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Live fast-die young: Scaling CO2 fertilization effects from leaf to ecosystem levels

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Global environmental changes are rapidly altering the functioning and structure of terrestrial ecosystems.Particularly, rising CO_2 atmospheric concentrations have been reported to increase photosynthesis by increasing carbon assimilation and water-use efficiency. This leaf-level CO_2 fertilization effect may lead to an increase in the biomass stock in forest stands. However, previous studies argued that an enhanced tree growth rate is associated with a reduction in the longevity of trees, thus reducing the ability of forest biomass to act as carbon sinks over long timescales. In addition, faster growth may lead to an acceleration of self-thinning whereby tree density in the stand is reduced due to progressive mutual shading as tree crowns expand and a resulting increase in shaded individuals' mortality. Nevertheless, previous results relied on empirical relationships between tree growth rates and longevity, without considering any positive effects of elevated CO_2 on individual tree's carbon balance. Individual-based forest datasets such as tree ring width data and forests inventories have been widely used to monitor long-term changes in forest demography. Yet, the mechanistic underlying these processes remains poorly understood and challenges persist in upscaling from individual measurements to higher level of organization.

Here, we use a vegetation demography model (LM3-PPA) which simulates vegetation dynamics and biogeochemical processes by explicitly scaling from leaf up to ecosystem level by resolving leaf-level physiology, growth, and height-structured competition for light, using the perfect plasticity approximation (PPA). Using this simulation model, we investigate the links between individual trees' carbon balance under rising CO_2 levels, their longevity under alternative mortality parametrizations, and the implications for forest dynamics and self-thinning rates. Inventory data from long-term forest reserves is used to assess empirical support for these simulated links. Specifically, we test the hypothesis of *faster growth-earlier death* in order to assess forests' capacity to store carbon under environmental changes. This provides key mechanistic insights to reveal whether increased CO_2 fertilization on leaf-level photosynthesis positively affects tree's C balance and thereby reduces the mortality under competition for light in the canopy.