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Hydrology and Earth System Sciences Discussions

# *Interactive comment on* "The water footprint of electricity from hydropower" *by* M. M. Mekonnen and A. Y. Hoekstra

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We thank the reviewer very much for the comments and address them below point by point:

1. The first note by the reviewer concerns the definition of the WF concept and the question when water consumption is called blue water consumption and when green water consumption. If rainwater is not stored on or in the soil, but runs off into groundwater or surface water, it is called blue water (Hoff et al., 2010; Savenije, 2000). Water that falls directly into surface water becomes immediately blue water. Therefore, evaporation from a reservoir is evaporation of blue water. If the water from the reservoir would not evaporate, the water would run off, so that's why reservoir evaporation sub-



tracts from the runoff (blue water) flow in a river.

2. The WF measures the evaporation, whether 'necessary' or not. When assessing the WF of crop production, one considers full ET, while only part of ET really benefits the plant. When assessing the WF of industrial production, one considers the water evaporation during processing, while this evaporation loss can often be reduced and is not necessary. Similarly, we estimate the WF of hydro-electric production by estimating the total ET from the reservoir. Indeed, the hydroelectric generation does not profit at all from this evaporative flow.

3. The study by Gerbens-Leenes et al (2009) did not consider any specific reservoir, but only made an effort to make a first rough, global estimate of the WF of hydropower by taking global estimates of water evaporation from reservoirs and hydroelectric generation. We can add to the literature review now the recent paper by Herath et al (2011) that assess the WF of hydroelectric generation for eight plants in New Zealand, and another recent paper by Pfister et al (2011).

4. The source of information regarding the statement that our selected plants are primarily for hydropower is World Bank (1996). Other purposes can include water storage for irrigation or flood mitigation, but since the dams selected have been 'primarily' constructed for the purpose of hydroelectric generation, we assume that most of the economic value of the reservoirs lies herein. See further our response to reviewer #1, who also observed this point (note #3).

5. That is now possible with two new, recent studies published (Herath et al., 2011; Pfister et al., 20110. We find a wider range of values, because we study much more dams, but the ranges published in the two other studies nicely fit within out range.

6. We can take different measures regarding ET. Each measure has a different meaning and requires a different interpretation. We can basically distinguish three relevant indicators: (1) total ET from the reservoir, (2) net ET from the reservoir, and (3) the difference of ET before and after the reservoir (i.e., the difference between the 'ET from

the reservoir' and the 'ET from the area before the reservoir was built'). In a paper that was recently published, after our paper was submitted to HESSD, Herath et al (2011) apply all three methods to show the differences.

The total ET tells something about the total volume of water evaporated and not usable for another purpose. This is the definition of 'water footprint', which is a measure of consumptive water use and aims to quantify the volume of water allocated for a particular purpose so that it is no longer available for another purpose. Net ET from a reservoir shows how a reservoir affects the river flow. The river flow after the dam is lower than the river flows (and other side inflows) that enter the reservoir, because of ET, but P into the reservoir is added, so the lowering of river flow is equal to net ET.

Finally, the difference between ET 'with' and 'without' reservoir, shows the impact of building the reservoir on downstream river flow, so it's an hydrological impact indicator. The hydrological impact measured by the difference between ET-with and ET-without is a different indicator than 'water footprint', because the latter aims to show total water consumption for a particular purpose (here: hydro-electric generation). At least part of the water evaporating from the reservoir did also evaporate in the time previous to the construction of the reservoir (from the land area that is now flooded). This evaporation should be included in the 'water footprint'. The ET from that previous land area is no longer allocated to crop production or natural vegetation in that land area, because with the reservoir it is now associated with the reservoir purpose, which is hydroelectric generation. If one is not interested in the issue of water allocation but in the issue of downstream hydrological impact, one will look at only the changed ET as a result of dam building.

7. With considering 35 reservoirs we have made a big step compared to earlier rough global estimates (Gerbens-Leenes et al, 2009) and the two recently published studies (Herath et al., 2011; Pfister et al., 2011) that study only a few reservoirs each. We agree that if time is spent on collecting data for other reservoirs worldwide, in future studies one can arrive at a true global estimate based on reservoir-specific estimates.



One cannot extrapolate our estimate for 35 reservoirs to a global estimate, because we have considered the largest reservoirs, which are not representative for all reservoirs. Also, the largest reservoirs are not fairly distributed over the globe.

The minor comments can all be included in the revised manuscript.

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