Biogeosciences Discuss.,
doi:10.5194/bg-2016-161-AC4, 2016

Biogeosciences
Discussions
Open Access
EGU

Interactive comment on "Soil carbon response to land-use change: Evaluation of a global vegetation model using meta-data" *by* Sylvia S. Nyawira et al.

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Received and published: 24 August 2016

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Response to E. Marin-Spiotta of the paper entitled "Soil carbon response to land-

use change: Evaluation of a global vegetation model using observational meta-analyses"

Ref.: bg-2016-161

Below are the reviewers suggestions (***bold italic font***) and our responses to each point (normal font). In some of our responses, we have cited text from the revised manuscript (*italic font*).

Thank you for your comments, which have helped us greatly in improving our manuscript. We would like to clarify that there were some changes requested by one of the reviewers prior to the publication of the manuscript on discussion. Therefore, some of the line numbers in this review refer to the older version of the manuscript at the quick report stage. To be consistent, we have added the new line numbers that match the current manuscript on discussion in parenthesis.

This study uses published results from temperate and tropical meta-analyses that calculate mean responses of soil carbon change to different land-use transitions from field measurements of paired plots to better constrain estimates of belowground response to land-use change at a global scale simulated by a dynamic global vegetation model. To my knowledge, this is the first time global syntheses of data from published meta-analyses have been used to compare to results from models. The research takes advantage of a large effort to synthesize global temperate and tropical data on soil C to estimate the response of soil C stocks to major land use transitions.

Overall, the writing could be improved to more clearly describe the modeling approach and to distinguish it from past efforts. Some sections have minimal

text (for example, description of the observational data and the meta-analyses approach), and while the attempt to be concise is appreciated, more information would make it easier for readers to understand and attempt to replicate the approach.

We have expanded section 2.3 and 2.4 to make it easier for readers interested in replicating the results (see response to B. Guenet). We have also expanded the section describing the meta-analyses (section 2.1) as follows:
"In this study, we use results from the meta-analyses by Poeplau et al. (2011) in the temperate regions and Don et al. (2011) for the tropical regions including 95 and 385 published studies, respectively. The published studies include sites from different countries in the tropics and temperate regions. The site studies were conducted using two main experimental designs: paired plots comparing soil C between two adjacent sites with different land use types, and time series where the soil C of a particular site was monitored overtime after LUC. The paired plot approach is used to construct chronosequences comprising of plots with different ages after LUC that use one of the plots, with the prior land use, as the reference site. The paired plot based approach goes a long with a higher methodological uncertainity in the data due to differences in the inherent soil properties such as texture between the plots, which affect the response of soil C to LUC. In contrast, the time series observational data are without such uncertainties, but very few time series are available to investigate the response of soil C to LUC. In calculating the soil C changes across the different sites, the reference site was always assumed to be in equilibrium.
The meta-analyses defined the following criteria for including the site studies: (1) climate conditions, age of the current land use, and the relevant site characteristics such as soil type, texture and land-use history had to be provided, (2) studies on organic and wetland soils were not included and (3) for paired plots the sites had to be adjacent to each other to reduce uncertainties due to the spatial variability of soil properties unrelated to the LUC (Don et al., 2011; Poeplau et al., 2011). Any studies that did not match

any of the criteria were excluded in the compilation. The soil bulk densities were used to calculate the soil organic carbon in Mg/ha. Mass correction was applied to account for changes in density with depth (Ellert and Bettany, 1995). In addition, Poeplau et al. (2011) used different variables, such as climate, time after LUC and the clay content, to derive carbon response functions (CRFs) describing the temporal response of soil C to LUC for the temperate regions. The response functions include general CRFs that account for only time after the LUC and specific CRFs that account for other site properties. Table 1 shows the LUCs represented in the two meta-analyses that are included in our study."

The discussion dives directly into details of the model but would benefit from an overall summary highlighting the main findings of the paper and being organized around the take home messages of the research. An effort to frame the discussion in a bigger context will help identify novel insights to a broader audience who may not be familiar with the modeling approach but is still very interested in the findings. For example, consider starting the discussion with section 4.1.4 (which has a great discussion of scale between the models and the field observations) then going into the details of the crop harvest and fire, then discussion of the challenges (current section 4.2.1).

We have re-organized the discussion section to focuss on three key aspects that are important for the broader audience. (1) The general approach for evaluating DGVMs against the meta-analyses, (2) the causes of model deviation from the meta-analyses that we identified for the DGVM JSBACH, and (3) the challenges that are involved in model-data comparison.

The use of the term "meta-data" in the title and throughout the paper to represent results from a meta-analyses (a specific statistical test that calculates differences (effect size or response ratio) between data points) is confusing and

inaccurate (and distracting) as this term has a different formal definition ("data that describes other data"). To avoid unnecessary confusion, please use an alternate term, such as "field data", "observations", "observational data" or "results from meta-analyses." The term meta-data in the paper is used to refer to meta-analyses (published studies using the specific statistical approach), to the results of these analyses and to general syntheses of published data, further adding to confusion, as these are not the same.

We have removed the word meta-data and adopted meta-analyses and observational data in our manuscript.

In a few places, it is unclear how data used in the model simulations is then related to the land cover types and information associated with the observations of soil carbon change. For example, how are the different plant functional types, especially the different forest PFT, related to the 4 idealized land use classes? Given that the observational data used in this paper is heavily biased towards tropical sites (from Don et al. 2011 vs Poeplau and Don 2015), it is expected that the land cover description of the sites in the published literature do not match the PFTs at the global scale in the DGVM.

This is a good point. The land cover type description is indeed an important factor when comparing soil carbon changes with meta-analyses. In JSBACH there are four forest PFT distinguished in terms of their phenology (broadleaf and decidous) and location (tropical and extratropical). Our grid cell selection criteria ensures that the selected regions include only the PFTs existing in the particular regions. Therefore, the comparison of the simulated soil C changes with the data by Don et al 2011 includes regions with only tropical PFTs, while the comparison with Poeplau et al 2011 includes extratropical PFTs. We added the paragraph below in Section 2.3 to clarify how we derive the distribution of the different PFTs contained in each land cover map.

"We create idealized land cover maps for four vegetation types; forest, crop, grass and pasture. In these cover maps the entire globe is covered by each of the four vegetation types. The regions where one of these vegetation types does not exist are masked out in our comparison of simulated results to the meta-analyses (see section 2.4). Each land cover map consists of several PFTs: Forest land cover contains evergreen and broadleaf PFTs in the tropical and extratropical regions, while crop, grass and pasture land cover contains both C3 and C4 PFTs. To create the idealized land cover maps we start with a present day JSBACH land cover map obtained by remapping observed vegetation distribution into PFTs (see Friedl et al. (2010) and supplementary material section S1). In the grid cells where two PFTs belonging to the same vegetation type already exist, e.g., in a grid cell with both tropical deciduous and tropical evergreen from observed vegetation distribution, we scale the cover fraction to the entire grid cells based on their relative distribution."

In addition, where do the plant productivity measurements used in the model come from and how do these relate to the types of vegetation and their growth rates from the observational soil carbon studies?

Plant productivity is either simulated directly by JSBACH (standard set of simulations) or prescribed from observations. Section 2.3 describes where these measurements come from (flux net measurements extended globally using machine learning algorithms). See previous response on how the PFT distribution within a land cover type is derived.

How do the model simulations address uncertainties in field soil C measurements? For example, the values given in section 3.1 are averages with some associated error. What is the size of this error, how does this variability affect the carbon response functions, and how then do these influence modeled re-

sults?

You are correct that field measure can be quite uncertain. However, in our comparison we do not force the model with the observed soil C from the meta-analyses, but just compare the two. Because we do not use observed soil C as forcing in our model, there are no propagated errors from the meta-analyses to our simulated results. The carbon response functions used are derived from the meta-analyses. The standard deviation provided in our comparison provides a measure of the spread in the considered regions and sites. Therefore, assessing the error associated with the meta-analyses is outside the scope of our study.
We have added a sentence to discuss uncertainties associated with the methodological designs used to obtain the observational-data in the meta-data analyses (section 2.1).

Page 1, line 23: Soil C changes with LUC are not only influenced by differences in inputs, but also outputs, and alteration to processes that store C in soils.

We have re-written the sentence as follows;
"Soil C changes due to LUC are caused by changes in soil C inputs and outputs when one vegetation type is replaced by another. Changes in soil C inputs stem from differences in litter quality and quantity, while the changes in outputs stem from alteration of soil decomposition processes that govern stabilisation of carbon in soils."

The last paragraph of section 4.1.1 in the discussion briefly starts to address other factors that can influence soil C decomposition that are not included in the model. Some further discussion on how the focus on plant litter chemistry and climatic variables as controls on C cycling that is the basis for the biogeochemical component of the model and the absence of other mechanistic controls on soil C turnover and how they may influence differences between simulation

results and observational data would enhance the paper.

We have extended the discussion in section 4.1.1.
"The carbon model used in this study simulates soil C based on the plant chemistry and climate. Recent studies have shown that the inclusion of microbial dynamics and priming processes in biogeochemical models can improve model agreement with observations (e.g., Wieder et al., 2013). As these processes are different across land-use types, the inclusion of such processes in future generation of DGVMs may lead to improved simulated soil C response to LUC."

Page 4, line 13-20 (line 2-10): This paragraph discusses grid cells with only one vegetation type and also proportions of grid cells undergoing different land use transitions from different vegetation types. Please clarify which approach was taken in the paper and distinguish between old approaches (for example, additive soil C pools with LUC) and the new one proposed in this study.

We have re-written the paragraph to clarify that we use idealized and not realistic LUC simulations. The goal of this paragraph is also to discuss why we need to do idealized simulations and not use realistic LUC simulations in evaluating DGVMs.
"We perform idealized LUCs in which only one vegetation type covers the entire globe and which is subsequently to another type. The idealized simulations approach prevents interference of soil C changes that occur due to different types of LUCs occuring simultaneously in a grid cell or due to sequences of LUC over time. Such interferences occur in realistic LUC simulations. Here, most grid cells in the globe contain a mixture of different vegetation types and at a given year different LUCs may occur. For example, part of the forest in a grid cell may be converted to crop and at the same time part of the grass be converted to crop. Many DGVMs do not separate the soil C for the different PFTs and have one soil C pool for all the PFTs. Those that separate the soil C, e.g. JSBACH, typically add the soil C of the old PFT to the new PFT after LUC.

Therefore, soil C change resulting from a specific LUC cannot be obtained using such realistic simulations. The idealized simulations approach used in this study ensures that starting with equilibrium soil C from one land use then changing to another land use, the resulting soil C change can be associated with the specific LUC."

Page 5, line 3 (Page 4, line 26): What are the four idealized land use cases? These could be identified here or earlier in the description of the observational data and the meta-analyses.

We have clarified that the four idealized land use cases refer to crop, forest, grass and pasture.

Minor comments

Page 1, line 5-11: Consider the following sentence reorganization: "Our simulated results show model agreement with the observational data on the direction of changes in soil carbon for some land-use changes, although the models generally estimated smaller magnitudes of change. The conversion of crop to forest resulted in a simulated soil carbon gain of 10% compared to a gain of 42% in the data, whereas the forest to crop change resulted in a simulated loss of -15% compared to -40%. The model and field data disagreed for the conversion of crop to grassland. The simulations estimated a small soil carbon loss (-4%), while field data indicate a 38% gain in soil C with the same land-use transition. These model deviations from the observations are substantially reduced by explicitly accounting for crop harvesting and removing burning in grasslands from the model."

We have adopted the suggested changes and re-written the section as follows;
"Our simulated results show model agreement with the observational data on the di-

rection of changes in soil carbon for some land-use changes, although the model simulated generally smaller magnitude of changes. The conversion of crop to forest resulted in soil carbon gain of 10% compared to a gain of 42% in the data, whereas the forest to crop resulted in a simulated loss of -15% compared to -40%. The model and the observational data disagreed for the conversion of crop to grasslands. The model estimated a small soil carbon loss (-4%), while observational data indicate a 38% gain in soil C for the same land-use change. These model deviations from the observations are substantially reduced by explicitly accounting for crop harvesting and neglecting burning in grasslands in the model."

Page 1, line 17: suggest deleting: "(hereafter meta-data)" as this is an incorrect use of this term.

We have deleted this and adopted meta-analyses throughout the manuscript.

Page 1, line 18: add references to the meta-analyses here

We have added an example reference for the meta-analyses here. The full list of references is provided later in paragraph 3 in the introduction where we discuss the meta-analyses.

Page 2, line 7: Rewrite: "Despite the dependence of the soil carbon response to local conditions of soils, climate and management practices, regional and global syntheses of published data can be useful to aggregate local-scale measurements on soil carbon changes and estimate mean responses to different

LUCs using a meta-analyses approach."

We have re-writen the sentence as suggested.

Page 2, line 8 and 10: Here meta-data should be replaced by meta-analyses.

See our response to the terminology concern.

Page 2, line 10 and Page 3, line 7: what is meant by "harmonize"a temperate ? Can you use another term?

We have re-written the sentences and removed the term “harmonize”.

Page 2, line 15: Marin-Spiotta and Sharma (2013)’s work did not use a meta-analyses approach

We have removed the reference from the paragraph describing meta-analyses.

Page 3, line 5 (line 3): replace "the meta-data" with "results from the meta-analyses"

We have replaced meta-data with results from the meta-analyses.

Page 3, line 6 (line 4): The "quality criteria" sentence structure is awkward. Consider: "These meta-analyses were conducted on paired plots of similar soil type and texture, to reduce uncertainties from hetereogeneous soil properties unre-

lated to the land-use transition."

See the response to the meta-analyses section (section 2.1).

Page 3, line 30 (line 21): Replace windbreak (check definition) with windstorm.

We have replaced windbreak with windthrow.

Page 4, line 3-5 (Page 3, line 22-25): Consider rewording: "The decomposition rate of litter is controlled by its chemical composition, as determined by its solubility (acid, water, ethanol and non-soluble hydrolysable pools) and the presence of a slow decomposing humus pool." It is unclear from the text whether the humus pool is part of the plant litter or a soil organic matter pool? Does the model include above and belowground litter pools?

We have clarified that all the litter pools and the humus pools in YASSO are treated as part of soil organic matter. We have added two sentences to explain the difference between above and belowground litter.
“Additionally, litter is split into aboveground and belowground where the aboveground litter burns while belowground litter does not. All the litter pools–aboveground and belowground–and the humus pool are summed up in obtaining the total soil carbon.”

Page 4, line 26 (line 15): replace "ran" with "run"

We have replaced ran with run in the sentence.

Page 10, line 6: above refers to what?

We have removed the term above in the restructuring of the discussion section.

Figures 1 and 2 are hard to read. Consider that the green, orange and brown col-

ors will be difficult to distinguish for readers with color-blindness, which affects almost 10% of males in many European and English-speaking countries. The grey background also reduces the contrast between the lines, and the lines are too small and hard to see.
Figure 3. See earlier comment about choice of colors.

We have changed the colours in the figures to colours that aid in color-blindness. Additionally we have increased the thickness of the different lines.