A wheat model with detailed account of C and N metabolism

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CN-Wheat: a Functional-Structural Plant Model of CN Metabolism in Wheat

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Project Breedwheat

Introduction

Context & Approach

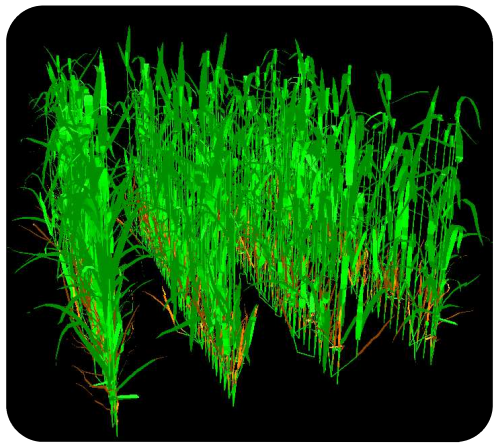
Context of global change

- Improve crop production and environmental impacts.
- Better comprehension of crop functioning and how the effects of multiple environmental factors are integrated by plants.

Functional Structural Plant Models (FSPMs): what is it?

(Godin & Sinoquet, 2005)

- Individual-based models, crop represented as a population of individuals.
- Explicit and botanical description of plant architecture.
- Accounts for the interactions between plant architecture, functioning and environment.

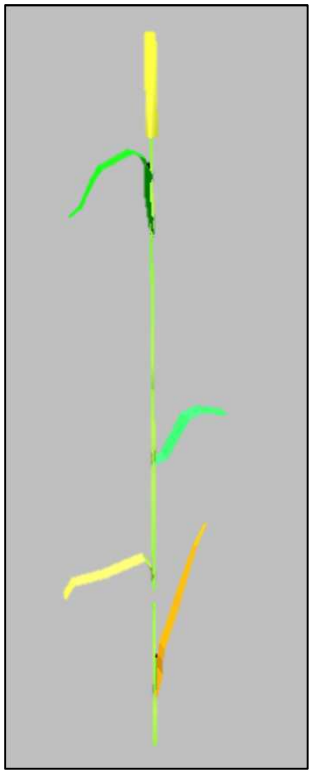


Adel-Wheat (Fournier *et al.*, 2005)

Introduction

Aims of the Wheat FSPM

- Breedwheat project: improve the competiveness of the French wheat breeding sector



Definition/ identification of ideotypes, parameters of interest maximizing grain yield and quality under sustainable agricultural systems and climate scenarios

- Expected outputs from the model :
  - Representation of wheat architecture (3D).
  - Allocation of Carbon (C) and Nitrogen (N) within the plant.
  - Grain production and filling.
  - Interactions between CN status and morphogenesis (leaf growth, tillering).

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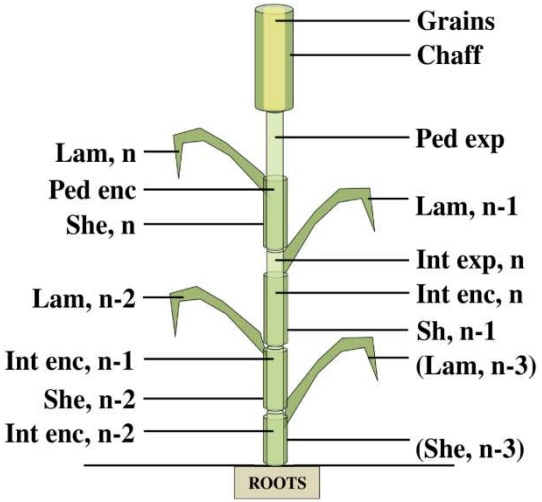
Model description

Model description

Model compartments

Plant structure

- Culm scale and described as:
  - A set of photosynthetic organs
  - A root compartment
  - Grains
- Interactions among culms through light competition and a simplified sub-model of soil



CN metabolites

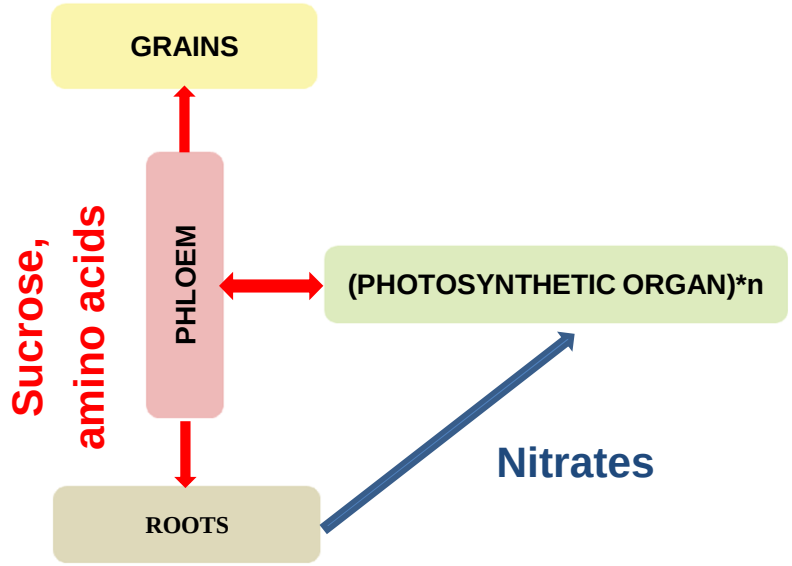
- Each organ includes the main CN materials:
  - Structural mass
  - Storage metabolites : fructans, starch, proteins.
  - Mobile metabolites: sucrose, amino acids, nitrates.

Model description

Physiological processes

- Variations of metabolites according to physiological processes.
  - Environment: light interception, temperature, transpiration
  - Acquisition of resources: photosynthesis, N uptake by roots
  - Respiration
  - Syntheses (Michaelis-Menten) and degradations (1st order kinetics)
  - Morphogenesis and tissue death
  - Transports: **loading** (diffusion), **unloading** (roots, grains) and through **transpiration** flux

- Physiological processes driven by:
  - Environment (light, temperature, CO_2, N soil…)
  - Metabolite concentrations
- Set of differential equations



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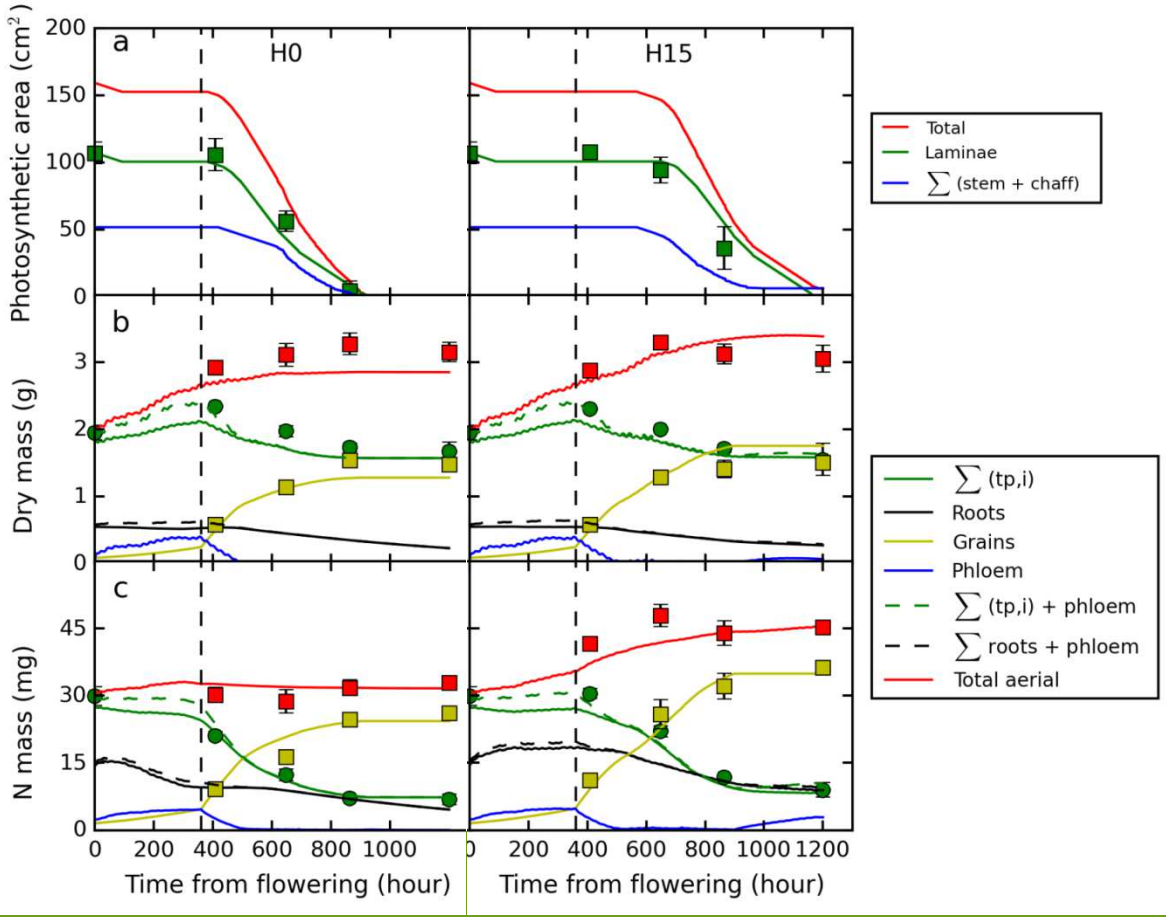
Model evaluation & behaviour

Model evaluation & behaviour

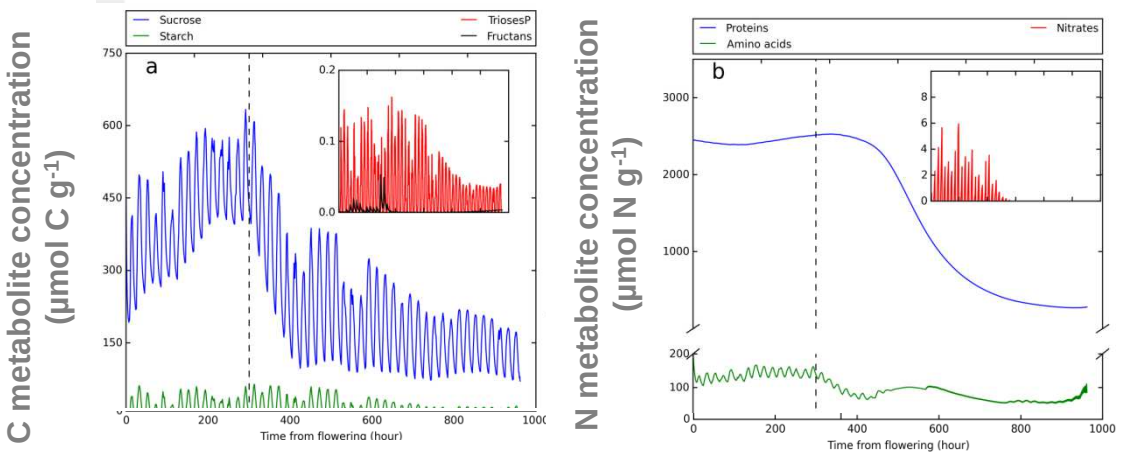
Green area, dry & N masses

- Experimental data: winter wheat with 3 different fertilisations applied at flowering (H0, H3 and H15)
- Accurate simulations for green area, dry and N masses



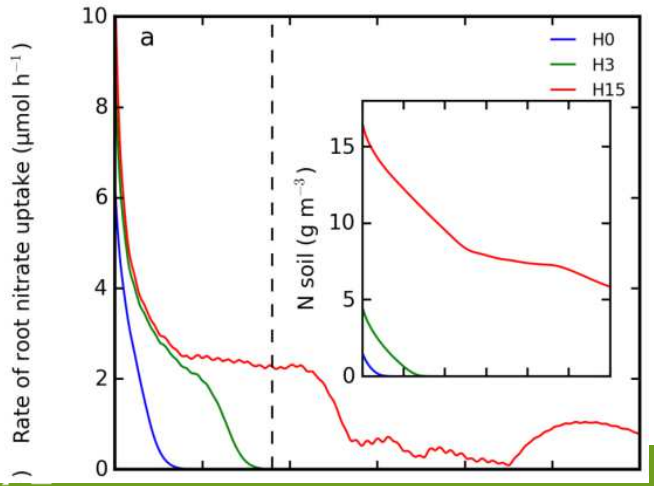
Model evaluation & behaviour

C-N in shoot & roots

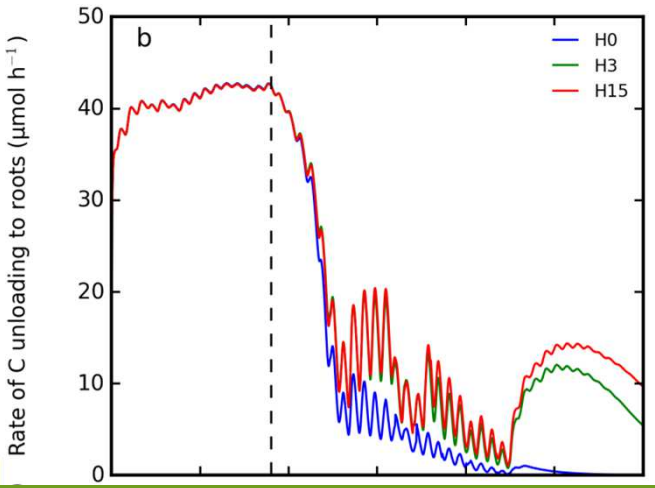


Flag leaf lamina

- Model provides access to internal variables.
- Metabolite concentrations, distribution and dynamics



- Roots N uptake
- C unloading



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Conclusions

Conclusions

- Fully mechanistic approach for integration of Carbon (C) and Nitrogen (N) metabolisms.
- Central role given to metabolite concentrations
- Resource allocation is an emergent property of the model
- Our results suggest that this approach is pertinent.
- The model provides insights into the interplay of C-N metabolism, assimilate partitioning and its regulation (shoot/root, grains…).
- Identification of potential traits for plant breeding (production, low N practices…).

Thank you for your attention