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

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

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

Poitiers | France | 18 june 2019

Context

1 Soil organic carbon (SOC) stability

- SOC residence time:
  → **from hours to millenia**
  (Trumbore, 1997)
- 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; Franko and Merbach, 2017; Cécillon et al., 2018)

Context

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)
  - its optimization in the AMG soil carbon model strongly improves SOC simulations
  (Clivot et al., 2019)

Context

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)*
  - its optimization in the AMG soil carbon model strongly improves SOC simulations *(Clivot et al., 2019)*
- 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; Skjemstad et al., 2004; Zimmermann et al., 2007)*
  → ***meaningful in non-equilibrium conditions***
  → ***methods correlated, but marginally validated*** *(Skjemstad et al., 2004; Leifeld et al., 2009; Herbst et al., 2018)*

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

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

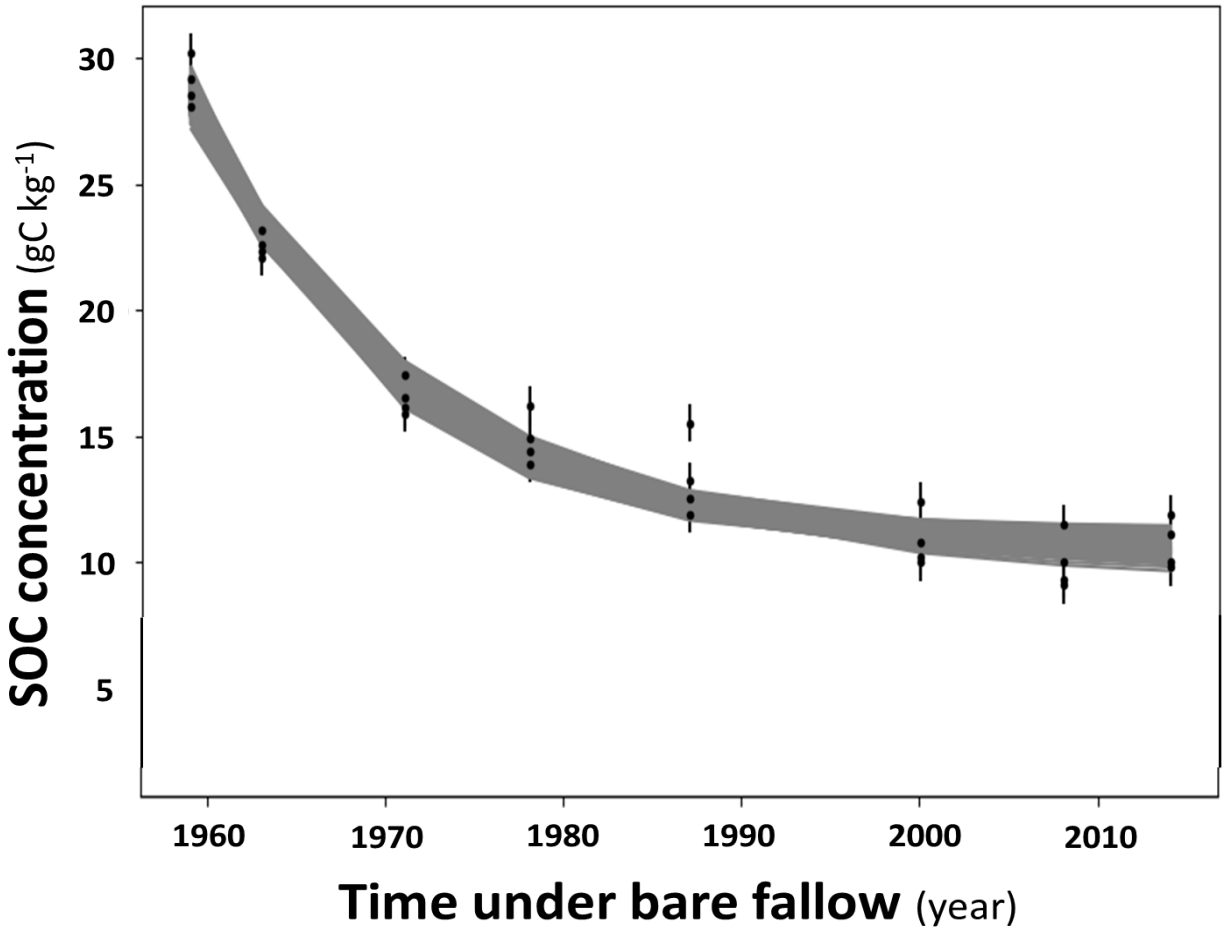
2 steps

1. **Extend the method based on Rock-Eval to measure stable SOC**
   → ongoing process based on a study published in Biogeosciences (Cécillon et al., 2018)

2. **Does initializing the stable SOC pool of the AMG model using the Rock-Eval method improve simulations of SOC dynamics ?**
   → Test on 7 long-term agricultural trials in France (Kanari et al., in prep)

1 Extend the method based on Rock-Eval to measure stable SOC

→ ongoing process based on long-term bare fallow (LTBF) experiments



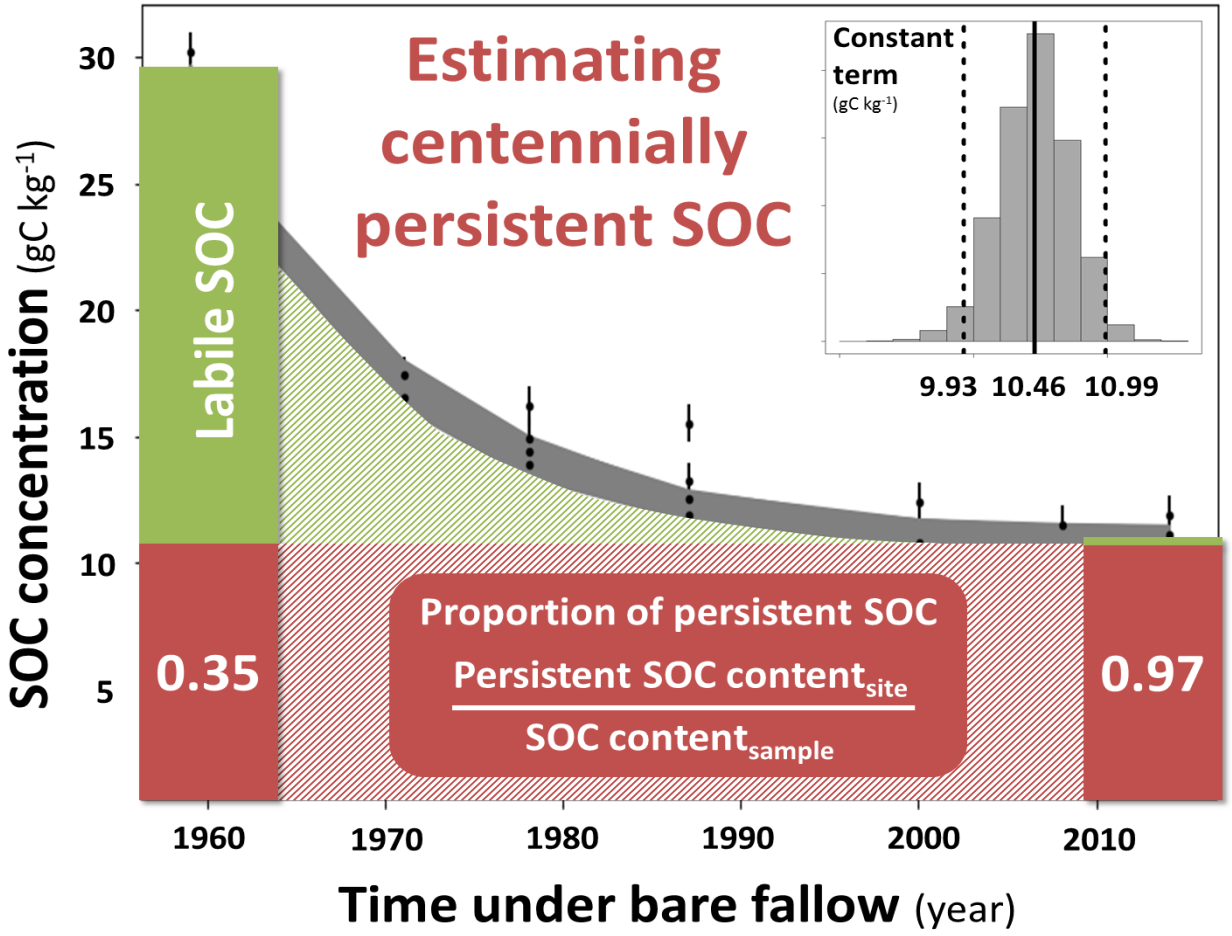
$$y(t) = ae^{-bt} + \text{stable SOC}$$

Long term bare fallow soils become gradually enriched in stable SOC

Barré et al., 2010; Cécillon et al., 2018

1 Extend the method based on Rock-Eval to measure stable SOC

→ ongoing process based on long-term bare fallow (LTBF) experiments



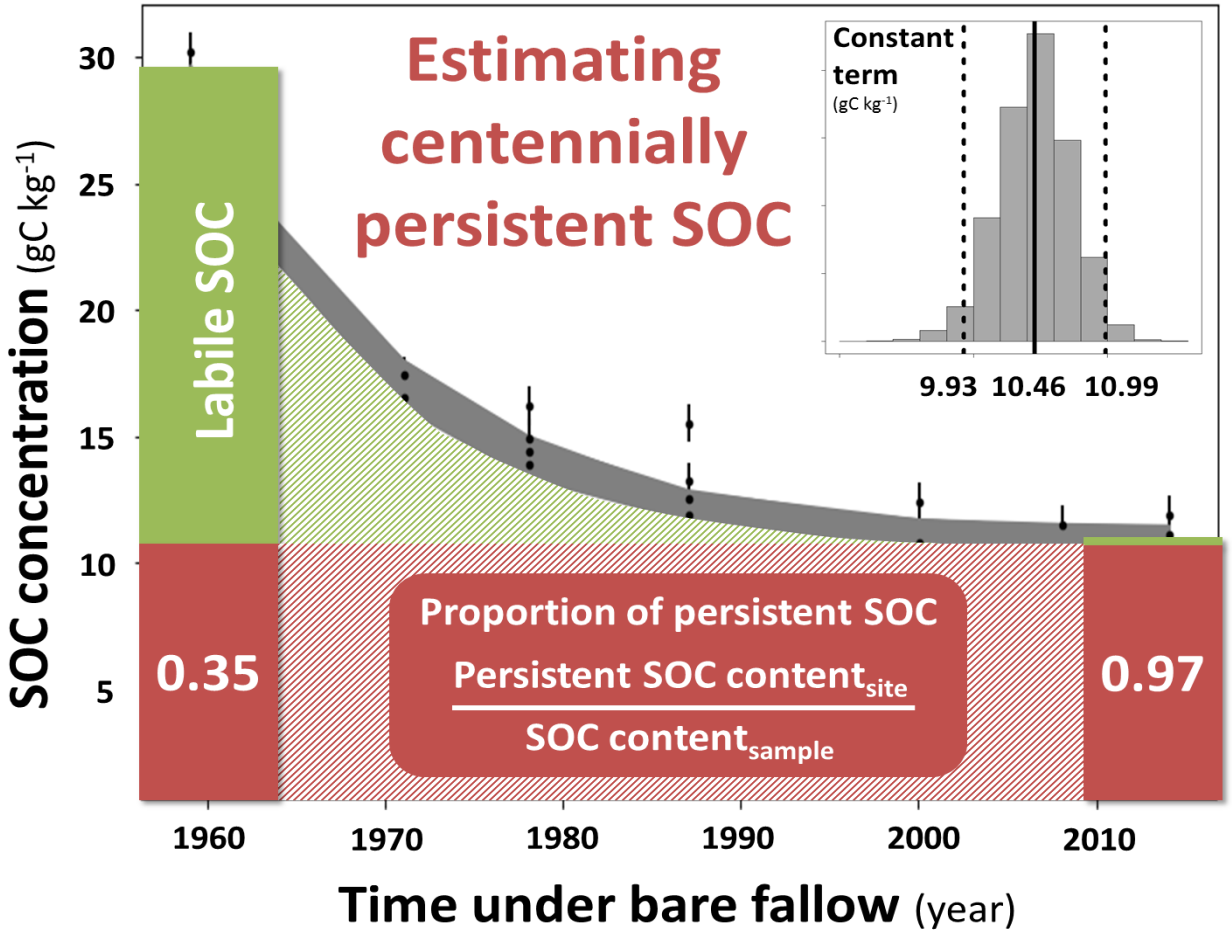
$$y(t) = ae^{-bt} + \text{stable SOC}$$

Use of archive soils from LTBF sites + adjacent agricultural fields

Barré et al., 2010; Cécillon et al., 2018

1 Extend the method based on Rock-Eval to measure stable SOC

→ ongoing process based on long-term bare fallow (LTBF) experiments



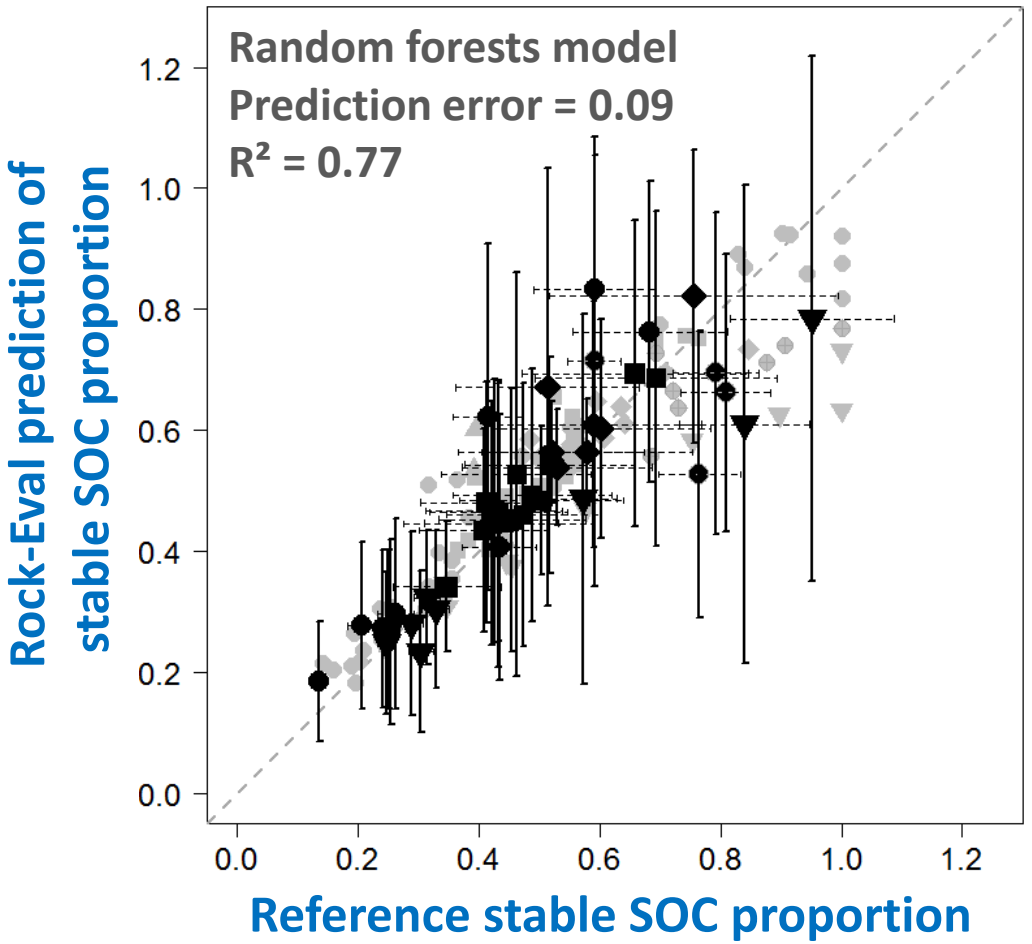
$$y(t) = ae^{-bt} + \text{stable SOC}$$

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

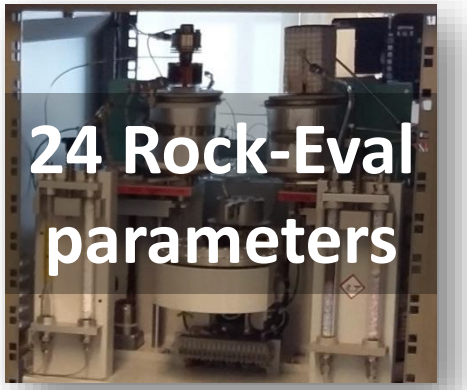
Cécillon et al., 2018 + new samples courtesy of B. Christensen, U. Franko, I. Merbach

1 Extend the method based on Rock-Eval to measure stable SOC

→ ongoing process based on long-term bare fallow (LTBF) experiments



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



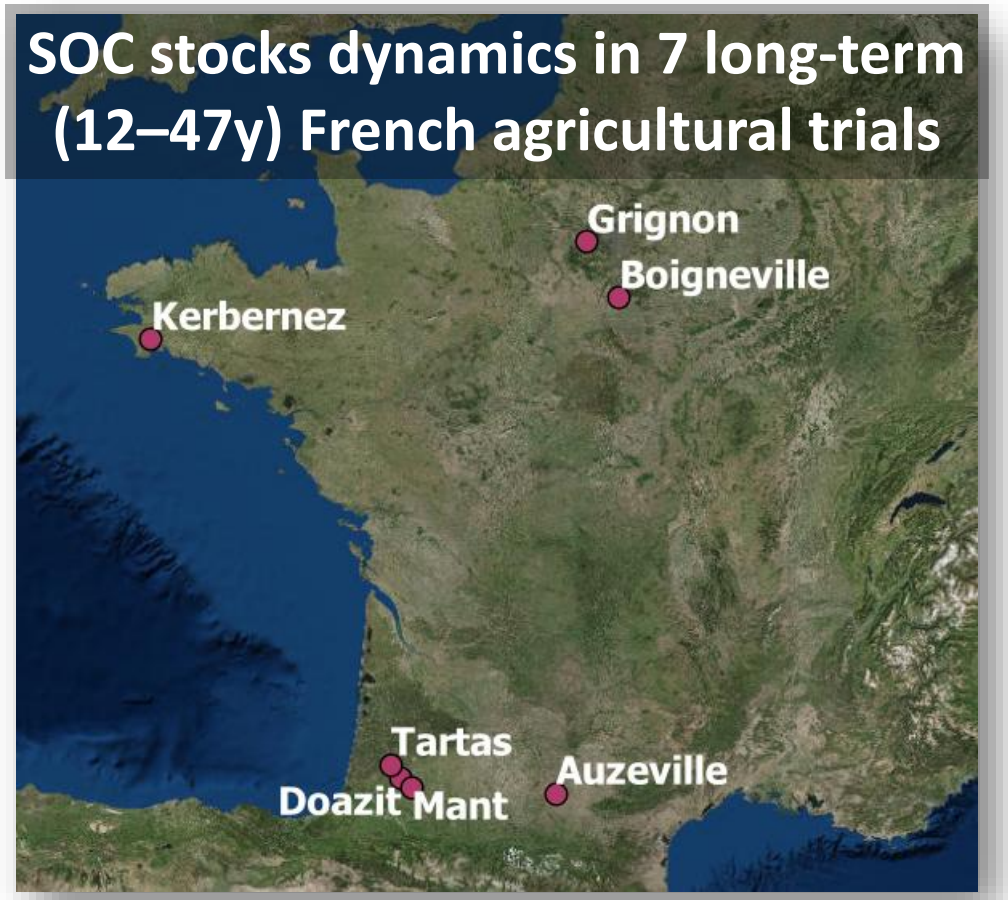
Versailles Rothamsted Grignon Ultuna Askov Bad Lauchstädt

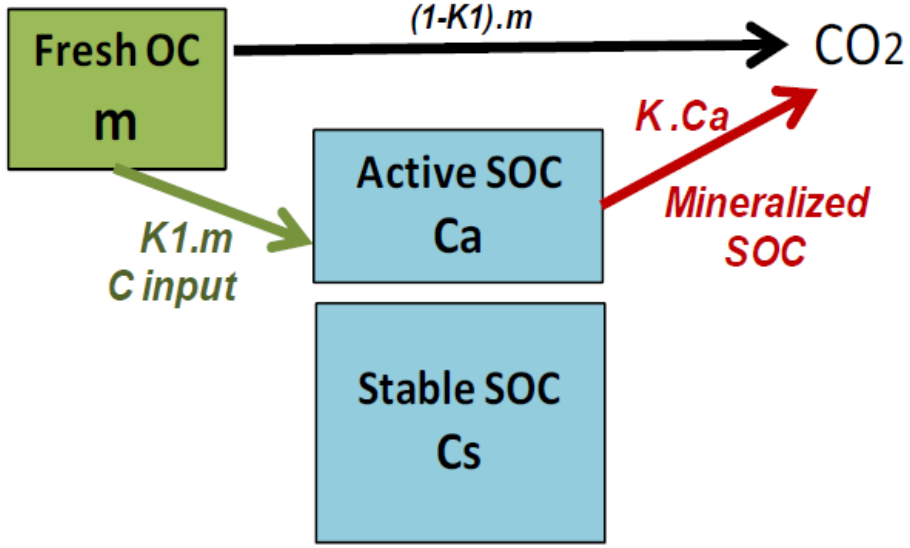
Validation (44 samples)

Calibration (90 samples)

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

2 Does initializing the stable SOC pool of the AMG model using Rock-Eval improve simulations of SOC dynamics ?





$C = Ca + Cs$

$dC/dt = K1.m - K.Ca$

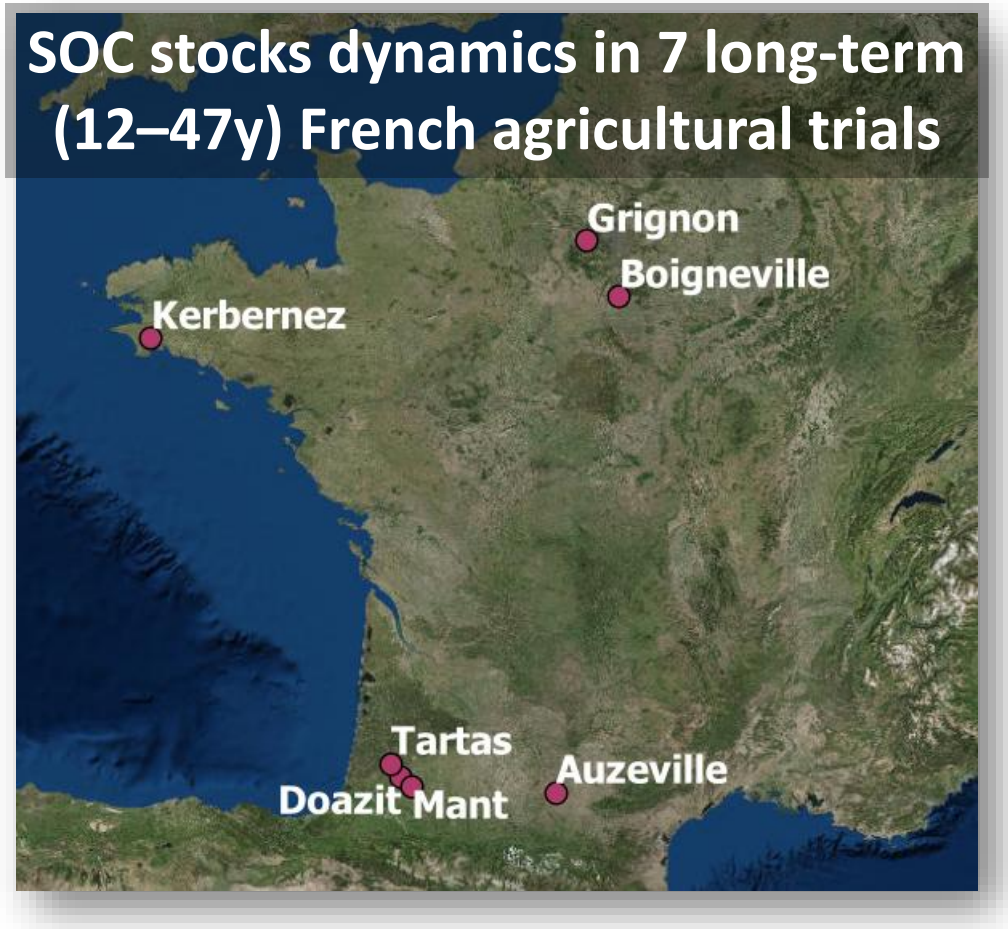
$Cs/C_0 = 0.65$

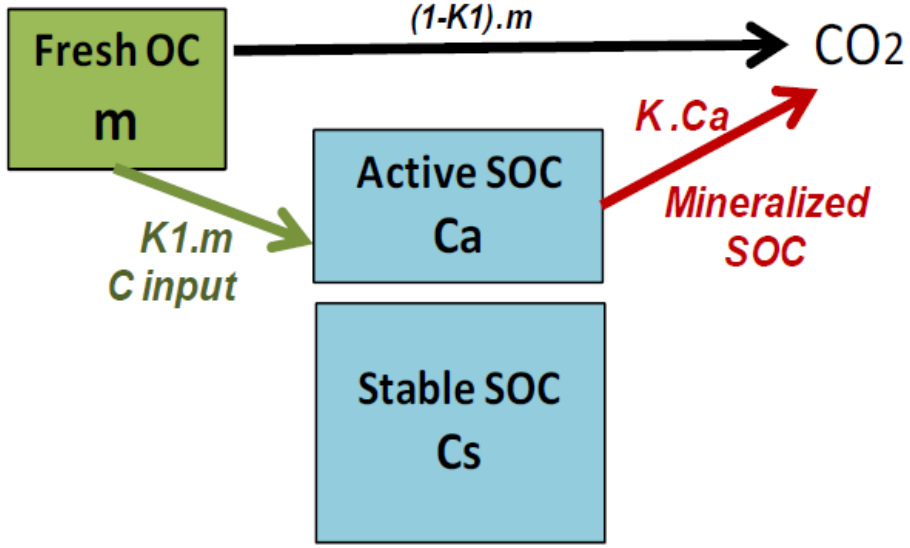
Default value in cropland

Fluxes and pools of SOC in the AMG model

Duparque et al., 2013; Clivot et al., 2019

2 Does initializing the stable SOC pool of the AMG model using Rock-Eval improve simulations of SOC dynamics ?





$C = Ca + Cs$

$dC/dt = K1.m - K.Ca$

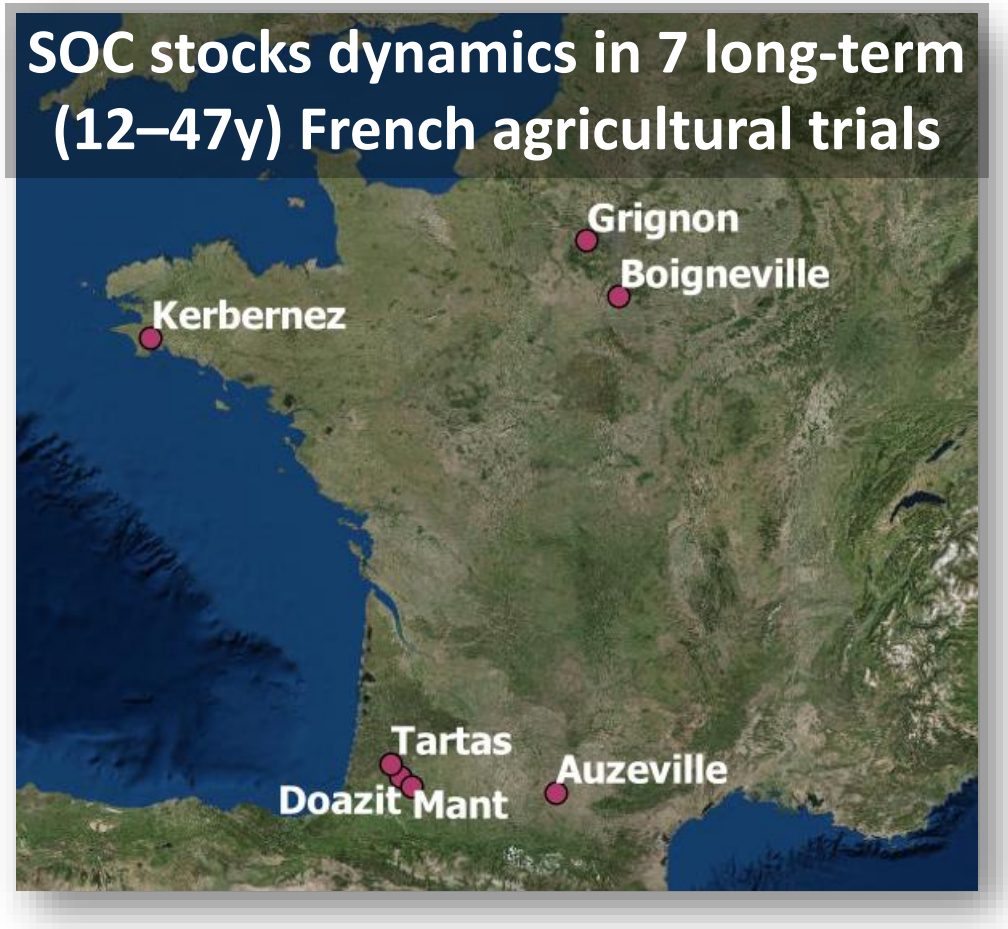
Cs/C_0 = ?

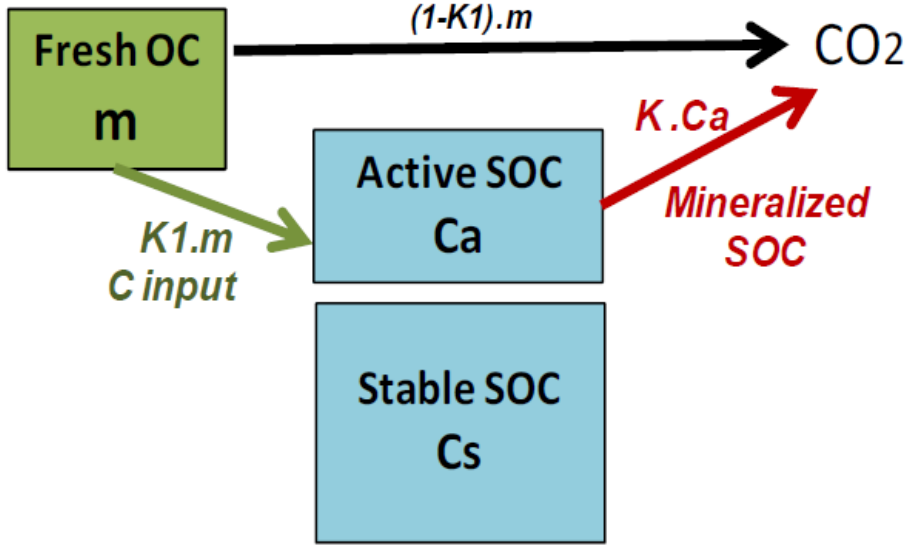
Rock-Eval on archived soils

Fluxes and pools of SOC in the AMG model

Duparque et al., 2013; Clivot et al., 2019

2 Does initializing the stable SOC pool of the AMG model using Rock-Eval improve simulations of SOC dynamics ?





$C = Ca + Cs$

$dC/dt = K1.m - K.Ca$

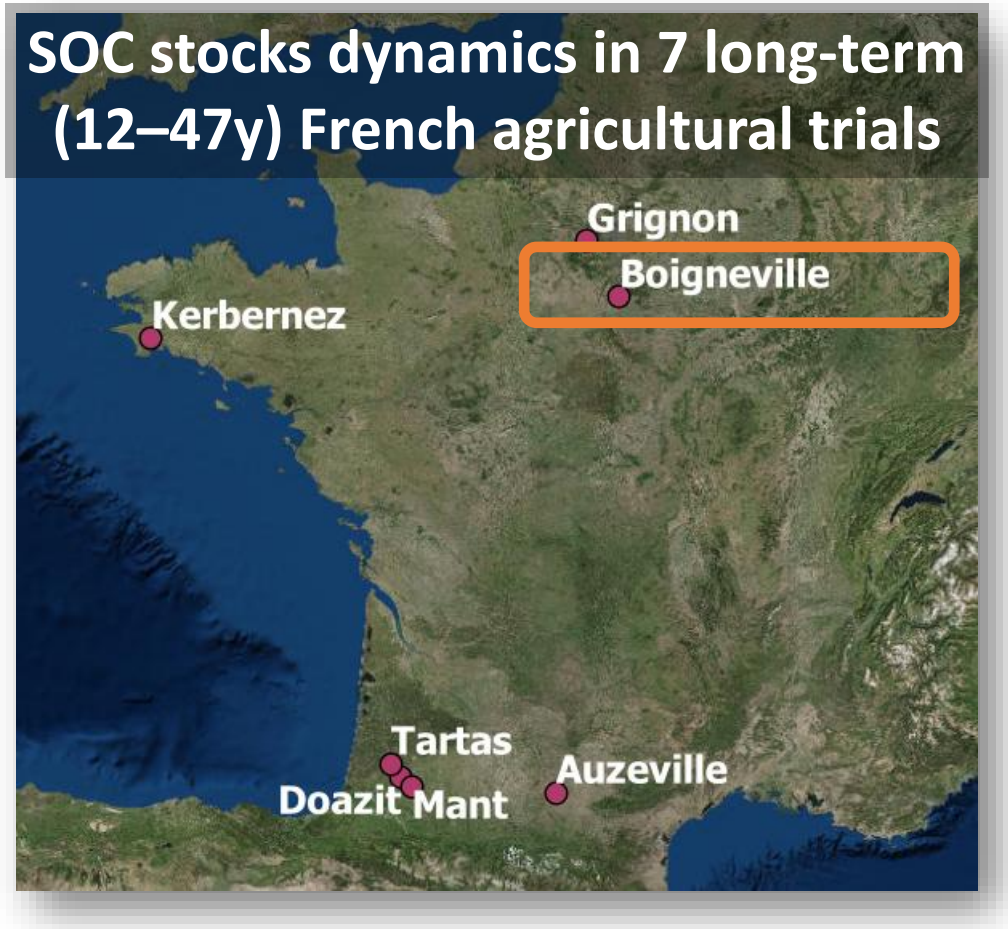
Cs/C_0 = ?

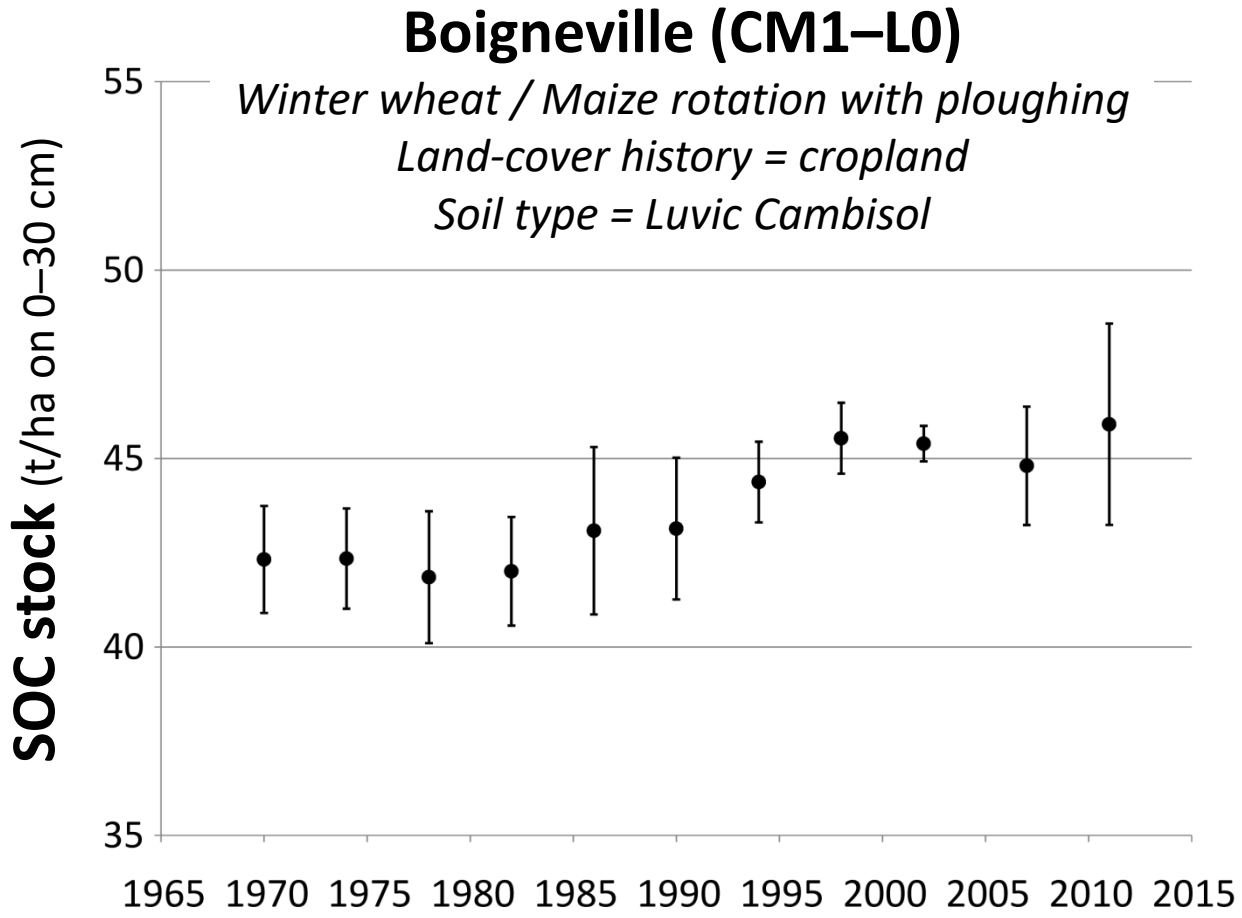
Optimized to match data

Fluxes and pools of SOC in the AMG model

Duparque et al., 2013; Clivot et al., 2019

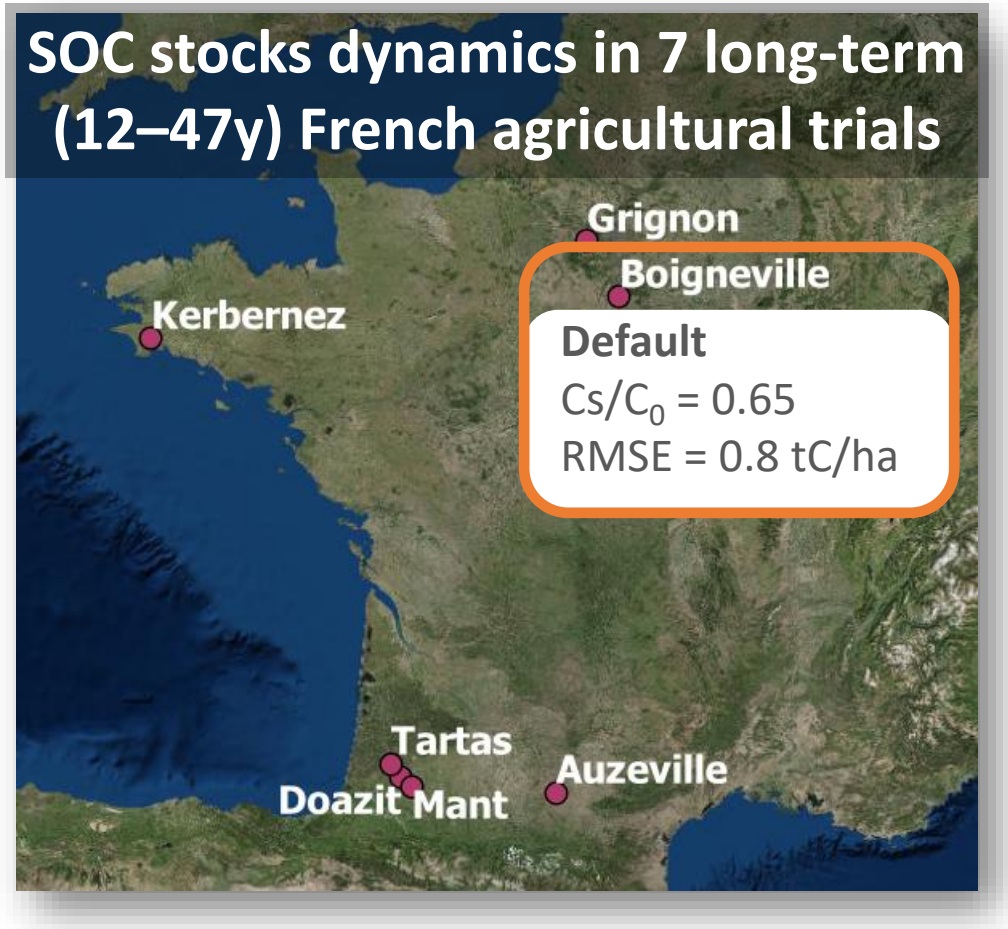
2 Does initializing the stable SOC pool of the AMG model using Rock-Eval improve simulations of SOC dynamics ?

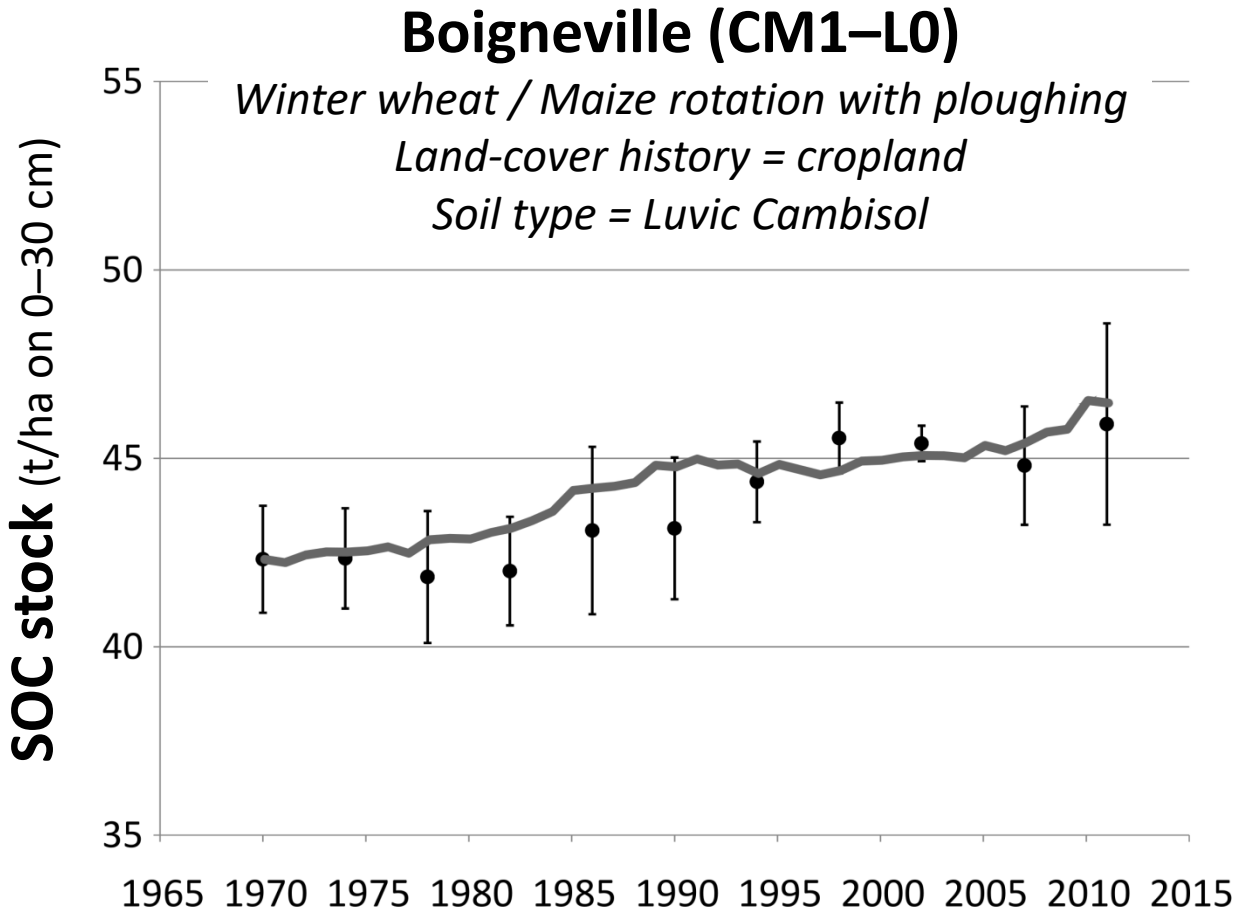




Clivot et al., 2019; Kanari et al., in prep

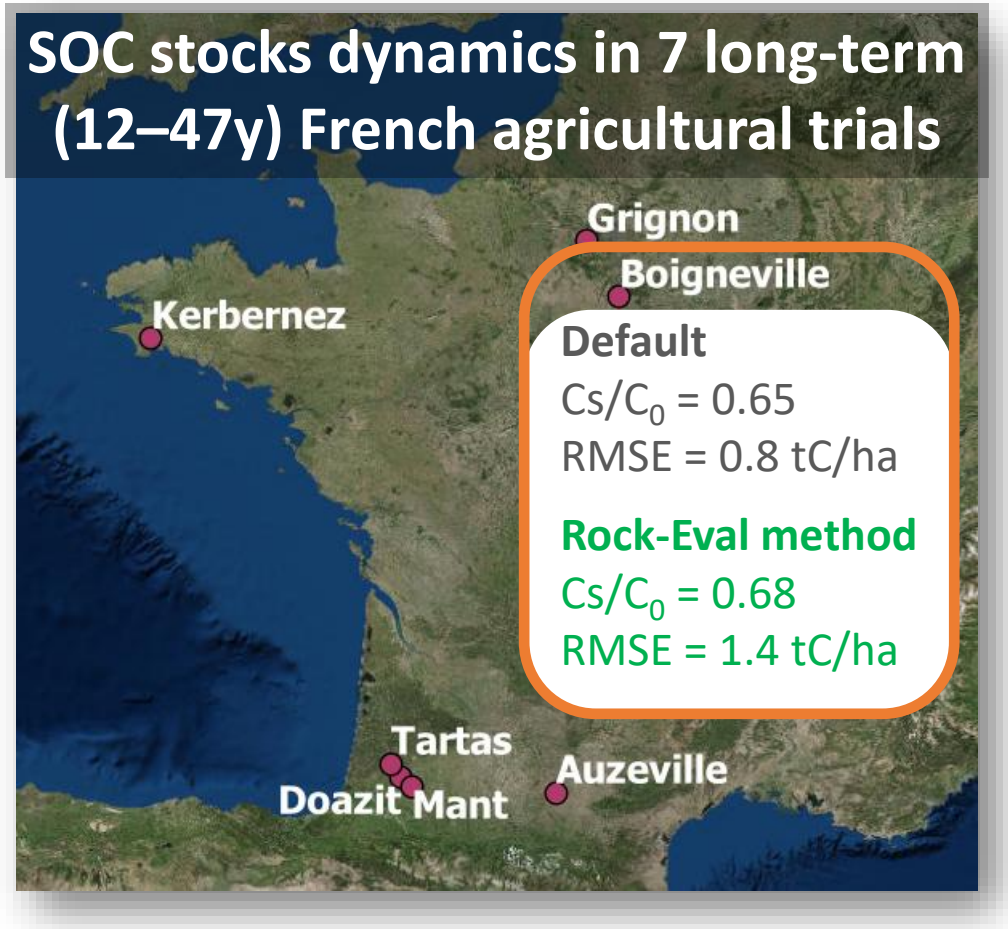
2 Does initializing the stable SOC pool of the AMG model using Rock-Eval improve simulations of SOC dynamics ?

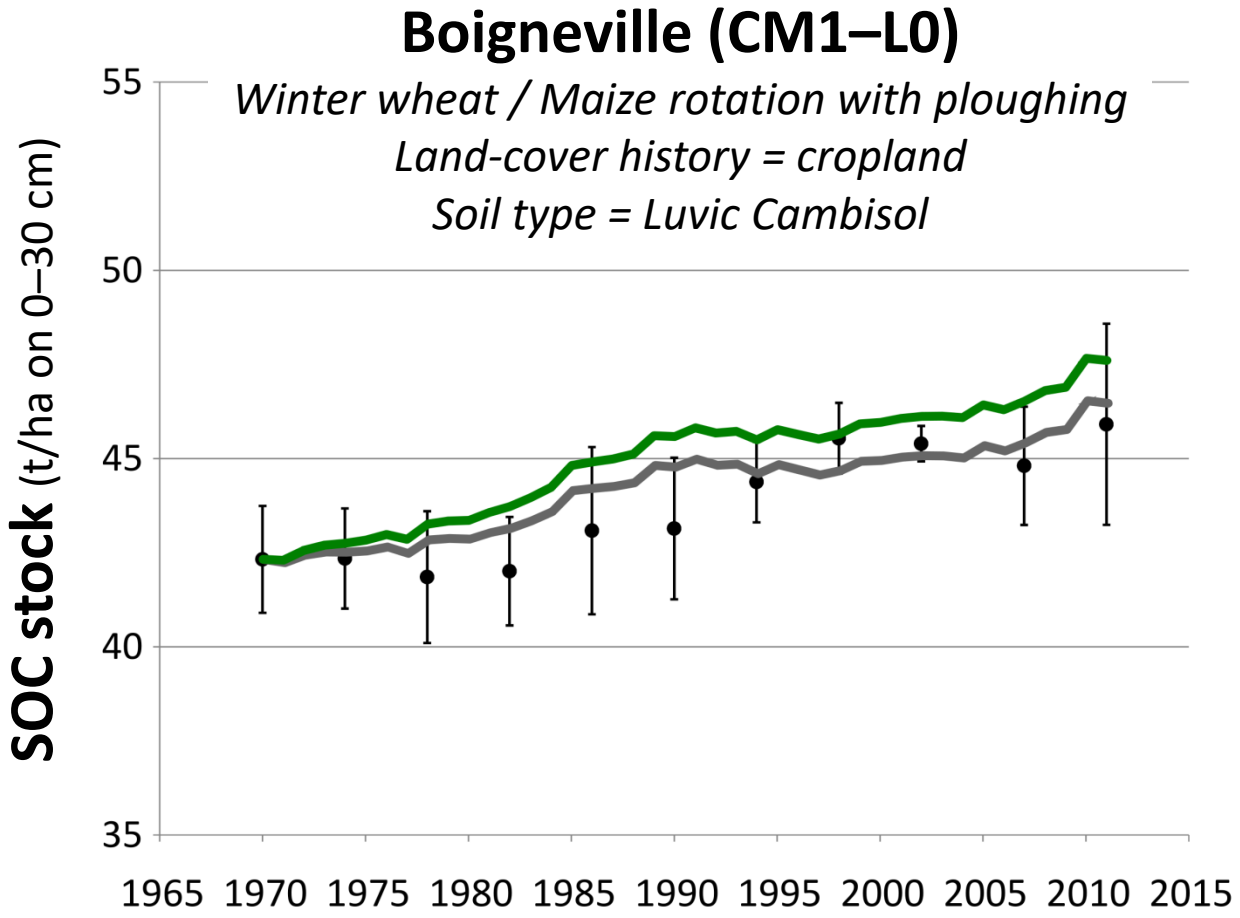




Clivot et al., 2019; Kanari et al., in prep

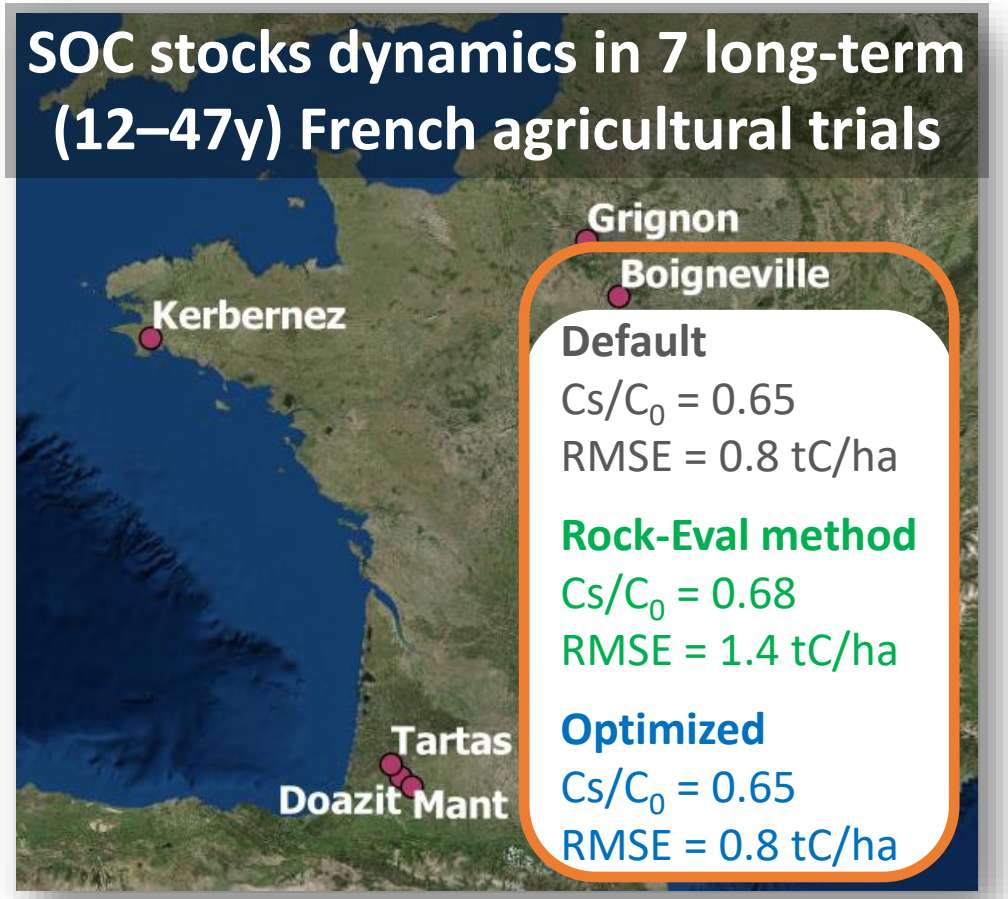
2 Does initializing the stable SOC pool of the AMG model using Rock-Eval improve simulations of SOC dynamics ?

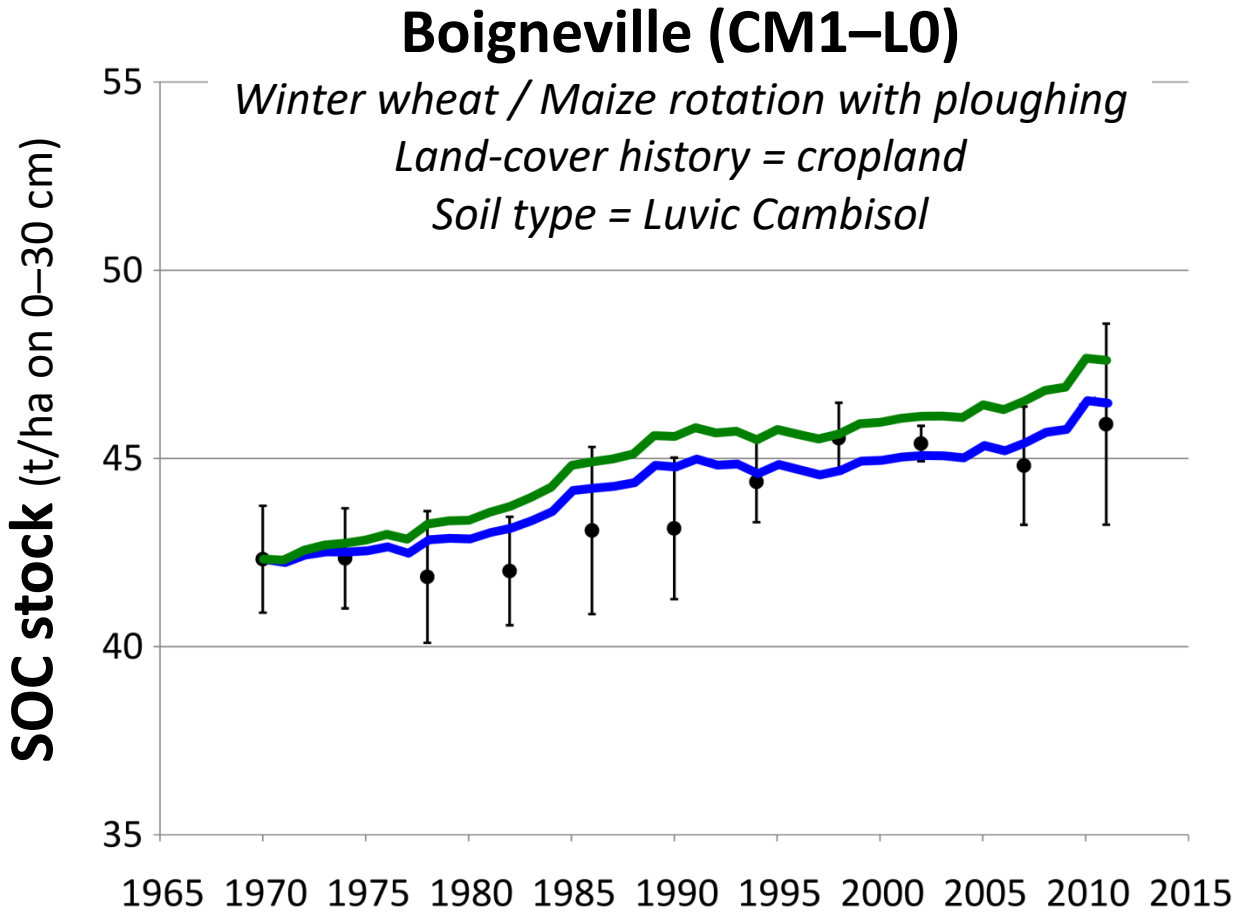




Clivot et al., 2019; Kanari et al., in prep

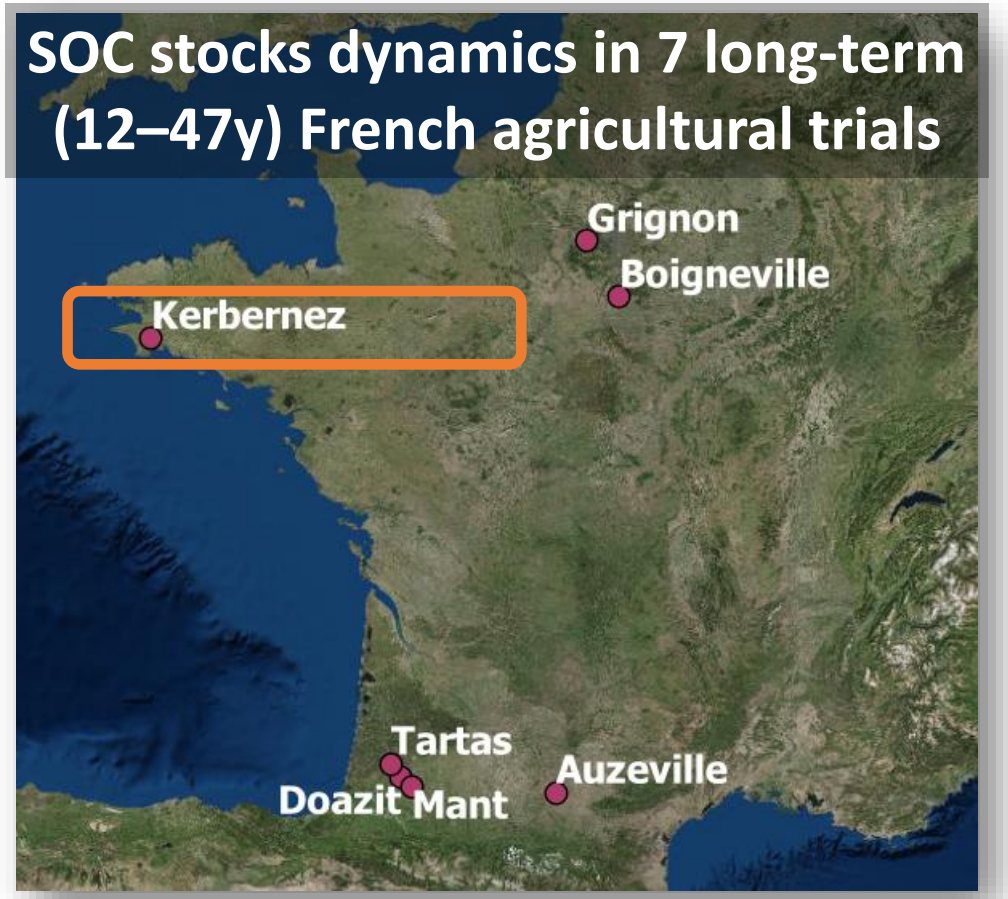
2 Does initializing the stable SOC pool of the AMG model using Rock-Eval improve simulations of SOC dynamics ?

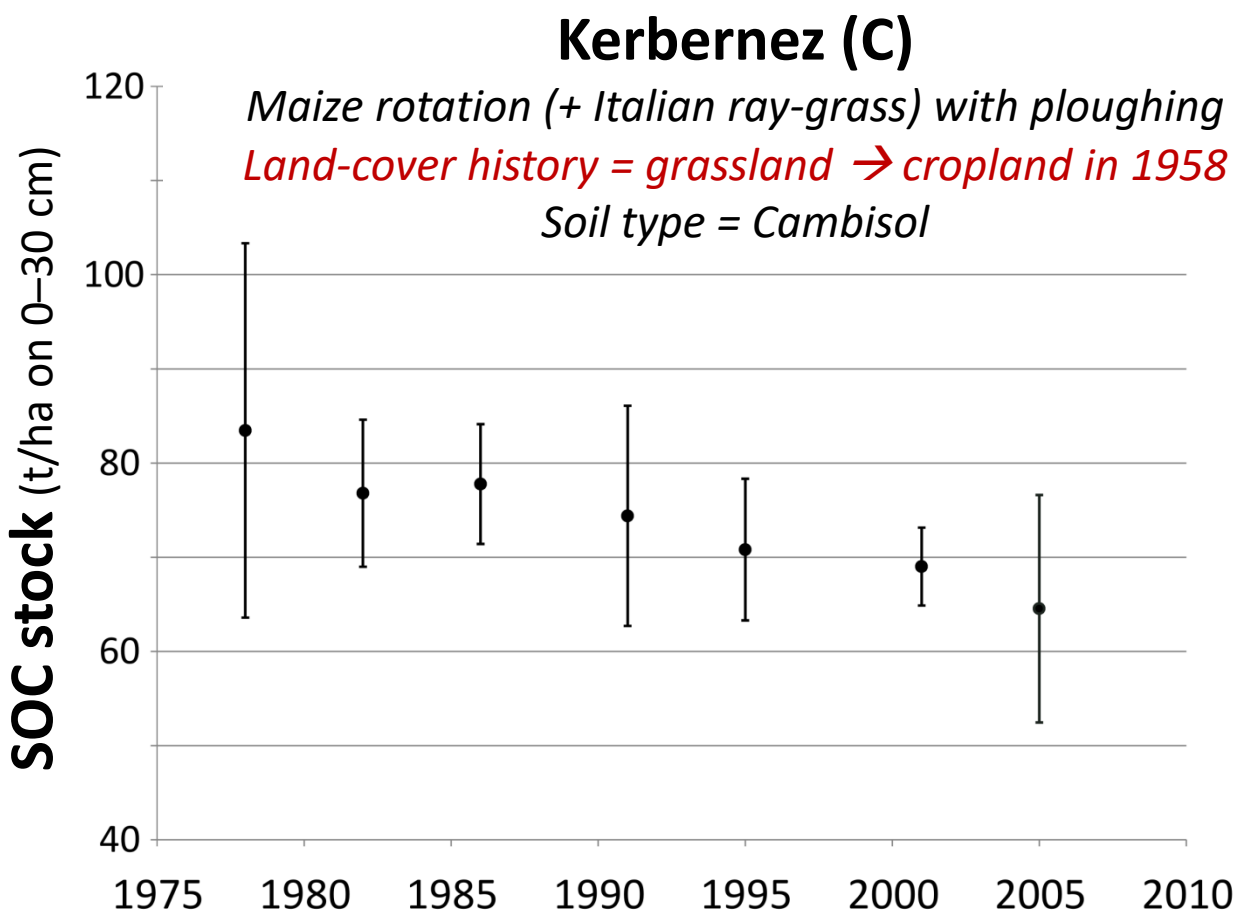




Clivot et al., 2019; Kanari et al., in prep

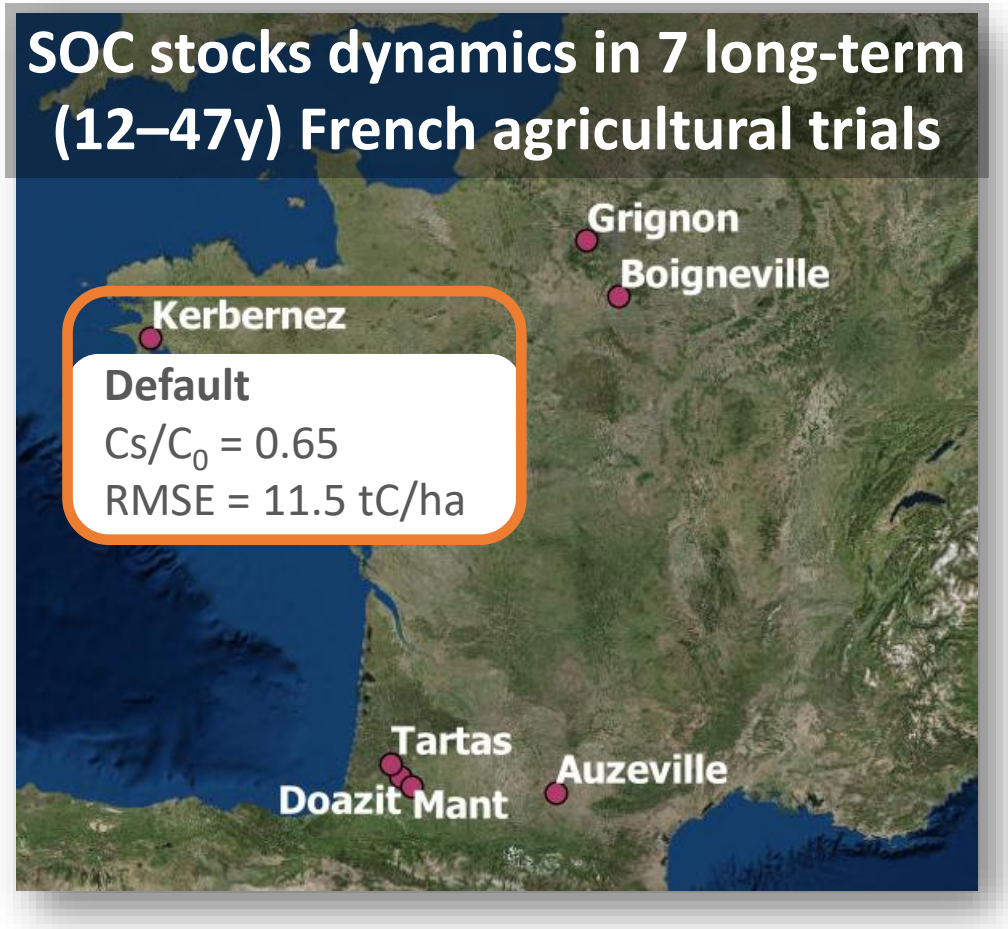
2 Does initializing the stable SOC pool of the AMG model using Rock-Eval improve simulations of SOC dynamics ?

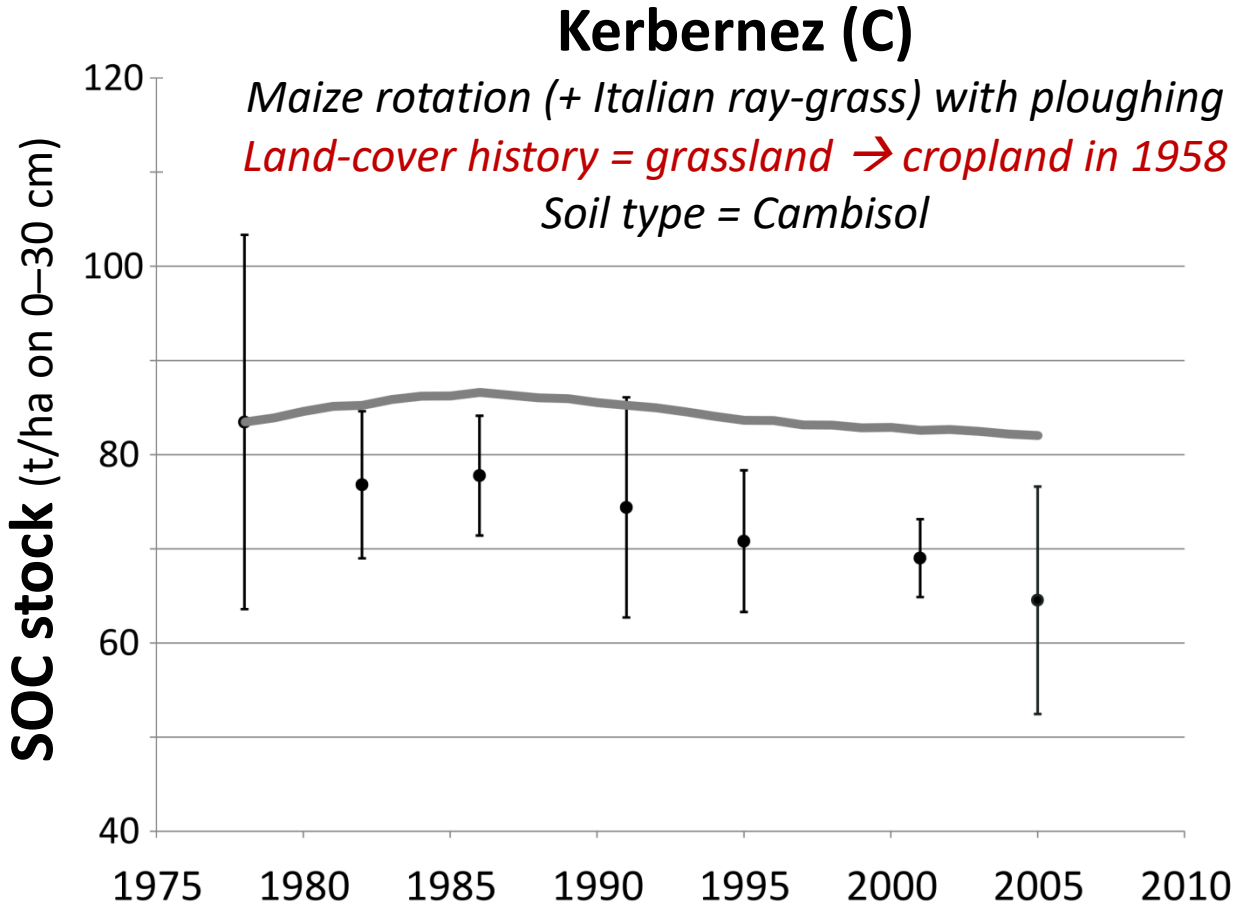




Clivot et al., 2019; Kanari et al., in prep

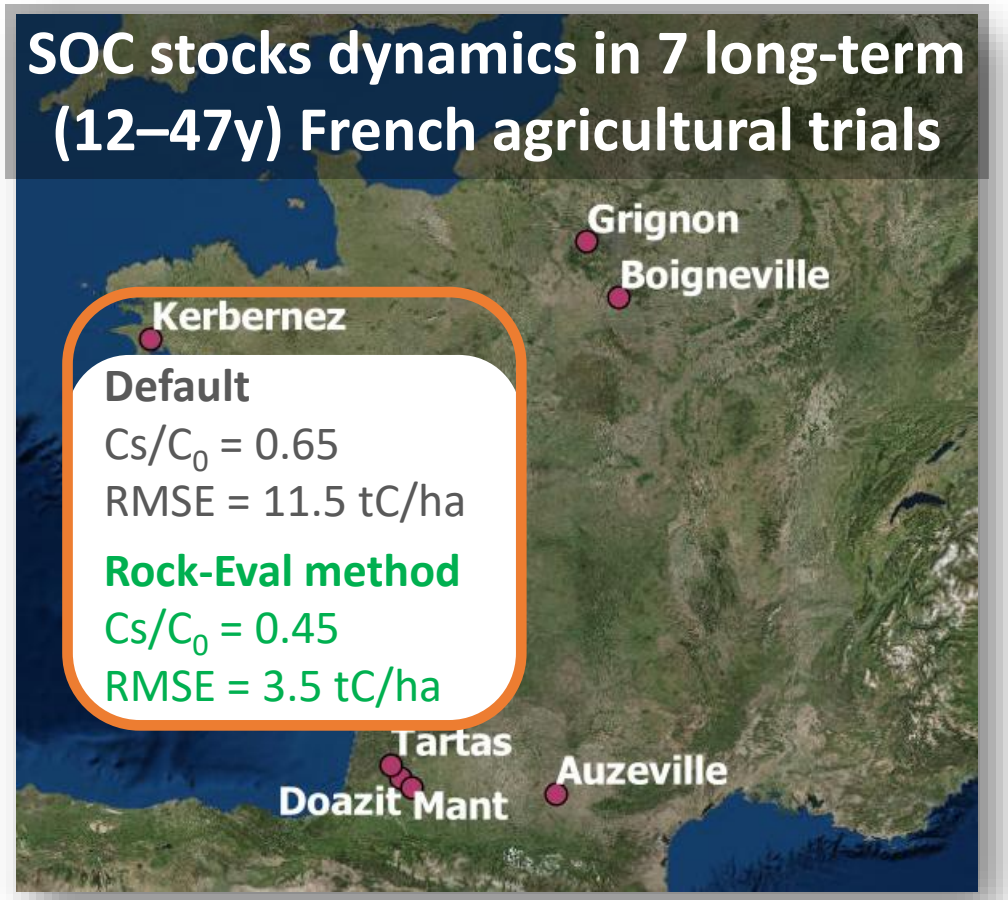
2 Does initializing the stable SOC pool of the AMG model using Rock-Eval improve simulations of SOC dynamics ?

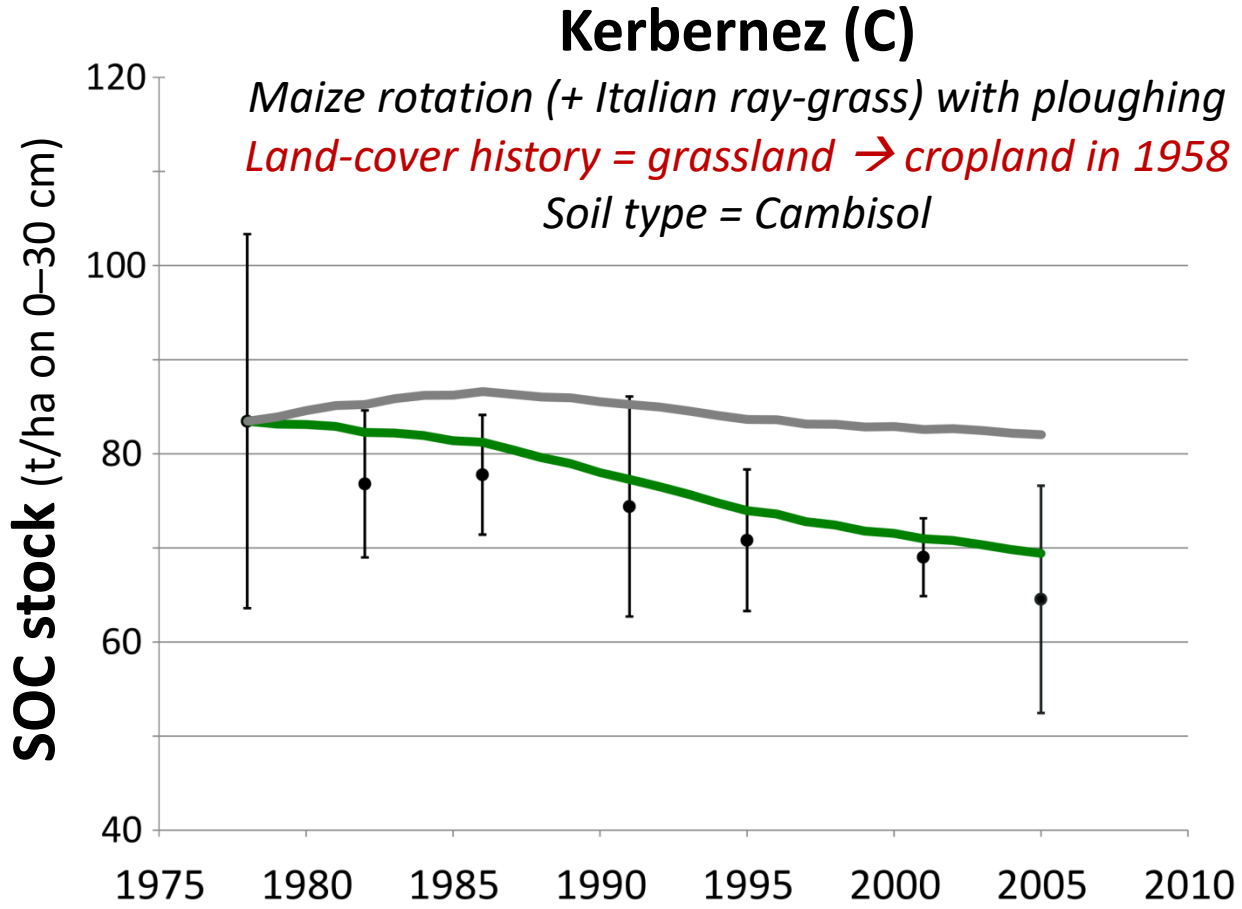




Clivot et al., 2019; Kanari et al., in prep

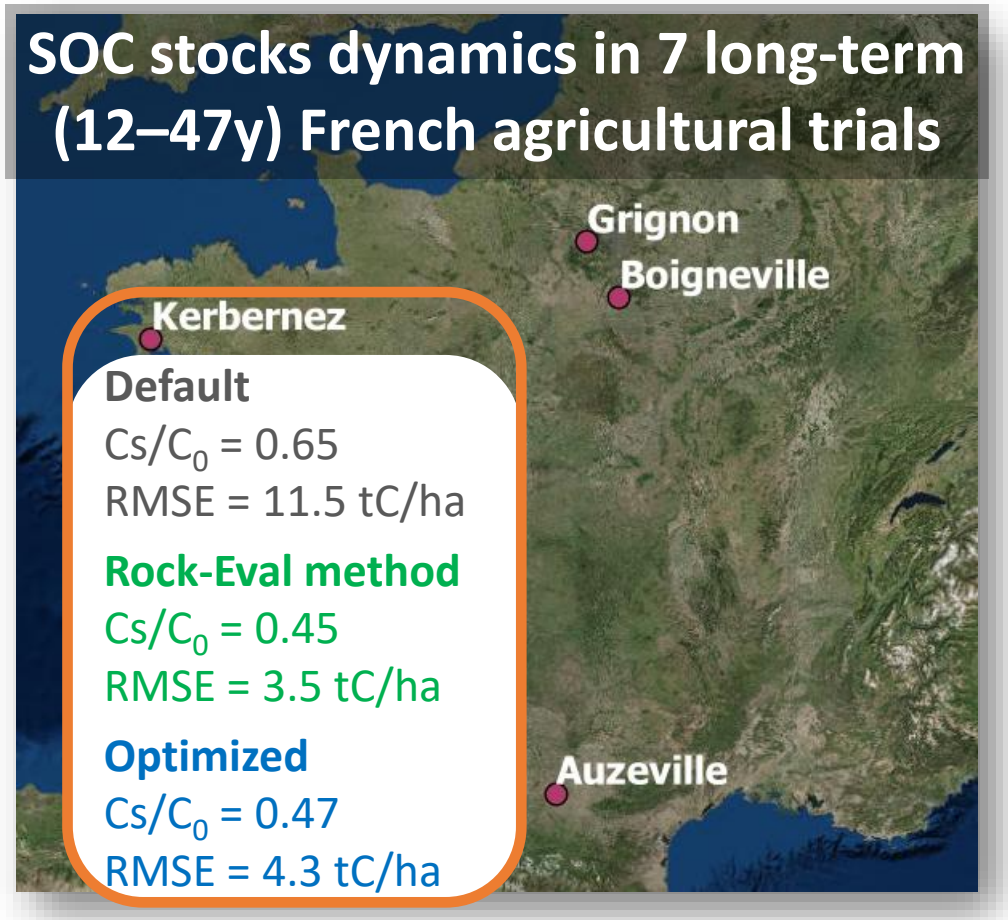
2 Does initializing the stable SOC pool of the AMG model using Rock-Eval improve simulations of SOC dynamics ?

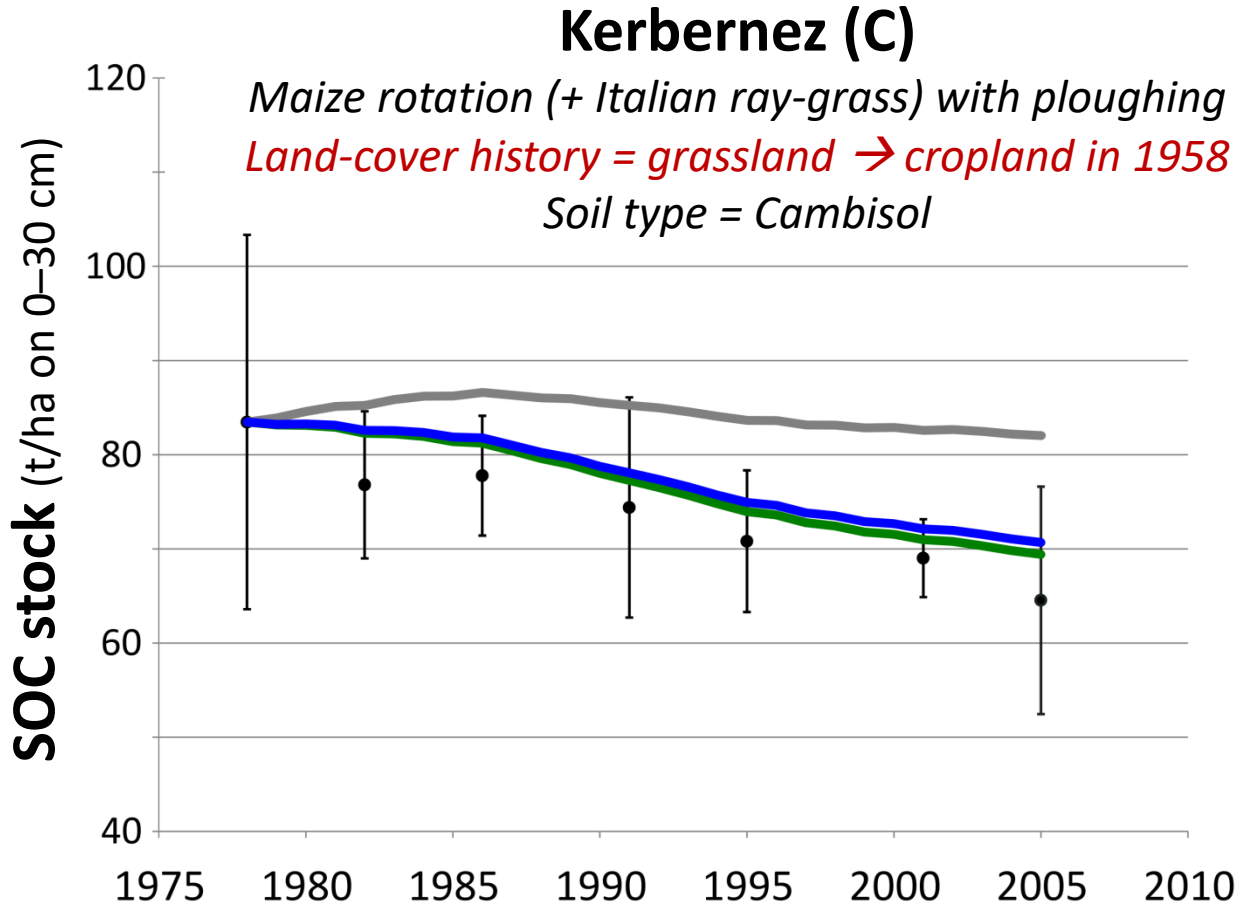




Clivot et al., 2019; Kanari et al., in prep

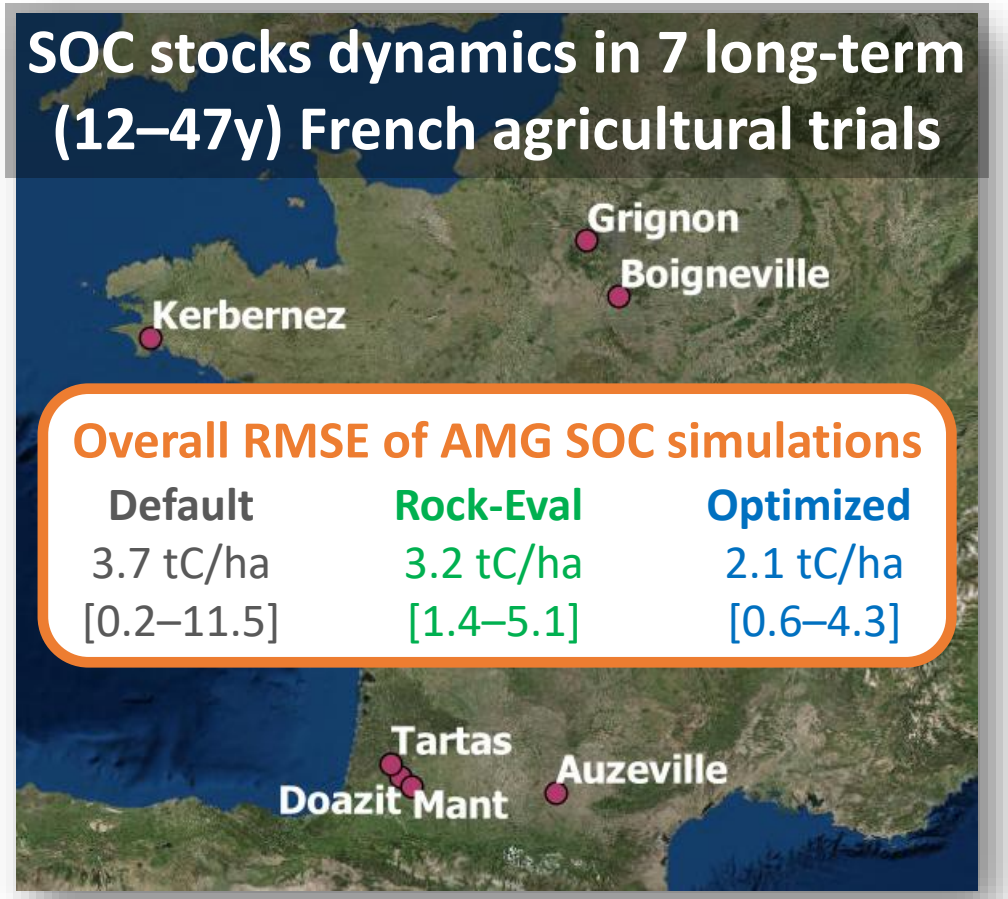
2 Does initializing the stable SOC pool of the AMG model using Rock-Eval improve simulations of SOC dynamics ?

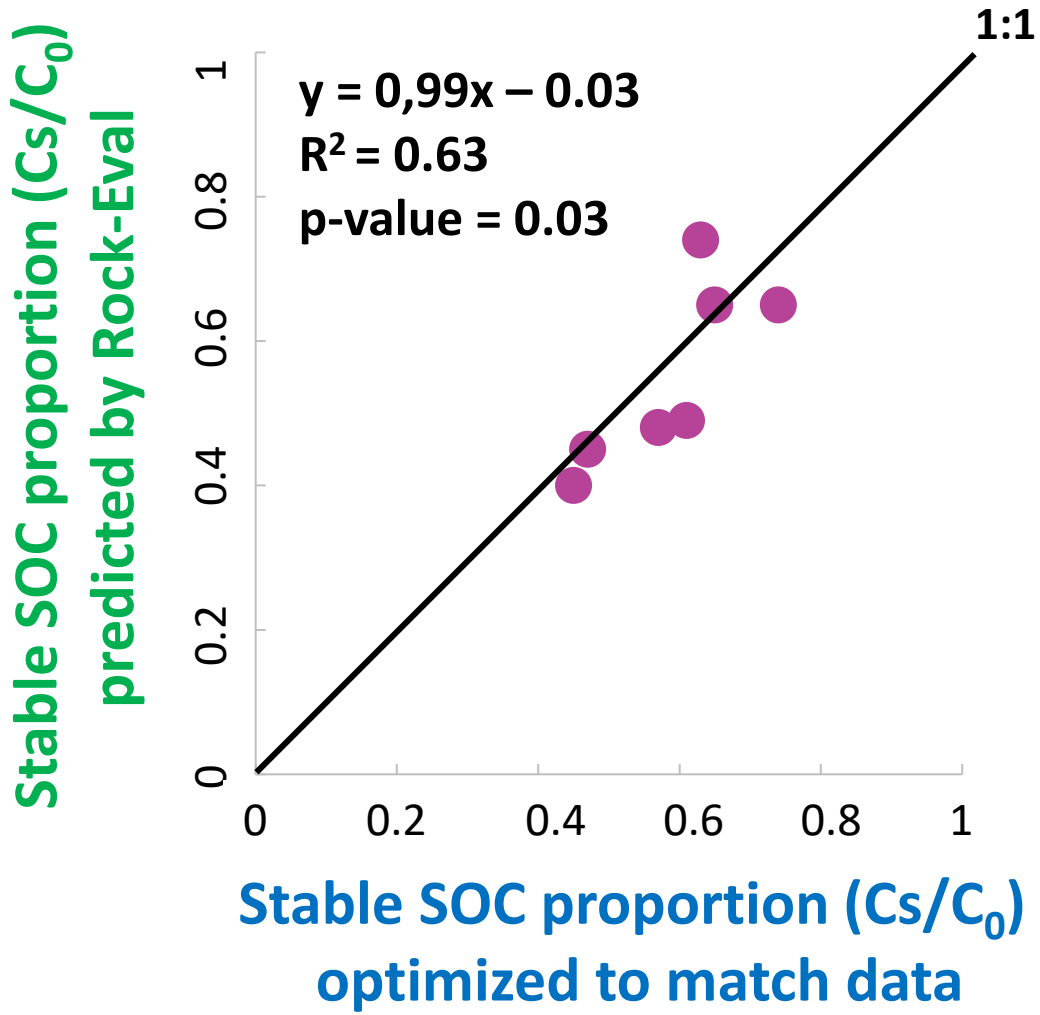




Clivot et al., 2019; Kanari et al., in prep

2 Does initializing the stable SOC pool of the AMG model using Rock-Eval improve simulations of SOC dynamics ?





Clivot et al., 2019; Kanari et al., in prep

Conclusions

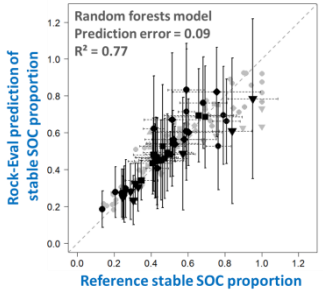
→ AMG model initialized using the Rock-Eval method is more accurate ! 😊

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

What's next ?

1

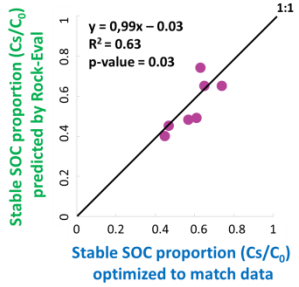
Rock-Eval-based method to predict stable SOC proportion



- 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)

Thank you for listening !

…and to all people who have initiated and maintained these highly valuable long-term trials

Contact: lauric.cecillon@irstea.fr

© R. Cardinael

© O. Crouzet

© T. Kätterer

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

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

Poitiers | France | 18 june 2019