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Plant accessible water storage in the unsaturated root zone and its interactions with climate – a key to understand catchment storage, the partitioning of water fluxes and transit times in different environments.

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The water storage capacity in the unsaturated root zone of soils is the principal source of nonlinearity in the response of terrestrial hydrological systems. This storage capacity between field capacity and the permanent wilting point represents the water volume required by and accessible to vegetation to ensure continuous access to water to bridge dry periods. With detailed data on root depths and soil porosities, this volume can be estimated. While such data may be available for individual plants or for small forest stands at experimental sites, they remain problematic to acquire for scales larger than that, let alone for entire catchments.

Zooming out to the macroscale and following evidence that plants efficiently develop root systems to meet the canopy water demand while minimizing sub-surface resource allocation provides a new perspective on the understanding of the storage capacity in the unsaturated root zone (Sumax). A series of experiments based on data from more than 400 catchments across a wide gradient of climates and landscapes strongly suggests that Sumax can be robustly estimated at the catchment scale based exclusively on long-term water balance data, independently of detailed information on root systems and soil porosities. It is essentially controlled by climate characteristics, such as precipitation seasonality or the aridity index and, in a feedback, by different types of vegetation. Based on further data from catchments that underwent well documented land use change (i.e. deforestation), experiments suggest that these storage capacities are not only significantly and predictably affected by deforestation, but also that Sumax exhibits distinct post-deforestation signatures in different environments, which can be directly linked to contrasting changes in post-deforestation hydrological response dynamics in these systems.

More specifically, while in humid climates with little seasonality vegetation only needs to develop small additional storage volumes for continuous access to water, much larger root-accessible water volumes are needed in seasonal climates. Consequently, deforestation in the latter does affect the partitioning of water into drainage and evaporative fluxes, and thus the fundamental hydrological response dynamics, much stronger than in the first case. Due to a more significant reduction of the storage capacity, less water can be stored for eventual evaporation and plant transpiration, while more water is available for drainage. These changes in how catchments store and release water as a function of storage capacity in the unsaturated root zone, does not only affect stream flow and its signatures, such as runoff coefficients, but also catchment-scale transport dynamics: further experiments demonstrated that changes in the root zone storage capacity due to deforestation significantly alters transit time distributions. In particular during storm events much higher proportions of young water reach the stream. This does not only have implications for the nutrient budget of a system but also changes the susceptibility of a system to pollution. Pollutant inputs will be more directly and with less attenuation routed to the stream, resulting in higher pollutant peak concentrations. This in turn illustrates the importance of vegetation for moderating peak pollutant concentrations in streams.