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Interactive comment on “The soil N cycle: new insights and key challenges” by J. W. van Groenigen et al.

J. W. van Groenigen et al.

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Received and published: 15 February 2015

We would like to thank the reviewer for the feedback on our manuscript, which we felt really helped improve the coherence and structure. Below, we respond to all points raised by the reviewers. In order to ensure a complete rebuttal, we have not deleted any text from the original review. Per issue raised, we have clearly indicated the comments of the reviewer as well as our response.

Reviewer #3: This MS is intended as a review of the principal key insights which have been gained in relation to soil N cycling over the past decade or so (i.e. 2003-), and to posit some key challenges as perceived by the authors for future research in the area. It is stated that it is not intended to be a comprehensive literature review of N

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cycling phenomena, nor to deal with coupling of the N cycle to other elements to any extent. As such, there is a qualified personal perspective to the topics and challenges, and this is admissible given this has been openly declared. However, there needs to be some guarding against this becoming – or being intended or used – as a manifesto for any form of prioritisation – these are after all the opinions of the authors per se and have not been through a large scale ratification process (some online debate via the SOIL portal notwithstanding). Thus I think some more explicit caveat statement in relation to this is needed. Taking it on these terms, (and thus that it should not include my personal opinions !), the MS is I think successful, very well written, and generally engaging. Areas I am familiar with are accurate, and I felt informed about topics less well known to me.

Response: Thank you!

Reviewer #3: I note a few topic gaps which struck me, but as stated above, this is not my paper, thus I note them merely for the authors to consider: Section 2.1 : A notable omission with respect to “F-BNF” in this section is that there is no consideration of N-fixation via soil surface biological assemblages, notably cyptogamic crusts. Amounts of N input via this route, on an ecological scale in natural systems are significant and ought to be considered. Also missing is any mention of free-living fixation in agri-systems, e.g. associative rhizosphere fixation – what are current perspectives on this, and knowledge/opportunity gaps?

Response: We adjusted the section on N₂ fixation as suggested by this reviewer, reviewer #2 and Dr Pöschl. We refer to the rebuttal to the latter two for details.

Reviewer #3: Section 2.4 : No mention of denitrification rates, extent or patchiness, in pastures and especially GRAZED pastures, which is also a notable omission given their global significance and the challenges arising with these more complex and heterogeneous systems.

Response: We have added a sentence to make the point that animal grazing and ex-

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cretion can create hotspots of N deposition, mineralization, nitrification, denitrification and N₂O flux (de Klein et al. 2014).

Reviewer #3: Section 3.2 : No mention of ‘priming effects’ here, which is a highly pertinent concept here – it does not just apply to C.

Response: Cheng et al. (Cheng, W.X., Parton, W.J., Gonzalez-Meler, M.A., Phillips, R., Asao, S., McNickle, G.G., Brzostek, E., Jastrow, J.D., 2014. Synthesis and modeling perspectives of rhizosphere priming. *New Phytologist* 201, 31-44.) define ‘priming’ as “the stimulation or suppression of soil organic matter (SOM) decomposition by live roots and associated rhizosphere organisms when compared to SOM decomposition from rootless soils under the same environmental conditions.” Although the entire text in our manuscript is focused on this concept of ‘priming’, there was indeed no explicit mention to the term itself. We have added it in the revised text: “Rhizodeposition may enhance microbial growth and activity and stimulates production of microbial exoenzymes that mine for more complex soil organic N compounds, a process often referred to as ‘priming’”.

Reviewer #3: Section 3.3 : Common mycorrhizal networks not mentioned, and a phenomenon the significance of which still not really sorted out, especially for N.

Response: We have not considered the aspect of common mycorrhizal networks because we basically agree with reviewer #3: too little work has been undertaken on the impact of common mycorrhizal networks on soil N cycling (see Simard et al., 2012, Mycorrhizal networks: Mechanisms, ecology and modeling; N cycling is only briefly and indirectly touched upon in this review work). It would take away the attention of the main message of this paragraph, which has a main focus on the impact of mycorrhizal type on soil N cycling.

Reviewer #3: The abstract contains details of content but no summary of the key recommendations. These are also then not summarised in the concluding section either, so remain dispersed throughout the text. Thus at least there needs to be synthetic

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section at the end which summarises the key points.

Response: We agree and have addressed this comment by incorporation a blueprint for further action in the conclusion.

Reviewer #3: There are too many repetitive and platitudinous closing sentences for each section apropos 'more work is need on this or that which will lead to news insights into such and such.' This has likely arisen as a result of each section being dealt with more or less independently, so some smoothing and polishing would make the paper more connected and coherent.

Response: We agree with the reviewer, and have changed the ending of all sections related to the 8 key challenges. Platitudinous statements have been removed or rewritten, and some of the closing sentences have been moved to the newly added conclusion section.

Reviewer #3: Otherwise I mainly have minor points of clarity / editorial type issues to note: P624-L7 : 'mitigation' is not an appropriate word in this context. 'mitigation' means "The action of reducing the severity, seriousness, or painfulness of something", and these surely do not apply to the N cycling processes in a general sense, only to some specific aspects, and then it is a question of perspective.

Response: We agree, and have altered the formulation (see also our response to the other reviewers).

Reviewer #3: P625-L7 : 'maintain' not 'upkeep'

Response: Changed.

Reviewer #3: P625-L19 : 'regimes' not 'regime'

Response: Changed.

Reviewer #3: P626-L8 : carry out 'apparently' ever more complex

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Response: Changed.

Reviewer #3: P626-L12 : define what is meant by 'missing'

Response: We now explain that it is unaccounted for in the revised text.

Reviewer #3: P628-L8 : defined as 'Ánvia' the infection

Response: Changed

Reviewer #3: P628-L19 : 'loses' not 'looses'

Response: Changed

Reviewer #3: P629-L8 : 'relatively large' not 'high'

Response: Changed

Reviewer #3: P631-L14 : 'selectivity' not 'selectiveness'

Response: Changed

Reviewer #3: P634-L8: What do you mean by 'modular' – the term is used again later, and it's also unclear there.

Response: Changed

Reviewer #3: P633-L15: define DNRA on first use

Response: Changed

Reviewer #3: P634-L14 : 'Gram' not 'gram' (Gram was a microbiologist.....)

Response: Changed, thank you!

Reviewer #3: Page 634-L20 : There is certainly a vast body of literature on denitrification ('soil and denitrification' returns some 6,500 hits on Web of Science...), and much current research effort. So it is apparently ironic if this is indeed 'the most poorly understood process in the N cycle'.... or actually, is it ? Can you qualify this assertion?

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Response: Yes, the reviewer is right and we qualified this statement, stating that it is especially the quantification of this process which still presents formidable problems.

Reviewer #3: P636 : Links here to Section 2.2 ?

Response: We have added a link to Section 2.2 as suggested.

Reviewer #3: P636-L26 : NO, denitrification hotspots and hotmoments have been known to occur, actually especially in field crops, for a very long time!

Response: We have revised this text to clarify that “there has long been recognition of the potential for hotspots and hot moments denitrification to occur within crop fields or pastures.”

Reviewer #3: P637-L24 : Does pH really control leaching ? such that it should be first in this list?

Response: We have modified this sentence by adding an example of a biochemical process (nitrification) next to the example of a physical process (N leaching), removing the impression that we suggest that pH would be a factor controlling leaching.

Reviewer #3: P640-L1 : Why does the further work have to be ‘molecular’ in nature?

Response: We have revised this sentence to indicate which kind of further research, apart from molecular work, is needed to study the mechanisms behind soil faunal effects on increasing soil N₂O emissions.

Reviewer #3: Section 3.2 : No mention of ‘priming effects’ here, which is a highly pertinent concept here – it does not just apply to C.

Response: See our response above to a similar comment by this reviewer - we now mention priming.

Reviewer #3:P644-L8 : ‘nutrient’ not ‘nutrients’ – and what do you mean by ‘organic nutrient cycles’ – unclear or illogical at least.

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Response: Changed. And we changed the formulation of 'organic' nutrient cycles.

Reviewer #3: P644-L25 : What do you mean by 'mine'?

Response: We added a short description, they make N available by stimulation of N mineralization.

Reviewer #3: P645-L8 : Benefit for what / to whom ?

Response: Agreed, we have changed the wording in the text to make this item clear.

Reviewer #3: P648-L14 : What do you mean by 'phylogenetic signals' ? How were they 'corrected' for?

Response: This was a mistake, we have changed it into "phylogenetic relations", in line with previous statements in this section.

Reviewer #3: Section 4 is relatively curt, especially in terms of conclusions or future vision. And, then in Figure 1 there is indeed only 1 'challenge'. Really the only thing now outstanding in this respect?

Response: In our view, this is indeed the most pertinent challenge with respect to modelling

Reviewer #3: Figure 1 : Manuscript is accurate at this stage – remember to change to 'paper' when at proof stage!

Response: Thank you :-). Corrected!

Reviewer #3: Figure 3 : What is meant by 'fertiliser denitrification' ? And especially as a counterpart to 'nitrifier-coupled denitrification' ? I think I can infer, but it took time, so worth explaining.

Response: We think it is rather clearly described in the caption (and the text): it is the direct denitrification of nitrate applied as fertilizer, compared to denitrification of previously nitrified ammonium. We have added the word "direct" in the caption and

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hope this makes it more clear.

Reviewer #3: Figure 4 : In caption, put numbers at start of associated terms, not at end.

Response: Changed.

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