Response to comments by Referee#1 Dr. Patrick Keys on "Aerial and surface rivers: downwind impacts on water availability from land use changes in Amazonia"

We thank referee #1 Dr. Keys (hereafter the referee) for the suggestions and comments to help us improve the manuscript.

Weng et al. (hereafter, the authors) explore the role of land-use change on the hydrology of the Amazon, focusing on the implications of changes in evaporation on moisture recycling, precipitation, and subsequent runoff. The authors identify key regions in the Amazon that are particularly sensitive to changes in continental moisture recycling, and further identify how different land-use change scenarios can impact hydrology.

I find the study to be interesting, relevant, and timely. I recommend the paper receive minor revisions, prior to acceptance for publication in HESS. I will summarize my comments briefly, and then lay out more detailed comments below

The paper is on the cutting edge of land-use change & moisture recycling research, in the sense that it is examining sensitive regions to land-use change, the role of internal-watershed vs. external-watershed land-use change impacts, and the importance of different types of land-use change having very different types of consequences on hydrology. I encourage the authors to emphasize the 'cutting-edge' nature of their work a bit more, and be more bold in their conclusions.

We appreciate the positive feedback from the referee on the originality of the findings. We also perceive the underscoring of the novel part of our study helpful for communicating our results more efficiently to the community and have revised the conclusion (P13. L3-16) regarding this point.

I'm very interested in the development of the 'most influential precipitationshed' (MIP) concept. However, the MIP is essentially a definition of a precipitationshed boundary. The precipitationshed boundary that contains 100% of evaporation is the entire planet (at least in the context of the WAM-2layers). Thus, anything less than that domain requires the selection of a boundary. There is quite a bit of discussion on boundary selection and comparative advantages and disadvantages in the existing literature (e.g. the 70% boundary in Keys et al. (2012), the identification of the 'core precipitationshed' as a persistent, inter-annual source of moisture in Keys et al. (2014), and the discussion of the 1% boundary in Keys et al. (2017)). It is good that the authors are innovating on the concept of the precipitationshed, but I think the MIP should be put into better context as an approach for quantifying a boundary.

We agree with the referee that the precipitationshed boundary used in the manuscript needs further discussion in the context of previous studies. We added the citations suggested by the referee in Sect 2.1.3. "Previous studies have suggested and discussed different thresholds to delineate a precipitationshed boundary, e.g., 70% (Keys et al., 2012) or 1%

(Keys et al., 2017) threshold of continental recycled precipitation" We have also clarified the MIP definition in Sect. 2.1.3. The basic idea of the MIP is to emphasize the spatial heterogeneity within the precipitationshed. The 40% threshold that we choose to identify the MIPs in our study is due to the model resolution that we used (as the referee has also pointed out later) and the geographical region that we focused on. Our intention was also to approach a threshold that could be reasonable in land use experiments, since the larger threshold MIP of a given sink has larger total influence on the sink's rainfall, but has also a larger size, meaning that it is rather theoretically to have homogeneous land use change. Thus we have also improved the narrative for this part in Sect 2.1.3 by adding "In the present study, we propose a threshold that is a trade-off between the relative influence on the sink's rainfall and the size of the area where land use change could occur homogeneously.".

Regarding the MIP, I think that the authors need to emphasize more clearly that the 40% threshold is related to grid resolution (as far as I can tell, the only reference to this is at line 22-24).

Yes, it is possible that other studies operating on a finer grid resolution or focusing on different study regions can have a smaller threshold apply to all grid cells (P.5 L21-24). Our application of the 40% threshold in our study area appears plausible in reflecting important regions on moisture contribution to a given sink and can provide a hint for further studies operating on similar modelling resolutions and regions. We have included clarification on this both in Sect. 2.1.3 and Sect. 5.

Again, I think this paper is quite good, and is in need only of minor revisions before publication.

We thank the referee for the positive feedback on the manuscript and appreciate his suggestion that is helpful for improving the manuscript.

P2 L4 This sentence is confusing, especially the section ": : :operate under uncertainties of the undergoing land use change: : :". Please revise.

Revised as suggested.

P2 L24-25 I suggest the authors remove the part of the sentence ": : :,which has not been covered in depth by previous studies", since many studies have looked in detail at how land-use change might impact the hydrological regime in the Amazon. There is still much work to do of course, but there has still been quite a lot of research into land-use change, moisture recycling and the hydrological cycle throughout the Amazon.

We agree with the referee and removed the mentioned part in P2 L24-25.

P2 L22 Consider including Badger & Dirmeyer (2015) and Keys et al. (2016). Badger and Dirmeyer conducted a detailed examination of the climate impacts of land-use change in the Amazon, including a very detailed analysis of the hydroclimate. Keys et al. examine the role of vegetation change on moisture recycling, including a regional focus on a part of the

Amazon experiencing rapid land-use change (as well as using the WAM-2layers for the moisture tracking).

Thanks for the suggestion, we included the suggested literature and also added other references.

P2 L26 If this is the first instance of the abbreviation 'SDGs', please spell it out. Also, which of the 17 SDGs are the authors referring to? Consider adding some specificity here and a citation to support the relevance of moisture recycling (I'm not doubting its relevance, but it would be useful for the authors to chart this relevance more clearly and specifically).

Thank the referee for pointing this out, we revised it to make it more specific.

P5 L4 In section 2.1.3, the authors explain their concept of the 'most influential precipitationshed'.

From my understanding, this is simply a threshold-based boundary, correct? As stated earlier, this a very interesting idea, but the authors ought to acknowledge that this is one of several methods for delineating a precipitationshed boundary. I highlighted the previous studies in my General Comments that have discussed boundary methods. Essentially, the 40% MIP is the boundary which provides 40% of continentally recycled precipitation, correct?

The referee understood our analysis correctly. We agree with the referee's comment and have put it in the context of existing literature in both Sect. 2.1.3 and Sect. 4.4.

P6 L26 It would be useful to remind the reader that MIP essentially means the 40% terrestrial moisture recycling boundary (again, assuming I understand it correctly).

As the referee pointed out earlier, we have added clarification on the boundary context of the MIP threshold in Sect. 2.1.3. Thus we referred to Sect. 2.1.3 here and added the "40% threshold" description to avoid confusion. However, we decide to keep the MIP to hint to the readers the step's underlying purpose.

P7 L12 What is meant by "with high spatial efficiency"?

We mean stronger control per unit area and added this in the revision.

P7 L13 Why does the MIP account for 50% of the Amazonian evapotranspiration? Shouldn't it be 40%? Please clarify for easier interpretation of the result.

The Amazonian evapotranspiration contributes about 80% of the continental sourced rainfall in the sensitive areas. The MIP accounts for half of this 80% but has the size of 3.5% of the Amazon basin. We have added explanation in the revision.

- P8 L7 A bit confusing. Please replace "adding an extra time: : : on the original flow" with "more than doubling: : : the original flow"
- P8 L22 Perhaps replace "fashion" with "pattern"?
- Replaced as suggested.

P8 L30 Very interesting finding!

Thanks!

P9 L6-7 The finding about the rice planting not having very large impacts on run-off makes me curious about seasonal impacts (e.g. trees evaporate at different times than crops, etc.). Did you explore seasonal impacts? If so, please include some information on that analysis; if not, please include a few comments as to why it is outside the scope of this present work.

The seasonal variation was indeed outside the scope of our question since we focus on the spatial difference of land use change impacts on the annual water availability. We have stated in Sect.4.5 Limitation (P12L19) that future work focusing on specific purposes should take seasonal impacts into account.

P9 L20 "As it controls half the Amazonian evapotranspiration: : :" Again, I am confused about whether the MIP represents 50% or 40%.

The evapotranspiration from the Amazon basin contributes about 80% of the continentally sourced rainfall in the sensitive areas and we have revised it in P.7 to avoid confusion that would arise also in this part.

P10 L25 Do the authors mean "increases" where they wrote "increments"?

Yes, we changed that into "increases" in the revision.

P11 L12 The authors should consider citing Wang-Erlandsson et al. (2017) since they find these same types of results. Both the Wang-Erlandsson paper and this paper are currently in HESSD, and it would be useful as a reader to see they find complimentary results using a variation in methods. In the interest of full disclosure, I am a co-author on the Wang-Erlandsson et al. article, and will suggest to the lead author of that paper that they also cite this work (for the same reasons I suggested already).

We found the suggested discussion paper interesting as it finds similar effect from land use change on runoff through moisture recycling from global analysis. We added a citation to the manuscript.

P13 L2-5 Here the authors could be bolder in their conclusions about what is important and novel about their work. E.g. The importance of relatively small source areas for sensitive regions in the Amazon; also the importance of extra-basin land-use change on basin runoff.

We have revised Sect.5 Conclusion (P13. L3-16) to emphasize these points.

- P14 L1 Confusing sentence ": : :strong controls on the rainfall and runoff regimes of the sensitives." I think the authors are missing a word; perhaps "sensitive regions"?
- P14 L1-2 I recommend removing the final sentence since it is unnecessary.
- Fig 2 & 3 Both figures need a label on the colorbar
- Revised as suggested.

References

Keys, P. W., Van Der Ent, R. J., Gordon, L. J., Hoff, H., Nikoli, R. and Savenije, H. H. G.: Analyzing precipitationsheds to understand the vulnerability of rainfall dependent regions, Biogeosciences, 9(2), 733–746, doi:10.5194/bg-9-733-2012, 2012.

Keys, P. W., Wang-Erlandsson, L., Gordon, L. J., Galaz, V. and Ebbesson, J.: Approaching moisture recycling governance, Glob. Environ. Chang., 45, 15–23, doi:10.1016/j.gloenvcha.2017.04.007, 2017.