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Discussions

Interactive comment on "HESS Opinions: A Planetary Boundary on Freshwater Use is Misleading" *by* Maik Heistermann

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I would like to thank Dr Perry for his comments. I agree with most of his points, and, as should be evident from the opinion paper, I also share his concerns towards the water footprint concept (although, admittedly, this issue is not at the heart of the manuscript under discussion).

Nonetheless, I would like to briefly respond to the quantitative approximation of the global water balance, and the relative role of irrigation in this balance, as outlined by Dr Perry. A word of warning, though: as this is the 7^{th} response in this interactive discussion, I will be starting to repeat myself. But I'll try hard to focus on some new aspects.

Dr Christof Lorenz, who authored SC2 in this discussion, will probably have more re-

cent figures on the global water cycle, as compared to the source cited by Dr Perry (UNEP 2008, which is mainly based on the famous synopsis by I. A. Shiklomanov in Gleick 1993, which itself goes far back to sources from the 1960s and 1970s). But surely, for the sake of Dr Perry's argument, those numbers will suffice.

In his argument, he uses an utterly simplistic approach to approximate the proportion of consumptive water use by irrigation in the overall terrestrial evapotranspiration (ET): he assumes that every irrigated hectare of cropland adds some 1000 mm ET per year as compared to rainfed management. Scientists around the world, including the PB community, keenly work on advanced monitoring and simulation techniques in order to improve such estimates, and I am sure Dr Perry will agree that lumping together all irrigated croplands in terms of ET is a gross simplication. Still, his ballpark figure of 3000 km^3 (which he refers to as "incremental ET") actually comes quite close to the 2600 km^3 estimate of consumptive blue water use as published by Rockström et al. (2009) and Steffen et al. (2015). It would be even closer if Dr Perry took the 261 million hectares as a basis that are, according to FAO AQUASTAT, actually irrigated (instead of 300 million hectares).

So far so uncontroversial.

Dr Perry then puts that 3000 km^3 figure in relation to the terrestrial ET according to the UNEP (2008) source. Depending on whether or not inland lakes are included in the terrestrial ET, the proportion of terrestrial ET *"attributable to irrigation"* corresponds to 4.6 or 4.1 percent respectively, or, roughly, *5 percent*. He concludes that *"marginal increases"* in these 5 percent do not have the potential to trigger global scale regime shifts.

How does that correspond to the planetary boundaries literature?

It doesn't. The PB literature does not relate consumptive blue water use to terrestrial ET. Although Rockström et al. (2009) note that *"a planetary boundary for freshwater resources must [...] be set to safely sustain enough green water flows for moisture*

feedback (to regenerate precipitation) [...], and secure the availability of blue water resources for aquatic ecosystems", they admit that *"the close interactions between land and water, and between vapor flows and runoff, make it difficult to define an appropriate freshwater boundary that captures the complexity of rainfall partitioning across scales."* Instead, they *"propose runoff depletion in the form of consumptive runoff or blue water use as a proxy for capturing the full complexity of global freshwater thresholds."* In the extensive supplementary to Rockström et al. (2009), this idea is elaborated at length (pp. 10-16), but it can be summarized in brief, if I may: consumptive blue water use is assumed to (somehow) disturb terrestrial soil moisture feedbacks (or, according to hydrological theory of colors, *"green water flows"*) at large scales (*"monsoonal scales"*). Since there is no evidence to support that hypothesis, it is argued that *"the deleterious green water changes [...] occur 'upstream' of, and are interlinked with, river depletion. Therefore, river depletion in the form of consumptive blue water use is chosen as a proxy for the full complexity of the highest risk for global water thresholds."* No effort is made whatsoever to demonstrate that consumptive blue water use is in fact an adequate proxy to represent such *"deleterious green water changes upstream"* (of where a river is depleted). I tend to assume that such an effort would hardly be successful (but nonetheless worthwhile): in my response to Prof. Savenije (RC2 in this discussion), I already pointed out that irrigation itself could rather be considered an intensification of terrestrial moisture recycling, and can thus be assumed to act differently from processes such as deforestion. Maybe we should boost irrigation to enhance terrestrial moisture recycling? Just kidding... because upstream freshwater consumption and its potential contribution to terrestrial moisture recycling might, in fact, be counterbalanced by a decrease of evapotranspiration in downstream wetlands, estuaries or inland lakes (the Aral Sea being the textbook example). Those interactions (and compensation effects) are surely worth being investigated! I dare to hypothesize, though, that any "deleterious effects" on terrestrial moisture recycling occur *downstream*, not *upstream* of where river depletion is felt.

Anyway, the PB literature does not attempt further to investigate the role of consumptive

blue water use in terrestrial ET (or green water flows). Instead, it focusses on the fraction of consumptive blue water use (2600 km^3 per year) in the *"12,500 km^3 per year of river runoff [that] is potentially available for human appropriation"*. That fraction amounts to roughly 21 percent. The 12,500 km^3 figure is then, more or less arbitrarily, reduced to define the "safe operating space" of 4000-6000 km^3 per year, corresponding to a fraction of 43-65 percent.

I admit that playing around with those numbers can be fun, but it does not tell us anything about how consumptive water use might irreversibly affect the global water cycle, or the Earth system as a whole.

Attention, though: Neither a 5 percent nor a 21 or 65 percent figure should - as such - be mistaken as an evidence *of* or *against* the existence/relevance of feedback mechanisms (although, to be precise, Dr Perry actually argued that *changes from* the 5 percent should not be expected to have a global impact). In non-linear systems, small changes in drivers can potentially trigger dramatic consequences. But without further evidence and *understanding*, this is nothing more than a commonplace in systems theory. *"As long as Earth system science does not present compelling evidence, the exercise of assigning actual numbers to such a boundary is arbitrary, premature and misleading"* - I am already starting to quote myself, but I gave a fair warning above.

Altogether, I could not agree more with Dr Perry that a planetary freshwater boundary actually distracts attention, although it claims to rise awareness (see RC3 by Prof. Gerten). It distracts attention from actual water management, and it distracts attention from fundamental research that is required to better understand the Earth system.

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