The spectrum of ecosystem functional properties

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Understanding the coordination of ecosystem functions across biomes and climate is still a major challenge that hampers our ability to properly predict biosphere response to climate change. Theories such as the leaf economics spectrum and the least cost investment strategy postulate that plants optimize the rate of investment in transpiration, photosynthetic capacity, and nitrogen (N) allocation dependent on the ratio of their costs to gain given their resources and environment.

In this contribution we test whether theories about functional traits coordination at leaf and organs level are emerging at ecosystem scale. We further investigate the existence of a global spectrum of ecosystem functional properties, and analyze how state of the art terrestrial biosphere models reproduce the spectrum.

To do so we used data of CO₂, water and energy exchange for 164 sites (1237 site years) from the FLUXNET LaThuile and FLUXNET 2015 datasets with at least 3 years of data. For 61 sites, we were able to compile site information on canopy-scale measurements of foliar N concentration, maximum leaf area index, and stand age, from the literature.

We find evidence that a global spectrum of ecosystem functional properties exist, and that most of the variability (66.2%) is captured by three dimensions. The first dimension represents ecosystem productivity; the second the water availability gradient, and climate limitations to productivity; the third dimension reflects ecosystem respiration potential and carbon-use efficiency and is related to aridity and stand age and disturbance regimes. The first two dimensions of the spectrum are well captured by ecosystem models, while the third dimension is poorly reproduced. This might be related to the spin up of the models (steady-state condition) or to an incomplete representation of processes related to age that might limit the ability of models to accurately predict the dynamic carbon, water and nutrient cycling in ecosystems in disturbed areas.

Finally, we show across ecosystems globally that leaf level theories can be in some cases translated to the ecosystem scale. As a main example we found an inverse relationship between photosynthetic N and water use efficiency as postulated by the least cost investment theory across
FLUXNET sites. However, this is possible only when the contribution of vegetation is properly accounted for, and evaporation from soil and wet surfaces is removed from the analysis. This highlights that emerging biological patterns at ecosystem scale might be masked by other factors related to physical rather than biological responses.