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Plant phenological water cycle and implications for using δ^2H-alkanes as paleo proxy in a semi-arid tropical climate

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Lake Challa is a steep-sided crater lake situated in equatorial East Africa, a tropical semi-arid area with bimodal rainfall pattern. The δ^2H and δ18O of precipitation, lake water, groundwater, plant xylem water and plant leaf water were measured across different plant species, seasons and plant habitats in the vicinity of Lake Challa, as well as the hydrogen-isotopic composition of leaf wax n-alkanes (δ^2Hwax). Long chain n-alkanes of terrestrial plant leaf waxes provide information on plant-water relations and have been widely used as proxy in paleoclimate and paleovegetation reconstructions.

In our study, we found that plants rely mostly on water from the ‘short rains’ falling from October till December (northeast monsoon), as these recharge the soil pores after the long dry season. This plant-available, static, water pool is only slightly replenished by the ‘long rains’ falling from February to May (southeast monsoon), in agreement with the ‘two water world’ hypothesis according to which plants rely on a static water pool separated from a more mobile water pool that recharges the groundwater. Spatial variability in water resource use exists in the study region with plants at the lakeshore relying on water of different isotopic composition, i.e isotopically evaporated lake water at the lakeshore vs. non- or slightly evaporated precipitation in the savannah and on the crater rim. This spatial resource partitioning is recorded by elevated δ^2H values in the leaf wax lipids of plants at the lakeshore. The distribution of n-alkanes in the fresh leaves shows a unimodal distribution pattern reaching a maximum at n-C29 and n-C31 for both shrubs and trees, while C4 grasses are dominated by n-C31. However, the relative abundance of n-C31 was higher at the lakeshore compared to the savannah and crater rim (when grasses were not included).

According to our results, plant species and their associated leaf phenology are the primary factors influencing the enrichment in deuterium from xylem water to leaf water, with deciduous species giving the highest enrichment; while growth form and season have negligible effects. Growth form exerted a strong influence on δ^2Hwax, with more depleted values for C4 grasses compared to shrubs and trees. However, the variability on δ^2Hwax within the group of woody species remains large (range of $\sim$100 ‰. The variability in δ^2Hwax with season was plant-specific and ranged from no effect of seasonality to total dependency of seasonality.

Our observations have important implications for the interpretation of δ^2H of plant leaf wax n-alkanes from paleohydrological records in tropical East Africa, given that i) the water used by plants reflects only a small portion of the annual temporal variability in isotopic composition of precipitation and that ii) large variability on apparent isotopic fractionation is observed, though yet not fully understood.