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Guillaume Vitte, Fabien Ferchaud, Florent Chlebowski, Bruno Mary. Early detection of temporal Soil Organic Carbon stock changes by accounting for spatial variability. 21st ISTRO INTERNATIONAL CONFERENCE, ISTRO, Sep 2018, Paris, France. hal-04365007

HAL Id: hal-04365007

<https://hal.inrae.fr/hal-04365007>

Submitted on 27 Dec 2023

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21st ISTRO INTERNATIONAL CONFERENCE
25-28 September 2018 - Paris



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



Guillaume VITTE*, Fabien FERCHAUD, Florent CHLEBOWSKI, Bruno MARY
INRA, UR AgrolImpact

Introduction



- The **4 per 1000 initiative** (COP 21, 2015) aims at increasing **Soil Organic Carbon (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**

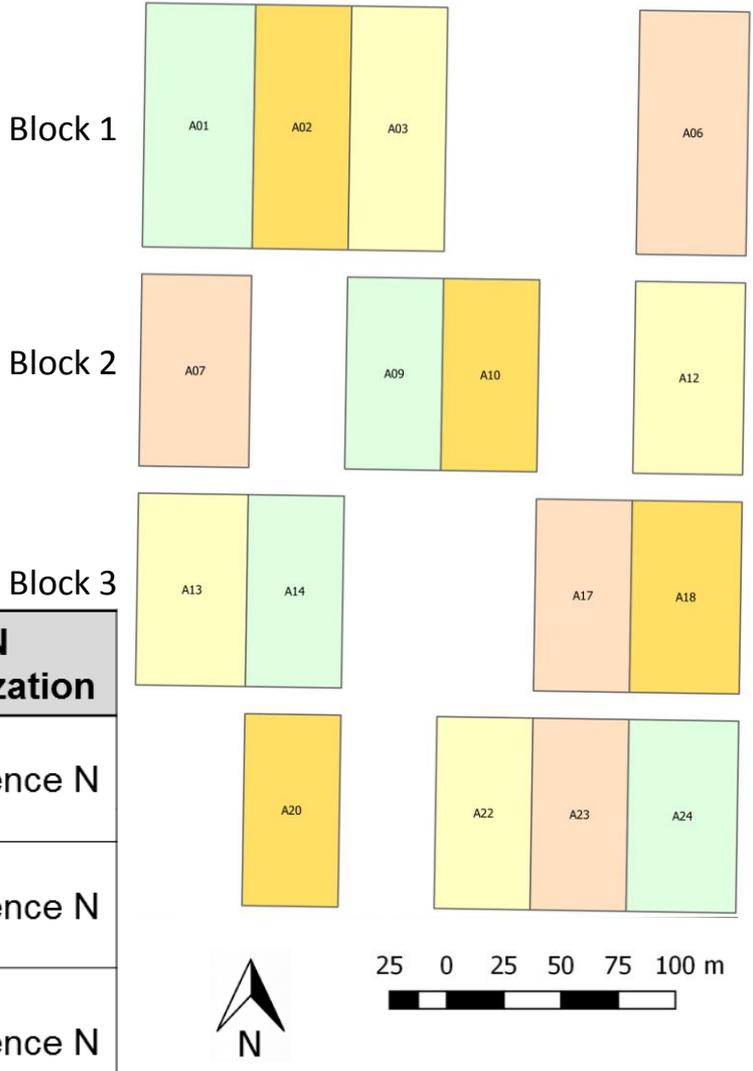
Approach

- **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

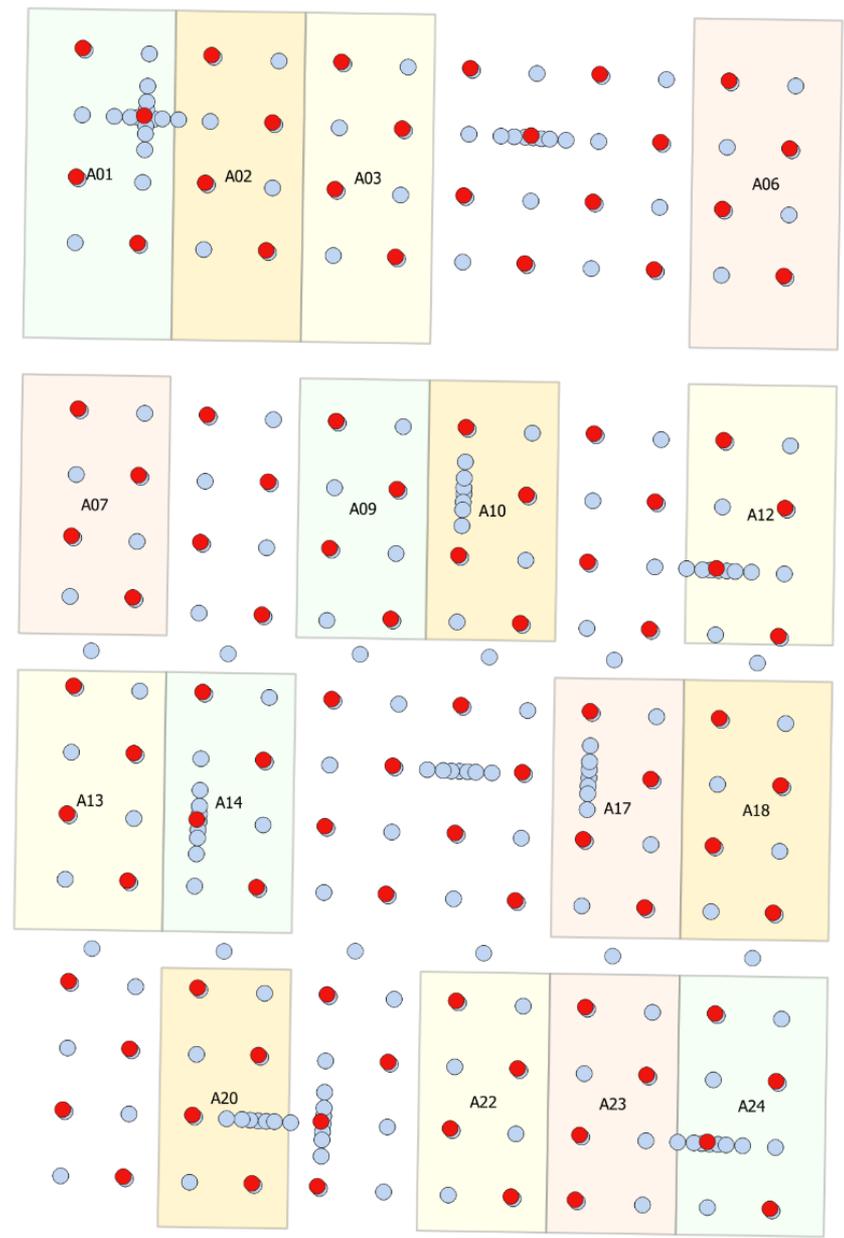


| Treatment | | Soil tillage | Crop residues management | N fertilization |
|---|--------------|------------------|--------------------------|-----------------|
| CONventional management | CONV | Annual ploughing | Returned | Reference N |
| Reduced Tillage | RT | Shallow tillage | Returned | Reference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

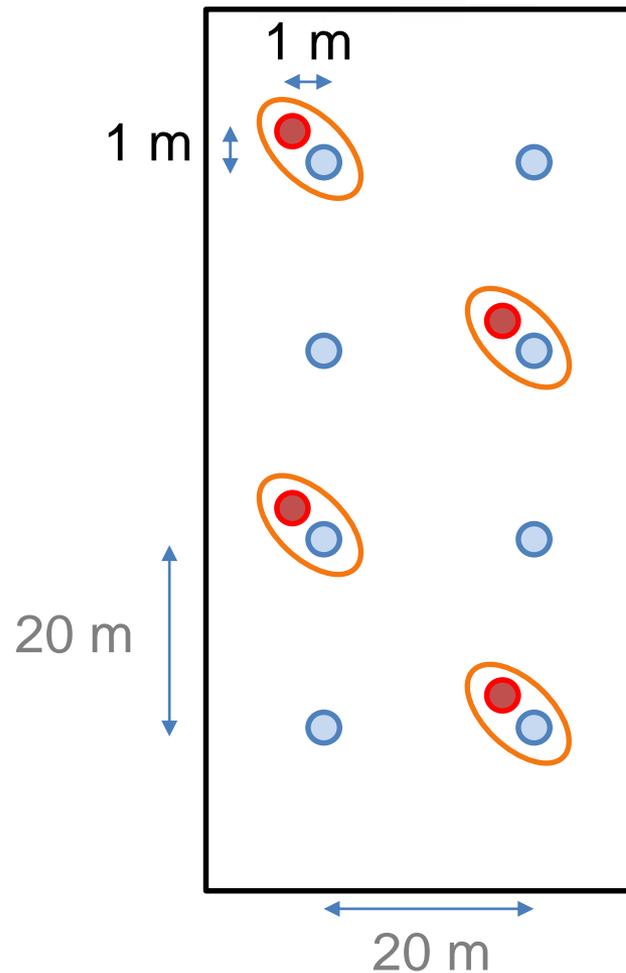
Soil sampling



- 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):

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

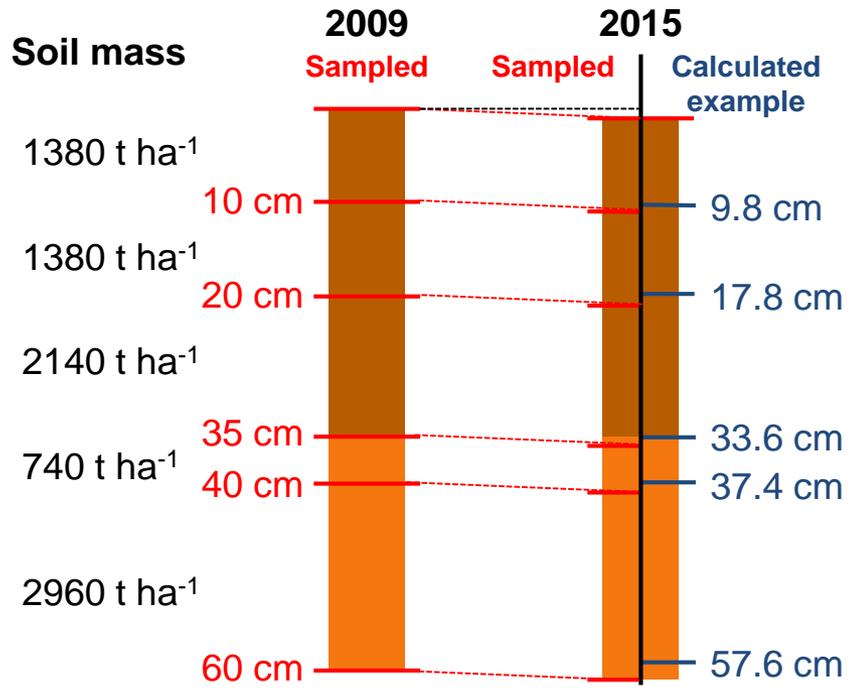
e_i = layer thickness (mm)
 ρ_i = bulk density (g/cm³)

- SOC stock (t/ha):

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

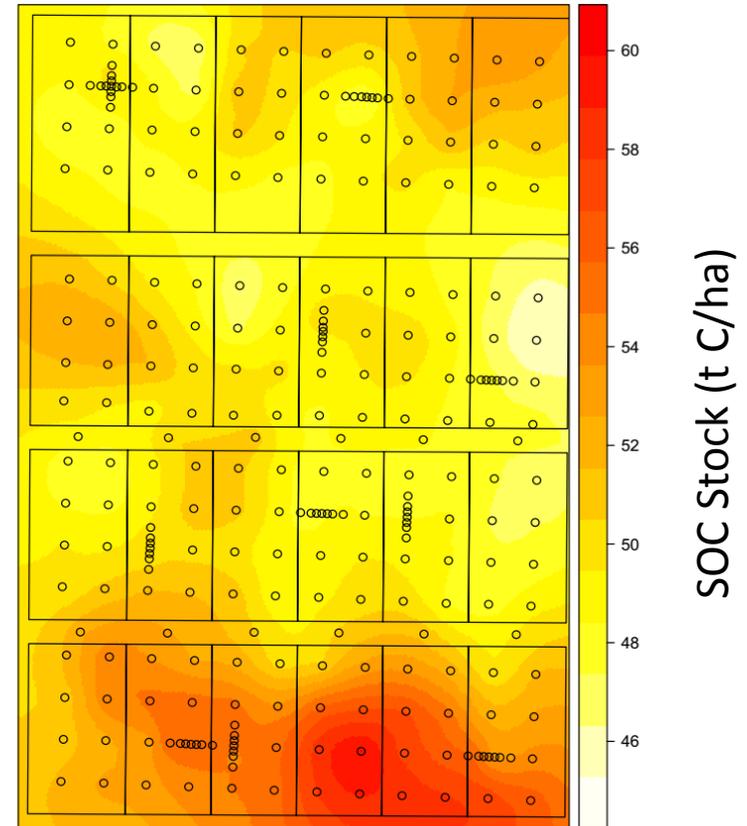
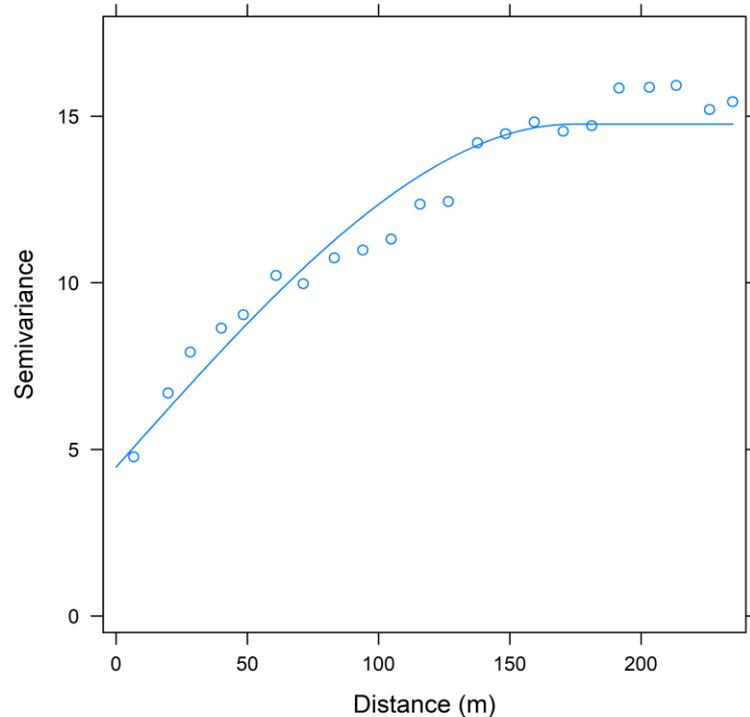
C_i = C concentration (g/kg)

- 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)

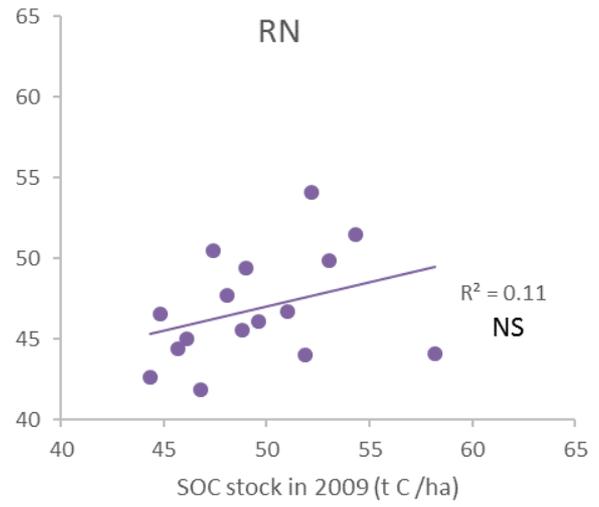
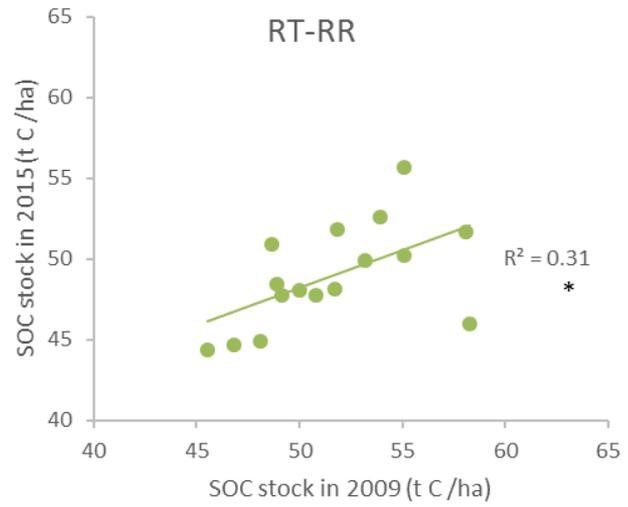
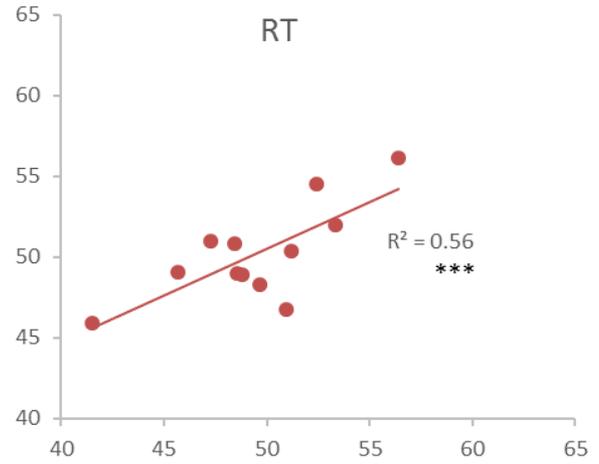
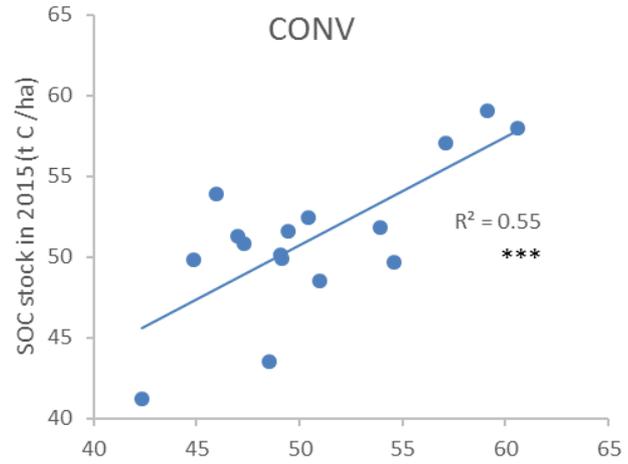


- Spatial variability well structured, consistent with published results
- More differences than expected from 41 to 64 t C/ha: > 20 t C/ha

Relationship between SOC stocks 2009 and 2015

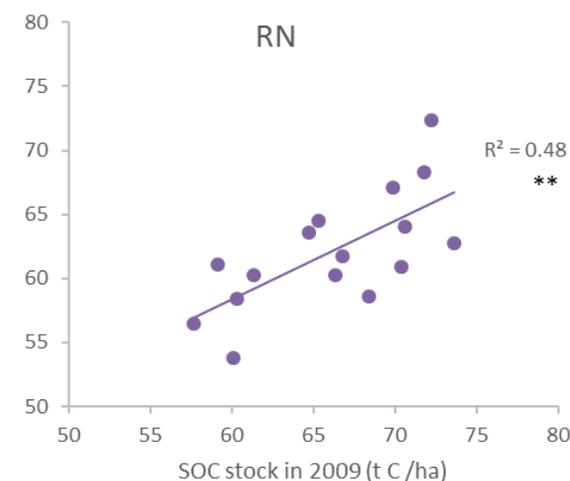
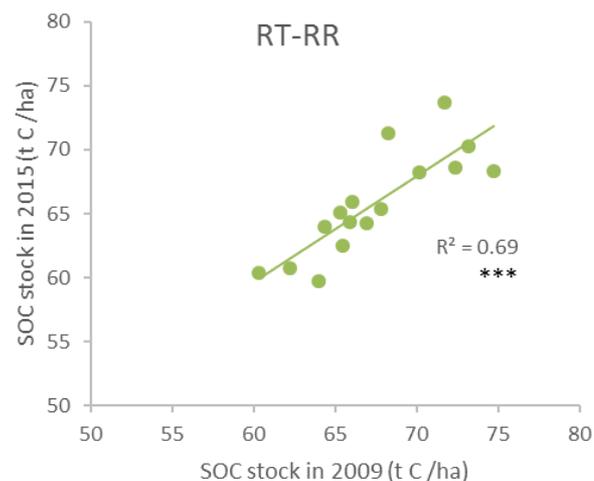
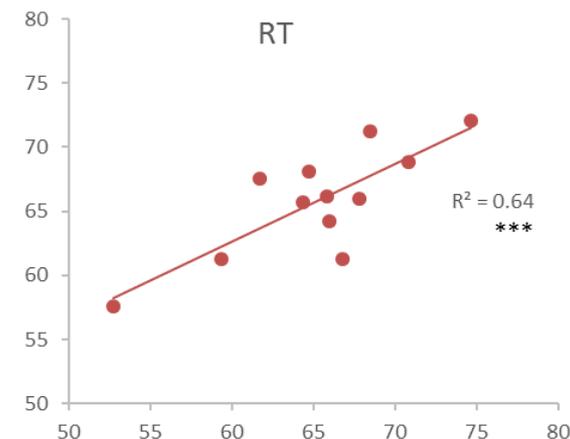
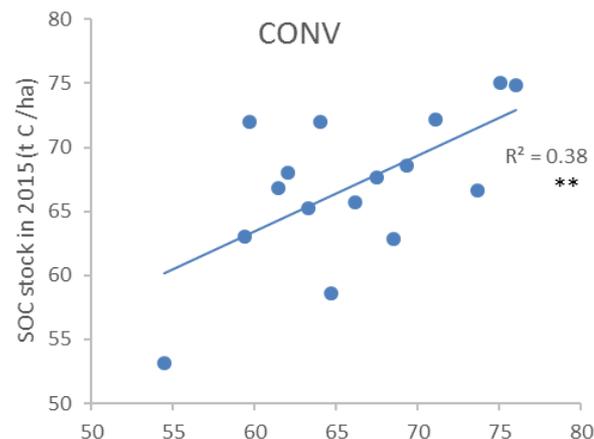
~ 0-35 cm

- 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

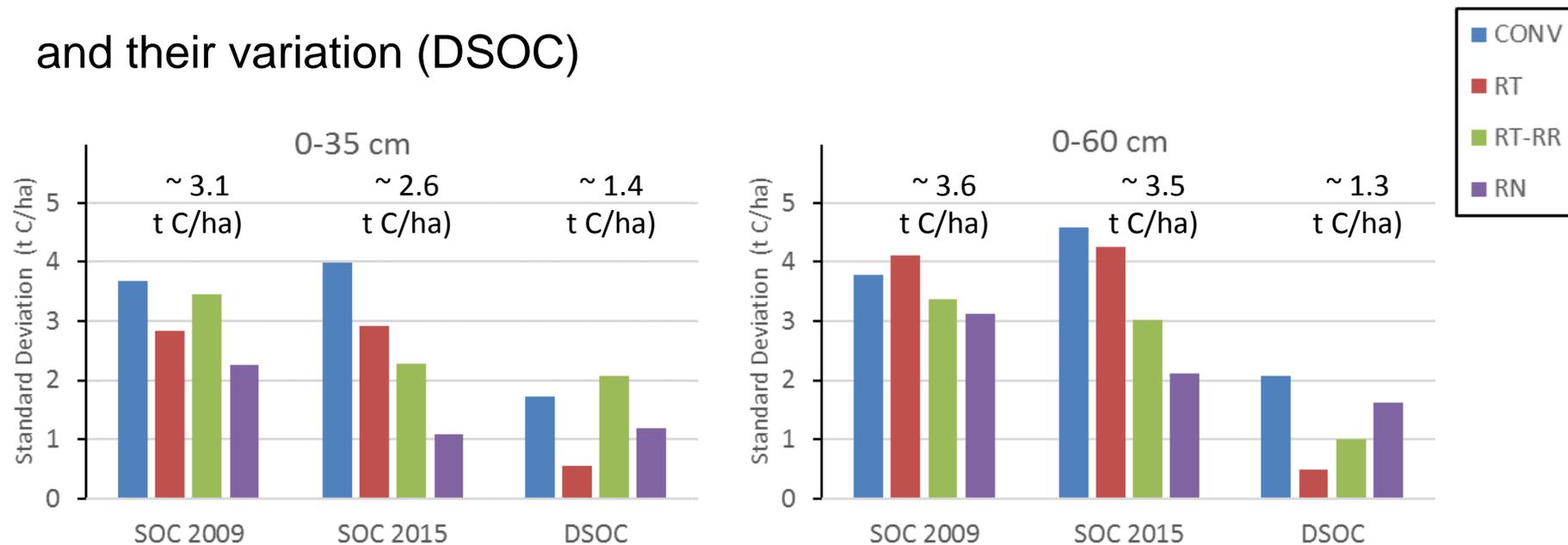


- Paired points
- Significant correlation between 2009 and 2015 for all treatments
- Higher correlation in ~ 0-60 than in ~ 0-35 cm

- In each point, SOC stock in 2015 depends on SOC stock in 2009
- Confirms the well structured spatial variability shown with the variogram

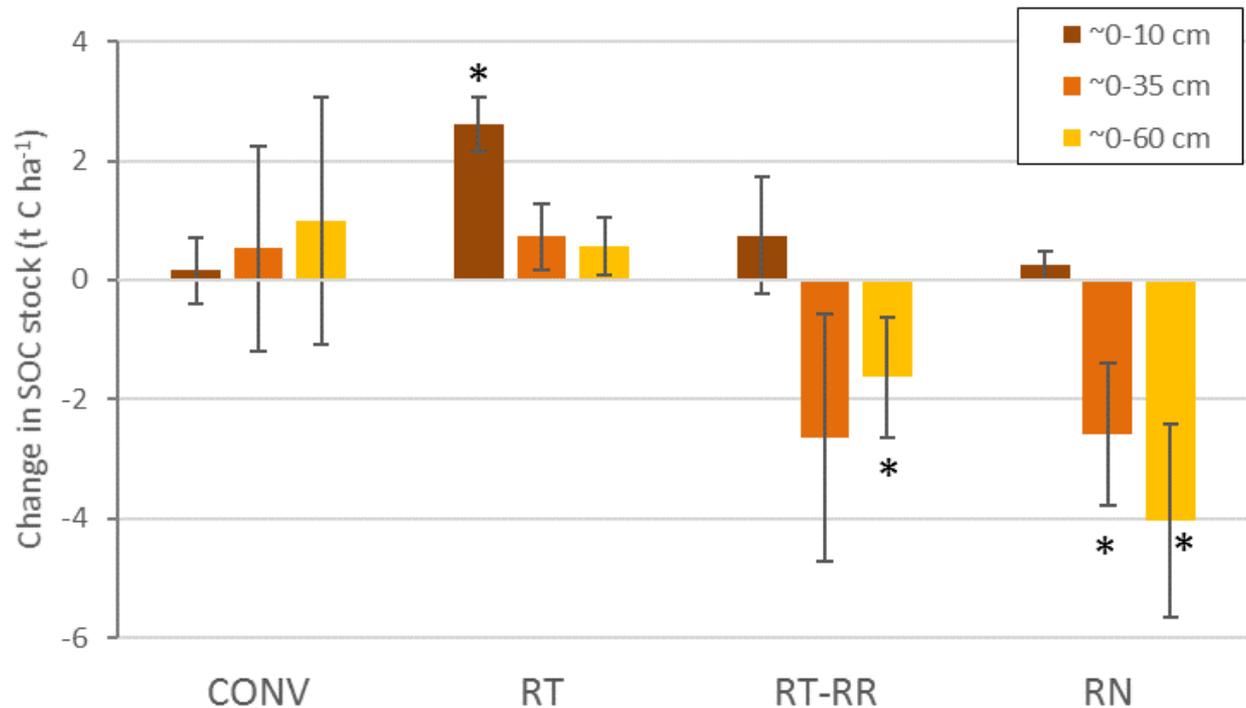
Variability of SOC stocks versus SOC stock changes

- 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)

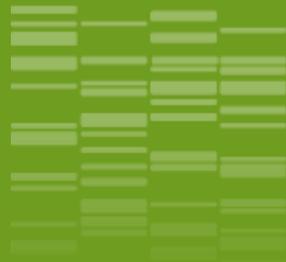
- Increase in SOC stocks ~0-10 cm for RT **but not** in ~0-35 or ~0-60 cm
- Decrease in SOC stocks ~0-35 and ~0-60 cm for RT-RR and RN

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

Thanks to my co-autors and to the staff of AgrolImpact Unit for their technical assistance

Acknowledgments for the financial support from:



Contact : guillaume.vitte@inra.fr