

GENERAL COMMENTS

The authors present an extensive and comprehensive study on soil N₂O fluxes and nitrogen dynamics in tropical wetland soils of the Pantanal region, including influences of precipitation and soil moisture dynamics. The study will make an important contribution to our still scarce knowledge about soil N dynamics and N₂O fluxes from tropical landscapes, and wetlands in particular. The topic of the study is well within the scope of Biogeosciences.

The introduction is largely well written, only the structure could be slightly improved. In general, the methodology appears well considered and sound, but needs to be more specific in some aspects. The results section needs major revisions. Currently, many values or ranges, which can often be read from Figures or Tables, are just laid out instead of summarizing and presenting main patterns. Unfortunately, hardly any statistical analyses have been conducted, which currently weakens this paper considerably. The findings need to be assessed statistically before publication. Also, the discussion should be critically revised and some parts of it should be transferred to the results section. For all these suggested revisions I am giving more specific suggestions below. Finally, the paper would gain by being edited by a native English speaker.

Once the paper has been carefully revised it will be a highly valuable contribution to the field of tropical biogeochemistry, which I am looking forward to see published.

SPECIFIC COMMENTS

Abstract

General: You use both the terms 'dry' and 'drained' when you talk of the conditions during the drying cycles. I think it would be easier if you just stick to one expression (e.g. dry).

P5992/L6: Please specify what 'long term' means here, i.e. duration of the study.

P5992/L7: Suggest to spell out ammonium, nitrate and oxygen since you hardly use the acronyms/chemical formulas afterwards in the abstract.

P5992/L8: CO₂ has not yet been defined as acronym. The abstract does not include any information so far about the carbon dioxide fluxes.

Was there a consistent pattern in the changes in inorganic N concentrations with moisture conditions? If so, I suggest to specify how the inorganic N pools changed, i.e. how high were concentrations during dry periods and flooding periods, respectively.

P5992/L11: Suggest to be more specific, e.g. how high were O₂ concentrations at 60 cm depth. According to your Fig. 5a, oxygen was not always similarly high down to 60 cm. Instead of writing that O₂ was depleted by rain events (was not captured as pronouncedly, Fig. 5a) maybe rather state that the system was mostly anaerobic in the waterlogged-site throughout all soil depths. (note: (a) and (b) are missing in Fig. 5).

P5992/L14: Please include duration of these measurements (i.e. what is 'rapid').

P5992/L15: Consider to tone down 'dominating' (e.g. 'important').

P5992/L17ff: Please give error estimates for the N₂O fluxes, e.g. standard errors.

P5992/L20: It may not be clear from only reading the abstract that this R² is from a multiple regression. The relationship with pH is not significant and should not be reported as a main finding in the abstract, please delete.

Introduction

P5993/L23: Is this a typo? (Low O₂ availability at high soil moisture contents stimulates denitrification, not nitrification). Suggest to also give the range of soil moisture content you are talking about (i.e. what is 'high'?).

P5993/L5: 'Higher N₂O release rates often occur...'

P5993/L10: Please insert a reference for the statement that denitrification is often considered to be the main N₂O producing process.

P5993/L21-P5994/L21: I think that this section can be much improved by restructuring. Currently, you jump a bit between the topics. You start with factors affecting nitrification and denitrification, then you state that N₂O release rates may be especially high in systems with rapid changes in soil moisture, afterwards again some statements of when (de)nitrification is likely important, next again aspects on changing soil moisture. I suggest to reconsider and improve the structure of these 3 paragraphs.

P5994/L23: In which aspect did the three sites differ? Please specify. The current expression sounds as if you have three seasons in the ecosystem, please improve the wording here.

Materials and methods

P5996/L1ff: From first reading it is not understandable which ones are the campaign sites, and why you have only 11 sites marked in Fig. 1b. Please make this clearer.

P5996/L11: I think that it may be a bit difficult to remember what the word 'level' means, please consider to give it a more meaningful name, e.g. 'landscape level' or 'moisture level'.

Fig. 2: Suggest to refer to Fig. 1b, i.e. '...indicates the period of local weather station monitoring at site A (Fig. 1b)'.

P5996/L27: At which depth was the pressure transducer installed?

P5997/L6: It has been shown that storage of tropical soil samples prior to inorganic nutrient extraction can significantly change the measurement results (Arnold *et al.*, 2008; Turner & Tania, 2009). E.g., for tropical lowland forest soils from Panama, samples which had been frozen at -35 °C for four weeks contained significantly higher concentrations of ammonium compared to samples which were immediately extracted. Please consider these studies, and expand on this issue. How long did you store the soil samples before extraction and, based on the above publications, (how) can this have biased your results?

P5997/L12: I don't find drying of the samples mentioned (but in the results you present values per gram dry weight of soil, e.g. for nitrate in Table 3)?

P5997/L13-15: Please insert the town for the reference to Rhizosphere Research Products. From the current description I am not quite sure about the setup. Did you take soil cores, insert the filters and re-inserted the cores in the original position?

P5997/L19: Please insert the town for the reference to Sartorius (and same below for RL Instruments and for several other references).

P5998/L7: How high were the calibration concentrations? Please specify. How many and at which depths were soil samples taken?

P5998/L9-12: Is this the same pH method as above for porewater? If so, please shorten/combine.

P5998/L13 and L16: How many samples did you take per plot, at which depth?

P5998/L17: Suggest to use 'landscape level', 'moisture level' or something similar (please see comment above).

P5998/L17: Dried for only 2 hours? This is quite short and shorter than usual to get oven-dry samples.

P5998/L20ff: Since the optodes were permanently installed, could they still be calibrated prior to measurements? If not, how could you assure that they remained measuring accurately? Please include a sentence on this issue.

P5999/L2: When where these samples taken?

P5999/L17: Why were gas fluxes not measured in level 3? Please make a note on this.

P5999/L19: Please comment on why you chose this insertion depth. I am wondering if inserting so (to my mind relatively) deep may have affected the soil respiration measurements due to e.g. excluding horizontal fine root ingrowth over a considerable depth?

P5999/L25: There is quite some discussion in the literature about how to calculate gas fluxes from time series of concentrations over time. Please insert the literature reference for the exponential calculation method you chose, and comment on why you used this calculation method. Please also include the units for the equation you used.

P6000/L4: In the result section, you are reporting differences, e.g. on P6000/L19-20, but in the Statistical methods section you do not mention how you tested for differences between sites or over time. Please make sure that results which you report in the Results section have been statistically verified, include the tests which you applied in the Statistics methods, and the respective statistical parameters (e.g. *P*-values) in the results section.

Results

P6000/L12: Please give the soil depth you are talking about for 'near the soil surface'.

P6000/L14: This would not only be evaporation but drainage as well.

P6000/L15: Please here, and throughout the manuscript, include error estimates for your mean values (e.g. standard errors). For example for temperature, mean values were very similar but, according to your Fig. S1, variability was more pronounced in the top soil than in deeper soil layers.

Fig. 3: It is not mentioned in the figure or legend in which years the measurements were taken but you frequently refer to sampling years in the results. Please include this information in the Figure. How about presenting Site A in just one panel, which includes all measurements over the two sampling years? It would reduce the figure to just 3 panels. I am also thinking about the choice of this presentation more in general – did you try to plot the data, instead of as barplots, as time series, with three different symbols for the three different landscape levels? I can imagine that this might make it easier for the reader to grasp the patterns, especially for sites with more frequent data like for nitrate at site A. This would be a graph similar to Fig. 7 where fluxes are presented as time series.

Are the units for ammonium and nitrate here $\mu\text{mol cm}^{-3}$, as opposed to $\mu\text{mol N cm}^{-3}$ as for TN in Table 1? Please use the same units throughout consistently.

P6000/L19-P6002/L4: Please verify all the statements about differences statistically, and give the respective statistical information. I think that this section (and also the results further below) may be a bit clumsy to read because so many values and ranges are mentioned. Please consider if all these are really necessary (since they can be read from Fig. 3a), or if you would focus on just some important ones. Also for pH I don't think it is necessary to mention all the values – just summarize...e.g. that porewater was generally acidic, varying between x and y across sites and sampling years. I also suggest to present the results from site A together for both years instead of splitting it up as it is currently done.

Fig. 4: I think that also this Figure might become more intuitive by presenting the patterns over time (on the x-axis) since this is the more common form, and readers are more used to it. I also suggest to have just one panel for site A. From the current legend it is not clear from which year the measurements are (can be guessed but not unambiguously).

P6001/L23: Fig. 4c?

Figs. S2-S4: It is not clear what the symbols mean, i.e. from which measurement dates/months they are.

Table 3: Please note why error estimates are not available for phosphate and for some other values. Unit for phosphate is missing.

Fig. 5: Please include in the legend at which landscape level the oxygen concentrations were measured.

P6002/L5-12: It is not necessary to give these values in the text since they can be found in Table 1. Please revise and shorten this section.

P6003/L11: How were flux rates integrated? Please include this in the Methods Section.

P6003/L4-25: Please revise this results section. Since the flux rates can be seen in Figs.7 and S9 please summarize the main patterns instead of repeating all ranges, limit yourself to mention a few central values if necessary (e.g. means and SE).

P6004/L5: N₂O fluxes are not at all related to pH, with a P-value of 0.138. Please exclude.

Discussion

P6004/L16: Please replace 'such a large' with another, more neutral expression.

P6004/L22: What type of ecosystems were these (e.g. forests?), and where in the tropics was this?

P6005/L3-15: In my opinion, this would be good as a results but not discussion section.

P6005/L15: During which period (water-logged, drained?) did Kern (1996) measure?

P6005/L18-22: And how do you interpret/judge about this comparison?

P6006/L12: Please include a reference for the last statement.

P6006/L17: You did not measure NO₃⁻ and NO₂⁻ concentrations in the slurries. Therefore I suggest not to state this as an unambiguous finding but rather tone it down as a possible explanation.

P6007/L11-14: Please avoid to repeat results unless it is necessary for the interpretation – here, you could just immediately refer to Table 3 instead of giving measured values once again.

P6007/L18-19: Even higher? E.g. $0.39 \text{ mmol N}_2\text{O m}^{-2} \text{ d}^{-1} / 0.001 \text{ mmol N}_2\text{O m}^{-2} \text{ d}^{-1} = 390$.

P6007/L22: Transitory emissions were increased 5-fold in the montane and 7-fold in the lowland forest in the study from Panama (Koehler *et al.*, 2009).

P6007/L26: N₂O fluxes were also stimulated by N-addition to the N-limited forest site, but the effect was much less pronounced than for the P-limited site (Hall & Matson, 1999).

P6008/L6-7: Suggest to rather include the comparison with the N₂O fluxes in the first paragraph.

P6008/L19: Can you verify this statement statistically, e.g. were VWC and N₂O fluxes correlated?

P6008/L28: N₂O fluxes were not significantly correlated to pH.

P6009/L5: Why is this a conservative calculation? I don't really understand that.

P6010/L6-17: This calculation is really interesting, but I think a bit difficult to follow right now. I needed to read through several times in order to understand what you calculated and what you argue. Please try to improve the presentation of this. In lines 14-16 this is an estimate, right, based on an extrapolation. Please make sure that this is made clear. For the contribution of the dried soil do you calculate $164 \text{ days} * 0.43 \text{ mmol N}_2\text{O m}^{-2} \text{ day}^{-1}$? That would give $70.5 \text{ mmol N}_2\text{O m}^{-2} \text{ day}^{-1}$. Please check and update (also in the abstract) if necessary.

P6009/L21-23: I think that this sentence does not tie very well with the rest of the paragraph, suggest to revise.

P6010/L18-20: Please specify the assumptions underlying this up-scaling, i.e. how many days of dry and wet conditions did you assume, based on which information? And please include a reference for the areal estimate of the Pantanal, and for the global emission budget.

P6011/L1-2: Well, obviously it does...

P6011/L2: Please avoid 'such a large' and choose a more neutral expression.

P6011/L4: N₂O is a stable trace gas and production can continue much deeper into the soil. For example tone down, that you assume ‘most of the N₂O production occurred’ in that soil layer, and give a reference of why such assumption might be adequate.

P6011/L11-12: Review also included N-oxide fluxes measured in Brazil and Costa Rica (Koehler *et al.*, 2009).

P6011/L16-19: This rather belongs into the Results Section.

P6011/L21: ‘a conservative estimate would be’

P6011/L23-24: I get different calculation results, please check. If I got it right (please excuse if I am wrong) it would be $0.1 \times 158.5 / 0.9 = 20.6$ for NO, and $0.2 \times 158.5 / 0.8 = 39.6$ for N₂?

P6011/L25-28: There are other nitrogen transformation and loss vectors, and the system is not necessarily in steady state. The total N-oxide fluxes (which are already based on a calculation including several assumptions) need not be exactly balanced by input. Please rephrase to make this more specific.

P6012/L10-11: 6- to 8-fold lower

P6012/L13: ‘of the estimated input by N₂ fixation’

P6012/L15ff: Atmospheric N deposition is also not included in the considerations.

P6012/L22: Please avoid expressions like ‘extremely large’ or ‘such large’.

P6013/L5: Please include a reference for the statement that the fluxes have so far been considered negligible.

P6013/L8: Please put your measured fluxes into perspective here again, i.e. what means ‘very high’, compared to what?

P6013/L11: ‘natural and pristine tropical systems’?

TECHNICAL CORRECTIONS

P5992/L7: ‘in laboratory soil slurries’

P5992/L8: ‘in situ surface fluxes’

P5992/L16: insert comma after ‘was precipitation’?

P5992/L18: Suggest to write ‘fluxes’ instead of ‘activity’, and spell out ‘10’

P5992/L24: rain-induced (insert dash)

P5993/L22: Nitrification and denitrification are responsible for the production of N₂O, not for the release.

P5994/L1: It is called ‘Hole-in-the-pipe’ model

P5995/L8: typo: Fig. 1a

P5995/L26: typo: Fig. 1b

P5995/L21/22: ‘This explains why the Pantanal receives...’

P5997/L4: ‘KCl-extracted’ (insert dash)

P5997/L11: ‘by the fluorometric method’

P5997/L20 and P5998/L5: ‘laboratory’ instead of ‘lab’

P5998/L22: ‘custom-built’ (please insert dash)

P5998/L24: ‘intervals’

P5999/L5: Please insert a comma: ‘slurry, measuring...’

P6000/L12: ‘...near the soil surface, and progressively less so’?

Fig. 4: ‘water-logged’

Legend to Fig. S6: ‘near sites a, B and C’

Legend to Fig. S7: ‘from the screening field campaign’

P6005/L5: ‘After 1-2 weeks of draining, the soil...’

P6005/L11: You did not measure throughout the drained season. Therefore rather tone down from ‘indicating’ to e.g. ‘suggesting’.

P6007/L5: delete ‘be’

P6007/L20-21: Koehler et al. 2009; ,nitrogen addition to'; ,N₂O emission peaks'
P6007/L23: 'phosphorus-limited'
P6007/L25 and P6009/L23: 'long-term'
P6008/L24: Fullstop missing after the sentence.
P6009/L6: 'rain-wetted' (and throughout the MS)
P6010/L10: 'precipitation-triggered'

References

- Arnold J, Corre MD, Veldkamp E (2008) Cold storage and laboratory incubation of intact soil cores do not reflect in-situ nitrogen cycling rates of tropical forest soils. *Soil Biology and Biochemistry*, **40**, 2480-2483.
- Hall SJ, Matson PA (1999) Nitrogen oxide emissions after nitrogen additions in tropical forests. *Nature*, **400**, 152-155.
- Koehler B, Corre MD, Veldkamp E, Wullaert H, Wright SJ (2009) Immediate and long-term nitrogen oxide emissions from tropical forest soils exposed to elevated nitrogen input. *Global Change Biology*, **15**, 2049-2066.
- Turner BLR, Tania E (2009) Short-term changes in extractable inorganic nutrients during storage of tropical rain forest soils. *Soil Science Society of America Journal*, **73**, 1972.