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Reply on RC2

Rainer Brumme et al.

Author comment on "Cycling and retention of nitrogen in European beech (*Fagus sylvatica* L.) ecosystems under elevated fructification frequency" by Rainer Brumme et al., Biogeosciences Discuss., https://doi.org/10.5194/bg-2021-11-AC2, 2021

RC2: I find the submission by Brumme et al. to be an interesting study, well-written and relatively thorough with valuable contribution to the literature on N cycling in beech forests under increased frequency of masts. I recommend the paper to be accepted for publication Biogeoscience after the identified conceptual and technical issues are carefully addressed.

Reply: Thank You for the positive recognition.

General comments

RC2: Although the study described the importance of litterfall on N cycling (L47-49), the specific effect of fructification frequency was only briefly mentioned (L72-75), and I recommend explaining it in more detail. In the introduction, more emphasis should be given on the reason behind the increased fructification frequency and its implication for N cycling in beech forest ecosystems with better connection to the research question to be answered, and this should be started in the abstract. In the results, showing the temporal pattern of mast frequency (result in thus those from literature) and exploring its relationships with some factors such as N deposition pattern would be interesting.

Reply: We agree that including an exploring analysis of the relationship between fructification and other factors such as N deposition, temperature, precipitation etc. would add another interesting perspective to our study. We therefore explained the effects of fructification in more detail and the implications for the N cycling in the introduction and the abstract. However we restricted the exploring analysis of such relationship for three main reasons:

First, we felt that the quantification of the effect strength and sensitivity of nitrogen deposition on the frequency of fructification have to be the subject of a separate study, as many variable would have to be included in the statistical approach. Effect of N on forest ecosystems in terms of soil processes, vegetation changes and growth are often the result of a cumulative N input (Schmitz et al. 2019; https://doi.org/10.1016/j.envpol.2018.09.101). Accordingly, the analysis of the correlation between N deposition and fructification is not straightforward. This is further complicated by the fact that nitrogen deposition is subject to enormous temporal dynamics (increases and decreases) in the period between 1900 and 2020 (Schmitz et al. 2019; https://doi.org/10.1016/j.envpol.2018.09.101). On the other hand, "only" litterfall measurements from the last 20-30 years are available from the study sites of intensive environmental monitoring.

Second, the main factors from other studies that influences the frequency of fructification were already described in the introduction and the associated references are given.

Third, we felt that the addition implementation (in addition to the nitrogen balance, the litterfall measurements and the ^{15}N experiment) of additional data and statistical methods in this manuscript might make the text hard to understand.

Thus, while we think an analysis of the temporal pattern of mast frequency and exploring its relationships with N deposition is clearly worthwhile, we would prefer not to make it part of this manuscript.

RC2: The 15N-labelled leaf litter exchange experiment should be explained in depth, and the calculation of the 15N-lablled litter N recovery in soil needs to be shown. It was not explained why the retention of 15N labelled litter N in plant (aboveground and belowground biomass) was not quantified. Were roots present in the soil samples? If so, the 15N recovery in the root should be presented.

Reply: Roots weren't analyzed, accordingly, results on ^{15}N recovery in roots cannot be presented. The calculation of the ^{15}N uptake by plants seems somewhat problematic from our point of view, since the area of the labelled 15N plots were too small. We have explained the methodological limitations in detail in the subsection 2.1.1 as follows:

"Nitrogen consist of two stable atoms, ^{14}N (99,634 %) and ^{15}N (0,366 %). During N transformation processes, the ratio $^{14}N/^{15}N$ may change due to isotopic discrimination. For an accurate estimation of the recovery of added ^{15}N in labelling experiments, $^{15}N_{na}$ is needed. The $^{15}N_{na}$ of the samples of the sites ranged from 0.365 % in the L layer to 0.368 % in 30 – 40 cm soil. The recovery of the added ^{15}N in a labelling experiment $^{15}N_{ex}$ (%) is calculated by subtracting $^{15}N_{na}$ from the measured enrichment of $^{15}N_S$ in the samples ($^{15}N_{ex} = {}^{15}N_S - {}^{15}N_{na}$ (%))."

RC2: It would have been more interesting to see how retention of 15N-labelled litter N differs from that of deposited N, which can be explained by presenting and/o discussing the results in this study with other 15N-labelling studies.

Reply: We took up your suggestion and we are now discussing the N retention in more detail by comparing the ^{15}N retention of labelled ammonium and nitrate with the retention of nitrogen in labelled leaf litter:

"Studies with ^{15}N labelled N deposition provide a useful insight into the initial retention processes of N deposition in ecosystems. Irrigation studies with ^{15}N labelled ammonium on undisturbed soil cores (30 cm length) from the SOB site in the field revealed a retention of 20 % in the organic layer and 26 % in the mineral soil over a period of 12 months (Brumme et al., 2009a). Irrigation studies of undisturbed cores from different soil depths of the SOB soil revealed a retention of 54 % in the organic layer and of 34 % in each of the mineral soil layers (0 – 10 cm, 10 – 20 cm depth) after a two-month irrigation with $^{15}NH_4$ at 8°C in the laboratory. Low nitrification rates (heterotrophic) at the SOB site (Bauhus et al., 1996; Brumme et al., 2009b) are responsible for the adsorption of ^{15}N labelled ammonium and contributed 3 % to the N retention of 54 % in the organic layer, 24 % of 34 % in 0 – 10 cm, and 30 % of 34 % in 10 – 20 cm soil depth. A high adsorption capacity for ammonium extended the residence time and the potential for transformation processes due to microbial immobilization and plant uptake in acidic soils and may increase the transformation of deposited ammonium in organic compounds. Nitrate was only marginally retained in the soil layers of the SOB site (< 3 %) as revealed by a comparable study with ^{15}N labelled nitrate (Brumme et al., 2009a). The less acid GW site revealed a similar retention of 45 % of ^{15}N labelled ammonium in 30 cm long soil cores as compared to the acid SOB site (46 % recovery). However, the adsorption of ammonium at the GW site was negligible due to high autotrophic nitrification. Most of the ^{15}N retained in the GW cores was transformed to organic compounds in the mineral soil. The high N retention in the mineral soil of the less acid GW site seems self-evident, as microbial biomass was two times higher at the GW compared to the SOB site, especially in the mineral soil, where it was five times higher (Brumme et al., 2009c). Ammonium retention was closely related to the microbial biomass at the SOB and GW soils indicating its dominant control on ammonium retention in forest soils in the short-term. Within the NITREX project, where the fate of doubled ^{15}N labelled $^{15}NH_4{}^{15}NO_3$ in throughfall was studied over a 12 month period, the retention was twice as high in the organic layer as in the mineral soil of a podzolic soil in Denmark (26 % versus 12 % recovery, Tietema et al., 1998). The uptake of ^{15}N by ground vegetation and trees amounted to 45 % of the applied ^{15}N showing that a large part of the deposited N was introduced into the internal N cycle. Most of them usually return back to the soil with litterfall in the following year and will be a subject of retention in the soil by mast products, as was observed in the ^{15}N labelled leaf litter exchange experiment. Thus, the initial microbial retention of N is one pathway into labile organic N compounds while the repeated plant uptake and litterfall of N is probably the preferential pathway for the transformation in more stable N compounds in soils."

Specific comments

RC2: L19-20: This part misses a logical connection between changes in fructification and its implication for N cycling that needs investigation.

Reply: Thanks for the comment. We extended the sentence: "But the processes involved are not fully understood, notably the effect of fructification on N fluxes".

RC2: L23-25: retention of litter N should come later when discussing N retention.

Reply: Thank you for the suggestion. We shifted the sentence accordingly.

RC2: L35: Consider adding a concluding statement about the important implication of this study.

Reply: We added the following sentence:

"These results have major implications for our understanding of the C and N cycling and N retention in forest ecosystems. Especially the role of mast products for N retention seems to need more research in the future."

RC2: L38-39: the effect of N deposition is presented as things of the past in this paragraph. Better to discuss it as a general issue that has been observed in past, still happening, and is expected to happen in the future using the right tense.

Reply: We agree. We changed the tense and added the sentence:

"Despite reduced sulphur emission since the beginning of the 1980s (Engardt et al., 2017) N deposition still exceeds the N demand for forest growth in unmanaged and most managed forests (Meesenburg et al., 2016; Fleck et al., 2019)."

RC2: L45-46: fragmented sentence; not well connected to the preceding one.

Reply: We agree and moved the sentence upwards.

RC2: L50-51: provide (a) reference (s).

Reply: We inserted a Reference at the end of the sentence:

“There is increasing evidence that the frequency of fructification in beech forests has increased when compared to that in the past decades (Reil et al., 2015).”

Reil, D., Imholt, C., Eccard, J. A., and Jacob, J.: Beech Fructification and Bank Vole Population Dynamics - Combined Analyses of Promoters of Human Puumala Virus Infections in Germany, PLOS ONE, 10, e0134124, 10.1371/journal.pone.0134124, 2015.

RC2: L71-72: Is it the effect on the amount of fruit produced?

Reply: This is only a hypothesis: We changed the sentence in the introduction to : “may affect the fruit production”

RC2: L85-86: Although, the sites used in this study are Level II plots, results from Level I plots from previous studies were also discussed in the result (e.g., line 250). Thus, I suggest giving brief introduction of the Level I and II plots in Europe here.

Reply: Thanks for the suggestion. We provided a brief introduction in this section.

“The study sites are Level II plots of the ICP Forests Intensive Monitoring Programme established under the UNECE Convention on Long-Range Transboundary Air Pollution (De Vries et al., 2003a). The Level II Intensive Forest Monitoring is carried out at about 800 selected forest ecosystems representative for the major European forest types with the aim to discover cause-effect relationships between stress factors such as air pollution and forest ecosystem responses. The Level I monitoring is based on a systematic 16 x 16 km grid and covers around 6000 plots, where annual crown condition assessments are carried out. So far, two forest soil condition surveys were conducted from 1985 to 1996 and 2004 to 2008, respectively (Cools and de Vos 2011).”

RC2: L99: Are the slope (precipitation) at the experimental sites small enough to exclude N losses from the plot through surface runoff in the N balance?

Reply: Ok, this point should be discussed. We entered in Table 1 the slope gradient for the seven study sites. Additionally we inserted the following sentence in the Text:

“The slope of the sites ranges from almost flat to a maximum inclination of 7.4°”. ….

“With regard to the maximum slope inclination and the estimated infiltration capacities, we assumed that N losses from the plots through surface runoff is of subordinate importance. Due to permanently formed macropores and low bulk density providing complete infiltration of precipitation surface runoff is generally rare in forest ecosystems (Jankiewicz et al. 2005; Neary et al. 2009).”

Jankiewicz, P., Neumann, J., Duijnisveld, W., Wessolek, G., Wycisk, P., and Hennings, V.: Abflusshöhe - Sickerwasserrate - Grundwasserneubildung - Drei Themen im Hydrologischen Atlas von Deutschland, Hydrologie und Wasserbewirtschaftung, 49, 2-13, 2005.

Neary, D. G., Ice, G. G., Jackson, C. R.: Linkages between forest soils and water quality and quantity. For. Ecol. Manage., 258, 2269–228, https://doi.org/10.1016/j.foreco.2009.05.027, 2009.

RC2: L133-142: Why is it called ‘net’ gaseous exchange and how was it estimated (L133)? Have you measured gaseous N uptake too? The N flux data should be moved to the result section.

Reply: NO can be taken up by soils. We are using chambers and the enrichment of gases in the chamber represents the net gas exchange. The data presented are published and only used for the calculation of soil N change by equation 1, thus it would be better in our opinion not to move it to the result section. We added the note:

“measured with the closed chamber technic”

RC2: L155-159: I am less supportive of this part. Where were those 300 seeds obtained from? Since the litterfall were collected from 1998-2008 for the three Bavarian sites, how the number of years without mast and mast year were presented as 22 and 11, respectively?

Reply: We agree. The wording of this section was misleading. We have rearranged the section and extended the sentence to make it more clearly as follows:

“For the Hessian and Lower Saxonian study sites we calculated the number of seeds from the measured dry weight (g DW m^2 $year^{-1}$) of annual seed litterfall flux by assuming a one single seed weight of 0.22 g (cv = 13%). This weight was determined by using a subsample of 300 seed from these sites. The calculated value showed a good agreement with other studies (Kaliniewicz et al., 2015; Bezdeckova and Matejka 2015). For Bavarian sites the seed mass was calculated by using a mean ratio between seeds and the sum of seeds + seed cupules of 0.14 for years without mast (n = 22), and a ratio of 0.37 (n = 11) for mast years. These ratios were derived from Rhineland-Palatinate (NHN, KHB, and NHQ sites) where the mass of seeds and cupules were separately measured between 1995 and 2005.”

RC2: L171-172: It is not clear why ‘the soil columns were cut into slices’. Or are you saying the soil cores were divided into layers?

Reply: We changed “cut into slices” into “divided into layers”

RC2: L175: This sentence about the 15N labelling experiment should come earlier as part of the above paragraph. I suggest revising this whole section 2.2 with more orderly description of 1) experimental design/establishment and then discuss, 2) sampling, and 3) Laboratory analyses.

Reply: We agree and rearranged the section 2.2.1

RC2: L182-183: Does that mean your data did not fulfill the normal distribution? If that is the case, have you tried some sort of data transformation?

Reply: The main reason for our approach to use r_{Spear} is the small sample size. We have only seven study sites and thus a small sample size. For this sample size, normality tests have little power to reject the null hypothesis. Therefore, small samples most often pass normality test (Ghasemi & Zahediasl 2012). A robust alternative is to calculate correlation coefficients according to Spearmann (r_{Spear}) (Rhodes et al., 2009; Sachs 1999), as we did in our study.

Ghasemi A, Zahediasl S. Normality Tests for Statistical Analysis: A Guide for Non-Statisticians. Int J Endocrinol Metab. 2012;10(2):486-9. doi: 10.5812/ijem.3505

Rhodes, J. R., McAlpine, C. A., Zuur, A. F., Smith, G. M., and Ieno, E. N.: GLMM Applied on the Spatial Distribution of Koalas in a Fragmented Landscape, in: Mixed effects models and extensions in ecology with R, edited by: Zuur, A. F., Ieno, E. N., Walker, N. J., Sveliev, A. A., and Smith, G. M., Statistics for Biology and Health, Springer, 469-492, 2009.

Sachs, L., 1999. Angewandte Statistik. 9. Aufl. Springer Verlag, Berlin. 881pp.

RC2: L192: Should not it be 'foliar nutrient'? The term 'N cycling' obviously represents a far more complex interaction processes and pools that are not presented under this section.

Reply: Thank you for your suggestion. We used "foliar nutrients" and "litterfall" instead of N cycling.

RC2: L221-230: The subtitle should reflect the data presented, not the method. What does the '15N excess' (L222) represent? How did you calculate it? The 15N excess, to my understanding, is the changes in 15N content of soil pools following the addition of 15 labelled litter N. I also wonder how the 15N recovery (Table 5) was calculated? The 15N excess (‰) and 15N recovery (%) should clearly and separately presented. This should be explained in section 2.2.1.

Reply: We agree. We changed the subtitle 3.2 to "Recovery of ^{15}N labelled leaf litter nitrogen in the soil". The description of the ^{15}N terms was incomplete, we extended the description in section 2.2.1 as follows:

"Nitrogen consist of two stable atoms, ^{14}N (99,634 %) and ^{15}N (0,366 %). During N transformation processes, the ratio $^{14}N/^{15}N$ may change due to isotopic discrimination. For an accurate estimation of the recovery of added ^{15}N in labelling experiments, $^{15}N_{na}$ is needed. The $^{15}N_{na}$ of the samples of the sites ranged from 0.365 % in the L layer to 0.368 % in 30 – 40 cm soil. The recovery of the added ^{15}N in a labelling experiment $^{15}N_{ex}$ (%) is calculated by subtracting $^{15}N_{na}$ from the measured enrichment of $^{15}N_S$ in the samples ($^{15}N_{ex} = {}^{15}N_S - {}^{15}N_{na}$ (%))."

RC2: L252: Which time reference is being referred to as 'in the past' since all the discussion so far indicated that mast frequencies has been increased.

Reply: We changed "in the past" by "before the 1960s".

RC2: Line259-260: Can you provide the temporal changes in mast production for the European beech forests? This will be useful to explore possible correlation between the temporal changes in mast frequencies and some possible global change factors (e.g., N deposition, as mentioned in the next paragraph).

Reply:

Thus, while we think an analysis of the temporal pattern of mast frequency and exploring its relationships with N deposition is clearly worthwhile, we would prefer not to make it part of this manuscript. A detailed description of our motivations we have given in the section "General comments ".

RC2: L191-294: In this part, texts about dry mass production, need to be either integrated into the rest of the discussion about litter N retention or be moved to section 4.1.

Reply: We agree and included the following text in section 4.1:

The annual amount of leaf litterfall of 2.76 to 3.88 Mg ha^{-1} (Table 3) was in the range of 36 old-growth forest stands of Fagus sylvatica across a broad gradient of soil fertility covering nine mesozoic and kaenozoic parent material types (three limestones, two sandstones, two clay stones, one sand and one loess substrate) (Meier et al., 2005). Despite large differences in soil fertility, the amount of leaf litterfall (2.95 to 3.33 Mg ha^{-1})

showed no significantly differences between the parent material types. Leaf litterfall in mast years did not differ from that in non-mast years (Tab. 3), as observed by Müller-Haubold et al. (2015). However, there is a significant correlation between total and leaf litter fall between the different sites (Tab. 6, Fig. 5). Corresponding correlations are known from the literature (Meentemeyer et al., 1982)". Note: Table 6 was former Table 7.

RC2: L305: What is the reason for humus degradation at the site? The negative ΔS could be due to the high N leaching at the site (Table 6). The site also has low retention capacity for new N input (litter N). Explain the reason for the low N retention at this site and its implication.

Reply: The reason behind the degradation of humus is not clear but it indicates a shift of mull type humus soils to mor type humus soils driven by soil acidification. Probably the formation of humus is disturbed by aluminum. However, the negative budget is too small and probably not significant which is why we only cited Ulrich (1992), for more information.

RC2: L314-315: This sentence about N deposition effect on N retention comes between two sentences that explains effects of P availability.

Reply: We agree and revised the section.

RC2: L340-341: 'When comparing historic data with results from litterfall observations across Europe since the 1990s an increase in fructification frequency seems likely'. Is it not certain?

Reply: Absolutely right our wording is not really accurate. We replaced "seems likely" with "is obvious".

RC2: L341-343: Focus on N, which is the main topic of this study, not carbon and other undefined 'nutrient'.

Reply: Ok we deleted 'nutrient'. However, in our opinion the C and N cycles are strongly coupled by several loops. Accordingly, C should also be considered

RC2: L349-350: this confounding effect has not been explained in the discussion. In the context of the study sites, what is the main cause of the soil acidification? Are the study forests considered as N-saturated?

Reply: You are right, we added the discussion about the effects of soil acidification on N retention (s. General comments)

Tables and Figures

RC2: Is it possible to reduce the number of tables (optional suggestion)? Can some of the data in the tables be presented in Figure?

Reply: Good proposal. We have changed Table 5 into a more readable figure.

RC2: Data should be presented with some measure of uncertainties; simple calculated SE would be nice.

Reply: We agree and inserted as indication of uncertainty and variation the coefficient of Variation (cv) after the given mean values in the text. We add a short explanation in the chapter 2.3 statistical analyses: "In addition, the coefficient of variation (cv %) was estimated as ratio of standard deviation and arithmetic mean."

RC2: Table 2: Present C, N, and P content for soil organic layer as you did for mineral soil? I would also be more logical to present the nutrient content before their stoichiometry.

Reply: We agree and have changed the order.

RC2: Table 6: values in the last column are confusing as they show fraction of fraction. Moreover, the values (which I assume to show 15N recovery in Organic layer divided by total recovery) do not much that when calculated using the 15N recovery data in Table 5 for most sites (e.g., BBR).

Reply: Thanks for the suggestion. We deleted the last column of Table 6 as we are discussing the amount of recovery in the organic layer, which is available in Fig. 2 (Note: the Fig. 2 referred here has been newly created from the former table 5 following your suggestion to reduce the number of tables).

RC2: Fig 5. The terms 'internal' and 'external' N cycle, as described here, is confusing, if not wrong. Commonly, internal N cycle in an ecosystem refers to N cycle between microbes, vegetation, and soil. The components in the schematic diagram and the direction of the arrows connecting them does not convey clear message. For example, all the DM and N in different litter type are not connected to the total litterfall. How are soil N pool, N deposition and N uptake are connected to other components in the diagram?

Reply: You are absolutely right, the description is misleading. The diagram shows only the detected effects of litterfall and soil properties on the N retention. We changed the first sentence in: „Schematic view of the detected effects of N uptake, total litterfall, TLF, leaf litterfall, LLF, and soil properties of the organic layer, OL and the mineral soil, MS, on the N retention by tree increment, INCR, the soil N pool change, ΔNS, the leaf 15N recovery, 15N RECOV, and on the seepage N output. "

RC2: Few technical corrections /writing

RC2: L26: While there is no fundamental rules on this issue, generally, numbers from zero through to ten are written as words, and larger numbers are written as numerals. Being consistent is more important.

Reply: Thank you: We follow the recommendation with one exception. When the numbers have units we used numerals.

RC2: L25: Comma should be added after 'In these forests'. The proper use of comma needs to be carefully checked in the whole text (e.g., L78, L101, L147, L148, L168… and a lot more)

Reply: We have checked the comma placement again.

RC2: L32: Change 'about' to 'only about'

Reply: We changed it.

RC2: L75: use 'N' instead of 'nitrogen' as you indicated it in the first sentence in the introduction. Check other places (e.g., 279)

Reply: We agree and used N instead of nitrogen. Other places were also examined.

RC2: L80: change 'soil specific' to soil-specific'

Reply: We changed it.

RC2: L98: delete the first 'deposition' and 'from the atmosphere'

Reply: We deleted it.

RC2: L108: It should be written as 'the BBR'. Check other places.

Reply: We have changed it and checked and adjusted the other places in the text.

RC2: L27: write 'site specific' as 'site-specific'

Reply: We changed it.

RC2: L29: It should be 'inventories'.

Reply: Yes! Thank you

RC2: L154: 'sites'. There was only one site at Rhineland-Palatinatehere (L87-88).

Reply: You are absolutely right, we added in the section "2.1 Study sites" the following sentence: "…and three sites in Rhineland-Palatinate, one at Neuhäusel (NHB, 704) and two other sites (Kirchheimbolanden, KHB, and Neuhäusel Quarz, NHQ,). KHB and NHQ were evaluated with respect to the litterfall fractions in order to disentangle the different properties of seeds and seed cupules (Table 4)."

RC2: L161: Write 'light exposed' as light-exposed'

Reply: We changed it.

RC2: L167-168: while the purpose of the PVC is obviously to create the plots, this is not clearly stated.

Reply: We agree and added "to create the plots"

RC2: L172: Change 'grinded' to 'ground'

Reply: We changed it.

RC2: L176: Change 'Numbers' to 'The number'

Reply: We changed it.

RC2: L181: It should be 'Statistical analysis'

Reply: We agree and have changed it.

RC2: L198: I think this section (2.4) is misplaced here. Should not it be at the end (after the main text)?

Reply: We agree and placed the section 2.4 (L188) at the end of the main text.

RC2: L199: Change 'each' to 'every'

Reply: We changed it.

RC2: L202: change 'amount' to 'the amount'

Reply: We changed it.

RC2: L203: Change ‘Mean changes’ to ‘The mean changes’

Reply: We changed it.

RC2: L232: Change ‘measured’ to ‘study’

Reply: We changed it.

RC2: L235: Change ‘were’ to ‘was’ and ‘Mean’ to ‘The mean’

Reply: We changed it.

RC2: L272: Change ‘nutrient rich’ to ‘nutrient-rich’

Reply: We changed it.

RC2: L295: Scientific names should be in italicized. Same issue in Table 1

Reply: we changed the scientific names in the text and in Table 1

RC2: L197: Change ‘2-years’ to ‘2-year’

Reply: We changed it.

RC2: L309: Change ‘high’ to ‘the high’

Reply: We changed it.

RC2: L325: Change ‘base rich’ to ‘base-rich’

Reply: We changed it.

RC2: L334: ‘that’ is better’ instead of ‘which’

Reply: We agree and changed it.

RC2: L347: delete the first ‘N’

Reply: We deleted “N”

RC2: L350: delete ‘still’

Reply: We deleted “still”

Reference

RC2: The referencing style needs to be carefully checked. Few examples where correction is needed are:

Reply: Thank you for pointing this out. There was really a lot of work to do!

RC2: DOI should be provided in consistent style (e.g., including URL.)

Reply: We provided all DOI’s in consistent style including the URL.

RC2: L433: Delete the date and month

Reply: We deleted the date and month

RC2: L493: the journal abbreviation is not correct

Reply: We changed it to “Glob. Biogeochem. Cycles“

Figures and Tables

RC2: Texts fonts (e.g., types) in the figure are different from that in the main text

Reply: We have now chosen the same font for the illustrations as for the text.

RC2: Figure pane labels are better be placed at the top left corner of each pane.

Reply: We have placed the figure pane labels for each figure at the top left corner

RC2: Fig 2 and 3: The year on the y-axis is not necessary.

Reply: According to our opinion the given recovery on the y-axis of Fig. 2 and 3 relates to a period of 5.5 years. Therefore, we think that it is not unimportant to specify the exact unit.

RC2: Fig 4: Capitalization of words in the y-axis label

Reply: We have changed the capitalization.