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Interactive comment on "Consumptive water use to feed humanity - curing a blind spot" *by* M. Falkenmark and M. Lannerstad

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The paper addresses a very important issue, namely, the evaluation of the alterations in consumptive water use that will take place in the future as a consequence of the expected increase in the demand of food. The implications of the increased water needs are analysed in detail by especially focusing on river depletion as a consequence of augmented water withdrawals.

I think the paper is very interesting and accurate. It presents an up-to-date analysis of the close links between food demand, agricultural water needs, river depletion and health of the riparian ecosystems. It is explained particularly well the distinction between green and blue water flows that hydrologists are not familiar with. The case studies presented to support the author's claims are interesting and well documented. In summary, I think this manuscript is a nice example of a social problem, with signifi-

cant political consequences at global scale, being quantitatively analysed on a scientific basis. Unfortunately, the implications of this type of problems are sometimes supported only with qualitative considerations, especially when the primary need is to gain consensus from the population. I think this paper indicates the correct way to follow.

As far as my opinion about the paper findings is concerned, I agree with the results and conclusions of the authors, especially with the general deduction that significant changes in green water flows can be foreseen for the future. However, it is my opinion that the authors have been excessively pessimist in some steps of their analysis.

My general opinion is that fresh water supply is indeed going to be a topical problem for the next years, but not to the extent the authors are picturing in the paper. My feeling is that progress in water supply systems and agricultural techniques will partially compensate for the increased needs of fresh water.

The authors' estimate an additional green water requirement of 3800 cubic kilometres per year in 2025 and 5600 cubic kilometres per year in 2050. These estimates are based on the implicit assumption that agriculture will maintain the same level of productivity and the farming practices remain unaltered. I think it is reasonable to believe that in the future the same amount of cultivated land will have increased production by consuming the same amount of water, as the changes in agricultural production in the last decades have clearly shown. Is this aspect considered in the presented analysis?

FAO is relatively optimistic that, at the world level, there will be sufficient agricultural production to meet increases in demand over the next thirty years. By 2030, for example, crop production in developing countries is projected to be 70% higher than in the 1990s. I do not think we should expect that this is gained at the expense of a full 70% increase of irrigation water. In particular, water will certainly be used more efficiently (this aspect is indeed considered in the manuscript, but I believe the authors underestimate its capability to reduce the water needs). The FAO corporate document titled "World Agriculture: Towards 2015/2030. An FAO perspective" (see

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http://www.fao.org/documents/) states that for the 93 countries from all parts of the world that are considered in the study, irrigation water withdrawal is expected to grow within 2030 by about 14%, from the current 2128 km3/yr (this estimate is coherent with the one reported in the paper) to 2420 km3/yr in 2030. This estimate is much lower with respect to the one presented by the authors, who foresee an increase of more than 100% in 2025. A possible explanation may be that the FAO estimates are already accounting for the improvement in irrigation efficiency. In fact, the FAO document states that the increase in water withdrawal is low compared to the 33% increase that is projected in the harvested irrigated area from now until 2030. Most of this difference is explained by the expected improvement in irrigation efficiency that should lead to a reduction in irrigation water withdrawal per irrigated hectare. A small part of this reduction is also a result of changes in cropping patterns for some countries such as China, where a substantial shift in the irrigated area from rice to maize production is expected; irrigation water requirements for rice production are usually twice those for maize. It seems that these estimates for the future water needs are more optimistic than the one presented in the paper. Did the authors account for a possible change in agricultural practices?

The FAO document concludes that, for the 93 developing countries considered in the study as a whole, irrigation currently represents a relatively small part of their total water resources and there remains a significant potential for further irrigation development. With the relatively small increase in irrigation water withdrawal expected between 1997/99 and 2030, this situation will not change much at the aggregate level. Locally and in some countries, however, there are already very severe water shortages, in particular in the Near East/North Africa region. I think it would be interesting to know what the authors think about this different point of view.

Another point that I think deserves to be discussed is the possible effect of climate change. The authors are not considering this aspect. I think it would be interesting to know why. Do the authors think that climate change would not affect their results

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much? I personally think that climate change will probably play, in terms of future water availability, a less important role with respect to what is pictured by many contributions presented in the scientific literature. However, we cannot ignore that many future climate scenarios foresee significant changes in water availability and that these may affect the results. Indeed, the noteworthy change in green water flows predicted by the authors is likely to have an influence on the climatic condition, at least at local scale. Significantly increased evaporation is not expected to result in increased precipitation? The authors rightly state that the total amount of water circulating in the water cycle is expected to remain the same. Thus I think it would be interesting to know the authors' opinion about the destiny of the evaporated water.

Some minor comments.

Introduction, Page 9, line 5: it is stated that what is asserted by Ambio (2004) is inconsistent with the general understanding that the amount of water circulating in the water cycle remains the same. I think this statement might be out of place here. It is certainly true that the total amount of water remains the same, but I think that Ambio (2004), by stating that "less and less water is available for human consumption", simply meant to say that the water available for human use is decreasing, for instance because of decreasing quality.

Section 2.1, page 10, line 15: it is stated "Since many of the water uses to which the withdrawn water is being put are through-flow based uses where the water after use returns to the water system, it is basically only the consumptive use component, or "evapotranspiration during use" that is relevant from the perspective of impact on downstream users and aquatic and coastal ecosystems. The return flow represents a quantity that can principally be reused over and over again down the river". I think this statement does not reflect what really happens in many real world situations. Indeed, the part of the withdrawn water that returns back to the river as return flow is very often polluted and is likely to flow back very far downstream (when not directly in the sea). Therefore, in practical situations, the evaporated water is not the only source of loss of

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fresh water availability.

Section 2.2, page 11, line 5: Lvovich or L'vovich as in the list of references?

Section 2.2, page 12, lines 10-15: it is stated that "..the Millennium Ecosystem Assessment sees terrestrial ecosystems as water-provisioning rather than water-consumptive, which is as they come out from a hydrological aspect". It seems to me that it is well known that forests, on the one hand, induce a reduction of water flows during high flow periods. On the other hand, they may contribute significantly to sustain the lower river flows. For instance, the Curve Number infiltration model (Soil Conservation Service, 1972) that is adopted, among others, by the well known HBV watershed model (Bergstrom, 1995), induces this type of an effect during continuous time simulation. Therefore, I think it is reductive to state that forests are water consumptive. Certainly a consumption of water is induced by them, but they also affect the distribution of water availability during time in a way that might be highly beneficial in certain climates. The same effect on water distribution is played by man-made reservoirs. Certainly they can induce river depletion in some seasons, but they may also sustain the lower river flows in other periods. In general, I see that the man induced effects in water distribution during time are not considered in the paper.

Section 3.3.1, page 15, line 10: are we sure that the Aral Sea is an appropriate example here? The depletion of Aral sea is undoubtedly one of the major natural disasters caused by water withdraw, but I think the major problem in that case was a mistake in agricultural planning. The water of the Aral sea was largely used to irrigate cotton plantations to sustain the U.S.S.R.'s economy. On average, cotton requires about 1000 mm of water to meet its requirements, while a medium maturity grain crop requires about 600 mm of water. It was probably only the illusion that Aral sea water was infinite to suggest the choice to cultivate cotton there. Similar disasters hopefully will not happen again in the future.

Section 4.1, page 18, line 27: please define C3 and C4.

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Section 4.1, page 19, line 15: it is stated that environmental flow should be from 30% to 50% of natural flow. Does this mean that at any time the minimum flow should not be lower than 30%-50% of the natural flow at the same time? I am not an expert about the situation in the tropics, but I would say that the current practice in Europe allows the withdrawal of more water.

References Bergstrom, S. 1995. The HBV model. In: V.P. Singh (Ed.), Computer models of watershed hydrology. Water Resources Publications, Highlands Ranch, CO.

Soil Conservation Service, 1972. National Engineering Handbook, Section 4, Hydrology. U.S. Dept. of Agriculture, Washington D.C.

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