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Modelling the transpiration of single maize plants using an explicit xylem flux model

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Introduction

Climate change will increase extreme weather events like heavy rain or drought periods. This will have an impact on crop yields. Most traditional crop growth models are based on daily time steps (Heinlein et al., 2017), and thus may not adequately simulate the impact of drought conditions on crop growth. Therefore, new mechanistic models, which consider plant-internal water transport, are developed. Until now this new modelling approach has been successfully applied to simulate the water flux in trees (Bittner et al., 2012; Hentschel et al., 2013; Janott et al., 2010), but crops as for example maize have rarely been considered so far.

Materials and Methods

The following measurements have been conducted at the research farm Scheyern in the North of Munich: (i) sap flow (Heat-Ratio-Method), (ii) stem diameters (dendrometer) and (iii) plant architectures (derived from terrestrial laser scans), each of four maize plants, as well as (iv) latent heat flux (eddy covariance). A xylem flux model for trees (Janott et al., 2010) has been integrated into the modular model system Expert-N 5.0. This xylem flux model has been adapted to simulate water flow in single maize plants by using plant-specific parameters and by calculating a specific leaf area distribution (Heinlein, 2017). The model system provides simulations of soil water content, sap flow, transpiration, latent heat flux, and stem diameters as a function of plant water contents.

Results and Discussions

High daily maxima of measured sap flow rates and latent heat flux as well as large diurnal amplitudes of stem diameter change can be linked to high daily maxima of radiation and temperature and to low values of relative humidity. Soil water contents are well simulated, but some deviations between model and measurements occur due to preferential flow.

The simulated plant water potentials (Fig. 1) show higher negative values in the roots, and lower negative values at the plants' top and at the leaf tips. The statistics demonstrate good agreements between simulated and measured sap flow. The daily amplitudes of stem diameters could just be simulated with shortcomings due to the beginning of senescence. The daily maxima of the latent heat flux were often underestimated by the model, but simulations and measurements show good overall agreement (good model efficiency).

Conclusions

The xylem flux model can be applied to simulate water transport in maize plants. The model is able to simulate water uptake and transpiration in a mechanistic way (long-distance water flow within the plant). Thus, it has the potential to better describe impacts of extreme weather events on crop growth, but further testing is still needed. Since the xylem flux model is able to relate sap flow, latent heat flux and stem diameters, the model could also be used to better plan and control irrigation.

Acknowledgements

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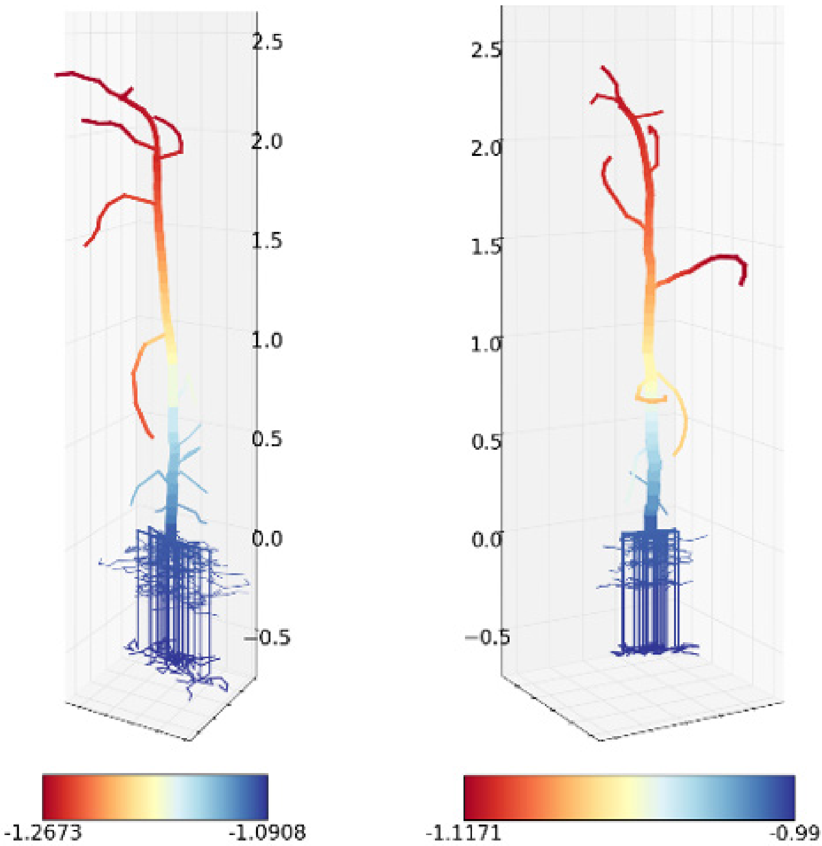

Figure 1. Laser scanned maize plants with simulated xylem water potential [MPa] at 15 July 2015 12:00.

Keywords: sap flow, eddy covariance, dendrometer, water flux.

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