

Referee Comments

Susanna Rutledge, University of Waikato (Referee #2)

This paper is the third in a series of papers prepared from a high quality dataset collected in 2013 on a research farm in Switzerland over a pasture rotationally grazed by dairy cattle. The first two papers focussed on CH₄ and CO₂ exchange, respectively, whereas the current paper rounds out the picture and discusses the carbon and greenhouse gas balances. The NECB was determined in two ways: both with and without including the cows within the system boundaries. The two approaches agreed very well (which is quite an achievement!) and found the pasture to be C neutral. The paper includes a thoughtful discussion about the applicability of either budget calculation approach. The main finding regarding the GHG budget was that the CH₄ from the animals was the main contributor to the GHG balance.

Currently there is great interest in the impact managed ecosystems have on the global climate, and the C and GHG balances of managed pastures form an important part of that discussion. As such, the paper addresses relevant scientific questions within the scope of BG. The manuscript presents novel concepts based on data that haven't been presented before. The analysis which focusses on the two budget approaches is novel and seems well-executed. I enjoyed reading this paper. It is well written, clear and worthy of publication in BG.

I do have some (mostly minor) concerns which need to be addressed before publication.

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. 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 EDM-intake (which would feed into F_c-grazing)? Also, do I read correctly that it is implied that the uncertainty for the amount of supplement feed provided was assumed to be zero? It would be helpful if the uncertainties in DM amount, DM content and C content were spelled out explicitly (e.g. P20082 L 2-3).
 - Section 2.4.3 uncertainties in excreta need more explanation. Uncertainties in which budget terms contributed to the uncertainties in F_c-excreta and how were uncertainties combined?
- 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 CO₂, CH₄ and N₂O 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.

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.

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 38.4kg 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? 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.

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?

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 -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.

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.

Minor comments

P20080-16. I assume the units of E_c -milk are $gC\ head^{-1}\ d^{-1}$? Add 'per day' to L16.

Section 2.4.2 L15. Is EDM-intake in $kg\ CM\ d^{-1}\ head^{-1}$? Add 'per head'

P20083-L6. What is EKL?

Section 2.4.2 L14 Replace 'meat gain' with 'live weight gain' to match wording in Section 2.4.1

Section 2.4.2 L17 Conversion factor needs reference.

Section 3.1, L13. 'The applied models' – it may be helpful here to refer back to Section 2.4.2

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 Australasian Dairy Science Symposium, Melbourne, pp. 463 - 464.

P20085 - L25. 'components of higher magnitude' – maybe just say 'larger budget components'

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

P20087-L22 If total losses in the NECB_{tot} method were indeed -189, the contribution of Fc-CH₄ cows to these losses was 9%, not 7%

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

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.

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

Just for completeness, I list all other aspects that I was asked to review and that I felt were satisfactory:

- Does the paper address relevant scientific questions within the scope of BG? Yes
- Does the paper present novel concepts, ideas, tools, or data? Yes
- Are substantial conclusions reached? Yes
- Are the scientific methods and assumptions valid and clearly outlined? Yes
- Are the results sufficient to support the interpretations and conclusions? Yes
- Do the authors give proper credit to related work and clearly indicate their own new/original contribution? Yes
- Is the overall presentation well-structured and clear? Yes
- Is the language fluent and precise? Yes, except in the few places where I have recommended alternative phrasing.
- Are mathematical formulae, symbols, abbreviations, and units correctly defined and used? I didn't notice any mistakes.
- Should any parts of the paper (text, formulae, figures, tables) be clarified, reduced, combined, or eliminated? No
- Are the number and quality of references appropriate? Some section would benefit from stronger links to the literature as discussed above.
- The length of the paper is appropriate for its content.
- P20088, L16-18 and Figure 4. Very neat analysis, very insightful!