Vegetation turnover and nitrogen feedback drive temperate forest carbon sequestration in response to elevated CO_2. A multi-model analysis.

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Predicting forest carbon (C) sequestration requires understanding the processes leading to rates of biomass C accrual (net primary productivity; NPP) and loss (turnover). In temperate forest ecosystems, experiments and models have shown that feedback via progressive nitrogen limitation (PNL) is a key driver of NPP responses to elevated CO_2. In this analysis we show that while still important, PNL may not be as severe a constraint on NPP as indicated by some studies and that the response of turnover to elevated CO_2 could be as important, especially in the near to medium term.

Seven terrestrial ecosystem and biosphere models that couple C and N cycles with varying assumptions and complexity were used to simulate responses over 300 years to a step change in CO_2 to 550 ppmv. Simulations were run for the evergreen needleleaf Duke forest and the deciduous broadleaf Oak Ridge forest FACE experiments.

Whether or not a model simulated PNL under elevated CO_2 depended on model structure and the timescale of observation. Avoiding PNL depended on mechanisms that reduced ecosystem N losses. The two key assumptions that reduced N losses were whether plant N uptake was based on plant N demand and whether ecosystem N losses (volatisation and leaching) were dependent on the concentration of N in the soil solution.

Assumptions on allocation and turnover resulted in very different responses of turnover to elevated CO_2, which had profound implications for C sequestration. For example, at equilibrium CABLE predicted an increase in vegetation C sequestration despite little increase in NPP, while O-CN predicted much less vegetation C sequestration than would be expected from predicted NPP increases alone. Generally elevated CO_2 favoured a shift in C partitioning towards longer lived wood biomass, which increased vegetation turnover and enhanced C sequestration.

Enhanced wood partitioning was overlaid by increases or decreases in self-thinning depended on whether self-thinning was simply a function of forest structure, or structure and NPP. Self-thinning assumptions altered equilibrium C sequestration and were extremely important for the immediate transient response and near-term prediction of C sequestration.