WHAT DO THE FIRST COMPARISON BETWEEN SOIL CARBON STOCK CHANGE AND FLUX BALANCE AT ICOS AGRO-SYSTEMS TEACH/ASK US ?

LIÈGE université Gembloux Agro-Bio Tech

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MRV4SOC PROJECT

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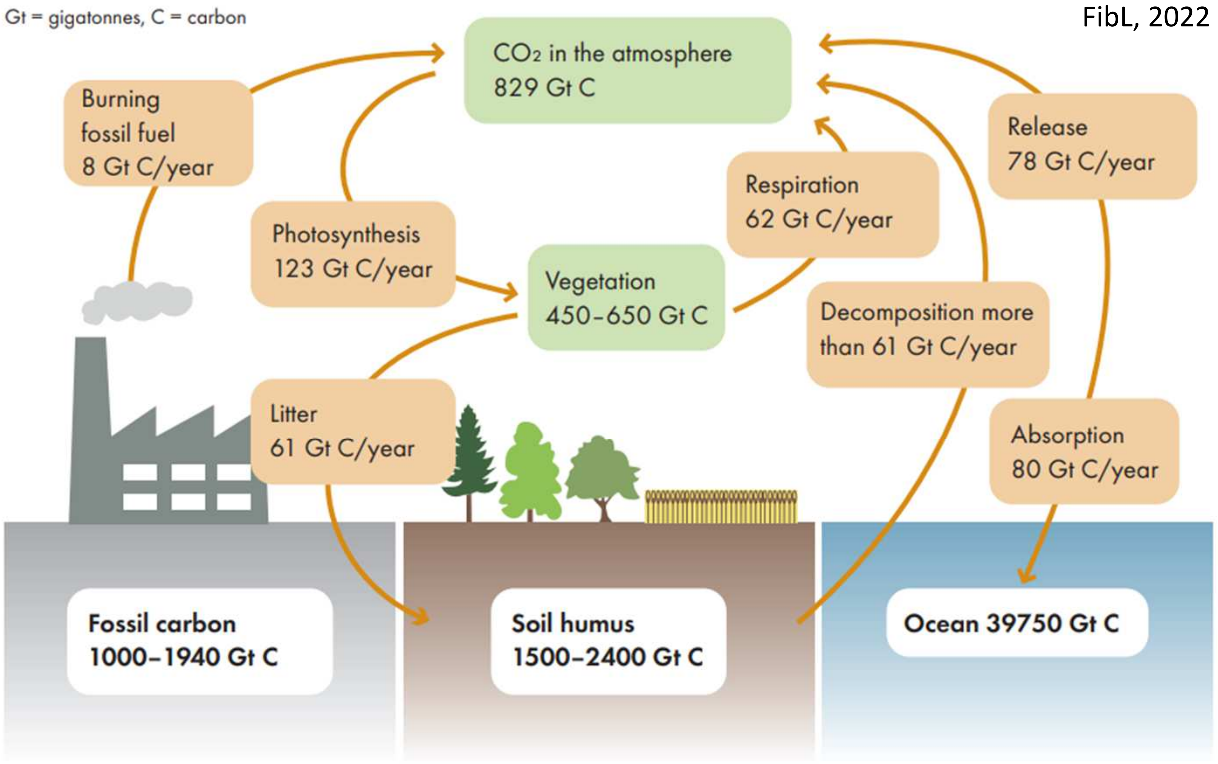
The importance of soil organic carbon

FibL, 2022



Humus build-up and decomposition play an essential role in the carbon cycle relevant to the climate. The CO_2 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]

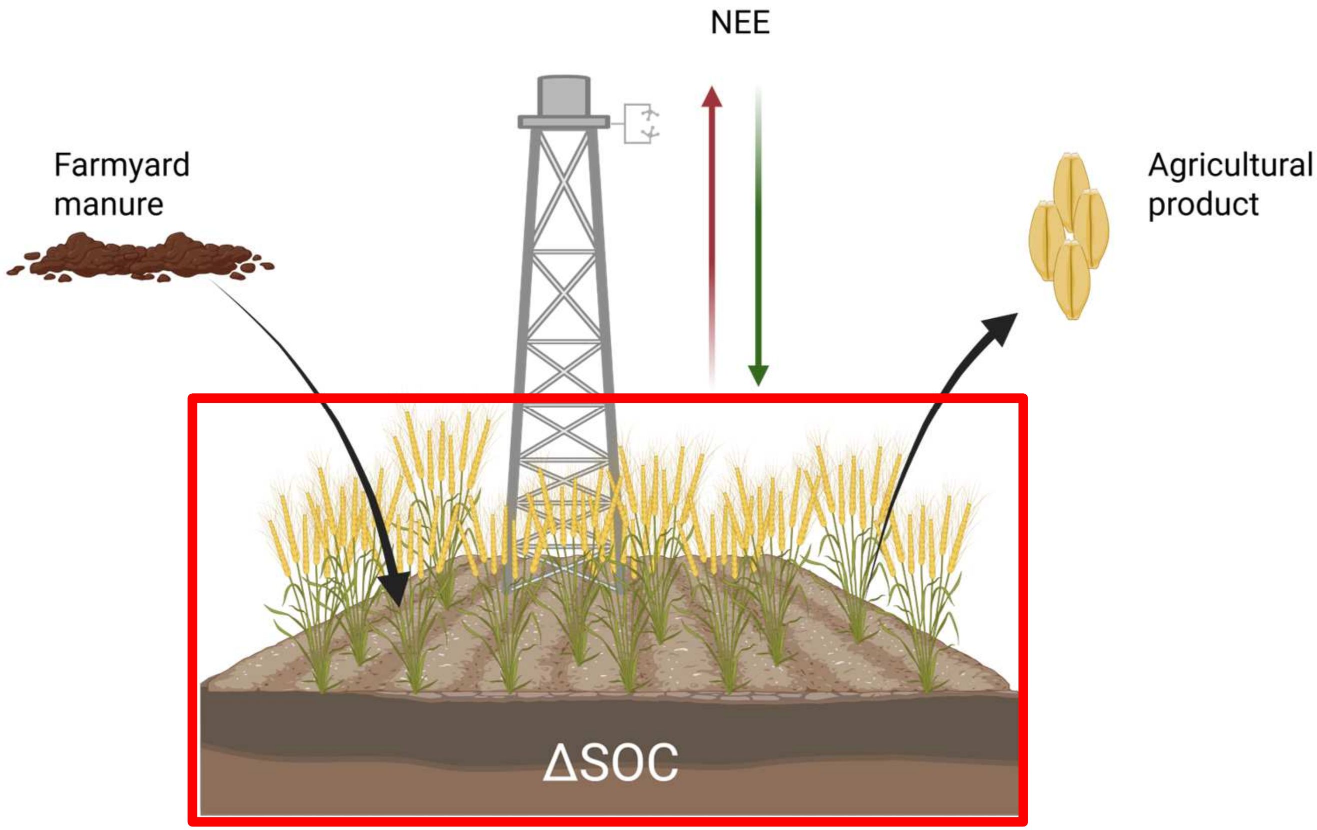
Critical for agriculture and climate

- Enhances soil structure, nutrient availability, and water retention
- SOC sequestration potential: offset 1/6 to 1/3 of anthropogenic CO_2 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



Multi-year SOC stock variation scale with the balance between vertical and lateral C fluxes

Numerous studies using EC have shown high SOC losses for croplands (~ 100 $gC/m^2/yr$)

Need of :
- Comprehensive uncertainty assessment
- Benchmarking with other methods

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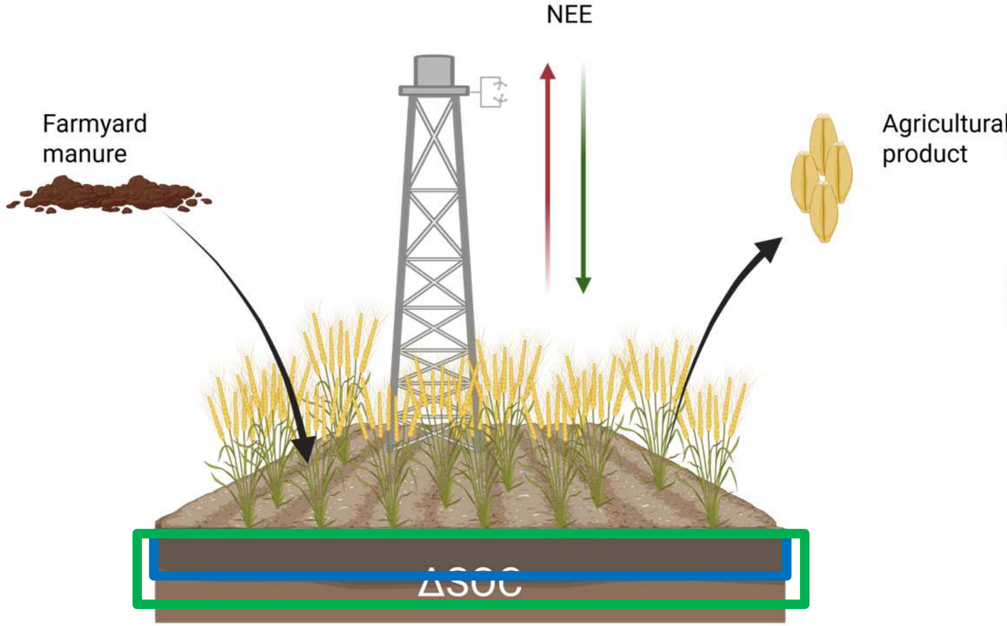
Model and inventories

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
- Down to 30 cm



Soil inventories

- Random sampling scheme
- Bulk density, organic C content, …
- Down to 60 cm

How does EC-based ΔSOC compares with inventories and process-based model simulations?

What are the uncertainties associated with each method?

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A case example in Lonzée (BE-Lon)

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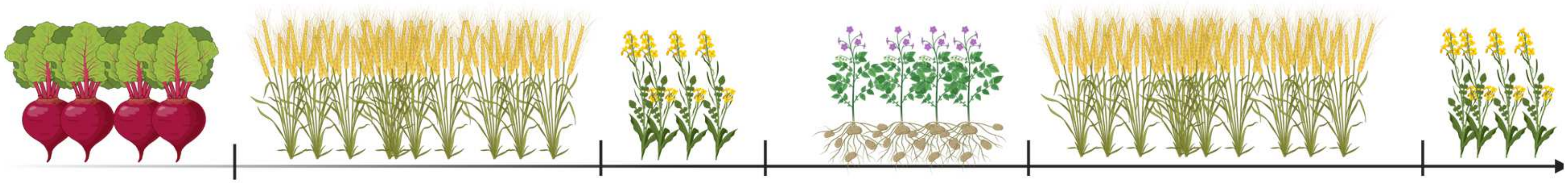
The Lonzée ICOS station (class 2)

Cultivated for more than 80y
Average temperature : 10.2 °C
Mean annual precipitation : 742 mm
Luvisol (clay/silt/sand ≈ 11/80/9 %)

Measurements of

- EC since 2004
- SOC stocks in 2007 and 2017



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Uncertainty assessment

Eddy covariance

Random uncertainty on:

- NEE : measurements (via ONEFLUX) and gapfilling
- Lateral C fluxes (via biomass measurements)

Systematic uncertainty on NEE:

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

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

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

Daily standard deviation on NBP

Random errors add up in quadrature

Systematic errors add up linearly

Both are assumed independent (no covariance term)

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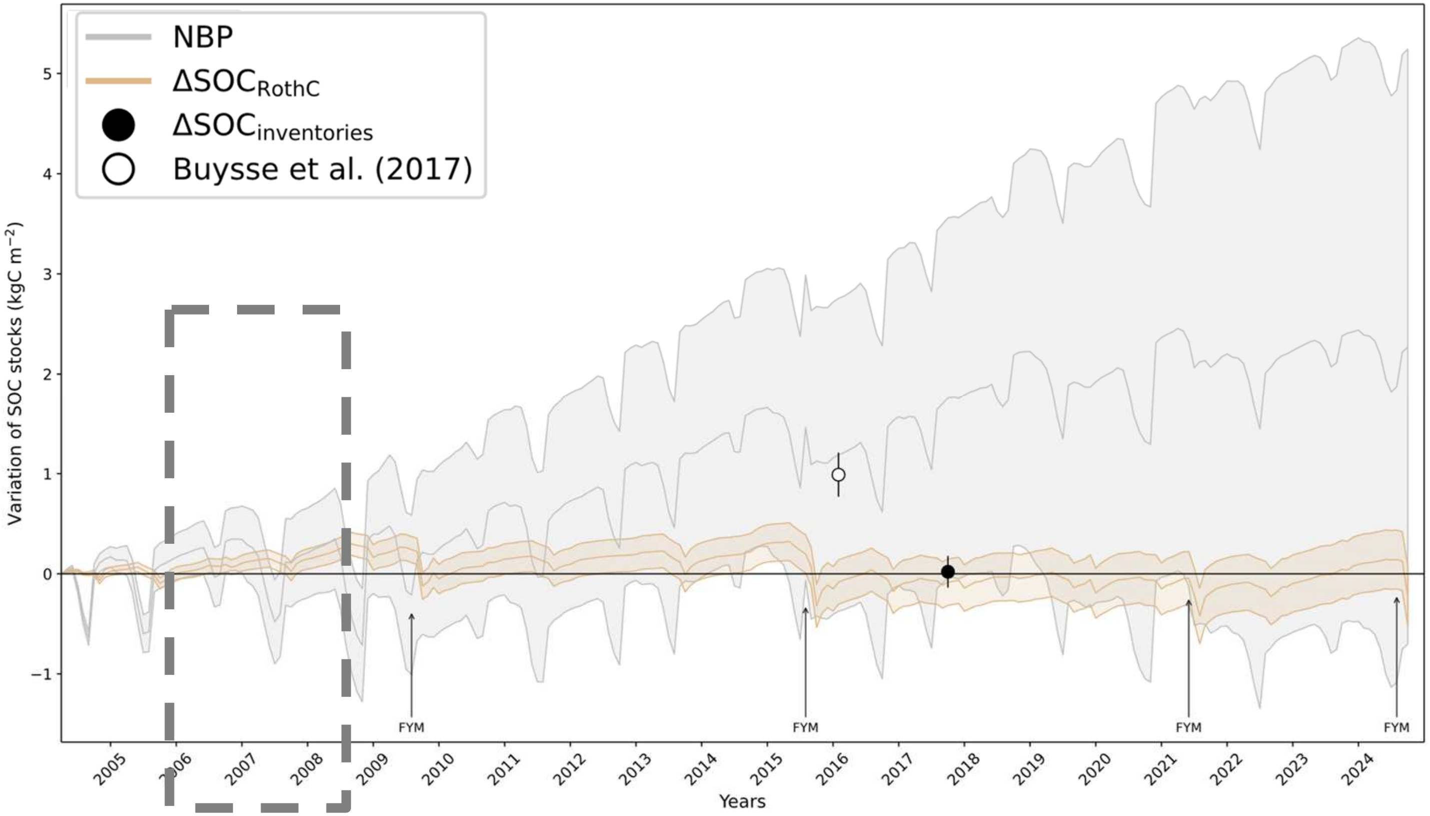
Comparison with RothC and inventories



- EC-based budget indicates a net loss of 109 ± 120 gC/m²/y
- The magnitude of the change between the two inventories was negligible
- Difference between inventories felt within RothC simulation range, supporting equilibrium

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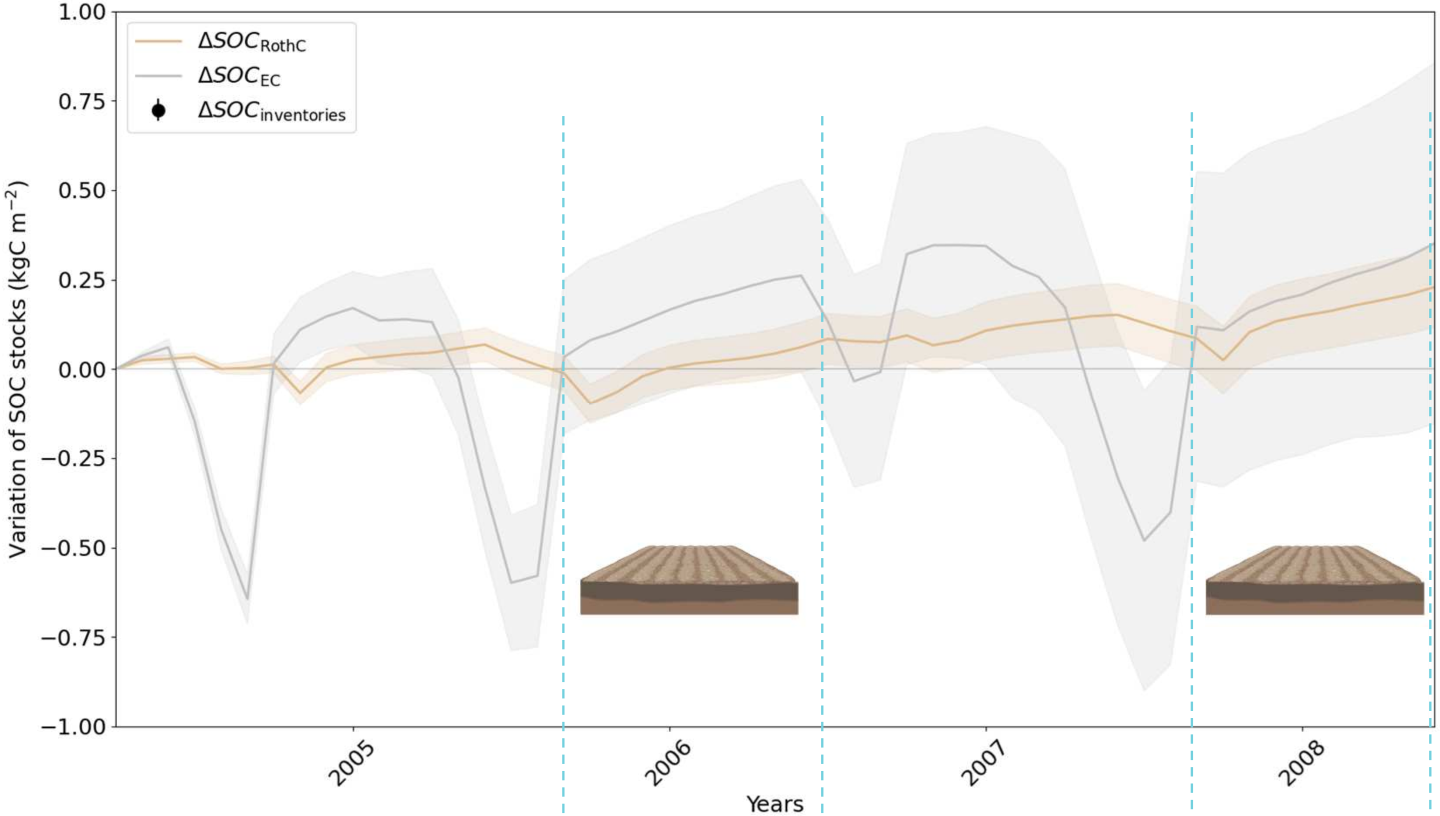
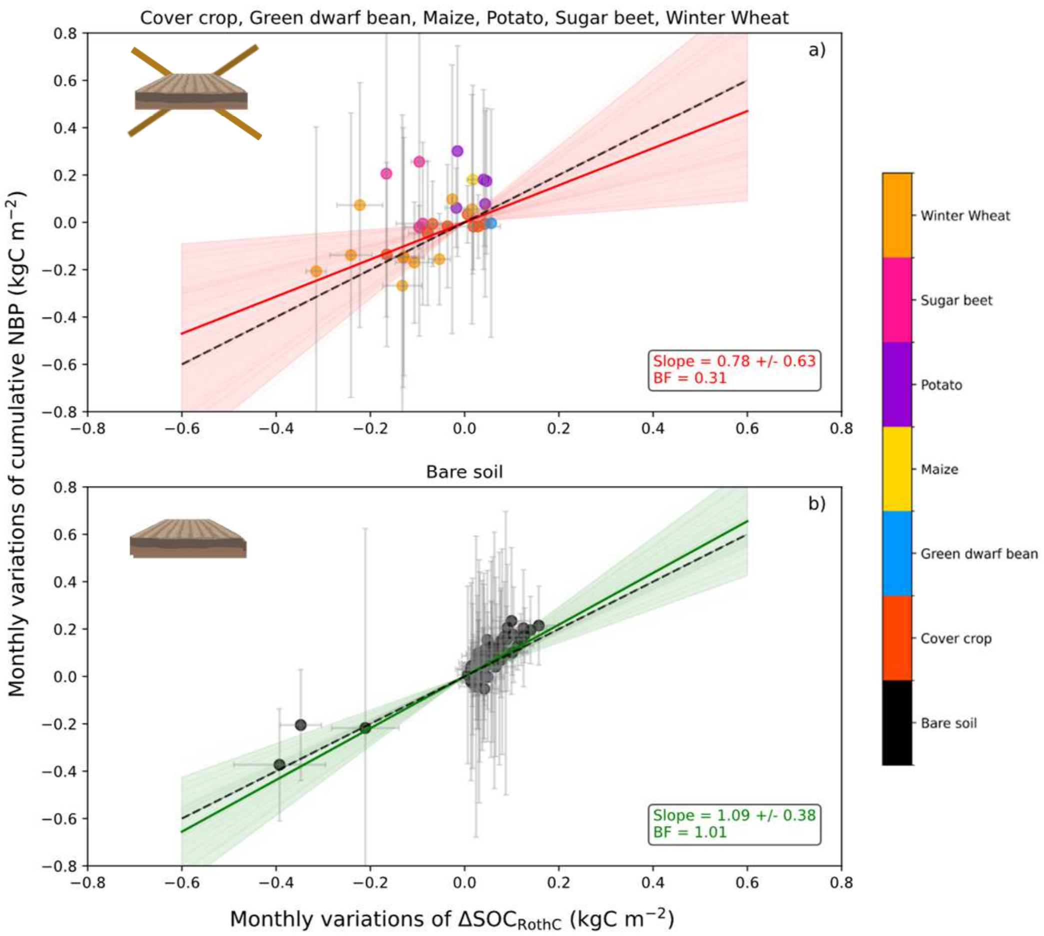
Comparison with RothC and inventories



- Agreement seems to be better under bare soil

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

Underestimation of C uptake ?

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 CO_2 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

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Challenges faced

Need for a uniformized flux computation procedure over the period and ensure no instrument-linked ≠

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
- Improvements related to spectral correction and ustar filtering protocols could substantially reduce these limitations, enabling decisive conclusions
- Robust SOC stock variation estimate in agriculture requires integrating multiple methods

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