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Leaf trait responses to soil nutrient gradients across contrasting rainfall regimes in Western Australia

Daniil Scheifes[1], Jan Lankhorst[1], Jisun Kim[2], Shu Tong Liu[3], Catherine Morfopoulos[4], Hans Lambers[3], Paul Drake[3], Karin Rebel[1], and Hugo de Boer[1]

[1]Copernicus institute of Sustainable Development, Utrecht University, Utrecht, Netherlands
[2]Department of Landscape Architecture and Rural Systems Engineering, Seoul National University, Seoul, South Korea
[3]School of Biological Sciences, The University of Western Australia, Perth, Australia
[4]Department of Life Sciences, Imperial College London, Ascot, UK

Understanding how the relative availability of nitrogen (N) and phosphorus (P), together with water supply, influences plant photosynthesis and carbon allocation is crucial for accurate land surface models. Eco-evolutionary optimality theory provides a theoretical framework to model ecosystem responses and posits that carbon assimilation is optimized through coordinated investments in photosynthetic capacity and transpiration by minimizing their combined costs. Yet, it remains unclear how the availability of water and nutrients influences the leaf-level investments in photosynthetic capacity and transpiration.

We measured photosynthetic and leaf structural traits across N to P availability gradients in the ecosystems of Jurien Bay and Warren River in Western Australia. Both systems occur on soils developed on coastal sands and are arranged along chronosequences, but differ markedly in climate. Mean annual rainfall increases from 533 mm y□¹ at Jurien Bay in the north to 1185 mm y□¹ at Warren River in the south, while mean annual temperature decreases from 19.0 °C at Jurien Bay to 15.2 °C at Warren River.

Across gradients of N and P availability, photosynthetic capacity traits (A_{sat}, A_{max}, V_{cmax}, J_{max}) showed relatively modest variation compared with leaf structural traits (leaf N, leaf P, LMA) in both ecosystems. The ratio of leaf interior to atmospheric CO_2 concentrations (C_i / C_a) showed a positive relationship with the balance of N versus P availability in Warren River, but not in Jurien Bay. Differences in C_i / C_a between ecosystems suggest shifts in the coordination between carbon gain and water loss that were not fully explained by differences in photosynthetic capacity alone, and suggest interaction between water and nutrient availability.

Our work presents new observations on leaf trait responses across natural nutrient gradients that contribute to our understanding of how nutrient and water availability jointly shape the coordination between photosynthetic capacity and stomatal regulation.