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From Budyko to biodiversity: Macroecological insights from evapotranspiration partitioning

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Transpiration is the cog that connects the water cycle to the carbon cycle. Yet in the majority of hydrological studies, transpiration is lumped together with evaporation, as if it did not matter exactly how the water moved from the land surface to atmosphere. However, as techniques are developed to partition the two, it is increasingly possible and useful to examine how transpiration varies among catchments, and to explore what hydrological and ecological theory may provide one another as a result.

The framework for this study begins with the Budyko curve – the curve, or more accurately the cloud of data, that traces how precipitation (P) is partitioned into runoff and evapotranspiration (ET) along an aridity gradient. The first question becomes: How does a catchment's transpiration fraction (T/P) vary with aridity? Four lines of analysis are used to answer this question. They include basic logic, a numerical ecohydrological toy model, a global land surface model, and the limited observational data that exist. Together, these lines of analysis strongly suggest that the transpiration fraction (T/P) of a catchment's water balance is a maximum at intermediate values of aridity, dropping off to zero as aridity either increases or decreases from that point. The evaporation fraction (E/T), conversely, increases monotonically with aridity. The precise location of the T/P peak is as yet unclear, but does not appear to be far from the boundary between water- and energy-limited conditions. The peak in transpiration fraction reflects an ecosystem's resource limits in terms of both water and energy supply. As energy increases beyond the water available, as in water-limited ecosystems, transpiration will increasingly lose out to evaporation. Conversely as water increases beyond the energy available, the transpiration will increasingly lose out to runoff and groundwater recharge in energy-limited ecosystems.

Because of the centrality of transpiration to both hydrology and ecology, this hydrological peak in a catchment's transpiration fraction has implications for the structure and composition of the catchment's ecosystems. Higher transpiration begets higher net primary productivity. Higher productivity is also linked to greater diversity, as more resources foster greater niche partitioning. Furthermore, macroecological studies show that diversity increases with total evapotranspiration, and peaks at intermediate PET, the theory being that diversity stems from both water and energy requirements. These regional patterns in diversity are tantalisingly similar to the hydrological underpinnings of the Budyko curve. When plant diversity data are re-analysed in the context of the ET partitioning described above, regional trends in diversity show a close correspondence to trends in transpiration fraction. The link also appears to translate to animal diversity patterns, which is not surprising given animals' reliance on primary productivity.

Together, the hydrological and macroecological analyses presented here reinforce the argument for a tight coupling between the water and carbon cycles, as well as offer a more biophysically meaningful environmental predictor for diversity patterns – namely aridity. Ultimately, this study underscores the reciprocal roles of diversity in catchment water balance, and of evapotranspiration in ecosystem composition and structure.