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Interactive Comment

Interactive comment on "Deforestation in Amazonia impacts riverine carbon dynamics" *by* F. Langerwisch et al.

F. Langerwisch et al.

fanny.langerwisch@pik-potsdam.de

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We thank the reviewer for the time she/he took and for the very helpful comments provided, which will help us to improve the manuscript.

Anonymous Referee #1 (Received and published: 20th November 2015)

Carbon gets transported in water and hence exported from terrestrial ecosystems in particulate organic, dissolved organic or inorganic form. The current manuscript estimates these fluxes and their changes due to climate change and deforestation for the Amazonian basin from preindustrial times until 1950. It further extends the climate change impact until 2100. This is an extension of another paper in discussion: Langerwisch et al., Climate change increases riverine carbon outgassing while export to the ocean remains uncertain, Earth Syst. Dynam. Discuss., 6, 1445–1497, 2015. It looks very much to me that the current paper is an extension of Langerwisch et al. (2015). I would have appreciated if the authors also cite it like that. For example the natural vegetation climate change runs of the current paper seem to be exactly the model runs from the other study. I see no harm in this. Being more frank about it, would have open up the avenue to include more results of the other paper in this study. For example, I would have appreciated that the results of Fig 7 of the other paper would be also in Fig 6 of the current paper.

Reply: Thank you for these comments. The current paper is indeed a follow up paper of Langerwisch et al. (2015), which consist of the model description and a first application under solely climate change effects. The current manuscript estimates the combined effects of climate change and deforestation by conducting simulations from 1901 to 2099. We will make the differences and similarities between the two papers clearer in the current manuscript and will incorporate relevant results from Langerwisch et al. 2015 to improve Fig. 6 for comparison.

The manuscript left the impression that the effects of climate change (CC) and deforestation (Defor) are not well disentangled. I know that it was tried and it might only be the presentation. Why Defor and CCDefor is the E-metric and CC only is the D-metric? It is very confusing. Defor would have also been cleaner if climate were not changed. Then one could have done, CC, Defor, the combined, and the combination effect. The metrics are confusing, as mentioned. Why do I need the logarithm? There exist logarithmic axes and colour scales. And the authors have also their problems with it: for example they talk about 5% and then use the strange 10ËĘ-0.02. Just use logarithmic scales then the text becomes also more natural.

Reply: Our aim was to understand how and where the changes in climate and deforestation affect the riverine carbon dynamics the most. Therefor we calculated either the differences caused by deforestation only (future status under natural vegetation vs. future status under deforestation) or the effects of both drivers (past status under natural vegetation vs. future status under deforestation). The effects of climate change only has been published in Langerwisch et al. (2015). For better comparability we will add the data for climate change only to Figure 4. We used the logarithm to depict the small and larger changes in a comparable manner. For instance showing the rather small effects of climate change (e.g. Figure 3) in contrast to the larger changes caused by deforestation. We also used that in the text, mentioning an increase of about 5% (equaling a value in the figures of 100.02) or a decrease of about 5% (equaling a value in the figures of 10-0.02). We think this is an appropriate way to present the changes which is similar to the option suggested by the reviewer.

I think that the regions R1-R3 are not really exploited in the manuscript and can be removed. They are only showing up in Fig 6, and are also of limited interest there.

Reply: Thanks for this suggestion. We kept all regions for better comparability to Langerwisch et al. (2015). The regions differ in the intensity of climate change and deforestation effects. We don't exploit them in detail but still think it's interesting to see more regional effects. For instance looking at Figure 6 one can clearly see the differences between R1, which is mainly climate change affected, and R3, which is heavily impacted by deforestation.

There are two issues that really disturbed me reading the manuscript: 1. the figures are incomprehensible and 2. there is no insight into the relevance of the research.

Reply: We thank the reviewer for raising these points, we added a detailed response to these two points in the next paragraphs and hope this will improve the clarity of the figures.

While the figures look appealing at first, there are plenty of problems: 1. There are hardly any labels on the figures. What is plotted in Fig 6, for example. All axes need labels. And the colour bars. 2. The text in the figures is much too small. I had to go to 200% on my screen to be able to read Figs 1-5 and to 300% for Fig 6. It was impossible on paper. 3. The colour schemes are beyond me: a) In Fig 2, the colour scheme is not

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centred, i.e. the green fraction is smaller than the red fraction. b) In Figs 3 and 5, the colour bar has sections with colours that span a large section (e.g. yellow) and colours that span a very little section (e.g. orange). This merges all values from about 0.15 to 0.4 (yellow) and from 0.45 to 0.55 (orange). A well-known problem with for example the rainbow colour bar. 4. Fig 6 is unreadable. Text too small, no labels, I cannot separate the lines. I have to enlarge the figure to 300%-400% to be able to distinguish anything. But not more because then the figure gets blurry. 5. I would have loved to see both land use change scenarios in Fig 2 instead of the bar charts for R1-3. 6. Fig 4 should include not only CCDefor but also CC and Defor only. It should also include errors, e.g. on the values given. 7. The green and red borders in Fig 5 are indistinguishable. Think about something else for the distinction.

Reply to all figure remarks: Thanks for the constructive comments.

ad 1. We will add more information to the figures (which is until now only to be found in the caption). We will add labels on the color bars and the axes.

ad 2. We will increase the font size to enhance the readability.

ad 3a. Figure 2 shows the input and therewith only the data already published by Soares-Filho et al. (2006). Rather than including more information we will remove this figure, which will provide additional space for enlarging the other figures. See also ad 5.

ad 3b. We chose this color scheme to show the general spatial trends in the study area. We are aware that some of the detailed information gets lost this way, but we still believe that this way of displaying the data is adequate.

ad 4. We will rearrange the inset figures and will enlarge the main figures 6A-C. We hope to increase the readability of the figure this way.

ad 5. To see both deforestation scenarios in detail we suggest to consider Soares-Filho et al. (2006). We will remove this figure to get more space to display the results of our

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study better and refer to Soares-Filho (2006) for further information on the deforestation scenarios. See also our reply ad 3a.

ad 6. We thank the reviewer for this suggestion which is indeed a valuable point. However, by including also the CC and Defor signal separately we think the figure would get even harder to read. We will add a remark that the detailed information on CC can be found in Langerwisch et al. (2015). A measure of the errors is depicted as the shaded area. We will add the description of the error range in the figure caption.

ad 7. By having green and red cell borders we want to distinguish the cause of the changes, which itself is shown by different cell colors. To show the dominance of CC and Defor for up to 2000 cells is not easy. We already tried different approaches, but think that this is the best option to still distinguish the colors in the cells itself. We also tried different colors for the borders, which superimposed the cell colors too much. Making a colored, a dashed or horizontally/vertically lined overlay would make the cell color un-recognizable. After testing different options for display we decided to use the green/red cell borders. We will add some more information to Figure 5 to improve the readability to give the reader some guidance.

I am also missing insights about the relevance of the study; some people would probably say that a research question is missing. If there is deforestation than there is less new carbon input and hence carbon export decreases. This is quite logical. So is the flux important? The numbers of POC and TOC in Fig 4 are a factor of 1000 less than the pools. So it looks like a small flux to me. What is wrong with my view?

Reply: We thank the reviewer for pointing to this important issue. We will improve the respective text in the introduction to explain the context and relevance of our main research objective better, so that the reader knows how to put our results into the wider context.

There is less C input into the ocean. Is this important for the ocean? Do the fish depend on it? Does the carbon cycle care?

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Reply: The reduced input of organic material to the ocean will negatively affect the respiration and production off the coast, since these depend on the imported organic matter (Cooley and Yager, 2006; Körtzinger, 2003; Subramaniam et al., 2008). To clarify this we will add more information on the effect of changes in the amount of organic material discharged to the ocean for the ocean's regional characteristics and the consequences in the discussion section.

What is the influence for the Amazonian rainforest? I guess nutrients are transferred by inundation. How much is it related to POC and DOC and how much to IC. It might be that nutrients are transferred abiotic and are hence rather like IC and not so very influenced by deforestation.

Reply: The effect of deforestation is mainly a reduction of transported organic material, which acts as a nutrient supply for down-stream inundation forests. To clarify this we will add more information on the consequences of deforestation to the forest in the introduction and the discussion section (4.3).

These are all questions that might be asked and interesting for the community given that it is going to be published in Earth System Dynamics.

Reply: Thank you for raising these issues it will certainly help us to improve the manuscript in this respect and provide some guidance to the reader on why our study is an important contribution. We hope to sufficiently improve the manuscript with the above-mentioned replies.

I am also desperately looking for an explanation what happens after 2050. Why is POC and CO2 suddenly decreasing? The two scenarios were similar up to 2050. Then land use change stops. Why should it then suddenly decrease so strongly? There must be something else happening which should be revealed to the reader.

Reply: Thanks for this remark. We tried to explain and discuss this in the discussion (section 4.2) but apparently this was not sufficient. We will add a more detailed explanation to this paragraph. In summary the reasons are (besides the already mentioned complete removal of the vegetation) the following: During inundation the cells are partly or completely covered with water, which leads to the export of organic material. After the gradual decrease of forest cover (and therewith input of organic material) before 2050, there is a depletion of the remaining organic material in the following years. This can explain the harsh decrease of POC and outgassed carbon after we kept the deforested area constant.

Minor remarks are:

1. Why extrapolating land use to the past? Why not taking historical land use maps such as of Pongratz et al.? I would have done no land use change at all before 2000 so that the references in the denominators in the metrics are always the same.

Reply: Thanks for this remark. Pongratz and colleagues did an important step towards understanding global land use change for the last centuries. However, the classification of land-use types is different and cannot be easily combined with the future LUC scenarios. So, there are conceptual limitations to combine these two data sets. Additionally, the large transformation of forests in the Amazon basin to agricultural land began in the late 1950 with the establishment of the Belém-Brasilia Highway and later of the Transamazon Highway (in the 1970). For Amazonia this is considered as the beginning of the 'modern period of Amazon clearing' (Fearnside and Hall-Beyer, 2007). Additionally, the model LPJmL, which provides vegetation information to RivCM, requires historical land-cover information to correctly capture transient carbon dynamics. LPJmL is initialized with climate and land-use data and starts to simulate vegetation dynamics from bare ground. Unlike LPJmL, other vegetation models initialize their vegetation using land-cover maps of a particular year. We cannot do that with LPJmL. We will add a more thorough explanation why we used the backward trends for our work in the methods section 2.2 – 'Climate change and deforestation data sets'.

2. Longer and shorter to what in Table 1?

Reply: Table 1 describes the characteristics of the three sub-regions. In Langerwisch et al. (2013) the effects of climate change on the inundation patterns in these regions have been estimated. The statements in Table 1 on 'inundation length' and 'inundated area' refer to differences of past and projected inundation - longer or shorter inundation in comparison to the reference period (Langerwisch et al., 2013). We included this information to show how much of the terrestrial-riverine system is already affected by climate change only. We will add some clarification on that to Table 1.

3. I would remove R1 to R3 from Table 2.

Reply: We'd like to keep them because of the above mention reasons that in Figure 6 for instance one can clearly see how large regional differences are, between areas that are mainly influenced by climate change or deforestation. Having spatially explicit climate change and deforestation scenarios enables us to also see spatial difference within the Amazon basin instead of only focusing on basin-wide averaged values. We hope to improve the presentation of our results in a better structured way.

4. Why are the proportions not adding up to 100% in Table 3?

Reply: We only show the fraction of affected area. The sum of the climate change dominated and the deforestation effects dominated cells equals the sum of all dominated cells, which might be well below 100%. To avoid confusion, we will change it to 100% of affected area and then proportion of these 100% to either climate or deforestation dominance in Table 3.

5. I was wondering if the arrow in Fig 1 that shows the CO2 feedback of LPJmL to the climate models is true? It is not written in the text.

Reply: There is no feedback from the vegetation model LPJmL to the atmosphere. Both, LPJmL and RivCM, use the atmospheric CO2 concentration based on the SRES scenarios and the climate provided by the General Circulation Models. There is no arrow going from LPJmL to the climate models.

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As an aside, the present study also cites that "The ability of the coupled model LPJmL–RivCM to reproduce current conditions in riverine carbon concentration and export [...] has been shown and discussed by Langerwisch et al. (2015)." This is summarised in Table 4 of the other paper. The ability seems to be reasonable for the concentrations but rather weak for export. I would see the model system therefore rather as a tool to study sensitivities rather than projections.

Reply: Thanks for this comment. As this was also mentioned in the reviews for the other manuscript (Langerwisch et al., 2015) we will shift the main conclusion of the manuscript to show that RivCM is more a general tool to assess land-river-interactions, rather to reproduce regional characteristics in detail. We will also update respective sections (last two paragraphs of the introduction, and first paragraph of the discussion) in this manuscript.

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