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Hydrology and Earth System Sciences
Discussions

Interactive comment on "Water consumption from hydropower plants – review of published estimates and an assessment of the concept" *by* T. H. Bakken et al.

T. H. Bakken et al.

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Thanks a lot for providing very valuable feedback and providing deeper insight into the complexity of calculating the water consumption/footprint of hydropower plants. As much of the feedback provide by Wörman

The response to the reviewer's comments is as follows:

Issue 1 raised by reviewer: The authors make an important point in stressing the relevance of using the change in water consumption introduced by the power production plant and the importance of system boundaries for this issue. In my opinion these are

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important standpoints for assessing the water footprint and would have liked a clearer recommendation on how the change in evapo-transpiration should be assessed and the effects of different approaches.

Response from authors: The issues of gross versus net water consumption ('change caused by the HP-project) and the issue of setting proper spatial boundaries for the analysis are definitely of major importance in order to clarify how the water consumption should be calculated. This is shown by comparing gross versus net estimates and also exemplified by the specifics of cascaded hydropower plants. At current stage we have no clear recommendations in how to handle this except for stating that this must be clarified. We consider the scope of this paper is to review existing estimates for water consumption and a critical discussion on what we think are shortcomings/weaknesses in the currently used methodological approaches, and clear recommendations/proposals for improvements are at this stage not discussed. We do, however, plan to continue our research within this field, and hopefully publish suggestions/proposals for an improved methodological approach, accompanied with case studies.

Issue 2 raised by reviewer: There is also a brief discussion in the paper e.g. mentioning that "water hungry vegetation" present before the exploitation "will to limited extent change the original evaporation". However, in order to explain the water footprint one would have to consider the change in landtypes resulting from a hydropower project, the shift in area between landtypes even outside the reservoir itself and the associated evapotranspirations are key to understanding the water footprint. And; Especially in multi-purpose projects, involving e.g. municipal water supply or irrigation, and cascade hydropower the land area of the analysis has to be selected more generally than expressed by the evaluated water consumption expressions.

Response from authors: Yes, we fully agree, and again the issue of setting the proper spatial boundaries of the analysis is essential to clarify. We also appreciate that the issue of secondary effects/indirect changes in e.g. land use/land types outside the

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reservoir area are addressed/given attention by the reviewer. Furthermore, the reviewer raises the issue of changes in water use patterns introduced by the hydropower project, which is neither discussed in the paper. We will include 1-2 sentences about this in section 3.1 where gross versus net water consumption is discussed.

Issue 3 raised by reviewer: Further, a change in water level in a reservoir has a corresponding effect on adjacent groundwater levels and possibly damming effect in the river system. Thus, since the paper includes a discussion on these methodological problems, it could have specifically included a general expression for or recommendation how to equate the water footprint.

Response from authors: Yes, the change in groundwater levels due to the regulation might cause changes in the evapo-transpiration rates, which also should be accounted for when calculating the water consumption/footprint. We will include a short sentence about this in section 3.1. As explained earlier in our response to the reviewer, we feel that proposing clear recommendations/proposals for a new methodological framework are outside the scope of this paper, but will be central for future research and hopefully published at a later stage.

Issue 4 raised by reviewer: Last paragraph – the issue of setting the proper temporal resolution and especially time span of the analysis.

Response from authors: The importance of this issue depends on which water consumption estimate we want to have. If we want an estimate of the water consumption for the previous years (e.g. for reporting), we can ignore this since we do not want to predict for the future.

But if we want an estimate of what will be the water consumption of a hydropower utility the coming years, this issue is very relevant, especially due to past and future changes in climate. The reviewer is concerned about both bias and uncertainty in estimates of annual averages. Concerning the bias it is important the period of averaging is long enough to cover typical cyclic phenomena (e.g. el ninjo / la nina) and that the typical

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correlation length of the auto-correlation is shorter than the averaging period. Concerning uncertainty, it is true that the autocorrelation will increase the uncertainty in the estimate of an average value (i.e. reduce the number of effective independent observations), and that long timer time series are needed to obtain higher precision. There are, however, many other factors that also contributes to biases and uncertainties in the estimation of evapotranspiration and water consumption since these estimates depends on several measurements that are interpolated to obtain spatial fields and then models are used for estimating the evapotranspiration. The measurements, the interpolation and the models lead to biases and uncertainties in the estimates, and an assessment how important the sampling uncertainty (uncertainty due to limited amount of data) is compared to the uncertainty in the evapotranspiration estimates themselves would be interesting to assess.

The reviewer also raises the issue how to handle changes in climate (temperatures, precipitation) and land use when estimating water consumption. We think that one solution to this is to let the estimates include possible temporal trends so that water consumption estimates depend on time. I.e. a water consumption estimate for a hydropower utility for the coming 30 years based on historical data, should carefully address any trends in historical data used for the estimate and express how eventual trends are extrapolated into the future. This extrapolation of trends will also contribute to biases and uncertainties in the water consumption estimate.

A few additional changes that will be made by the authors in the revised manuscript:

1.The reference to the article by Demeke et al. (2013) contains a misspelling of the second author; this will be corrected to A. Mynett.

2. The following article Bakken, T. H., Skarbøvik, E., Gosain, A. K., Palanisami, K., Sauterleute, J., Egeland, H., Kakumanu, K. R., Nagothu, U. S., Harby, A., Tirupataiah, K., and Stålnacke, P.: Optimizing water allocation with use of the Building Block Methodology (BBM), J. Hydroenviron. Res., 2013b was never published in J. Hydroen-

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viron. Res. Instead it has been published in Journal of Sustainable Development, Published by Canadian Center of Science and Education, doi:10.5539/jsd.v6n8p93, with basically the same content.

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 10, 8071, 2013.