Earth System Dynamics

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Discussions

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Interactive comment on "Future supply and demand of net primary production in the Sahel" *by* Florian Sallaba et al.

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Sallaba et al. present a coupled modelling system comprising a land-use model and an emulator of NPP outputs from the LPJ-GUESS vegetation model. They apply this coupled system for the Sahel to assess the likelihood of local food demand exceeding local supply during the 21st century, finding that this is the case in all but one SSP scenario, with many SSP-RCP combinations resulting in the lower 95% confidence bound of demand exceeding the upper 95% confidence bound of supply. CO_2 fertilisation and intensification of cropping were found to be important drivers of supply, but population-driven increases in demand where most influential. Overall, I find the manuscript to be well conceived, fairly clearly written and informative, and I recommend publication if the following concerns/queries can be addressed

Major comments

I presume the LPJ-GUESS simulations used to calibrate the BME model were potential natural vegetation (would help if this was explicitly stated)? In which case I wonder how effectively NPP of natural ecosystems can be used as a proxy for NPP of agricultural ones. NPP is not independent of plant type, and the distinction between natural vegetation, which may well be woody, and cereal and pasture vegetation may be particularly relevant in the Sahel, where the deeper roots of trees may have access to water resources that herbaceous plants cannot use. Can the authors demonstrate that such effects are not large, both in the LPJ-GUESS model and also based on any observations in the Sahel or analogous ecosystems?

Whilst the BME model is evaluated against LPJ-GUESS, any evaluation of the extent to which LPJ-GUESS can accurately represent actual NPP in the Sahel region is lacking. The references given (pg. 4 l. 14) did not address this ecosystem and also used a version of the model lacking carbon-nitrogen interactions, which leads to quite different vegetation simulations for the Sahel (Smith et al., 2014). Evaluation of the model response for the Sahel is necessary to give credence to the comparisons of supply and demand, which strongly depend on simulated absolute values for NPP. Whilst there is no gold-standard NPP (or GPP) dataset to compare against, comparison against NPP from the ESMs used to assess uncertainty, along with comparison of GPP against the alternative approaches of Jung et al. (2011) and Zhao et al. (2005) could go a long way towards increasing confidence. Alternatively (or additionally), FAO yield statistics could be used to evaluate the "yields" calculated here. Although none of these sources of comparison are likely to be low in uncertainty in the Sahel region, as it stands we have no idea how well LPJ-GUESS performs in this region - and current DGVMs cover a wide range of possibilities at regional scales (Sitch et al., 2015).

On the theme of evaluation. I'm not clear from the manuscript if PLUM land-use simulations are normalised in some way to the dataset of Hurtt et al. (2011) in 2000, or if they represent a purely "PLUM version" of the Sahel land-use in 2000. The former would

raise the question of how much the model drifts from the observed towards its preferred state at the start of the simulations. The latter suggests the need for a comparison of the PLUM initial state with current observation-based estimates (such as Hurtt et al., 2011). I realise there are significant difficulties in modelling actual land-use, but surely the size of any discrepancies and the resulting implications should be discussed?

Minor comments

pg. 2 l. 31. Why does a 31% population increase lead to a 100% increase in NPP requirement? What information is missing here?

pg. 6 l. 16. I'm confused about the cropland cover, I thought it was taken from PLUM? How is Hurtt being used here?

pg. 6 l. 23. Surely the total amount of NPP for human appropriation must be the sum of NPPcereal_demand and NPPgrazing_demand, not just NPPcereal_demand alone? As parts of both cereal and grazing demand contribute to animal raising, the current definition is inconsistent. Was it meant to be something like "total amount of annual NPP for human appropriation via cropland"?

The SSP-RCP scenario likelihoods seem rather important. Rather than referring the reader to another paper, maybe you could include them in this analysis? For instance along the right y-axis of Fig. 3b?

pg. 7 l. 29-33. This text reads as if it was originally located before the first paragraph of 2.1.3, and some of the text would seem to be more logically located there, where this likelihood matrix is first mentioned.

pg. 9 l. 11. I would say that the shortfalls in SSP5-RCP6.0 and SSP5-RCP8.5 are pretty sustained. They just don't run to the end of the century. Consider rephrasing?

More generally, regarding the discussion of "shortfalls", it seems strange that you only consider shortfalls to occur when the 95% confidence limits do not overlap (and demand is higher of course). To my mind this lack of overlap of the confidence limits

suggests very high likelihood of shortfalls, but the best guess result shows shortfalls occurring for a larger number of scenarios. For instance, on pg. 11, l. 26 it is stated that "statistically significant shortages never develop" in the context of SSP1, but that doesn't seem quite right. Assuming non-skewed distributions of uncertainty (big assumption, I know), then when the best estimate of demand exceeds the best estimate of supply there is a more than even chance of shortages occurring, but it's not possible to say with high certainty that a shortage will occur until the 95% limits no longer overlap. Consider rephrasing also?

pg. 9 l. 22. Reference to Table 3 here?

pg. 12 l. 3. Regarding, "so strong efforts should be made to reduce these gaps", this is too simplistic. Efforts to close yield gaps have other environmental and socio-economic consequences which are not addressed here, meaning that this statement cannot be supported by the presented evidence. I suggest to remove this recommendation. Going beyond this however, can you say anything about the potential additional yield by closing yield gaps in this region, and whether such efforts could alleviate the shortages simulated? Maybe PLUM can provide the necessary data?

pg. 12 l. 24. Where is the attribution of supply increases to additional rainfall and CO2 fertilisation shown in the results?

pg. 13 l. 7. The relative attribution of supply growth to climate/co2 and closure of yield gaps would be very informative, allowing the results to be interpreted more subtly. Your approach seems to be suitable to make this isolation.

pg. 13 l. 12. I would take the opposite view. The extent to which models appropriately represent CO2 fertilisation is not clear, and the difference in NPP trends between models is very large (e.g. Friend et al., 2014; Körner, 2006; Pugh et al., 2016; Rosenzweig et al., 2014). Therefore, I think it is fair to say that we have no more confidence in the trends than we do in the absolute levels. Moreover, the reference here to Fig. A2 does nothing to support the point, as the point of comparison is an LPJ-GUESS simulation,

not observations.

pg. 13 l. 22. You could also briefly mention irrigation water availability projections here (Elliott et al., 2014).

Grammatical/typographical

pg. 1, l. 20. "surplus, while" pg. 1 l. 23. "diet" pg. 2 l. 13. "global food security is not ensured" pg. 2 l. 16. "world, where" pg. 2 l. 19. "own land, where", also full stop missing after "pastoralism" pg. 4 l 32. Should "estimates to the total area", read " estimates to sum over the total area"? I don't think you translated NPP to total area literally? pg. 5 l. 22. Replace "Furthermore" with "Therefore" pg. 5 l. 32. "choice, and the" pg. 6 l. 13, 14, 20. "Fig. 2" should be "Fig. 1"? Also there are several boxes in red in Fig. 1 so "box outlined in red" is of limited use, and the distinction between cereal and pasture products can't be seen in the picture. pg. 8 l. 4. "Hence, one" pg. 10 l. 2. Only two countries are listed. pg. 12 l. 26. "mobilization is one method local" pg. 12 l. 31. "increase" pg. 14 l. 2. I think this would read better as "the Sahel is likely to experience NPP shortages in most SSP scenarios due to" pg. 14 l. 7. Reference formatting. pg. 14 l. 25. "show" rather than "assume"? pg. 15 l. 2. "will outstrip supply during the 21st century". pg. 15 l.12. "unfolds, a relatively"

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