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Earth System Dynamics Discussions

Interactive comment on "The influence of vegetation dynamics on anthropogenic climate change" *by* U. Port et al.

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Dear reviewer,
thank you very much for reading our manuscript and for your comments.

General comment:

Referee: This paper is not worth publishing as written and needs a major revision. To make worth publishing, the new science should be highlighted and the rest shortened.

Author: The aim of this study is to assess vegetation-climate and vegetation-

carbon cycle interactions initiated by a plausible CO2 emission scenario. As carbon cycle dynamics act on very long time scales, our work is based on simulation on the time scale of centuries. We agree that some mechanisms we deal with are already known. Nevertheless, we compare the detected mechanisms with each other and relate them to anthropogenic climate change which is new for the scenario we use and the time scale of centuries. Besides, we find and discuss new mechanisms. At this point, we need to work at the manuscript as we agree that we need to emphasis the firstly detected mechanisms more clearly, for example, results on vegetation dynamics in North Africa or the impact of vegetation dynamics on the global carbon cycle. We will also try to shorten the manuscript where appropriate. However, we think that we should not shorten the manuscript significantly. In our opinion, it is necessary for the purpose of this study to discuss the atmospheric as well as the biospheric changes followed by the climate changes due to vegetation dynamics as we do so in the manuscript.

Specific comments:

1) *Referee: Please make it clearer whether land use coexists in the grid cell with natural vegetation in these simulations. I think you just say that "vegetation cover shifts due to land-use are neglected."*

Author: It seems like we need to emphasis more clearly that we do not include land use change and the vegetation changes only naturally. Thus, we change 490/26 to:
Vegetation cover shifts due to land use are not included, i.e. the biosphere changes only naturally.
and add the following to the introduction (489/11):
As we focus on natural land cover changes, we only include natural vegetation

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dynamics and neglect anthropogenic land-use change.

2) *Referee: You say "Analyzing the impact of veg. dynamics on climate change on a time scale of several centuries is unique" BUT all the feedbacks that you describe are well known. So I recommend focusing on the new findings and, thus, shortening the manuscript significantly.*

Author: We agree that some mechanisms and feedbacks are known. However, to our knowledge, this is a first study where an Earth System Model of full complexity is used to assess the effect of vegetation dynamics on climate change and carbon cycle based on a CO2 scenario up to year 2300. Furthermore, there are only a few studies on the biogeochemical effect of natural vegetation cover changes. So far, we could not find a publication for a detailed analysis of the impact of natural vegetation cover changes on the global carbon cycle during anthropogenic climate change. We will modify the sentence to state more clearly that our study is unique.

3) *Referee: Relevant reference missing: Mathews et al. (2004)*

Author: Matthews et al. 2004 asses and discuss the influence of historical land cover changes (natural vegetation changes plus land-use change) on climate in detail from 1850 until 2000 based on model simulations. They find effects which we also identify. Nevertheless, as our study cope with natural vegetation changes only, while Matthews et. al 2004 include natural vegetation changes and land-use change, it would we confusing for the reader to cite them here.

4) *Referee: You say "vertical levels" but the correct terminology is "levels in the vertical"*

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5) *p. 490 line 28 I think you need to add "further" between "and differences"*

Author: Yes, thank you. We will change both.

6) *Referee: 492/19 state regions of precipitation changes more precisely: parts of western North America to 'Alaska', add 'eastern North America', change 'western South America' to 'northwestern South America', add 'eastern South America'.*

Author: We will specify the description of the precipitation changes and change 490/19 to:

Precipitation changes over land are weaker than over the ocean (Figure 4). Precipitation increases over land occur in parts of Alaska, eastern North America, Siberia, as well as in eastern and northwestern South America. Precipitation decreases in Australia as well as in parts of the Amazon region.

7) *Referee: You seem to have skipped reference to Fig. 7 here. Figure references must ascend by one each time.*

Author: Figure 7 is discussed on page 495 line 22.

8) *Referee: p. 493 line 9 I think you mean "a few gridcells of the Amazon region"*

Author: Right, there are only three grid points where NPP decreases. Nevertheless, they need to be mentioned since NPP increases or stays constant in all other regions. We will add 'parts of' to 493/9.

9) a) *Referee: p. 494 line 26: why does tree cover continue to increase?*

Author: This is likely due to different physiological parametrization of the trees an shrubs in the model and difficult to investigate in more details.

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9) b) *Referee: And... p. 496 lines 11-16: Similar question about stronger water stress and weaker CO2 fertilization. Are these stronger and weaker at any point in DYN relative to the control?*

Author: The water stress is stronger in the DYN simulation since precipitation decreases. The CO2 fertilisation is weaker in 2300 in the DYN simulation than in 2120 since the atmospheric CO2 concentration declines.

9) c) *Referee: Why are trees less sensitive than grasses? Are grasses C4?*

Author: Predominantly, yes, the grass that occurs in the Sahara is C4 grass. In the model, C4 grass does not respond to increased atmospheric CO2 concentration as strong as the other PFTs. In other words, the fertilisation effect is weak. Since physiological effect of CO2 is less pronounced for C4 grass, C4 grass does not benefit from the CO2 fertilisation and trees have an advantage over grass.

9) d) *Referee: How come trees survive drought better than shrubs? Is this a model bug or feature that you need to address?*

Author: The model simulates a competition between trees, shrubs, and grasses based on NPP: PFTs with higher NPP have advantage. Due to elevated CO2 and increased water use efficiency, trees in our model becomes more competitive than shrubs due to higher increase in NPP. Whether this is a model artefact is difficult to judge. We are not aware about observations or experiments of tree-shrub competition in elevated CO2 environment.

10) *Referee: 496/20: "higher" seems lower to me.*
11) *Referee: p. 497 line 7: do you mean to say Figure 12?*

Author: Yes, you are right. We will change both.

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12) *Referee: p. 497 line 17: You need to explain better. I see cooling in Nov, Dec.*

Author: Indeed, the manuscript is confusing at this part. We wanted to point out, that the warming caused by the albedo gets weaker in summer and a counteracting cooling due to increased evapotranspiration occurs. We change the manuscript as follows:

During this season, the warming impact of albedo reduction weakens and the influence of increased evapotranspiration becomes more dominate. The strengthening of the impact of the evapotranspiration differences is evident in the weaker warming in July and August in the DYN than in the STAT_PS simulation.

13) *Referee: p. 497 line 25: Does your model simulate trunks, branches, and twigs explicitly?*

Author: The carbon cycle model does not simulates the trunks, branches, and twigs of trees. However, the albedo module takes into account the snow-masking effect of deciduous forest since it is well quantified in observations.

14) a) *Referee: Up to here, I have a minor comment: Something about the organization and presentation feels more complicated and hard to follow than necessary. May help to insert subsections (to the existing or some alternate structure) associated with processes.*

Author: We thought about how to organise the study a lot as we have to show and discuss climate differences, vegetation differences, and interactions in the transient simulations. Finally, we structured the manuscript chronologically since it seems to be the easiest for the reader to follow. First, the climate change and the resulting vegetation changes until the end of the emission periods are presented and discussed. We chose the year 2120 since at this point the

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atmospheric CO2 concentration is largest leading to the strongest CO2 fertilizsation. In the second part, the climate change and the vegetation changes at the end of the simulation are discussed, followed by the interactions between them. To makes it easier for the reader, we have to subsections for the biogeophysical and the biogeochemical effect. We think that adding more subsections would unnecessary fragment the text.

14) b) *Referee: ...and a major comment related to the minor one: The little new science that you present seems lost in all the old science. Please simplify and shorten the paper and focus on the few new things so that these may stand out easily.*

Author: In general, as stated above, the aim of this study is to analyse the vegetation changes and vegetation-climate as well as vegetation-carbon cycle interactions due to an plausible CO2 emission scenario. Consequently, some effects we deal with are already known, but we analyse and discuss them for a plausible CO2 emission scenario and on the time scale of centuries, which have not been done before. Nevertheless, please name us the certain parts of the manuscript, where you think the findings are not new or unnecessarily discussed so we can comment on them specifically.

15) *Referee: p. 498 line 13, you say "the smaller cloud cover leads to a cooling since the loss of thermal radiation is larger" and I wonder if this means that you are dealing with nighttime clouds here. Otherwise would not you get an increase in incoming solar?*

Author: We relate the decrease in thermal radiation to decreased cloud cover and water content, i.e. the water vapour feedback. To express this more clearly, we change the text:
Compared to the STAT_PS simulation, tree cover is smaller in the DYN simulation leading to less evapotranspiration initiating two counteracting effects. Lower evapotranspiration rates cause a warming since sensible heat fluxes are higher and latent

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heat fluxes are lower. Furthermore, weaker evapotranspiration leads to a cooling as specific humidity is smaller and thus, the loss of thermal radiation is larger. However, the cooling due to the smaller specific humidity is weaker than the warming due to the decrease in latent heat flux.

16) *Referee: p. 499 line 5: Why are there no diffs in land, ocean, and atm. C storage between DYN and STAT before the emissions cease but there ARE diffs after the emissions cease?*

Author: The differences in the carbon pools between the DYN and the STAT simulation are most pronounced at the end of the simulation since the carbon cycle responds slowly to vegetation dynamics. Looking at the terrestrial carbon pools, we find that differences in the litter pool due vegetation dynamics occur already in the 20th century, while the soil pool does not respond until the end of the 21th century to vegetation changes. This long response time in the soil pool illustrates that carbon cycle dynamics act on long time scales.

17) *Referee: p. 500 line 3: What simulation could you do to get this number without extrapolating?*

Author: We can assess the biogeochemical effect of vegetation dynamics by comparing STAT_PS and STAT. However, the biogeophysical effect on global annual mean temperature is small (0.05 K) and is not statistically significant. That is why we do not calculate this number explicitly.

18) *Referee: The Conclusions section is more like a summary and could represent what the manuscript should look like after you shorten it, except in the sections where you will focus on new science. Other than summarizing the results, please come up with some conclusions from this work.*

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Author: We agree and will rewrite the conclusion part.

20) a) *Referee: At some point in the manuscript you distinguish biogeographical from biogeophysical and biogeochemical. Are you consistent in your usage of these terms throughout?*

Author: We use the term biogeographical to express the spatial distribution of vegetation. You are right, at some points we used the term it is inappropriate. To avoid confusion, we change
489/8 to: *changes in the biosphere*
491/11 to: *changes in the biosphere*
497/1 to: *net effect of vegetation dynamics on climate.*
499/23 to: *additional land carbon uptake due to vegetation dynamics*

b) *Referee: Also would it be clearer to present "total biogeophysical" and "total biogeochemical" and "biogeophysical due to biogeographical" and biogeochemical due to biogeographical"?*

Author: We focus on the influence of changes in the vegetation cover on climate. Besides, physiological changes affect climate. We are not able to separate these effects based on our simulations. Thus, we can not see "biogeophysical due to biogeographical" and biogeochemical due to biogeographical". We will state that more clearly in the manuscript.

21) *Referee: Table 1: Forest is a biome. Do you mean trees?*

Author: Yes, we do. We will change it.

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