The water “shoesize” vs. footprint of bioenergy

Gerbens-Leenes et al. (1) quantify water use of the most relevant global bioenergy crops except palm oil. This is a welcome addition to the existing literature, which often only focuses on “carbon footprints.” Although carbon footprints have been shown to capture a large portion of overall environmental effects for many products and services, the agricultural sector needs additional consideration of other environmental indicators (2). In particular, land use and water consumption can be of substantial importance. Calculating a water footprint is therefore crucial for agriculture-based products.

As the carbon footprint elaboration has shown, a clear concept and definitions of terms are required for proper communication (3). While in carbon footprinting weighting between various greenhouse gases according to global warming potentials is needed, we think that a distinction between the various origins of water use is useful, because the resulting environmental impacts vary largely from region to region. For instance, 1 L of water consumed in the Colorado watershed does not compare to 1 L of water from the Mississippi, because water is much more scarce in the Colorado watershed. Therefore, an extension of the work performed by Gerbens-Leenes and colleagues seems necessary to us, to capture environmental relevance. To clarify our view, a water footprint scheme consistent to that of carbon footprinting in terms of the relevant features is presented in Table 1. It deviates, in part, from the water footprint as presented by Gerbens-Leenes et al. and shows that a further discussion of the concept is necessary.

In the proposed scheme, only consumptive blue water is considered, because it describes the additional loss of available water resource in a watershed. This is in agreement with the concept presented by Gerbens-Leenes et al., because they quantify irrigation water as the consumptive fraction, and not the total use. “Green water” consumption

Table 2. Total global average water footprint of energy content in biofuels

Crop	Total water (from ref. 1), m ³ /GJ	Blue water (from ref. 1), m ³ /GJ	Water stress index (based on ref. 4)	Water footprint (Colorado-m ³ - equivalent), m ³ /GJ
Ethanol				
Sugar beet	59	35	0.434	30
Potato	103	46	0.380	35
Sugar cane	108	58	0.456	53
Maize	110	43	0.287	25
Cassava	125	18	0.087	3
Barley	159	89	0.320	57
Rye	171	79	0.336	53
Paddy rice	191	70	0.490	69
Wheat	211	123	0.488	120
Sorghum	419	182	0.430	157
Biodiesel				
Soybean	394	217	0.217	94
Rapeseed	409	245	0.683	335
Jatropha	574	335	0.251	169

“Total water” and “blue water” values are taken from ref. 1. Blue water is then weighted by the crop average water stress index (WSI), resulting in the water footprint. The water footprint is here normalized over the reference WSI value of the Colorado watershed (WSI of 1.00) resulting in Colorado m³ equivalents.

of agricultural systems may be neglected, similar to biogenic CO₂ emissions in carbon footprinting, if it is comparable to the green water demands of the natural vegetation at the specific site. However, we disagree on the water footprint definition, assuming that the water footprint should reflect the environmental impact. We perceive the reported definition of Gerbens-Leenes et al. rather as a water “shoesize” requiring a specific weight for becoming a footprint. Hence, we suggest a spatially varying water stress index (WSI) to weight the water consumption (shoesize), as a function of water scarcity (4). For illustration purposes, we calculated the stress-weighted footprints of biofuels according to ref. 4 based on the data presented by Gerbens-Leenes and colleagues. We normalized them with the WSI of the Colorado watershed resulting “Colorado-m³-equivalents” in analogy to CO₂ equivalents (Table 2). The resulting volumes show some interesting and relevant alterations to the results of

Table 1. Suggestion of a water footprint scheme and comparison to the existing carbon footprint scheme

Described feature	Water footprint scheme	Carbon footprint scheme
Environmental concern	Resource consumption (input)	Greenhouse gas emission (output)
Flow perspective	Total water consumption	Total carbon emission
Neglected flows	Green water* consumption	Biogenic carbon emissions
“Shoesize” (unweighted relevant flow)	Blue water† consumption (plus change of green water consumption compared to natural vegetation)	Fossil carbon emissions (plus biogenic carbon emissions from land transformation, e.g. cut-down of rainforest)
Specific weighting	Based on location (regional water stress)	Based on substance (global warming potential)
Footprint (weighted relevant flow)	Reference watershed m ³ -equivalent (water consumption weighted with watershed-specific Water Stress Index and expressed in terms of reference flow)	CO ₂ equivalent (fossil carbon emission weighted with substance-specific Global Warming Potential and expressed in terms of reference substance)

*Green water is the water, which is available on-site (precipitation and soil moisture).

†Blue water is runoff water used for irrigation (groundwater or surface water).

Gerbens-Leenes et al. (1). For instance, jatropha has a considerably lower footprint than rapeseed, maize is now favorable over sugar beet, and cassava has clearly the smallest water footprint. Such differences reflect the global distribution of biofuel production and the according water scarcities. They become even more pronounced if biofuels from specific regions are compared.

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