Water dynamics in the soil-plant continuum: which features regulate the uptake?

Lobet, G.[1*] , Javaux, M.[1], Pagès, L. [2], and Draye, X.[1].

1. Earth and Life Institute, Université catholique de Louvain, Croix du Sud 2, 1348 Louvain-la-Neuve, Belgium
2. Plantes et systèmes horticoles, INRA, Domaine Saint Paul - Site Agroparc - 84914 Avignon Cedex 9, France
*. Corresponding author: guillaume.lobet@uclouvain.be

Introduction

Drought is becoming a major constraint on crop production worldwide. Water availability sets the upper limit for transpiration and affects photosynthesis and yield through its effects on stomatal conductance. It is therefore important to improve the ability of plants to manage water resources from their environment in optimal ways.

The water uptake capacity of a plant is largely influenced by (i) soil exploration (root architecture), (ii) hydraulic conductivity of individual root segments, (iii) quantity and capacity of bulk-to-rhizosphere water flow, and (iv) regulation of stomatal conductance. These factors must be considered simultaneously if we aim to tailor plants towards improved water deficit resistance.

We present here a new model, PlaNet-Maize, which encompasses the entire soil-plant-atmosphere continuum with a resolution down to individual root segment. The model simulates individual maize plant growth and development, along with water uptake.

Model architecture

PlaNet-Maize is a functional-structural whole plant model. It uses an **object-oriented structure** to implement the different plant parts as connected *articles.*

Every article represents either a segment or a meristem (root, leaf or stem) (fig. 1) and has its **own behavior and endogenous environment**. Articles transport, consume or product substance and are able to grow and generate new articles.

Higher level behaviour arises from the transport of substances in the network of articles

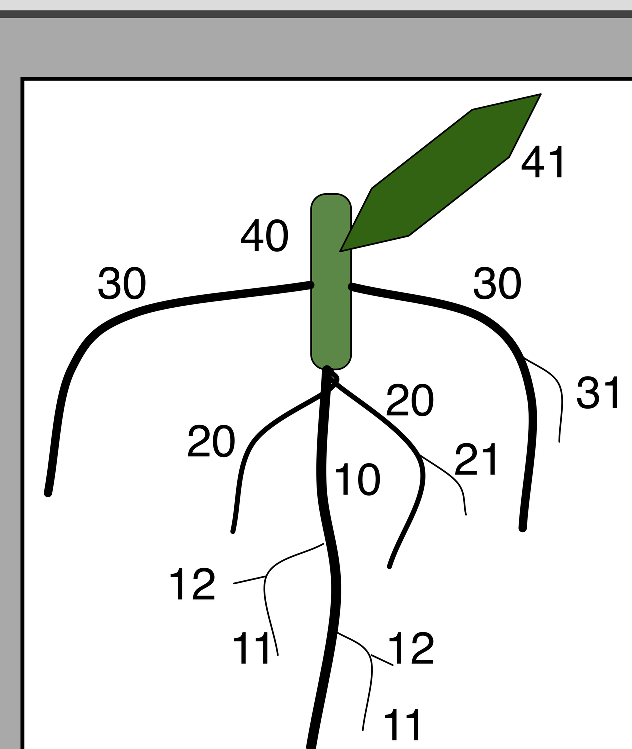


fig 1: Different objects in PlaNet-Maize

Water flux resolution

PlaNet-Maize uses a set of linear equations to **compute the water fluxes** between the different articles and between the articles and their exogenous environments (Doussan *et al.*,1998). This approach considers the soil-plant-atmosphere system as an **electrical circuit** (Landsberg and Fowkes, 1978) (fig. 2).

Once the fluxes have been calculated, the translocation of substance such as ABA can be integrated in the model.

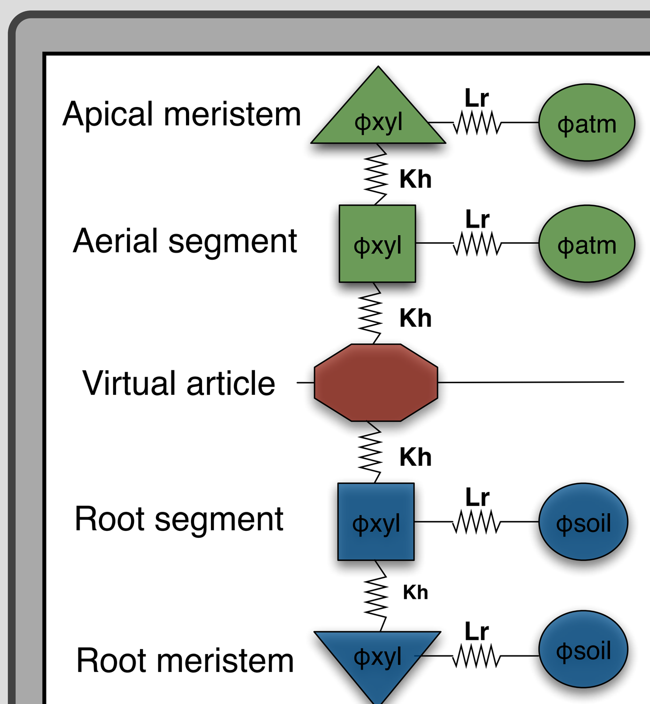


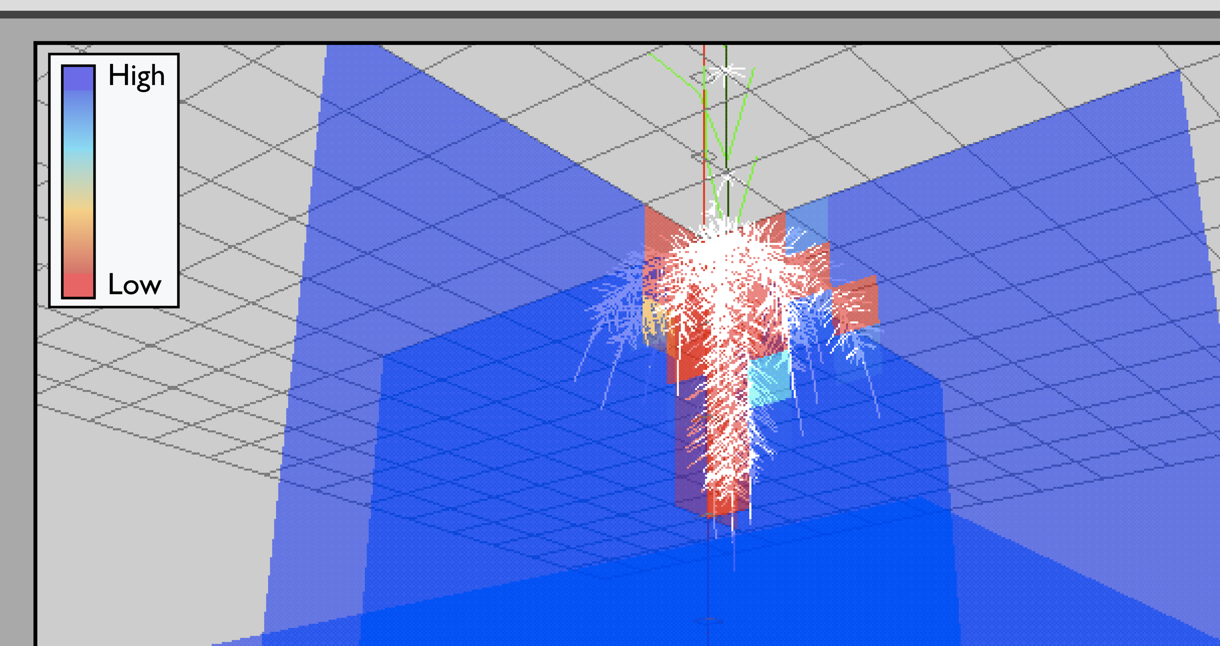
fig 2: Hydraulic structure of a plant in PlaNet-Maize

The model encompasses a **soil module** which simulates soil water content depletion but not the water fluxes inside the soil. We plan to link PlaNet-Maize with a soil based model, R-SWMS (Javaux *et al.*, 2008).

Model output

Several features can be displayed during the simulation, such as **water content** of the soil (fig. 3) and the plant (fig. 4) or radial and axial resistance and fluxes of the different plant articles.

fig 3: Visual representation of the water potential of the different soil parts as simulated by PlaNet-Maize.



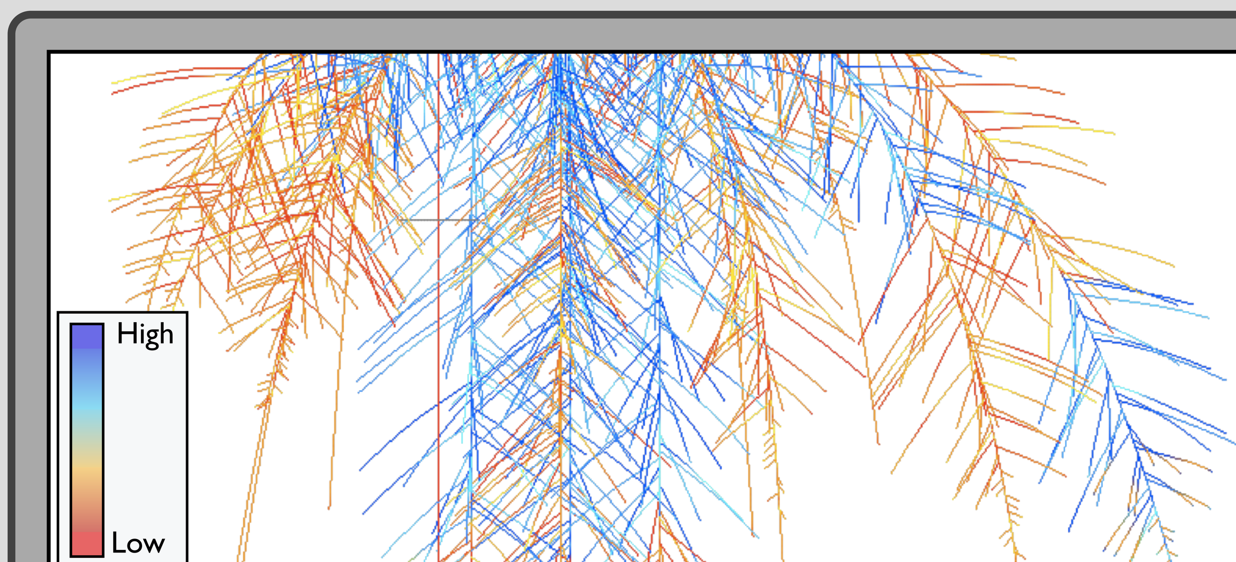
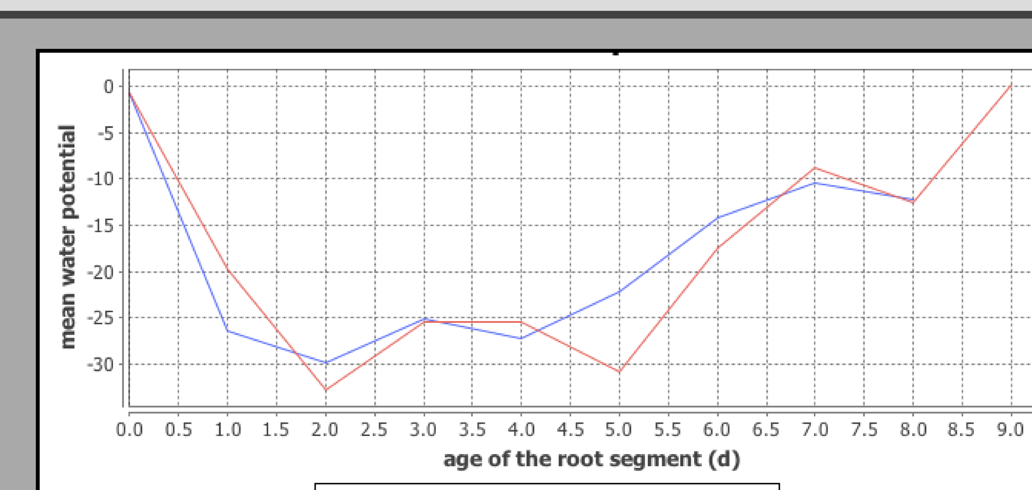


fig 4: Visual representation of the water potential of the different root articles as simulated by PlaNet-Maize.

Thanks to the objet-oriented structure of the model, data about every single article such as its water potential (fig. 5), size or age can be collected and analyzed.

These informations can be exported to a database for further analysis.

fig. 5: Example of a simulation result. The graph shows the average mean water potential along the roots



Conclusions

PlaNet-Maize:

- simulates the **growth and development** of a whole maize plant
- resolves **water fluxes** in the soil-plant-atmosphere system down to the root / leaf segment
- simulates basic **soil water content** depletion

Current work:

- integration of a more realistic soil model
- implementation of stomatal behavior
- implementation of long distance signaling

References

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Landsberg and Fowkes [1978], Annals of Botany, 42, 493-508