

Interactive comment on “Nitrogen inputs and losses in response to chronic CO₂ exposure in a sub-tropical oak woodland” by B. A. Hungate et al.

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Received and published: 29 April 2014

We appreciate the reviewer's comments and here provide our responses, along with a description of how the comments inspired changes to the manuscript.

1) I like that the authors attempt to control for potential fractionation during fixation, by incorporating the $\delta^{15}\text{N}$ signal of a non-fixer. However, it is not clear to me how the authors arrived at the equation on page 67. Perhaps helpful to the reader would be either a reference or a bit more detail on how the authors arrived at the equation. It is otherwise hard to judge whether the assumptions made are correct.

Authors' Response: We appreciate the suggestion, as we reviewed the equation and C1337

found a typesetting error. The correct equation is:

$$pf = (\delta^{15}\text{NO} - \delta^{15}\text{NG}) / (\delta^{15}\text{NO} - \delta^{15}\text{N Go}),$$

where $\delta^{15}\text{NO}$ is the $\delta^{15}\text{N}$ signature of the oaks, $\delta^{15}\text{NG}$ is the $\delta^{15}\text{N}$ signature of the N₂ fixer from the experimental plot, and $\delta^{15}\text{N Go}$ is the $\delta^{15}\text{N}$ signature of the N₂ fixer prior to tracer $\delta^{15}\text{N}$ application.

We also now cite the source of this mixing model, Shearer and Kohl (1986). Their formulation used the $\delta^{15}\text{N}$ signature of the nodulating plant grown in an N-free medium, thus capturing the $\delta^{15}\text{N}$ signature associated with 100% fixation (and any fractionation). Based on our argument that *G. elliottii* obtains nearly all its N from fixation, using the signature of plants prior to label application is a reasonable proxy. In any case, the difference is small, because the observed value (-2.2‰ is close to 0‰ the atmospheric signature.

Shearer, G., and Kohl, D.H. N₂ fixation in field settings: Estimates based on natural $\delta^{15}\text{N}$ abundance. *Aust. J. Plant Physiol.* 13,699-756, 1986.

2) I would like to know from the authors why they decided on analyzing leaf litter for herbivory instead of live leaves. Is there a potential that the herbivory damage was done after litterfall?

Authors' Response: By analyzing herbivory on leaves captured in litter traps, we assess the effects of herbivory over the entire lifetime of a leaf. Assays of live leaves may underestimate herbivory for this reason. The reviewer is correct that, after leaves senesce, detritivores continue to consume them. However, our sampling collected leaves soon after they senesced and fell from the plant, minimizing the time that detritivores could have eaten them. Furthermore, detritivores are distinct organisms from the herbivores that consume live leaves, and the approaches we used to estimate herbivory assessed the nature of the damage to the leaf tissue, allowing it to be attributed to herbivores.

3) ^{15}N tracer recovery. Is there a possibility that N leaching and movement into the depth in the CO_2 enriched site might have been caused from increased water use efficiency? Less transpiration would increase percolation and the potential of tracers to move with water?

Authors' Response: We agree, this is another possible explanation, and we have added text to acknowledge this, so that the revised explanation reads:

"Increased leaching with elevated CO_2 has been observed, and may be caused by a combination of increased water use efficiency resulting in greater downward water flux through the soil profile (Jackson et al., 1998), along with increased turnover of soil organic matter in response to rising CO_2 ."

4) I would like to suggest that the authors mention in the discussion the major findings in their earlier paper when they talk about ecosystem N accumulation. From my reading of Hungate et al., 2013, N accumulated in the above ground pools at the cost of the belowground pools. This helps to better understand the overall ecosystem response. It seems that the live vegetation is mining for nitrogen (and other nutrients), yet the ^{15}N tracer experiments and the N fixation data suggests otherwise. A nuanced discussion of this will be a benefit for modeling community.

Authors' Response: Excellent suggestion, and we have tried to synthesize the diverse lines of evidence from this experiment that lend insight into CO_2 effects on the N cycle. We have added the following paragraph to the "Summary" section of the paper, and modified the final paragraph slightly, to address this point.

Evidence from this experiment suggests that eleven years of chronic exposure to increased CO_2 concentrations elicited disequilibrium in the N cycle, with increased rates of internal N transformations, no change in N inputs, and increased N losses. Specifically, elevated CO_2 accelerated rates of internal N transformations, including soil N mineralization (Langley et al. 2009; McKinley et al. 2009), which likely contributed to increased N uptake by plants (Hungate et al. 2013). Nitrogen losses also increased,

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at the scale of increased turnover of N through plant tissues, consistent with the increased ^{15}N dilution in plant tissues reported previously, along with no change in net plant N capital (Hungate et al. 2013). Elevated CO_2 also appeared to enhance N losses at the scale of the soil profile: the pattern of lower ^{15}N recovery in plots exhibiting greater downward movement of ^{15}N in the soil profile suggests increased leaching losses. Thus, processes that make nutrients available to plants can also promote nutrient losses. Finally, we found no evidence that elevated CO_2 enhanced N inputs via N_2 fixation. Together, these results paint a picture where more rapid cycling of N with elevated CO_2 is unlikely to be sustained.

These findings provide an empirical point of contrast with model projections in which elevated CO_2 enhances N_2 fixation and reduces leaching (Thornley and Cannell, 2000). This is an important conclusion for modeling responses of future C uptake by the biosphere, given the strong influence of N cycling and N accumulation on the biosphere's capacity to assimilate and store C (Thornton et al., 2007; Churkina et al., 2009; Arnett et al., 2010; Zaehle and Dalmonech, 2011).

Interactive comment on Biogeosciences Discuss., 11, 61, 2014.

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