Changes in leaf nitrogen and phosphorus content from observations and a land surface model: evidence for increasing nutrient imbalance in Europe

Silvia Caldararu1, Katrin Fleischer1, Lin Yu2, and Sönke Zaehle1

1Max Planck Institute for Biogeochemistry, Department of Biogeochemical Signals, Jena, Germany (scaldra@bgc-jena.mpg.de)
2Centre for Environmental and Climate Research, Lund University, Lund, Sweden

Increasing atmospheric CO₂ concentrations can be a driver for higher ecosystem productivity across the globe but nutrient availability may limit subsequent biomass growth. Concurrently, increased anthropogenic nitrogen (N) deposition introduces a relatively large amount of N into the system, thus potentially alleviating N limitation. However, this new N input could push ecosystems into being limited by other resources, most importantly phosphorus (P) in mid- and high-latitude systems, leading to what has been termed an NP imbalance. While the ecological theory behind the processes described above has been discussed on many occasions, it is yet unclear what the actual spatial and temporal patterns of such an imbalance are, as well as the ecological processes and drivers behind such observed patterns.

Here, we use leaf N and P data from a large European monitoring network, ICP forests, in conjunction with a land surface model, QUINCY (Quantifying Interactions between terrestrial Nutrient CYcles and the climate system), to explore the patterns and drivers behind nutrient limitation at European forest sites. The overall trend in observed leaf N and P content as well as N:P ratio show an increasing nutrient limitation from 1990 to 2015, as well as a shift towards P limitation. However, the observed spatial patterns of change in leaf nutrient content vary strongly with soil nutrient availability, N deposition and leaf habit. The effect of leaf habit suggests that leaf growth strategies play an important role in dealing with nutrient availability and controlling observed ecosystem responses.

We use the QUINCY model to explore the drivers behind the observed leaf nutrient trends. We perform simulations with fixed levels of atmospheric CO₂ as well as in the absence of anthropogenic nitrogen deposition. We show that the decrease in leaf N and P content is attributable to increased atmospheric CO₂ while the changes in N:P stoichiometry are reproducible with increased N deposition. Additionally, the model can only predict observed trends when representing physiologically-realistic responses of leaf stoichiometry to nutrient availability. The use of a process-based model allows us to attribute drivers to the observed changes in leaf nutrient content. This research helps the development of data-constrained, process-based models which can potentially be used to predict changes in ecosystem nutrient
limitation, and implicitly growth and carbon storage, under future scenarios