Interactive comment on "SOC sequestration potentials for agricultural management practices under climate change" by Herzfeld et al. (2021)

Dear Editor and Referee,

We would like to thank the anonymous referee for the valuable and constructive comments that will help to improve the manuscript. In the following, we will address all the comments by referee #2 and respond to these. Line numbers in our response refer to the marked-up version of the manuscript, which we will upload as soon as the option is available.

Referee #2:

Preface: This manuscript used a processed-based model to simulate the cropland SOC stocks change historically and in the future under different climate scenarios. The historical simulations of global and cropland SOC stocks are comparable with previous studies. The future projections with various agricultural practices show that residue management has a greater impact on SOC stocks as compared to tillage. This study provides important insight on preferred management to maximize cropland SOC storage under climate change. My main concern is that the future simulations did not include the impact of irrigation**.** Besides increasing temperature and CO2, climate change also has a strong impact on regional precipitation, in turn, the soil moisture and vapor pressure deficit. Studies have shown that soil moisture has a strong impact on the global carbon cycle (e.g. Humphrey, V., et al. (2021). "Soil moisture-atmosphere feedback dominates land carbon uptake variability." Nature 592(7852): 65-69.). In this study, the authors only mentioned croplands were separated into the irrigated and rain-fed areas in the historical simulations (line 122-124). Did the future simulations use the same irrigation management as the year 2015? Can the authors at least clarify their method of determination of the irrigated and rain-fed areas and add discussion on the impact of irrigation practice and its interaction with other managements on cropland SOC stocks. I look forward to reading a revised version of this manuscript.

Response to preface: Thank you for your review and the useful recommendations to improve the manuscript. To reply to your main concern, irrigation and water interactions with the biosphere are indeed important drives of productivity and impacts plant growth, and irrigation is considered in our future simulations. LPJmL accounts for an irrigation scheme of blue and green water consumption (Rost et al., 2008), as well as different irrigation systems, such as sprinkler, surface, and drip irrigation (Jägermeyr et al., 2015). Irrigation water partitioning is dynamically calculated in coupling to the modeled water balance and climate, soil, and vegetation properties (Schaphoff et al., 2018). In our future simulations, we do not account for adjustments in irrigation systems or irrigated areas that could be implemented in response to changing climate conditions, but as we generally do not account for future land-use change, we keep the irrigation system, as well as the rainfed/irrigated share, constant throughout the future simulation period as in the year 2005. The irrigated and rainfed area was separated based on the Land-Use Harmonization – LUH2v2 data, as described in line 143-146. On irrigated cropland, we simulate potential irrigation, which assumes unlimited water resources available for irrigation rather than constraining irrigation to surface discharge, which underestimates irrigation water withdrawals that also tap groundwater resources.
Still, we also believe that the role of irrigation systems on cropland SOC dynamics should be considered in future analysis. As previous studies using LPJmL have shown, for example in semiarid regions, irrigation is responsible for an increase in soil carbon (Bondeau et al., 2007).
We updated the model description and explained the irrigation scheme of LPJmL in more detail (lines 88-91) and describe the irrigation setting in the simulation protocol in lines 130-132. We added a discussion on the irrigation effectiveness to the lines 466-467, 469-471, and 507.

Referee comment 1: The "SOC sequestration potential" in the title seems to be misleading. Sequestration indicates SOC accumulation even under climate change as long as we use proper management. However, the results of this study show that the global SOC stocks decrease under all climate scenarios and management. I think using something like "SOC stock dynamics" is more appropriate.

Response to comment 1: Thank you for the suggestion. We changed the title to "SOC stock dynamics from agricultural management practices under climate change".

Referee comment 2: The impact of various agriculture practices, such as residue management, tilling, and irrigation should be described in the introduction to set up for the results and discussion.

Response to comment 2: We have extended the introduction by a description of tillage, residue management, and irrigation effects in lines 38-50.

Referee comment 3: Line 115 – the potential natural vegetation data need a reference.

Response to comment 3: We do not use any external data on potential natural vegetation (PNV), but LPJmL can compute the natural vegetation composition and dynamics internally. The PNV simulations simply ignore the land-use input data and assume that there is no land use. We have added additional text to clarify this to line 136-137.

Referee comment 4: Line 237-238 – this description of h_dLU_area05 is quite confusing. Can the authors describe this scenario in the method?

Response to comment 4: We are sorry for the confusion caused. Please see the response to comment 5 below.

Referee comment 5: Line 240-243 – the h_dLU_area05 scenario described here is more clear, but it still should be described in the method and be listed as one of the scenarios in Table 1, because it is related to the main conclusion that cropland SOC stock decrease over history.

Response to comment 5: Thank you, we are aware that the calculation of the results of the h_dLU_area05 might cause confusion. While 'h_dLU' refers to the simulation set up as described in Table 1, the extension '_cropland_SOC' and '_area_05' refers to the post-processing of model results. In the '_area_05' case, the results are calculated as described in Eq. (4) and (5). This was not clear in the original text and has been updated now.
We have improved the description of the h_dLU_area05 scenario analysis in the method section in lines 206-212. We also added the calculation reference to Eq. (4) and (5) in the results section in lines 273-274. We hope that this clarifies the calculation of results.

Referee comment 6: Line 248-249 – this sentence needs some editing. Did the authors mean the calculation of the actual decrease in SOC stocks from LUC considered areas that were converted to cropland at any time over the entire period (1700-2018)?

Response to comment 6: This is indeed the case. For the calculation of SOC loss from LUC, we only considered the areas which are actually converted from PNV to cropland at any point in time between 1700 and 2018. Because SOC density is generally lower on cropland compared PNV, SOC is reduced. We edited the sentence in lines 279-283 for clarification.

Referee comment 7: Line 272 – what lead to the sudden jump of SOC, turnover rate, and litterfall between 2000 and 2005 in all management scenarios?

Response to comment 7: Cropland SOC increases in all management scenarios between 2000 and 2005 as land-use patterns are dynamic and only kept constant after 2005. So this reflects the increase in cropland area between 2000 and 2005. The same holds true for turnover rates, where prior to 2005 newly deforested land is added to the cropland pool, where decomposition rates are high because of the unusually high amount of fresh material after deforestation. There is no jump in litterfall prior to 2005, and after 2005 the different management practices show strong effects on the SOC pool, turnover rate, and litterfall. We have added text to the caption of figure 3 for clarification in lines 314-316.

Referee comment 8: Line 379-382 – the mechanism of SOC forming should be better described and referenced here. The number of residues that can be retained on cropland also depends on both the quantity and quality of residues. The priming effect is not always positive. Since the authors discussed the compensating effect of higher productivity and turnover rates in the following paragraph, the effect of temperature on organic matter decomposition should be described here to set up the following discussion.

Response to comment 8: We have updated this section in lines 419-425 and added a more detailed description of how C is transferred to the soil and SOC formation occurs. We now also discuss in lines 427-431 that the model only considers temperature and moisture as drivers of the decomposition but no the quality of residues left on the field.

References:

Bondeau, A., Smith, P. C., Zaehle, S., Schaphoff, S., Lucht, W., Cramer, W., Gerten, D., Lotze-Campen, H., Müller, C., Reichstein, M., and Smith, B.: Modelling the role of agriculture for the 20th century global terrestrial carbon balance, 13, 679–706, https://doi.org/10.1111/j.1365-2486.2006.01305.x, 2007.

Jägermeyr, J., Gerten, D., Heinke, J., Schaphoff, S., Kummu, M., and Lucht, W.: Water savings potentials of irrigation systems: global simulation of processes and linkages, 19, 3073–3091, https://doi.org/10.5194/hess-19-3073-2015, 2015.

Rost, S., Gerten, D., Bondeau, A., Lucht, W., Rohwer, J., and Schaphoff, S.: Agricultural green and blue water consumption and its influence on the global water system, 44, W09405, https://doi.org/10.1029/2007WR006331, 2008.

Schaphoff, S., Bloh, W. von, Rammig, A., Thonicke, K., Biemans, H., Forkel, M., Gerten, D., Heinke, J., Jägermeyr, J., Knauer, J., Langerwisch, F., Lucht, W., Müller, C., Rolinski, S., and Waha, K.: LPJmL4 – a dynamic global vegetation model with managed land – Part 1: Model description, 11, 1343–1375, https://doi.org/10.5194/gmd-11-1343-2018, 2018.