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REVIEWERS COMMENTS AND RESPONSES OF THE AUTHORS
(Authors responses = blue writing)

COMMENTS TO THE AUTHORS

Editor/Chief-Editor Landbauforschung

We will accept your manuscript incorporating major revisions based on the comments of the reviewers. So please take into account the reviewers' recommendations to strengthen your position and to sharpen scientific evidence of your conclusions and write a short response to each of the comments.

We also got some further comments from the reviewers. They are listed below for your further consideration for improving the text:

- Their summation that grass is the optimum ruminant feedstuff rather ignores the fact that the grass production achievable in NZ (and a limited number of other regions around the world) is simply not possible in many areas. Not necessarily the optimum but usually the cheapest. Anywhere temperate grasses dominate, and assuming adequate moisture, pasture will have roughly the same annual yield – it's just that in cooler zones that yield is achieved in a much shorter time frame, eg total pasture yield in northern Germany per ha per year is similar to that of NZ's lower North Island, it's just that it occurs over 6 months instead of 12. Obviously this requires much more forage conservation (silage) in Germany compared to NZ but assuming no distortion due to subsidies, conserved forage should still be cheaper ($ per MJ) than concentrates. Under a seasonal system, cows are dry during winter and thus there is a reduced demand for feed at this time. It does, of course, depend how far north we are discussing. For example Ireland is easy due to the Gulf Stream but Sweden or Scotland may be more of a challenge. Could write a whole paper on this subject!
- Data cited as being present in Figure 2, is absent and Figure 2 presents an entirely different data set. - referred to a different figure in a previous draft…deleted
- However, many measures are described very briefly and some important things are missing (e.g. general introduction on the production systems in NZ, potential of secondary plant metabolites and improved grazing management for CH4 reduction, relevance of NH3 losses)." Addressed

Please follow strictly the instructions for authors. The revised version of your manuscript will be evaluated again by the Chief editor and, if necessary, by the reviewers.

The reviewers raised a lot of points that needed discussion (see below). If I had included everything in the paper it would have been way too long so I've tried to limit the additions requested by them. I hope I have adequately addressed most of their concerns.

Reviewer # 1:
Summary and specific issue
The manuscript aims to describe the development of GHG emissions from ruminant production in NZ and proper measures to reduce these. According to this the manuscript fits to the topic of the specific issue "Exploration and mitigation of greenhouse gas emissions in ruminant and grassland systems" The presented results derived from national GHG inventories, showing a large contribution of CH4 and N2O with increasing trends on total emissions from the agricultural sector. The majority of the UAA in New Zealand is used for ruminant production purposes with decrasing number of animals for sheep and vice versa for dairy. However, the authors also observed a increasing efficiency in terms of GHG emissions per unit of product for sheep but a lower trend for dairy. In brief, there are several mitigation measures

described for CH4 and N2O emissions, whereby vaccines for CH4 reduction and improved nitrogen cycling with lower external use of mineral fertilizers are highlighted as most promising strategies.

General comments

The paper gives a good overview about the situation of GHG emissions from the agricultural sector in NZ. However, most of the measures are not new and most of them are described very briefly with only a few references. Moreover, I would appreciate if the authors could give more information in the introduction chapter about the UAA in NZ and the share of land use types. Some more sentences about the dairy systems itself (herd sizes, breeds, milk-yield, supplement use, N-surplus etc) would be helpful to understand the current situation of production and the impact of the proposed mitigation measures. I have some more detailed concerns, which is described further below:

Detailed comments by line

Line 6-12: Please give some more information about the UAA and land use types (e.g. share of permanent grassland, arable). Its not clear what the current intensity of production is of the pastoral systems. The dairy sector has a big importance for NZ. Please describe the avg production parameters in brief. Addressed

Line 22-29: I don´t think a pie chart is necessary here. My preference would be a stacked barchart comparing the increase in emissions between 1990- today. This would give a better overview about the trend as well as the share of emission sources. Sorry, I don't agree. A stacked bar chart over 27 years would be quite complex. The idea of doing a linear regression was to simplify the trend since emissions from different sources have varied markedly over time. Comparison with the rest of the economy is addressed in the text.

Now it implies that CO2 from urea and lime are of great importance but I guess in comparison to CH4 and N2O it is not. It totals 15% of the growth in emissions, relatively small but still significant

Line 26: Can you give an additional comment on the share of emissions from external resources? Now addressed at lines 42/43

Line 29-30: Direct CO2 release from lime application is not a consequence of microbial activity. It's a typical bicarbonate formation in solution, whereby CO2 is released. For urea it's an enzymatic reaction. Point taken! Addressed line 54

Line 50-53: There is no reference mentioned here! Done

Line 57: Delete "(as are dairy cows typically in the northern hemisphere)" Done, but I'm not sure what the objection is here

Line 58: Add: "….emission intensity per kg DM-intake". I've added the correct measurement

Line 58-60: This fact is heavily dependent on the soil type and management. On the system level it is still part of the debate, if intensive systems generate a lower CF in comparison to low-input systems. Indeed, the total emissions per cow/ha will increase but it is not clear for the "footprint". Latest results showed that both, low-input and intensive, show a potential for low emission on product level (e.g. Lorenz et al, 2019 https://doi.org/10.1016/j.jclepro.2018.11.113). However, out of many reasons this statement might be true under NZ conditions. Thanks for the reference. As the paper points out, attempting to compare the CF of different systems across different countries that have used different metrics is rather difficult. The difference between emissions intensity (kg CO2eq/FPC kg milk) and emissions per ha as a true measure of environmental impact are discussed under "Resource Efficiency"

I am also wondering, why you do not refer to the potential of improved grazing management to reduce CH4 emissions per kg DM intake? Grazing of dairy cattle in NZ is generally well managed. Any improvements are unlikely to have an effect on methane unless it involves reducing cow numbers (ie increasing per cow intake which tends to improve FCE)

Line 66-68: The authors completely ignored the discussed advantages of particular plant species rich of secondary plant metabolites (e.g. tannins) with a positive effect on methane formation. This was already discussed in the literature for sheep and dairy (e.g. Bhatta, R., 2015. Reducing Enteric Methane Emission Using Plant Secondary Metabolites. In: Sejian, V., Gaughan, J., Baumgard, L., Prasad, C. (Eds.), Climate Change Impact on Livestock: Adaptation and Mitigation. Springer India, New Delhi, pp. 273-284). NZ evidence is inconsistent in this regard. Chicory may have some effect at certain stages in its

growth but dosing animals with tannins has been unrewarding. Certainly tannins assist with reducing urinary urea output (and thus N2O) due to a greater proportion of dietary N being partitioned to faeces. Plantain appears to be the most helpful plant in this respect (see lines 214-219)
Line 119: delete "." after "…to provide a" Done
Line 161:Add a reference! Done
Line 164-171: In this paragraph there is nothing mentioned about NH3-volatilization. Indeed, the N2O fluxes from manures storages might be low but NH3-emissions as indirect GHG are high and are dependent on storage time and temperature. Moreover, NH3 losses from slurrys are of foremost importance for the nutrient efficiency of manures. Maye this is for lower importance under NZ conditions as the quantity of storage is low due to the high rate of grazing days per year. When the latter is true, you can just mention or explain that fact. Done. I've also added some background (lines 193 – 206)
Line 173-176: Its not directly the precision testing of the soil-N-status. A lot of work is going on to measure the N-status indirectly by N-sensors (N-status in leaves). Even though this investments are high these techniques might be of larger importance in the future combined with remote sensing systems. Yes indeed. Anything would be useful! I've deleted the reference to soils
Line 192: please use the full name of nBTPT Done
Line 207-212: No reference used in the whole paragraph! Addressed
Line 219: What do you mean with associated CO2 emissions? Not clear! The CO2 emitted as a result of hydrolysis - inserted
Line 222: Not specified in the manuscript: What do you mean exactly with integrated? Rewritten

A check if all conclusions are justified an supported by the results
I like to conclusion, however, the statement that vaccination is the only solution to reduce the CH4 emissions seems to me less evidence based in the text as there are many concerns about animal health in this context. I would recommend to delete this sentence in the conclusion. I state "Unless a practical feed additive is developed…" With respect to vaccination, I'm quoting the NZ Parliamentary Commissioner for the Environment. Reference added

A check of the need for tables and figures, and the adequacy of the references
I would recommend to use a stacked barchart for figure 1 instead of a pie chart. The percentage of increases are good to know but the share on total emissions is much more important for me. Moreover, I would try to avoid black colored letters on a red background. I've moved the numbers to the outside
References are used very extensively.

Recommendation
After improvements the manuscript can be considered for publication: **Major revision needed**

Reviewer # 2:

General comments and recommendation

This is an interesting opinion piece about GHG mitigation from pastoral livestock systems in NZ. The authors make some good points about the unique challenges of GHG mitigation in pastoral systems. It is generally a good overview that is strong on opinion, but in some cases, weak on supporting evidence. I am not clear who the target audience would be for such a paper. The depth of analysis is somewhat superficial and certainly not to the level that I would expect for a scientific audience. It might be acceptable as a white paper meant to inform readers that have little in-depth knowledge. Yet, at the same time if it is for general readership, I would expect less use of undefined, colloquial terms. There are also many vague statements, and many statements lack supporting references or data. **The recommendation would be that the paper needs a major revision, in which the authors provide greater depth in their analysis, before it would be acceptable.** The writing style is also very causal, with a lot of undefined and non-scientific terms used. Some examples see further below:

Specific comments by line

"P2 L51 "In sheep a reduction can amount to 4-6%". What does this mean? In sheep or for sheep production? Percent of what? By when will this be achieved? Clearer language needed here. Reference added

L51 What about for dairy? Many dairy breeding companies around the world are now selecting on the basis of methane potential. What is the scope for NZ? Work is being done in this area (genetic analysis) but is of relatively low priority for the reasons mentioned

L62-65 I find it surprising that the authors did not at least acknowledge 3–nitrooxypropanol inhibitor, which will be on the market in the EU early 2021. I recognize there may be difficulty of supplementing 3–NOP on pasture, but what about slow release forms or supplementation at the time of milking? At the very least some discussion of the potential is needed here. Supplementing at milking only works for a brief period. Short discussion on slow release mechanisms now included

L67. What is forage rape? This sentence is not informative. Botanical name inserted

L72 20% reduction per animal? Or by the industry if adopted at 100% or some other adoption rate? Both How was this percentage determined or what is the basis for this 20%? Estimate by scientists involved in the project (reference added)

L98 What is "animal wastage" . I can understand feed wastage, but how can animals be "wasted"? This is a common term used in NZ . Primarily cows that do not get pregnant but also those that die for various reasons or must be culled due to low production or chronic disease eg mastitis, lameness. The latter animals may or may not be fit for human consumption; if not, they become pet food (zero income for the farmer).

L109. Where does this number of 5% come from? Just seems like it was pulled out of a hat. Reference added

L178 Latin names for chicory and plantain. Done

L184. I am not sure the authors use the word carbohydrate correctly. Carbohydrates in ruminant diets are mainly starch, sugar, and fiber. Obviously increasing carbohydrates will dilute out nitrogen, but if the nitrogen is in the forage, how do you increase carbohydrate concentrations without feeding grain? Feed maize (or grain). Substitution means less grass is eaten (inserted). Is there potential to breed grasses for low-N content? Don't know but low N grasses such as subtropical species tend to have low digestibility. Supplementing grass with maize will decrease N content of the diet but it isn't really about increasing carbohydrate, but rather maize is low in nitrogen content. Yes. Maybe what is meant here was increasing the fermentable carbohydrate or starch content to improve nitrogen use efficiency (capture) in the rumen? The protein content of temperate species varies markedly through the season. If no synthetic N is applied in summer, protein levels may drop low enough for some rumen recycling of urea to occur. This is discussed in the reference at line 184. In any event, this concept is very poorly explained and needs to be re-written.

L199 "It is important to read such figures in context" What does this mean? rewritten

L201 -205 What is the reference for these numbers? Beef+Lamb (ref already included)

L207-212 Same here? Beef+Lamb (ref already included)

L209 What is MS? Milk solids (now line 18)
L227 Do you completely ignore the potential of animal breeding then? See above Is there no potential for lick blocks that supply inhibitors? Too much variation in individual intake What about the potential for early life intervention to manipulate the animal's rumen microbiome? Can't see how this would work
L239 Grass is not always the cheapest feed in all countries. There are many farms in China and Japan that import forage such that it is more costly than grain. Such systems may only be viable due to subsidies. They are probably neither economically nor environmentally efficient. Also, your argument does not consider the additional land area that is required. It depends. You need land to feed cows. Whether you use the land to grow grass or grain, it comes down to two things: the economics of producing the MJ per ha actually consumed by the animal *and* the environmental impact of that land use.
L239 and 240. By "grass" do you mean forage? Not sure…Yes
L243 What are "herb" species? Eg chicory and plantain. This is a common botanical description of non-grass species
L251-255 I do not see any basis for this conclusion about the northern hemisphere. If pasture availability is only 4-6 months in northern countries, this means 6-8 months of the year where the cows have no pasture/feed. How would this work? This conclusion is not supported at all be the paper, and is strictly based on the authors' opinions rather than an in depth analysis with supporting evidence. The other reviewer also raised this point – see comment above. I'm not sure if there is space to add this discussion to the paper…

REVISED VERSION

Editor/Chief-Editor Landbauforschung

We are pleased to inform you that **we'll accept your revised manuscript "Position Paper: Greenhouse Gases from Pastoral Farming – a New Zealand Perspective"**, which you submitted to Landbauforschung – Journal of Sustainable and Organic Agricultural Systems after some final corrections.

There are still some open questions and suggestions by the two reviewers left, please find them below. Please clarify and correct these points.

Reviewer # 1:
The authors addressed most of the questions of the reviewers. Accordingly, I have only minor comments (see further below). After revision it can be considered for publication in the journal.
Line 137. The full stop is not placed correctly done
Line 174: Change "N2O" to "N_2O". Please check the whole document. Do accordingly for "CO_2" and "CH_4". Done but unfortunately my version of excel doesn't allow subscript for charts...
Line 185: That herbicides trigger denitrification is a very general comment. Please specify. Reference supplied
Line 198: Eliminate one of the full stops. done

Reviewer # 2:
The authors present a highly opinionated, superficial perspective on options for GHG reduction. I think it is very important that it be clearly stated that this is their interpretation based on their assessment of the situation. It's a position paper, not a review! I am sure that other researchers in NZ would not agree with this interpretation. For example, they completely discount the potential of animal breeding and use of inhibitors That is not the case; as I have pointed out these are longer term strategies with technical issues and of unknown efficacy– not sure some of their colleagues working on these topics would fully agree with this synopsis. As stated previously, many of the claims they make lack supporting references or data. Everything important is referenced. Space precludes further details.

Addition of the short description of NZ dairying is helpful, but it would also be helpful to the international audience if the approximate fat and protein corrected milk yield could be provided (it can be calculated as per the International Dairy Federation guidelines). Most readers will not understand milk solids, but would understand milk yield. Done
There is still an overuse of colloquial and local terminology that is not universally understood.
In terms of the conclusion, I must admit that I don't understand the statements: " The strongest growth in agricultural emissions since 1990 has been due to N2O…""plus associated CO2 released as a result of soil hydrolysis of urea" and "The *growth* in methane emissions since 1990 has been considerably less than the growth in CO2 emissions" "from the energy sector" in view of Figure 1. The figure shows the increase is actually greater for methane (46 vs 39%). Perhaps I am missing something here, so this needs some clarification. I think I've made it clear much of the CO2 in Fig 1 is directly due to urea application; add 39 and 12 and you get 51 Alternatively, Figure 1 might be best represented as a histogram for 1990 vs 2017, so the relatively growth of each gas is clear. Unfortunately, comparing only 2 years may give a misleading impression due to year-to-year variation. A linear regression better demonstrates the trend over time.