

REVIEWERS COMMENTS AND RESPONSES OF THE AUTHORS

Revision Notes by authors (blue-written)

We thank the editor and both reviewers for a careful analysis of our paper and constructive comments. Guided by these comments, we have revised the paper. Please find below a response to every reviewer comment.

COMMENTS TO THE AUTHORS

Editor/Chief-Editor Landbauforschung

We will accept your manuscript incorporating major revisions based on the comments of the reviewers.

Generally your vision in the position paper is fed by a smoothly functioning 'digital monitoring network with state-of-the-art-algorithms'. Difficulties to generate proper farm data in an appropriate density and quality (e.g. feed quality and intake in ruminant systems) will come up. Also you imply that there are existing models for any application and situation. This is questionable and debatable - but your position is that merging and applying existing skills on a broad scale is a necessary step to gain new information and to initiate (self-)regulatory mechanisms.

As you are on a high level of abstraction your position paper needs more examples on practical possibilities for a successful performance. Some examples on techniques and models that are already available, that are in use or have been used to mitigate greenhouse gas emissions from ruminant and grassland systems (the systems we are targeting in our issue). You should try to present more information on how exactly existing knowledge and known obstacles might be used to successfully develop something new (maybe on prototype level). These comments are also under consideration of the comments of the two reviewers.

Maybe this can be supported due to the possibility we newly offer to include more references (up to 20) in position papers.

Response: Thank you for your evaluation. The implementation of a digital monitoring network will certainly face many questions and an intensive debate. An argument also used by one reviewer is that the collection of very detailed farm information may not be feasible. However, existing policies in the agricultural sector require farmers already to submit very detailed information. This proves that farmers do submit detailed information if there are sufficient financial incentives.

Our position is that emissions quantified with accepted state of the art models should be financially more attractive than simplistic approaches with higher uncertainty. We have included and referenced more examples of scientific models used for quantifying agricultural emissions.

As we received different evaluations concerning the feasibility of your 'digital monitoring network' in practice and in the political reality, and anyway dare willing to publish positions, we would like to reserve the right to publish the reviewers comments in addition to your paper. Naturally under reservations that they and you authorize this after having a second view on your revised paper. We'll stay in touch with all participants until publication to approach a transparent and satisfactory outcome.

So please take into account the reviewers' recommendations to strengthen your position and write a short response to each of the comments. 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.

Specific Responses to Reviewers

Reviewer # 1:

Summary and specific issue

The authors propose a digital monitoring network with five components –scientific tools, cooperating farmers, an user friendly IT platform, cooperating governmental authorities and interest groups as well. This network should combine sophisticated scientific models with a comprehensive management information. The network should collect available information to a comprehensive tool for a better assessment of agro-environmental impacts beyond greenhouse gases.

The need of a digital monitoring network is based on the fact that diffuse non-point emissions are difficult and expensive to assess. On the one hand the network might replace costly measurement devices and on the other farmers may gain benefits by taking part in the network by using the platform information for an improved farm management.

The article represents a Position paper which fits to the issue of Landbauforschung. The paper is easy to understand. The readability is good.

Generally comments

The idea of a monitoring platform and a more holistic approach to improve farm management and to reduce environmental impacts is absolutely welcome. But this idea is neither really new nor easy to implement in practice. The motivation for farmers to take part in the proposed network does not convince completely. It might be beneficial to spent subsidies for their contributions.

Response: Thank you for your comments. We are aware that many studies during the past decades have used models to estimate agricultural emissions and have added more references to existing approaches. We believe that there should be a financial motivation for farmers to participate. In the revised manuscript (last paragraph of section 2), we explain this argument.

And it is another open question whether this procedure generates the required emission reduction for the cattle farming sector. But the purposed platform might be an useful tool to reduce excess and avoidable environmental impacts.

Response: Emission reductions can be achieved through more emission-friendly production systems or through changes on the consumption side. For example, if there is no more room to decrease emissions per kg cattle meat, total emissions from the cattle sector could still decrease by producing (and consuming) less meat.

Detailed comments

Line 1: The digital monitoring is not only usable for greenhouse gas emissions but also for many other assessments (efficiency of production, labour efficiency, nutrient flux). The title should be reconsidered.

Response: Generally, we agree with the reviewer's argument. In both the original and revised manuscript, we conclude: "The complex modelling system would also permit monitoring of agro-environmental impacts beyond greenhouse gases, including nutrient and pesticide leakages to water bodies and soil erosion." Our paper focuses –for the time being– on monitoring of greenhouse gas emissions from livestock: 1) The special issue in Landbauforschung is dedicated to livestock, 2) Greenhouse gas regulations are a dominating topic in current political discussions, 3) A position paper has very limited space. To discuss other agro-environmental impacts or private farming benefits (productivity and labor efficiency) in appropriate detail would require much more space. For these reasons, we would like to keep the original title.

Line 9: It should be clarified whether the all-embracing greenhouse gas emissions of all livestock categories/animals are viewed or only the cattle sector. If all categories/animals are viewed it would be commendable to give a short overview on the ratio of different animal categories.

Line 37: Please reveal whether the whole livestock sector is focussed or only the cattle livestock sector.

Response: Our proposed system is not (meant to be) limited to the cattle sector. We have clarified this point in the revised manuscript. We agree that it would be useful to provide more details on the contribution of different animals. However, we have already slightly exceeded the available space for our position paper and the information of estimated contributions from different animal categories is readily available in the scientific literature or databases such as FAOSTAT.

Line 49/50 and 60/61: Models can be improved by measurements. It might be better to combine both tools than to propose that „expensive measurement devices“ can be replaced. From the current state of presented knowledge this proposal appears to be very optimistic. This applies also for the statement that „an important determinant for the accuracy of these predictions is the quality of input data“.

Response: We agree fully. Models need to be validated and validation requires observations. We have clarified this point in the revised manuscript and have emphasized the importance of observations for model validation (Conclusion section, second paragraph).

Line 116/117: The current situation of environmental impacts of livestock shows that the statement „if little is known about a farmer’s management, one has to assume the worst“ does not really fit to the current situation. It may rather be discussed, whether environmental impacts have been neglected in former times.

Response: The quoted statement reflects the economic principle that a risk adverse society prefers unbiased and certain information to biased and uncertain information. The reviewer is right that current policies seem to ignore this principle. Our (disruptive) idea is that it matters whether a more uncertain or biased approach is used for quantifying emissions or whether a state-of-the-art approach is used. In the revised manuscript, we clarified this point and deleted the sentence in question.

Line 123: Please check, why there is no feedback from interest groups back to the IT platform.

Response: We have now included feedback from users. See also response to Figure 2 comment below.

Conclusions

The conclusions do not base upon own measurements. They rather base on general information concerning the well-known problems of assessing the environmental impact of cattle farming. It is an open question whether the digital network replaces „costly measurement devices“. Measurements will be necessary and indispensable until the input data quality is not sufficient for a modelling with an adequate accuracy.

Response: In our paper, we describe a position but do not perform experiments. We agree that mathematical models should be supported by measurements (see also response above on model validation).

However, the suggestion to improve the input data quality for model-based assessments by a combination of scientific models with advanced farm management information is evident and required as well.

Figures and References

Figure 1 gives an overview of the all-embracing emission of livestock systems. If all animal categories are included in this figure it should be noted in the underline.

Response: We refer to all animal categories and have clarified this point in the revised figure caption.

Figure 2 gives an overview of the designed digital emission monitoring system. Viewing this figure the question arises, why interest groups can't give input back to the IT platform.

Response: We already discussed such an option before the initial submission. We did not include user feedback because we did not see a direct link to the regulation of greenhouse gases. Based on the reviewer's comment, we now have modified Figure 2 and included feedback from users. Feedback or queries from interest groups could be used to collect opinions and to tailor information to users. For example, interest groups could use the platform to ask for specific information (e.g. average emissions of certain animal categories in certain regions) subject to confidentiality restrictions.

The figures show the essential problem and the intention of authors how the problems may be mitigated. The figures are meaningful for the entry into the text.

The relatively small number of references appear to be adequate for a Position paper with 10,000 characters.

Quality and significance

The digital emission monitoring system may be an appropriate tool to improve the efficiency of livestock and mitigate environmental impacts. However, it is probably not sufficient to reduce the emissions sufficiently from this sector. A better networking is recommendable but this idea is not really new. The significance and scientific quality of the paper is therefore only satisfying.

Recommendation

The Position paper needs minor revisions and some specifications, respectively.

Reviewer # 2:

The manuscript 'Farm level digital ...' proposes a system that combines process based model that should run at individual farm scale by scientists using data delivered by the farmers to a common IT platform that help both policy makers and other stakeholders in understanding (and regulating) agricultural policies.

This idea is neither new nor realistic. The manuscript is based on the assumption that only policy instruments that require the exact measurement of GHG emissions can be effective and that therefore it is essential to enable the quantification of farm-level emissions. This premise is questionable and is not the logic of current mitigation policies that much more focuses on farm practices that are known to reduce GHG emissions and that require support for their implementation which is not necessarily linked to the actual level of GHG emissions.

Response: Thank you for your comments. We agree with some of your arguments but disagree with others. The 'idea not being realistic' is a vague judgement which could mean politically, economically, or technically not feasible or sensible. We do believe that our proposed system would be a major change for agricultural businesses and would perhaps lead to intensive discussions and opposition by various interest groups. However, we also believe that the current regulation of external agro-environmental impacts is not efficient. We don't see a need to follow "the logic of current mitigation policies". We agree that there is a certain correlation between certain farm practices and greenhouse gas emissions. However, there is a high degree of uncertainty. The impact of farm management practices on greenhouse gas emissions depends on many detailed factors. We explain these details in the first section of our paper.

The proposed framework shall motivate farmers to deliver very detailed data to a common and open IT platform. There is a bottleneck of obtaining farm-level data today - even for use in much simpler models - and attempts to overcome this are expensive and difficult.

Response: We are aware of the mentioned bottlenecks. However, the data which are needed are possible to collect. Livestock systems where feeding of individual animals is controlled via computer chips, have some of the detailed data already in digital format. Current agricultural policies already require farmers to submit very detailed information. We believe that financial incentives and improved software could induce farmers to use a digital monitoring system.

Currently it is un-thinkable to make farm level data public in most countries due to data confidentiality concerns and regulations.

Response: We did not and do not propose to make farm level data public. Farmers would submit detailed data to secure servers controlled by authorities. In many countries, people submit income tax statements electronically or manage personal bank accounts through the internet. When implementing the proposed system, data privacy experts should be involved to ensure that the system uses proper data protection mechanisms.

The use of process-based models sounds great as they are so detailed, but the authors don't take into consideration the need of calibration, validation, review, quality control which would be an immense administrative burden.

Response: We agree that calibration, validation, review, and quality control of the involved models is an important issue. Due to journal space constraints, we did not elaborate this issue in the original submission. The proposed system would certainly need a testing phase (at least two years) similar to the implementation of other systems (e.g. the electronic toll collection). There would be an administrative burden at least initially. Whether this burden is "immense" or higher than the burden of alternative policy instruments is an open question. Some German farmers estimate the current work time to submit information to authorities at about 10%. We believe that existing IT enterprises could help farmers at reasonable cost to compile and submit information.

The fact that process based models are so detailed makes them also more vulnerable to missing data and applying them outside the calibration domain. Indeed, it is the exact role of the IPCC to provide Tiered method for the estimation of farm-level emissions (aggregated to the national scale). Even for relatively simple Tier 2 methods often the data are not available (at national scale). Farm surveys try to include such characteristics in their questionnaire against the resistance of statistical offices who want to protect the farmers from increased administrative burden.

Response: The different IPCC methods (Tier 1, Tier 2, etc.) were developed for national emission inventories. Many countries do not have detailed farm management data available. Hence, simple methods are needed. Our paper is not about national emission inventories although an established system could support national inventories. Our paper is about farm-level estimation of greenhouse emissions. The detailed farm management data needed by process based models can be collected by the farmer. The farmer is free to decide whether a) he/she compiles detailed information to do a more exact estimation of greenhouse gases or b) uses less detailed methods with increased uncertainty and penalties for uncertainty. We clarify the motivation for detailed methods now in the introduction section (lines 10-14).

The European Commission's proposal for a new post-2020 CAP includes a 'Nutrient Management Tool' that more or less has the same underlying concept outlined in the manuscript - its goal is solely to support the farmer with information how to increase the nutrient use efficiency (being correlated also with GHG emissions) knowing that the farmer will be reluctant to disclose her data.

Response: The 'Nutrient Management Tool' may have some similarity to our approach. However, as the reviewer points out, it is not meant to internalize agricultural externalities. We are aware that farmers are reluctant to disclose information. However, a majority of farmers in the EU submit every year very

detailed information to receive financial support from the Common Agricultural Policy. This proves that farmers are (reluctantly) willing to submit information if there is a sufficient economic incentive.

On the other hand farm level tools to immediately quantify emissions are existing and already widely used (e.g. Cool Farm Tool). This is on the initiative of the industry.

Response: We are aware that emissions can be and have been estimated with simple methods and crude tools. The Cool Farm Tool is such a crude tool, which does not take into account intra-annual weather conditions, soil properties, soil tillage operations, dates of management operations etc. Its methods are similar to simple Tier 1 methods from the IPCC. In the revised manuscript, we now mention already existing tools and their limitations (first paragraph).

Indeed, as the authors hook this article on the use of carbon price / carbon trading / emission ceilings it might be rather the industry who further pushes also the use of GHG quantification tools - but then the framework would need to look rather differently than depicted in the manuscripts.

Response: The industry could and should be involved. However, all state-of-the-art quantification tools have been developed and validated in the scientific community over several decades. There is no need and little time to reinvent the wheel and redevelop intermediate or sophisticated quantification tools by industry. We believe that IT enterprises which develop farm management software (for book keeping, precision agriculture, etc.) could modify existing software solutions to facilitate the information exchange between farmers and sophisticated emissions tools. If the use of sophisticated emission quantification tools has significant financial incentives for farmers, then IT enterprises have an incentive to offer the integration of or link to these tools.

As a conclusion, I think that the manuscript develops a nice idea, but this idea is not novel (nor disruptive) and is already pursued as far as possible. As such it reads more like a nice but not thought-through idea that will not help to mitigate emissions from livestock products, as it misses any critical discussions of challenges, barriers, or concrete actions in the right direction. I don't think the manuscript is fit for publication.

REVISED VERSION

Editor/Chief-Editor Landbauforschung

Please take into account the reviewers' recommendations. Obviously your position is under discussion now. So I recommend to improve the text further according to the comments below to reach a vision that is respecting practical demands of payments that are linked with environmental outcome. The final revised version of your manuscript will be evaluated again by the Chief editor.

Reviewer # 1:

After a moderate overworking of the position paper by the authors I would recommend to accept the publication in the present form.

Response: Thank you for your time and effort.

Reviewer # 2:

Dear authors, thank you very much for your responses to my comments. It would be fun continuing the discussion, however, I will restrict commenting the remaining issues in the revised version. I do have still several concerns with the manuscript.

Response: Thank you for your time and effort.

Main concern regards the financial incentive. The idea is to sanction the use of simplistic methods for GHG accounting assuming a higher uncertainty around the data and link this with a financial loss. As you also agreed to my comment, this financial element is key, but it is not further elaborated. Actually, I think that this is the only truly disruptive element that the manuscript could have: the change from a practices-based payment system (as far as associated with environmental objective) to a results-oriented payment system, with result being actual pressure on the environment. In my view, as long as this is not clearly elaborated in the manuscript, it remains an academic piece with little impact.

Response: We agree that the change from a practices-based payment system to a results-oriented (emission-based) payment system would be a major change. In the revised manuscript, we have added this explicitly.

Second, I am still not convinced that cited models could really lead to an improvement. Yes, you include now concrete examples of models, yes you mention that efforts in calibration, validation etc are necessary. Yet you state that the proposed system replaces costly measurement devices, without quantifying what the effort would be - there will be a trade-off between number of validation sites and accuracy.

Response: It is correct that we do not quantify the effort of model calibration and validation. There is no scientifically agreed standard for validation. Nevertheless, there is a qualitative benefit of validation cost over measuring cost. Validation cost are initial set-up cost occurring one time. Measurement cost would occur continuously. The revised manuscript says in the conclusion section: "Emission measurements would still be needed for model validation, however, only at certain intervals on selected sites."

There is the risk that a combination of variables outside the space of validation leads to outliers in the result with likely consequences for the farmer's payments? For scientific purpose, those outliers are acceptable and can be dealt with - but in 'real world' settings they must be avoided.

Response: We agree in principle. However, we expect that outliers would occur relatively infrequently if the modelling system is well validated and if the input data quality is high. Nevertheless, the digital platform should be programmed in such a way that strong outliers will trigger an alarm, where a scientific maintenance team will analyze and solve the problem at no additional cost to the farmer. Assuming that the corrections improve the model, outliers would then decrease over time.

Further: what costly measurement devices? Do you intend to say the devices if one would go for a 'result-oriented' payment system without a digital platform?

((Editor: As we felt a bit confused about the last two sentences, Reviewer # 2 clarified what he means:))
I mean: emissions are currently not really monitored. Therefore there are no measurement devices to replace. If policy decided that emissions need to be monitored, then they would be needed (and might be costly). But this is not the case.

Response: We agree that there are no systematic measurement devices installed. In the revised manuscript, we have changed the wording to "where validated state-of-the-art scientific models eliminate the need for costly measurement devices" and do not use the word replace any longer.

Third, but related, you correctly list a number of factors that determine CH₄ and N₂O emissions that all must be taken into consideration. For most of them I agree that it would be good to take them into consideration. But for example rainfall: if at a field rain is regular and the farmer uses the practice that is most adapted to this pattern in terms of emissions per yield achieved. But in one particular year the rainfall is different, leading to higher emissions, without the farmer having the possibility to intervene. Thus he might face a penalty in addition to a possible loss in harvest. Would that be the price that the farmer(s) have to pay/risk to take?

Response: We understand the argument. However, we do not think that this example warrants a modification of our proposal. First, while the variability of weather may sometimes lead to higher

emissions, at other times it may lower emissions. Hence, losses and benefits will cancel to some extent. Second, if there is a small chance of large penalties, farmers may opt for an insurance similar to existing climate insurances in agriculture. Third, we envision the digital monitoring system not just as an accounting tool to estimate emissions in the recent past but also as a decision support tool. Farmers could use this tool to estimate the emission robustness of different management alternatives under a range of historical or projected weather conditions.

Smaller issues:

- Please consider also emissions embedded in farm inputs, in particular imported feed, but also GHG emissions embedded in fertilizers (beyond energy)

Response: We did not plan to omit embedded GHG emissions. However, we believe the bulk of embedded emissions relates to energy. For example, the Haber-Bosch process to manufacture nitrogen fertilizer is very energy intensive and thus emission intensive. A part of the description of Figure 1 reads “Fertilizers, pesticides, buildings, and machinery contain embedded energy”.

- IPCC Tier 2 calculated emissions from a number of input parameters (similar as process based models do, but obviously with a few assumption to reduce the burden), but they are no 'Tier 2 EFs' for CH₄ emissions from enteric fermentation.

Response: There is a variety of methods to calculate emissions. While some are very simplistic, others are of intermediate sophistication. We believe that farmers should not be forced to use a particular emission accounting system. However, as discussed above, the use of less sophisticated systems leading to higher bias or uncertainty should receive a smaller incentive (or higher disincentive).

- Another issue is that automatic collection of most data is possible on farms beyond a certain size, which might disadvantage small farmers. If this is not intended a remedy should be included in the manuscript.

Response: We agree that automatic data collection may be easier to implement on larger rather than smaller farms. However, if there is a public interest to support small farms than society should support small farms directly for the service (i.e. a certain landscape pattern) they provide. We do not think that small farmers should be indirectly supported through greenhouse gas emission exemptions or waivers.

Editor/Chief-Editor Landbauforschung

Final accept after second revision

We are glad to inform you, that we accepted your “Position Paper: Farm-level digital monitoring of greenhouse gas emissions from livestock systems” after your revisions in its current form. Our Reviewer #2 also appreciates the responses given and changes made to the manuscript.