Assessing SOC variation following cover crop introduction: the potential of combining soil and remotely sensed crop models

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Context

- Agricultural soils can play a crucial role in mitigating climate change by sequestrating atmospheric carbon through the production and burial of biomass (*Pellerin et al., 2021*).
- Decision-making tools are needed to assess Soil Organic Carbon (SOC) change following adapted management practices at plot scale and over large areas. Therefore it requires :
  - Regular and accurate estimates of carbon inputs from crop residues.
  - The use of dynamic soil C models using initial soil parameters and carbon inputs.

➔ **Uncertainties associated with the methods used to estimate C inputs to soil affect the accuracy of SOC changes and need to be reduced.**

Uncertainties of allometric equations

Existing methods for estimating soil carbon inputs are based on yield data and allometric equations (e.g., *Bolinder et al., 2007*).

However, there are uncertainties associated with this method, in particular because :

- Estimates of extra-root carbon are subject to high uncertainty and can account for 65% of root carbon (*Gill et al., 2002*)
- Large uncertainties in estimating below-ground C inputs in relation to root:shoot ratio (Fig. 1) :
  - from **142 to 424 gC.m^{-2}.yr^{-1}** for wheat.

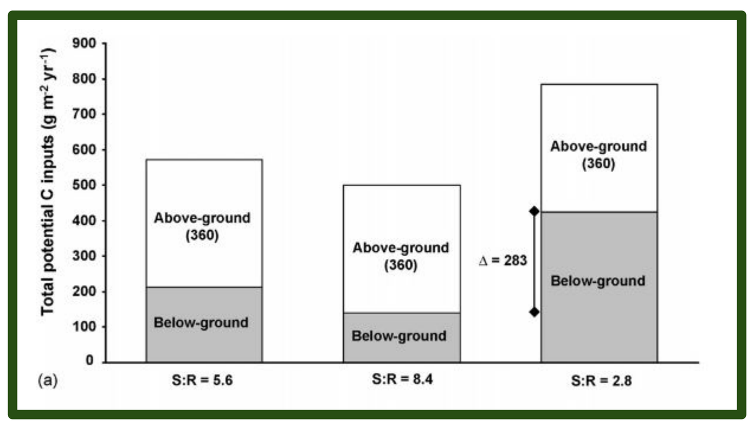


Fig 1. Uncertainty associated with the annual C input from below-ground net primary productivity (From Bolinder et al., 2007)

Differences between methods

Several allometric equations exist and can be used to calculate soil C inputs, but they have some limitations :

- They are developed using data from different geographical regions.
- Allometries may have changed through time.
- They cannot be used without yield data (e.g., for cover crop).

Keel et al., (2017) compared five commonly used allometric equations for calculating C inputs from yield and showed that they lead to significant differences (Fig. 2).

These differences depend on crop type and are larger for leys (i.e., **6.6 MgC.ha^{-1}.yr^{-1}**) while they are smallest for beetroot (i.e., **0.36 MgC.ha^{-1}.yr^{-1}**).

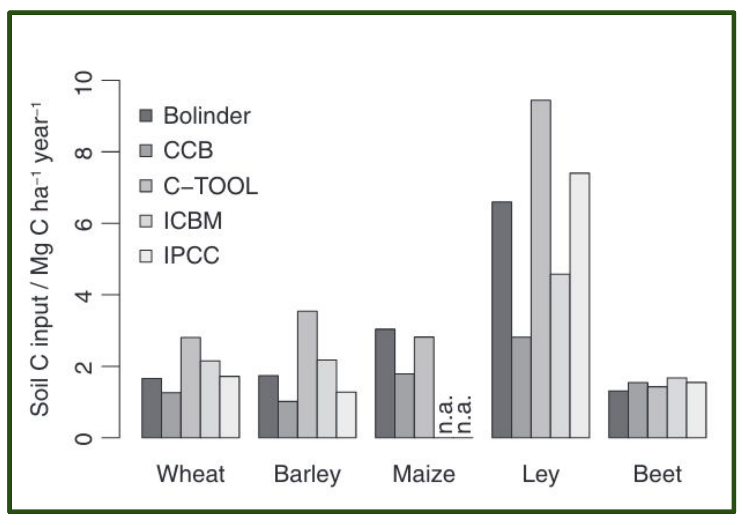


Fig 2. Soil C inputs from different crop types and estimated with five different allometric equations (from Keel et al., 2017)

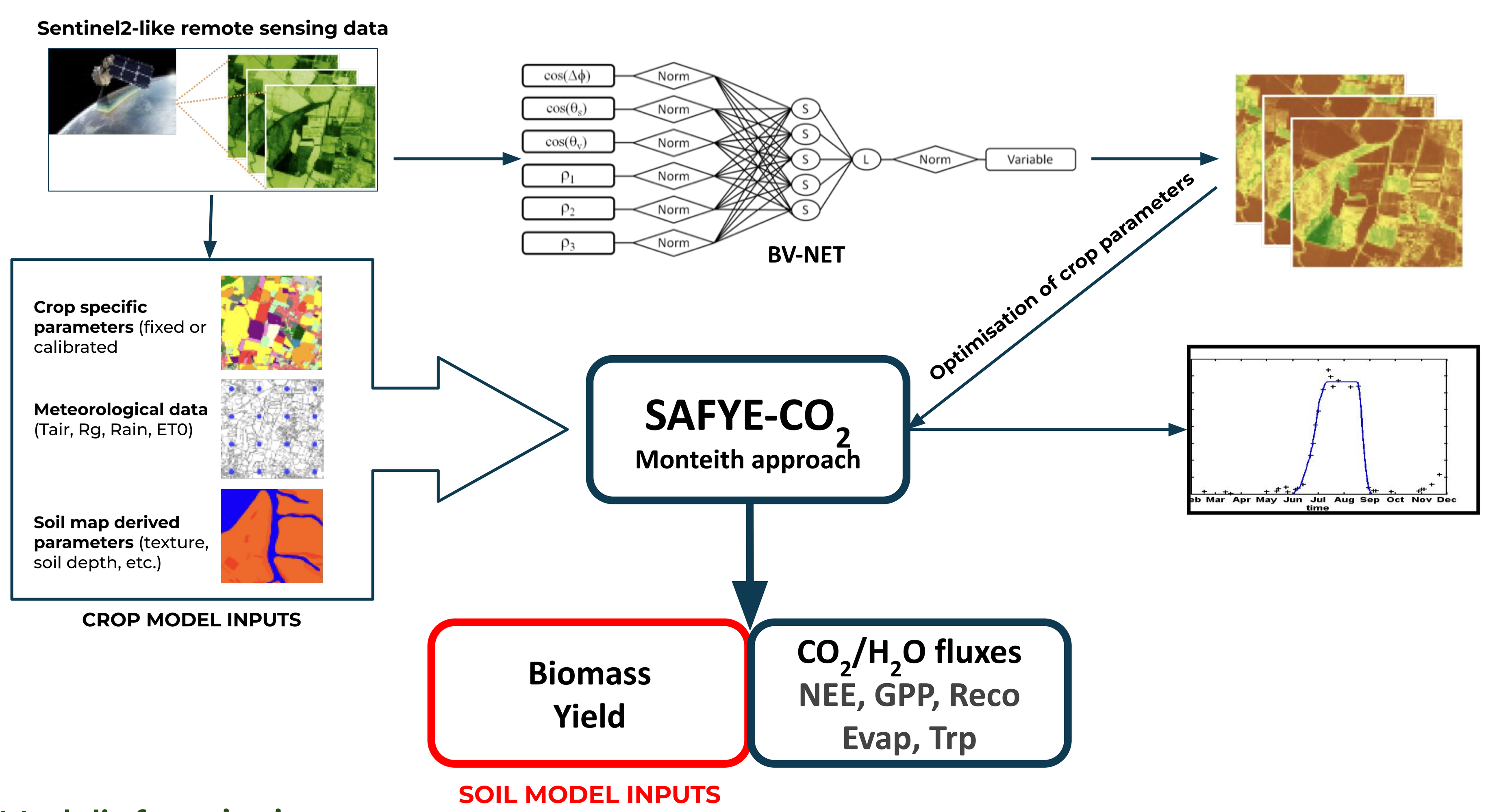
C inputs derived from crop model

The use of a remotely sensed crop model to estimate C inputs could reduce the uncertainty in C input estimates. It has several advantages :

- Crop specific parameters derived from CO_2 flux measurements.
  ⇒ Takes into account all C fixed by plants (including roots and exudates).
- Can provide estimates of C inputs at satellite spatial resolution (i.e., 10m for Sentinel-2).
  ⇒ Takes into account the spatial heterogeneity of crop development.
- Specific to the application area of the model as it is driven by remote sensing data.
- Do not rely on agricultural statistics.
- Allow the estimation of C inputs from cover crops.

Combined use of soil and crop models

SAFYE-CO_2 (*Pique et al., 2020a, b*) is a parsimonious agro-meteorological model working on a daily basis. Remote sensing GAI is assimilated in the model and allows the calibration of several crop-specific parameters.



Model's functioning

Model's validation - Wheat

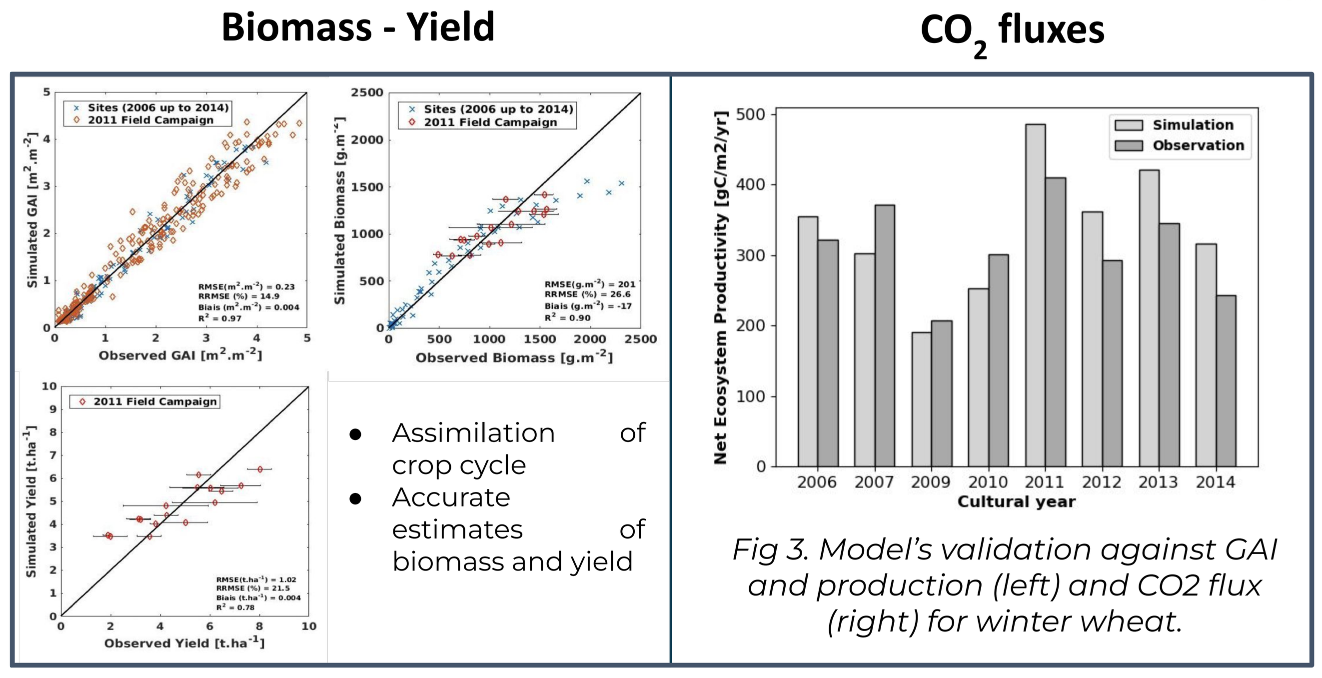


Fig 3. Model's validation against GAI and production (left) and CO2 flux (right) for winter wheat.

- All observed cultural years act as atmospheric carbon sink.
- Differences between observed and simulated range from **73 gC.m^{-2}.yr^{-1}** (30%) to **17 gC.m^{-2}.yr^{-1}** (8%).
- Overall, the model reproduces the observed NEP with an RMSE of **61 gC.m^{-2}.yr^{-1}** (20%).

Conclusions and Perspectives

Current methods using allometric equations to estimate C inputs are uncertain and could lead to inaccurate estimates of SOC change following adapted management practices.

The combined use of soil and remotely sensed crop models allows to :

✓ Reduce uncertainties

✓ Derive C inputs from remote sensing observations, i.e., not to rely on agricultural statistics.

✓ To assess the C input from cover crops, which have been identified as the most important potential for C storage in soils in France (*Pellerin et al., 2021*).

This work responds to the need for harmonised methodologies to drive the agricultural transition and, in particular, to protect the soil by ensuring that more carbon is stored through adapted practices.

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