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Biogeosciences
Discussions

Interactive comment on "Effect of legume intercropping on N_2O emission and CH_4 uptake during maize production in the Ethiopian Rift valley" *by* Shimelis G. Raji and Peter Dörsch

Anonymous Referee #1

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General comments This paper reports results from an experiment conducted in Ethiopia measuring yields and GHG fluxes from maize cultivated as monocrop and intercropped with 2 legumes. There is an urgent need to increase the empirical base quantifying GHG fluxes from agricultural systems in Sub-Saharan Africa and therefore this study could be a valuable contribution to the literature. Understanding the interactions between cereal and legume crops and quantifying C footprints are also commendable scientific goals, and requirements to design future climate-smart farming. However, this study seems to have a number of experimental shortcomings that require at least clarification to be able to assess its suitability for publication in Biogeosciences. These are the most important issues to be addressed:

1. The introduction doesn't follow a logical flow. It includes interesting hypotheses, although the authors either do not properly attempt to answer the hypotheses or do it insufficiently. Example: "Legumes affect emissions by providing organic N or by modulating the completion between roots and microbes for soil N". The authors could have added how these processes are 'modulated', and use the appropriate methods to quantify species competition and microbial processes. 2. The methods are poorly described to assess the value of the experimental data. I indicated shortcomings in Specific comments below. 3. The discussion is mostly a compilation of literature conducted elsewhere reporting GHG fluxes from intercropping including legumes. I would expect a reflection of the results against the relevant literature.

A modest aim for this paper could have been simply documenting the GHG flux measurements and explaining the patterns observed, using all the data collected and conducting a sensitivity analysis for the fluxes that have been roughly estimated, such as the contribution of the legumes to N inputs, the emission factors and the emissions intensity.

Because there are very few experiments measuring GHG fluxes in Africa, I would suggest a thorough revision addressing the shortcomings, to re-consider this manuscript for publication.

Specific comments Introduction L39 The use of inorganic fertilisers doesn't necessarily reduce the soil methane sink. Please explain.

L40 remove 'by contrast'. It doesn't follow naturally from the previous sentence.

L41 the concept of CSA – coined by FAO – doesn't talk about profits. Please revisit original source.

L43 I don't think the understanding of GHG fluxes in SSA is limited. There is a scarcity of quantified GHG fluxes in SSA, and limited experimentation on which CSA practises would be suitable for the SSA context. Please rephrase.

L49 Crop production can be a major source of N2O emissions when fertilisers are used. This is not often the cause in East African agriculture. There are empirical studies that show that.

L53 strange reference to 'upland soils' here. Please explain why the focus is suddenly shifted towards upland soils.

L58 soil management practices are not the only controls of the factors affecting soil N2O fluxes. Soil type and climate are major determinants, which don't depend on management.

L59 The position of the two first references in this sentence is not logical. Please revise.

L68 diversification, rotation and intercropping do not always enhance productivity. Please rephrase.

L71 please add reference that shows that legume improve N uptake of the cereal crop in the Rift Valley (this is a large area across countries!). There is evidence in favour and against this.

L86 rates of 100 kg N per hectare are very uncommon in Africa. Please consult the literature on fertiliser use for the continent.

L89 increasing. Remove or replace 'accordingly', doesnt seem to fit the meaning of the sentece.

L93 add 'the' to 'the' release. Please explain how root exudates release 'extra N'.

L95-96: are these the hypotheses this study wanted to test?

L110-112: these hypotheses don't have any mechanistic underpinning, and are therefore weak. Time measured in weeks is unlikely to be a fixed effect, since the effects of management such as sowing date, choice of species and cultivar on yields and GHG fluxes will depend on soil and weather.

L115 because there are so few experiments measuring GHG fluxes in Africa, and more modest aim for this paper could have been simply documenting these measurements and explaining the patterns observed.

Methods L121-126 please report soil type using a known classification, e.g. WSD. And please add measure of dispersion to the reported soil properties, and weather variables.

L128 Please explain the 6 treatments clearly here. No clear which are the treatment is Table 1, and how they were imposed. Treatments seem to be listed in Table 2, although there is no consistency in labels used in Tables and Figures.

L130 only one cultivar? Wouldn't the reserachers have expected cultivar effects on the treatments?

L31 only one sowing date each year? I understood from the objective and hypothesis that the authors wanted to test the effect of sowing date (L110) on GHG fluxes.

L133 fertiliser rates per hectare? I am surprised to read that N fertiliser was applied to the intercropping treatment. Was there a scientific basis to half the rate? If yes, please add reference to previous experimental work.

L136 I would have expected an effect of plant density. These were fixed.

L141 why half removed? did you measure this variable amount of mulching applied to the plots? This is not really a welcome variation to the treatments, and could have affected the data analysis and assumptions on treatment effects.

L151 why didn't the measurements of fluxes start before planting to capture background GHG fluxes?

L152 what was the frequency of sampling? Weekly? There is evidence that less than weekly sampling doesn't capture the variation of GHG fluxes in a crop's cycle. See Barton et al. 2015 Scientific Reports volume 5, Article number: 15912 (2015)

L159 Helium filled?

L185 these treatments were not introduced before.

L187 Was bulk density measured? If yes, how?

L195-L198 Not having assessed belowground biomass and the amount of N fixed by the legumes is an important shortcoming of this study. Specially because the authors pose the hypothesis in the introduction (L95-96) that "Legumes affect emissions by providing organic N or by modulating the completion between roots and microbes for soil N". Without having quantified belowground N and N2 fixation, there results are less useful as a contribution to test this hypothesis.

L199 until here, it wasn't indicated that there were different sowing times for maize and legumes. Treatments must be clearly explained at the beginning.

L202-204 this is another shortcoming, having assumed the 'release' of 50% and 30% of the N during the growing season doesn't help with hypothesis testing. The authors could have followed at least inorganic N in the soil.

L213 this emission factor is not really meaningful given all the assumptions used to estimate N input.

L221 Was grain moisture content measured?

Results L236-237 to be able to measure peaks, N2O fluxes must be measured continuously after fertiliser application. There is typically a peak 6-48 hours after application. The dataset unfortunately doesn't show baseline emissions that happened before the treatments were imposed.

L 280-295 I find this section on EFs speculative because there are large uncertainties in the estimation of N input as described in the methods section.

L318 this should be explained in the methods section with all assumptions and reported as absolute emissions not GWP. This section is not clear, and need to consistently

explain Fig 2 and 5. Fig 5 doesn't include letters showing the contrasts.

L330-340 this belongs more to results than to discussion.

L349-354 because the researchers didn't measure N2 fixation, this sentence is speculative. Also attributing the lack of relationship between N input and legume N yield and N2O fluxes to the variability of fluxes is speculative, since the estimation of the N input and yield are very uncertain and based on strong assumptions.

L375-378 the data shown in Fig 2 doesn't show that intercropping legumes increases emissions 'risk' further than cultivating fertilised maize. If that were the case, there would be a consistent effect across years, and all legumes would increase emissions.

L381 unfortunately the experimental data of the one experiment in Ethiopia presented here is insufficient to claim that N2O fluxes in the sub-sequent year are negligible under SSA conditions. It is unfortunate that the researchers didn't follow the dynamics of inorganic N in the soil or plant N uptake when they sampled GHG fluxes.

L385 it is also unfortunate that the researchers don't present data of N2O fluxes and soil N dynamics off-season. So this observation remains speculative.

L385 not clear what is meant with 'emissions were at par', neither why this is striking.

L395 the lack of explanation to the effect on mulching actually calls to explain this by measuring consistently the factors driving N2O fluxes such as moisture content and availability of substrate (inorganic N) over time.

L397 the relative effect of soil moisture vs inorganic N could have been tested if the researchers would have collected such data. Now this conclusion leads to speculation.

L398-410 this study doesn't present solid evidence to sustain this claim, because sowing date doesn't control per se GHG fluxes, but determines the state of soil and weather that the soil+crop system will experience. So giving prescriptions of sowing dates that are not tied to indications of environmental conditions wouldn't be useful at all. In

addition, this research didn't find any consistent evidence that legumes increase the emissions beyond the fertilised crop according to Fig 2, which shows that one treatment had higher N2O fluxes than the control.

L412-420, this section needs re-writing to make a comparison instead of a list of studies and their findings.

L420-424 for this comparison to be useful, please report the biomass measured that was added in year 2 across treatments.

L428, in my opinion the EFs should be re-worked with uncertain parameter ranges to be able to assess how far there are from IPCC. This statement is too crude given the procedures used to estimate the EF.

L433 the levels of N inputs could have been underestimated because there were no measurements of the real contributions of the legumes. Which soil has been used over decades? Not clear. Intense use of soils usually leads to loss of fertility not enrichment.

L441 dynamics of inorganic N not measured.

L454-474 this piece of text is not needed because it cannot be compared with the experimental results reported here. I would suggest contrasting the experimental results with the literature and avoiding listing all that is known for legumes in completely different climates.

L482-482 I understood that the researchers didn't measure the N 'carry over effects'. So this point is speculative.

L485-487 this statement could be verified at least against the soil moisture data.

L494 please consider environmental conditions instead of referring to sowing date alone. You could also discuss what would be the incentives for farmers to reduce N2O emissions.

L500 indeed more studies would be needed to confirm and to explain the results ob-

tained. I would suggest reflecting on the need to quantify N2 fixation, and to follow N mineralisation, especially key for legumes.

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