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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 deals with the steadily increasing water scarcity due to increased water withdrawals. Water withdrawals are expected to further increase, mainly due to an increased need for food for a growing population. The authors argue that when dealing with water scarcity one should be analytically clear, and distinguish water withdrawals from consumptive water use and return flows. Consumptive water ruse is the amount of water that is evaporated in the process of using it. I infer that this is the "blind spot" that the paper sets out to uncover.

This is an important paper, although the argument could gain in clarity in one important aspect. The paper could also draw one practical conclusion more clearly. There are also a few minor points that the paper raises. This I attempt to elaborate in this interactive comment.

The paper presents an important graph: figure 6. This figure depicts the historical developments of human interference in the water cycle, starting with the undisturbed situation with vegetation that maximized the transpiration component of the hydrological cycle; the resulting blue water flux was therefore relatively small. The clearing of natural vegetation for arable agriculture and grasslands by man led to a decrease in transpiration, because the human-induced vegetation cover was less dense, and an increase in the blue water flux. What the graph fails to indicate is that this also led to an increase in non-transpirative evaporation, i.e. the unproductive evaporation from the soil surface increased.

Subsequently man invented irrigation, which represents a “blue-to-green re-direction”. In addition improvements were achieved in rainfed agriculture. The observed increase in irrigated and rainfed yields resulted in an increase in crop transpiration and hence a decrease in blue water fluxes.

The authors then argue that the required additional increase in crop yields may, in many regions, clash with the water requirements of the aquatic environment. The authors mention one way of getting more with less, namely through the “vapour shift” (Rockström, 2003), i.e. the efficiency gain that occurs when crop yields increase. When farmers’ fields are more intensively cultivated, and nutrients are artificially added to the soil and dry spells are bridged by supplementary irrigation, crop yields (production per unit area) will increase. Whereas transpiration (the productive component of total evaporation) will inevitably increase, the non-productive evaporation component (evaporation directly from (soil, water, leaf and other) surfaces) will decrease. Therefore, with increasing crop yields total evaporation will increase less then proportional. This represents a real water saving at the basin scale. Johan Rockström, in his work, rightly emphasises the importance of this “vapour shift” (see Rockström, 2003; Falkenmark & Rockström, 2004).

Because of the above, it is expedient to distinguish between crop transpiration and all other forms of evaporation. Analytically both fluxes are to be distinguished because they essentially differ. Transpiration is a biophysical process; it occurs in living organisms and is a necessity for their survival and growth, both in flora and fauna. All other forms of evaporation are physical processes. Moreover, the distinction should be made because transpiration is a productive process for which there is no substitute (you cannot have biomass without it having consumed and transpired water), whereas all other forms of evaporation may be considered non-productive losses for which there often are substitutes. Two examples of the latter: (a) storing water in reservoirs represents a net water loss in areas where potential evaporation exceeds rainfall, and may be substituted by storing water in aquifers; (b) soil evaporation may be minimised by covering the soil surface with mulch: natural materials such as crop residues or plastic sheets.

All this is not new, and has been previously argued by other authors, such as Savenije (1998, 2004), who coined the term "white water" to denote all non-transpiration evaporation. If we would distinguish between green and white water fluxes, then Figure 6 (Falkenmark and Lannerstad, 2004) could look as the graph below.

Figure 1: Adaptation of Figure 6 by Falkenmark and Lannerstad (2004), distinguishing green water and white water

To view the figure, please follow the link below: http://www.copernicus.org/EGU/hess/hessd/1/7/figure_referee2.pdf

The length of the yellow arrows in Figure 1 indicates how much of the precipitation is consumed through transpiration and used to produce biomass. The present transpiration flux may be similar in magnitude to the undisturbed situation, albeit that part of the transpiration is now from irrigated crops, its source being blue water. The yellow arrow to the right of the graph shows that additional productive transpiration may be gained, possibly allowing sufficient food to be produced for a growing population. The additional water will be gained from two sources: the vapour shift, i.e. the shift from non-productive evaporation to productive transpiration, and through irrigated agriculture, involving a shift from blue to green water. Only the first shift represents a real gain with hardly any externalities. The second shift may cause serious externalities and has environmental impacts (river depletion etc.). Figure 1 clearly shows that increasing the productive use of water is not necessarily a zero-sum game!

The paper by Falkenmark and Lannerstad make all of the above points, and they argue these points convincingly. However they fail to draw the obvious conclusion, namely that it makes more sense, from a water perspective, to intensify existing agriculture then to extend the arable area. The focus should be on increasing crop yields, i.e. production per unit of land area. Having reached this point in the argument, the authors could also have emphasised the importance of chemical fertilisers, as the required yield increases largely depend on the adequate availability of nutrients. It could be argued that applying fertilisers is the most effective strategy to increase the productive use of rainfall.

The above constitutes the substantive part of this comment. Below are some smaller points that the paper raises.

- The authors criticise “water demand management” for focusing too narrowly on “plugging the leaks”, which will not necessarily lead to real water gains at the basin scale (p.10). This is in my view only partially correct. First, decreasing the losses implies decreasing water diversions and also decreases return flows, which in any case will relieve pressure on the resource and will decrease environmental impacts. Second, in agriculture, water demand management measures nearly always translate into increased yields and increased water productivity. In my view this should be one of the preferred win-win options to be advocated by Falkenmark and Lannerstad.

- The authors rightly argue that there should be an upper limit to river depletion. They mention a rule of thumb that sets this limit to 70% in semi-arid areas (p.19). I want to emphasise here that such a level of river depletion is very severe indeed and will have huge consequences for all kinds of natural processes on which many livelihoods depend. Reduced water fluxes often have larger than expected impacts. This is because threshold functions drive key hydraulic processes. A typical example is the regular occurrence of small floods that serve many functions simultaneously (sediment transport and nutrient redistribution, aquifer recharge, recession agriculture, spawning of fish, pushing down salt water intrusion etc.). The building of reservoirs and increased water abstractions upstream nearly always attenuates the hydrograph and frequently reduce small flood flows so that the river water tops the banks less frequently. For the Incomati river in Southern Africa, where consumptive blue water use nears 50% of blue water generated, we found that small floods that naturally occur every second year (exceeding 500 Mm3/month) would now only occur once every five years (Sengo et al., 2004).

- The concept of the remaining “degrees of freedom” in water scarce river basins (p. 21 and Figure 5) is not explained and requires elaboration.

- The authors advocate the trade of virtual water. This is commendable. The problem is that the only data that are available on virtual water trade are based on countries, and not basins; whereas data on water use and water scarcity can only be accurately estimated for basins. The observation that “an approximate doubling of the present food trade in only just beyond 20 years” will be needed (p.23), requires a qualification: does this refer to trade between basins or between countries?

- In order to lessen the pressure on our limited water resources and “reducing future consumptive water use demands”, the authors advocate a less water demanding diet, which, according to the authors, translates into a diet with less animal proteins (p.28). In my view, their observation would only be true for proteins from animals that are fed on fodder produced under irrigated conditions. For all other meat, and this represents probably most meat products, their observation would not hold. Consider the case of Botswana, one of the driest countries on earth. As a large beef exporter, this country is one of the great virtual water exporters of the world. Although this may appear inefficient, it is not. It may in fact be the most efficient use of erratic rainfall in that country. A failure to distinguish between green virtual water and blue virtual water may therefore make the virtual water debate largely useless. Eating less rainfed beef is not likely to increase water availability anywhere on earth!

- Finally there are a few editorial weaknesses that need to be corrected. The use of units is not always correct (e.g. p. 14 line 6: the correct unit is Mm3/yr; p.16 line 18: the correct unit is km3/yr or, preferably, 109 m3/yr or Gm3/yr since km3 is an odd unit which may be (correctly) interpreted to mean 1000 m3). I found one inaccuracy with numbers: the figure of 2,100 km3/yr does not represent all blue water withdrawals as estimated by Shiklomanov but all blue consumptive water use (p.19); the figure of 2,500 km3/yr on p.20 is therefore also incorrect. The Limpopo is wrongly placed in Figure 5 (p.39). Water crowding in the Limpopo should be around 2,000 persons per flow unit of 1 Mm3/yr and not 4,000; the use to availability ratio in the Limpopo is around 40%, not 20%. This would make the Limpopo less of an outlier.

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