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Non-linearities and thresholds in water partitioning, storage and release in different ecohydrological units

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Water partitioning between transpiration, evaporation and runoff is controlled by climatic and water storage characteristics; yet our current knowledge of varying dominant retention and partitioning mechanisms remains limited. For some forested catchments with clear seasonal distinctions, recent work has revealed the existence of partitioned ecohydrological systems where plant - and stream-water are sourced from different subsurface water stores. It is still unclear what the roles of non-linearities are in different water-energy regimes and how soil and vegetation properties might influence such partitioning of water stores.

This study aims to better understand the spatio-temporal controls on water residence times and hydrological responses at the catchment scale in a northern headwater catchment in Scotland. Here, the climate is usually consistently wet with low evapotranspiration rates. Within this context however, the study period involved an exceptionally dry summer. We explored non-linearities and thresholds in catchment input-output relationships and investigated the role of soil-water-vegetation interactions on water partitioning, storage, and release along different hillslopes during contrasting hydro-climatic conditions. Different ecohydrological units included poorly draining soils in riparian zones and freely draining soils on hillslopes, and both forested and non-forested sites were considered. Soil moisture dynamics and stable water isotope signatures of different waters (precipitation, stream-, soil -, and plant xylem-water) were examined throughout the year (winter and during the growing season that included the relatively dry summer) to identify plant water use, assess water movement, and explore vegetation-water linkages.

The results indicate that threshold behaviour in runoff responses at the catchment scale can be linked to apparent differences between soil water dynamics and residence times of different hydropedological units. Linear input-output relationships exist when runoff is dominantly generated from the permanently wet riparian zones. In contrast, the freely draining hillslope soils show larger dynamic storage changes, and non-linear runoff generation processes can be related to temporary high soil wetness on the hillslopes. However, vegetation impacts are limited and the isotope data suggest that there is no strong evidence for the formation of two different ecohydrological subsurface water stores for either soil types at any time. Such contrasting results in relation to those of previous studies might be attributed to the overall relatively high subsurface storage, and the area's radiation energy-limited climate that lacks overall strong seasonality in high precipitation inputs. The results therefore suggest that the formation of different subsurface water stores might depend on thresholds in the water-energy balance, and as such depend on geographic and climatic conditions.