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ABSTRACT TITLE: Partitioning CO_2 fluxes with isotopologue measurements and modeling to understand mechanisms of forest carbon sequestration

ABSTRACT: Ecosystem models differ widely in their predictions of how forest carbon dynamics will interact with a changing climate, and that interaction is a large source of uncertainty in predictions of future climate. We are investigating the mechanisms controlling carbon sequestration at the Harvard Forest by integrating stable carbon isotope analyses with a suite of measurement approaches including eddy covariance, soil chambers, plot trenching, and minirhizotrons. The data are being integrated in—and used to refine—the Ecosystem Demography 2 (ED2) model.

Here we present key results to date. Using eddy covariance measurements of the forest-atmosphere exchange of $^{12}CO_2$ and $^{13}CO_2$, we partitioned the net ecosystem CO_2 exchange (NEE) into photosynthesis and respiration on an hourly timescale—a longstanding goal in carbon cycle science. Photosynthesis (and canopy-integrated stomatal conductance) showed a linear response to sunlight with no evidence of saturation, but the slope of the linear response increased with cloudiness, presenting the illusion of saturation. The response of stomatal conductance to light was the same throughout the day and throughout the year despite large changes in atmospheric and soil moisture. Ecosystem respiration was relatively constant throughout the day and night but varied greatly with the flux tower footprint. Our analyses suggest that ecosystem heterogeneity around the flux tower contributes substantial bias to eddy covariance measurements of NEE, as well as to standard predictions of ecosystem photosynthesis and respiration.

The isotopic compositions of photosynthetic assimilation and belowground respiration imply that the effective age of the substrate for belowground respiration was about 2 weeks. The isotopic composition of belowground respiration showed little or no diel cycle but varied by 1 ‰ over distances as short as 2 m, perhaps due to the heterogeneous distribution of roots; flux tower measurements indicated that the magnitude of variation did not increase at larger spatial scales. Fine root production peaked in early June and again in mid September. Root nonstructural carbohydrates decreased from mid May to July, coinciding with increases in root production and respiration. Fine root turnover time ranged from 4.5-16 years. We trenched one of our two chamber plots in late 2012 to help investigate the role of roots in 2013.

Finally, we have developed a new version of ED2 that simulates the carbon isotopes. Driven by our measurements, this model will be used to explore the implications of ecosystem carbon allocation mechanisms for carbon sequestration and feedbacks to climate.