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Biodiversity effects on the water balance of an experimental grassland

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Plant species richness increases aboveground biomass production in biodiversity experiments. Biomass production depends on and feeds back to the water balance, but it remains unclear how plant species richness influences soil water contents and water fluxes (actual evapotranspiration (ETa), downward flux (DF), and upward flux (UF)). Our objective was to determine the effects of plant species and functional richness and functional identity on soil water contents and water fluxes for two soil depths (0-0.3 and 0.3.-0.7 m). To achieve this, we used a water balance model in connection with Bayesian hierarchical modeling.

We monitored soil water contents on 86 plots of a grassland plant diversity experiment in Jena, Germany between July 2002 and January 2006. In the field experiment, plant species richness (0, 1, 2, 4, 8, 16, 60) and functional group composition (0-4 functional groups: legumes, grasses, non-leguminous tall herbs, non-leguminous small herbs) were manipulated in a factorial design. Climate data (air temperature, precipitation, wind velocity, relative humidity, global radiation, soil moisture) was measured at a central climate station between July 2002 and December 2007. Root biomass data from July 2006 was available per plot. Missing water contents per plot and depth were estimated in weekly resolution for the years 2003-2007 with a Bayesian hierarchical model using measured water contents per plot and centrally measured soil moisture. To obtain ETa, DF, and UF of the two different soil depths, we modified a soil water balance model which had been developed for our study site. The model is based on changes in soil water content between subsequent observation dates and modeled potential evapotranspiration which was partitioned between soil layers according to percentage of root biomass.

The presence of specific functional groups significantly changed water contents and fluxes with partly opposing effects in the two soil depths. Presence of grasses decreased water contents in both depths, DF in topsoil, and ETa in subsoil, but increased ETa in topsoil. As grasses produce less shade than other plant functional groups because of their leaf morphology, higher ETa in topsoil could be explained by higher soil evaporation. Moreover, grasses have an extensive, shallow rooting system which facilitates exhaustive water use from the upper soil layer and therefore probably decreases water contents and DF. Species richness did not significantly affect water contents and fluxes in both soil layers except that the relation between species richness and water contents in subsoil changed over time. This can be explained by two equivalent but opposite effects. Transpiration increases with biomass which is positively correlated with species richness. By contrast, soil evaporation decreases with species richness because the greater vegetation cover in species-rich communities produces more shade. We conclude that the contrasting effects of plant species richness on transpiration and evaporation counterbalance each other and that functional traits of specific plant functional groups mediate the biologically-induced changes in the water balance.