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Exploring the existence of hydrological tipping points at the catchment-scale

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The identification of tipping points in the water cycle has been recently ranked Nr. 1 in the list of the top 23 unresolved problems in Hydrology by the International Association of Hydrological Sciences (IAHS) and as a priority in the field of hydrology and water resources by several studies. Such daunting task is mainly attributed to the concerns that greenhouse gas emission climate change may tip the water cycle into an unfavorable new state. Up to date, tipping points occurring in complex dynamical systems have been identified across a large set of disciplines. In most proven tipping points, hydrologic variables are always taken as the control variables, as changes in water fluxes and stocks are known to act as stressors of socioecological systems, and the affected aquatic and terrestrial ecosystems as the response variables. The main objective of this study is to explore the existence of tipping points in catchment-scale freshwater availability, that is, the tipping points were the response variable is catchment water storage. We first review the existence of reported tipping points in the field of hydrology and water resources, to establish a coherent framework for the identification of hydrological tipping points. We explore their mathematical existence at the catchment scale by Linear Stability Analysis, illustrating cases with potential functions and bifurcation diagrams. We then explore any possible contribution to the existence of hydrological tipping points by adding complexity to the hydrological dynamic system through the inclusion of sociological feedbacks. We find that even with the inclusion of the moisture feedback of evapotranspiration to precipitation, constant socioecological conditions will most likely not present tipping points of water storage in the catchment. However, the inclusion of socioecological feedbacks does generate tipping points under certain assumptions, even without assuming a moisture feedback between evapotranspiration and precipitation. We hope that this study sheds some light on the existence, conditions, assumptions and characteristics of large-scale hydrological tipping points with long-term implications.