

## ***Interactive comment on “Virtual water highway: water use efficiency in global food trade” by H. Yang et al.***

**H. Yang et al.**

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The authors are thankful to Chapagain, Hoekstra and Savenije for their comments on our paper. Below we provide our responses to their comments:

- Response to the comments on innovation of the paper.

The quantification of virtual water flows has been a topic of interest to many researchers in the virtual water field. This has resulted in a number of publications on the relevant issues since 2002 (including our own paper published in *World Development* in 2002). However, we consider that this should not be a reason for other researchers to restrain themselves from further tackling the similar issues. As we can see from the list of references provided by Chapagain, several of their own studies on the topic were conducted after the publications by Oki et al. (2003); Oki and Kanae, 2004. Fraiture et al. (2004). Clearly, they believe that there is a need for a further discussion on the similar issues even though other people have touched them.

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It is true that now it has been a general consensus that the global food trade has led to a reduction in global water use in food production, although not all researchers are positive about the meaningfulness of such saving (e.g., Fraiture et al., 2004). In the revised version of the manuscript, the discussion on the magnitude of water saving has been shortened. We kept the visual illustration of the amplification of virtual water flows from source to destination because such an illustration has not been seen in the literature.

We disagree with the comments that ‘the basic concept behind our paper has been explored by a number of authors in the recent past’. Both the two referees and Chapagain et al. have mentioned in their comments that the partitioning of the virtual water flows into a blue and green water component is ‘new’ or ‘indeed innovative’. In the revised manuscript, this part of the discussion is strengthened.

In our paper (both the earlier version and the revised version), we acknowledged the use of the virtual water content estimated by Hoekstra and Hung (2003), we shortened the details in the revised version (see Section 2.1 for detail).

- Response to the comments on the lower opportunity cost and environmental impacts of green virtual water

The judgment on the lower opportunity cost of the green virtual water as opposed to blue virtual water is based on the definition of opportunity cost. By definition, the opportunity cost of water is its value in other uses, such as in municipal, industrial, or recreational activities, and ecosystems. Blue water has many other uses. Irrigation often yields lower economic returns than that in the domestic and industrial sectors. Green water has fewer uses in comparison to blue water. The opportunity cost of blue virtual water is thus higher than the opportunity cost of green virtual water. As for the environmental impacts of blue water use in comparison to green water use, we realize that it is a complicated issue and a generalization may not be appropriate. We therefore deleted this statement in the revised manuscript.

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- Responses to the comments on the physical water saving and economic benefits of the saving.

We acknowledge that in the earlier version of the paper we did not pay sufficient attention to the meaning of “water saving” for different countries with different water resources endowments. We fully agree that a broader perspective is required in order to make any conclusion on the efficiency gains and losses involving virtual water trade. In the revised manuscript, we substantially extended the discussion of the relevant issues at the country level. The detail is provided mainly in Section 3.3 and Section 5 of the revised manuscript.

- Responses to the comments on the virtual water content used in the calculation of the virtual water flows.

We appreciate the comments and believe there is a need to notify the factors that affect the accuracy of the estimated virtual water contents. The specification of the factors is presented in Section 3.1.

- Responses to Specific issues:

Page 2, line 14-16. We agree with this point and dropped the discussion on the negative environmental impacts of irrigation on importing countries.

Page 2, lines 23-26. We agree with the comments and have made changes accordingly.

Page 3, line 1-3. We added studies by Yang and Zehnder, 2002; Fraiture et al. (2004) and Hoekstra and Hung (2005) here. However, we did not include Chapagain and Hoekstra, 2004, Chapagain et al, 2005a, Chapagain 2005b because these papers are not published in the international journals and they are also not accessible from internet.

Page 3 line 25-26. This point is taken. The blue water and green water in relation to irrigated and rainfed agriculture is clarified.

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Page 21. Table 3. The statement on the environmental impacts of blue and green water use is dropped.

Page 23. Figure 2. Figure 2 in the earlier version of the paper is dropped.

Page 24. Figure 3. The arrows show the direction of the net virtual water flows across the 14 regions of the world. The colors chosen are random. The caption is clarified in the revised manuscript.

Page 25. Figure 4. We added a paragraph in Section 2.3 to specify the source of the data used in this study. The scale of the map is dropped.

- Responses to the summary of the comments.

The revised manuscript has scaled back the discussion on the virtual water flows in the international food crop trade. We extended the discussion to the county level for advancing the understanding of the socio-economic and environmental implications of virtual water trade.

We agree with Chapagain, et al. that the lack of data is a challenge to a more precise partitioning of green and blue virtual water flows. The lack of data has been a reason for our study to make some assumptions in the green and blue water partitioning. A good news is that we have recently developed a GIS based crop growth model, which is highly promising for be used to quantify the contribution of blue and green water to crop yield in any geographical locations based on the available data. It would certainly be beneficial to the virtual water study and the policy supporting if we make concerted efforts to combat the challenge. It would be detrimental, on the other hand, if we deny each other's research efforts because one of us has been working on it.

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