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Volumetric water footprints, applied in a global context, do not provide insight regarding water scarcity or water quality degradation

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ABSTRACT

Many authors have presented estimates of volumetric water footprints in the context of describing and comparing the water requirements of crop production and industrial activities. In recent years, water footprints have been proposed as indicators for use in assessing the sustainability, efficiency, and equity of water allocations in a global context. That perspective is notably ambitious, given that volumetric water footprints contain information pertaining to just one resource, with no consideration of scarcity values, opportunity costs, or the impacts of water use on the environment, livelihoods, or human health. The suggestion that water scarcity must be assessed from a global perspective also is misplaced. Water scarcity and water quality degradation arise in local and regional settings. The impacts and potential remedies must be evaluated at those levels, by scientists and public officials charged with determining the policies and investments needed to ensure wise use of water resources. Efforts to extend access to clean, safe, and affordable water to the millions of households lacking such access also must be designed and implemented locally. Public officials will not gain useful insight by comparing volumetric water footprints in a global context. Water scarcity and water quality degradation cannot be resolved by reorganizing production activities across river basins and continents.

1. Introduction

In a recent contribution to *Ecological Indicators*, Hoekstra (2016) critiques the scarcity-weighted water footprint that has been proposed for use in life cycle assessments, and has been adopted by the International Organization for Standardization (ISO) as the preferred method for calculating and reporting water footprints (ISO, 2014; Pfister et al., 2015). Much of the author's critique reflects his perspective that water scarcity is a global issue, and that water allocation across competing uses should be viewed in a global context (Hoekstra and Mekonnen, 2012; Hoekstra and Wiedmann, 2014). In particular, Hoekstra (2016) suggests that because the global demand for water is increasing, policy makers must measure and compare the pressure that all products place on the global water supply. To this end, Hoekstra (2016) proposes that the volumetric water footprint promoted by the Water Footprint Network is superior to the scarcity-weighted water footprint adopted by the ISO. He suggests also that accounting for water scarcity within river basins or in a local or regional context is not appropriate, because water use in any basin reduces the volume of water remaining for other uses at some location within the global context.

Much of the discussion in Hoekstra (2016) mischaracterizes water scarcity and its impacts on the environment, natural resources, livelihoods, and human health. My goal in this paper is to demonstrate the inaccuracies in that discussion and to describe alternative perspectives regarding water scarcity, allocation, and use in both rainfed and irrigated settings. It is not my goal to take sides in the discussion regarding which water footprint should have been adopted for use in the ISO framework. I do not assess the method for calculating the scarcity-adjusted water footprint proposed by other authors (Ridoutt and Pfister, 2010, 2013; Boulay et al., 2015a, 2015b). Rather, I seek to set aside the notion that a volumetric water footprint, which does not account for water scarcity, can provide meaningful guidance regarding water policies, investments, or water allocations. Volumetric water footprints are silent on the issues that matter most in determining whether water allocations are sustainable, efficient, or equitable (Wichelns, 2015a). It is not possible to assess those issues and to determine optimal policies and investments only by calculating the volume of water consumed in a given process or chain of processes.

I endeavor also to demonstrate the importance of considering water scarcity in local and regional settings. Although water is a global resource, as described quite well by the hydrologic cycle,

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water scarcity is a local and regional issue. It is essential that local and regional water users and policy makers assess scarcity conditions in their domains, and implement appropriate policies, incentives, and strategies to manage water wisely. Investments in extending access to water and improving water quality also must be evaluated and implemented locally. The global perspective described by Hoekstra (2016) is incorrect. One cannot successfully address matters of water scarcity or water quality degradation without considering local or regional issues and solutions.

In sum, I describe four perspectives that contrast with those presented in Hoekstra (2016): 1) Water scarcity is not a global issue, 2) The impacts of water use vary with location and with time, 3) Irrigated agriculture cannot be replaced by improving the productivity of rainfed agriculture, and 4) Local water scarcity and water quality degradation impair the health of millions of urban and rural residents, worldwide.

2. Water scarcity is local and regional

Hoekstra (2016) suggests that because water is a global resource, water depletion also has a global character. In the author's view, water use in any location subtracts from the sum of global water available for other uses. Thus, the environmental impact of water use in any location is the same: "Every litre of water consumption, whether in a water-rich or water-poor river basin, and whether [soil moisture, effective rainfall, surface water, or groundwater], will reduce the water volume remaining for other uses, and thus has equal environmental relevance." The author suggests that water scarcity is a global phenomenon, and the notion of a volumetric water footprint is analogous to a carbon footprint.

Characterizing water scarcity as a global issue is compelling, but inaccurate. While water can be viewed as an international resource in areas where countries share rivers, aquifers, and watersheds, water scarcity and water quality are largely local and regional issues (Gawel and Bernsen, 2011c; Gawel, 2014; Perry, 2014). Water scarcity arises when the demands on local and regional resources exceed the available supply. Water quality is degraded most often due to inappropriate practices within a river basin, province, or country. While acknowledging important issues regarding transboundary resources, generally there is little relationship between water consumption in one region and water scarcity or water quality in another (Gawel and Bernsen, 2011b; Wichelns, 2015b).

This perspective pertains also when considering the similarities or differences in carbon and water footprints. Some authors have suggested the two types of footprints are similar (Hoekstra, 2009, 2016; Ercin and Hoekstra, 2012). Yet, the characteristics of each are quite different, due largely to differences in the impacts of carbon emissions and water use on the environment. Carbon emissions essentially have the same impact on the atmosphere, regardless of where the emissions are generated. The sum of global carbon emissions is the pertinent measure when considering impacts regarding global warming. By contrast, the impacts of water scarcity and water quality degradation are realized in local and regional settings (Gawel and Bernsen, 2011a; Wichelns, 2011; Perry, 2014). For this reason, the two footprints are not analogous. Reducing the carbon footprint of an activity generates a globally relevant impact. This is not the case when reducing a volumetric water footprint.

It is helpful to note also that both carbon and water footprints lack information describing the cost of reducing the size of either footprint in any setting. Thus, the metrics are not helpful in determining optimal strategies (Gawel and Bernsen, 2016). It is not the case that all footprints should be reduced or that larger footprints are necessarily more harmful than smaller footprints. One must know the incremental benefits and costs of reducing a given footprint to determine the optimal course of action. Lacking that information, decisions based only on the estimated size of a carbon or water footprint likely will be incorrect from an economic perspective.

Table 1
Considering the impacts of moving production from one river basin to another, based only on comparison of volumetric water footprints.

	Current Situation		With Reorganization	
	Basin A	Basin B	Basin A	Basin B
1. Sustainable water footprint (units)	50	250	50	250
2. Volumetric water footprint (units)	100	200	50	200
3. Production (units)	100	100	50	200
4. Water footprint per product	1.0	2.0	1.0	1.0
5. Water productivity	1.0	0.5	1.0	1.0
6. Employment (persons)	300	400	140	900
7. Energy (units)	80	280	30	600
8. Labor per unit of output	3.0	4.0	2.8	4.5
9. Energy per unit of output	0.8	2.8	0.6	3.0

Notes: Rows 1 through 5 are taken directly from Table 1 in Hoekstra (2016). Rows 6 through 9 have been added, to demonstrate the potential impacts on employment and energy use.

Consistent with his view that water scarcity is a global issue, Hoekstra (2016) suggests that considering water scarcity within river basins is not appropriate, in part, because production activities can be reorganized across basins, in the interest of minimizing global water footprints. The author provides an example of the potential gains from reorganizing agriculture according to water footprints. That example depicts agricultural production in two river basins with the same surface area, but with different water endowments.

The maximum sustainable water footprints are 50 units in Basin A (water scarce) and 250 units in Basin B (water abundant) (Table 1). Hoekstra (2016) suggests that aggregate output can be increased if the farmers in Basin A reduce their production (from 100 to 50 units), while the farmers in Basin B increase their production (from 100 to 200 units). The farmers in Basin A maintain the same average water consumption per unit of output (1.0), while reducing output by one-half (from 100 to 50 units). The farmers in Basin B reduce by one-half the amount of water consumed per unit of output (from 2.0 to 1.0), thus enabling them to double their production (from 100 to 200 units) with no increase in water consumption. The result is an increase in aggregate production of 50 units and a reduction in aggregate water consumption of 50 units. Such a scenario appears to be feasible, in terms of the arithmetic. However, the author has not considered any of the direct and indirect costs involved in effecting such a shift in production patterns, the implications on the use of other scarce resources, or the impacts on the livelihoods of individuals and households engaged in agriculture and supporting industries.

Suppose that prior to reorganizing agricultural production, the farmers in Basin A employ 300 persons and use 80 units of electricity, while the farmers in Basin B employ 400 persons and use 280 units of electricity, (Table 1, rows 6 through 9). With reorganization, the farmers in Basin A employ 140 persons and use 30 units of electricity, while farmers in Basin B employ 900 persons and use 600 units of electricity. These plausible values, which reflect diminishing marginal returns to labor and energy inputs in both basins, provide additional insight regarding the potential implications of reorganizing agricultural production according to the relative availability of a single input.

Prior to reorganization, the farmers in Basin A use less labor and less energy per unit of output, than do farmers in Basin B. With reorganization, the differences in those measures become larger, such that farmers in Basin B use 61% more labor and five times as much energy, per unit of output, as farmers in Basin A. Perhaps more