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Benchmarking simulations of forest regrowth across Europe

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Dynamic global vegetation models (DGVMs) are essential for quantification of the response of land carbon storage to changes in atmospheric chemistry, climate, and land cover. While DGVMs are often evaluated concerning carbon responses to changes in CO_2 and climate, local responses to changes in land cover have received less attention. This is of concern as DGVMs are needed to project the long-term consequence of afforestation or deforestation on the land carbon balance under climate. Here, we present an assessment of the Organizing Carbon and Hydrology in Dynamic Ecosystems (ORCHIDEE) model, one of the state-of-the-art DGVMs, aiming to evaluate the simulated growth in forest biomass carbon stocks across the European Union against comprehensive observational data.

We conduct a model-data comparison of biomass growth using databases that contain paired observations of above-ground biomass (AGB) and plant age, categorized across various age groups spanning from very young (0-19 years) to old (>99 years) forests for boreal and temperate forests. The biomass dataset encompasses a harmonized collection from multiple open forest inventory databases, comprising 603 sites across Europe for six plant functional types (PFTs). On average, the stands are approximately 58 years old, with a mean AGB of 6.4 $kgC.m^{-2}$. The findings indicate that simulations replicate the observed trend: AGB increases rapidly in young stands (<60 years old) and moderately saturates in later ages (>60 years old). However, the observed AGBs exhibit broader ranges and have more extremes than the simulated values. This is expected as observations refer to individual species, while our simulations are on the level of PFTs, which are an assemblage of species. Moreover, the comparisons reveal that the model underestimates AGB for temperate needleleaf evergreen forests, with a median deviation of approximately 60% from observed values. We propose a recalibration of the maximal rate of carboxylation and gross primary production fraction lost as growth respiration to reduce this deviation to less than 10%.

Our study highlights the potential of using observational biomass data to assess and calibrate DGVMs. This approach significantly enhances the ability of DGVMs to accurately reproduce the short-term land carbon sink response to reforestation. We provide a protocol that can easily be adapted to evaluate and recalibrate other DGVMs for the same purpose.