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Critical soil conditions for oxygen availability to plant roots: improvement of the Feddes-function

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Research on the effect of soil aeration on plant root functioning has been an important field of interest for long. Plants use oxygen for the respiration (energy providing) processes in their cells, i.e. plants need oxygen to keep their metabolism running. Plant species that are not adapted to wet conditions are dependent on oxygen provision from the gas phase of the soil.

We developed a model able to simulate oxygen stress, based on knowledge about physiological and physical processes of oxygen consumption and oxygen provision to plant roots. A sensitivity analysis provided insight into the most important parameters for oxygen stress. Subsequently, we used our model to calculate the reduction of root water uptake as a result of water-logging. Thus, our model is an improvement of the Feddes-function, which describes root water uptake as a function of pressure head only. An appropriate calculation of the sink term variable is needed for simulations (e.g. with SWAP) of the soil moisture conditions and plant growth under wet conditions.

The model was based on the coupling of two diffusion processes: (1) from the atmosphere through the soil to the gas phase of the soil near the roots (macro-scale) and (2) from this gas phase into the root (micro-scale). On the basis of the diffusion on the micro-scale, the minimum required oxygen concentration in the gas phase of the soil was calculated. On the basis of the diffusion on the macro-scale, the corresponding

minimum gas filled porosity that is needed to realize this oxygen concentration was calculated.

The minimum gas filled porosity of the soil that is needed to provide plant roots with a sufficient amount of oxygen was variable with soil type, temperature and depth, but was hardly variable with organic matter content. The uniform critical values for oxygen stress that are used in the Feddes-function are too optimistic; oxygen stress already starts at higher gas filled porosities of the soil. Within a soil type, the sink term variable is non-linear with temperature, gas filled porosity and depth. Therefore, we hypothesize that a calculation routine as developed in our research is needed to calculate the sink term variable in models like SWAP accurately.