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What can be learned from combined event runoff and tracer analysis in a semi-arid, data-scarce catchment?

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Hydrological processes in small catchments are not quite understood yet, which is true in particular for catchments in data scarce, semi-arid regions. This is in contrast with the need for a better understanding of water fluxes and the interactions between surface- and groundwater in order to facilitate sustainable water resources management in such environments, where both floods and droughts can result in severe crop loss. In this study, event runoff coefficient analysis and limited tracer data of four small, nested sub-catchments (0.4 - 25.3 km2) in a data scarce, semi-arid region of Tanzania helped to characterize the distinct response of the study catchments and to gain insights into the dominant runoff processes. The estimated event runoff coefficients were very low and did not exceed 0.09. They were found to be significantly related to the 5-day antecedent precipitation totals as well as to base flow. This indicated a close relation to changes in soil moisture and thus potential switches in runoff generation processes. The time scales of the “direct flow” reservoirs, used to compute the event runoff coefficients, were up to one order of magnitude reduced for extreme events, compared to “average” events. This suggested the activation of at least a third flow component, besides base- and direct flow, assumed to be infiltration overland flow. Analysis of multiple tracers highlighted the importance of pre-event water to total runoff, even during intense and high yield precipitation events. It further illustrated the distinct nature of the catchments, in particular with respect to the available water storage, which was suggested by different degrees of tracer damping in the individual streams. The use of multiple tracers subsequently allowed estimating uncertainties in hydrograph separations arising from the use of different tracers. The results highlight the presence of considerable uncertainties, emphasizing the need for multiple tracers in order to avoid misleading results. This study shows the value of hydrological data collection over one whole wet season using multi-tracers to improve the understanding of hydrological functioning and thus for water resources management in data scarce, semi-arid environments.