Synthesis of Four Forest CO₂ Enrichment Experiments Demonstrates a Strong and Sustained Decadal Carbon Sink in Aggrading Temperate Forest Biomass

Anthony P. Walker¹, Martin G. De Kauwe², Belinda E. Medlyn³, Sönke Zaehle⁴, Colleen Iversen¹, FACE-MDS team, and Richard J. Norby¹

¹ Environmental Sciences Division and Climate Change Science Institute, Oak Ridge National Laboratory, Oak Ridge, Tennessee, USA
² Macquarie University, Department of Biological Sciences, New South Wales 2109, Australia
³ Hawkesbury Institute for the Environment, Western Sydney University. Locked Bag 1797 Penrith NSW 2751 Australia
⁴ Biogeochemical Integration Department, Max Planck Institute for Biogeochemistry, Hans-Knöll-Str. 10, 07745 Jena, Germany.

Contact: Anthony Walker [walkerap@ornl.gov]

Predictive understanding of the future terrestrial carbon sink remains elusive. Forest responses to increasing CO₂ are a large contributor to uncertainty in this understanding. Synthesizing data from the only four, decade long, forest CO₂ enrichment experiments replicated at the forest stand scale, we show a strong, decadal-scale CO₂ sink in aggrading forest biomass. Across ambient and elevated CO₂ treatments, biomass increased over the decade of the experiments in a linear relationship with NPP, i.e. CO₂ did not affect the relationship between biomass increment and cumulative NPP. However, because wood allocation increased as NPP increased, the retention of NPP as biomass was more efficient under increased CO₂. Each forest showed strong within treatment variability in NPP suggesting that the factors governing the retention of NPP as biomass across a range of natural climatic and edaphic variability also govern the retention of CO₂ stimulated NPP.

At the two sites that were not confounded by uncertainty or adaptation to frequent fire disturbance, state-of-the-art ecosystem models under-predicted the biomass stimulation by CO₂. This under-prediction was caused by an under-prediction of both the NPP response to CO₂ and the increase in the wood allocation fraction in response to CO₂. These data, synthesized as part of the Free Air CO₂ Enrichment Model Data Synthesis (FACE-MDS) project, clearly demonstrate a sustained long-term stimulation of forest biomass in response to CO₂ concentrations predicted for the middle of the century. Properly accounting for this CO₂ stimulation of biomass in aggrading forests will be necessary for accurately projecting the future terrestrial carbon sink.