Using plant trait data to extend a theory of global ecosystem function

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There remains large uncertainty about the global exchanges of carbon between the atmosphere and the terrestrial biosphere under different environmental change scenarios. Ecosystem and Earth system models rely on photosynthetic capacity (maximum rates of carboxylation ($V_{cmax}$) and electron transport ($J_{max}$)) to simulate carbon assimilation. Photosynthetic capacity has been related to environmental and climatic constraints, but also to leaf and soil nutrients. Views differ on which are more important.

We assembled and analysed a large dataset of global observations of photosynthetic and other leaf traits. Photosynthetic capacity was best predicted based on optimality hypotheses. $V_{cmax}$ standardized to 25°C ($V_{cmax25}$) was proportional to light availability, and increased towards colder and drier environments – as expected due to the greater biochemical investment required at lower temperatures, or when stomata are more closed. The ratio $J_{max25}/V_{cmax25}$ declined with growth temperature (also predicted). However, theoretical predictions slightly underestimated $V_{cmax}$ at high growth temperatures, and overestimated it at low growth temperatures. This bias might be due to the difference between leaf and air temperatures.

Statistical models for photosynthetic capacity (all species, and site means) overestimated $V_{cmax}$ in low-P leaves. Analysis of a subset of the data showed that leaf P tends to increase with measured soil P. A relationship of model bias to leaf N appears in the all-species analysis – perhaps reflecting a correlation of $V_{cmax}$, leaf N and light levels within communities. But site-mean analysis showed no such bias, and leaf N showed no relationship to the soil C:N ratio. These results support a previously noted dependency of $V_{cmax}$ on P availability; but not the control of $V_{cmax}$ by N availability that has been assumed in many models.