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Interactive comment on “The relevance of uncertainty in future crop production for mitigation strategy planning” by K. Frieler et al.

Anonymous Referee #1

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General comments: This paper, based on work from the Inter-Sectoral Impact Model Intercomparison Project, integrates outputs from a suite of climate, crop production, hydrologic, and biogeochemical models to explore the impact of increasing food demand in a changing climate. To do so, they introduce a framework for evaluating tradeoffs between two uncertain outcomes. This is interesting and important. However, the manuscript fails to fully explain and explore the implications of the risk framework it introduces. Additionally, the paper uses the example of crop production and carbon storage in non-cropland as an illustrative tradeoff. The use of an example is helpful, but the manuscript itself focuses far too much on how the models inform the content of the illustrative question instead of exploring how the uncertainties among the models affect the conclusions.

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Specific comments: It is not at all clear what the risk assessment and decision framework introduced by the authors is. Though it is never explicitly stated, I assume that the framework the authors propose/introduce is the “associated” probability density function (4-15; Fig 1). The authors need to describe this framework at much greater length. What makes it a framework and not just a probability density function describing a sensitivity analysis? What is the rationale behind what is incorporated within the pdf and what shifts the pdf? For example, why does it integrate the uncertainty from demand and crop models but not from crop management? And how is it both for a prescribed global-warming level yet incorporates uncertainty from climate change? Is the framework flexible enough to incorporate anything in the pdf and the choices the authors made about inclusion versus “shifting” are simply illustrative? If some impacts are off scale and swamp all other uncertainties, it would make sense to exclude them from the pdf and instead “shift” it, but it’s not clear this is the case here, and it’s certainly not stated. Similarly, for the natural carbon sinks pdf, a huge number of important factors remain fixed – is this again arbitrary and illustrative?

I am not particularly convinced by the authors stated tradeoff of food for land ($N = T - F$), especially because it’s not clear they can or wish to consider intensification. If I am correctly interpreting the framework, the authors need to discuss how or if the framework is useful if there is not a direct one-to-one tradeoff between two things. I assume, however, that the point the authors wish to make here is that what matters is how and where the two pdfs overlap. Indeed, this is interesting. But the implications of the shape and relative position of the two pdfs need to be made much more clear. The authors never explain in the text what the “exemplary area” is, for example, though presumably what is interesting and novel about this approach is that the shape and overlap of the tradeoff pdfs, and thus what the height and slope of the pdfs look like around the “exemplary area,” tells us something about how hard or precarious a tradeoff will be. It is not a problem that the authors don’t “provide a full quantification of the different pdfs” (5-17) given that the example is meant to be illustrative, but they need to discuss the implications of different pdfs and how their findings inform them.

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The introduction is very focused on the food production/carbon sink tradeoff. However, the bulk of the paper and the research questions introduced in the second to last paragraph focus on this only to a limited extent. The questions and paper seem to be much more focused on 1) how much land is actually required to grow the food demanded, and 2) how do the uncertainties inherent in the different specific models and different model-types affect this. It would be helpful to the reader if the introduction laid this out.

Throughout the paper, a clearer focus on the uncertainties revealed by the model intercomparison would be helpful. Thus, I suggest the authors focus less on the findings of the models vis a vis the illustrative questions and more on what the uncertainty illuminates. For example, it's not news that crop production on current agricultural land won't feed the future (8-25). What's interesting is how big the spread is among the models, in conjunction with the fact that the crop models appear relatively insensitive to the choice of climate model – I would like to see the authors focus on that. I would also like to see a clearer focus on the qualities of the models that cluster or suggest particular outcomes. The paragraph at 9-15 begins to do this, but it would be helpful if the authors drew the point out more explicitly instead of making the reader work for it.

I assume the focus is on uncertainty largely because this is a model intercomparison study. If I am wrong about the focus of the paper and it is indeed meant to focus on the findings of the illustrative food vs. carbon question, the authors need to explain why a MIP was necessary and should rephrase the title and other parts of the introduction. In addition, the bar is then much higher for the authors to defend the assumptions made in the models.

Overall, the results and discussion vis a vis the relative uncertainties among the specific models and among model types are interesting but very hard to follow. First, it would be very helpful if the numerical findings were presented as figures in addition to being listed in the text. Second, it would be clearer if the authors focused on one crop at a time and walked the reader through the full range of uncertainties associated with that crop. As it is currently presented, the emphasis ends up being on the different

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performances among the different crops. Third, I'd like to see more interpretation and discussion of the results. For example, does the spread among models occur because some models are intrinsically more similar, or because there is indeed more uncertainty in some types of models? It would be helpful to the reader if the authors more clearly laid out the differences in assumptions and uncertainties among the models (something akin to the annotated tables in the supplement) and why they matter, with less emphasis on the particulars of the uniform assumptions among the models.

The authors use a land use change model (MAGPIE) to spatialize cropland expansion. Apparently land use models were not part of MIP. This doesn't undermine the study in any way, but the authors need to discuss how using a single land use model with many, many assumptions introduces substantial uncertainty, especially because it appears to be playing off the nature of the GCMs (11-25).

Technical comments: Why is bioenergy production invoked in the abstract and introduction but not addressed in the paper.

Please define a food production unit.

It would be very helpful to the reader to have a compact table with a list of the models used instead of having to go to the supplement.

Within the results and discussion, there are frequent references made to moving the pdf to the left or right (10-25). No context is provided, however – even if they can't quantify the shift of the pdf, does the action in question move the pdf relatively a lot or a little?

More quantification and discussion of what various numbers mean would be helpful. The authors state that it “remains unlikely” that current cultivated land is sufficient (10-25). Do they mean 51% or 90%?

The paper states a 60% irrigation efficiency is used for all models (10-5). Is runoff available to downstream irrigators? I imagine this is very important, especially given

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that in a non-trivial number of places water withdrawals already far exceed the somewhat arbitrary cutoff of 40% of available water. Realistically, assumptions such as no runoff and using no more than 40% of water are fine give the focus of the paper on model intercomparison, but if the focus is on the findings then the assumptions need to be clearer, better explained, and better defended.

Many of the figures, particularly in the supplement, are so small and dense that they are unreadable. Lines with different marker symbols look identical.

Supplementary figure 5: Are the bars and dots are the same as the ones in Figure 2 (not figure 1)? Also, there are no bars.

Irrigation water availability point 3 twice (supplement 12-22)

Spread of alpha parameter –refers to Figure 3 but this is clearly not the subject of main text 3 or S3 (supplement 16-8).

Supplementary figure 8. The dark blue square and light blue triangles are basically unreadable. As presented, they are identical.

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