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Vegetation function and non-uniqueness of the hydrological response

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Through local moisture uptake vegetation exerts seasonal and longer-term impacts on the watershed hydrological response. However, the role of vegetation may go beyond the conventionally implied and well-understood "sink" function in the basin soil moisture storage equation. We argue that vegetation function imposes a "homogenizing" effect on pre-event soil moisture spatial storage, decreasing the likelihood that a rainfall event will result in a topographically-driven redistribution of soil water and the consequent formation of variable source areas. In combination with vegetation temporal dynamics, this may lead to the non-uniqueness of the hydrological response with respect to the mean basin wetness. This study designs a set of relevant numerical experiments carried out with two physically-based models; one of the models, HYDRUS, resolves variably saturated subsurface flow using a fully three-dimensional formulation, while the other model, tRIBS+VEGGIE, uses a one-dimensional formulation applied in a quasi-three-dimensional framework in combination with the model of vegetation dynamics. We demonstrate that (1) vegetation function modifies spatial heterogeneity in moisture spatial storage by imposing different degrees of subsurface flow connectivity; explore mechanistically (2) how and why a basin with the same mean soil moisture can have distinctly different spatial soil moisture distributions; and demonstrate (2) how these distinct moisture distributions result in a hysteretic runoff response to precipitation. Furthermore, the study argues that near-surface soil moisture is an insufficient indicator of the initial moisture state of a catchment with the implication of its limited effect on hydrological predictability.