Hydrol. Earth Syst. Sci. Discuss.,
https://doi.org/10.5194/hess-2017-347-RC1, 2017

Hydrology and Earth System Sciences Open Access
Discussions

Interactive comment on "The effect of northern forest expansion on evapotranspiration overrides that of a possible physiological water saving response to rising CO_2: Interpretations of movement in Budyko Space" *by* Fernando Jaramillo et al.

Anonymous Referee #1

Received and published: 17 July 2017

Overview This manuscript addresses causes of water balance changes in Swedish forests during the period 1961 to 2012. Water balance changes were encoded in estimates of the evaporative fraction, i.e., annual actual evapotranspiration over precipitation (E/P). The estimated changes in E/P were explained by climatic changes due to precipitation and potential evapotranspiration and by ecosystem changes due to standing forest biomass. The authors conclude that E/P increased 1961-2012 and attribute this increase to increased forest cover, despite a concurrent increase in precipitation

(i.e., decrease in the aridity index). The authors anticipated a reduction in E/P due to CO2 fertilization and interpret observed increased E/P as evidence that increased forest area overcompensated for any CO2 fertilization effect.

The authors address a question of broad interest with relevance to water and carbon budgets from watershed to global scales. As noted by the authors, recent high profile papers have addressed the CO2 fertilization effect on the water balance directly (Betts et al. 2007) and in conjunction with climate, land use, and leaf area (Piao et al. 2007). As another example, Swann et al. (2016) and Milly and Dunne (2016) both suggest CO2 fertilization-induced decreases in ET may partially mitigate currently projected changes in continental drying and drought severity. The current paper follows in the footsteps of Piao et al. (2007) by addressing the effect of reforestation on basin-scale evapotranspiration in the context of simultaneous CO2 and associated climatic changes.

In general, the hypothesis and analysis were well thought out and executed. Broadly, I think the clarity of the paper could be improved. And, more specifically, I have some difficulty understanding the analysis linking evapotranspiration changes to forest expansion rather than CO2 fertilization.

"Possible physiological water saving response to rising CO2" The authors state in their title that the ET increase from forest expansion overrides ET decrease from rising CO2. The authors then present evidence that (1) the aridity index decreased over time due to an increase in precipitation; (2) this decrease in aridity index lead to a decrease in E/P, as expected from the Budyko curve; and (3) there was an overall increase in E/P. This increase in E/P was then attributed to changes in forest standing biomass. There was no evidence or estimate of the CO2 fertilization effect and, therefore, I find it difficult to conclude that this effect was present and indeed over-compensated.

To address this issue, I would suggest the authors reduce the focus on CO2 fertilization in the title and abstract. My intuition is that the CO2 fertilization effect was relatively weak in this ecosystem. The atmospheric CO2 concentration increased approximately 85 ppm (315 too 400 ppm) over the study period, 1961-2012. In a meta-analysis of the FACE experiments (Ainsworth and Rogers 2007), trees showed one of the lowest responses of stomatal conductance to elevated CO2 (~20% decrease). In these experiments, CO2 was increased from 366 ppm to 567 ppm, an increase 2.35 times that experienced from 1961 to 2012. As a first guess, one might expect less than 10% decrease in stomatal conductance whereas the authors show that forest standing biomass increased 25% and 55% in boreal and temperate watersheds (Figure 8).

Further, in several places, the authors make the same argument based on results of species-specific responses. See page 2, lines 9-20 and page 7, lines 14-23. To paraphrase, the watersheds studied are dominated by coniferous species and CO2 water saving response has not been observed in these species.

In conclusion, there is little evidence to expect a CO2 water saving response in the studied watersheds. Therefore, I do not think it is appropriate to set up the paper with this hypothesis that is later not supported with the data. On the other hand, I do think it is appropriate to address this weak CO2 effect as one reason why an increase in E/P was observed, as the authors have done on page 7.

Specific comments

Hydroclimatic Data:

1) The temporal scales of the data are inconsistent. For the Penman-Monteith model, the long-term mean annual geostrophic wind at 1000 meters above sea level is used. Given fine-scale variability in windspeed and its local, leaf-scale effect on transpiration, this approach is not warranted. This is especially true for comparison with the Langbein and Hargreaves models, which use daily temperature as model input. My suggestion is to remove the Penman-Monteith analysis and use the 3 other sources for PET.

2) The discussion in the first paragraph surrounding equation (1) is disorganized. My

suggestion is to place the description of the P data before equation (1). Then follow with the sentence, "We used annual P and R data to calculate . . ." after you've described what the annual P and R data are.

Budyko Framework:

1) I am not familiar with the Psi notation for evaporative index and typically see it written as E/P or something similar. It may help the reader to be consistent with notation from your references.

Linking the residual effect Delta Psi_r to forest change:

1) I don't understand equation 8. It is described as a five-year moving average, but there is only a j and j+1 term – does this mean only the current and previous year are used in the calculation?

Figure 2: Can you re-orient the arrow from t1 to t2 to be consistent with your result of decreasing aridity index? That would make the figure easier to read.

Figure 3: Can you include a separate Budyko plot for the early and late time periods? That would give the reader a general, more intuitive sense of how the watersheds moved in the Budyko space.

Figure 6: What is the y-axis label in this figure? Same for Figure 7.

References

Ainsworth, E.A. and Rogers, A., 2007. The response of photosynthesis and stomatal conductance to rising [CO2]: mechanisms and environmental interactions. Plant, cell & environment, 30(3), pp.258-270.

Betts, R. A., Boucher, O., Collins, M., Cox, P. M., Falloon, P. D., Gedney, N., Hemming, D. L., Huntingford, C., Jones, C.D., Sexton, D. M. H. and Webb, M. J.: Projected increase in continental runoff due to plant responses to increasing carbon dioxide, Nature, 448(7157), 1037–1041, doi:10.1038/nature06045, 2007.

Milly, P.C. and Dunne, K.A., 2016. Potential evapotranspiration and continental drying. Nature Climate Change, 6, pp.946-949.

Piao, S., Friedlingstein, P., Ciais, P., de Noblet-Ducoudre, N., Labat, D. and Zaehle, S.: Changes in climate and land use have a larger direct impact than rising CO2 on global river runoff trends, Proc. Natl. Acad. Sci. U. S. A., 104(39), 15242– 15247, doi:10.1073/pnas.0707213104, 2007.

Swann, A.L., Hoffman, F.M., Koven, C.D. and Randerson, J.T., 2016. Plant responses to increasing CO2 reduce estimates of climate impacts on drought severity. Proceedings of the National Academy of Sciences, 113(36), pp.10019-10024.

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