# Optimal Allocation of Leaf-Level Nitrogen Explains Covariation of $V_{cmax}$ and $J_{max}$

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**Abstract.** The maximum rate of carboxylation, $V_{cmax}$, and the maximum rate of electron transport, $J_{max}$, describe leaf-level capacities of the photosynthetic system and are critical in determining the net fluxes of carbon dioxide and water vapor in the terrestrial biosphere. Although, both $V_{cmax}$ and $J_{max}$ exhibit high spatial and temporal variability. Many models of photosynthesis employed in terrestrial biosphere models assume constant values for $V_{cmax}$ and $J_{max}$ at a reference temperature ignoring intra-seasonal, inter-annual, and water stress-induced variations. Although general patterns of variation of $V_{cmax}$ and $J_{max}$ have been correlated with groups of species, climates, and nitrogen concentrations, scant theoretical support has been provided to explain these variations. We present a new approach to determine $V_{cmax}$ and $J_{max}$ based on the assumption that a limited amount of leaf nitrogen is allocated optimally among the various components of the photosynthetic system in such a way that expected carbon assimilation is maximized. The optimal allocation is constrained by available nitrogen, and responds dynamically to the near-term environmental conditions of light and water supply. The resulting optimal allocations of a finite supply of nitrogen replicate observed relationships in nature, including the ratio of $J_{max}/V_{cmax}$, the relationship of leaf nitrogen to $V_{cmax}$, and the changes in nitrogen allocation under varying water availability and light environments. This optimal allocation approach provides a mechanism to describe the response of leaf-level photosynthetic capacity to varying environmental and resource supply conditions that can be incorporated into terrestrial biosphere models providing improved estimates of carbon and water fluxes in the soil-plant-atmosphere-continuum.