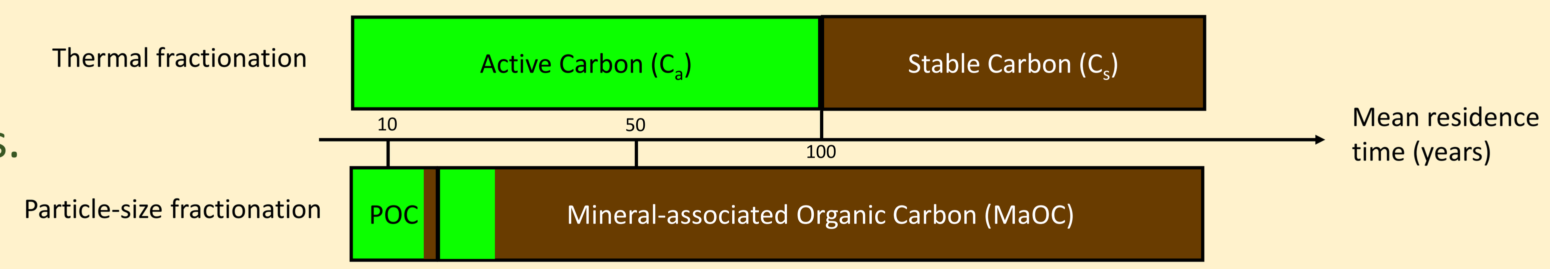
IV) Comparison of the MaOC fraction with previous datasets

We compared our MaOC dataset with a previous large dataset (n=352) of MaOC fractions obtained on the European LUCAS survey. Contrary to our hypothesis and previous studies, our results raise questions on whether the MaOC saturates at all.



Discussion and conclusion

- Our hypotheses based on previous works (Balesdent et al., 1996; Cécillon et al., 2021) regarding the size of the fractions and their drivers were globally confirmed by the data analysis: C_a and POC, as well as C_s and MaOC, show strong differences in size, on top of differences in MRT (Balesdent et al., 1996; Cécillon et al., 2021), as summarized on the bottom figure. Pedology is the dominant factor for all the fractions, but climate and land use have a much greater importance in POC and C_a, which is consistent with the fact that these compartments are very dependent on the fresh inputs.
- Although the proportion of both labile pools is smaller in croplands than in forests and grasslands, it is surprising that the POC fraction is similar in grasslands and vineyards.
- Our results suggest that the MaOC fraction does not saturate with TOC.



Acknowledgements

The École Normale Supérieure de Paris is greatly acknowledged for the funding of my PhD. The ADEME and EJP Soil external call (Freacs project) are greatly acknowledged for their support.

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