

## Response to comments

**Paper #:** GMD-2023-114

**Title:** *Modeling biochar effects on soil organic carbon on croplands in a microbial decomposition model (MIMICS-BC\_v1.0)*

**Journal:** *Geoscientific Model Development*

### **Editor:**

#### **Comment #1**

Thank you for your extensive revisions to the manuscript! They've made it much easier to follow, but there are still some confusing spots. Please see the attached supplement for requested changes that will further improve the organization and other pieces. Although these may seem like extensive changes, I feel that it's now at a point where I can review it myself and don't need to involve the reviewers.

#### **Response #1**

We thank the Editor for the additional comments and the careful review. Please see the detailed point-by-point response below.

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#### **Comment #2**

##### **Organization:**

Lines 327-30: This sentence should be moved to the end of the paragraph at Line 276.

#### **Response #2**

Moved as suggested.

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#### **Comment #3**

Lines 357-64: This should be its own paragraph.

#### **Response #3**

Revised as suggested.

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#### **Comment #4**

Lines 366-72: The information here should be moved to a new paragraph after the paragraph ending Line 276.

#### **Response #4**

Moved as suggested.

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#### **Comment #5**

Lines 392-400: Because the calibration and validation gave largely the same results in terms of best-performing model, this description of the calibration set metrics can probably be removed to simplify the paper a bit.

#### **Response #5**

Removed as suggested.

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#### **Comment #6**

Line 419: Sect. 3.1.2 label should say "analyses" (plural) instead of "analysis" (singular).

#### **Response #6**

Revised as suggested.

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#### **Comment #7**

Lines 420-427: There are three analyses whose results are described in the three sentences of this paragraph. That's confusing! They should each be their own paragraph—or, ideally, subsection (3.1.2, 3.1.3, 3.1.4). This will allow you to dedicate more space to them, explaining what they mean for subsequent analyses you will present.

- At the beginning of each, remind the reader what the purpose of the analysis was, and add parentheticals referring back to the Methods section where it was described.
- Lines 423-5: This should be moved to Sect. 3.1.2 and given its own paragraph (and expanded).

#### **Response #7**

As suggested, the sentences in **Section 3.1.2** were given their own paragraph, and each sentence was expanded to make it clear:

“To explore the possible effects of soil moisture on SOC dynamics through affecting different processes (**Section 2.3.2**), we assumed that the microbial turnover ( $\tau$ ) was also affected by soil moisture in addition to the microbial reaction velocity ( $V_{\max}$ ). The model with the soil moisture effects does not predict SOC concentrations more accurately ( $R^2=0.46$ ,  $RMSE=5.06$  g kg<sup>-1</sup>,  $AIC=198.9$ , Fig. S9b) than the MIMICS-TSM<sub>b</sub> version where  $V_{\max}$  and  $K_m$  are affected ( $R^2=0.52$ ,  $RMSE=5.05$  g kg<sup>-1</sup>,  $AIC=198.6$ , Fig. 4d, Fig. S5b). It may be because the inclusion of soil moisture effects on  $V_{\max}$  and  $\tau$  complicates the model processes, and other microbial-related observations such as soil microbial carbon and soil heterotrophic respiration are needed to further constrain these processes in MIMICS.

We analyzed the responses of the MIMICS model to changes in input variables, in order to identify the important variables and explore possible missing processes related to these variables (**Section 2.3.2**). The perturbation for input variables of MIMICS shows that the size of steady SOC pool is positively correlated with NPP and Clay, but negatively correlated with MAT and BD. The responses of steady SOC to the perturbation of BD, MAT and NPP are relatively large (Fig. 5). Improving processes associated with these variables in MIMICS will enhance the prediction accuracy of the model.”.

The analyses on **Line 423-5** in the original manuscript were moved to **Section 3.1.1** in the revised version and expanded in its own paragraph on **Line 411-416** as: “To align with the resolution of climate input variables used in the transient simulations (**Section 2.3.1**), we tested MIMICS after aggregating cropland SOC sites within each  $0.5^\circ \times 0.5^\circ$  grid cell instead of using each site directly, and the model can reproduce about 45%~55% of the SOC spatial variation (Fig. S10), slightly lower than that using site-specific data ( $R^2=0.51\sim 0.56$ , Fig.4e). This shows that site-specific data is more accurate for model simulation, but the small difference also suggests that using grid climate data ( $0.5^\circ \times 0.5^\circ$ ) to drive the model has a relatively small impact on predicting SOC in the transient simulations.”.

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#### **Comment #8**

Lines 435-7: As with lines 392-400 (see above), this description of the calibration metrics can probably be removed.

#### **Response #8**

As suggested, we removed the description of model calibration.

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#### **Comment #9**

Lines 444-6: This should only mention results from the validation dataset, not the calibration.

#### **Response #9**

As suggested in **Comment #5**, the calibration results were removed.

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#### **Comment #10**

Lines 448-50: As with lines 392-400 (see above), this description of the calibration metrics can probably be removed.

#### **Response #10**

Removed accordingly.

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#### **Comment #11**

Lines 468-72 (Fig. 7 caption): To make it easier for the reader to understand the differences between this and Fig. 6, simplify by just saying "As Fig. 6, but for models based on MIMICS-TSM<sub>b</sub> instead of MIMICS-T." You can make similar changes for supplemental Figs. S11 ("As Fig. 6 but for calibration step instead of validation") and S12 ("As Fig. 7 but for calibration step instead of validation" and/or "As Fig. S11 but for models based on MIMICS-TSM<sub>b</sub> instead of MIMICS-T").

#### **Response #11**

As suggested, we modified the caption of **Fig. 7** to "**Fig. 7** As Fig. 6 but for models based on MIMICS-TSM<sub>b</sub> instead of MIMICS-T". The caption of **Fig. S11** and **Fig. S12** were modified as: "**Fig. S11** As Fig. 6 but for model calibration instead of validation" and "**Fig. S12** As Fig. 7 but for model calibration instead of validation", respectively.

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#### **Comment #12**

Figs. 8, S14:

(1) Is there a difference between these other than S14 being short-term and 8 being long-term? If not, simplify the caption for S14 by just describing its difference from 8.

(2) Why does Fig. S14 have a row for  $\Delta$ SOC but Fig. 8 doesn't?

#### **Response #12**

(1) There are no major differences except that **Fig. S14** in the original manuscript is short-term and **Fig. 8** is long-term. As suggested, we modified the caption of **Fig. S13** (i.e., **Fig. S14** in the original manuscript) to: "**Fig. S13** As Fig. 8 but for short-term SOC changes with biochar addition."

(2) It is also conducted for long-term  $\Delta$ SOC but not shown in **Fig. 8**. It has similar results to short-term  $\Delta$ SOC in **Fig. S14** in the original manuscript. These results were not further discussed in the manuscript, and we deleted the first row for  $\Delta$ SOC in **Fig. S14** to be consistent.

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#### **Comment #13**

Lines 493-9: This should be a separate paragraph.

#### **Response #13**

Revised as suggested.

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#### **Comment #14**

**Misc.:**

Sect. 3.1 is titled "Performance of different MIMICS versions for simulating cropland SOC". However, it only has results for MIMICS without biochar. It should be renamed to reflect this.

#### **Response #14**

As suggested. We modified the title of **Section 3.1** to "**3.1 Performance of MIMICS versions without biochar for simulating cropland SOC**".

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#### **Comment #15**

Line 297: "New-Ralphson" should be "Newton-Raphson" (note, no L).

#### **Response #15**

Revised as suggested.

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### Comment #16

Lines 349-50: This sentence just repeats (in different words) the sentence at Lines 350-2, right? Suggest deleting.

### Response #16

We removed the first sentence as suggested.

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### Comment #17

Lines 352-6:

- This would be much easier to read as a numbered list with line breaks.
- (3) can be more concisely rewritten by describing only its differences from (2).
- (4) can be more concisely rewritten by describing only its differences from (3)

### Response #17

Revised as suggested.

As suggested, we adjusted these sentences as a numbered list with line breaks. We modified the description of the test (3) and (4) on **Line 364-366** in **Section 2.3.3** to make them more concise: “

(3) with further one new biochar-related parameter (the decomposition rate coefficient,  $f_v$ , Eq. 16) optimized and  $f_v$  included in all decomposition processes (MIMICS<sub>TSMb-BC<sub>DV</sub></sub>);

(4) as (3) but  $f_v$  only included in the fluxes from SOC<sub>a</sub> to MIC pools (MIMICS<sub>TSMb-BD<sub>DV-SOCa</sub></sub>).”

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### Comment #18

Line 362: "MIMICS-T that have" should be "MIMICS-T, which had".

### Response #18

Revised as suggested.

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### Comment #19

Lines 365-72: Explain why this test is being conducted. i.e., why is it a problem that most biochar addition experiments are short? What additional value will you gain from the long-term experiment described here?

### Response #19

As suggested, we added sentences on **Line 281-286** in **Section 2.3.1** to explain the reason: “The stabilizing processes of SOC after biochar addition are usually slow, and the long-term impacts of biochar addition on SOC may be different from the short-term impacts (Ding et al., 2011). Therefore, long-term SOC observations with biochar addition are needed to validate possible mechanisms and evaluate the model performance of simulating SOC stability with biochar addition. However, the duration of most biochar addition experiments is short (74.2% data < 3 years), and we thus extended our collected control SOC data to 8 years according to the decomposition curve of biochar in soil fitted by a double first-order exponential decay model (Fig. S4; Wang et al., 2016).”

The extended long-term SOC data were used for model calibration and validation, resulting in a set of parameter values that address the long-term biochar effects on SOC (**Table S3**) and exploring the possible mechanisms for stabilizing SOC in the long term (see **Section 4.2.1**).

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### Comment #20

Line 376: "availability carbon" should be "availability of carbon".

### Response #20

Revised as suggested.

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### Comment #21

Line 377: What was the original value of  $f_{ba}$ ?

### Response #21

The original value of  $f_{ba}$  is assumed 20% in **Section 2.2**. We modified the sentences on **Line 379-381** in **Section 2.3.3** to make it clear: “We thus tested the MIMICS<sub>TSM<sub>b</sub></sub>-BC versions using a different initial value of the partitioning coefficient from biochar carbon to SOC<sub>a</sub> ( $f_{ba}$ ) (2% according to Lychuk et al., 2014, compared to the original initial value of 20% in **Section 2.2**). The partitioning coefficient of  $f_{bp}$  and  $f_{ba}$  were also optimized to evaluate the model performance”.

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### Comment #22

Lines 378-9: What does "the partitioning coefficient of  $f_{bp}$  and  $f_{ba}$  were optimized to evaluate the model performance" mean? Didn't you just say  $f_{ba}$  was set to 2%.

### Response #22

$f_{ba}$  is the initial value before calibration, and it is allowed to be adjusted in the optimization process. We clarified this point in **Response #21**.

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### Comment #23

Lines 379-81: Were the sensitivity tests here conducted in a factorial way? Or did you only perturb one parameter at a time?

### Response #23

We conducted the sensitivity tests by perturbing one parameter at a time and controlling other parameters unchanged. We modified the sentence on **Line 381-385** in **Section 2.3.3** to make it clear: “Considering the uncertainties in the MIMICS-BC parameters, we conducted a sensitivity test of biochar-related parameters (i.e.,  $f_d$ ,  $f_v$ ,  $f_{bp}$ ,  $f_{ba}$ ), microbial-related parameters (MGE,  $\tau$ ) and input variables (i.e., Rate\_BC, Age\_BC, NPP, Clay, SM) by perturbing one parameter at a time while keeping all others unchanged for each site. Four perturbation levels of -50%, -25%, 25% and 50% were set.”.

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### Comment #24

Lines 404-6: Put "Compared to MIMICS-def" at the beginning of this sentence (and delete the similar phrase at the end). Putting that information at the end makes the sentence hard to understand at first.

### Response #24

Revised as suggested.

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### Comment #25

Lines 410-2: Does MIMICS not represent the effect of flooding on SOC decomposition? This is implied but not actually said.

### Response #25

The soil moisture factor was added in MIMICS, which can represent the effects of flooding on SOC decomposition, but information on flooding at each site is not available. We modified the sentence on **Line 405-409** in **Section 3.1.1**: “It is probably because the flooded condition in the paddy field limits SOC decomposition, which is partly supported by the weaker correlation between SOC and NPP for rice ( $R^2=0.06$ , Fig. S7d) than that for maize and wheat ( $R^2=0.77$  and  $0.54$ , Fig. S7a, g). Although MIMICS-TSM<sub>b</sub> has the soil moisture processes (**Section 2.1.4**), but the flooding conditions in the paddy field are not available and are not explicitly forced in these rice sites.”.

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### Comment #26

Lines 414-8 (Fig.4 caption): Mention that values for the bar graphs in Fig. 4e can be found in Fig. S5.

### Response #26

As suggested, we added a sentence in the caption of **Fig. 4**: “The values for the bar graphs in Fig. 4e can be found in Fig. S5.”.

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**Comment #27**

All scatter plots: Best-fit lines should not extend beyond the lowest and highest X-axis values of the data points.

**Response #27**

As suggested, we adjusted all the scatter plots in the manuscript and supplementary information accordingly.

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**Comment #28**

Lines 455-6: "Among the different MIMICS<sub>TSMb</sub>-BC versions, MIMICS<sub>TSMb</sub>-BC<sub>DV</sub> shows the best performance (Fig.7). " It does have the best R<sup>2</sup>, RMSE, and AIC, but its slope is much farther from 1 than either BC<sub>DV</sub> or BC<sub>DV-SOCa</sub>. If I were considering adopting one, I would choose one of the latter, which makes me think those are "better."

**Response #28**

We are afraid the editor may wrongly refer to **Fig. 6** for this sentence. In **Fig. 7**, it does show that “Among the different MIMICS<sub>TSMb</sub>-BC versions, MIMICS<sub>TSMb</sub>-BC<sub>DV</sub> shows the best performance (Fig. 7).”. In addition, BC<sub>DV</sub> in “but its slope is much farther from 1 than either BC<sub>DV</sub> or BC<sub>DV-SOCa</sub>.” should be “BC<sub>D</sub>”?

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**Comment #29**

Line 475: "or" should be "and".

**Response #29**

Revised as suggested.

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**Comment #30**

Lines 479-80: But increases (introduces) bias related to SM.

**Response #30**

Yes, we modified the sentence on **Line 485-487** in **Section 3.2.2** to make it more comprehensive: “MIMICS<sub>TSMb</sub>-BC<sub>DV</sub> incorporating the biochar impacts on microbial decomposition rate further reduces the correlations between model biases and variables of Rate\_BC, Age\_BC and BD, but it increases biases related to SM.”.

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**Comment #31**

Line 493: Delete "that".

**Response #31**

Removed as suggested.

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**Comment #32**

Lines 543-4: This sentence mentioning the work of Juice et al. (2022) doesn't seem to contribute anything. What did they find?

**Response #32**

As suggested, we modified sentences on **Line 550-553** in **Section 4.1.2** to explain the related founding from Juice et al. (2022): “Juice et al. (2022) modeled tillage effects on SOC loss through transferring protected SOC into unprotected, i.e., from SOC<sub>p</sub> to SOC<sub>a</sub> in this study, and the model can well capture the historical SOC dynamics in the agricultural system with intensive managements such as different crop types, tillage or fertilization.”.

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**Comment #33**

Line 568: Incubation has not been previously mentioned; please define.

**Response #33**

According to the words mentioned in **Section 2.3.1**, we modified “incubation time” to “Age\_BC”.

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**Comment #34**

Line 573: "In the MIMICS<sub>TSMb</sub>-BC versions that include the adsorption process" should be changed to "In the MIMICS<sub>TSMb</sub>-BC versions, which include the adsorption process".

**Response #34**

Revised as suggested.

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