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Modelling vegetation responses to climate change using a second generation dynamic vegetation model : uncertainties due to ecological scale limitations

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Second generation Dynamic Global Vegetation Models (DGVMs) have recently been developed to explicitly represent the ecological dynamics of disturbance, tree-to-tree competition for light, and succession. These models represent a major advance in terms of ecological realism. Nevertheless, second-generation DGVMs are not currently parameterized to represent seed distribution, small-scale spatial heterogeneity, genetic variation and other stochastic ecosystem processes that slow the dynamics of competitive exclusion and promote ecosystem functional diversity with respect to how plants respond to climatic stress. We used a modified second-generation DGVM to demonstrate how the representation of these processes can impact on predicted community structure and how the different contemporary community structures alter climate change responses. We constructed a growth-vs-risk axis of plant diversity defined by the quantity of carbon allocated to labile carbon storage, and using this simulated ecosystem, predict the response of an Amazon forest site to climate and CO2 forcing. A sensitivity test to variation in four currently unconstrained parameters pertaining to dispersal, seed mortality, and the stochasticity of competitive exclusion generated high uncertainty in community composition, which in turn leads to highly contrasting impacts of CO2 fertilisation and climate warming on forest structure and biomass. This generates a range of predictions of vegetation carbon stocks in 2050 equal to the magnitude of current forest biomass. Model predictions of net ecosystem carbon fluxes and LAI do not differ greatly between realizations, meaning that correct prediction of these properties is no guarantee that future predictions are accurate. We conclude that DGVMs require better constrained formulations of these fine-scale spatial ecological processes. Bottom-up prediction of ecosystem functional diversity could be improved using results from fine-scale spatially explicit models to generate useful parameterizations that can be applied at larger scales, however, given our limited ability to explain functional diversity in extant ecosystems, it is also likely that top-down constraints on model runs will be necessary to discount model scenarios that are unlikely given recent observations of the response of ecosystems to episodic climatic stress and imposed artificial manipulation.