Response to Interactive comment on "A global and high-resolution assessment of the green, blue and grey water footprint of wheat"

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Response to Stefan Siebert:

#1. The grey water footprint is used as an indicator of the degree of freshwater pollution that can be associated with the leaching of fertilizer and other agricultural chemicals to the freshwater system. It is defined as the volume of freshwater that is required to assimilate the load of pollutants based on existing ambient water quality standards (Chapagain et al., 2006; Hoekstra and Chapagain, 2008, Hoekstra et al., 2009). The grey component of water use, expressed as a dilution water requirement, has been recognised earlier by for example Postel et al. (1996) and Chapagain et al. (2006). The model presented does not simulate physical processes like denitrification and dilution. The loss of N to the atmosphere, the uptake of N through vegetation and the accumulation of N in the soil is accounted for by assuming that only a percentage of N applied leaches to groundwater or runs off to surface water (the leaching-runoff faction). We have assumed a leaching-runoff fraction based on data available in literature. The grey water footprint was calculated following the method presented in the water footprint manual (Hoekstra et al., 2009) using Eq. (6). We will improve the text to better explain the issue of leaching and runoff.

#2. We have taken the water footprint of wheat and wheat products as in the exporting country. When a product is exported from a country that does not produce wheat, we have assumed the global average water footprint of wheat for that export flow. If we consider the case of Saudi Arabia, the total virtual water export was calculated based on the water footprint per ton of wheat as in Saudi Arabia. Table 1 shows that Saudi Arabia does have net wheat import, as pointed out by the reviewer. Accordingly, the country also has net virtual water import as a result of wheat trade. However, the virtual water imports are dominantly green, while the exports are dominantly blue. As a result, one can see that Saudi Arabia has a net virtual water export of *blue* water.

Table 1. Water footprint of domestic wheat production and virtual water import and export for Saudi Arabia (1996-2005).

	Quantity* (ton/yr)		Water footprint/virtual water (Mm3/yr) Green	Blue	Grey	Total
Domestic wheat production	2057862	Water footprint of domestic wheat production	501	2299	389	3189
Wheat import	162355	Virtual water import related to wheat import	53	21	13	87
Wheat export	39827	Virtual water export related to wheat export	9.2	42.2	7.1	58.6

* Import and export quantity expressed as wheat equivalent. Data on wheat and wheat derived products import and export from ITC (2007). Wheat derived products are converted to wheat equivalent by using the product fraction.

We agree with the reviewer that, theoretically, estimates of virtual water exports can be improved by tracing the origin of all exports. This, however, is a very laborious piece of work, contributing little to the improvement of the estimates. We can illustrate this for the case of Saudi Arabia. Table 2 shows the calculated virtual water export related to wheat export when we link exports partly to domestic production and partly to imports and when we calculate the water footprint of exported products based on the real countries of origin, applying the second equation on p.41 of Hoekstra et al. (2009).

Table 2. Weighted average water footprint per ton of wheat and the associated virtual water export (1996-2005)

Average water footprint of wheat in Saudi Arabia considering both domestic production and imports (m^3/ton)				Virtual water export (Mm3/yr)			
Green	Blue	Grey	Total	Green	Blue	Grey	Total
249	1045	181	1475	9.9	41.6	7.2	58.8

#3. The water footprint is calculated only for the crop growing period. We have not included the ET outside the growing period. We have assumed that farmers start planting (sowing crops) after the soil has received enough rain or irrigation so the soil moisture at the root zone is assumed to be at field capacity at the beginning of the growing period.

#4. If we consider only the consumptive (green + blue) water footprint of wheat, the water footprint under rainfed is more or less the same as for irrigated land indeed. We will correct the text in this matter. The total water appropriated for the production of wheat also includes the water polluted due to the leaching of fertilizers to freshwater which makes the water footprint per ton of wheat for irrigated lands to be more than that for rainfed lands. What we are trying to stress is that irrigated agriculture is not as productive as it commonly believed to be.

References:

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