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Next generation plant functional types - the importance of life history, disturbance, plasticity, evolution and strategic trade-offs

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Improving physiological process representations in Dynamic Global Vegetation Models (DGVM) has recently received substantial attention, in particular concerning processes related to photosynthesis. I argue, however, that life history traits, which are largely neglected by current DGVMs, can be more important for ecosystem structure and carbon dynamics.

To illustrate this, I present model results and data that show the overwhelming importance of disturbance, which is poorly represented in most DGVMs, and life history traits, such as longevity, for ecosystem carbon storage. I also present two simulations of the potential natural vegetation (PNV) of Europe. In one simulation, the Lund-Potsdam-Jena (LPJ) DGVM was run with the standard set of Plant Functional Types (PFTs). In the second simulation, the model LPJ-GUESS, which has adopted ecophysiological process representations from LPJ-DGVM but simulates tree population dynamics, tree age and size distributions, and canopy structure at greater detail, was run with the major tree species occurring in Europe. While LPJ-DGVM failed to reproduce the PNV of Europe, LPJ-GUESS succeeded. The discrepancies between the simulation by LPJ-DGVM and the 'real' vegetation include ecosystem characteristics that are important in atmospheric coupling, such as phenology (evergreen or deciduous). One key difference between the two models is that LPJ-GUESS accounts for species differences in shade tolerance.

Other important neglected aspects of plant functioning are plasticity and evolution. A large number of functionally important traits can vary by up to a factor of four within species, which is much more than the differences within species. These traits, include, for example, base respiration rates, longevity, needle longevity, and the ratio of leaf area to sapwood cross-sectional (which determines hydraulic conductance on a leaf area basis). Therefore, static PFT or tree species parameters should in models be replaced by PFT-specific relationships between environmental factors and traits.

The TRY database could be used for establishing such relationships and to identify strategic trade-offs that limit the possible combination of traits. The functional significance of a particular trait depends very much on the associated traits, which is why exploring relationships between single traits and the environment can be misleading. If trait-offs can be derived with the database, these can be hard-wired into DGVMs. I hypothesize, for example, that there exist PFT-specific relationships between a large number of traits defining a trade-off between high maximum transpiration and photosynthesis (being associated with high growth rates and strong competitive ability under high water availability) and maintaining water flow and carbon assimilation at low water availability. Related traits might include max. height, maximum photosynthetic capacity (Vcmax), leaf density, minimum leaf water potential, stomatal sensitivity, wood density, xylem conductivity and xylem vulnerability.

How plants function is generally much better understood than currently represented in DGVMs. Thus, much work remains to be done in order to adequately represent plants and their diversity in models and to link plant and ecosystem functioning.