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Modelling C allocation in response to nutrient availability

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Carbon (C) allocation in ecosystems is a key variable of the global terrestrial C cycle. While photosynthesis governs the amount of C that enters ecosystems, its subsequent allocation to compartments with different life times determines its over-all residence time and variations in allocation patterns drive changes in ecosystem C balance and its response to environmental change. A better understanding of the controls on allocation is thus key to improving global vegetation models that commonly rely on using fixed partitioning factors.

Observational data suggests variations of ecosystem structure and functioning along large-scale gradients of resource availability. Below-ground C allocation, inferred as gross primary production minus above-ground biomass production increases along gradients of decreasing nutrient availability. This is not only due to more root growth, but also due to enhanced production of exudates and stimulation of root symbionts and has been interpreted to reflect optimal plant allocation decisions under a varying soil fertility status.

Here, we propose a model that accounts for trade-offs between (i) growth in above-ground and (ii) below-ground plant compartments, (iii) exudation to the rhizosphere and root symbionts and (iv) temporary storage in non-structural pools. By postulating the maximization of long-term growth under a given (seasonal regime) of soil nitrogen (N) availability, we attempt to reproduce observed large-scale gradients.

The model is formulated based on a C cost for different N uptake decisions, where the cost is a function of N availability, root mass, and soil temperature (for biological N fixation). On a daily time scale, ecosystem N uptake may be realized by C exudation to the rhizosphere and/or symbiotic fixation of atmospheric N_2. On an annual time scale, allocation to roots versus leaves is adjusted to soil inorganic N availability and modeled to yield maximum total growth. Exudation versus temporary storage of C is modeled to balance seasonal and annual variations in N availability and demand and yield a minimum multi-annual cost of N uptake.

We present first results where the model is applied along a gradient of N availability. Predictions are tested against a data set of total below-ground allocation and C use efficiency across global scales. Opportunities and limitations of such an implementation in global vegetation models are discussed.