Multiyear high-resolution carbon exchange over European croplands from the integration of observed crop yields into CarbonTracker Europe

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Motivation

The terrestrial biosphere is the most uncertain and variable component of the global carbon cycle [1]. Part of reducing that uncertainty comes with better modeling the cropland share of the terrestrial carbon cycle.

Model-data integration method

We use the WOFOST crop growth model [2] to represent the water-limited crop growth (our model first guess) of various crop species over Europe. We then integrate European grain yield observations to scale crop growth down to observed levels.

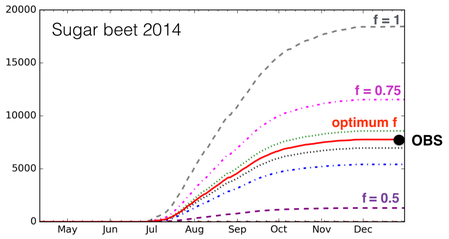


Fig. 1: Tested values of scaling factors and their impact on grain yield along the growing season.

Optimization outcome:

We compute one optimum scaling factor per region, year and crop species. We then obtain optimized crop fluxes at 25x25 km resolution.

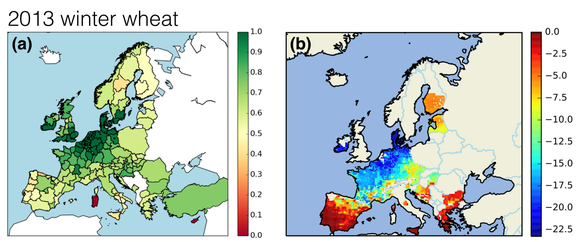


Fig. 2: (a) Optimum scaling factors and (b) resulting J-J-A monthly mean GPP ($g_C\ m^{-2}\ d^{-1}$).

Cropland carbon balance:

We add an exponential function of temperature for soil respiration [3] to the WOFOST fluxes:

NEE = GPP + R_{crop} + R_{soil}

NEE = GPP + TER (eq. 1)

Validation at various sites

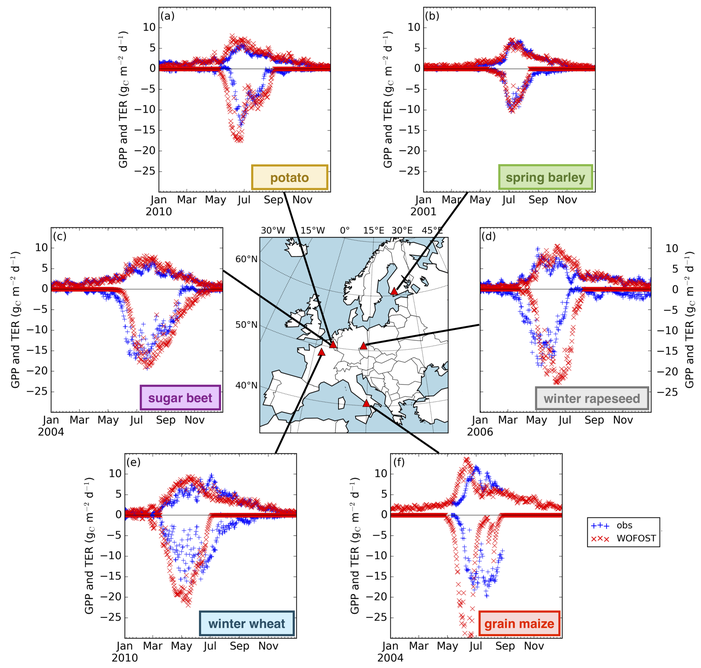


Fig. 3: One year of modeled and observed daily GPP and TER ($g_C\ m^{-2}\ d^{-1}$) at five FluxNet sites located in three major European climate zones: Mediterranean (Italy), Temperate (Belgium, France, Germany), and Cold (Finland).

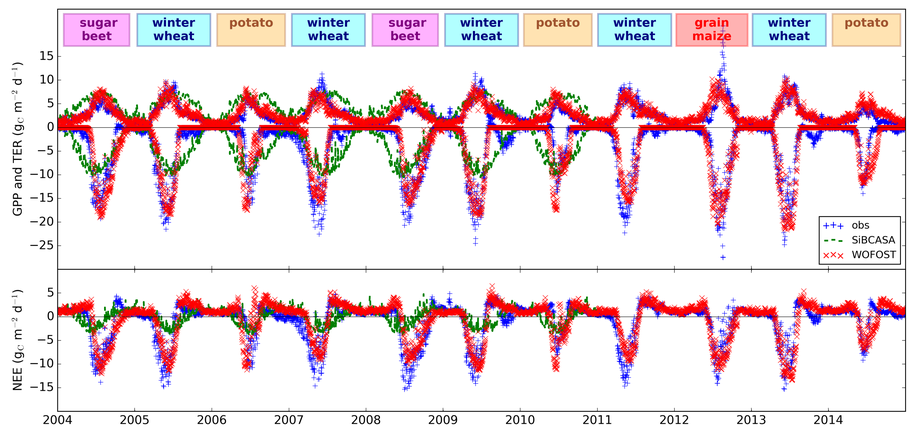
The optimized WOFOST model is able to represent the crop-specific timing (short growing season of 2-3 months) and magnitude (10-30 $g_C\ m^{-2}\ d^{-1}$) of the daily CO_2 exchange above croplands.

It is moreover able to simulate cropland fluxes within three of the most important climate zones of Europe.

Validation of multi-annual CO_2 exchange

Fig. 4: 10 years of observed and simulated GPP, TER, NEE fluxes at the Belgian FluxNet site Lonzee.

The optimized WOFOST model is able to represent the inter-annual variability of NEE.



Abbreviations

R_{crop}: crop respiration

R_{soil}: soil respiration

GPP: gross primary production

TER: total ecosystem respiration

NEE: net ecosystem exchange

WOFOST: our crop growth model

SiBCASA: a global vegetation model that simulates crops as managed grassland

Take-home message

To our knowledge, this is the first study attempting to use grain yield as an additional stream of data to constrain cropland NEE. The optimized WOFOST model performs great against FluxNet observations of GPP, TER and NEE.

Current and future steps

Currently:

- drought case study

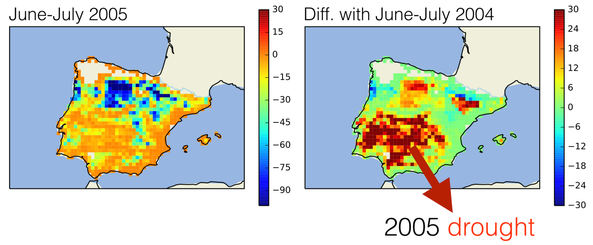


Fig. 5: monthly mean NEE of cultivated grain maize ($1e^{-6}\ g_C$ grid $box^{-1}\ s^{-1}$) in the Iberian peninsula.

Mid- to long-term:

- feed cropland NEE to a forward or inverse atmospheric model (e.g. WRF or CarbonTracker Europe), see the improvement on the CO_2 mole fractions or posterior CO_2 fluxes
- addition of a harvest module and lateral transport of carbon scheme for a full carbon balance [4]
- carbon fluxes made available through the ICOS carbon portal

References

[1] C. Le Quéré et al. (2013) The global carbon budget, *Earth Syst. Sci. data*.

[2] A. de Wit et al. (2007) Crop model data assimilation with the Ensemble Kalman filter for improving regional crop yield forecasts, *Agric. For. Meteorol.*.

[3] J. Lloyd and J.A. Taylor (1994) On the temperature dependence of soil respiration, *Functional Ecology*.

[4] T.O. West et al. (2011) Regional uptake and release of crop carbon in the United States, *Biogeosciences*.