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Earth System Dynamics
Discussions

Interactive comment on "Potential impact of climate and socioeconomic changes on future agricultural land use in West Africa" *by* K. F. Ahmed et al.

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We thank the reviewer for the thoughtful comments and suggestions. In the following, please find out point-to-point response to the reviewer's comments:

The manuscript "Potential impact of climate and socioeconomic changes on future agricultural land use in West Africa" addresses role of climate change and socioeconomic changes for possible future changes in land use in Western Africa. This assessment is conducted using a particular algorithm that considers both societal and physical drivers in the attempt to meet all demand for food with an adequate local/regional supply. Results are presented for the middle of the 21st century using climate scenarios from two

different sources. These are compared to the current situation.

While I think that this is an interesting aspect that definitely deserves some attention (particularly given the expected societal pressures on agricultural production in that region in the coming decades), I am not sure that the proposed algorithm provides the methodological basis to successfully tackle this question. There are several issues with the model that I would like to address in the following:

1. First, there is the question of scale. The authors use land use data at the scale of 0.5 degrees resolution, which is quite substantial if you consider that the size of individual farms employed in the production of food crops is considerably smaller. When the results of the simulations in this paper indicate a land use change in a particular pixel, does this mean that a large number of farmers simultaneously alter their production patterns? Is this realistic?

Response: Point well taken. We acknowledge the fact that the spatial scale of 0.5 degree is too coarse to simulate the cropping pattern in each individual farm. It is extremely difficult, if not impossible, to capture the farmers' decision-making at individual farm level for a large region. Although many existing land use models, which can simulate the farm-level changes, are applicable at much smaller scale, they do not address the need of climate models for land use change information at the regional scale. In our study, we attempt to address the climate model needs and simulate the land use-climate interaction at the regional scale, and to facilitate national-level policy-making in devising strategic framework to address the potential impact of climate and socioeconomic factors on future agricultural land use. The focus, therefore, is not on analyzing and projecting cropping pattern in each individual farm, and the land use algorithm presented here is not capable of doing that. Instead, we are interested in the long-term aggregated outcome, assuming that all farmers will eventually adapt to the changed crop yields in their land use practice. Therefore, the algorithm assumes similar science-informed decision-making by all the farmers under a particular pixel, which implies the similar cropping practice at each individual farms. To address this

comment, we have added a paragraph to explicitly discuss this issue in the revised manuscript (line 443-456).

2. A second aspect is that the assessment merely compares two different points in time (middle of the 21st century and today). Both societal development and changing environmental conditions are dynamic processes and therefore the state that is reached in the middle of the 21st century depends on the development trajectories between the two points in time that are considered. A gradual environmental change has a distinctly different impact on the adaptive capacity of agricultural production than a development with few but drastic changes. This is a critical point that definitely should be addressed in the model setup as it has a profound influence on the simulation results.

Response: Point well taken. Technically, LandPro can be applied in both transient mode and equilibrium mode. In this study, LandPro is used in equilibrium mode to project future land use changes over several decades without considering the transient processes between the present and the future. Applying LandPro in transient mode (which necessitates performing the crop modeling and regional climate modeling in a transient mode as well) will introduce several additional uncertainties, of which the most significant one has to do with the time scale of decision making in adapting to the changed crop yield. Therefore, in this study we mainly focus on developing the algorithm of LandPro and applying the model in equilibrium mode to perform a scenario study. This study should form the basis for additional studies and additional model developments to account for the factors influencing the transient changes of land use. Studying and projecting transient land use in West Africa will be the focus of our follow-up research. To address this comment, in the revised manuscript, we discussed the issue of equibrium versus transient application of the LandPro model (line 476-485).

3. When looking at the comparison between the different climate change scenarios that are analyzed, I find hardly any difference between MIROC and CESM. What does this actually imply? Does this mean that the algorithm is particularly stable with regard to changing climate conditions? Or are both climate scenarios practically the same to

start with so that such similarity in the results can be expected? If the latter is the case, why do you analyze both? Here it would be really helpful to obtain more details on these assessment results.

Response: There are two main reasons which cause similar land use change projection by LandPro under both climate scenarios. First, the dynamically downscaled climate of MIROC and CESM were bias corrected using the SDBC methodology. The bias correction eliminates substantial differences between two climate scenarios related to the bias of raw climate model outputs. These results in a better agreement between the two sets of climate forcing data used to run the crop model DSSAT projecting future crop yield. Second, our study indicates that the future land use change would mostly be dominated by the changes in socioeconomic factors in the region. Therefore, although there are some differences in the projected climate-induced changes in future yield under the MIROC and CESM climate, the magnitude of its influence on future land use pattern generally tend to be minimal. In response to this comment, we have added a paragraph to specifically clarify this issue in the revised manuscript (line 281-289).

4. Furthermore, the assessment does not consider an aspect of current economics that is fundamental to all areas of the world: trade. We cannot consider a single area without its connection to surrounding regions and the rest of the world. How do food imports into the region ease the pressure on land from the demand side? In my view this has a substantial impact on the development of land use as obviously there will be a fundamentally smaller demand on additional agricultural land if local production can be substituted or augmented by imports.

Response: In our study, to test the sensitivity of LandPro projections to the input demand, the model was run for three different demand scenarios which include the “local production” scenario (assuming the provision of international trade) and the “total demand” scenario (in the absence of international trade), and trade was one of the outputs from the IMPACT model that is used as an input for LandPro. Figs. 3, 4 and 5

and the related discussion highlight the influence of different demand scenarios (with and without trade) on agricultural land use change in the region under future climate. Thus, the significance of international trade in projecting the future land use scenarios was already addressed in our study.

Special comments:

p. 1133, lines 10-15: The first part of this paragraph is hard to understand. Please rephrase to make it clearer what you intend to say.

Response: The sentence was rephrased to address the comment.

p. 1134, lines 5-10: Are these the research questions that you all want to address in this paper? While some aspects are touched upon, e.g. the aspect of human decision-making is not picked up again in detail (only mentioned briefly on p. 1146). So why is this mentioned here then?

Response: Please note that the discussion related to Figs. 6, 7 and S2, and Tables S2 and S3 are related to detailed discussion on implication of agricultural decision-making on future land use change.

p. 1134, line 16: Why is this particular comparison chosen?

Response: Hurtt et al. (2011) projected future (2005-2100) land use scenarios following four Representative Concentration Pathways (RCPs) according to the Fifth Assessment Report (AR5) of the Intergovernmental panel on Climate Change (IPCC), and created a unique grid-level dataset for both the historical land use and the future carbon-climate scenarios. To our knowledge, there is no other study which projects grid-level land use for West Africa under future climate scenarios. We therefore think this comparison will provide important information for readers interested in such datasets.

p. 1134, line 25: Where does this gap come from?

Response: The term “gap” here indicates the difference between the IMPACT-projected

future demand and LandPro-calculated future supply based on present-day harvest area and future yield.

p. 1135, eq. 1: Some variables are attributed to the future, some to the present. Why is this? Here a justification for your choice appears necessary.

Response: As we mentioned in our response to the comment above, the LandPro-calculated deficit for a particular crop indicates the difference between the IMPACT-projected future demand of a particular crop and its future supply based on future yield and present-day harvest area (i.e., the future supply if land use were to stay at the present-day level). The positive deficit value implies that, given the future yield, the supply will not be sufficient to meet the future demand without agricultural expansion, and therefore, the model projects an expansion in harvest area.

p. 1136, lines 1-5: Here a more detailed description of “best” and “worst” would be helpful.

Response: The terms have been described accordingly in the modified manuscript (line 156-161).

p. 1137, lines 8-10: This is a very strong assumption that should be justified.

Response: The scaling factors used in the equation (2) account for mixed cropping and the ratio of harvest area occupied by “major” crops (simulated by DSSAT for this study) to harvest area occupied by other “minor” crops in the region. Both the factors are largely influenced by dietary habits, and are likely to stay stable in the absence of major shift in dietary habits. Therefore, in the application of LandPro to the mid-century in West Africa, we assumed that scaling factors will remain stationary in the future. In response to this comment, we discuss this issue in the revised manuscript to address the possible confusion related to the assumption (line 185-189).

p. 1140, lines 1-10: Here, some reference to the dynamics between the future and the current state would be helpful.

Response: As we mentioned in our response to the second major comment, in this study, we focused on developing the algorithm of LandPro and applied the model in equilibrium mode to perform a scenario analysis. Application of LandPro in transient mode to evaluate the land use change dynamics is the scope of our future research.

p. 1140, lines 10-18: Two significant digits are too many in the given description of model results as this suggests a precision of the results that is definitely not there. Instead, it appears useful to include uncertainties of the results as well. Several adjustments would have to be made to the results section to account for possible updates in the methodology.

Response: We reformatted the results to address the comment. We have discussed the possible sources of uncertainties in LandPro projections. Future crop yield data and trade-adjusted demand, which were used as inputs to LandPro, could represent the major source of uncertainties in our results. To address the uncertainty in crop yield data, we included two future climate scenarios (MIROC and CESM) in our analysis to project the future crop yield. The impact of the uncertainty related to the trade-adjusted demand projected by IMPACT has been examined using the sensitivity experiments in the manuscript. Additionally, the governing rules of the LandPro algorithm, which are controlled by human decision-making process which largely varies across the region, involve uncertainties because of the inherent variability. To account for these uncertainties, we performed the scenario analysis by modifying the rules to provide an envelope for the future land use patterns.

p. 1145, lines 20 ff.: The farmer's adaptive potential is a very important point that should be stressed. Considering that the success of agricultural production is highly dependent on the farmers' actions, I think that this actually is the critical point in the attempt to address the increasing pressures on agricultural systems worldwide.

Response: We acknowledge the significance of farmers' adaptive potential in determining future pattern of agricultural land use. Therefore, we analyzed the influence

of farmers' adaptive action, which is characterized by their decision-making related to the cropping practice based on scientific information on future crop productivity, on the overall land use land cover changes. Based on our results, we indicated the implication of farmers' science-informed decision making on future crop area expansion in the region. In response to this comment, we have reiterated the importance of farmers' adaptive potential in the revised manuscript (line 438-442). However, many agricultural adaptations (e.g., use of irrigation, fertilizer and other crop management techniques) are generally determined by regional or local agricultural practices and greatly vary from one place to another even in a specific country. Assessing the implication of those agricultural adaptive techniques on future land use land cover changes is beyond the scope of this study.

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