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Interactive comment on "Quantifying nitrogen losses in oil palm plantations: models and challenges" *by* Lénaïc Pardon et al.

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Referee: With the rapid expansion of oil palm the environmental consequences beyond initial conversion need to be quantified. The manuscript describes a comprehensive comparison of existing models that can be used to predict N losses from oil palm, both at qualitative and quantitative level. The tables of which processes are included (or not) can help in further model development, borrowing ideas within the modelling community, retaining what seems to work best. As there is no established empirical data set that can serve as comparison, it is not easy to see which models over- or under-estimate the overall loss, beyond what the discussion indicates. The manuscript will hopefully trigger further critical analysis, and is worth publication in Biogeosciences.

Reply: Thank you for your constructive and precise comments which improved the

clarity of the manuscript. They also invited us to emphasise some issues which can be useful then to target potential improvements in modelling N losses in oil palm plantations.

Referee: The manuscript takes the various models at 'face value', without comparing the underlying equations. As leaching is identified as the dominant process of N loss across the models, it will be good to provide further detail on why the various models provide different estimates. I assume that the basic equation for leaching losses as the net vertical water transport multiplied by average concentration of mineral N in soil solution holds true across all models. Variation in results could then be based on differences in ET (with vertical water transport equal to rainfall -ET) or concentration. The latter will vary with N form (fraction of mineal N as ammonium vs nitrate), sorption of ammonium and nitrate to the soil, or any preferential flow that allows water to bypass mineral N. Please add a paragraph or two to the dicussion that takes this debate a bit further.

Reply: Thank you for this comment, we agree that it is useful to discuss more about the reasons why leaching estimates are different, since it is the dominant N loss pathway. The different ways of modelling leaching by the models are described in the section 2.1.2. in Material and method (lines 139-152), and only the three process-based models (APSIM, SNOOP, and WANULCAS) simulate explicitly water flows. Therefore we added these precisions (line 454) to focus on two processes likely to drive these differences in leaching estimates: "For instance, interactions between zoning and N inputs might occur in WANULCAS, as the mineral N input from fertiliser was applied close to the trunks where water infiltration might be higher due to the stemflow. Another potential important interaction might happen with the simulation of N immobilisation and mineralisation in soil. Indeed, in WANULCAS, mineralisation of residues and empty fruit bunches caused high losses through leaching in the first years of the cycle, while in APSIM, immobilisation of N dominated the dynamics over several years and losses through leaching were delayed and much lower."

Referee: Identification oc clay content as key variable points to interactions via sorption and/or microbial dynamics – again, a bitfurther discussion of the underlying mechanisms that are included in the model is of interest. One would expect pH to play a substantial role, as it influences nitrification as a process – is that included in any of the models?

Reply: Thank you for this comment. As the sub-models tested in the sensitivity analysis are not process-based models, we could not discuss the underlying mechanisms. However, we are preparing another study focused on a sensitivity analysis of APSIM-Oil palm in which we tested variables and discussed the underlying processes simulated. Therefore, we added these 3 sentences in the discussion (Line 534): "The sub-models included in the sensitivity analysis were regression models which did not simulate processes explicitly. Some parameters not taken into account in these models may have an influence in other process-based models. Therefore, it could be interesting to perform complementary sensitivity analyses focused on process-based models, such as APSIM."

Referee: It may be good to include some further words of caution to use of the 'portfolio of models' rather than a single one – in the absence of further empirical studies.

Reply: Thank you for this proposal. We added this sentence in the discussion (L 468): "Therefore, our results call for caution with regard to the choice of a single model to simulate N losses in oil palm. In absence of further empirical studies available to test these models, we would recommend to use several models to perform N losses predictions."

Referee: There is no specific reason to believe that the average is closer to the truth than any of the values in the range of results obtained...

Reply: Yes, we agree with your comment. However, we identified the value of 74 kg N.ha-1.yr-1 as a plausible estimate, following a nitrogen budget reasoning (assuming no nitrogen is stored in the soil over the growth cycle, L 430-438), rather than because

it would be the average of the results for all models.

Referee: Overall I recommend the manyscript to be published with some minor revisions. Comments that may be taken into account in a final version: Around line 45 it may be good to give some a priori reasons why porcess models adjusted to temprate conditions might not work, without adjustement, to tropical conditions: faster decomposition, different dominant clay minerology, different soil microflora and fauna, ... reference could be made to: Richards, M., Metzel, R., Chirinda, N., Ly, P., Nyamadzawo, G., Vu, Q.D., de Neergaard, A., Oelofse, M., Wollenberg, E., Keller, E. and Malin, D., 2016. Limits of agricultural greenhouse gas calculators to predict soil N2O and CH4 fluxes in tropical agriculture. Scientific reports, 6.

Reply: Thank you for this very relevant reference. We added the reference in the text (L 57), and we mentioned explicitly a priori reasons (as examples) why N dynamics are expected to be different under tropical climate and perennial crops (L 44): "N losses under perennial tropical crops are expected to follow specific dynamics, given for instance the highest temperature and rainfall, and the high amount of crop residues recycled over the growth cycle."

Referee: Around line 48 a distinction may be made between models that are primarily used for 'response to management' type studies, and those that are supposed to provide an accurate mean

Reply: Ok, we completed a sentence to add this interesting distinction (L 50): "Nowadays, models are also widely used to estimate the emission of pollutants for the purpose of environmental assessment, aiming either at simulating accurate mean emissions, or at estimating the impact of management practices on emissions."

Referee: Line 74 reference for Morris please

Reply: Reference added, thank you.

Referee: Line 240 Please clarify which reason applied. Aren't all models 'open

source'? to which model

Reply: Ok, we clarified the sentence (L 245): "Process-based models were not included in the sensitivity analysis as the source code of SNOOP was not accessible and APSIM and WANULCAS were not directly programmable without adapting the models structure to run the sensitivity analysis, which fell beyond the scope of this study."

Referee: Line 245 a range from 10 to 190

Reply: Ok, we added 2 sentences in the discussion to raise awareness on these wide ranges and remind the reason of choosing such ranges in the sensitivity analysis (L531-534) : "When the sub-models did not specify ranges for emission factors, we used ranges from -90

Referee: Line 267 Please provide the calculated yield levels and average annual external N inputs that correspond with this result, along with rainfall and ET

Reply: Ok, we added the ranges for these values (L274). "Annual estimates were 20-25 t of fresh fruit bunches.ha-1.yr-1 for yield, 132-147 kg N.ha-1.yr-1 of N inputs (mineral fertiliser, atmospheric deposition, biological N fixation, empty fruit bunches and previous felled palms), 2407 mm.yr-1 of rainfall and 932-1545 mm.yr-1 of evapotranspiration."

Referee: Line 336 Was application of EFB only considered at planting time?

Reply: Yes, as we said at line 211 in MM, "Organic fertiliser, i.e. empty fruit bunches, was applied around the palms for the first two years as a typically used rate of 184 kg N.ha-1.yr-1."

Referee: Line 375 Any differentiation by clay minerology in any of the models?

Reply: There is no differentiation by clay mineralogy in any of the models.

Referee: Line 446 If fertilizer is added close to the trunk in a zone with average of above-average water infiltration, a high leaching loss is to be expected, unless there

are contravening processes of preferential water uptake in this zone...

Reply: Thank you, we added this more precise description in the discussion (as cited above, L454): "For instance, interactions between zoning and N inputs can occur in WANULCAS, as the N inputs from fertiliser is applied close to the trunks where water infiltration might be higher due to the stemflow."

Referee: Line 490 The Richards reference cited above suggests that there are real knowledge gaps on the N2O emissions for any current model

Reply: Our sentence was more related to the need of modelling N2O, NOx and N2 emissions in a comprehensive way. But you are right, in order to contextualise this discussion, we added a sentence and a reference about N2O modelling (L505): "Finally, despite the difficulties of understanding and simulating the complexity of processes driving N2O emissions (Butterbach-Bahl et al., 2013), N2O, NOx and N2 should be modelled in a more comprehensive and systematic way."

Referee: Typo's Line 429 Some words missing?

Reply: Thank you, we checked the Line 429, but it seemed correct to us.

See final comment for the revised manuscript containing all the revisions.

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