

C-LLAMA 1.0: a traceable model for food, agriculture, and land-use

Author comment: We thank the reviewer for their comments on the revised manuscript. As with the previous iterations of feedback it is abundantly clear that you have taken significant time and effort to assist in the improvement of this manuscript and for that we are very grateful. We have attempted to address all the points raised although given the relatively short timeframe in which to make these changes their extent is less than the previous revisions.

Overall response

This is a revision of a previously reviewed manuscript. The authors have made extensive revisions in response to reviews and have improved the paper. However, there are still some issues that need to be addressed prior to publication.

1) The framing is still incomplete. What gap does this model fill? The IAM discussion is not very relevant as the goal of this model is stated as being different than the goals of IAMs. I suggest looking at the model goal and the potential model uses in the discussion and then developing an introduction that shows how this model is needed to address such questions (which may or may not involve pointing out how IAMs are inadequate for the task).

A thorough food system science literature review should help with this framing by providing the background and impetus for this type of model. Furthermore, there are other simplified models out there to discuss and compare to. For example, check out the SIMPLE model:

https://www.gtap.agecon.purdue.edu/resources/res_display.asp?RecordID=4021

<https://www.sciencedirect.com/science/article/abs/pii/S1364815220304205>

2) Further clarification is needed, and some equations need to be checked, particularly for livestock. See details below.

3) I also suggest showing additional results of the examples and discussing the implications. This helps demonstrate the usefulness of the model in the context of the gap it is aiming to fill.

Specific comments and suggestions

Abstract

What are some key findings of the evaluation and sensitivity analyses?

e.g., the model behaves as expected under historical extrapolation, under the sensitivity analysis, and under a vegetarian scenario that reduces land use area

AR: Thank you for your comment, we have added to the abstract to convey these points.

Introduction

line 17: "afforestation"

AR: This typo has been corrected.

lines 32-34: You have not yet introduced c-llama. I suggest making a more general statement regarding the value of simpler, more confined models (preferably with a reference). There is a model called SIMPLE originally developed by Uris Baldos and Thomas Hertel that may be relevant here.

AR: Thank you for your comment, the premature reference to C-LLAMA has been removed and replaced with text regarding the general applicability of simple models.

line 38: spiritual successor? do you mean spatial successor?

AR: Thank you for your comment, this turn of phrase is perhaps not applicable here and has been removed.

Food system efficiency

line 156: can you give a qualitative definition of F_{target} here? otherwise it is difficult to fully understand the parameter and also the following explanation for Japan and Korea having low values.

Actually, I didn't find the definition in section 4.1

AR: Thank you for your comment, this was an oversight when changing the anchor scenario to project food supply rather than prescribe it. A brief description of F_{target} has been added with two references.

line 160: "efficiency" in place of "industrialization"?

AR: Industrialisation has been replaced with efficiency.

Food production

line 212, eq 7: I think the denominator should be the product of $1-\mu$

AR: this is correct, thank you for pointing this out. (This is correct in the code!).

Livestock

lines 257-258: these numbers appear to be feed efficiency, which is the inverse of FCR

lines 265-268 (eq 10): the feed quantity is higher than the output production quantity. Make sure you are actually using FCR and not feed efficiency.

lines 268-271: clarification needed: I assume you are talking about μ -non-forage here.

AR: Thank you for these comments. I was incorrectly describing feed efficiency as FCR as you point out, which has now been corrected. Eq 10 has also been updated to reflect this.

lines 273-275: due to the FCR, this is not a valid way to calculate the forage feed demand. you need to use eq 10 and μ -forage. The same FCR may be used due to data limitations, but FCR could vary based on forage vs feed (and even the type of feed).

AR: Thank you for your comment. We agree that there is a factor of $1/FE$ (or FCR) missing here and the text has been updated to reflect this.

lines 278-279: Is this the maximum proportion of each waste type available for a given product? Or the maximum proportion of the product diet filled by the given waste type? It seems like the latter based on the table title in the appendix. You need both of these, which are different, for eq 11, but you use only one.

AR: z is the latter as you suggest, however it is also used for the second purpose in the summation at the end, see the next comment.

lines 288-296: This does not seem correct. First of all, the z multiplied by D should be different than the z used to determine the fraction of available waste for product j in term S . The former is related to how much needed feed comes from waste, while the latter is related to the fraction of each waste stream directed to each product. Second, the first term needs to be removed from the summation and calculated as the minimum feed-from-feed value, using $1 - \sum(z_{jw})$ with z_{jw} being the max proportion of feed coming from waste w . Third, the S term needs to be added to the minimum feed-from-feed value instead of subtracted because the S term calculates the amount of feed energy not available from waste. As it is, you are summing slightly different and slightly adjusted minimum feed-from-feed values to overestimate the final value. Also, G in the text should be ω .

AR: Thank you for these comments, Equation 11 was structured incorrectly as you point out. These ratios are deliberately the same, the final $Z / \sum(Z)$ is the fraction used to direct waste to each product, I was unable to find data regarding how waste is distributed among livestock groups. However, since these ratios convey a 'propensity' of the livestock to the consumption of the waste stream I believe this makes sense. The second and third points you make have been addressed as you suggest.

Land use

It seems like you would need to calculate the food crop area first, then the waste component of feed because you don't know harvest residue availability until crop area is determined, then fodder component of feed to get fodder crop area, and then finally pasture area. Is this correct?

AR: This is correct, the order of calculations in the model itself is different to the order in which they are discussed here.

lines 351-352: Why not just calculate the yield trajectory from the yield data? It seems like an unnecessary step to do the feed calcs and subtraction and then calibrate to the yield value.

AR: Thank you for your comment, the text here was not clear and has been updated. The reason for this is the behaviour described in Appendix F. The calibration factor is based on the anchor rather than being scenario specific, but the subsequent land-use scaling is scenario specific to address minor discrepancies at the boundary between historic and modelled in non-anchor scenarios.

Anchor scenario

line 376: the modelled reversal in Europe pasture needs to be explained. if this is based on historical data/trends, then pasture should not be increasing after it has been decreasing historically.

AR: This is a result of the trade mechanic, almost all of this pasture expansion occurs in Russia, which ranks 4th for global beef production and consistently in the top 6 for other animal products (I have traced the pasture area back through the model; the increase in area comes from an increase in production demand, a direct result of the trade mechanism). We appreciate that the trade method is a significant limitation of the model but don't believe that it undermines the efficacy of the model for broad scale sensitivity experiments. I have added a sentence to explain this.

Sensitivity

line 442: Isn't the anchor projected diet based on historical trends? Then it isn't idealized.

AR: thank you for your comment, this sentence was a mistake left over from the previous iteration and has been edited to convey the increasing calorie intake (from the projection rather than prescription).

line 450: do you mean “setting” rather than “halting”?

AR: setting is a better word here, thank you for this suggestion.

Discussion

I suggest you tie your sensitivity and vegetarian example to the potential uses of the model and what we can learn from it. For example, show how different land use types change under the vegetarian scenario and discuss the implications.

AR: Thank you for your comment, some discussion of the validity of the vegetarian scenario and potential further uses of the model has been added.

Figure A2

n number of countries does not add up

AR: Thanks for your comment, the numbers in the caption were incorrect, the figure numbers are correct (I had failed to exclude states with zero / NaN production in the caption).