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Does plant diversity affect the water balance of established grassland systems?

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The water cycle drives nutrient cycles and plant productivity. The impact of land use on the water cycle has been extensively studied and there is experimental evidence that biodiversity modifies the water cycle in grasslands. However, the combined influences of land-use and associated biodiversity on the water cycle in established land-use systems are unclear. Therefore, we investigated how evapotranspiration (ETa), downward water flux (DF), and capillary rise (CR) in topsoil and subsoil are related to land-use and plant diversity in established, commercially managed grassland and compared these results to findings from experiments where plant diversity was manipulated.

In three Central European regions (“Biodiversity Exploratories”), we studied 29 grassland plots (50 m x 50 m; 9-11 plots per region) from 2010 to 2015. The land-use types cover pasture, mown pasture, and meadow in at least triplicate per region. On each plot, we measured soil water contents, meteorological data (hourly resolution), cumulative precipitation (biweekly), plant species richness, the number of plants in the functional groups of grasses, herbs, and legumes (annually), and root biomass (once). Potential evapotranspiration (ETp) was calculated from meteorological data per plot. Missing data points of ETp and soil water contents were estimated with Bayesian hierarchical models. ETa, DF, and CR were calculated for two soil layers with a soil water balance model. The model is based on changes in soil water storage between subsequent observation dates and ETp, which was partitioned between soil layers according to root distribution. Water fluxes in annual resolution were statistically analyzed for land-use and biodiversity effects using repeated-measures analysis of variance (ANOVA).

Land-use type did not affect water fluxes. Species richness did not influence DF and CR. DF from topsoil was higher on plots with more grass species, which is opposite to the results from a manipulative biodiversity experiment. The number of grasses and herbs influenced CR into topsoil. ETa from topsoil decreased with increasing species richness while ETa from subsoil increased. Opposing effects on ETa in the two soil layers were also observed for the numbers of herb and legume species. In manipulative biodiversity experiments, opposing effects on ETa from different soil layers are explained by higher plant cover and biomass in species-rich mixtures, reducing evaporation by shading of the topsoil, and deeper roots in species-rich mixtures, facilitating water use and increasing transpiration from subsoil. In our study, biomass decreased with increasing species richness because fertilizer application increased biomass production and decreased species richness. Plots with more grasses showed lower ETa from topsoil than plots with less grasses. However, the within-subject effects indicated higher ETa from topsoil in years with more grasses on individual plots than in years with less grasses. The latter finding complies with the results from a manipulative biodiversity experiment, which has homogeneous soil properties and management. The opposite between-subject effect is probably caused by variations in environmental conditions between plots. This indicates that processes controlling the biodiversity-water cycle relationship vary in real-world systems with environmental conditions, which are largely controlled for in manipulative biodiversity experiments.