



**MRV4SOC
PROJECT**



Eddy covariance diverges from inventories and modelling on soil organic carbon stock evolution in a Belgian cropland over five rotations

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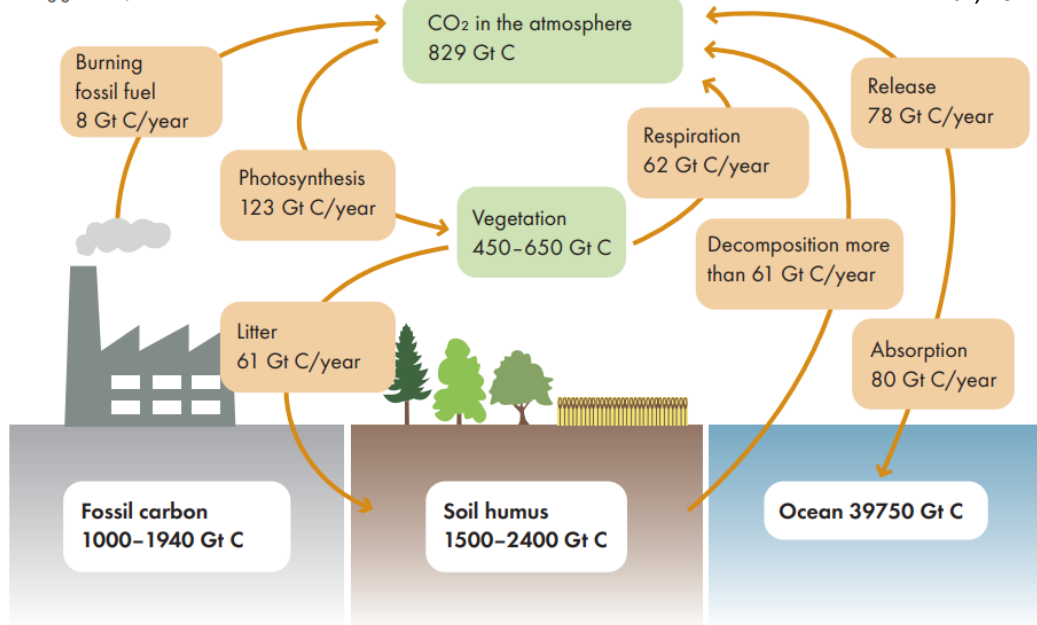
Funded by
the European Union



The importance of soil organic carbon

Gt = gigatonnes, C = carbon

FibL, 2022



Humus build-up and decomposition play an essential role in the carbon cycle relevant to the climate. The CO₂ content of the atmosphere is currently increasing by 3.3 Gt C annually. C exchange with carbonate rocks, by far the largest carbon sink, is much slower and is therefore not listed here. Source: Graphic designed by Heinz Flessa, adapted by FiBL, using IPCC data^[2]

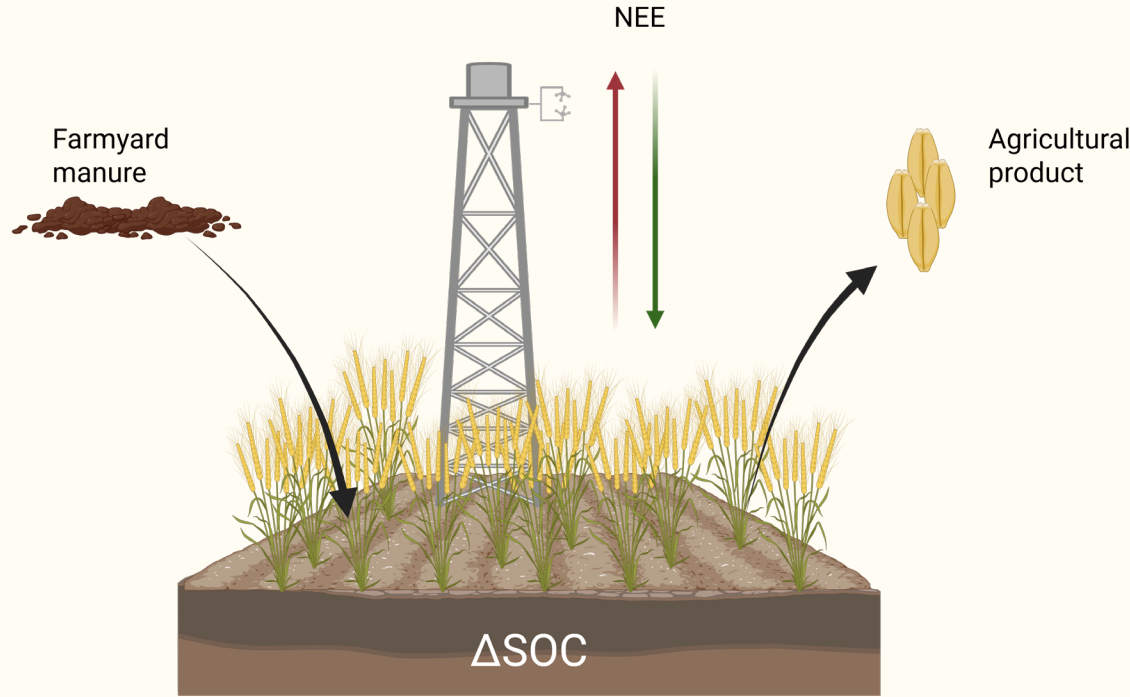
Critical for agriculture and climate

- Enhances soil structure, nutrient availability, and water retention
- SOC sequestration potential: offset 1/6 to 1/3 of anthropogenic CO₂ emissions

Robust methods to quantify SOC changes over time are essential for:

- Sustainable land management strategies
- Implementation of monitoring, reporting, and verification (MRV) tools

SOC and eddy covariance



Numerous studies using EC have shown **high SOC losses** for croplands ($\sim 100 \text{ gC/m}^2/\text{yr}$)

Need of :

- Comprehensive uncertainty assessment
- Benchmarking with other methods

SOC stock variation should scale with the balance between vertical and lateral C fluxes

The Lonzée site



Lonzée ICOS station (BE-Lon – class 2)

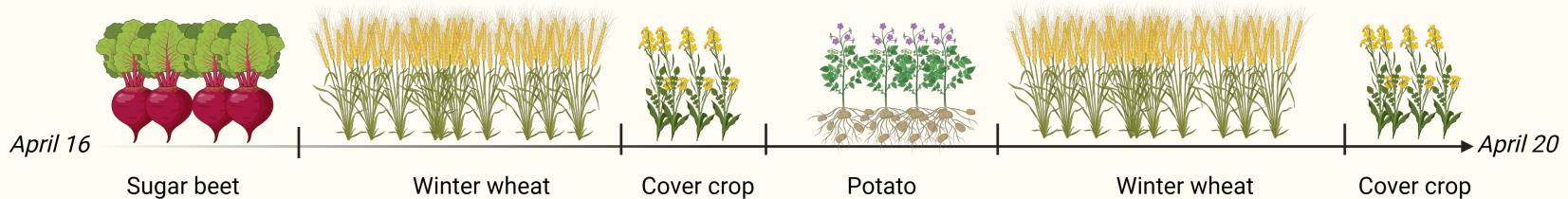
Cultivated for more than 80y

Average temperature : 10.2 °C

Mean annual precipitation : 742 mm

Measurements of

- EC since 2004
- SOC stocks in 2007 and 2017



Models and inventories

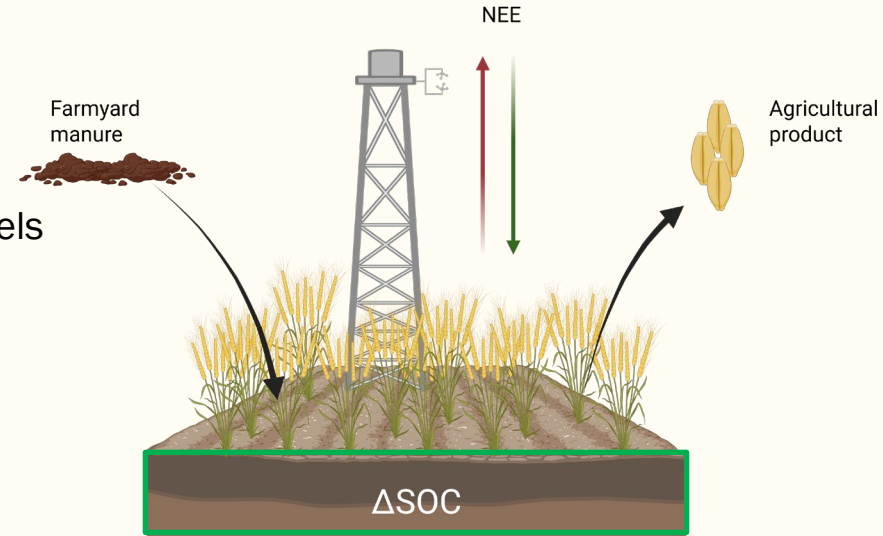
Process-based model

Rothamsted Carbon Model (RothC):

- used in national inventories and Earth System models
- requires C inputs and meteorological data
- provides monthly SOC stock simulations

Soil inventories

- Random sampling scheme
- Bulk density, organic C content, ...



How does EC-based SOC compare with inventories and process-based model simulations?

What are the uncertainties associated with each method?

Eddy covariance

$$\Delta SOC_{EC} = \sum_t^{t'} (NEE - C_{imp} + C_{exp})$$

Random uncertainty on:

- NEE : measurements (via ONEFLUX) and gapfilling
- C_{imp} , C_{exp} (via biomass measurements)

Systematic uncertainty on NEE :

- Spectral correction (site team post-processing)
- Friction velocity threshold (via ONEFLUX)

$$\sigma_{NBP,d} = \sqrt{\left(\sqrt{\sum_{i=1}^t \sigma_{NBP,i}^{rdm^2}} \right)^2 + \left(\sum_{i=1}^t \sigma_{NBP,i}^{sys} \right)^2}$$

Daily standard deviation on NBP

Random errors add up in quadrature

Systematic errors add up linearly

Both are assumed independent (no covariance term)

Soil samples

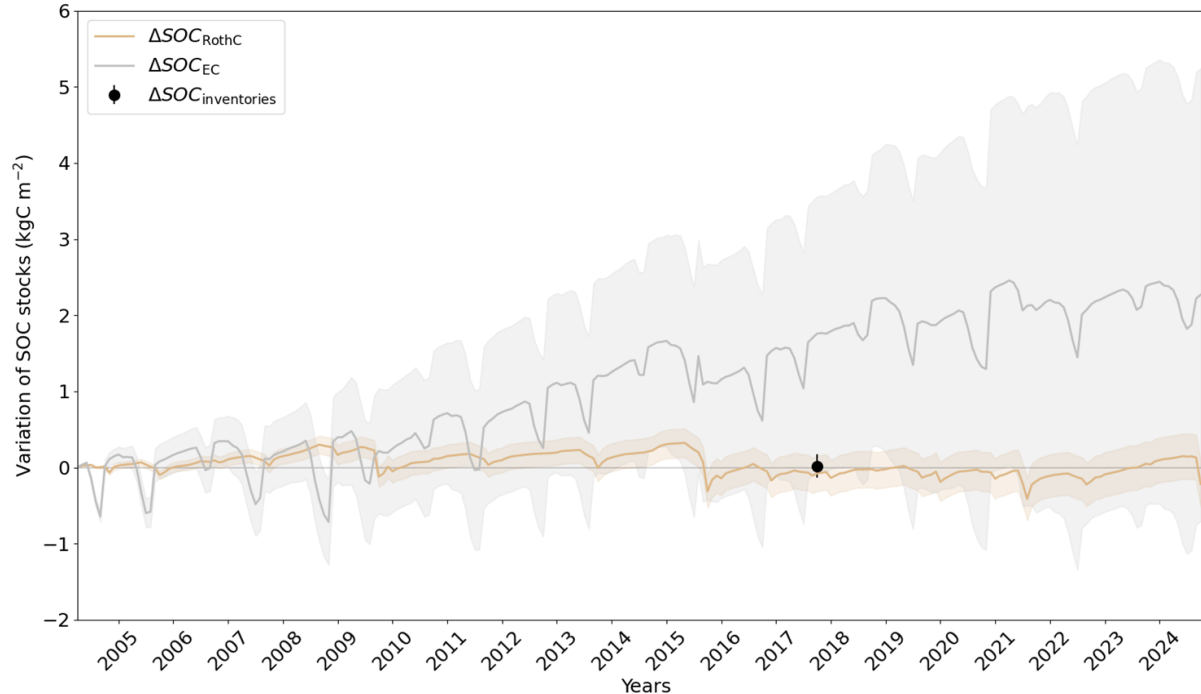
Mean difference between the two inventories assessed by bootstrapping (equivalent soil mass method)

RothC

Monte-Carlo simulations :

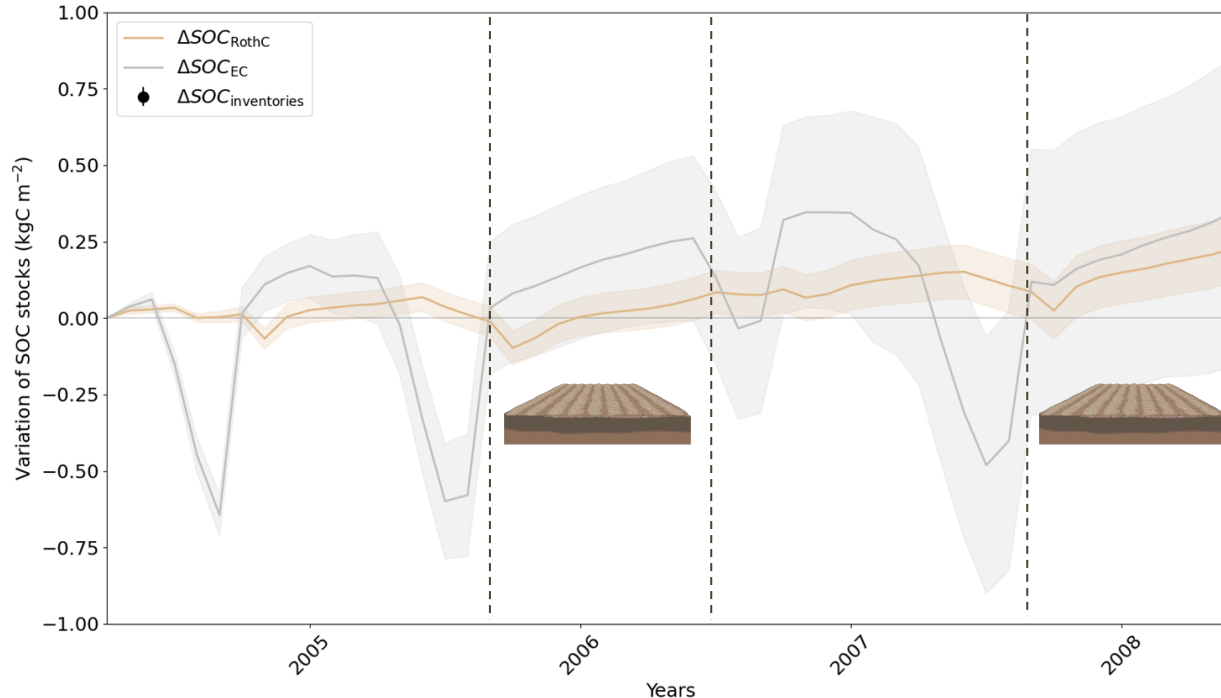
- Measured uncertainty on inputs
- Assumed uncertainty on model parameters

Comparison with RothC and inventories



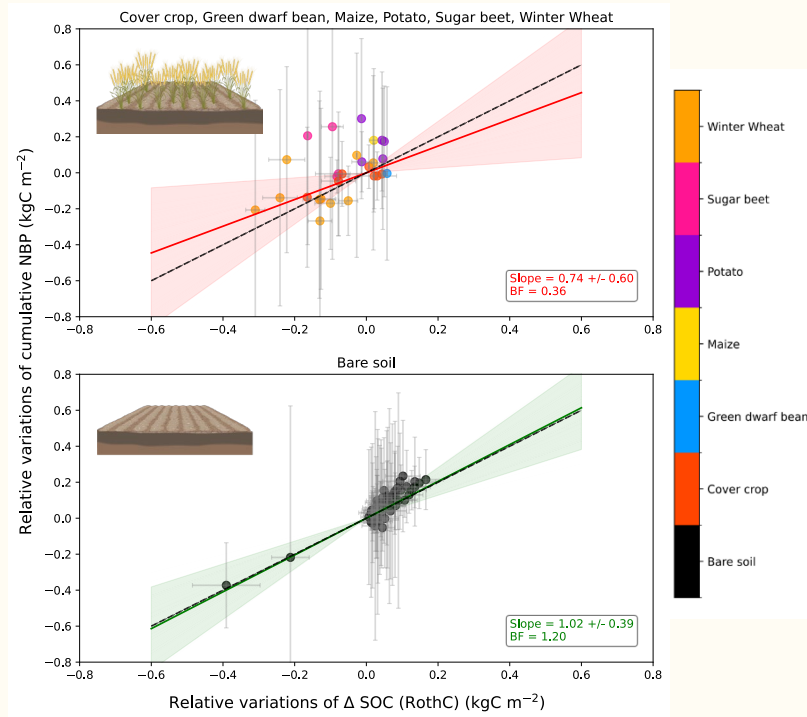
- The magnitude of the change between the inventories was negligible
- Difference between inventories felt within RothC simulation range, supporting equilibrium
- EC-based budget indicates a net loss of 120 ± 122 gC/m²/y

Comparison with RothC and inventories



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- Difference between inventories felt within RothC simulation range, supporting equilibrium
- EC-based budget indicates a net loss of $120 \pm 122 \text{ gC/m}^2/\text{y}$

Comparison with RothC and inventories



- EC and RothC diverge under vegetation but converge under bare soil
- Both agree on the sink pattern of winter wheat, but the magnitude does not match
- Since C inputs in RothC are derived from biomass measurements, it highlights a discrepancy between biometric measurements and EC fluxes

An underestimation of carbon assimilation ?

If SOC stocks are at equilibrium, NEE should scale with the balance of lateral C fluxes

How far they diverge:

$$CBC = \frac{\sum NEE}{\sum C_{exp} - C_{imp}} = 74.6 \%$$

Missing turbulent CO₂ flux ?

Energy balance ratio:

$$EBR = \frac{H + LE}{Rn - G} = 71.9 \%$$

- Forcing EBR closure via NEE could reconcile EC data with RothC and inventory estimates
- The link between energy balance non-closure and NEE underestimation remains unclear

Conclusion

Challenges faced

Inventory areas in 2007 and 2017 were different

→ Comparison performed on a reduced dataset based on strata comparison

C inputs in RothC are critical for realistic SOC simulations

→ Measurements of above-ground biomass left on the field at harvest

→ Estimation of below-ground biomass from measurements of plant anatomical properties

Take-home message

- Systematic errors (spectral correction, u^* threshold) outweighed random noise
- Limitation related to in spectral correction and u^* filtering protocols could substantially reduce these limitations, enabling decisive conclusions
- Robust SOC stock variation estimate in agriculture requires integrating multiple methods

Thank you for listening

