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Quantifying the effects of species interactions in a global plant diversity model

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How important are inter-species interactions in determining global species diversity, abundances and vegetation productivity? In order to explore these issues we must go beyond existing plant functional type models and capture population dynamics to track species composition dynamics under non-equilibrium conditions [Jeltsch et al. 2007]. This is of particular importance because biogeochemical fluxes and diversity may be strongly influenced by the effects of particular sets of species and how these sets of species change over time [Botkin et al. 2007]. Previous work has shown how local climate is important in determining species diversity and abundance. In particular, the Jena Diversity (JeDi) model (based on the approach of Kleidon & Mooney 2000) assumes that global vegetation patterns can be largely explained in terms of the success and failure of different 'species' (where a 'species' is a particular growth strategy) that vary in response to local climate [Kleidon & Mooney 2000]. The JeDi model successfully reproduces the global biodiversity pattern and major terrestrial biomes as the emergent properties of different sets of plant functional traits [Reu et al. 2009, subm]. These established results allow us to examine how inter-species interactions in the form of competition for shared resources alter diversity, abundances and carbon fluxes steady states, and also how such steady states are reached.

We extended the JeDi model in order to include an explicit notion of space. The occupied space of each species was explicitly calculated as the gains and losses of space due to the emergent specific characteristics of the 'growth strategies', such as number of seeds, total biomass and respiration. Space is gained by germination and colonisation via competition. Space is lost due to exclusion via competition and mortality. This leads to two forms of competition: seeds compete for bare space and bigger species exclude smaller ones by appropriating resources such as light and nutrients. By implementing these assumptions into a simple numerical model, successional dynamics are observed in which fast reproducing species initially increase in abundance with a slow increase in species with larger biomass. Competition for space and/or competition for resources leads to stable multi-species steady states. We explain these stable multi-species states as a result of the balance between fast growing small plants and slow growing large plants. This balance is altered by the mortality rate which can be seen as incorporating senescence as well as environmental perturbations (such as climatic variation) that would constrain vegetation. Our results shed light on the Intermediate Disturbance Hypothesis as a range of mortality rates
produce maximum amounts of species diversity.
Our results demonstrate how population dynamics may be incorporated into global vegetation models. We believe this is of critical importance for the assessment, analysis and prediction of biodiversity and biogeochemical dynamics in ecosystems that are subject to stresses and perturbations, inter alia, climate chang.

References:
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