Major revision: 'Simulation of soil carbon dynamics in Australia under a framework that better connects spatially explicit data with ROTH C'

Dear authors

The handling editor decided to reject your paper following the recommendations of two referees. This decision was overturned by the Chief Editors following your appeal to the editorial board. I was asked by the editorial board to handle your manuscript.

I am happy to invite you to submit a suitably revised version of your manuscript, considering the comments by the two referees and my comments. Your revised manuscript will be sent out again to review.

Authors: We thank the Editor, Dr Joos, for taking the time to review our manuscript, the two reviews and our responses to the reviewers. Below, we describe the major revision of our manuscript, which are as the editor suggests and considering the the two previous referee's comments and our responses.

Please carefully consider the comments made by the two reviewers and change your manuscript to address these points where appropriate.

Authors: Thank you, we have done so.

I suggest that you add a few lines early on in the manuscript to clarify the setup of your sensitivity simulations with altered carbon input to soils under constant climate and provide an explanation/justification on the range of input fluxes selected to address the second and third main point of referee #2. In this context, please consider replacing the word "prediction/predict" with "simulations/simulate" or similar to avoid the impression that results represent a prediction of the future evolution of soil C in Australia.

Authors: Thank you for the suggestions. We addressed these points by: (i) reformulated our aims to emphasise the site-specific initialisation and optimisation performed; (ii) clarifying that the simulations to assess potential increases in C stock were made using constant climate (we made this clear throughout the manuscript), and a plausible range of C inputs; and (iii) emphasising that we wanted to test a wide and representative range of C inputs. Regarding

this last point, in the revision we added: "These rates were selected to represent a wide range of C input levels that would be either physically achievable or manageable (e.g. manure addition) (Maillard and Angers, 2014)." Please note that animal manure was used as fertilisers by 11% of agricultural businesses worldwide. About 2.1 million Mg of animal manure were applied in 2011-12. Also, we include a reference to Maillard and Angers (2014) who, in their global meta-analysis, report manure addition ranging from 0 to around 400 Mg in crop management systems.

Reviewer #1 perceived your work and presentation as very technical. You kindly offered to further emphasize the science questions in your reply to reviewer #1. It would, in my opinion, indeed be useful to provide a few additional lines further describing the context and motivation for your model framework and your sensitivity simulations in the introduction, thereby complementing the context and motivation already provided. I may be wrong, but I got the impression that one motivation of this study is to prepare the ground for further application of your model (i) in assessments of Australian National Greenhouse Gas Inventory (line 50) used for the reporting under the UNFCCC process (?) and (ii) to pay farmers for efforts to stimulate extra carbon transfer to soils (line 51). I also interpret your text on line 51, that your model may be used to estimate the change in soil carbon stock over a 100-yr period under constant climate in response to measures by farmers, and in turn, this estimate is used to pay farmers. In any case, I would welcome further motivation in the manuscript why you are performing this model exercise, e.g., also building on your answer to reviewer #1 on page C5 in the reply ("Our work addresses important scientific questions pertinent to Australian soils: e.g. how…").

Authors: We appreciate the suggestions. To address these points, we (i) improved out title to 'Simulation of soil carbon dynamics in Australia with RothC' — thus removing the said misleading focus on the 'framework'; (ii) re-formulated our aims to better describe the significance and innovation of our work—as per our responses to the referees, and (iii) clarified the motivation of our work, according to our previous responses to reviewer #1. Thus, in the revision, we write: "Here, we report on simulations of the organic C stocks in Australian soils

with ROTH C using a standardised approach that synthesises and processes measurements and data for prediction at a correct scale. Our motivation for developing this research is to help answer questions around soil C that are pertinent to Australian soils and ecosystems under different land uses and management. Our aims are to: (i) derive baseline estimates of soil organic C stock and composition by site-specifically initialising the model with measurements of POC, HOC and ROC and an optimised ratio of decomposable plant material (DPM) to resistant plant material (RPM), which represents the decomposability of incoming biomass, (ii) simulate over a 100-year period, with constant climate and a plausible range of C inputs, the potential to increase organic C stocks as well as the potential vulnerability to C loss across Australia, and (iii) to identify the soil and environmental controls of the change in soil C stocks.".

Reviewer #1 noted that section 2.3.4 is unclear. The description of your iterative procedure to estimate soil C input in section 2.3.4 should indeed be improved. What do you mean exactly by "We tested six different values of DPM/RMP ratio ... We then perform the simulation iteratively ..." Did you run for each value of DPM/RPM an iteration to estimate C input for a given DPM/RMP value? The sentence on l. 169/170 is unclear: "We ran the model for 100 years [ ] until equilibrium conditions occurred." Maybe you want to say that you run the model several times for 100 yr with slightly different C input until equilibrium is achieved? Does this also imply that the TOC inventory at the end of the iterative procedure is the same as prescribed at the beginning of the iteration (apart from the bacterial pool? Where the soil pools initialized again with the measurements after each simulation in the iteration? Please describe your simulation protocol more precisely.

Authors: We agree that our description was unclear. We have improved the description of these methods and are confident that in the revision, our description of these methods is clear. We now write: "We tested six different DPM/RPM ratios (0.67, 0.96, 1.17, 1.44, 1.78 and 2.23) to estimate baseline C inputs and to assess the sensitivity of the simulated TOC, POC and HOC to this parameter... For each DPM/RPM ratio, we run the simulations at each of 4,431 sites for 100 years. Specifically, for each ratio at each location, we performed the

simulations iteratively by re-initialising the POC and HOC pools with the measured C fractions and with a change in the monthly input of plant residues and farmyard manure equivalent to 1/100 of their initial values. This was repeated 1000 times or until equilibrium was achieved. We considered only monthly C inputs in the simulations. The weather data used in the simulations represents the conditions of the baseline period between 1991–2010, which were repeated over the 100-year simulation...".

Regarding the equilibrium assumption, it is not clear to me why you need to estimate soil input iteratively. Could this not be done by setting C input equal to all C loss fluxes?

Authors: This is a misunderstanding. The wording was unclear, we agree. We improved the description of these methods and hope to have clarified the procedure (see above). The simulations were performed for each DPM/RPM ratio at each location for 100 years. For each ratio at each site, the model was run iteratively by re-initialising the C fractions with the measurements and by changing the C inputs slightly, by 1/100 from their original values. This run up to 1000 times or until the model reached equilibrium. In Roth C, when the ratio of DPM/RPM (i.e. the quality of the organic matter) is fixed, iterative adjustments to the amount of C inputs is needed because we do not know all C losses that will occur and we don't know the C inputs needed to compensate the losses.

In general, I found your proposed text modifications appropriate in response to the comments of referee #2. Please implement these changes when revising your manuscript for re-submission. Please also consider whether additional clarifications may help to avoid misunderstanding and address comments where you did not indicate any action in your response

Authors: Thank you. We have implemented the changes in the text as proposed in our previous responses and have made the additional clarifications to prevent misunderstanding.

I am looking forward to receiving your revised manuscript. Thank you for submitting your work to Biogeosciences.

Yours sincerely,

Fortunat Joos

Further minor comments:

L80: Please provide the reference state (Temp, soil water veg. cover, ..) for the specified values of the decomposition rate coefficients.

Authors: The reference state is the average conditions at Rothamsted, which was reported by Jenkinson and Rayner (1977). We have added the following sentence and listed this reference: "Its reference state for the decomposition rate constants was reported by Jenkinson and Rayner (1977)".

261/262: please clarify this sentence. It is unclear why an increase of 39% is larger than an increase of 59%?

Authors: Apologies for the confusion. We have revised the sentence to "The soil under native grazing was the most vulnerable with the increase in POC (35%) and HOC (59%), showing that the labile POC increased more proportionally than that of the other land uses.".

Figure 3: I had the same issue with overlapping labels as referee #2. Please check your figure and, perhaps, select slightly smaller fonts.

Authors: We have corrected the figure.

References

Maillard, É. and Angers, D.A. (2014) Animal manure application and soil organic carbon stocks: a meta-analysis. Glob Change Biol, 20: 666-679. https://doi.org/10.1111/gcb.12438

MLA (2002) Safe Use of Manure and Effluent - A Technical Users Manual, Published by Meat & Livestock Australia (MLA) Limited. ISBN 1 74036 362 0.