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The potential impacts of increasing temperatures on old-growth forest biomass density

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Global atmospheric and climate change could alter forest carbon stores, potentially causing important positive or negative feedbacks on global change. For example, rising temperatures are likely to influence old-growth forest biomass density (biomass per unit area), and thereby could make old growth forests sources or sinks of carbon to the atmosphere, but the magnitude and direction of likely change continue to be debated. It is difficult if not impossible to run experiments on sufficiently large spatial and temporal scale to capture global change impacts on old-growth biomass in different forest types. Thus, models that capture the key physiological impacts of global change on forest carbon budgets are a critical tool for assessing impacts of climate and atmospheric change. The expected changes in temperatures are similar to spatial temperature variation observed currently and, therefore, models explaining current variation in old¬-growth forest biomass can be directly applied to predict expected equilibrium biomass after a transitional period lasting decades or centuries. In a recent paper (Larjavaara and Muller-Landau 2012. Temperature explains global variation in biomass among humid old-growth forests. Global Ecology and Biogeography), we developed a physiologically motivated model for global variation in old-growth forest biomass. We modelled annual GPP as a function of monthly average temperatures (minimum and maximum) and sun angle, and modelled plant biomass "maintenance cost" (including autotrophic respiration and construction required to maintain biomass) as a function of temperatures alone. We then used fitted models for GPP and maintenance cost to predict old-growth forest biomass density under different climates. We found that highest old-growth biomass is expected in maritime temperate climates in which temperatures remain between 5˚C and 25˚C for most of the year, and in which the ratio of GPP to maintenance cost is thus the highest. In tropical climates, the high maintenance cost lowers the ratio of GPP to maintenance cost, and makes it energetically impossible to support very large trunks. In continental temperate climates, warm summers and cold winters lower the GPP to maintenance cost ratio, and thus old-growth forest biomass. Our predictions explained 50% of global variation in old-growth forest biomass density in an independent dataset. In this paper, we use our previously fitted models of temperature effects on GPP and maintenance costs to project the impacts of increasing temperatures on old-growth forest biomass in humid climates. Model projections suggest that old-growth biomass per area of forest will increase significantly in temperate and boreal climates due to longer growing seasons, and decrease significantly in tropical climates due to the increasing energetic costs of temperatures above 30˚C. Field measurements have found, on average, increasing old-growth forest biomass worldwide, in agreement with our projections for temperate and boreal forests but contrary to our projections for tropical forests. Our projections do not consider the impacts of increasing atmospheric carbon dioxide and increasing nitrogen deposition, which are both likely to positively impact old-growth forest biomass, and may outweigh the negative impacts of temperature alone in tropical forests.