bg-2018-435

Author response to comments of referee #1

We'd like to thank reviewer #1 for his careful and detailed review and appreciate his valuable comments.

In the following list, the referee comments are printed in *italic* and author responses are printed in blue. For the majority of the minor (language related) comments we fully adopt the referee suggestions. Below only the comments are listed that required a specific response.

General comments

1. However, one main point that needs to be addressed is the final conclusion; I strongly disagree that you can conclude that an optimised diet (with additional maize silage) in system M leads to a 25% reduction effect for N2O emissions based on the smaller area needed for grazing. The authors need to take the N2O emissions related to the maize production used in the diet into account; otherwise this comparison is not valid.

It needs to be noted here, that we only considered the N_2O emissions related to the cow excreta on pasture in this study. This is in line with the IPCC concept for emission factors and inventory calculations that generally relate the N_2O emissions to specific N inputs (see Introduction line 8-10). The comparison of different agricultural production systems with full accounting of the production chain (life cycle assessment) is beyond the scope of this study and will be published elsewhere.

Yet we agree that the use of the term “system” and the corresponding phrasing was not always clear and consistent. We will rephrase the conclusion to clarify that the statement “the emissions showed a clear difference of about 25 % between the two systems” specifically concerns the N_2O emissions related to the cow excreta on the pasture. As mentioned in the conclusion, this demonstrates the mitigation potential of a N-reduced (N-optimized) feeding strategy. The latter does not necessarily require supplement maize silage feed but may also be achieved by an improved energy to protein ratio of the pasture grass.

2. Generally the authors need to be more careful with figure and table captions. The structure of some tables needs to be improved and the authors need to be more carful with units, especially when presenting cumulative fluxes (table 5). There are many abbreviations that were not explained (e.g. ECM, FAD, Q, A, V) or not very clearly (FD, FU, FU,temp, Fbg), which makes equations difficult to understand (section 3.2.2 and 3.2.3). Improving figures and tables and explaining abbreviations will help to make the manuscript easier to read.

We agree with the reviewer and will take his suggestions (see detailed comments below) for improving figures and tables into account. Furthermore, we will explain all abbreviations in more detail.

Detailed comments

P1, line 26/27: This conclusion is not correct, as the N2O produced during the production of Maize fed to the animal is not included in the calculations!

See answer to general comment #1 (above).

Introduction:

P1, line 30: Please add a reference for the GWP of N2O.

A reference will be added (IPCC, 2014).

P2, line 6: Please insert "from excreta" after "N loading. . . was shown previously" and insert N after exceptionally high.."

"From excreta" would not be correct here as the referenced study showed the effect of different N loading rates of inorganic fertilizer nitrogen on N_2O emissions.

The "N" was inserted as suggested.

P2, line 16: Please give a suggestion of how emissions could be reduced if individual contributions are better understood.

We will add the following sentence: "A better understanding of the individual contributions would also be very helpful to reduce the emissions, as e.g. dietary changes typically affect the excreted urine N which is mainly responsible for the high N_2O emission associated to excreta (Dijkstra et al., 2013)."

Material and Methods:

P3, line 15: use average values for clay, silt and sand from table 1

We will follow the suggestion of referee #2 and only keep the reference to Table 1 (omitting the values in the main text).

P3, line 17: The range of 10-50 and 7-40 % of Lolium and Trifolium is quite large; could you give an average ± stdev and the method of how it was assessed?

We will add the following information: "The vegetation consisted of a grass-clover mixture typical for Swiss pastures (78 ± 12 % grasses and 15 ± 10 % legumes; main species: *Lolium perenne* and *Trifolium repens*, 10 sampling times between May and September).

P3, line 25: You write that the optimized protein content reduced the N input to the pasture. Did you measure this? Otherwise, just write that it was expected to reduce the N input to the pasture.

We would like to keep the sentence unchanged. The reduction was calculated with the animal N budget model. That model (as explained in Sect. 2.3) uses measured data (e.g. milk yield, body weight gain, feed N contents) to calculate the excreted N.

P4, line 18: Please add the name of the model and give a reference

Unfortunately, there exists no official name or model reference. However, the model is based on the work by Bracher et al. (2011) and is used for the calculation of the Swiss greenhouse gas inventory. The model was used in other studies as well (Bell et al., 2017; Voglmeier et al., 2018). We will include the reference to Bracher et al. (2011).

P4, line 20: Move this sentence up to the end of the sentence (line18-20)

After rephrasing the previous sentence, we would like to keep the sentence position unchanged.

P5, line 10: change (Fig.2) to (Fig.2b)

Will be changed accordingly (but to Fig. 2a ➔ soil moisture).

P5, line 20-21: I am not quite sure if I understand this modification. Did you add a vent to the box? Then better to call it vent than inlet as the inlet is connected to the QCL. Please be more specific: I assume the 4 cm is the diameter and the 1m is the length of the vent tube and the 10 cm is the length of the foam material within the tube? What is the foam made of?
We agree with the reviewer that the modification was not properly described. As the referee assumed, a vent tube (to ambient air) was added instead of a fully closed circuit originally used in the Fast-Box. We will be more specific and describe the vent tube in more detail in the revised version.

P5, line 22: As you don't show or discuss any soil respiration measurements, I suggest to delete this information.
We would like to keep this information, as the CO_2 soil respiration was used as a proxy to check if the chamber was properly sealed (as discussed in Sect. 2.4.3).

P5, line 24: Insert "the" after "The inflow off. . ." I assume by "the inlet" you mean " the vent"? As the FB chamber is a closed dynamic system (acc. to Hensen et al.2006).
Will be changed accordingly (see also response above).

P5 line 26: please add explanations to all abbreviations used in equation 1 (V, A, Fcham)
Will be added accordingly.

P6 line 12: please give the make of the thermocouple
Will be added in the revised version.

P7 line 24: 500; add unit
Will be added ("500 data points").

P8 line 12: change (see Fig 2) to (see Fig. 2c). Please show the harvest event in the Figure (see comments to Figures)
Will be changed to Fig. 2c. We will show the harvest event in the Figure (as described in the answers to the Figures).

P8 line 33: Can you give a time period for the soil temperature classes?
The time period spans over the GOP. We will include this information.

P11 line 8/9: This last sentence is not clear. Please clarify which fluxes you are talking about (individual emission source; paddock or system M/G?)
We will omit this sentence as it is not necessary.

Results:
P11 line 12: "they varied significantly"; significantly different from what? Background fluxes?
The half-hourly fluxes showed generally a high variability during the grazing season. We will rephrase the sentence and state our intention more clearly.

P11 line 13: mention the harvest, were they increased after the harvest?
There was a short increase in N_2O emissions directly after the harvest event. We will include this information in the text.

P12 line 15-19: In Figure 8 FU,temp and FD,temp are fluxes averaged over 3 days, while in the text you are describing average daily values (?), which is confusion. I suggest to show average daily values in Figure 8, or use different abbreviations (e.g. FU,temp3d vs FU,temp1d), or only discuss 3d averages in the text. Its not clear what the "absolute highest FUtemp" is (5117 ug N2O-N m-2h-1), if the highest average value is 660 ug N2O-Nm-2h-1.

We agree with the referee that the paragraph is a bit confusing. We will rephrase it and only describe the 3-day averages plus individual single fluxes.

P12 line 20: you mention that Dung related emissions "showed a relation to excreta age", please mention what kind of relation. Please change "dung patch emissions" to "dung patch fluxes"

The relation can be seen in Fig. 8. We will add a reference to the Figure. Additionally we will change "dung patch emissions" to "dung patch fluxes".

P12 line 25: Were the background fluxes not also sign. smaller compared to dung patch emissions? Looks like it in figure 8.

The background fluxes are also sign. smaller than dung patch emissions. We will rephrase the sentence to "…were significantly smaller compared to the excreta emissions".

P12 line 32: How do you justify to set negative values to zero?

The measured 3 days averages are all above zero. We only set the corresponding values of the fitted function (second order polynomial) after about 25 days to zero. The function as used in our study (Fig. 8, Eq. 4) would always result in negative values, which would not be representative for the measured values anymore.

P13 line 6: As "FD,temp" is not influenced by environmental conditions it equals FD (?)This should be stated here.

We will include this information.

P13 line 7-14: Please define the three sectors. I suggest to insert (<0.27, 27-33, >0.33) after ". . .by three different VWC sectors." It would help to show this in a graph.

We follow the referee's suggestion and insert (<0.27, 27-33, >0.33) after "… VEC sectors". However, we do not want to include a graph as the paper already has quite a high number of graphs and the additional information provided by a graph would be comparatively low.

P13 line 13: do you mean "similar values" or comparable to what? Can you add a stdev?

We meant similar values. The values including the stdev would be 12 ± 3 µg N_2O-N m^{-2} h^{-1}. We will include this information in the text.

P14, line 17: It's not clear where the grazing period ends, therefore please add this information into the table (see comments table 10b).

We assume, that the referee means Fig. 10b. We will include this information in an updated figure.

P14 line 25-27: these two sentences are not very clear. What do you mean by variations? The magnitude of fluxes varied less? I suggest to replace "rather limited" with "less pronounced"

With variations, we meant the temporal variability of the magnitude of the fluxes (the blue dots in Fig. 10c versus the red dots in Fig. 10c). We will rephrase the sentence to "Nevertheless, the temporal

variability of the up-scaled 30 min FB fluxes was less pronounced". Furthermore, we will rephrase "rather limited" with "rather weak".

P15 line 2: But in Figure 11 it looks like fluxes were slightly higher for up-scaled FB fluxes.
We agree with the referee on this mistake. We will correct it by replacing "…slightly lower…" by "slightly higher".

Discussion:

P15, line 20/21: I don't understand this sentence
We agree with the reviewer, that the sentence was confusing and thus we will rephrase it as follows: "We assume that the EC fluxes are on average representative for the whole pasture system, although the contribution of the central paddocks X.11, X.12 and X.21, X.22 to the EC footprint is generally higher than the contribution of the other more distant paddocks (Fig. 4).

P15, line 25: Include "(data not shown)" at the end of "other characteristics" as you didn't show any productivity (yield). Delete "Also" at the beginning of the next sentence.
Will be changed accordingly.

P15, line 28-p16 line 4: This paragraph is difficult to understand. I strongly disagree that you can conclude that an optimised diet in system M leads to a 25% reduction effect for N2O emissions based on the smaller area needed for grazing. You need to take the N2O emissions related to the maize production into account, otherwise this comparison is not valid.
See answer to general comment #1.

P16, line 23: 1.03 kg N2O-Nha-1y-1, please explain in more detail how this value was calculated. This value should have been shown in the results section 3.3.2.
The value was calculated by using Eq. 5 (as stated) similar to the cumulative background emission in Fig. 12b (green area) but for the entire year using measured soil moisture. We will explain this more clearly in the text. This full year extrapolation value was only calculated for comparison with literature values. Therefore we think, it should not be part of the result section, as this section focuses on the grazing period (between March to November).

P16, line 26/27: This last sentence is out of context
We intended to provide a second way how these background fluxes on pastures can be stimulated. Nevertheless, we agree with the referee that this was not clearly stated and thus we will rephrase the sentence.
"On pastures, these background emissions can also result from trampling of the cows which can further stimulate the N_2O production via denitrification due to soil compaction (Bhandral et al., 2007)."

Tables:

Table 1: As soil depth is not really a parameter I suggest to re-arrange the table; one column for each soil depth, with missing values in each column as the different parameters have not been measured in all soil layers

We will try to re-arrange the table for better readability.

Table 2: What does ECM stand for? Please explain abbreviation (maybe in footnote).

It is the energy corrected milk. We will add this abbreviation in the table caption.

Have the animals been weighted before and after the experiment? Was the weight increase considered in the calculations of the excretion (heavier animals will excrete more)?

The animals have been weighted on a daily basis and the weight increase is considered in the calculations of the excretions. This is roughly described in Sect. 2.3 and in full detail in the referenced article by Voglmeier et al. (2018) for the same experiment. We will include more information on the animal measurements in Sect. 2.3.

Table 3: Please add information of flux measurement method (FB)

Will be added accordingly.

Table 4: Please describe what the different equations are: Parameterisations of 3 day average fluxes from EB measurements, split into background, dung and urine fluxes.

We will add this information.

"The equations are based on 3-day average fluxes from FB measurements on different emission sources (background, urine and dung patches)."

Table 5: I assume that you are showing cumulative fluxes. You need to mention this together with the time scale (per GOP?). I suggest to simplify the table by only having two parts; add a dotted line above the N input and to move the FB urine and FB dung fluxes above the EFs. Please add N input from dung. What does FAD stand for?

We will add the information about cumulative fluxes and the time scale. Furthermore, we will try to simplify the table as suggested. We can add the N input from dung, but actually wanted to keep that out of the table as it can simply be calculated from N total – N urine. FAD was a term used in a development version of the manuscript and thus will be deleted.

Table 5: What is "EC integral system emission EC," ? Reading in the text (P15, line 28-31) I have the impression these fluxes are up-scaled FB fluxes to the whole system. If they are EC emissions, please describe more carefully in the text. The unit is confusing as it is an emission (concentration per area per time). Reading in the discussion I understand what you mean, but in the table it's not clear. Maybe you can explain in a foot note. "EF total" is calculated from EC, while "EF urine" and "EF dung" are calculated from up-scaled FB measurements (or not?) This needs to be stated clearly.

The value/units represent integral emissions for the entire pasture area and the investigated grazing period. In order to prevent confusion and misunderstandings, we will change the units of this type of results (also in the abstract and in the main text) and express them in units of N_2O -N cow^{-1} h^{-1}, which has an equivalent meaning.

In addition we will reorganize the Table in a more logical way and include a footnote with detailed information on the listed quantities.

Figures:
Figure 1: P29 line4 Insert "(triangles)" after "the two EC towers. . ."
Will be added accordingly.

Figure 2 b): Move the legend, or change the scale so the bars for the high precipitation events in June and July are not cut off.
Will be changed accordingly.

Figure 2d): Add arrows for fertiliser application dates and for harvest date
We will add this information on Fig. 2c.

Figure 3: Change the area showing a) to being transparent
Will be changed accordingly.

Figure 5: Please explain the reason for dotted frame. It's confusing that the lines connecting #dung and # urine patches to "Paddock flux dung patches" and "paddock flux urine patches" cross the arrows leading to "paddock flux background" and "paddock flux urine patches", it looks like they are feeding into them as well. Try to show clearer (maybe with a curved line over the crossing line).
The dotted frame indicates a further processing step. We see, that this is actually not needed and will instead use the standard frame. We agree with the reviewer, that the crosses are a bit confusing and thus we will update the graph (as suggested, probably with a curved line).

Figure 6: Add arrows for exact fertilisation and harvest events. Add the date of the skipped value. It would be good to include the information of grazing periods in the graph to explain the increased fluxes.
We will add arrows for the exact fertilization and harvest events and we will add the date of the skipped value. Furthermore, we will add the information that for the analysis of grazing related emission, the non-shaded periods of Fig.6 were used. Detailed information of the rotational grazing regime is already displayed in Fig. 3c.

Figure 7: I suggest to change the unit to ug N2O-N m-2h-1, it makes it easier to read the values in the graph and to compare to values you describe in the text (for Figure8, where ug N2O-N m-1h-1 are used). In the legend insert "from different sources" after "the comparison of fluxes.." and add the information that the fluxes were measured with FB technique.
We agree with the referee and we will change the units and add the information on the flux measurement technique in the legend.

Figure 8: Same comments about units as for Fig. 7. Please add in legend that fluxes were measured with FB. Are there any standard errors for the background fluxes, or were they too small to be seen? I suggest to change to x-axis description to "age of excreta [d]". Give information about the fitted curves (refer to equation 3+4).
We will change the units and the x-axis description to "age of excreta [d]" and we will add a reference to Eq. 3, 4.
There are standard errors for the background fluxes, but these are too small to be seen. We will add this information in the legend.

Figure 9: Same comments about units and mentioning that FB method was used as for Fig. 7.
We will change the units as requested.

Figure 10: It would help to add the grazing period in either Fig 10 b) or c)
The grazing phase spans over the full time scale as indicated in the legend. The up-scaled paddock fluxes of four single paddocks can be seen in Fig. 10b.

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IPCC, 2014: Climate Change 2014: Synthesis Report . Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)], IPCC, Geneva, Switzerland., 2014.

Voglmeier, K., Jocher, M., Häni, C. and Ammann, C.: Ammonia emission measurements of an intensively grazed pasture, Biogeosciences, (15), 4593–4608, doi:doi.org/10.5194/bg-15-4593-2018, 2018.