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Interactive comment on "Critical impacts of global warming on land ecosystems" *by* S. Ostberg et al.

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We thank Anonymous Referee 1 for his or her constructive comments which highlight several parts that seem to be hard to understand, while also suggesting some additional analysis.

Regarding the primary areas of concern raised:

1. Documentation of impact metric and climate scenarios:
    - We thank the referee for pointing out that the description of the impact metric needs some clarification. We agree that understanding the concept of the metric is central to evaluating the results we present. We will therefore work to improve the legibility of our description and provide more detailed definitions. While we will somewhat expand our description of the Γ metric

      originally developed by Heyder et al. (2011), we will refer the reader to that paper for technical details how exactly the metric is computed. We use the same computation except for some changes to the ΔV component which are already explained in the supplementary part of our paper.
    - The description of the climate scenarios in our paper is not meant as a full technical documentation, but rather to point out differences between our scenarios and the more commonly used (bias-corrected) GCM runs for the SRES scenarios. Ours is one of several studies based on the new "PanClim" climate dataset. The generation of these climate scenarios is described in depth in Heinke et al. (2012), currently available as a discussion paper at Geoscientific Model Development Discussions and recently resubmitted with minor revisions for final publication in GMD. While providing the technical details would go beyond the scope of our paper we will try to make the concept better understandable. The referee suggested adding a schematic figure. There is a flowchart explaining the data generation steps in Heinke et al. (2012). We will inquire whether this can be re-used or redraw it for our revision, as we realise that this would be important to understand the procedure. In addition to the documentation, the full dataset of climate scenarios will be made available for download at http://www.panclim.org in the near future.
2. Relative importance of metric components: To allow some conclusions on the underlying processes the referee suggests adding a breakdown into the components making up the Γ metric for a selection of the biomes. We are aware that, because of its rather abstract nature, the Γ metric alone does not convey the type of projected ecosystem change. This can be considered a disadvantage. However, the aim of our study is to provide a global overview of areas at risk of severe ecosystem change. By using the Γ metric as a proxy we specifically focus on the overall magnitude of change instead of the individual processes driving that

change, which differ between regions and sometimes even between GCMs for the same region. Since it may help to understand how different biomes respond we will add further information either to the supplementary or the main text.

3. CO_2 fertilisation effect and its impact on the metric: LPJmL explicitly includes a CO_2 fertilisation effect. In many regions CO_2 fertilisation increases Γ values, while in others it partially counteracts climate-driven changes, resulting in lower Γ values. CO_2 increase and climate change are closely linked and therefore occur together to produce biogeochemical shifts in the biosphere. It is not the purpose of this particular study to disentangle the individual contributions of CO_2, temperature, radiation and precipitation change, but rather to evaluate the joint multi-dimensional shifts in vegetation produced. While there is still some debate about the long-term magnitude of CO_2 fertilisation and the potential role of nutrient co-limitations in some biomes, generally a complete absence of fertilisation effects is not realistic and therefore of academic interest. Model results agree well with historical observations that already show an impact of changing climate and increasing atmospheric CO_2 on the biosphere (Holden et al. 2013, Schaphoff et al. 2013). We will add some discussion of CO_2 effects on Γ to the paper.

The specific stylistic recommendations (not listed here) will be implemented by some rewording and small additions to the text. Our responses to the other comment are as follows.

We agree that quantifying potential impacts on ecosystems is also important for adaptation. However, in light of the generic nature of our indicator, our results are probably more suitable in a mitigation context where the goal is to avoid impacts. Adaptation planning requires further details on the specific ecosystem changes and how these changes affect human societies.

All temperature changes in our manuscript refer to changes of the global mean temperature compared to preindustrial level unless expressly stated otherwise. As this is

ambiguous in the abstract we will replace “warming” with “global warming”.

Need for multiple ensemble members: We already acknowledge this, as the patterns that form the basis of the pattern scaling process used for the scenario generation are extracted from several realisations per GCM. We will mention this in the revision.

Actually, all variables from equation 1 are defined in the following paragraph. But since that paragraph seems to be hard to understand we will reword and expand it.

As mentioned above we will add some breakdown into the metric components and also add an example to the supplement explaining how a change from category A to B can produce a different impact metric than a change from B to A (suggested on page C247).

Cultivated regions are based on MIRCA2000 (Portmann et al. 2010), as modified by Fader et al. (2010). We will add the references to the paper and also refer the reader to Figure S1 which shows the cultivated areas.

The specifics of how MAGICC6 is applied in the creation of the PanClim climate scenarios are given in Heinke et al. (2012) and preceding papers on that model. The MAGICC6 model itself is described elsewhere. Therefore, we believe that discussing it here goes beyond the scope of our study.

While all the non-Arctic regions showing up in red in figure 2a in the paper may be water-limited regions the change is indeed temperature-based: Because of the temperature increase a bio-climatic limit is crossed and we model a shift from C3 to C4. Plants using C4 photosynthesis are more water-efficient, resulting in higher productivity (page C248).

We group our results by increase in global mean temperature (GMT) because it is a commonly used global indicator of climate change. There is no comparable global indicator for precipitation. However, our climate scenarios feature both temperature and precipitation changes, and also radiation changes. In fact, most of the disagreements

between scenarios for one level of GMT increase are caused by GCM differences in local precipitation rather than local temperature change. Regions with consistent precipitation projections among CMIP3 models are likely to show up as regions with high model agreement in our results (page C248). Separating precipitation effects would require a major effort and a substantial reshaping of the analysis and paper, see above comment on CO_2.

"Soil water content" in table 1 refers to the top-most 0.5 m layer. We will clarify.

The "arrows" in figure caption 1 refer to the vertical lines marking the differences between 2, 3.5 and 5 K. We will change the figure and/or caption to clarify.

We will combine the breakdown into the components making up Γ for different biomes with a more detailed exploration of the curves in figure 3.

Supplemental figure S1 shows the managed land fraction in each grid cell that we exclude during the aggregation of affected areas. Of course it should be cited in the relevant parts of our methods description. We will add the reference.

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