Forest age and gross primary productivity explain annual net forest carbon balance.

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Forests dominate carbon exchanges between the terrestrial biosphere and the atmosphere. In the long term, this net forest carbon dynamics is driven by ecological disturbances and forest management. However, the interaction among biotic and abiotic factors that drive forest-atmosphere carbon exchanges is poorly understood, limiting our ability to predict how future environmental and ecosystem changes influence the global forest carbon sink. Here, we conducted an observational synthesis to empirically determine to what extent climate, soil properties, nitrogen deposition, gross primary productivity (GPP), forest age and management influence annual net ecosystem productivity (NEP) variability across 123 forest eddy-covariance sites worldwide. Our multivariate empirical NEP models explained 54% to 64% of annual NEP variability in a leave-one-site-out cross-validation analysis. Forest age and GPP were the main drivers of NEP variability, explaining together around 40% of NEP variance. The contribution of the age effect on NEP was similar across climate zones or plant functional types (PFTs). Assuming a non-linear forest age-NEP relationship increased both our model performance and the relative importance of forest age, and avoided confounding forest age effect with other factors like nutrient availability. These findings suggest that effects of forest developmental stage, GPP and environmental factors
must be considered to accurately model NEP variability in space and time, when either statistical data-driven approaches or process-based carbon cycle models are used.