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Does forest growth acceleration lead to denser stands? Insights from Swiss forests and mechanistic modelling

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Forest demographic processes - growth, recruitment and mortality - are being altered by global change. The changing balance between growth and mortality strongly influences forest dynamics and the carbon balance. Elevated atmospheric carbon dioxide (eCO_2) has been reported to enhance photosynthesis and tree growth rates by increasing both light-use efficiency (LUE) and water-use efficiency (WUE). Tree growth enhancement could be translated into an increase in biomass stocks or could be associated with a reduction in the longevity of trees, thus reducing the ability of forest ecosystems to act as carbon sinks over long timescales. These links between growth and mortality, and the implications for forest stand density and self-thinning relationships are still debated. Scarce empirical evidence exists for how changing drivers affect tree mortality due to existing data and modelling limitations. Understanding the causes of observed mortality trends and the mechanisms underlying these processes is critical for accurate projections of global terrestrial carbon storage and its feedbacks to anthropogenic climate change.

Here, we combine a mechanistic model with empirical forest data to better understand the causes of changes in tree mortality and the implications for past and future trends in forest tree density. Specifically, we test the Grow-Fast-Die-Young hypothesis to investigate if a leaf-level CO_2 fertilization effect may lead to an increase in the biomass stock in forest stands. We use a novel vegetation demography model (LM3-PPA) which includes vegetation dynamics with biogeochemical processes allowing for explicit representation of individuals and a mechanistic treatment of tree mortality. The key links between leaf-level assimilation and stand dynamics depend on the carbon turnover time. In this sense, we investigate alternative mortality assumptions about the functional dependence of mortality on tree size, tree carbon balance or growth rate. These formulations represent typical approaches to simulate mortality in mechanistic forest models. Model simulations show that increasing photosynthetic LUE leads to higher biomass stocks, with contrasting behavior among mortality assumptions. Empirical data from Swiss forest inventories support the results from the model simulations showing a shift upwards in the self-thinning relationships, with denser stands and bigger trees. This data-supported

mortality-modelling helps to identify links between forest responses and environmental changes at the leaf, tree and stand levels and yields new insight into the causes of currently observed terrestrial carbon sinks and future responses.