Carbon Dynamics of Forest Recovery under a Changing Climate: Forcings, Feedbacks, and Implications for Earth System Modeling

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Regenerating forests make major contributions to the global carbon (C) cycle, and understanding how global change will alter patterns of regeneration and C storage will be necessary to predict the rate of atmospheric CO_2 increase in future decades. We are using a combination of data synthesis and modeling to understand how C cycling in forests varies as a function of ecosystem age, how these patterns vary globally with respect to climate, and how expected changes in atmospheric CO_2 and climate will impact the long-term dynamics of forest regrowth.

To advance understanding of patterns of the C dynamics of forest recovery, we are compiling a new database, the Forest C database (ForC-db), which contains data on C stocks and fluxes in forest ecosystems along with each site's disturbance history. This database contains >14,000 records from >1,400 stands, making it the largest and most comprehensive database on ground-based measurements of C stocks and flows in forest ecosystems globally. Using the tropical component of ForC-db (TropForC-db; >2,200 records from >445 stands), we show that the rate of biomass accumulation in regenerating tropical forests is jointly shaped by climate and disturbance history. Specifically, forest regeneration is faster in everwet than in seasonal climates, slower following cultivation or grazing than other disturbance types, and faster in planted than in naturally regenerating forests. We expect that this database will prove useful for model evaluation and for quantifying the contribution of secondary forests to the global C cycle.

To understand how elevated CO_2 and climate change affect the long-term dynamics of forest regrowth, we are modeling the dynamics of forest recovery using the mechanistic size- and age-structured Ecosystem Demography model (ED2). We have applied the model to Duke Forest, drawing upon data from the FACE experiment, age chronosequence, and eddy flux towers for model parameterization and evaluation. We show that elevated CO_2 is likely to increase the rate of biomass accumulation and community turnover and to alter the successional pathway and mature forest composition. Model predictions of mature forest biomass and ecosystem-atmosphere exchange of CO_2 and H_2O are sensitive to assumptions about nitrogen limitation; both the magnitude and persistence of the ecosystem response to elevated CO_2 are reduced under N limitation. Regardless, our model simulations demonstrate that elevated CO_2 will result in a general acceleration of forest regeneration while altering the course of successional change and having a lasting impact on forest ecosystems.