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Integrating hydrology and biogeochemistry in drylands: the Kalahari Transect as a model ecosystem

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In dryland ecosystems patterns of both nutrient and water availability limit the spatial and temporal dynamics of plant growth. Traditionally, water and nutrient (e.g., nitrogen) have been explored separately in terms of the individual constraints they place on ecosystem function within water-limited ecosystems. We demonstrate that integrating hydrology and biogeochemistry in arid environments leads to better understanding of ecosystem patterns and processes across a wide range of dryland environments. Our presentation is based on the synthesis of a set of extensive field data and experiments on soil biogeochemistry (e.g., soil available nutrient concentrations, soil isotope compositions), hydrological parameters (e.g., soil moisture, rainfall) and vegetation structure (e.g., tree heights, tree spacing distances) from a homogenous mega-transect (the Kalahari Transect) in southern Africa, The synthesis shows that water availability determines nitrogen availability across regional rainfall gradients, but that these patterns are strongly mediated at local scale by vegetation patchiness, which plays an important role in nitrogen re-distribution and availability. In addition, we show that both water and nitrogen availability contribute to the maintenance of tree/grass composition within dryland ecosystems. Specifically, the consistently higher foliar δ^{15}N and lower soil δ^{15}N of C_3 plants compared to C_4 plants suggests that C_4 plants are superior competitors for nitrogen, while differing C_3 and C_4 foliar δ^{13}C relationships with rainfall for C_3 plants and C_4 plants indicates that C_3 plants are superior competitors for water. Finally, we show that spatial and temporal patterns of water availability determine the forms of nitrogen dominance with impacts on subsequent plant adaptations. Our synthesis demonstrates that integrating ecohydrological and biogeochemistry observations are necessary to provide holistic views of the complex processes governing dynamics of dryland ecosystems.