Using hyperspectral plant traits linked to photosynthetic efficiency to assess N and P partition

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Abstract

Spatial prediction of photosynthesis requires an understanding of how foliage nitrogen (N) and phosphorus (P) regulate this process and the relationship between these elements and scalable spectral proxies. Hyperspectral imagery has been used to predict important photosynthetic variables such as the maximum rate of carboxylation (V-cmax) and electron transport (J(max)). However, our understanding of how generally applicable these relationships are for plants that are limited by N and P, characterised by respective mass based ratios of N/P <= 10 and N/P > 10, is still incomplete as most studies assume N and P co-limit photosynthesis.

Hyperspectral imagery and measurements of photosynthesis were obtained from one-year old Pinus radiata D. Don, grown under a factorial combination of N and P treatments. Using these data, the objectives of this study were to (i) identify whether trees were co-limited or independently limited by N and P, and then use hyperspectral imagery to (ii) partition N and P limited trees, (iii) build models of N and P from a range of hyperspectral indices and (iv) explore links between key plant traits and both V-cmax and J(max).

Compared to the use of all data, which assumes co-limitation, markedly stronger relationships between N and P and photosynthetic capacity were obtained through splitting data at N/P = 10 (independent limitation) for both V-cmax (R-2 = 0.40 vs. 0.59) and J(max) (R-2 = 0.38 vs. 0.64). A random forest model was used to accurately partition N from P limited trees and the two main variables used within this model were Photochemical Reflectance Index (PRI) and Solar-Induced Chlorophyll Fluorescence (SIF). Using data from the P limiting phase, the most precise models of P were created using PRI (R-2 = 0.75) and SIF (R-2 = 0.52). Indices that were proxies for chlorophyll were the most precise predictors of

N within the N limiting phase but strong positive relationships were also evident between N and both PRI (R-2 = 0.83) and SIF (R-2 = 0.57). Through their correlations with N and P, there were strong positive relationships between both SIF, PRI and V-cmax (R-2 = 0.78 and 0.83, respectively) and J(max) (R-2 = 0.80 and 0.83, respectively) that were generalisable across both N and P limiting ranges. These results suggest that quantified SIF and PRI from hyperspectral images may have greater precision and generality for predicting both foliage nutrition and biochemical limitations to photosynthesis than other widely used hyperspectral indices.

Palabras clave

Palabras clave de autor: High resolution hyperspectral; N:P ratio; Nitrogen; Nutrient limitation; Phosphorus; Reflectance
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