bg-2015-599

Answers to Referee Comments of Susanna Rutledge (Referee #2)

We'd like to thank Susanna Rutledge for her valuable comments and inputs. We really appreciate here detailed comments to improve our manuscript.

(referee comments are printed in *italic*, author responses are printed in blue)

Main concerns

1) *For a paper that claims to discuss the uncertainties in the NECB ('flux uncertainties' is even in the title), the uncertainties are really not very well discussed in the paper. I assume the calculations have been done correctly, but they need to be described in much more detail to allow their reproduction by fellow scientists. In several sections (e.g. in P20078, L27/28; Section 2.4.1, L24; Section 2.4.3) short descriptions of final uncertainty estimates of the components of the NECB have been provided, but almost all these sections need to provide more information and clarification. An additional section in the Supplementary Materials would be most useful so that the main text remains uncluttered.*

   We agree with the referee. As suggested, we will add a more systematic and detailed description of the uncertainty calculation/estimation of the various carbon budget components in the Supplementary Material (see also details below).

   For example:

   - *I realise that for feed intake (Section 2.4.2) the uncertainties may be very hard to determine. Was any attempt made to estimate the uncertainty in $E_{DM\text{-}intake}$ (which would feed into $F_{C\text{-}grazing}$)?*

     The referee is right with the statement that the uncertainty of the feed intake is most difficult to determine. We consider the (systematic) uncertainty of the used intake estimation model as the most important factor. This uncertainty could not be determined directly but had to be estimated based on other literature studies evaluating the performance of similar model approaches. We will include a description of this uncertainty estimation in the revised version.

     Also, do I read correctly that it is implied that the uncertainty for the amount of supplement feed provided was assumed to be zero?

     This is not the case. As stated on P20082 L2, the uncertainty of the supplement feed ($F_{C\text{-}feed,off}$) was estimated to 6%. The uncertainty is low, because the effective feed amount was generally measured (weighed) for each cow.

   - *It would be helpful if the uncertainties in DM amount, DM content and C content were spelled out explicitly (e.g. P20082, L2-3).*

     We consider the uncertainty of the C content (directly measured) as much lower than the uncertainty of the DM amount. Yet, we will add these uncertainties in more detail in the revised version.

- *Section 2.4.3 uncertainties in excreta need more explanation. Uncertainties in which budget terms contributed to the uncertainties in $F_{C\text{-}excreta}$ and how were uncertainties combined?*
  Originally, we quantified the excreta term as the residual of the animal C budget (which makes the quantification of an independent uncertainty very difficult). But a reconsideration based on the referee comment led us to the conclusion that it is preferable to estimate the excreta term (and its uncertainty) separately based on the measured feed digestibility. We will add this modified calculations in the revised version.
  In this way the closure of the animal C budget can serve as a really independent (and illustrative) consistency test. The modified calculations have a very minor influence on the NECB results and do not change the respective conclusions.

2) *It would be helpful if the actual contribution and uncertainties of the components of the GHG balance would be provided in the supplementary material (in addition to Figure 5 in the main text). It would appear that nowhere in the paper the contributions from CO_2, CH_4 and N_2O are actually summed to one total GHG budget. It is unclear to me why the authors haven't done this. This would also allow the GHG budget to be compared with that found in other studies.*
   We will add a table with the numbers of the GHG budget components in the supplementary material. Because the focus of the paper is on the carbon budget and not on the GHG budget (which is only presented for context reasons, see also comment to referee #1), we did not present the numbers explicitly in the text.
   It also has to be noted that the system limits for a full GHG budget are not necessarily the same as for the carbon budget. The NECB equaling the carbon stock change of the pasture field is intrinsically a property of the pasture (soil) itself, independent of the system boundaries chosen for the calculation. In contrast, choosing different system boundaries leads to conceptually different GHG budgets (e.g. including or excluding the CH_4 emission from enteric fermentation) that may not be comparable with the results of other studies. To better illustrate the focus of the paper and to reduce the expectation of the reader to find a full GHG budget, we will change Sect. 2.5 from 'Greenhouse gas budget' to 'Comparison to other greenhouse gas fluxes' and Sect. 3.4 from 'Greenhouse gas budget of the dairy cow pasture' to 'Comparison to other greenhouse gas fluxes of the dairy cow pasture'. The text, including the abstract, will be revised accordingly.

Other comments

Methods

The budget calculations considered only the 99 days of the year that the cows were grazing the study site (P20075, L10). However, later on the authors state that the NECB was determined for a full calendar year (P20075, L25). These statements are confusing because they seem to contradict each other. From reading a further explanation on P20078 I assume the statement in P20075, L10 only applies to cow-related C fluxes and not all budget components. If this is correct then the statement in P20075, L10 needs re-phrasing to make this clear.

The last sentence of Sect. 2.1 (P20075, L10) seems to mislead the reader (also referee #1 commented on this issue). We monitored the CH_4 and CO_2 exchange of the studied pasture field during the entire year 2013. However, the cow herd only spent a total (summed) period of 99 days on the

investigated pasture. This is first due to the seasonal cycle with a dormant winter period and secondly due to the lower than expected productivity of the pasture during this year (see P20075 L7ff). In order to better illustrate this situation, we will add a Figure with the pasture days in the revised manuscript (see Fig R1 in answers to referee #1). While the carbon budget (NECB) for quantifying the soil C sequestration of the study field is quantified for the entire year, some animal related budget components are first determined for the cow herd and thus need then an appropriate time attribution to the study field (here 99 days for the year 2013). We will therefore rephrase the corresponding statements as suggested by referee #2.

Section 2.4.1 about live weight increase: I couldn't follow these calculations. If cows weighted on average 640 kg (Section 2.1, L25), then a 6% increase would equal about 38.4 kg per cow over the grazing season of 99 days. Per day, per cow, this is 0.38 kg and not 0.2 kg. Did I miss something?
The formulation in the original manuscript seems to be misleading and will be clarified. The increase of the live weight of the cows was determined for the entire grazing period (209 days = 9 April to 4 November 2013) and not just for the "grazing days" (99d) on the investigated pasture. Per day, this is 0.2 kg $head^{-1}$ d^{-1} (=38.4 kg $head^{-1}$ / (209 d)).

I would also add here the full calculations about the implications of LW increase presented currently in P20084-L26 onwards (which requires the C content of meat which is currently missing from Section 2.4.1) so that it is dealt with in one place.
We will move the calculations in P20084-L26 to Sect. 2.4.1 as suggested by the referee.

Results and discussion

P20090, L3-6. Can the authors give a possible explanation for this difference in NECB between your findings and these other studies/study sites?
Explanations for the differences are manifold (inter-annual variability, different climatic conditions, different managements types, soil types, etc.). We abstained from a comprehensive comparison of the NECB to the results of other studies/sites because, as stated in the paragraph following P20090 L6, we think that several years of measurements are necessary for a meaningful comparison of such budgets.

P20091, L4-6. I agree that the simultaneous application of both methods is useful as a consistency check, and am impressed at the level of agreement of the two methods. However, as I understand it the two methods were not entirely independent because the estimation of $F_{C\text{-}grazing}$ *(needed for Method II) was not based on actual measurements of pasture biomass removed, but instead derived indirectly from milk production (which was also used in Method I). This may be worth mentioning.*
The statement is correct. We will mention, that the two methods are not totally independent. However, as mentioned above, the uncertainty of the grazing/feed intake is mainly due to the systematic error of the applied model rather than due to the error of the milk yield used as model input.

P20091. The (size and contributions from individual gases of the) GHG budget should be discussed in more details and the findings compared to other studies. I realise that the GHG budget may not have been the main focus of the paper, but if the authors choose to present the results regarding the GHG balance, they need to link them better to the existing literature. I feel it would also be worth adding a few words about the GHG balance to the abstract.

See again the answer given under Main Concerns 2. Because the GHG budget is not the main focus, we will remove any statement concerning the GHG budget from the Conclusion (i.e., P20091, L9-15) and change the sections 2.5 and 3.4.

Minor comments

We thank Susanna Rutledge for all her minor comments improving the manuscript. We will consider them in the revised version. Here only the comments that need an answer are listed.

P20083, L6. What is EKL?

EKL is the Swiss Federal Commission for Air Hygiene (Eidgenössische Kommission für Lufthygiene EKL) and is used here as a citation. We will change this and add "... based on the report of the Swiss Federal Commission for Air Hygiene (FCAH, 2004)". The Reference will also be changed to English.

Section 2.4.2 L17 Conversion factor needs reference.

This conversion factor can be found in the IPCC 2006 Guidelines, reference will be added.

P20085, L13. This proportion of C excreted in dung was actually not determined by Rutledge et al, 2014 but by Woodward, S.L., Waghorn, G.C., Bryant, M.A., Benton, A., 2012. Can diverse pasture mixtures reduce nitrogen losses? In: Jacobs, J. (Ed.), Proceedings of the 5th Autralasian Dairy Science Symposium, Melbourne, pp. 463-464.

Reference will be changed as suggested.

P20085, L28. I got −189 gC m^{-2} y^{-1} when I add up all exports in Table S2 for NECBtot, not −245?

The referee calculated correctly. This number was a mistake. We will change it to −189 gC m^{-2} yr^{-1}.

P20087, L22 If total losses in the NECBtot method were indeed −189, the contribution of $F_{C\text{-}CH4,cows}$ to these losses was 9%, not 7%

will be changed

P20087 last paragraphs of Section 3.2. It may be worth stating that even if small losses of ~10 gC m^{-2} y^{-1} were added to the calculated NECB's, the conclusion wouldn't change (i.e. the would remain C neutral)

We will add a sentence at the end of the last paragraph of Sect. 3.2, stating that even if leaching and erosion would be considered, the conclusions on the budget result do not change.

P20089, L18-19. You may want to add a reference to Kirschbaum MUF, Rutledge S, Kuijper IA, Mudge PL, Puche N, Wall AM, et al. Modelling carbon and water exchange of a grazed pasture in New Zealand constrained by eddy covariance measurements. Science of the Total Environment. 2015; 512–513(0):273-86. They also concluded the risk of underestimating cow respiration losses if grazing events are not captured completely.

We will add this reference.

P20090, L26-27. Awkward phrasing. Maybe say "… carbon-neutral budget, both methods resulted in considerable uncertainties, with slightly lower uncertainties when using the NECBtot approach (system…."

Thanks for the suggestion. We will change the text accordingly.