Response to the reviewer's comments

A millennium of arable land use – the long-term impact of water and tillage erosion on landscape-scale carbon dynamics

Öttl, L. K., Wilken, F., Juřicová, A., Batista, P. V. G., Fiener, P.

EGUSPHERE-2023-1400 | Original research article

We are grateful for the constructive and thorough feedback and thank the reviewer for his suggestions. At this stage of revision, we only answered the general comments. Each detailed comment will be individually addressed in the final revision of our manuscript. Please find the answers to the reviewer's comments in the text below. The original comments of the reviewer *are written in* blue *and our reply in black and italics.*

Reviewer #1 (Marijn van der Meij) – General comments:

Öttl and colleagues present a very comprehensive modelling study on the effects of soil redistribution on soil organic carbon stocks over millennial timescales. The manuscript provides detailed information on changes in agricultural practices, erosion intensities and the effect on SOC fluxes over this period.

The authors simulate a large variety of modelling scenarios, with varying erosion intensities and SOC dynamics. I think this is one of the first times that such a sensitivity analysis is performed in soil-landscape evolution studies. I'm impressed with the amount and quality of the work from the authors, but I have two main concerns which should be addressed before the paper can be published. These relate to the structure of the manuscript and missing information on certain data and definitions.

I detailed these concerns below and added more explanation and additional smaller comments in the attached PDF.

With best regards,

Marijn van der Meij

We thank the reviewer Dr. van der Meij for this encouraging feedback and for the substantial review, which will help to improve the manuscript.

Structure of the manuscript

I feel that a clear structure is missing in parts of the manuscript, which makes it difficult to understand what is presented. With a revision of the structure, this should be easy to improve. Examples are

- the Methods section, where inputs, parameters, calibrations and justifications are presented in a mixed manner;
- The Results section, where a logical order of the results is missing;
- A missing overview of all the different scenarios that have been simulated. For example, only in the Results and Discussion it becomes clear that there are also simulations with and without deep C burial. A table with all scenarios would be helpful here.

We are grateful for the suggestions regarding the structure of our manuscript. We will critically revise the structure of the methods and results sections, as this will help improving the understanding of the presented research. Moreover, we will elaborate the different realisations and scenarios more clearly in the methods section to avoid any confusion in the results and discussion section. A table with the scenarios will be added.

Missing information

When reading the manuscript, I found several terms, data sources and modelling settings that were not introduced in the text. Examples are:

- The definition of a heavily eroded soil, both for the classification from remote sensing and in the model results (line 285, Section 3.1);
- The SOC-depth profile from forest soils that were used as initial condition (Fig. 3). This data is not introduced in the text;
- The absence of updating the topography after soil redistribution. This is mentioned for the first time in Section 4.4.1. I was surprised this was not included, as it has a big impact on erosion and SOC dynamics over 1000 years and should be relatively easy to include;
- A Discussion on how the size of the simulated landscape affects the model results. In other words, what are the benefits of simulating the entire Quillow catchment instead of the test sites?

We thank Dr. van der Meij for the careful reading of the manuscript and finding missing information that is essential to understand our research. Of course, we are happy to revise the manuscript and incorporate the following details:

1) *In the methods section we explain the term "**heavily eroded soil**" (l. 282ff) as follows:*

   "The heavily eroded hilltops are visible in remote sensing data due to their brighter colours resulting from an exposure of the subsoil horizon partly consisting of glacial till (Figure 4)."

   We would like to reformulate this sentence to make clear that brighter colours at eroded hilltops do not necessarily indicate exposed parent material but the incorporation of parent material into the topsoil:

   "We qualitatively defined heavily eroded areas as the locations where bright subsoil material could be identified at the land surface by remote sensing images, which is indicative of the partial incorporation of glacial till into the plough layer due to extreme soil truncation. The exposure of such subsoil material implies that ca. 1 m of soil was removed by erosion (Van der Meij et al. 2017)."

2) *We are very grateful that Dr. van der Meij found this mistake regarding the missing data source of the **SOC-depth profile from forest soils**. We parameterised the forest soils according to Calitri et al. (2021). We apologise for the missing information, but unfortunately it was lost during manuscript rewriting. A description of the dataset will be included in the methods section in the revised version of our manuscript.*

3) *We will mention the **absence of updating the topography after soil redistribution** in the methods section of the revised manuscript, so the reader is not confused in the discussion. We did not include an update of the digital elevation model (DEM) in our study, because compared to earlier studies dealing with DEM update, which mostly focused on bulk soil, we do not think that this can be easily implemented in an approach where SOC dynamics following soil redistribution are modelled. Modelling a millennium of soil redistribution by water and tillage in a yearly time step would require a DEM update every year. If the change in topography due to erosion and deposition is accounted for, this typically results in pits in the DEM. For models using flow or sediment routing, these pits have to be removed before the new DEM can be used in the next time step. The typical way handling this problem is filling the pits or redistributing soil to fill the pits with soil from their surroundings (Peeters et al. 2006). If SOC stocks as well as SOC sequestration and mineralisation are modelled, pit filling would strain the mass balance of SOC in the landscape or it is not clear what kind of soil and SOC is moved into the pits to fill them. Due to these difficulties, we decided not to account for a DEM update. To discuss the effect of a missing DEM update upon SOC balance we included the scenarios with and without deep carbon burial in the discussion section (already there in the current version of the manuscript). To clarify the use of these scenarios, we will extend the methods section (see our answer to the comment above).*

4) *The main reason to **model the entire Quillow catchment** was to illustrate the effect of long-term soil redistribution on SOC stocks and dynamics in an entire landscape, while most small-scale erosion studies are often allocated at test sites which are specifically prone to erosion (Auerswald et al. 2009). This substantially biases the results and hence conclusions, because at larger landscapes, there is a tendency for slopes to be less steep and more deposition takes place. In general, the chosen approach and scale was used to analyse an average state of a landscape rather than to perfectly describe one single field.*

References

Auerswald, K., Fiener, P. and Dikau, R. (2009) Rates of sheet and rill erosion in Germany - A meta-analysis. Geomorphology 111, 182-193.

Calitri, F., Sommer, M., van der Meij, W.M., Tikhomirov, D., Christl, M. and Egli, M. (2021) ^{10}Be and ^{14}C data provide insight on soil mass redistribution along gentle slopes and reveal ancient human impact. Journal of Soils and Sediments 21(12), 3770-3788.

Peeters, I., Rommens, T., Verstraeten, G., Govers, G., Van Rompaey, A.J.J., Poesen, J. and Van Oost, K. (2006) Reconstructing ancient topography through erosion modelling. Geomorphology 78(3-4), 250-264.

Van der Meij, W.M., Temme, A.J.A.M., Wallinga, J., Hierold, W. and Sommer, M. (2017) Topography reconstruction of eroding landscapes. A case study from a hummocky ground moraine (CarboZALF-D). Geomorphology 295, 758-772.