Initializing the stable pool of soil carbon models using Rock-Eval thermal analysis to improve their accuracy

Pierre Barré, Lauric Cecillon, François Baudin, Hugues Clivot, Fabien Ferchaud, Eva Kanari, Bruno Mary, Laure Soucémarianadin, Claire Chenu

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Context

1 Soil organic carbon (SOC) stability

- **SOC residence time → from hours to millenia** *(Trumbore, 1997, PNAS)*
- A **significant and strongly variable** amount of SOC is centennially stable

→ *5–16 gC kg^{-1} soil in agricultural soils from Northwestern Europe*
(Barré et al., 2010, BG; Franko and Merbach, 2017, Geoderma; Cécillon et al., 2018, BG)

→ Need for routine and properly validated methods to initialize the size of the stable SOC pool in SOC models

2 Routine knowledge on SOC stability is key to accurate SOC simulations

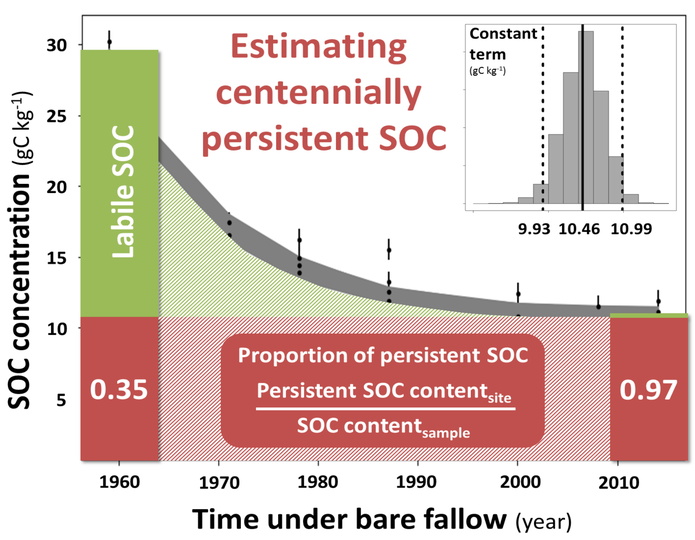
- **High sensitivity of SOC models to the size & age of the stable SOC pool**
  - poorly constrained in Earth System Models → 40% overestimation of SOC storage potential *(He et al., 2016, Science)*
  - its optimization in the AMG soil carbon model strongly improves SOC simulations *(Clivot et al., 2019, ENVIRON MODELL SOFTW)*
- SOC pool with mean residence time > 100 years in soil carbon models: → from ***ca.* 15% (RothC)** to ***ca.* 65–70% (AMG & Century)** of total SOC at equilibrium
- Some proposed methods to initialize the size of SOC pools in RothC (including inert) *(Falloon et al., 1998, SBB; Skjemstad et al., 2004, AUST J SOIL RES; Zimmermann et al., 2007, EJSS)*
  - → ***meaningful in non-equilibrium conditions***
  - → ***methods correlated, but marginally validated*** *(Skjemstad et al., 2004; Leifeld et al., 2009, AGRON J; Herbst et al., 2018, Geoderma)*

Objective

Improve the accuracy of the AMG soil carbon model by initializing the size of its large & variable stable SOC pool using a method based on Rock-Eval thermal analysis

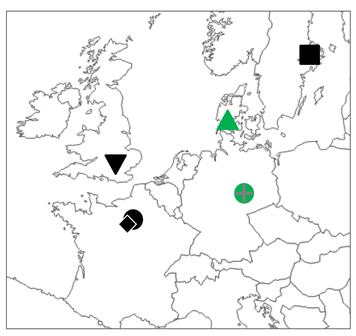
→ 2 steps

Step 1 → Extend the method based on Rock-Eval thermal analysis to measure stable SOC in agricultural soils



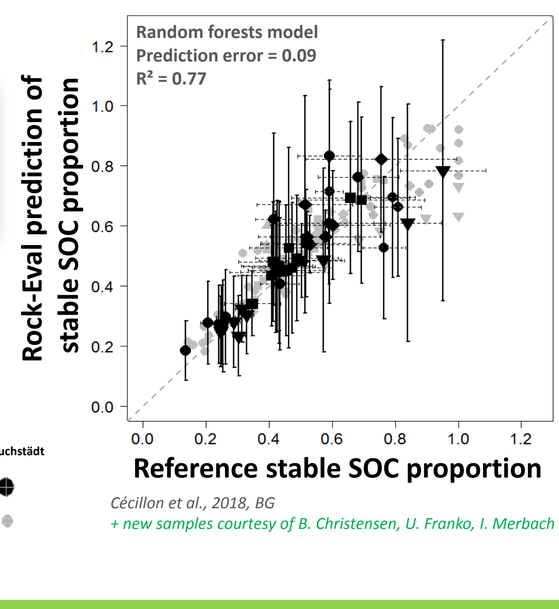
Use of archive soils from long term bare fallow sites + adjacent agricultural plots

$\gamma(t) = ae^{-bt}$ + stable SOC



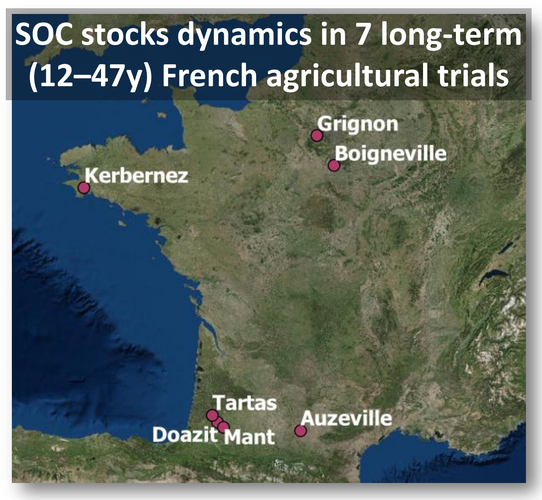
A set of 134 soil samples from 6 sites in Europe with estimated stable SOC proportions [0.14–1]

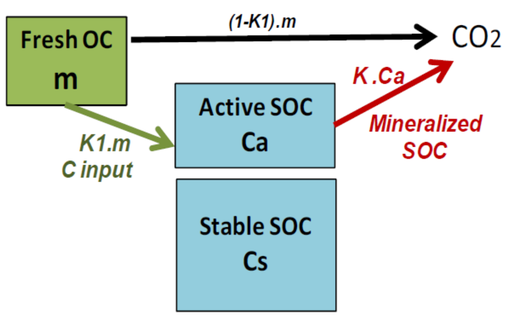
Proportion of stable SOC *as a function of* 24 Rock-Eval parameters



Cécillon et al., 2018, BG
+ new samples courtesy of B. Christensen, U. Franko, I. Merbach

Step 2 → initializing the stable SOC pool of the AMG model using the Rock-Eval method to improve its accuracy





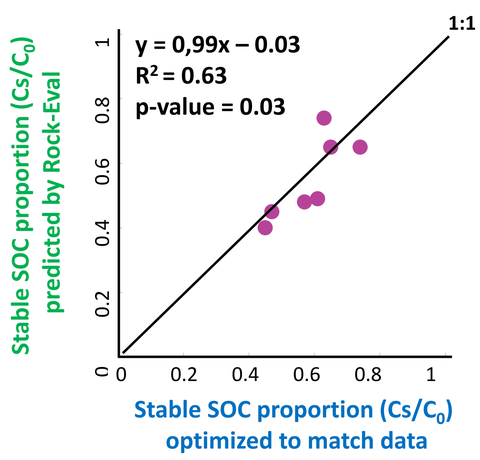
C = Ca + Cs
dC /dt = K1.m – K.Ca
Fluxes and pools of SOC in the AMG model

Duparque et al., 2013, pers. com.
Clivot et al., 2019, ENVIRON MODELL SOFTW

Cs/C_0 = 0.65
Default value in cropland

Cs/C_0 = ?
Rock-Eval on archived soils

Cs/C_0 = ?
Optimized to match data



Clivot et al., 2019, ENVIRON MODELL SOFTW; Kanari et al., in prep

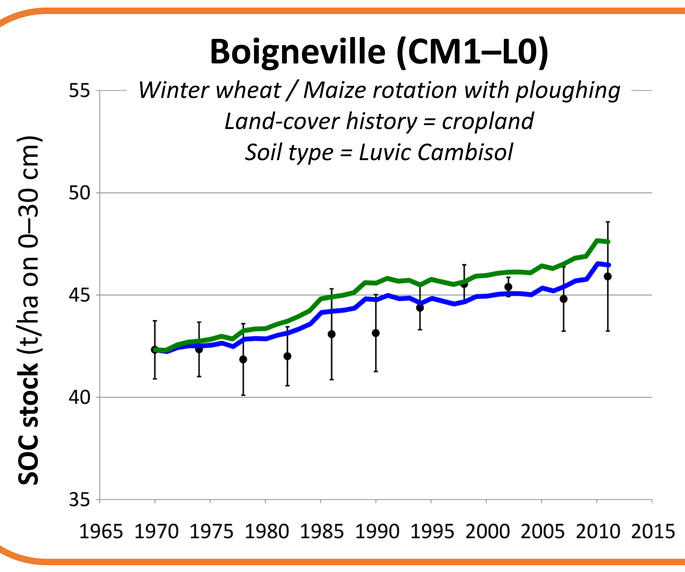
Overall RMSE of AMG SOC simulations

Default
3.7 tC/ha [0.2–11.5]

Rock-Eval method
3.2 tC/ha [1.4–5.1]

Optimized
2.1 tC/ha [0.6–4.3]

Boigneville (CM1–L0)



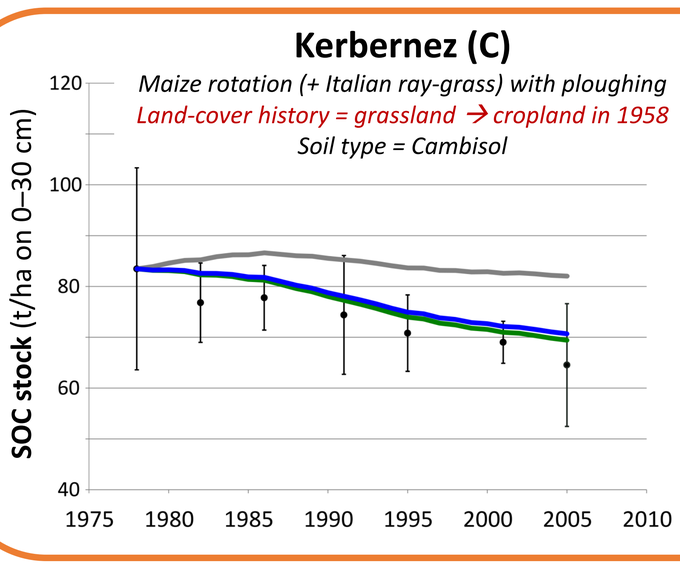
Default
Cs/C_0 = 0.65
RMSE = 0.8 tC/ha

Rock-Eval method
Cs/C_0 = 0.68
RMSE = 1.4 tC/ha

Optimized
Cs/C_0 = 0.65
RMSE = 0.8 tC/ha

Kanari et al., in prep

Kerbernez (C)



Default
Cs/C_0 = 0.65
RMSE = 11.5 tC/ha

Rock-Eval method
Cs/C_0 = 0.45
RMSE = 3.5 tC/ha

Optimized
Cs/C_0 = 0.47
RMSE = 4.3 tC/ha

Kanari et al., in prep

Conclusions

→ AMG model initialized using the Rock-Eval method is more accurate ! *(Kanari et al., in prep)*

→ Especially in fields with complex history of land-use or management practices

What's next ?

1. **Rock-Eval-based method to predict stable SOC proportion**
   - Increase the number of sites to improve the robustness of the model
   - Design new improved random forests models
2. **Soil carbon model initialization using the Rock-Eval based method**
   - Increase the number of sites
   - Test other models (RothC, ORCHIDEE)
   - Test other land-cover (grassland, forest)

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