Effect of adaptive root development in quantitative land evaluation studies


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Background and objective

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

This study investigates to what extent adaptive root development influences model outcomes in land evaluation studies.

Materials

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

Root water uptake is simulated by the concepts of Feddes et al. (1978 RD_s; Fig. 2) and Bartholomeus et al (2008), optionally combined with compensation by Jarvis (2011; $RD_{s,c}$)

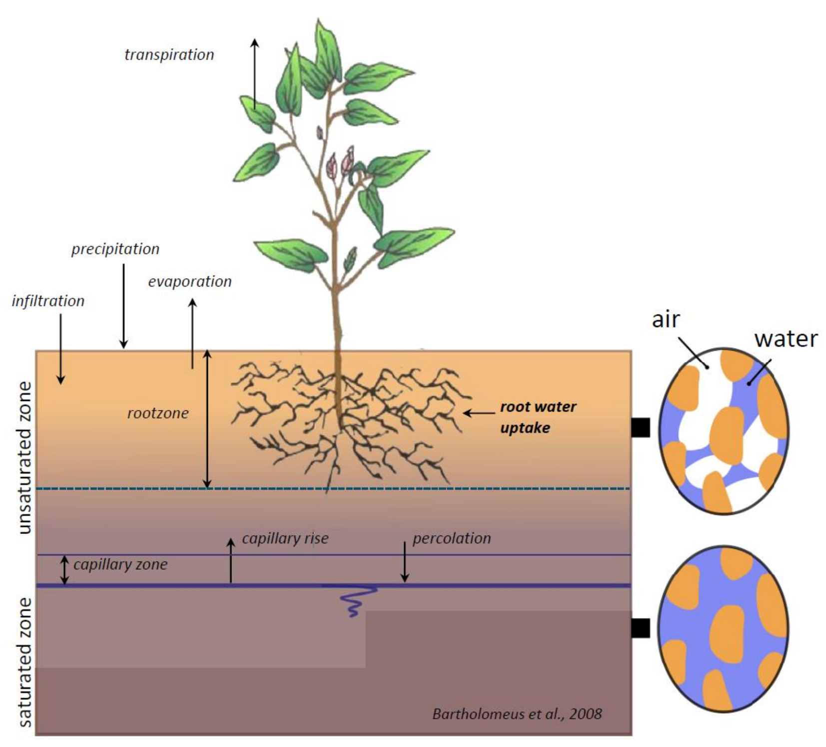

Figure 1. SWAP model.

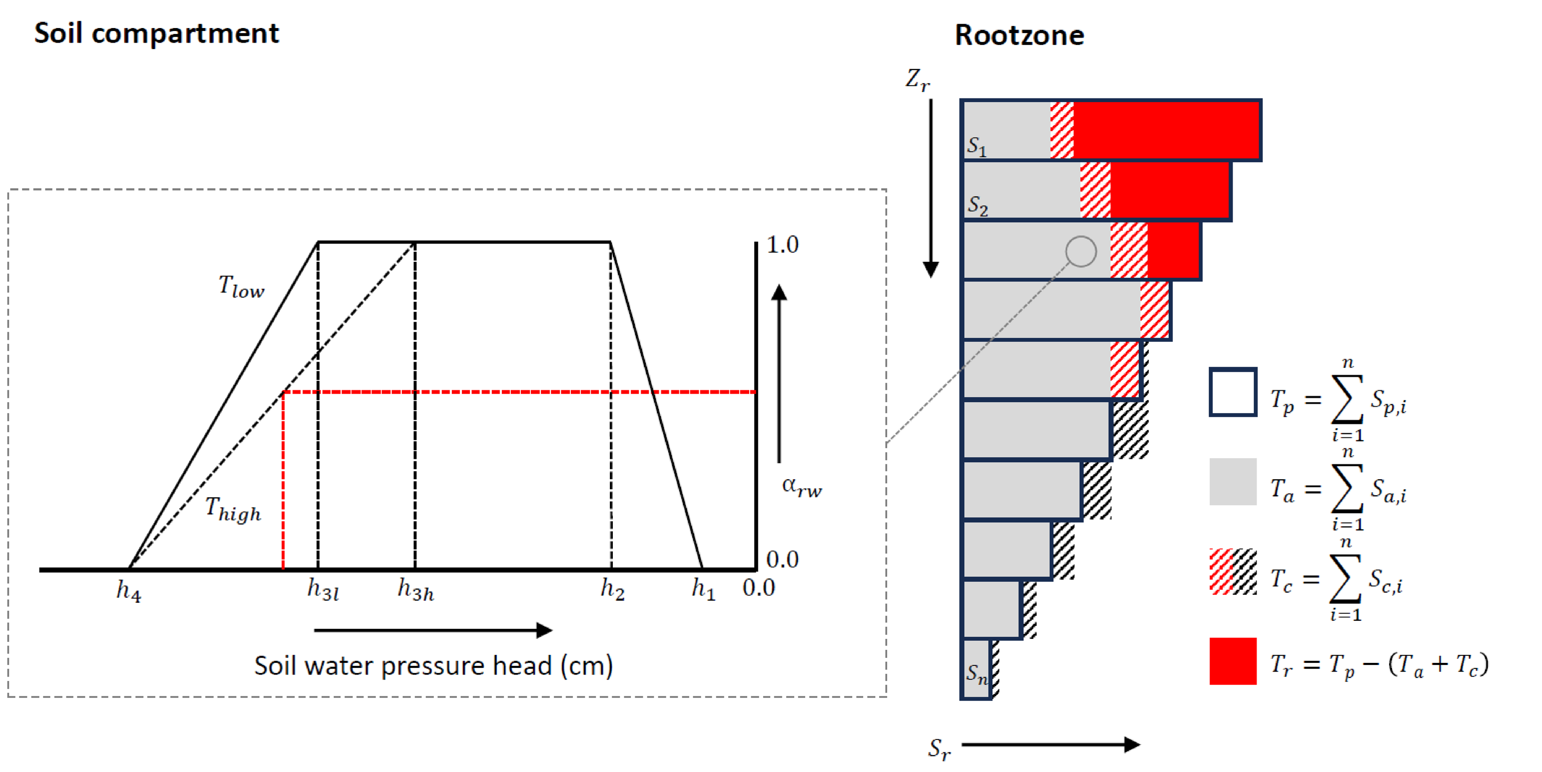

Figure 2. Root water uptake concept by Feddes (1978) and Jarvis (2011); with T_p and T_a the potential and actual transpiration, T_c the compensated reduction of transpiration and T_r the reduction of transpiration.

Method

The flexibility of plant roots and their ability to adapt to the environment is often neglected in crop and land surface models. Traditionally root extension is specified in advance and the root length density distribution is assumed to be static in time.

For a more realistic approach we implemented a simple and innovative root growth model ($RD_{a,c}$) which reacts to the hydrological conditions within the root zone. This means that newly formed roots will be assigned to regions where there is no or minor stress, and less or no new roots to regions where more water stress was experienced.

Proof of concept

In a rhizobox experiment root growth of maize was observed by Maan et al. (2023): root growth was mainly driven by vertical soil moisture distribution. Our adaptive root growth model could predict measured root data reasonably well (Fig. 3).

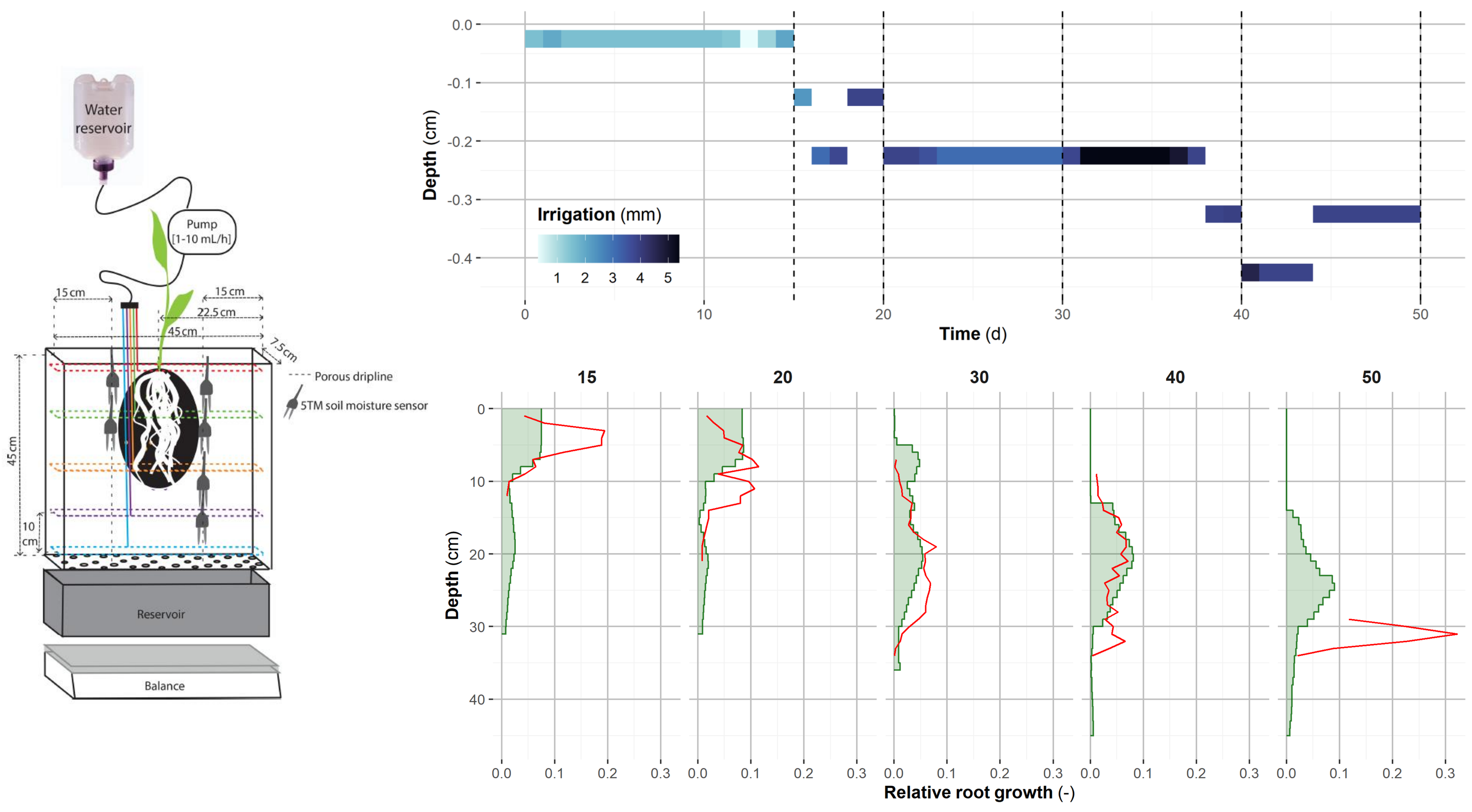

Figure 3. Schematic representation of the rhizobox experiment performed by Maan et al. (2023; left). The applied irrigation rate at specific depth (top right) and the observed (red) and simulated (green) relative root growth (bottom right).

Exploratory study

Adaptive root development results in similar patterns of root distribution and therefore similar yield reductions influenced by drought and oxygen stress, independent of the initial distribution. Figure 4 shows the range in results when different root distributions are used at the beginning of the simulation period for a common sand soil in the Netherlands with variation in hydrological conditions.

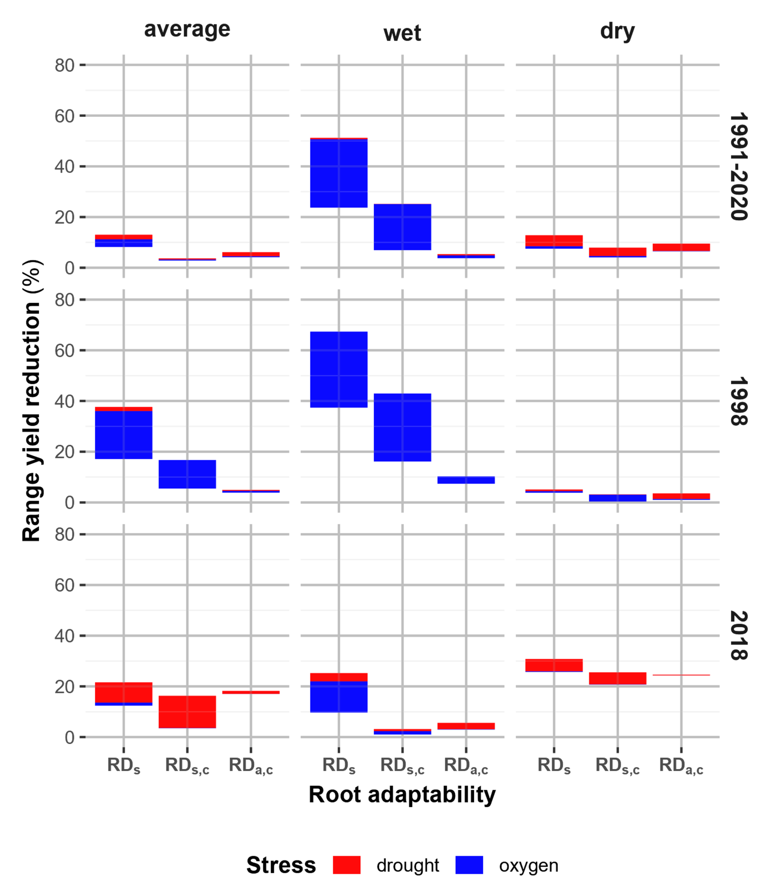

Figure 4. Range in yield reduction applying different initial root density profiles over long-term period (1991-2020), a relative wet (1998) and dry (2018) year; under average, wet and dry hydrological conditions; using static (RD_s), static with compensation ($RD_{s,c}$) and adaptive with compensation ($RD_{a,c}$) root adaptability; colors indicate drought (red) and oxygen stress (blue).

Conclusions

Adaptive root development:

- is able to mimic measured root growth data by Maan et al (2023);
- soil hydrological conditions determine where root growth or root death occurs;
- model results become less dependent on user-predefined root development.

References

- Bartholomeus e al. (2008). J. Hydrology 360 147-165. https://doi.org/10.1016/j.jhydrol.2008.07.029
- Feddes et al. (1978). Simulation of field water use and crop yield
- Jarvis (2011). HESS. 15: 3431-3446. https://doi.org/10.5194/hess-15-3431-2011
- Maan (2023). HESS. 27: 2341-2355. https://doi.org/10.5194/hess-27-2341-2023

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