

Interactive comment on “Quantifying Global N₂O Emissions from Natural Ecosystem Soils Using Trait-Based Biogeochemistry Models” by Tong Yu and Qianlai Zhuang

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Response: Thank you for the overall positive feedback. We have thoroughly revised the paper following your comments and suggestions.

1. The authors intent to estimate N₂O emission from natural soils during 1990-2000. However, the terrestrial ecosystems have been extensively disturbed and managed. It's unclear about what the natural soils mean in this manuscript. There is no detail information on how they generate the natural ecosystem data across the global land surface. Response: In this study, we did not include the processes introduced by human activities. A natural ecosystem here contains matured and undisturbed soil

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and vegetation excluding the effect of land use. For natural ecosystems data we used, please refer to Section 2.2 about the data organization. Specifically, the land cover data include soil texture and vegetation type, which are inherited from Melillo et al. (1993) and Zhuang et al. (2003).

2. Global map (Fig. 5) shows N₂O emissions from the cultivated areas where crops planted during 1990-2000 according to my knowledge. Do you consider background emission from cropland as natural emissions? Or you treat cropland as other types of vegetation? Response: In this study, we only considered natural ecosystem emissions. Croplands emission were not modeled. Please refer to Fig. 2 (top) from Melillo et al. (1993) for the distribution of natural ecosystems.

3. It needs to provide more explicit explanation on the role of microbe in N-containing gas formations and diffusions, mineralization/immobilization, nitrification/denitrification, etc. The figure 1 needs to include such information on microbial processes. Response: We revised Figure 1 to delete N fixation process that was not considered in this study. Now the figure 1 caption is “Schematic diagram of N₂O emissions and N cycling between plants, soils, and the atmosphere: The input of N from the atmosphere to soils through nitrogen deposition as nitrate and ammonia; microbial biomass dynamics were modeled; Nitrification is modeled as a function of microbial biomass, soil organic nitrogen, and physical conditions, more details refer to Yu (2016); N uptake by plants is modeled in original TEM (McGuire et al., 1992).”

4. The description of major equations is barely understandable for readers. There is no connection between these equations listed in the manuscript. The authors should provide equations focusing on N₂O fluxes. Response: The major equations listed in the text describe the trait of microbes related to nitrification. Limited by the length of the manuscript, more equations focusing on N₂O fluxes and other processes of N cycle can be referred to in Master's thesis of Yu, T. (2016). Tong Yu (2016), Quantifying the global N₂O emissions from natural ecosystems using a mechanistically-based biogeochemistry model, MS thesis, <http://docs.lib.purdue.edu/dissertations/AAI10145857/>

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5. The authors mentioned their previous model and used it to make comparison with the current version. They should have a description of their previous model and list the improvements in the methodology. Response: Thank you. We now added a brief description of our previous model in 2.2 Model Modification section. The improvements are described from line 20 to line 25 of Page 6.

6. They emphasized site-level estimates and climate data sources, but not for global simulations. There is no detailed information on the climate data source or description on climate variability during 1990-2000. Response: Thanks for pointing this out. For the global simulation period, the monthly air temperature, precipitation, cloudiness and vapor pressure data are from Climate Research Unit (CRU).

7. The authors should provide the method on how to extrapolate site-level estimates to the global level. Also, I am curious with the uncertainty range (7.1-10.3 Tg N yr⁻¹), but they did not give any explanations. Response: Please refer to Section 2.2 about the global forcing data organization and Section 2.3 for the parameters used for global simulation. We added a couple of sentences to describe how the parameters obtained from site-level parameterization to the global scale “We apply the site-level parameters for representative ecosystem types to grid cells at 0.5o x 0.5o resolution at the global scale. The ecosystem types are listed in Table 2 and their distributions are from Melillo et al. (1993).”

The uncertainty range of simulated N₂O emissions is induced from the range of parameters shown in Table 1. We also made this clear in the text line 10-12 on page 13 by adding a sentence “The uncertainty range of simulated N₂O emissions is induced from the range of parameters shown in Table 1” (section 3.3).

8. As also indicated in the manuscript, biological N fixation and denitrification can contribute a significant amount of N₂O emissions, but these processes were not included in this study. A paragraph should be included in the discussion sector to address this ignorance and its impact on the entire estimates. Response: Denitrification is simu-

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lated in this study, which can be referred to Yu (2016). Due to the length limitation, we want to refer the detailed description of denitrification process to Yu (2016). N fixation is not considered in this study. We deleted that process in Figure 1. In addition, we now added a paragraph in Section 4.3 to discuss the microbial effects on denitrification and effect of N fixation on current estimation.

9. They claimed that CN ratio plays a significant role in N₂O emissions, which is one of their objectives. They indeed mentioned CN ratio threshold in the methodology; however, nothing special has been described in the result or discussion sectors. Response: In this revision, in Result and Discussion sections, we did sensitivity tests on the effects of soil carbon and soil nitrogen, the latter is highly related to the growth and metabolism of microbes, in turn, affecting N₂O emissions.

10. The improved trait-based model is actually a hybrid of first-order and second-order expression. According to Fig. 4, I cannot tell the advantages of this improved model. They should provide more evidence. Response: Figure 4 showed some improvement based on both slope and R² values from two versions of model simulations. The previous model had a comparatively smaller R² and slope in comparison with observations, but overestimated N₂O emissions because the model ignored the N taken up by soil microbes. The comparison is shown in Section 3.1, page 9-10. Figure 5 showed that the improved trait-based model has a better performance by capturing seasonal variations. The comparison is shown in Section 3.1, page 10.

11. They found that tropical peatland has the highest N₂O emission, up to 5.7 kg N ha⁻¹ yr⁻¹. When I go back to that article, they chose this site because the peatland was converted to cropland and induced a much higher N₂O emissions. However, I guess this model is incapable to simulate land conversion and its impact. If you used this site, your estimates in Southeast Asia should be much higher than other previous studies. Thus, it is not appropriate using this site for model calibration. Response: Due to scarcity of quality observational data, we made a compromise to use this site data to do calibration. In this revision, we pointed that out in the text line 19 – 21 on page 10 by

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adding “We recognized the site data used from a cropland ecosystem converted from peatlands, which may be with higher N₂O emissions than natural ecosystems in the region. This may result in relatively high emissions from this type of land ecosystems in the region”.

12. In Fig. 2, I can only detect one site in the Congo Basin for model calibration. Based on my knowledge, this region may be a large source for N₂O emission. Thus, I suggest the authors to collect more data to re-calibrate their model. Response: Thanks for the suggestion. We have not been able to get more observed data for this region. We will keep eye on the literature to obtain more data when the data are available to improve our simulations in future studies.

13. The microbial biomass data was not well explained. We need to see more details about these data. Response: In this revision, we added a brief introduction to the source and organization of microbial biomass data from line 3 to 5 of Page 8. Limited by the length of our text, please refer to the following paper for more details about the original dataset:

Xu, X., P.E. Thornton, and P. Potapov. 2014. A Compilation of Global Soil Microbial Biomass Carbon, Nitrogen, and Phosphorus Data. ORNL DAAC, Oak Ridge, Tennessee, USA. <https://doi.org/10.3334/ORNLDAAC/1264>

14. It seems that the tables and figures can be further improved. For example, the table 1 and table 2 can be provided as a supplement file. The Fig.2 can be improved by removing the Antarctica regions. Fig. 3, 4 and 6 should be improved as the current resolution of figures is poor. In addition, there are two fig.4. Response: Thank you for your suggestion. We have fixed the error on Figure 4. We have removed the Antarctic region in figure 2. The resolution of figures was adjusted according to demand of journal.

15. Table 3a conflicted with details provided in section 2.3 of the paper, and tables 3 and 4 should be swapped to match the order given in the methods section. There

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was also repetition within the methods sections. Response: Thank you for your careful review. We have corrected the error.

16. Literature cited: Several new efforts in soil N₂O modeling have been published recently. Literature review should include recent modeling efforts. Particularly, I am surprised that the authors did not recognize a major NO₂ model inter comparison project- NMIP (Tian et al 2018). Tian, H., J. Yang, C. Lu, R. Xu, J. G Canadell, R. B.Jackson, et al. (2018) The global N₂O Model Intercomparison Project, Bulletin of the American Meteorological Society (BAMS), <https://doi.org/10.1175/BAMS-D-17-0212.1> Response: Thank you for the reference. We have carefully read this paper and added related results to Discussion section on page 14-15.

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