

Author response to

Interactive comment on “Controls of terrestrial ecosystem nitrogen loss on simulated productivity responses to elevated CO₂” by Johannes Meyerholt and Sönke Zaehle

Anonymous Referee #3

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We are very grateful to Anonymous Referee #3 for the positive comments on our manuscript and constructive suggestions to further improve its quality.

However, I have some questions about the paper. First, while the N loss differences of the experiments are well explained and show with nice graphics, the C accumulation is more difficult to understand. Especially in the global simulation, the three different routines show quite different N accumulation (fig 5), while the C accumulation seems to be insensitive to the N accumulation. This is the same when the C:N ratio is constant rather than flexible. The authors state that ‘the exact mechanisms are difficult to discern’, but that leaves me puzzled.. Did the authors look into more differences besides the C:N ratio’s? How does this result link to the earlier ‘experiments’ in the paper? Where is most of the N that is accumulated stored and how does this relate to the C accumulation?

This is indeed a crucial point in this MS. While further investigating our results for better explanation of the observed phenomenon, we found that Figure 5 erroneously displayed the N and C accumulation for 1850-2005 and not for 1850-2100 as claimed. Correcting for this (see revised Figure 5 below) affects the absolute magnitudes of accumulation, but does not change the qualitative observation since differences in global C accumulation are still rather insensitive to differences in N accumulation (especially in the boreal zone), and this phenomenon is not satisfyingly explained by stoichiometric flexibility (Fig. 5 flexible stoich.; Fig. A1 fixed stoich.). As Referee #3 suspects, the underlying reason for the lack of C accumulation response is the partitioning of N accumulation between vegetation and soils. While the initial response to added N would be increased production and vegetation N storage, at the time scale of the analysis N predominantly ends up in soil organic matter because of the longer time scale of soil carbon turnover compared to the relatively quick turnover of vegetation tissue pools.

Figure 5:

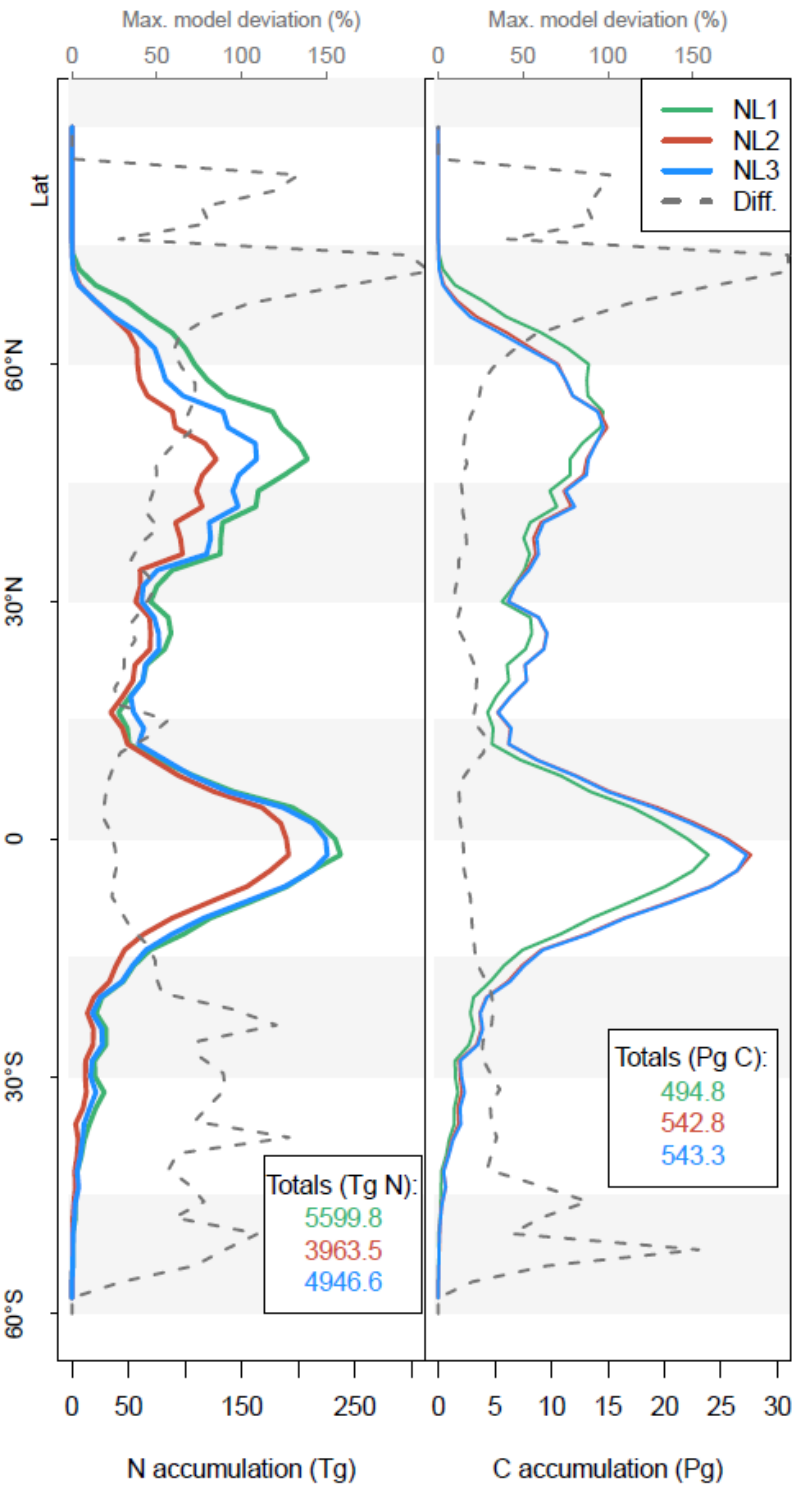
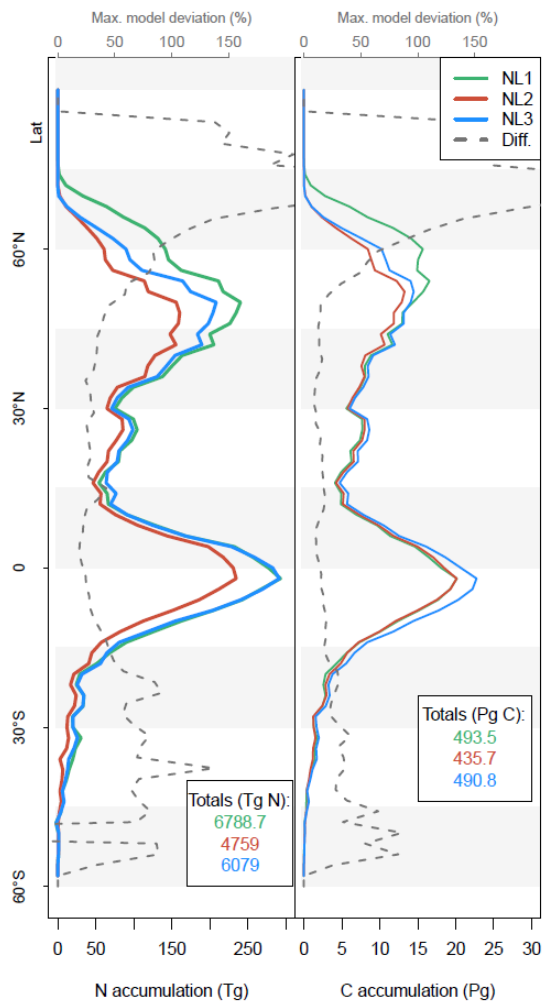


Figure A1:

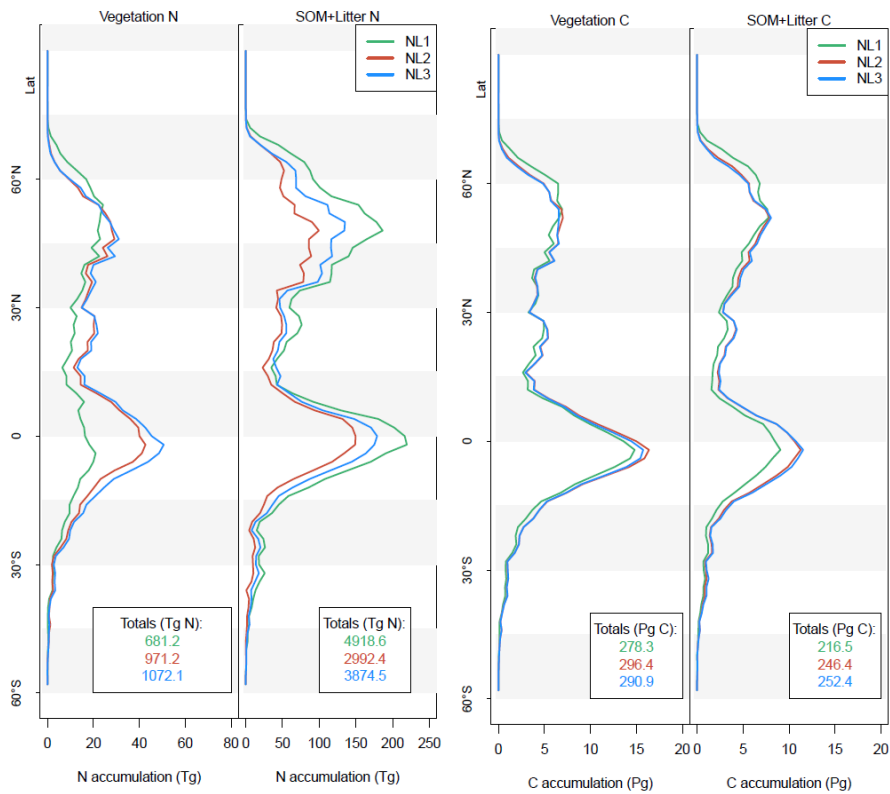


The NL1 model stores relatively more N in the soil, because the soil inorganic pool is more depleted of N in comparison with NL2/3, therefore N uptake and the vegetation N fraction are lower. NL2/3 can store relatively more N in high C:N vegetation, therefore higher N accumulation in NL1 does not result in higher total ecosystem C accumulation, and the model differences in N accumulation are rather suppressed in total C accumulation.

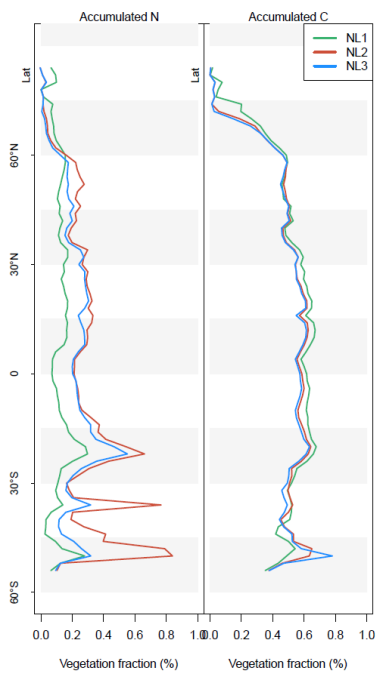
The detailed mechanics of this are best illustrated using the fixed stoichiometry version of O-CN, since ecosystem C:N only changes through changes in allocation to pools with different C:N ratios, whereas the flexible stoichiometry version also involves shifts in pool C:N ratios, which makes the explanation more complex and less tractable. Full analysis would also involve regional differences from climate and PFT specifics. However, the flexible stoich. version was found to give more realistic results when predicting ecosystem responses to perturbation (Meyerholt & Zaehle 2015, New Phyt).

We will revise the results and discussion sections with respect to the global analysis to give better explanation of the observed phenomena involving the points above, while keeping the MS reasonably easy to follow and relevant for a broad audience.

Partitioning of N (left) and C (right) accumulation:



Vegetation fraction of accumulated N (left) and C (right)



P1, line 37: the authors refer to figure 1, but this is confusing in this part of the paper.

Figure 1 illustrates model approaches to represent ecosystem-level N loss, whereas the cited text more refers to reality. We will remove the reference to Figure 1.

P4-5 & figure 1: the N loss formulations are well explained in words, but figure 1 is difficult to read on its own. Also, would it be possible to add N uptake somewhere in the methods? Since later in the paper we look at both N loss and C gain, it would be good to know the general N update scheme of O-CN, and how the Nloss routine of NL3 is altering the overall Nuptake routine in that formulation?

Following the Referee's advice, we will improve Figure 1 and its caption to be more self-explanatory, and additionally include N uptake by vegetation, as well as litterfall from vegetation to soil organic matter.

Zaehle & Friend (2010) offers a supplementary document that features a detailed description of the O-CN N uptake algorithm. The direct link between N loss and N uptake is soil mineral N availability. For clarity, we will add the O-CN description of N uptake to this MS.

P4, line 17: is leaching of NH₄⁺ equal to leaching of NO₃⁻?

For NL1, leaching occurred in proportion to drainage in equal proportions for NH₄⁺ and NO₃⁻. However, a fraction of NH₄⁺ is assumed to be sorbed to clay minerals and thus prevented from leaching and biogeochemical processing. For NL2 and NL3, we simulated one generic inorganic N species to conform with the imitated N loss algorithms.

P6, line 27: just to be sure, in the global model run you use fertilizer application, but no N-deposition? What is the rationale?

The global simulations feature constant fertilizer application and N deposition. Thereby, N deposition is not zero, but we avoided it being a perturbing factor over time.

P8, paragraph 3.1.3: This paragraph could use more explanation. Especially figure 2j is still unclear to me, as an example: why, with eCO₂, is the leaching loss so much reduced? Is this because N uptake is mainly inorganic N and will happen before leaching? Why is the gaseous loss in NL2 so much reduced?

eCO₂ drives down soil N concentrations, therefore it drives down leaching. Gas losses in NL2 are increased, not decreased. Gas loss in NL3 is decreased because there is much less excess N. Increased N uptake under eCO₂ decreases soil N concentrations, therefore reducing losses. The exception, as explained in the text, is NL2 gas loss, where increased soil C:N leads to increased N mineralization, which in this case mainly determines gaseous loss.

P10. Line 13: relative to 1850 values (285 ppm)?

Certainly, but also relative to 350 ppm (1988), which is the "control state" shown in Figure 4a,b,c. We will formulate this more concisely.

P10, line 34: The 1 sentence for figure 4g is quite limited. Could this be extended? It is relative to control CO₂ N loss? And how does it stand for N limitation?

We will point out stronger in the caption that this picture refers to the 350-550 ppm (1988-2052) response, and will dedicate additional main text to the observation that N loss responses differ most between models when soil inorganic N availability is low, i.e. high N limitation.