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

Anonymous Referee #2

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General comments This review addresses 8 key scientific challenges in the soil N cycle in order to formulate a comprehensive research agenda of soil N role for food and energy security, biodiversity conservation as well as climate stability. It's not said explicitly, but one gets the impression that the authors find that the importance of these processes, controlling factors and method for (the understanding of) the global soil N cycle has been underestimated. The first three key challenges concern assessment of the importance of the processes non- symbiotic N fixation, nitrifier denitrification and N₂O consumption for the global soil N cycle. The 4th challenge focusses on peak rates and hot-spots of denitrification. The next three challenges focus on moderators of soil N processes; soil fauna, plant root and mycorrhiza. The last one focus on improving understanding of soil N cycling by modelling based on ¹⁵N/ ¹⁸O experiments. The

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language and figures are of good quality.

This manuscript has in my opinion not yet reached its full potential. It contains eight mini reviews, some very good and some less good. What is the surplus value of addressing these key challenges in one paper? I suggest adding a discussion chapter in which the key challenges are weighted against each other by answering the questions; i) Are those key issues equally scientifically challenging? ii) Can solving one help unraveling another? More importantly, ii) Can you make a priority in the research agenda; which processes, moderators and modelling are most important for food and bioenergy security, which for biodiversity conservation and which for climate stability at the local, regional and global scales. How can new insights of these processes and moderators of the soil N cycle help to achieve multiple global challenges, food and bioenergy security, biodiversity conservation and climate stability? I anticipate that a good, general discussion chapter would greatly improve the conclusions, reach out and impact of this manuscript.

In addition, more consistency in addressing the key challenges in soil C cycle is desirable. A simple thing like using the same units for the fluxes of N fixation and N₂O consumption facilitates it for the reader to compare these fluxes. I found the division in soil N processes and moderators as presented in the abstract confusing as key challenge 2 is a combination of both and key challenge 4 neither of them. I suggest for each process including soil N processes moderated by soil fauna and/or mycorrhiza as well as rhizosphere processes, identify its moderators, hot-moments as well as hot-spots or hot-ecosystems (if there are any) and its challenges in progress of understanding, and as far as possible assess rates and uncertainties at the local, regional and global scales. That would be really helpful in establishing the research agenda of soil N role for food and energy security, biodiversity conservation as well as climate stability.

Finally make sure that all statements are well founded and avoid restricting to self-citations, this way you can create a much more inviting, open-minded climate for discussing this very important issue, the research agenda of soil N role in food and energy

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security, biodiversity conservation as well as climate stability.

Specific comments Abstract Make sure the formulation of each key challenge corresponds to that in introduction and especially content of chapters 2 and 3. The title creates high expectations. What are the new insights and the take-home message or conclusions? P624 L6-7 suggestion to replace ‘further understanding, measurement and mitigation of the soil N cycle’ with ‘further understanding and improved quantification of the soil N cycle allowing to enhance positive and mitigate possible negative effects’. P624 L24-25 Suggestion: Integrating improved understanding of soil N processes by advanced modelling based on tracing experiments

Introduction P625 L10 replace ‘after World War II’ with ‘since 1950’s’ P625 L8-L19 Much better than in abstract and figure 1 is really helpful, thanks! Still, double check that each description corresponds to the content of its key challenge and that each key challenge is placed in right chapter. If key challenge 4 is focusing on difficulties in measuring than it might suit better in Chapter 4 on methodology L12 N₂O consumption instead of reduction.

N₂ fixation 1. How large is the contribution of non-symbiotic N fixation in natural systems? This section clarifies that non-symbiotic N fixation is important in tropical forests in different succession phases, it also quantifies it, but non-symbiotic N fixation in other natural systems receive little attention. Much more attention is given to symbiotic N fixation in tropical forests. A more thorough discussion of and estimates of peatland’s, cryptogamic non-symbiotic N fixation globally would be helpful.

Nitrifier denitrification 2. How important is nitrifier denitrification and what are its main controlling factors? This section highlights nitrifier denitrification but it does not discuss controlling factors thoroughly or its global importance

N₂O Consumption 3. What is the greenhouse gas mitigation potential and microbiological basis for N₂O consumption? This section discusses thoroughly biological N₂O consumption but does not answer up to part 1 in key challenge formulation ‘the green-

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house gas mitigation potential’.

Denitrification 4 How can we characterize hot-spots and hot-moments of denitrification? This section answers well to the formulated key challenges and could serve as a model for the other sections. Please improve bases or moderate the statements in introduction P634 L20 ‘most poorly understood’ and P637 L13 ‘new ideas’ and ‘powerful new tools for extrapolation and validation’ which tools?

Soil fauna, plant roots and mycorrhiza I fully agree that these are important moderators but prefer processes and moderators be integrated in sections as suggested in general comments. P637 L17 ‘influence of fauna other than humans’ what about animal husbandry? P641 L4-5 please clarify ‘directs’ and ‘indirect’ effects of what on what?

15N tracing modelling P648 L22-24 skip L22-23 and reformulate to ‘This section focus on how process-oriented modelling based on 15N enriched techniques (references) can progress our understanding of soil N cycling dynamics.

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