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Interactive Comment

Interactive comment on "Review and classification of indicators of green water availability and scarcity" *by* J. F. Schyns et al.

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GENERAL

The Schyns et al review gives an inventory of past efforts to quantify and characterise green water availablity as compared to requirements for biomass production, and discusses the way forward to develop operational green water scarcity indicators. The following observations will primarily have their focus on conceptualisation issues and complications, and conclude by discussing future problems, emerging with increasing human pressure on the natural system, turning it into a socalled human-ecological system.

Green water availability, input and output

The concept builds on a limping similarity to blue water, a flow resource, whereas

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green water in its original sense of soil moisture is a site bound semi-static resource, withdrawn to meet flow-based consumptive use. In that sense, green water availability is basically a green water volume accessible to the roots, replenished by infiltrating rainfall. In this paper, green water availability is however conceived as a flow resource, defined as actual evapo(transpi)ration, i.e outflow from a certain land area.

Although confusing, this is fair enough since green water demand has a flow dimension. Also other scholars have made a similar move, as we will show. The resource is in other words seen as the actual E from land, which may be allocated to alternative evaporation-based water uses. The demand refers to what part of that resource is consumed for a certain purpose. What is confusing is however that green water outflow, as defined by the authors, is seen both as the resource and as the demand. This would make green water scarcity dimensionless.

The fact that other scholars choose to distinghuish between inflow (resource) and outflow (demand) is in my view nevertheless interesting and might be addressed, benefitting from recent studies on green and blue water availability and use by Weiskel et al (2014). They study different water balance situations in terms of vertical as opposed to horisontal input and output from a landscape section, and discuss the relations to human activities. Their approach has opened new ways to benefit from quantitative green/blue water analyses, introducing a whole set of blue/green indicators, already tested for more than 1000 water sites in US, indicators that the authors might find interesting to include in their overview.

A fundamental difference between the authors' and the Weiskel studies is that the latter defines green water availability as inflow to a system (rain), whereas this study defines it as the outflow (evaporation) from that system.

Blue water

In the Schyns et al paper blue water enters as a resource, parallel to green water. There is however some complexity involved in the approach, that might be clarified.

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Blue water enters in two ways in the analysis: as a conceptual indicator model (scarcity, crowding etc), and in its involvement in biomass production. The integrated blue/green studies referred to in the analysis basically involve blue water in the sence of a water resource parallel to green water. In this comment, we will also meet blue water as water taking certain pathways in the water cycle.

Water quality.

After some general observations, water quality has been left out of the discussion, however without mentioning that water quality tends to function differently for green as compared to blue water. Green water quality is basically a site-specific characteristic and relates primarily to soil fertility, whereas blue water quality enters as a characteristic of water usability i.a irrigation or “artificial green water production”.

Green water demand

The authors try to distinguish between human demand and other demand, which however turns out to be difficult. When comparing green water availability with green water demand, the latter is said to refer to human demand, a bit doubtful since humans do not consume green water directly, but only indirectly through food production and other biomass products.

Green water demand may refer to different purposes and different scale: landscape scale, cropland scale, biomass, or “environment” etc.. All green water demands are biomass-related. Basically, biomass demand may be natural or to various degree human-driven. The type varies with the function of the demand: to produce food (human driven), produce timber (can be partly natural, partly human driven), local ecosystem service production (“serve the environment”). The latter is seen as a parallel to “environmental blue water flow”, and probably refers to the minimum E from a landscape to safeguard essential ecological services and functions (regulating as well as provisionary functions).

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Green water scarcity

Basically, the authors distinguish green water availability and scarcity, the latter quantifying availability in relation to "demand" which basically refers to green water requirement, either more generally, or for a particular aim, such as crop production. But scarcity, besides referring to relation between human and nature, may also be due to natural conditions such as aridity, variability, etc. When use approaches some constraint, green water scarcity gets increasingly severe for the particular aim analysed, and develops into shortage in the sense of production deficit.

Comparison between green water availability and crop water demands is important in relation to discusssions of food security. Green water scarcity might have different causes. The authors present a long list of indicators of agricultural drought indicators, including socalled vegetation drought. A remarkable omission on the list of aridity indicators in the climatic moisture index CMI, used for instance in the seminal study by Vörösmarty et al (2005) of emerging water stress in Africa.

In this discussion of green water scarcity, it might be of interest to refer to the studies of rainfed crop production by Rockström&Falkenmark (2000 and later), from the perspective of crop water resource potential at a particular site. Green water scarcity is looked at from the perspective of the plant, and results from two types of deficiency. Distinction is made between on the one hand root-water uptake deficiency, due to damaged roots and mirrored in large non-productive soil evaporation losses and water surplus percolation; and on the other what we may refer to as infiltration deficiency, resulting in blue surface water losses (surface flow). The added outcome of these two losses is the very low crop yields typical for tropical rainfed agriculture (some 1 ton/ha only). This approach to green water scarcity involves the distinction between actual green water availability in the root zone as opposed to potenial green water availability, provided that the two deficiencies could be counteracted by conservation agriculture etc.

What we meet here is again the interdependence between green and blue water, not only "artificial green-water", generated by blue water irrigation, but also blue water as partly generated by limited infiltration of rain water, or poor waterholding capacity of the soil with surplus water percolating to form groundwater, also blue.

Green water footprint

This seems to refer to human-generated green water use, in the sense of greenwater-produced goods consumed by humans an a particular area/country, i.e. human-driven evaporation in terms of biomass production for human consumption. It is fair enough as long as agricultural production is concerned, but more floating when it relates to human-modified timber production and the like.

CONLUDING REMARKS

Efforts in expanding water scarcity conceptualisations from blue water only to green water, are certainly most welcome and laudable. The Schyns et al indicator overview would however, as showed above, benefit from some conceptual considerations and clarifications. It must also be essential to include the climatic moisture index CMI referred to above.

Future research

When it comes to future research, the authors particularly mention indicator usefulness for problems of (food) selfsufficiency challenges. In this connection I would like to add two comments.

The first refers to the need to aim for better conceptual clarity, not just a mechanical listing of existing indicators, irrespective of their soundness. Better distinction between the natural hydrological system and human activities in that system will for instance be essential as human activities increase further in intensity and effects. The recent hydrological paper by Vogel et al (2015), discussing the coupling between biophysical and social processes, might function as a source of inspiration.

The second observation refers to implications of the long time delays in internalisation,

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within the environmental community, of green water-based analyses. This makes the authors' study appear at the beginning of a new era when old concepts are getting shaky. In the present Anthropocene era, with its increasing human dominance, the thinking of the 1990's in terms of environmental impacts, protection of ecosystems etc is getting increasingly outdated. Most of the socalled "environment" is already impacted and the impacts less and less reversible.

The scientific community is now paying increasing interest both in now ongoing ecosystem modifications in response to climate change (i.a. permafrost melting etc), and to the widening appearance of socalled water-related tipping points of potential concern, i.e. approaching thresholds in natural systems (Rockström et al 2014 b). These tipping point phenomena may be driven by both land use changes, i.e. greenwater-related processes, and by water overuse, i.e. blue water-related. Such thresholds have to be met by management aiming at landscape scale resilience building.

Such resilience building will require a certain degree of cross-scale approaches involving landscape stewardship. A basic aim will be to achieve an optimal blue/geen water partitioning of incoming precipitation to secure parallel focus on two esential processes: 1) land wetness to safeguard biomass production, both to feed humanity, meet society's other biomass needs (including renewable energy) (Rockström et al 2012), and secure an adequate biodiversity; 2) moisture feedback to the atmosphere, in terms of a vapour flow/evaporation, large enough to secure regeneration of precipitation in vulnerable areas downwind (Rockström et al 2014 a).

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