CO_2 Enhancement of Forest Productivity Constrained by Limited Nitrogen Availability

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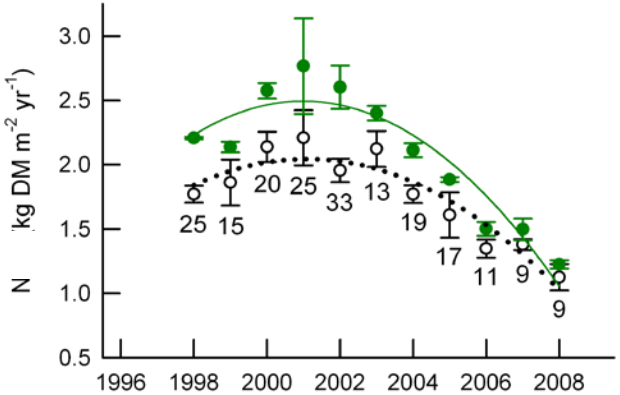
- **Climate models are sensitive to carbon cycle activity of land surface vegetation. With increasing atmospheric CO_2 concentrations, a stimulation of terrestrial productivity has been predicted to slow the rate of CO_2 increase.**
- **Model projections of such stimulations are not certain because of limitations imposed by limiting nutrients.**
- **The potential for nitrogen limitation to reduce the stimulation of net primary productivity (NPP) by elevated atmospheric CO_2 concentrations was assessed in a free-air CO_2 enrichment (FACE) experiment in a deciduous forest stand in Tennessee.**
- **NPP was significantly enhanced by elevated CO_2 during the first 6 years of the experiment, but as NPP subsequently declined, so did the enhancement of NPP in elevated CO_2.**
- **The decline in responsiveness to CO_2 is attributed to a constraint imposed by limited and declining N availability.**
- **These results provide a strong rationale and process understanding for incorporating N limitation and N feedback effects in ecosystem and Earth System models used in coupled carbon cycle–climate change assessments.**



NPP in ambient (black) and elevated (green) CO_2. The percentage difference is shown for each year.

U.S. DEPARTMENT OF ENERGY

OAK RIDGE NATIONAL LABORATORY
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Abstract:

Stimulation of terrestrial plant production by rising CO_2 concentration is projected to reduce the airborne fraction of anthropogenic CO_2 emissions. Coupled climate-carbon cycle models are sensitive to this negative feedback on atmospheric CO_2, but model projections are uncertain because of the expectation that feedbacks through the nitrogen (N) cycle will reduce this so-called CO_2 fertilization effect. We assessed whether N limitation caused a reduced stimulation of net primary productivity (NPP) by elevated atmospheric CO_2 concentration over 11 years in a free-air CO_2 enrichment (FACE) experiment in a deciduous *Liquidambar styraciflua* (sweetgum) forest stand in Tennessee, USA. During the first 6 years of the experiment, NPP was significantly enhanced in forest plots exposed to 550 ppm CO_2 compared to NPP in plots in current ambient CO_2, and this was a consistent and sustained response. However, the enhancement of NPP under elevated CO_2 declined from 24% in 2001-2003 to 9% in 2008. Global analyses that assume a sustained CO_2 fertilization effect are no longer supported by this FACE experiment. N budget analysis supports the premise that N availability was limiting to tree growth and declining over time —an expected consequence of stand development, which was exacerbated by elevated CO_2. Leaf- and stand-level observations provide mechanistic evidence that declining N availability constrained the tree response to elevated CO_2; these observations are consistent with stand-level model projections. This FACE experiment provides strong rationale and process understanding for incorporating N limitation and N feedback effects in ecosystem and global models used in climate change assessments.

Citation:

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