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Editorial

Water Footprint Assessment (WFA) for better water governance and sustainable development ☆

1. Introduction

Increasing pressure on the Earth's freshwater resources resulting from growing water consumption and pollution, in combination with the impacts of climate change, has led to widely accepted recognition of the centrality of freshwater in sustainable development and the critical need for improved water governance. Currently, more than 2.7 billion inhabitants in about 200 basins live with severe water scarcity during at least 1 month of the year [20]. Water scarcity and high water pollution levels can result in poor access to water for meeting basic human needs, increased water risk for companies and environmental degradation. While these problems have been well documented and are gaining increased attention, a clear and consistent approach addressing the use of water throughout the value chain, from primary producer to consumer and within river basins, has been lacking.

To better understand the linkages between humanity's productive activities and this growing pressure on the world's freshwater resources, the water footprint and subsequently, Water Footprint Assessment (WFA) were developed to measure the amount of water consumed and the pollution assimilation capacity used throughout a product's value chain and to assess its sustainability within both the local and global context [18]. The water footprint is an indicator that can be used to measure the direct and indirect water use (or the virtual water content) of a product, a facility, an organisation, e.g., a company, or a sector. The water footprint can also be applied to a geographic area, e.g., a river basin or nation, or an individual consumer or group of consumers. By considering the linkages between consumer goods and their water footprint, a new understanding of the processes that drive changes imposed on freshwater ecosystems is gained.

By providing a structured and consistent way to measure water use and pollution throughout the value chain and across different scales, the water footprint provides a common language that supports dialogue between the range of stakeholders contributing to and resolving unsustainable water use. The four-step process of WFA – setting goal and scope, water footprint accounting, sustainability assessment and response formulation – clarifies the environmental sustainability, economic efficiency and social equitability of water use and prioritises strategic actions. The sustainability assessment identifies hotspots where water use is violating sustainability criteria, where efficiency gains can be

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reasonably made and where allocation is unfair. Armed with this knowledge, governments, companies and individuals have the basis for understanding what is needed to move quickly toward sustainable, efficient and equitable water use.

2. The water footprint concept

In order to better understand the relationship between the consumption and production of goods and the underlying depletion and pollution of fresh water, Hoekstra [15] introduced the water footprint concept. Calculating and mapping the indirect water use of products can help to understand the global dimension of freshwater resources and assist in assessing the impacts of consumption or production on water resources [17,21]. The basic building block of all water footprint calculations is the water footprint of one single process or activity [18]. The water footprint is a multi-dimensional indicator, showing water consumption volumes, by source, and required volumes of water to assimilate anthropogenic loads of chemicals into freshwater bodies. A water footprint has three components, blue, green and grey water footprint, and is specified geographically and temporally. The blue water footprint is the amount of surface or groundwater evaporated, incorporated into the product or returned to another place or in a different time. The green water footprint refers to soil moisture from rainfall that evaporates from land used for crop or wood production or that is incorporated into the product. This component is relevant mostly in agriculture and forestry. The grey water footprint, reflecting pollution, is defined as the volume of freshwater that is required to assimilate the load of pollutants given natural background concentrations and existing ambient water quality standards.

The water footprint concept builds on a number of insights that are lacking in the traditional perspective on water use, which focuses on direct water use, blue water withdrawals and meeting discharge permits. These insights are: (1) looking at blue water withdrawals provides the wrong focus; instead the amount of water *consumed*, i.e., no longer available for other uses, gives a more detailed picture of how freshwater is being appropriated by human activities; (2) focusing on blue water resources (ground- and surface water) is inadequate, since *green* water resources (rainwater) play a major role in agricultural production, the largest water using sector, and improving the efficiency of the use of green water resources is part of the solution to the overexploitation of blue water resources; (3) understanding *indirect* water use, i.e. water use in supply-chains, is key in effectively managing water resources in the global context and building linkages between consumption in one location and production in another; and (4) water pollution, eventually leading to water unavailability to human use, is another form of freshwater appropriation, which should be taken into account by considering the load of pollutants instead of the concentrations in effluents, since the latter invites for diluting pollutant loads in order to meet emission standards.

3. Water Footprint Assessment Milestones

Water Footprint Assessment is an emerging interdisciplinary field of research, evidenced by the quickly increasing number of publications. WFA studies can feed the discussion in both the public and private sectors on environmentally sustainable, economically efficient and socially equitable water use and allocation and can also form a starting point for more in-depth local assessments of environmental, social and economic impacts of water use. Early water footprint studies have focused on quantifying water footprints of processes, products, companies and consumer groups. They were essentially restricted to water footprint accounting. Hoekstra and Hung [16] and Chapagain and Hoekstra [4] developed global water footprint statistics covering water footprints of crops, animal products, water footprints of domestic and industrial sectors, and virtual water flows between nations due to international trade. These early water footprint studies focused on blue and green water consumption. Chapagain et al. [5] introduced the idea of “dilution volume” that evolved into the “grey water footprint” in Hoekstra and Chapagain [17], which made the water footprint a holistic concept representing the full appropriation of freshwater resources in human activities. Using advancements in definitions and methodology, Mekonnen and Hoekstra [28,29] updated the green, blue and grey water footprint for agriculture, industry and domestic globally at a high spatial and temporal resolution. Gerbens-Leenes et al. [13], Dominguez-Faus et al. [7] and Mekonnen and Hoekstra [30] applied water footprint to the energy sector.

Going beyond water footprint accounting, Hoekstra et al. [20] quantified blue water scarcity for more than 400 river basins at a monthly level. Liu et al. [26] made a worldwide estimation of the past and future trends in grey water footprints of anthropogenic nitrogen and phosphorus inputs to the world's major rivers. This study showed that currently in about two-thirds of the basins the assimilation capacity for nitrogen and phosphorus has been fully consumed. In 2010, the Spanish government enacted a regulation to incorporate WFA in the process of developing river basin management plans [1] being the first government to require WFA to be part of river basin planning. Numerous national WFA's have been published recently (e.g. [10]). To ensure scientifically robust methods are applied and a fair comparison can be made between different water footprint studies, the Water Footprint Network, with its partners, developed the Global Water Footprint Standard [18]. Following the improvements in the global water footprint data noted above, the Water Footprint Network created the online WaterStat database to make water footprint data publicly available and developed the online Water Footprint Assessment Tool.

4. The Water Footprint Network

Recognising the need for learning and exchange about the water footprint, in 2008 seven players from different sectors – the University of Twente, WWF, UNESCO–IHE, World Business Council for Sustainable Development, International Finance Corporation, Netherlands Water Partnership, and Water Neutral Foundation founded the Water Footprint Network (WFN) to promote the transition towards sustainable, fair and efficient use of freshwater resources worldwide by advancing the concept of the water footprint and its application through WFA. Working together with and supported by its partners, WFN has engaged companies from various sectors, research institutes and government agencies to apply WFA to agriculture, industries (e.g. textile, paper, chemical, power, steel, and automotive) as well as to river basins. These studies contribute to the emerging field of WFA and provide immediate guidance to businesses and governments on linking WFA to their corporate sustainability strategy and public water policy formulations.

Over the years, WFN has contributed leadership on the water footprint in various global water forums, including the World Water Forums, the annual Stockholm World Water Week, the International Water Week in Amsterdam, the European Green Week in Brussels [27], the Planet Under Pressure Conference in London [41], and many national water events around the world. Standing on a strong foundation of sound science, WFN engages the range of stakeholders in improving the management and governance of our precious water resources through WFA research, application and capacity building.

5. The relevance of WFA to industry

Water scarcity and pollution are often closely tied to the structure of the economy and water impacts occur from many economic sectors. As reported by UNESCO–WWAP [38], agriculture accounts for about 70% of global blue water withdrawals and industry for 20%. However, much of the water abstracted by industries is returned to the catchment from which the water is withdrawn, therefore it does not count as consumptive water use; it is still available for other uses. If we look at blue water *consumption*, i.e. the blue water footprint, industry accounts for only 4% of the global total. While the water withdrawn is often largely returned, it is often not or insufficiently treated. In the latest global water footprint study [19], it showed that industries are responsible for 26% of humanity's total grey water footprint. This contribution, however, has probably been grossly underestimated, due to the conservative assumptions that were made in the study due to the lack of appropriate data on the pollutants discharged, treatment percentages, and qualities of treated and untreated industrial effluents.

Measurements of industrial water use have historically focused on direct operations. As the water footprint, which includes both direct and indirect water use, has been applied to industrial products, results have shown that in many cases the indirect water footprint is much larger than the direct, especially when there is an agricultural supply chain. For a carbonated beverage like cola, for example, the indirect water footprint has been estimated to be 99% of its total water footprint, due to the water footprint of the ingredients used [37,9]. These large supply-chain water footprints become important in the sustainability assessment, which can highlight suppliers located in water scarcity or water pollution hotspots. The dependence on suppliers located in hotspots generates critical risks to a company, which is not only a worry for the industries themselves [31], but also for investors [25,2]. Hence, good water stewardship and supply-chain management in the industrial setting is a key element in sustainable business strategy. As companies become aware of these water challenges, the associated water risk becomes a driving force for companies to develop new water policy and sustainability strategies.

Companies have quickly taken up the water footprint concept and have been applying WFA as part of their sustainability initiatives. Mirroring the advancements made in WFA research, companies have also been moving from doing only water footprint accounting, in the early WFA studies, to including sustainability assessment and finally response formulation. Companies are also using WFA to develop their water sustainability strategy and to address the growing water related risks challenging business viability and sustainability. Other initiatives such as the Alliance for Water Stewardship and the CEO Water Mandate are looking to WFA to provide necessary information for water stewardship and water disclosure, respectively. To date, a large range of companies – from the food and beverage sector to textile and apparel, pulp and paper, cosmetic, manufacturing and energy sectors – have used the water footprint and WFA to great benefit, see for example: SABMiller and WWF-UK [34], SABMiller et al. [35], TCCC and TNC [37], Coca-Cola Europe [6], IFC et al. [22], BIER [3], UPM-Kymmene [39], Sikirica [36], Jefferies et al. [24], Francke and Castro [11], and IFC et al. [23].

6. This special issue

WFA is an innovative and powerful method to measure the pressure on freshwater resources from human activities. By analysing water consumption and pollution in operations and along supply chains, assessing the sustainability of water use and exploring where and how water footprints can best be reduced, companies are strengthening their business sustainability while contributing to the overall sustainability of river basins. To provide an introduction to WFA in the industrial context and to encourage further uptake of this valuable tool, The Water Footprint Network and the Water Resources and Industry Journal jointly organised this special issue.

This collection of articles presents recent advances in research in and application of WFA. It consists of six individual papers and covers WFA for specific commodities and companies, WFA for river basins, links between water and carbon footprints, and new thoughts on integrating different types of footprint in a generalised framework.

Ruini et al. [32] evaluate the water footprint a product, Barilla pasta, including both operation water consumption and supply-chain water consumption. By looking at the variation of the product water footprint due to production site, local environmental conditions and agricultural techniques, the study infers a need to consider water-related production processes on a global scale when examining the water footprint of an international food company.

Gerbens-Leenes et al. [14] study the trends in the water footprints of poultry, pork and beef, considering the relevance and significance of the influence of lifestyle and consumption pattern on humanity's water footprint. The authors observe that three main factors drive the WF of meat: feed conversion efficiencies, feed composition and feed origin. They show that industrialised feed systems have a higher feed conversion efficiency than grazing and mixed systems, which contributes to the lowering of water footprints. However, industrial feed systems have higher ratios of concentrates to roughages, which contributes to larger water footprints, because concentrates have a larger water footprint per unit of weight than roughages.

Francke and Castro [12] study the relationships between the water footprint and carbon footprint of a cosmetic product. The objective of this study was to find out how these environmental pressure indicators can be synergistically applied in setting out future business sustainability strategies.

Vanham [40] contributes an assessment on the virtual water balance for agricultural products in river basins of 28 countries of the European Union. The results of this research show that the EU28 is a net virtual water importer for agricultural products, while there are large differences between different EU regions. Industrialised and densely populated river basins in Western Europe are big net virtual water importers. The study provides valuable information that can feed policy studies and debate at both national and EU levels.

The work by Dumont et al. [8] presents an application of the water footprint in the river basin context. The study analyses the green and blue water footprint of the Guadalquivir basin (Spain), with an emphasis on the groundwater footprint and its consequences on current and future depletion of surface water of the basin. This paper demonstrates that the water footprint indicator generates new debates and solutions on water management at basin scale. The study also indicates that reframing the water governance setting by integrating flexibility and equity while addressing climate variability in water allocation, based on water footprint information, could lead to improving water availability in the basin.

Rushfort et al. [33] propose a framework within which water footprint, ecological footprint and carbon footprint could be evaluated under different assumptions. The paper discusses the general utility of the framework for the design of appropriate footprint methods for any specific type of resource management or sustainability policy discussion. The proposed framework could help to explicate the impact of roles and worldviews of resource managers in the management of resources.

Through this special issue we hope to promote the application of WFA by sharing some recent examples of how the water footprint concept and WFA are being used to build a better understanding of the link between our water uses for production and the increasing problems of water scarcity and water pollution. Our aim is to stimulate further research in and applications of WFA and to support improved water governance by both the public and private sectors. Therefore, we wish to thank the authors and reviewers, the editors, publisher and managers of the journal who all have made valuable contributions to the publication of this collection.

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