Modeling the partitioning of assimilated C along the soil-plant-atmosphere continuum based on a ^{13}C labeling experiment

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Motivation: How do plants regulate the partitioning of C within the soil-plant-atmosphere continuum (SPAC) in varying soil and atmospheric conditions?
Challenge: Lack of a direct measurement of C flow through the SPAC.
Objective: To develop a new technique combining $^{13}CO_2$ pulse labeling with modeling of the C flow through the SPAC.

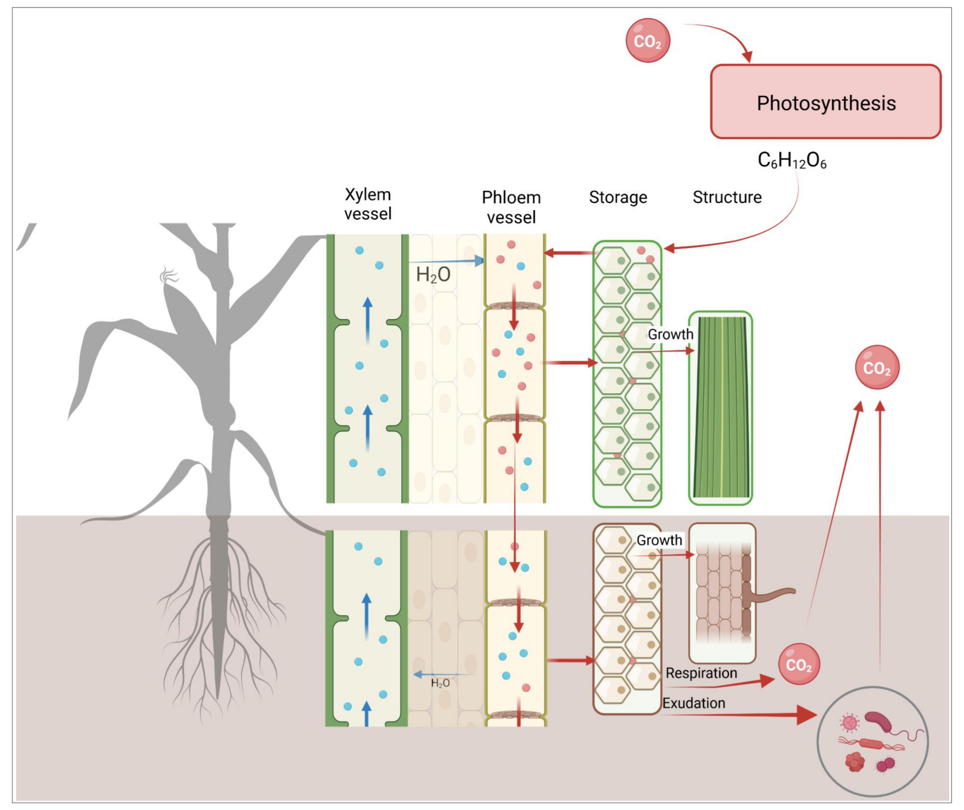

Fig. 1: Schematic of water and carbon cycle in the SPAC
(figure created with Biorender.com)

Methods

1) Pulse labeling

- 2h pulse labeling with $^{13}CO_2$
- Continuous measurement of the $^{13}CO_2$ flux from soil
- Quantification of the ^{13}C content in the shoots and roots

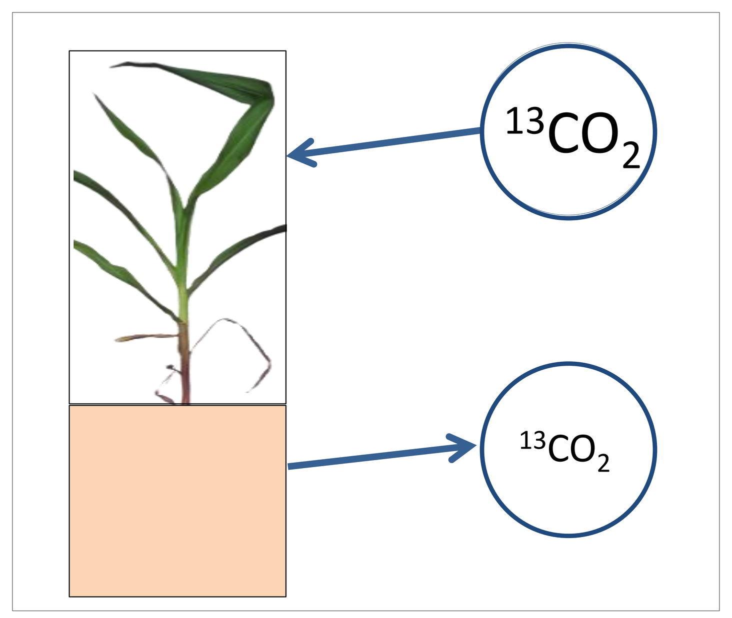

Fig. 2: Schematic of the experimental pulse labeling setup

2) Modeling of C flow through SPAC

- The model domain represents the SPAC (fig. 3).
- Constant transfer rates (K) between compartments
- Neglecting reverse flow and leaf respiration
- A system of ordinary differential equations were developed to describe C flow through the SPAC
- Transfer rates are inversely adjusted to best fit measured ^{13}C content and fluxes

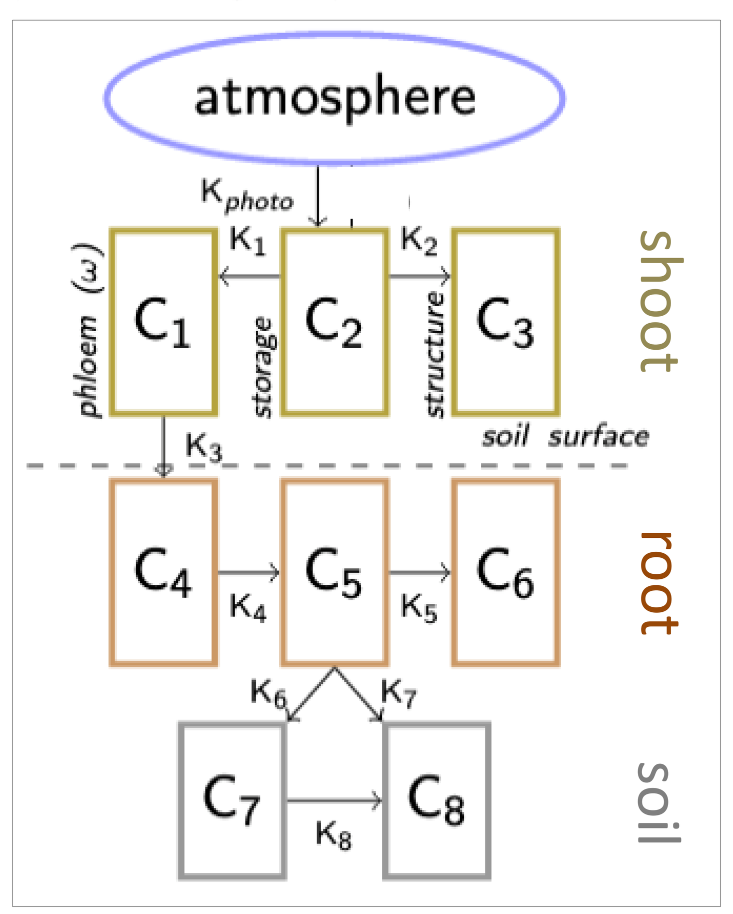

Fig. 3: Schematic representation of the SPAC into different compartments.

Results

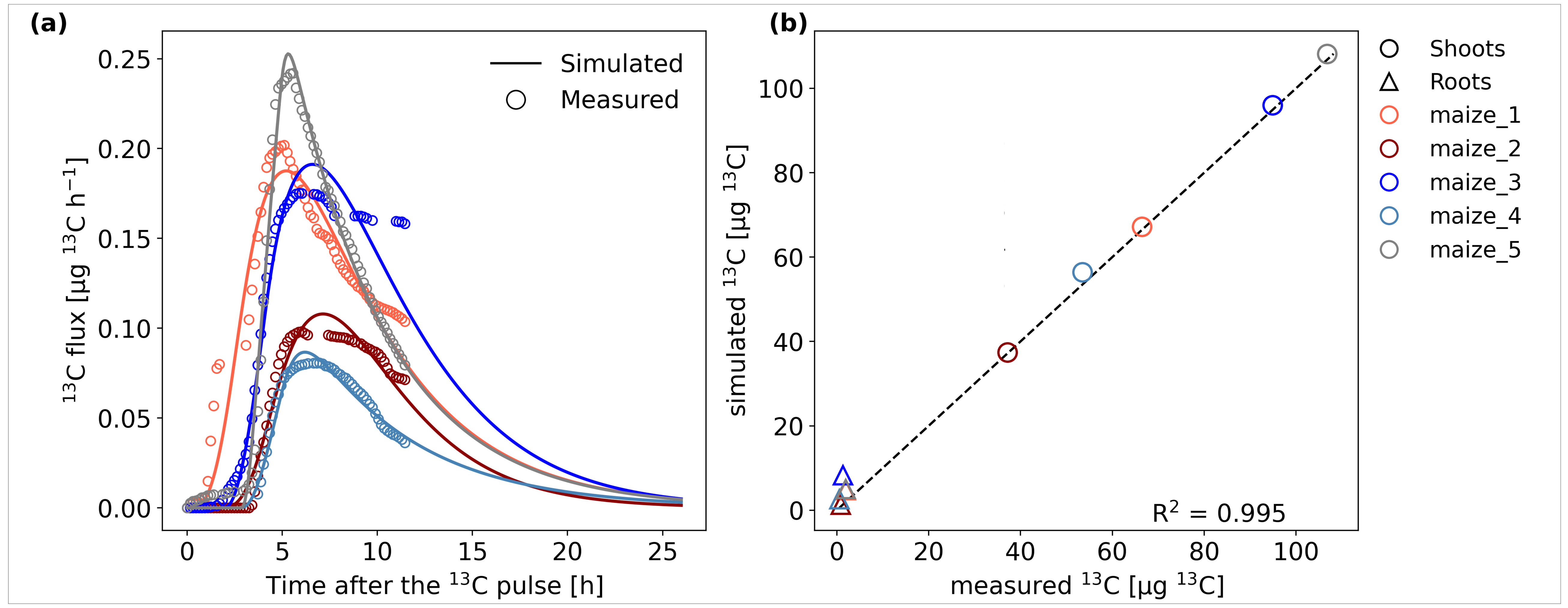

Fig. 4: **(a)** Measured and modeled ^{13}C flux from soil of the 5 maize replicates. Circles: measurements, lines: simulations. **(b)** Measured and fitted ^{13}C content in shoots (circles) and roots (triangles).

- Dynamics of $^{13}CO_2$ released from is plant is species specific - varying allocation rates and patterns
- Model reproduced the ^{13}C flux from the soil and the partitioning of newly assimilated ^{13}C within shoots and roots (fig. 4a and 4b)

- Sensitivity analysis reveals that model results are determined by mainly two parameters (phloem transport to roots (K_3), storage loading in roots (K_4))
- Model was not sensitive to root growth (K_5) and to microbial respiration (K_8) (fig. 5)
- Fitted parameters (K_1-K_9) were reproducible among different replications (n=4-5, e.g. fig. 6)

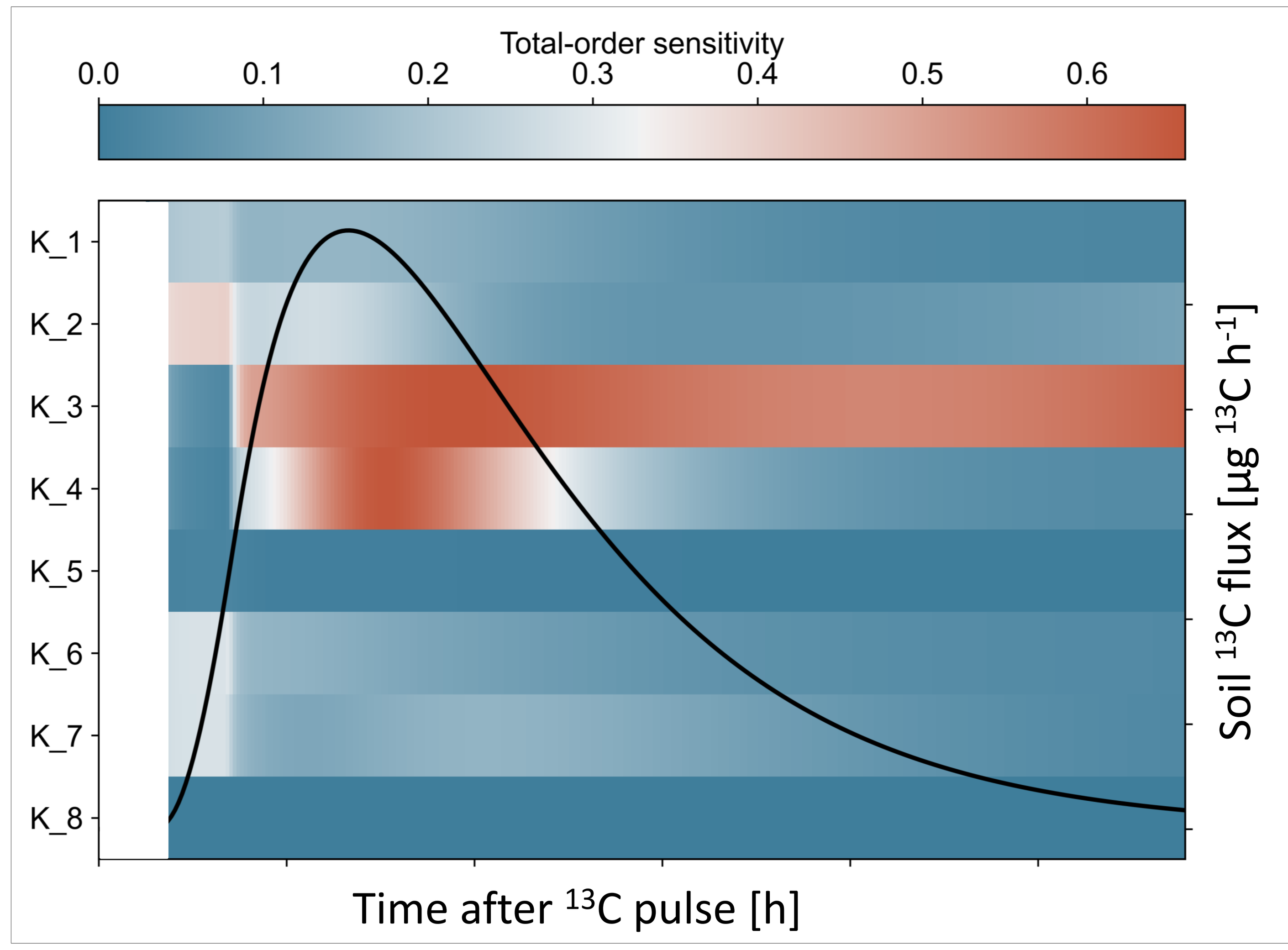

Fig. 5: Total sensitivity of the ^{13}C flux to model parameters.

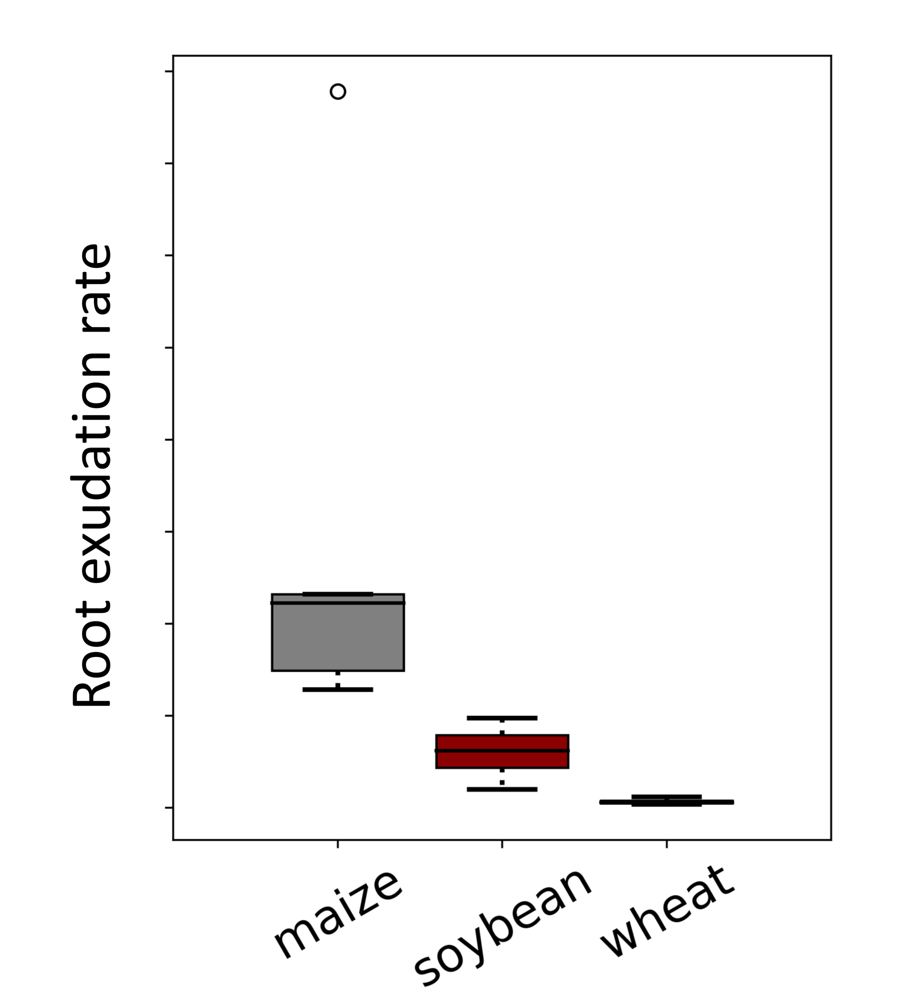

Fig. 6: Fitted root exudation rate for three plants.

Conclusions

- Pulse labeling approach combined with modeling can be a strong tool to study the partitioning of C
- Additional measurements of ^{13}C content in shoots and roots are needed to improve the sensitivity of the model to its parameters

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