Early detection of temporal Soil Organic Carbon stock changes by accounting for spatial variability

Guillaume Vitte, Fabien Ferchaud, Florent Chlebowski, Bruno Mary

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Early detection of temporal **S**oil **O**rganic **C**arbon stock changes by accounting for spatial variability

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INRA, UR AgroImpact

Introduction

- The **4 per 1000 initiative** (COP 21, 2015) aims at increasing **S**oil **O**rganic **C**arbon (SOC) stocks
- **Accurate assessment of SOC stocks and change rates**
- **Requires** (e.g. Meurer *et al.*, 2018):
  - Determination bulk density
  - Sampling to maximum tillage depth

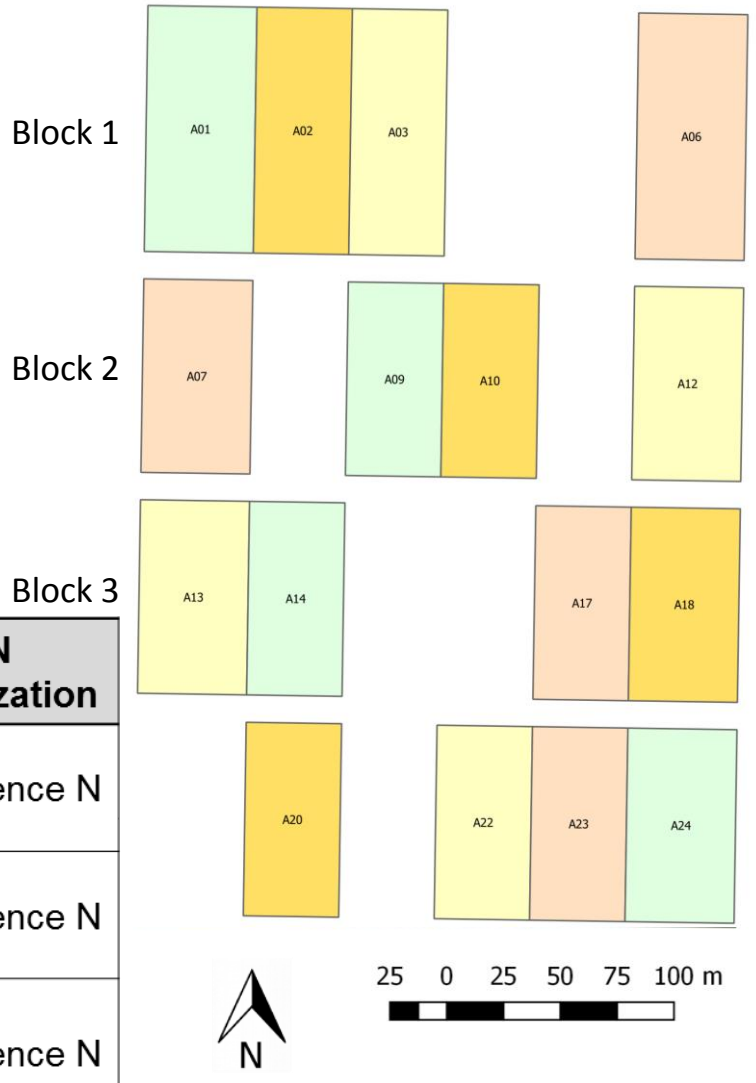
  } ➢ Equivalent Soil Mass
- **To improve this method**:
  - Use diachronic rather than synchronic measurements to take into account initial heterogeneity between plots and to calculate change rates (e.g. Costa Junior *et al.*, 2013; Olson *et al.*, 2014)
- **SOC spatial heterogeneity**

Approach

- **Objective** → To improve the diachronic method in order to detect early effects of treatments on SOC stocks
- **Means** → To take into account the intra-plot spatial variability by:
  - sampling soil at the same locations than at time 0
  - calculating temporal changes in SOC stocks in each location
- **To test this new method**, our approach was to:
  - Analyze initial spatial variability of SOC stocks
  - Evaluate the relationship between SOC stocks at time 0 and time t
  - Compare standard deviation between stocks and stock changes
- This method was applied to ongoing long-term experiment

ACBB long-term experiment

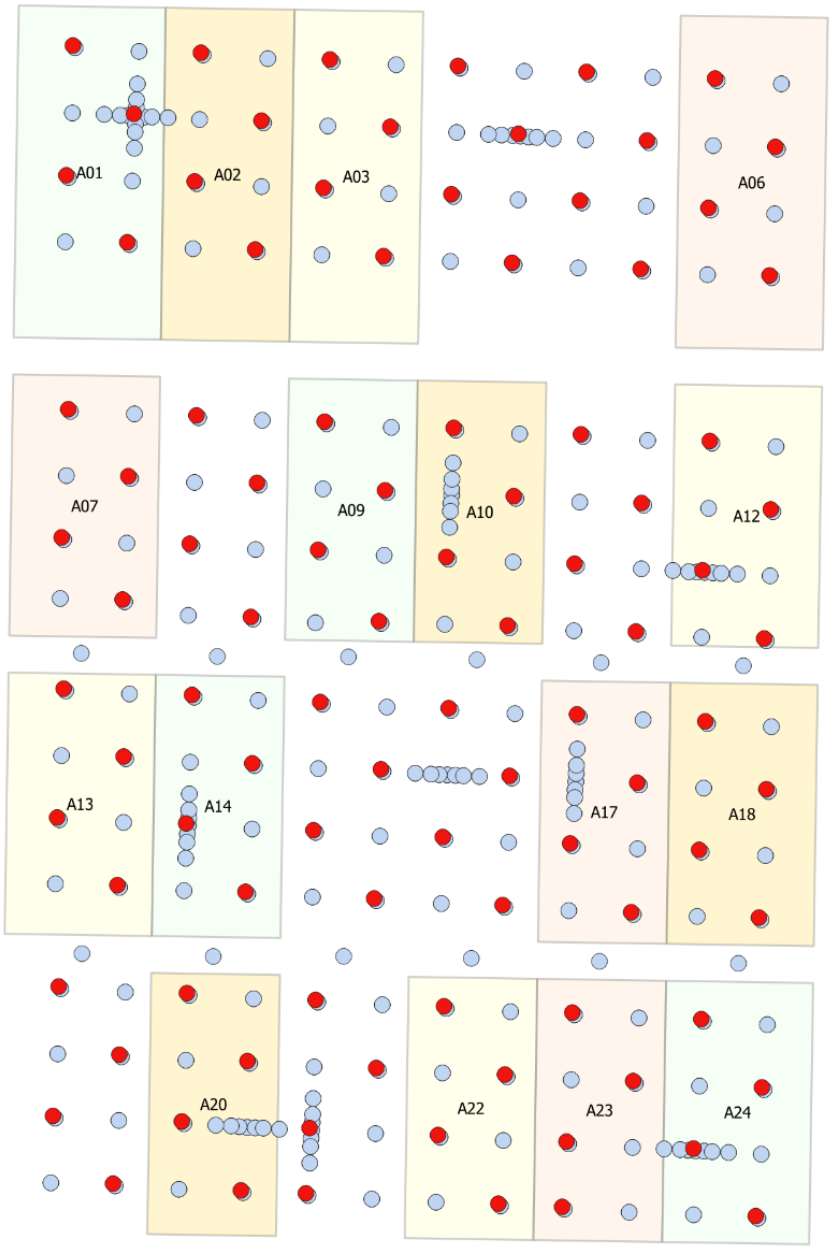
- Set up in 2009, in northern France
- Deep loamy soil (Orthic Luvisol)
- 6-year annual crop rotation
- 6 treatments randomized in 4 blocks



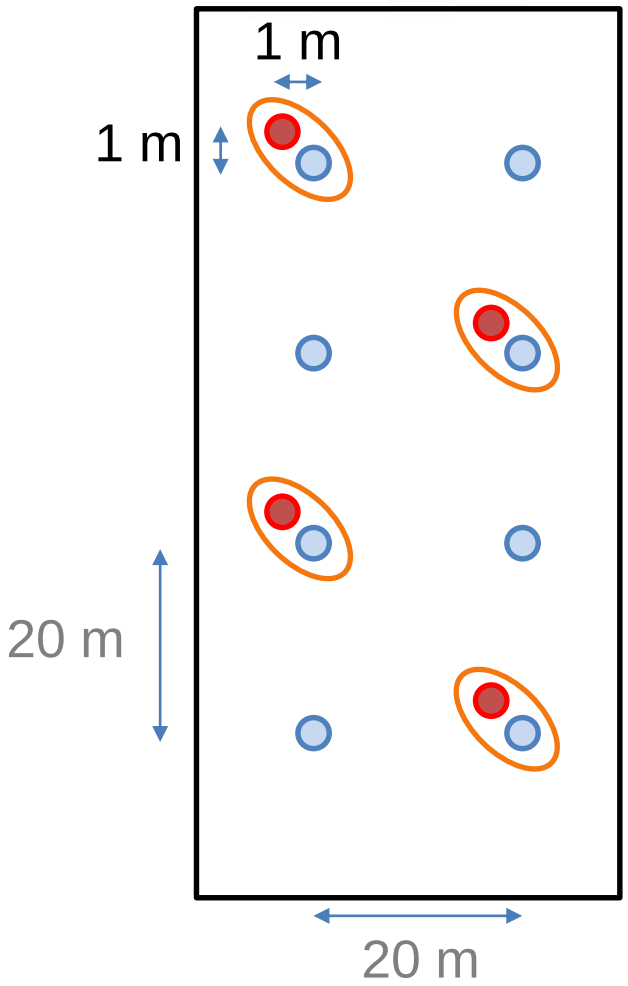
Treatment		Soil tillage	Crop residues management	N fertilization
CONVentional management	**CONV**	Annual ploughing	Returned	Reference N
Reduced Tillage	**RT**	Shallow tillage	Returned	Reference N
Reduced Tillage and Residues Removal	**RT-RR**	Shallow tillage	Exported	Reference N
Reduced Nitrogen	**RN**	Annual ploughing	Returned	35% Reference N

Soil sampling

- 5 layers: 0-10; 10-20; 20-35; 35-40; 40-60 cm
- 2009 (initial date):
  - 8 points per plot
  - + 11 transects
- 2015:
  - 4 points per plot



Soil sampling (2)



- Regular grid
- Sampling points with GPS

SOC 2009

SOC 2015

DSOC 2009-2015: paired points

Bulk density measurements

- 9 Layers: 0-5; 5-10; 10-15; 15-20; 20-25; 25-30; 30-35; 35-40; 40-60 cm
- 2009 (initial date):
  - 9 per block
  - No significant differences between blocks
- 2015:
  - 4 points per plot (same as for soil sampling)
  - Significant differences between treatments

Calculations of SOC stocks at ESM

- Soil Mass (t/ha):

$$M = 10 \sum_{i=1}^{y} e_i \cdot \rho_i$$

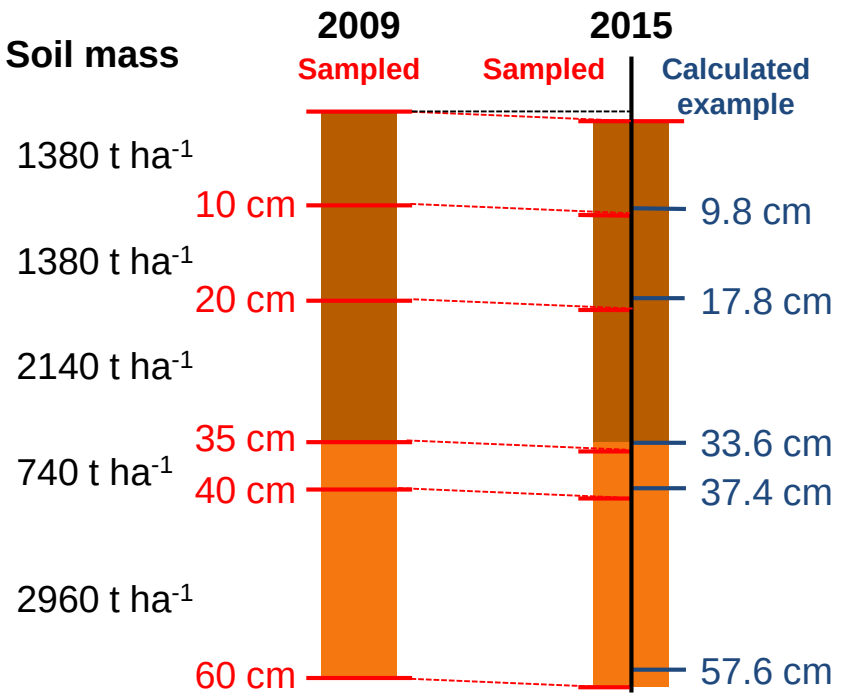
e_i = layer thickness (mm)
ρ_i = bulk density (g/cm^3)

- SOC stock (t/ha):

$$SOC = 10 \sum_{i=1}^{y} e_i \cdot \rho_i \cdot C_i$$

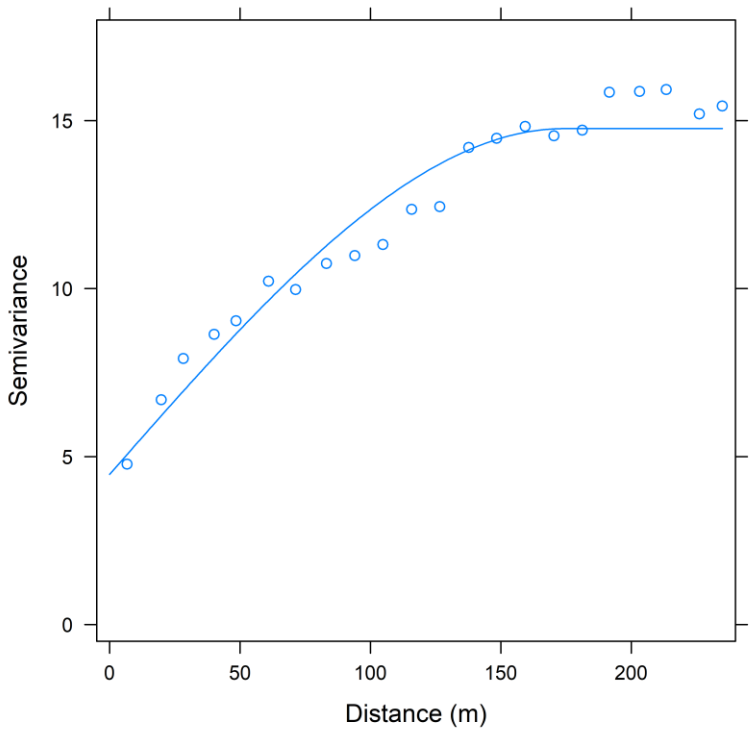
C_i = C concentration (g/kg)

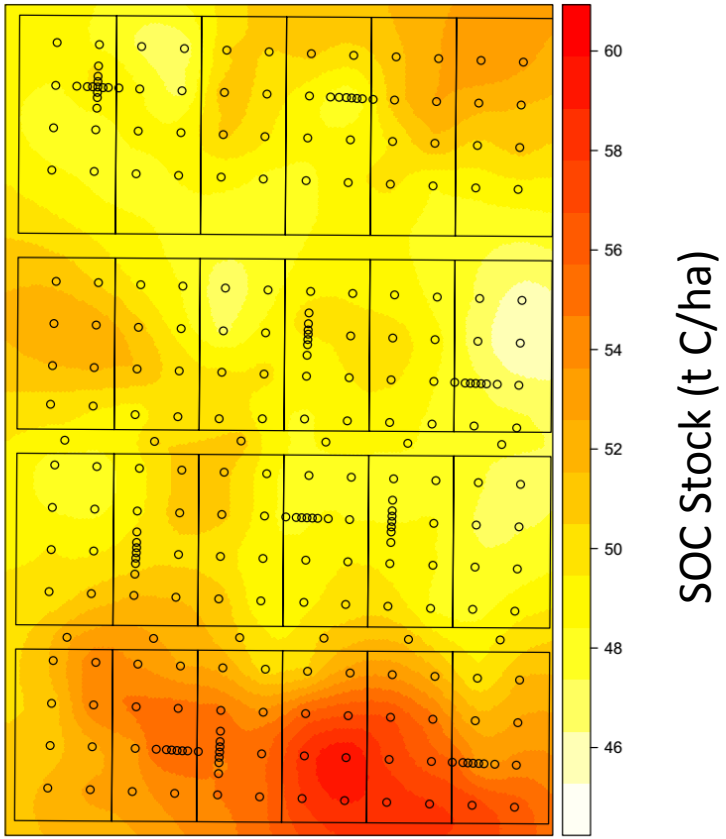
- Calculations made by layer of 1mm
- R package "SEME": calculations and statistics



- Equivalent Soil Mass (ESM):
  - ~ 0-10 cm: 1380 t / ha
  - ~ 0-35 cm: 4900 t / ha
  - ~ 0-60 cm: 8600 t / ha

Initial spatial variability of SOC stocks (0-35 cm)



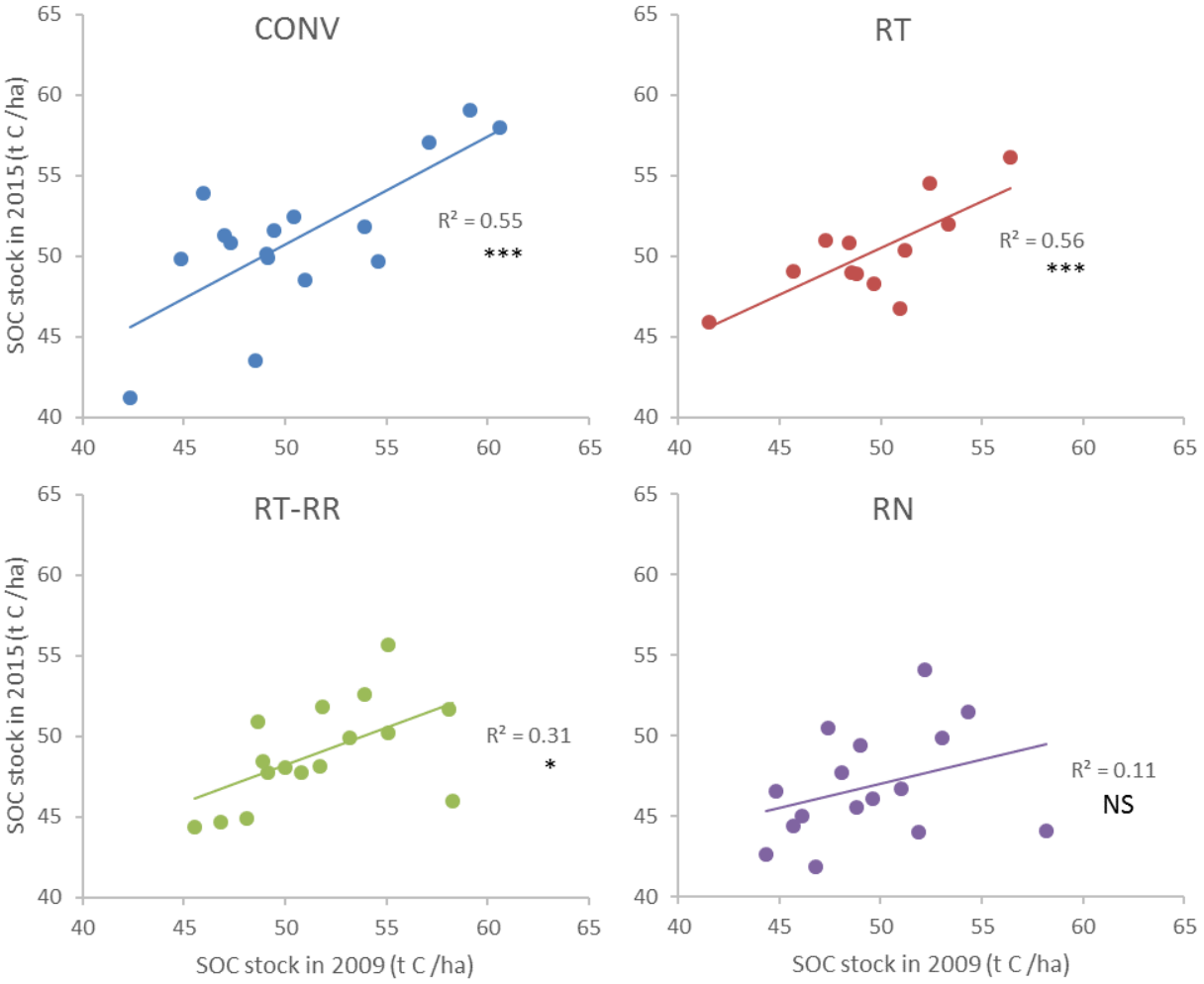


- Spatial variability well structured, consistent with published results
- More differences than expected from 41 to 64 t C/ha: > 20 t C/ha

Relationship between SOC stocks 2009 and 2015

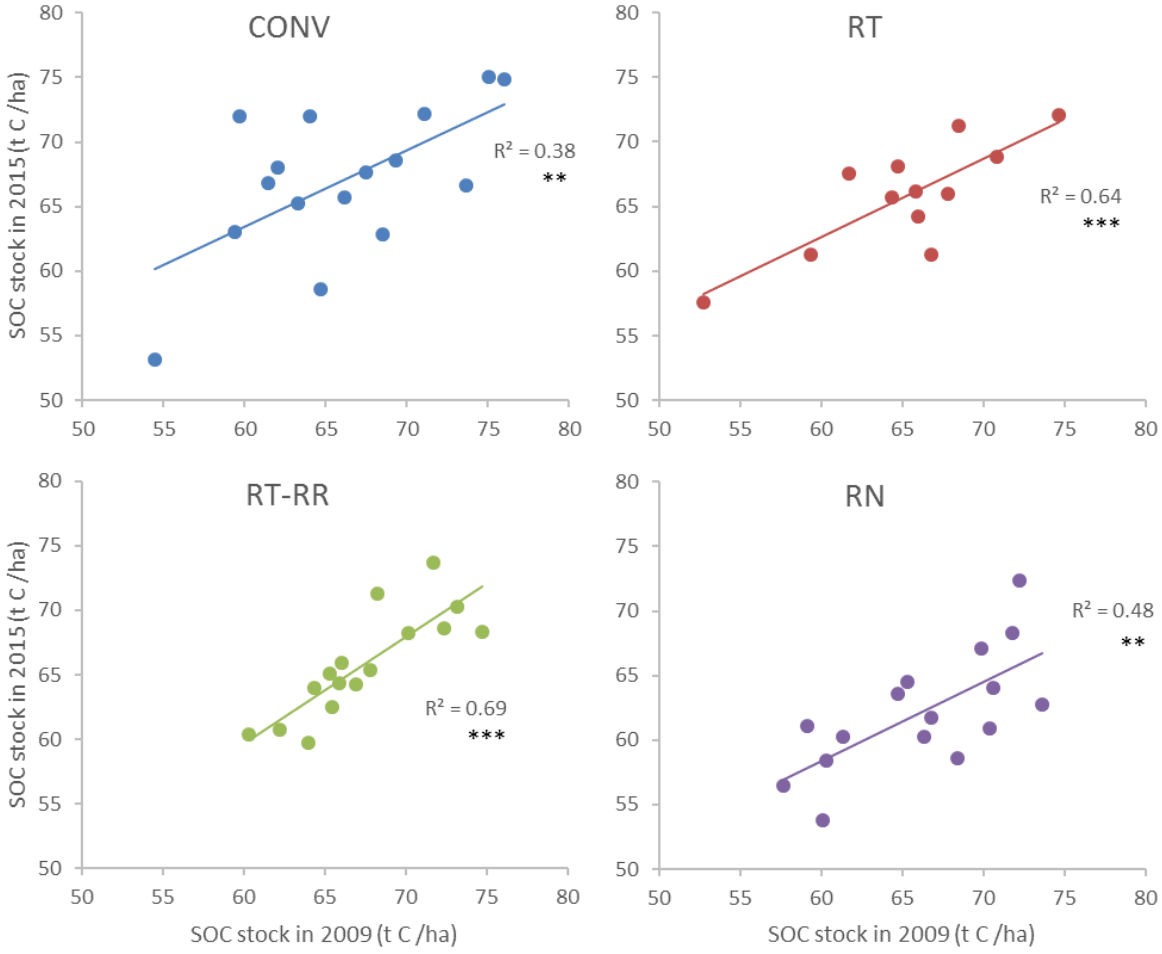
~ 0-35 cm

- Paired points
- Significant correlation between 2009 and 2015 for CONV, RT and RR-RT treatments



Relationship between SOC stocks 2009 and 2015 ~ 0-60 cm

- Paired points
- Significant correlation between 2009 and 2015 for all treatments
- Higher correlation in ~ 0-60 than in ~ 0-35 cm

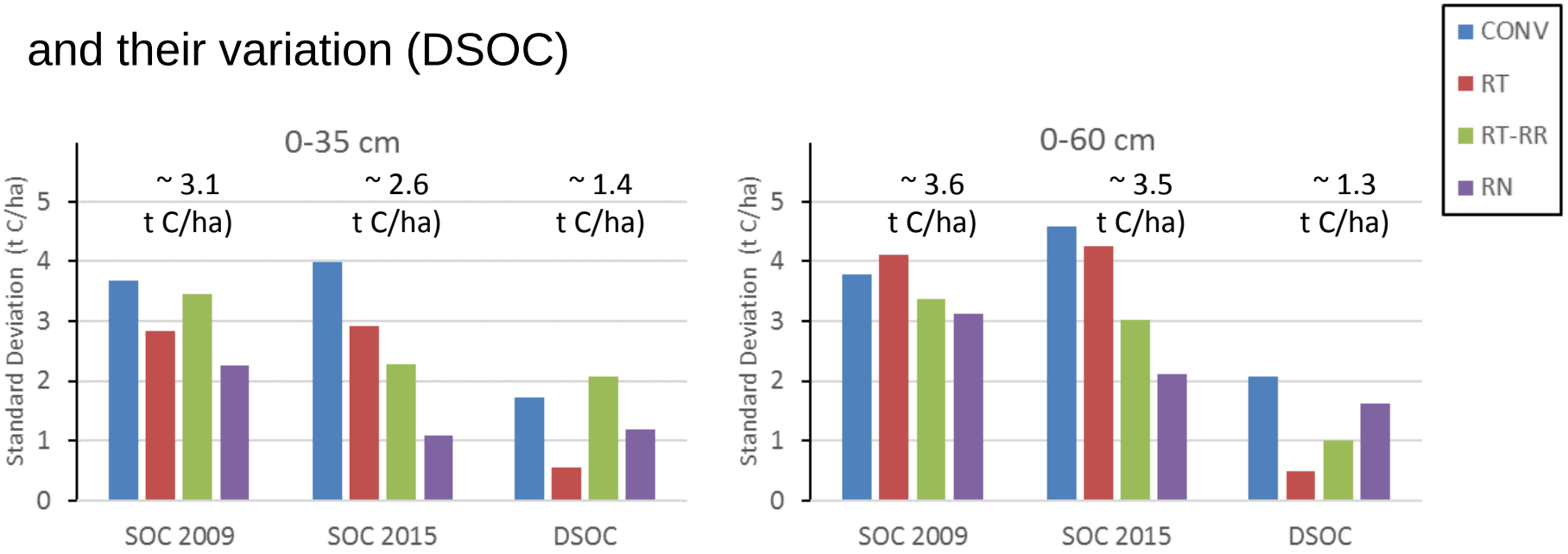


- In each point, SOC stock in 2015 depends on SOC stock in 2009

➢ Confirms the well structured spatial variability shown with the variogram

Variability of SOC stocks *versus* SOC stock changes

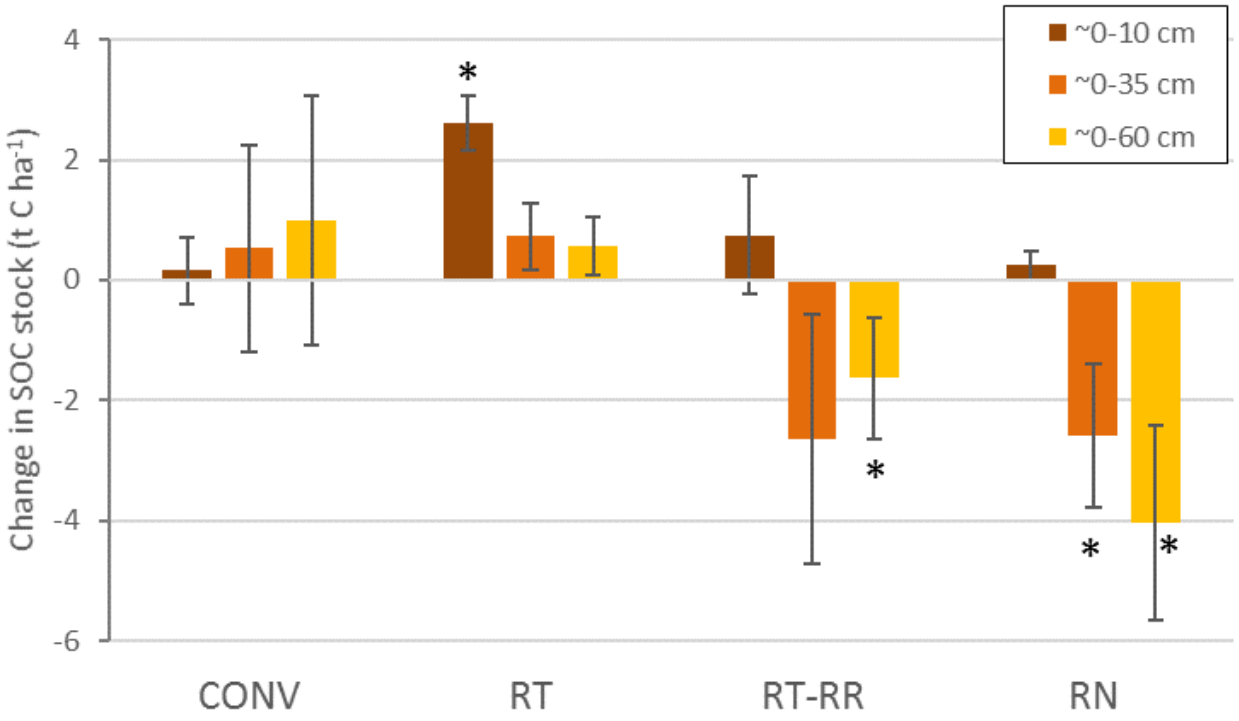
- For all treatments: Standard deviation in SOC stocks in 2009 and 2015 and their variation (DSOC)



- Lower standard deviation for DSOC than for SOC 2009 and SOC 2015
- Particularly for 0-60 cm

➢ Using stock changes allow to detect smaller effects than using stocks

Is there a significant change in SOC stocks between 2009 and 2015?



* = Significantly different from 0 ($p < 0.05$)

- Increase in SOC stocks ~0-10 cm for RT **but not** in ~0-35 or ~0-60 cm
- Decrease in SOC stocks ~0-35 and ~0-60 cm for RT-RR and RN

Conclusion about the methodology

- Possible to decrease the variability of temporal changes in SOC stocks by:
  - characterizing the initial spatial variability and
  - re-sampling very close to the initial point (~ 1 m)
- This method allows to detect:
  - smaller changes than with random sampling (~ 2 t C/ha) and
  - treatment effects after only 6 years
- It is particularly relevant for deep sampling

Conclusion about the effects of treatment

- In our ACBB experiment, temporal changes in SOC stocks:
  - were not influenced by tillage (RT *vs* CONV)
  - were driven by the amount of C inputs (RT-RR *vs* RT)
  - were probably driven by the lack of N when N surplus is negative (RN *vs* CONV)

Thank you for your attention

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Contact : guillaume.vitte@inra.fr