Estimating CO_2 fluxes of diversified crop rotations from STICS outputs

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XIII Séminaire STICS – Bordeaux, the 15th of November 2023

ICOS – Integrated Carbon Observation System

The idea

ICOS stations focus on specific pedo-climatic conditions and management

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Calibration and validation

Soil-crop model

Would enable the extrapolation to other contrasted pedo-climatic conditions and management

Climate change

Different crops

Management

The idea

ICOS stations focus on specific pedo-climatic conditions and management

Calibration and validation

Soil-crop model

Objectives

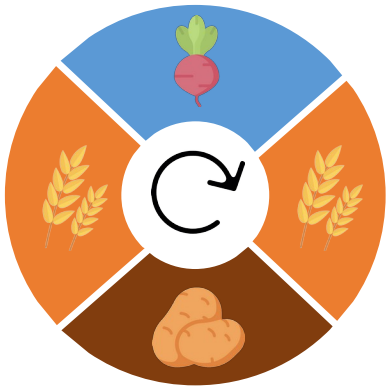
1. Elaborate, from field measurements, the methodology to compute CO_2 fluxes.
2. Discuss the influence of various environmental drivers on crop rotations CO_2 fluxes, based on both field observations and model simulations.

The BE-LON experimental site (Belgium)

- Experiment started in 2004
- Data collected: yield, crop growth, soil variables…
- But also CO_2 and N_2O exchanges

https://www.icos-belgium.be/ESLonzee.php#Lonzee. Picture by Eli Verheyen in 2018

- 4-year crop rotation: sugarbeet, winter wheat and potatoes

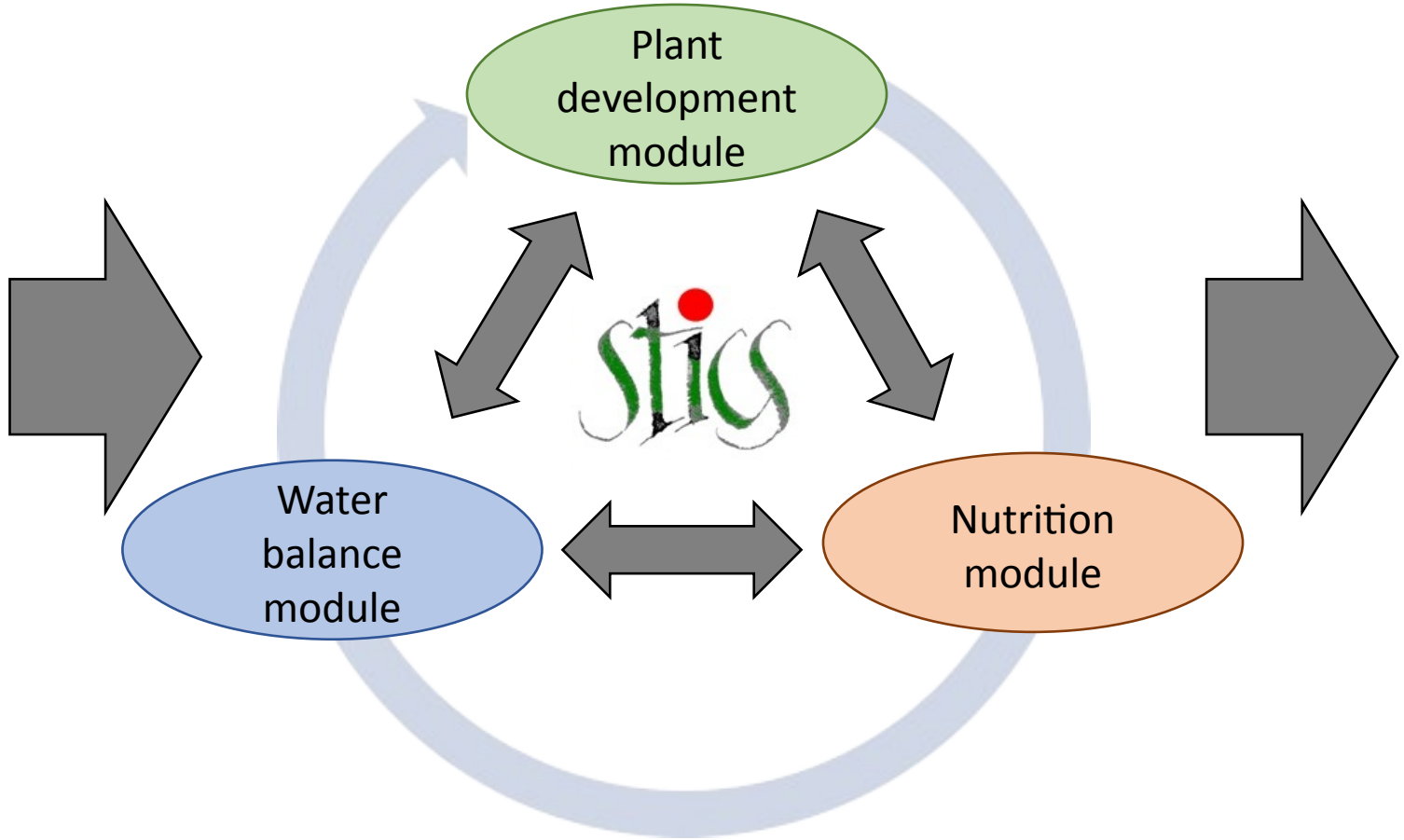


The soil-crop model STICS v9.2

INPUTS

- Plant
- Soil
- Climate
- Initialization
- Management

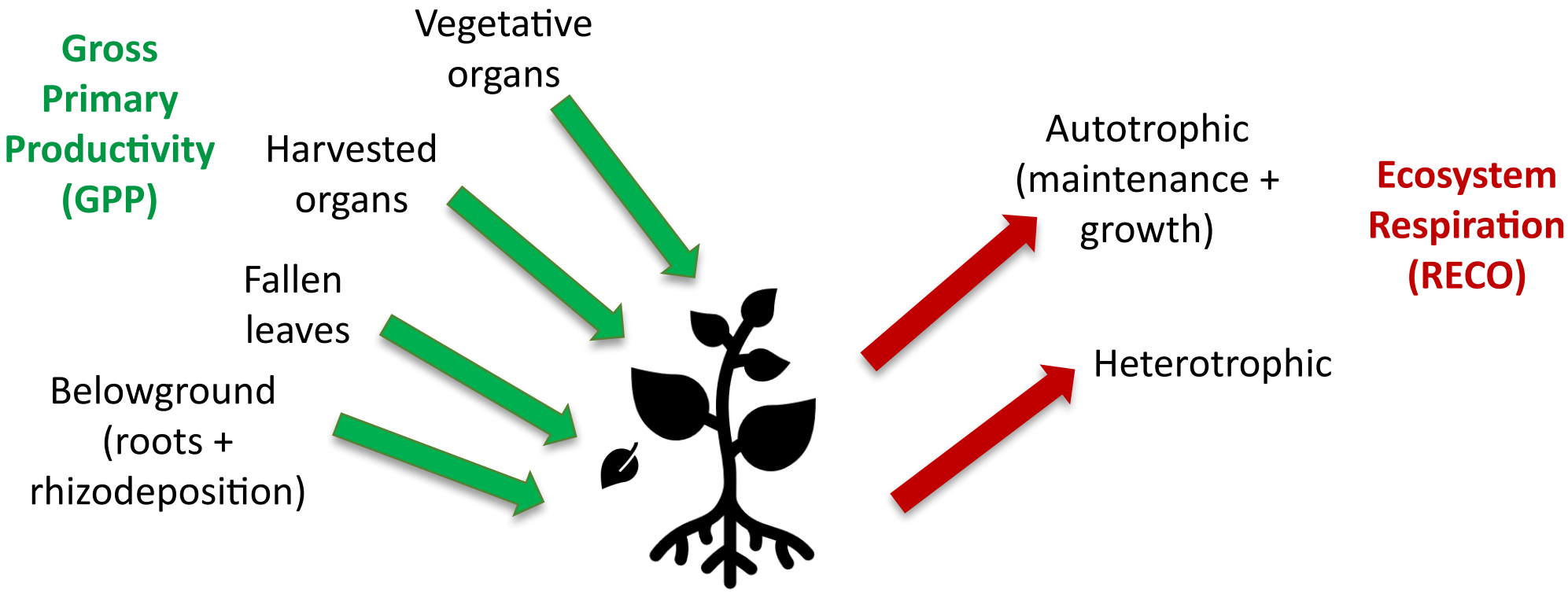
Model daily computation



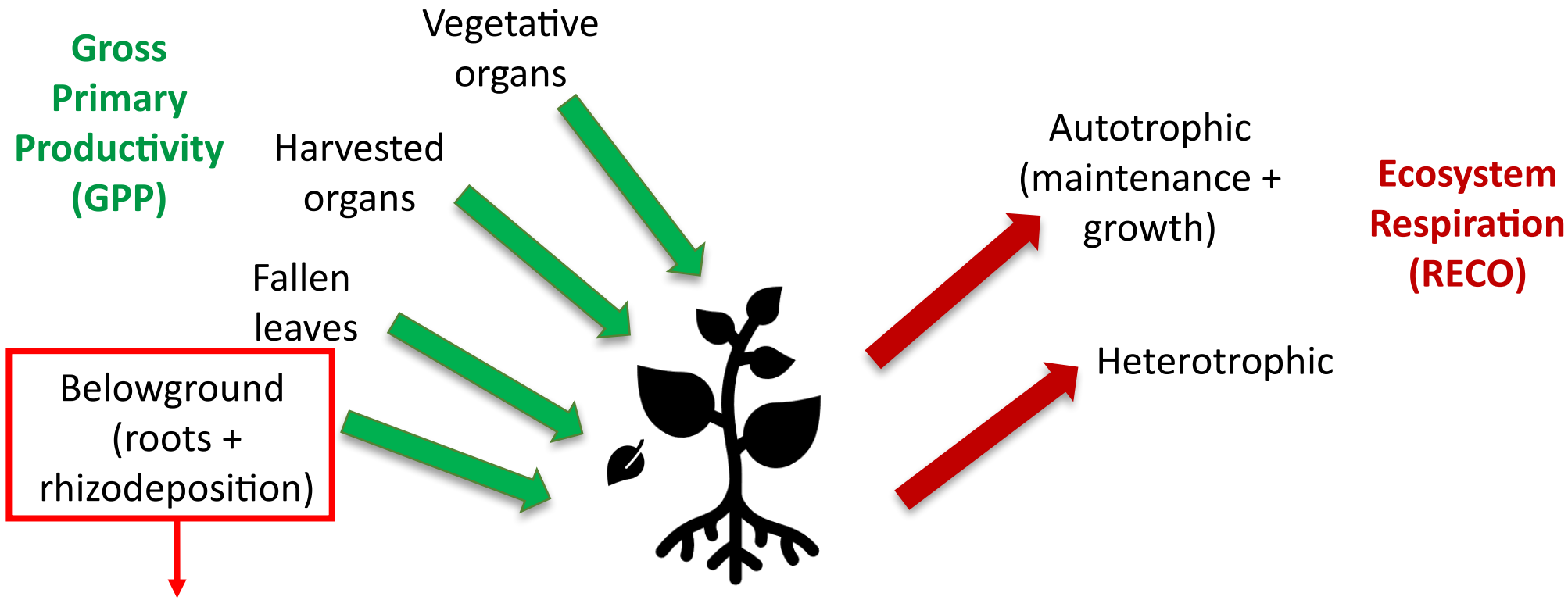
OUTPUTS

- Yield
- Stresses
- Soil bio-chemical state (SOC, N…)
- Water balance

Methodology

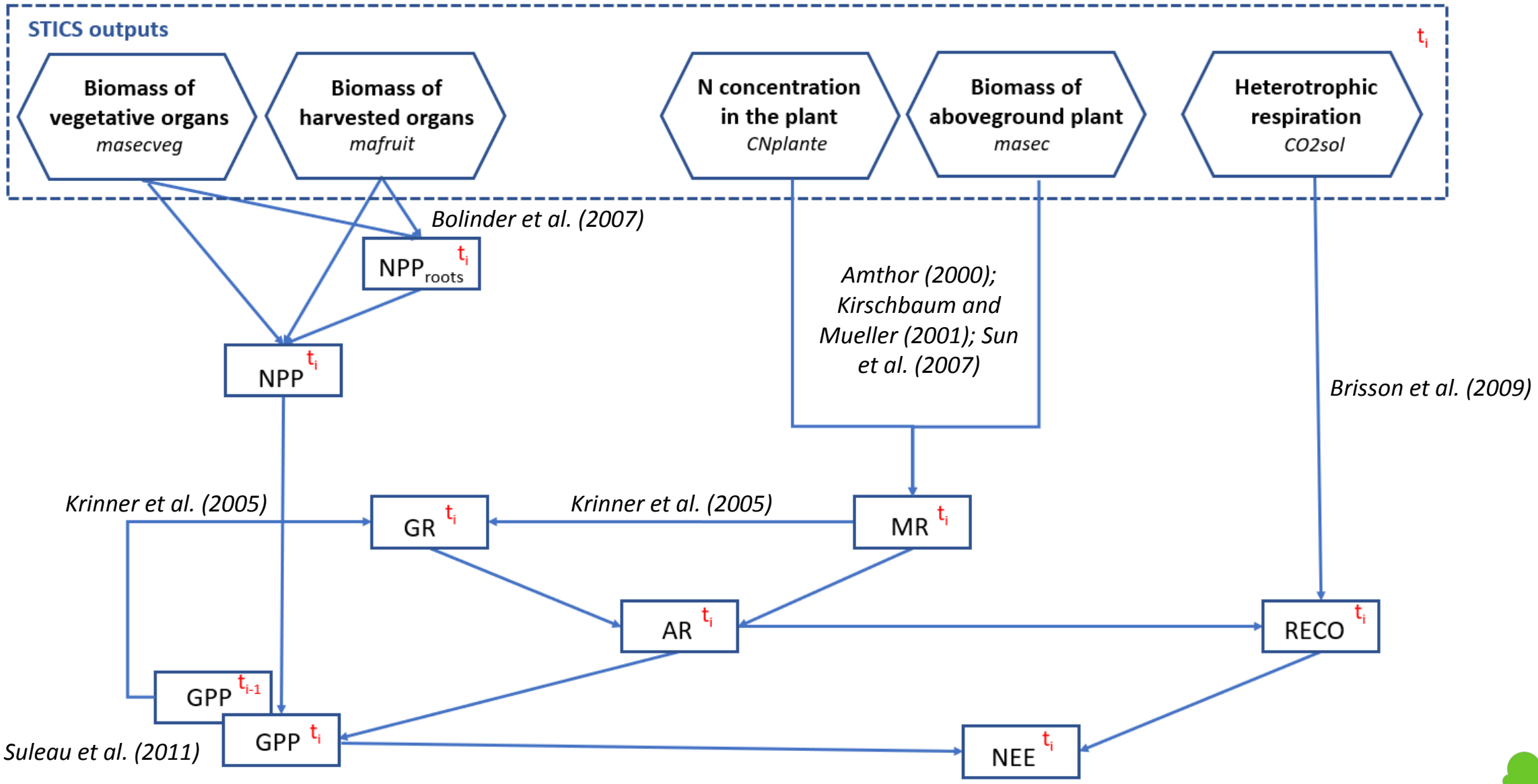


Methodology



Used a constant coefficient coming from shoot-root ratios and harvest indices, considering rhizodeposition (Bolinder et al., 2007).

Methodology

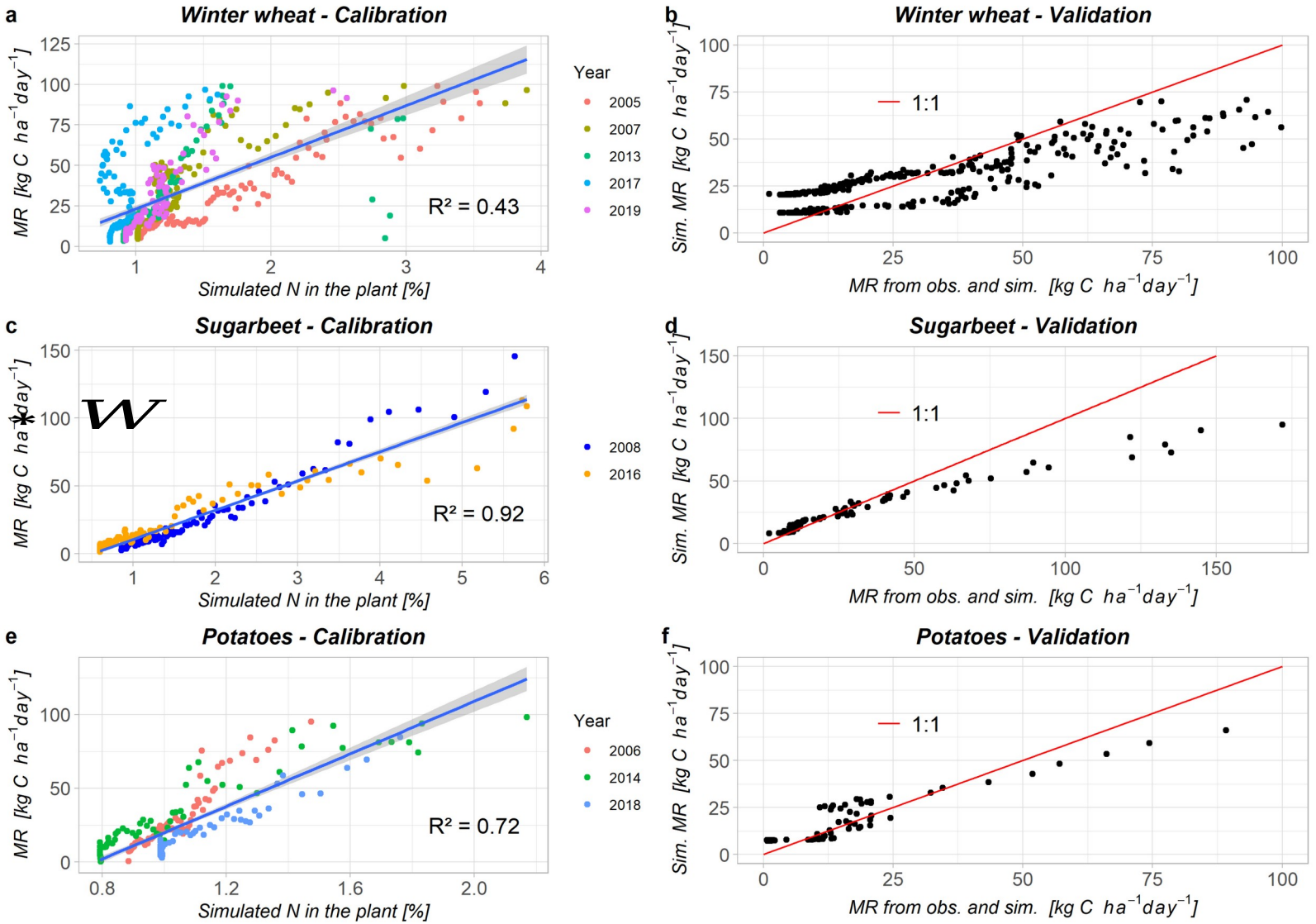


Results – Relationship between MR and plant N concentration

Following Amthor (2000), Kirschbaum and Mueller (2001) and Sun et al. (2007):

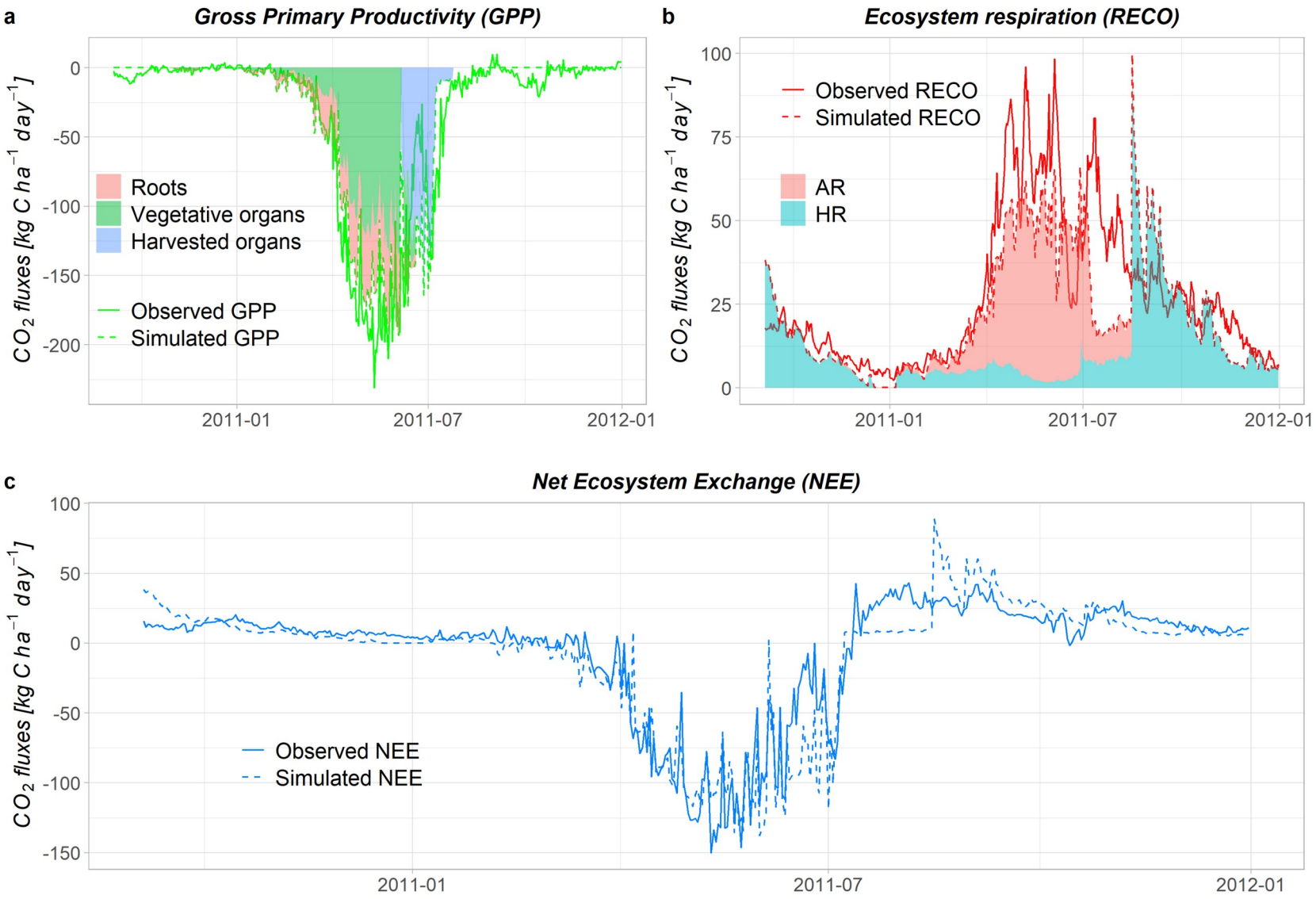
$$MR = (aN + b) * Q_{10}^{\frac{T-25}{10}} * W$$

$$aN_{sim_i} + b = \frac{RECO_{obs_i} - HR_{sim_i} - 0.28 * GPP_{sim_{i-1}}}{(1-0.28) * Q_{10}^{\frac{T_i-25}{10}} * W_{sim_i}}$$

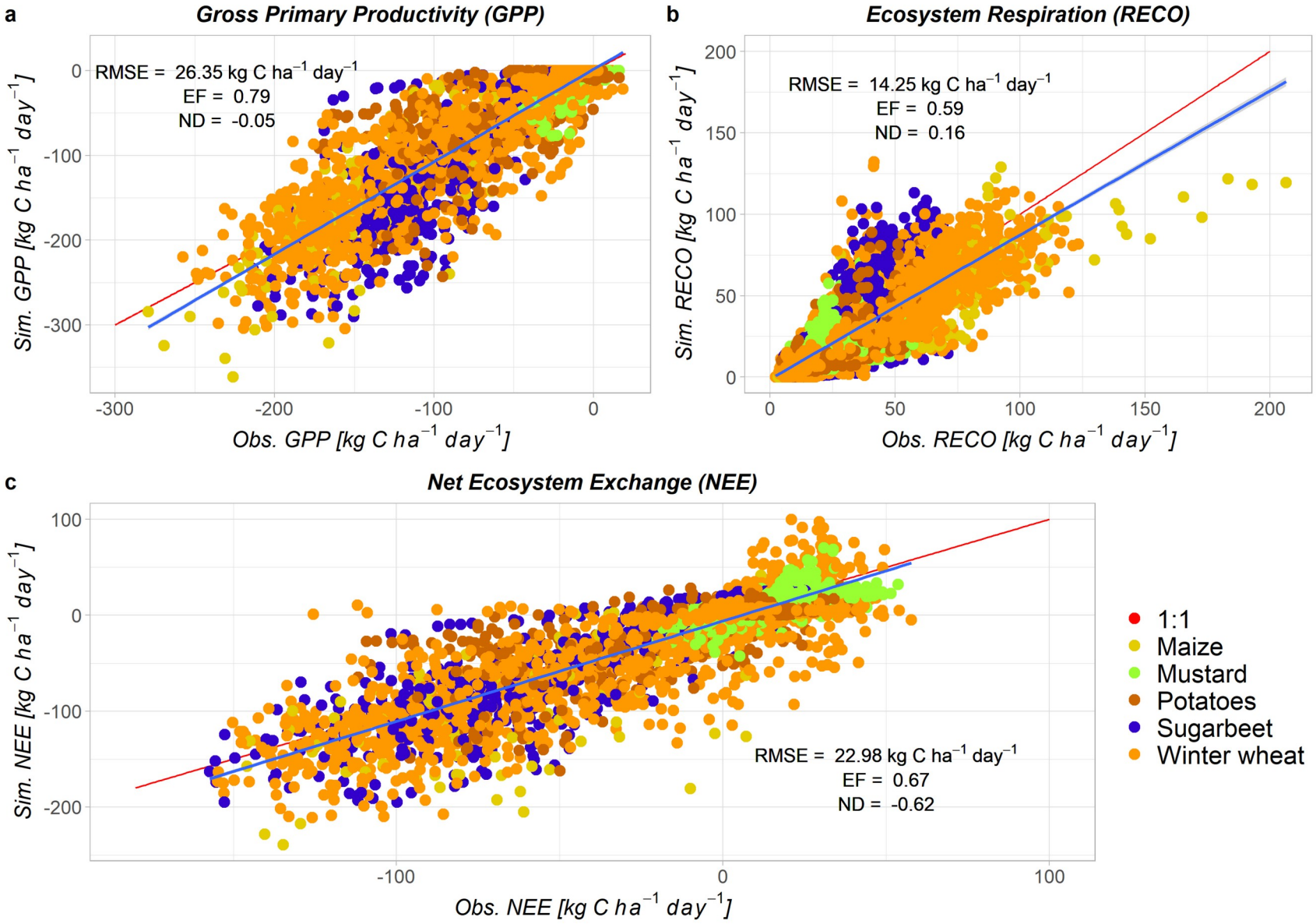


Results – Carbon dynamics illustration

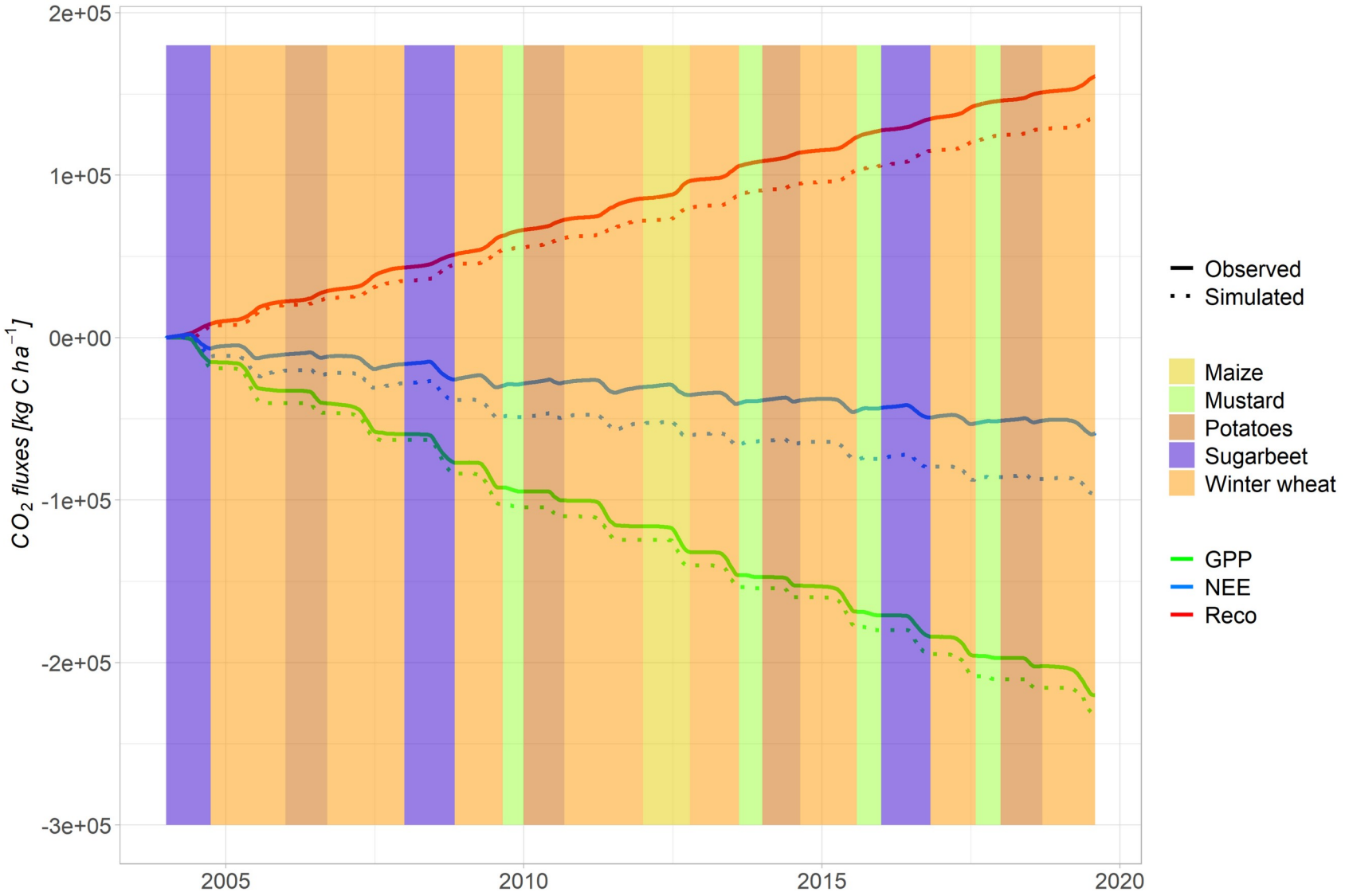
Winter wheat
2011-2012



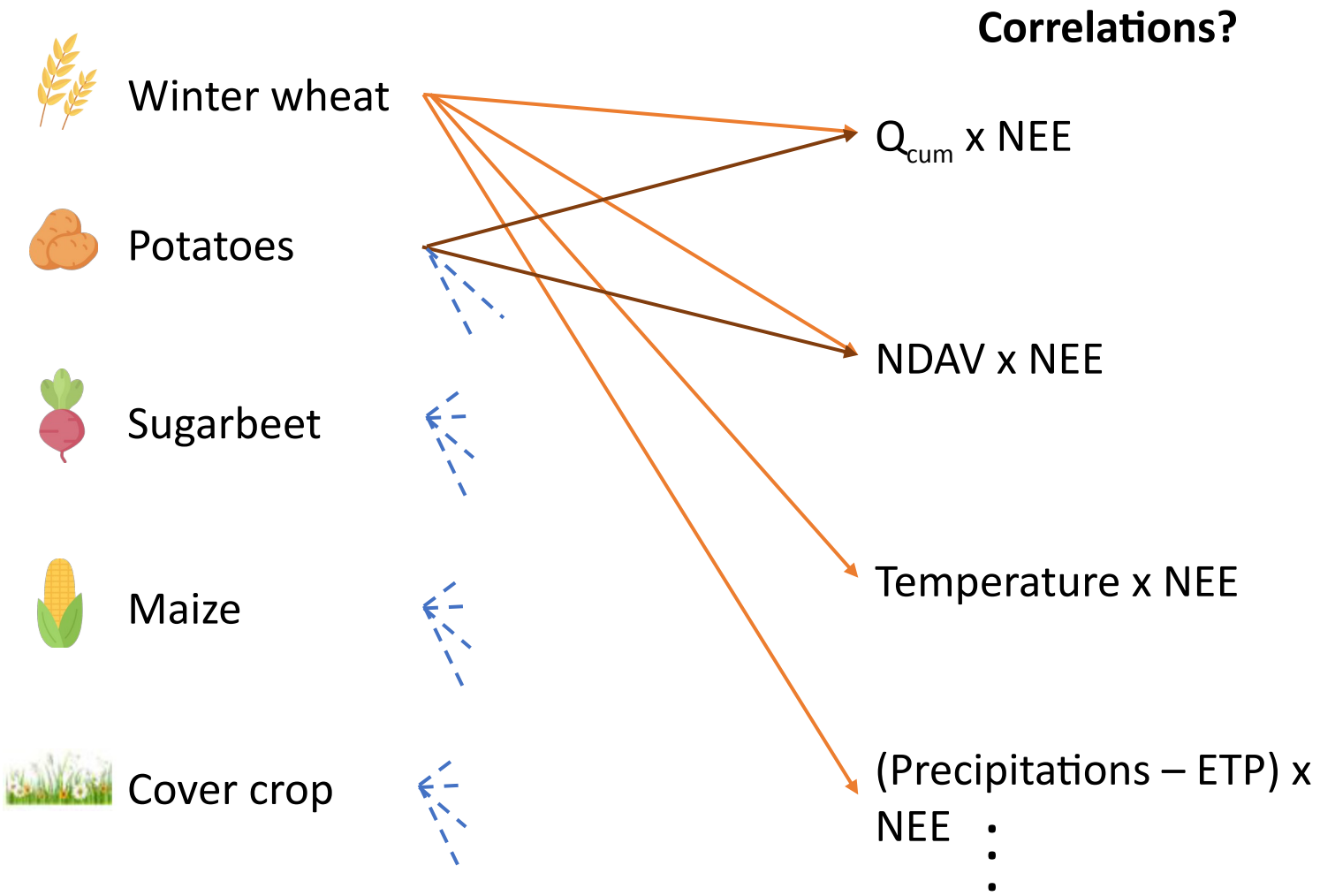
Results – Goodness of fit



Results – Carbon budget

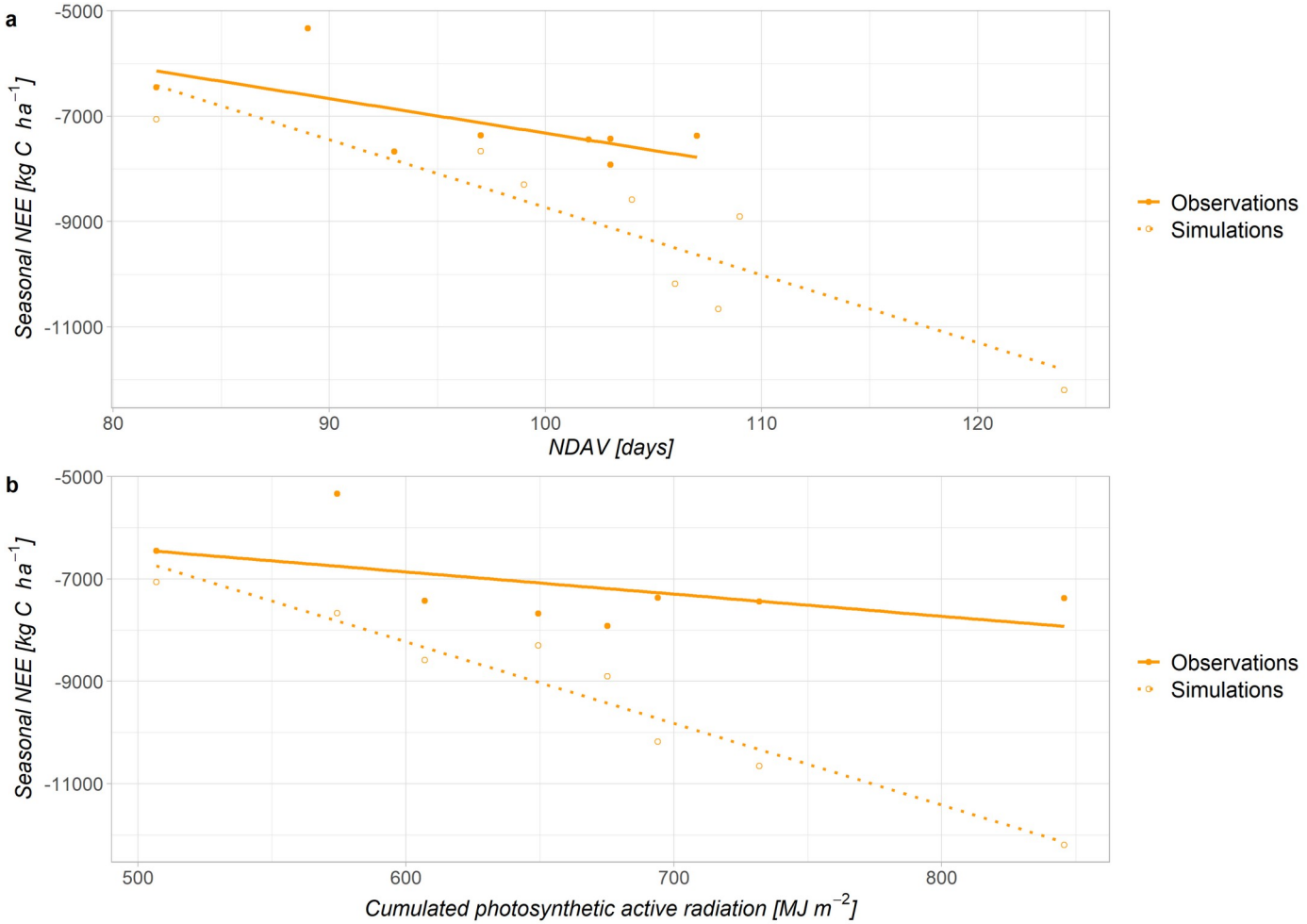


NEE inter-annual variability

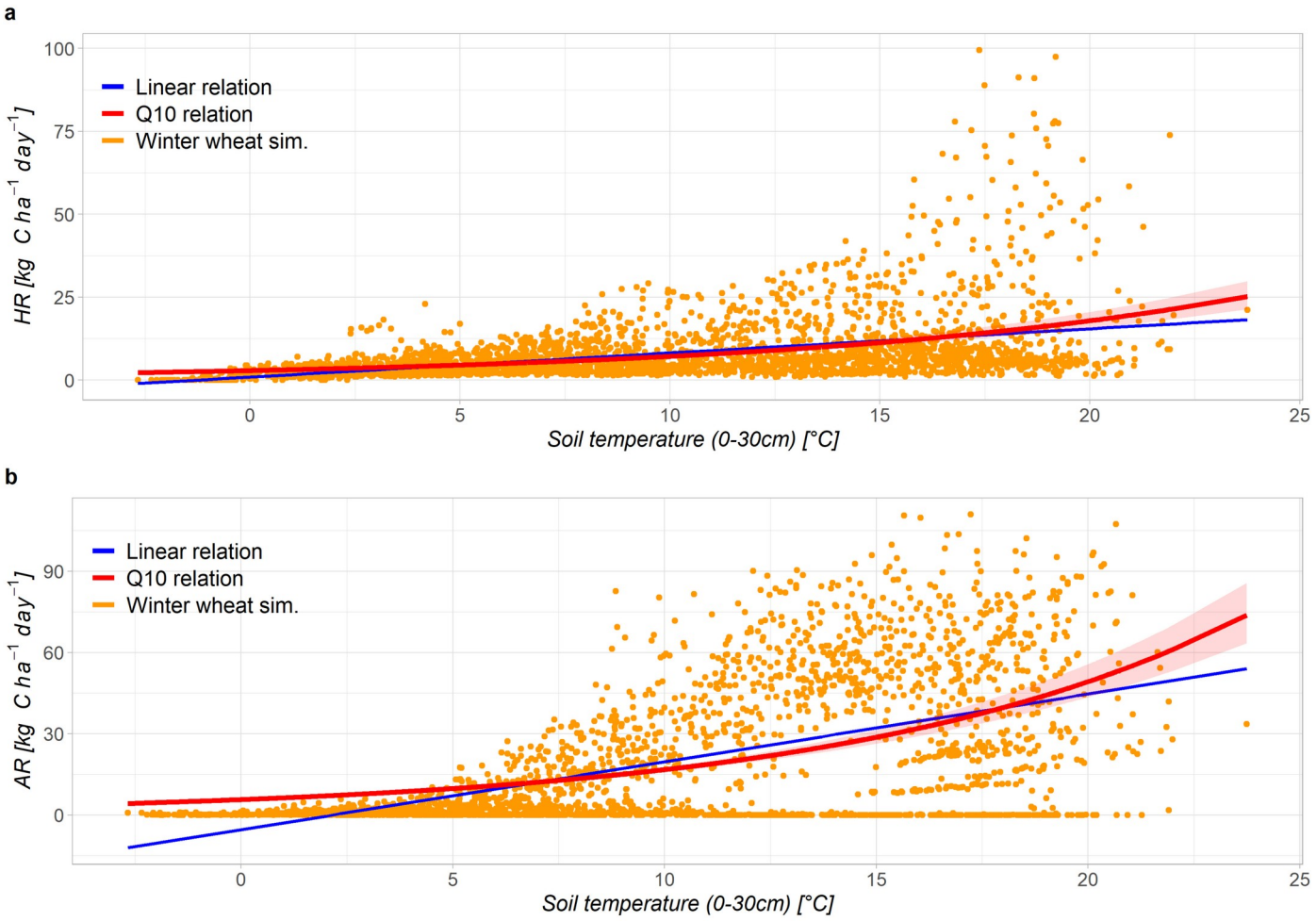


NEE inter-annual variability

- Objective: Quantify crop response to weather conditions
- Increased period of active vegetation and/or radiation increases C sequestration, in agreement with e.g. Buysse et al. (2017) and Ceschia et al. (2010)



NEE inter-annual variability



- The crop model allows to differentiate respiration components.
- Objective: Is HR more influenced by temperature than AR (Suleau et al., 2011)?
- We found a greater influence of temperature on AR than HR, in agreement with e.g. Zhang et al. (2013).

Conclusion

- The approach computes daily CO_2 fluxes (GPP, RECO, NEE) from soil-crop model outputs.
- The 16-year ICOS crop rotation of BE-LON was used to set-up the approach.
- The model must be good at predicting biomass and plant N *prior* looking at CO_2 fluxes.
- Goodness of fit efficiencies are encouraging, but normalized deviations suggest room for improvement before providing accurate carbon budgets.
- Environmental drivers of CO_2 fluxes inter-seasonal variability were identified.
- Its genericity makes it a valuable tool to investigate crop rotations CO_2 dynamics.

Picture by Eli Verheyen in 2018

What next?

- Update the methodology with STICS v10, and with the actual roots carbon pools

- Validate it under other G x E x M conditions
  - Also with grasslands

Picture by Eli Verheyen in 2018

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More information?

Delandmeter et al. (2023). Agricultural and Forest Meteorology

Simulations accuracy