Global Change Biology / Volume 26, Issue 10

PRIMARY RESEARCH ARTICLE

Forest responses to simulated elevated CO_2 under alternate hypotheses of size- and age-dependent mortality

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First published: 28 June 2020
https://doi.org/10.1111/gcb.15254

Abstract

Elevated atmospheric carbon dioxide (eCO_2) is predicted to increase growth rates of forest trees. The extent to which increased growth translates to changes in biomass is dependent on the turnover time of the carbon, and thus tree mortality rates. Size- or age-dependent mortality combined with increased growth rates could result in either decreased carbon turnover from a speeding up of tree life cycles, or increased biomass from trees reaching larger sizes, respectively. However, most vegetation models currently lack any representation of size- or age-dependent mortality and the effect of eCO_2 on changes in biomass and carbon turnover times is thus a major source of uncertainty in predictions of future vegetation dynamics. Using a reduced-complexity form of the vegetation demographic model the Functionally Assembled Terrestrial Ecosystem Simulator to simulate an idealised tropical forest, we find increases in biomass despite reductions in carbon turnover time in both size- and age-dependent mortality scenarios in response to a hypothetical eCO_2-driven 25% increase in woody net primary productivity (wNPP). Carbon turnover times decreased by 9.6% in size-dependent mortality scenarios due to a speeding up of tree life cycles, but also by 2.0% when mortality was age-dependent, as larger crowns led to increased light competition. Increases in aboveground biomass (AGB) were much larger when mortality was age-dependent (24.3%) compared with size-dependent (13.4%) as trees reached larger sizes before death. In simulations with a constant background mortality rate, carbon turnover time decreased by 2.1% and AGB increased by 24.0%, however, absolute values of AGB and carbon turnover were higher than in either size- or age-dependent mortality scenario. The extent to which AGB increases and carbon turnover decreases will thus depend on the mechanisms of large tree mortality: if increased size itself results in elevated mortality rates, then this could reduce by about half the increase in AGB relative to the increase in wNPP.