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Carbon fluxes and growth in a mature deciduous forest after 8 years of CO2 enrichment

Martin Bader (1,2) and Christian Körner (2)

(1) University of Western Australia, School of Plant Biology, Department of Agriculture and Natural Sciences, Crawley, Perth, Australia (martin.bader@uwa.edu.au), (2) University of Basel, Institute of Botany, Schönbeinstrasse 6, 4056 Basel

Carbon (C) uptake by forests constitutes half of the planet's terrestrial net primary production, therefore tree responses to rising atmospheric CO2 are critical to understanding the future global carbon cycle. Here we present the synthesis of an 8 year CO2 enrichment experiment in a ca. 100-year-old mixed deciduous forest in Switzerland, where the crowns of 12 mature trees have been exposed to $\sim$550 ppm atmospheric CO2. The use of fossil (13C-depleted) CO2 for canopy enrichment permitted isotopic tracing of the newly assimilated C. After the first growing season, mycorrhizal sporocarps associated with CO2-enriched trees already consisted of 62% new C implying a rapid flux of C from the canopy to soil biota. Owing to the slow dilution of old C pools, it took 4 years of growth under elevated atmospheric CO2 until newly formed leaves and wood comprised >90% new C. Trees receiving CO2 enrichment showed reduced sap flow (-10–15%) and higher rates of leaf photosynthesis (+40–50%) than control trees but did not produce more leaf or fine root litter. Specific leaf area and leaf nitrogen concentration remained largely unaffected by elevated CO2 but non-structural carbohydrates accumulated more strongly in leaves grown under high CO2 (driven by Quercus). The extra C assimilated in the CO2-enriched canopy did not translate into enhanced above- or belowground growth or biomass. Higher CO2 build-up (+35%) and a consistent stable C isotope signal in the soil pore space under CO2-exposed trees rather suggested enhanced C flux through these trees to the soil throughout the study period. However, rates of soil respiration cumulated over the growing season were similar under CO2-treated and control trees ($\sim$0.6 kg C m-2) indicating that the extra C channelled belowground was not rapidly respired back to the atmosphere. Instead higher leaching rates and diminished biodegradability of dissolved organic C derived from CO2-enriched litter suggest that some of the extra C entered the soil organic matter pool by sorptive stabilization. A larger portion of the extra C had also left the system through enhanced leaching of dissolved inorganic C in the mineral soil suggesting increased soil acidity and mineral weathering in such stands in a CO2-rich future.