Spatially heterogeneous grassland wetting patterns are controlled by canopy processes and antecedent soil moisture

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Vegetation induces spatial heterogeneity in water entering the soil as it partitions precipitation into net precipitation components. Net precipitation patterns have potential to influence spatial variation of percolation and soil water content, including hotspots of soil bypass flow. As a result, the canopy layer can be an important driver for changing soil moisture response to rainfall. In forest and shrub ecosystems the effect of canopy induced heterogeneity in water input on soil water dynamics has already been investigated, but rarely in grassland ecosystems, where the canopy is commonly characterized as homogeneous and uniform layer. However, observations in short vegetation points at a relation between canopy layer and soil moisture variability, indicating that short vegetation can also introduce heterogeneity and influence soil water dynamics. Yet, these observations are mostly confined to evapotranspiration, and no investigation has been extended for understanding the effect of spatially variable vegetation and net precipitation patterns on soil wetting patterns. Therefore, in this study, we investigated soil moisture response to rainfall in a grassland in temperate climate. Further, we explored the effect of wind speed, gross precipitation, throughfall patterns, vegetation height and antecedent soil moisture status on soil moistening after rainfall.

The grassland site (0.045 ha) is in Thuringia, Germany as a part of Hainich CZE and it is mown 2-3 times in a year. The field observation setup composed of closely paired (within 1.5 m in distance) net precipitation and soil water content measurements at 18 locations. Next to the field measurements in 2019 (April-August), we employed linear mixed effects model to untangle the role of canopy layer on soil moistening patterns from other abiotic factors. Also, we calculated spatially average water balance to trace soil storage recharge over the growing season.

We found that the increase in soil water storage was remarkably lower than water input regardless of foliage cover. Also, the water balance showed that topsoil (0-17.5 cm) stored less and less precipitation compared to the deeper part (17.5-37.5 cm) through the growing season despite the increasingly drier soil conditions, probably because of non-equilibrium fast flow. The mixed-effects model revealed that spatial variation of grass height is a significant driver for soil wetting patterns together with the average antecedent soil moisture status and precipitation. Soil wetting
was suppressed at locations with taller grass, especially under drier antecedent soil moisture conditions. However, the effect of throughfall patterns was obscured probably due to the prevalence of preferential flow. Our results suggest that drier conditions and grassland stemflow might reinforce and expedite preferential flow. The results confirmed that spatially varied grassland canopy together with soil moisture status alters soil moisture wetting patterns and indicates a strong influence of preferential flow on soil water patterns.