Implementing microscopic water uptake in soil-plant interaction modelling


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Background and objective

This study aims to quantify effects of water management on yield caused by drought, oxygen or salinity stress. Crop transpiration is one of the most important processes in simulating soil-water-plant-atmosphere interactions. Roots perform a crucial role by taking up water and thus contributing to transpiration and enabling crop growth.

This study compares different concepts for simulation of water extraction by roots.

Materials

In the Netherlands we use SWAP (swap.wur.nl, Fig. 1) for soil hydrology combined with the crop growth model WOFOST for simulating effects on transpiration and agricultural production.

The traditional macroscopic root water uptake (RWU) concept of Feddes et al. (1978; Fe; Fig. 2) can lead to overestimation of drought stress, even under relatively wet hydrological conditions.

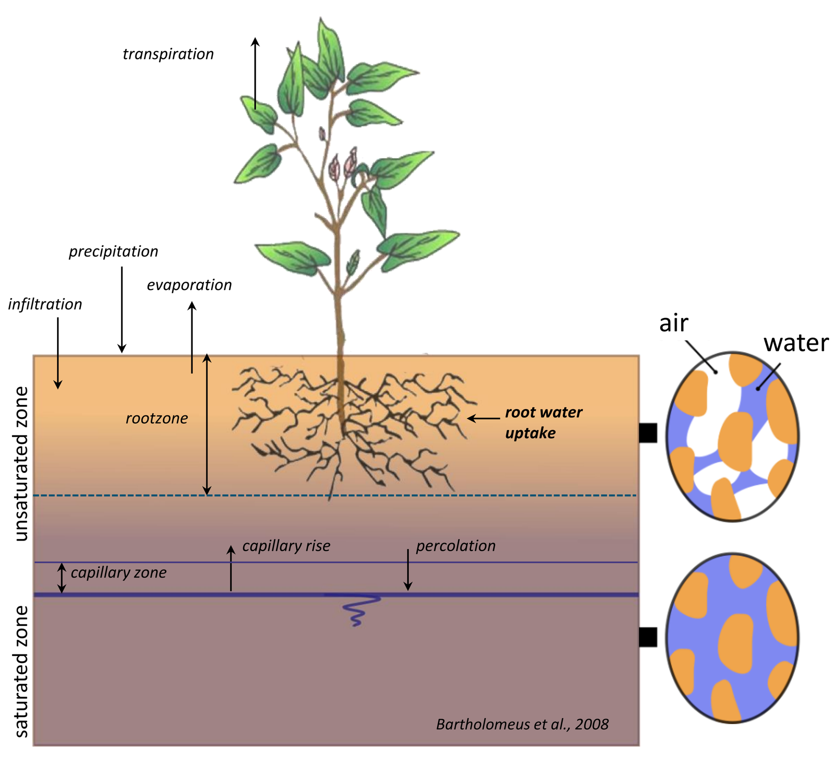

Figure 1. SWAP model.

Method

We implemented two published versions of so-called microscopic RWU: de Jong van Lier., 2013 (dJvL) and de Willigen et al., 2012 (dW) and compared yield losses simulated by macroscopic and microscopic RWU for the Netherlands during the period 1991-2020.

Microscopic concepts consider water fluxes in a soil column around the root which results in a water flux to the leaves considering hydraulic characteristics of both soil and plant (Fig. 3).

In this example we assumed a static, linear decrease in root length density distribution with soil depth. For de Fe-method we considered situations without (Fe_0) and with (Fe_1) Jarvis compensation.

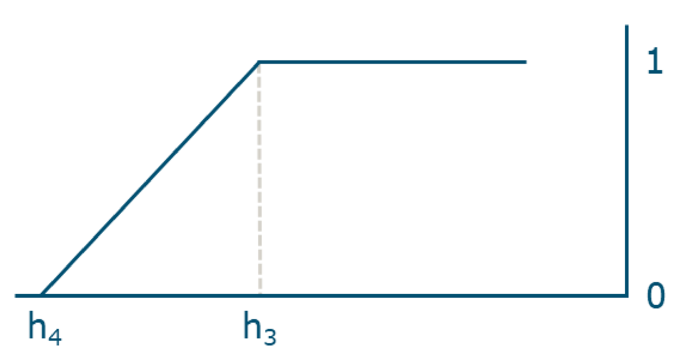

Figure 2. Macroscopic root water uptake by Feddes.

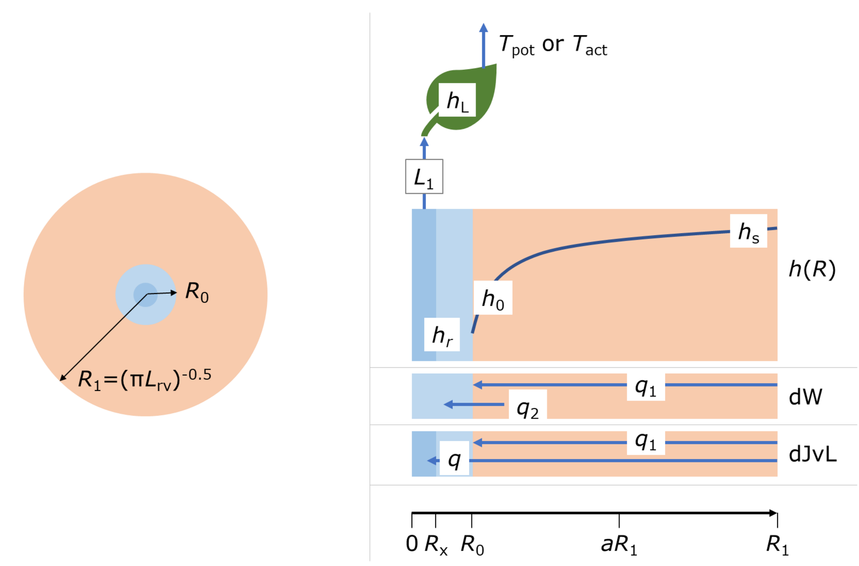

Figure 3. Microscopic root water uptake by de Jong van Lier and de Willigen, with left a cross section of a soil column around the root and to the right an impression of the pressure head and the path to leaf potential.

Results

Both microscopic concepts extract more water and so less yield reduction is simulated than according to the (un)compensated Fe-concept for all soils at shallow and deep groundwater levels (Fig. 4).

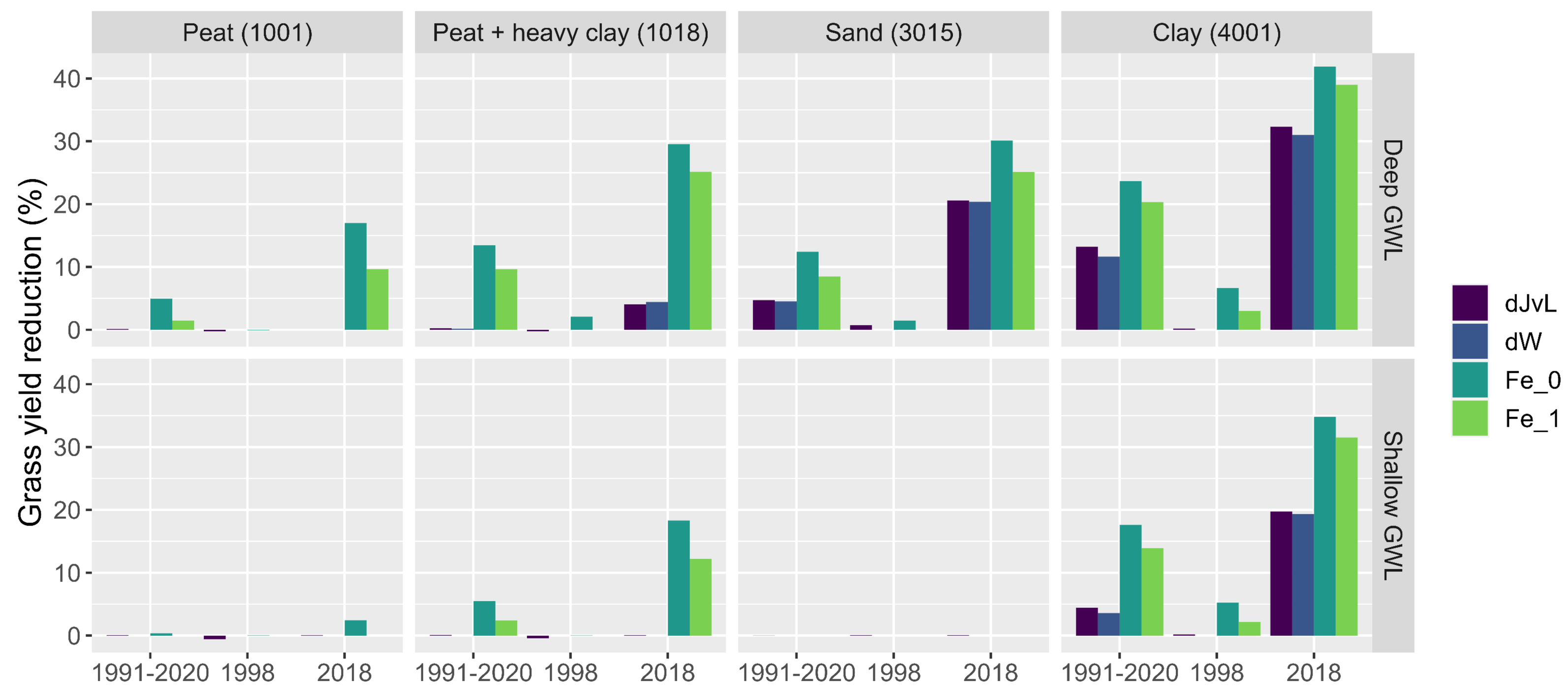

Figure 4. Simulated grass yield reduction for four soils at two groundwater level (GWL) conditions according to microscopic concepts of dJvL and dW and for macroscopic concept Fe.

Microscopic RWU results in a different uptake pattern in time and depth compared to the macroscopic concept (Fig. 5). Water uptake occurs where availability is most favourable (intrinsic compensation).

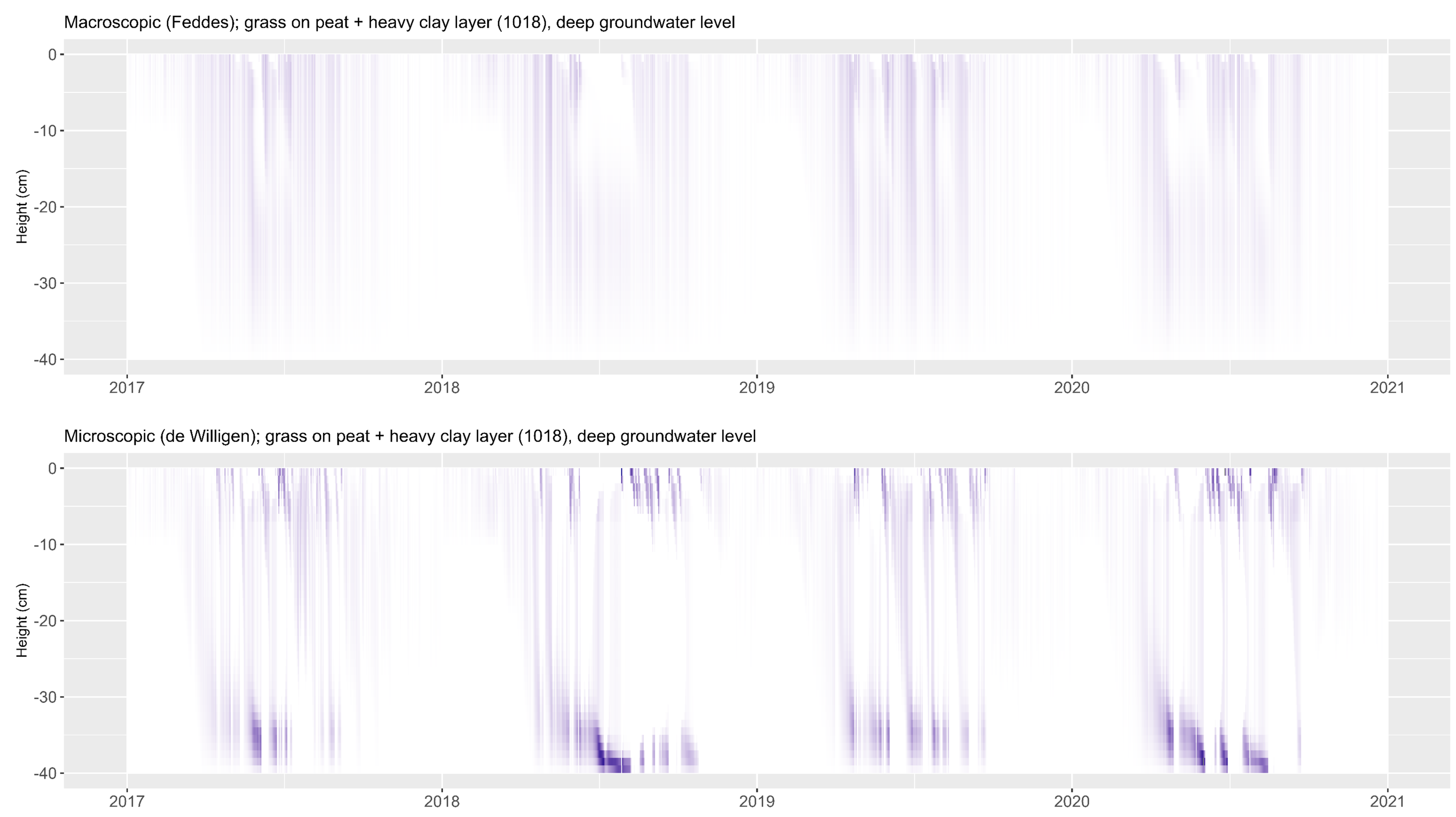

Figure 5. Root water uptake as a function of time and depth according to macroscopic (Fe, top) and microscopic (dW, bottom) concepts during 2017-2020 on peat with a heavy clay layer.

Conclusions

Compared to macroscopic root water uptake:

- The overall root water uptake is higher.
- Root water uptake depends on soil and crop characteristics instead of only crop characteristics.
- Water uptake occurs there where it is most easily available (intrinsic compensation).

Microscopic root water uptake:

- Comparable results for both microscopic concepts.

References

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- Jarvis (2011). HESS. 15: 3431-3446. https://doi.org/10.5194/hess-15-3431-2011

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