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Water Footprint: Help or Hindrance?

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ABSTRACT: In response to increasing concerns about pressures on global water resources, researchers have developed a range of water footprint concepts and tools. These have been deployed for a variety of purposes by businesses, governments and NGOs. A debate has now emerged about the value, and the shortcomings of using water footprint tools to support better water resources management. This paper tracks the evolution of the water footprint concept from its inception in the 1990s and reviews major applications of water footprint tools, including those by the private sector. The review suggests that water footprint assessments have been an effective means of raising awareness of global water challenges among audiences 'outside the water box' including decision makers in industry and government. Water footprint applications have also proved to be useful for the assessment of strategic corporate risks relating to water scarcity and pollution. There is evidence that these applications may help to motivate economically important stakeholders to contribute to joint efforts to mitigate shared water-related risks, although there have been few examples to date of such approaches leading to tangible improvements in water resources management at the local and river basin scales. Water footprint assessments have so far had limited influence on the development or implementation of improved public policy for water resources management and there is reason to believe that water footprint approaches may be a distraction in this context. Suggestions that international trade and economic development frameworks might be amended in light of global water footprint assessments have not yet been articulated coherently. Nevertheless, if used carefully, water footprint tools could contribute to better understanding of the connections between water use, economic development, business practice and social and environmental risks. In light of the review, a set of 'golden rules' is suggested for using water footprint tools in the broader context of awareness-raising, management of shared water-related risks and public policy development.

KEYWORDS: Water footprint, corporate water risk, water scarcity, public policy, freshwater management

INTRODUCTION

The strain on the world's water resources is becoming more acute. According to the medium variant of the 2010 Revision of World Population Prospects (United Nations, Department of Economic and Social Affairs, Population Division, 2011), there will be 2.3 billion more people on the planet by 2050. Providing sufficient food, water and energy for a growing world is a major challenge to science (Falkenmark, 2001). Economic development in many parts of the world means that more people are living 'thirsty' lifestyles characterised by greater purchasing power and a shift to increased meat consumption (Delgado, 2003; Kearney, 2010). The primary impacts of climate change will include more erratic precipitation patterns and increased variability in river flows and aquifer recharge (Intergovernmental Panel on Climate Change, 2012). Already, the withdrawal of freshwater in quantities and at rates exceeding natural renewal capacities is documented in many parts of the world including China, India, Mexico, the Middle East, the Mediterranean region, Central Asia, Australia, southern Africa and the USA (UNESCO-WWAP, 2006). Competition and conflict between water users is on the rise and freshwater biodiversity is in steep decline in many regions (Vorosmarty et al., 2010; WWF, 2012).

As pressures on water resources have intensified, the potential impacts of scarcity and pollution on a range of stakeholders, including businesses, have become clearer. A significant body of grey literature has emerged on this issue, and the concepts and typology of water-related business risks (including physical scarcity risks, regulatory risks and reputational risks) are now well established (JPMorgan and Global Equity Research, 2008; Pegram, 2010; Pegram et al., 2009). An increasing number of voices from the business community are urging concerted action to manage water resources better and a number of initiatives have begun to address business and investment risks from poor water management, focusing on risk assessment (WRI, 2011; WWF, 2011); practical efforts to improve local water management as a means of mitigating shared risks (SABMiller et al., 2010); increased engagement in high-level policy development (Addams et al., 2009); reporting of water risks (Irbaris, 2009); and knowledge-sharing between private sector stakeholders (UN Global Compact, 2007). Political leaders have also recognised water as an economic and geopolitical risk factor, as reflected in the speech of US Secretary of State Hillary Clinton on World Water Day 2012[1] and the message from the UN Secretary General Ban-ki Moon at the same event.[2] This broader concern about the need to manage water resources more effectively was reflected in the decision by China's State Council to emphasise the acceleration of water conservancy reform and development as a policy priority (Liu and Yang, 2012).

Simultaneously, and partly in response to private-sector demands for tools which could aid understanding of water-related business risks, researchers have developed concepts and methodologies for assessing water footprints. These approaches have sought to understand and measure the invisible or virtual link between consumption of goods in one part of the world and impacts from production of those goods on often distant water resources. As water footprint methods have evolved, and as they have been deployed in an increasing number of ways, they have attracted attention from policy makers and practitioners not only in the private sector and the research community, but also in governments and NGOs. The water footprint approach has also been the focus of critical review by the water expert community.

The purpose of this paper is to reflect on the various applications of water footprint methods and metrics, and on the criticisms of water footprint approaches, with a view to guiding their future deployment in the context of the management of water-related risks and the development and implementation of effective water resources management policy. The next section sets out the accepted definitions which underpin water footprint assessments. Subsequent sections describe the major water footprint applications to date and summarise the advantages and disadvantages of these applications, drawing on criticisms from the academic literature and the broader water expert community. Finally, conclusions are drawn on the merits and potential pitfalls of using water footprint approaches as an aid to water-related risk management and water resources policy and practice; and, drawing on these reflections, a set of 'golden rules' is set out to guide future use of water footprint tools.

WATER FOOTPRINT DEFINITIONS

A methodology for measuring human demands – or 'footprint' – on the biosphere was first developed in the early 1990s (Rees, 1992; Rees and Wackernagel, 1994). The initial seed for a separate water footprint was planted by Allan (1998), who coined the term 'virtual water' to describe water used in the production of imported goods and hypothesised that such virtual water imports were a partial solution to problems of water scarcity in the Middle East. These ideas took on more precise form once

[1] www.state.gov/r/pa/prs/ps/2012/03/186667.htm

[2] www.un.org/sg/statements/index.asp?nid=5938

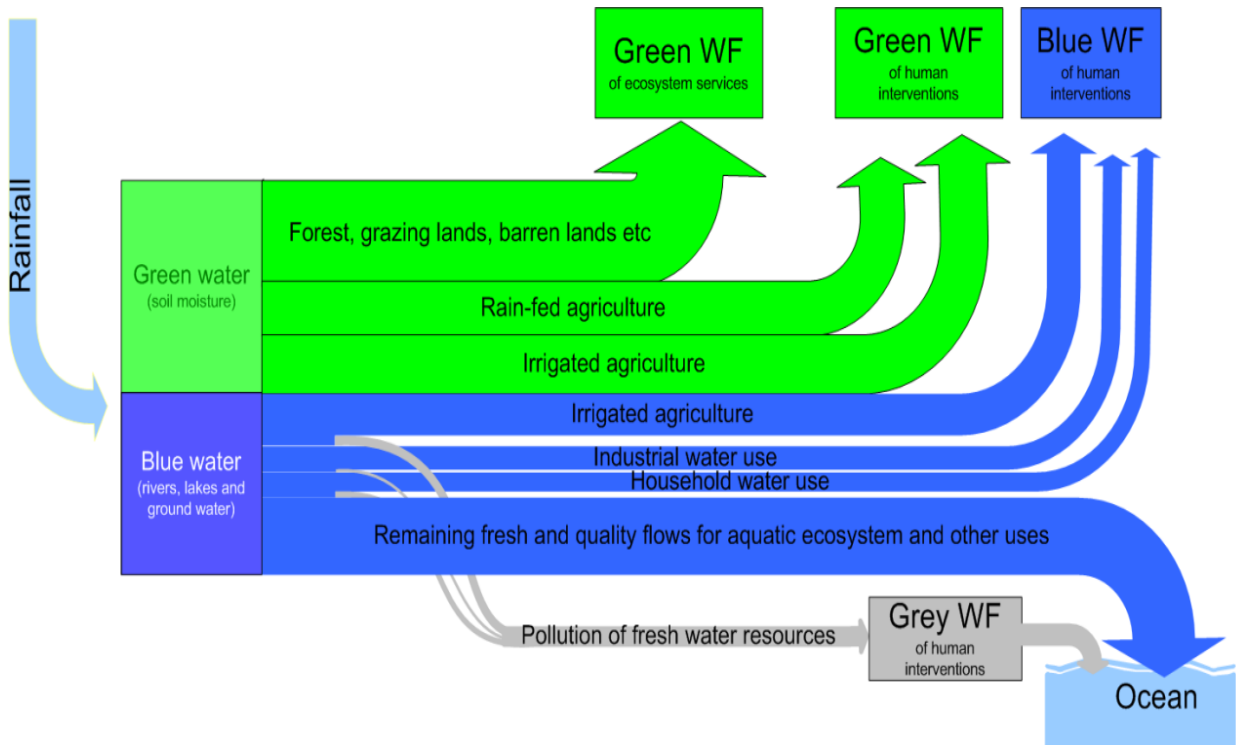
researchers began to quantify and calculate global virtual water flows and, from this, water footprints of specific products and of nations (e.g. Hoekstra and Hung, 2002; Chapagain and Hoekstra, 2004; Oki et al., 2003; de Fraiture et al., 2004; Yang et al., 2006).

According to Hoekstra et al. (2011),

> [t]he water footprint of a product is an empirical indicator of how much water is consumed, when and where, measured over the whole supply chain of the product... The water footprint of an individual, community or business is defined as the total volume of freshwater that is used to produce the goods and services consumed by the individual or community or produced by the business.

A water footprint (WF), normally expressed in volumetric terms (i.e. litres or m^3 of water), is therefore a multidimensional indicator that looks at both direct and indirect water use of a consumer or producer and that can show water consumption volumes by source and polluted volumes by type of pollution. All components of a WF can be specified geographically and temporally. WF differs from measures of 'water withdrawal' in that it does not include return flows, i.e. blue water withdrawal insofar as this water is returned to where it came from. Moreover, a WF normally considers green and grey water alongside blue water. A WF can also be disaggregated into direct and indirect WF components, sometimes also referred to as internal and external WF or, in the context of manufacturing and business contexts, operational and supply chain WF. The basic distinction is between water (blue, green or grey) consumed 'through the tap' and water embedded in products or processes. Figure 1 shows the schematic links between water use and the different types of water footprint in the context of the hydrological cycle (Chapagain et al., 2006).

Figure 1. Different components of water footprint and water partitioning in the hydrological cycle.



Green WF is the volume of green water (rainwater) consumed, and is a proxy for the volume of soil moisture used by rain-fed cropping. It is equal to the volume of water lost through evapotranspiration during crop growth. Blue WF refers to consumption of blue water resources (surface water and groundwater), whereby consumption refers to the volume of water that evaporates or is incorporated into a product or is transferred into another river or aquifer catchment through the production process. The blue WF is often smaller than the volume of water withdrawal because some water may return to the ground or surface water body from which it was withdrawn. Typically, blue WF consists of irrigation water and/or direct water use in industry or in homes, minus return flows. Grey WF is an indicator of the degree of freshwater pollution and is defined as the volume of freshwater required to assimilate the load of pollutants based on existing ambient water-quality standards. The grey WF concept reflects the notion that the impacts of water pollution can be expressed in terms of the volume of water required to dilute pollutants such that they become harmless (Falkenmark and Lindh, 1974; Postel et al., 1996; Chapagain, 2006; Chapagain et al., 2006; Hoekstra and Chapagain, 2008). Grey WF is based on the quality and quantity of polluted return flows (effluent), and quantification is based on the volume and existing water quality of the receiving water bodies. Not all grey water is derived from blue water; soil leaching means that rain-fed agriculture can have a grey WF too. In practice, such grey WF calculations are difficult and are often excluded from water footprint assessments.

A WF can therefore be presented either as a single volumetric number or as a set of component volumes each representing blue, green and grey and/or direct and indirect WFs (figure 2). It is important to note that, regardless of how it is presented, a WF is not in itself a measure of the economic, social or environmental impacts of water consumption and pollution (Hoekstra et al., 2011). The impact of any given volume of water use depends on a range of factors including the prevalent climatic conditions, geology, topography and run-off; the opportunity cost of different water uses and the degree of competition between different water users within a given river basin; the adequacy of local water governance arrangements and the range of stakeholders involved in decisions about water use priorities; the specific design and operation of water management infrastructure; the vulnerability of the river or wetland ecosystem to water abstraction; and the cumulative impact of pollution from different sources. WF also accounts provide spatio-temporally explicit information on how water is appropriated for various uses and on which groups of people might benefit from, or have an impact upon, this appropriation, in addition to the immediate user(s).

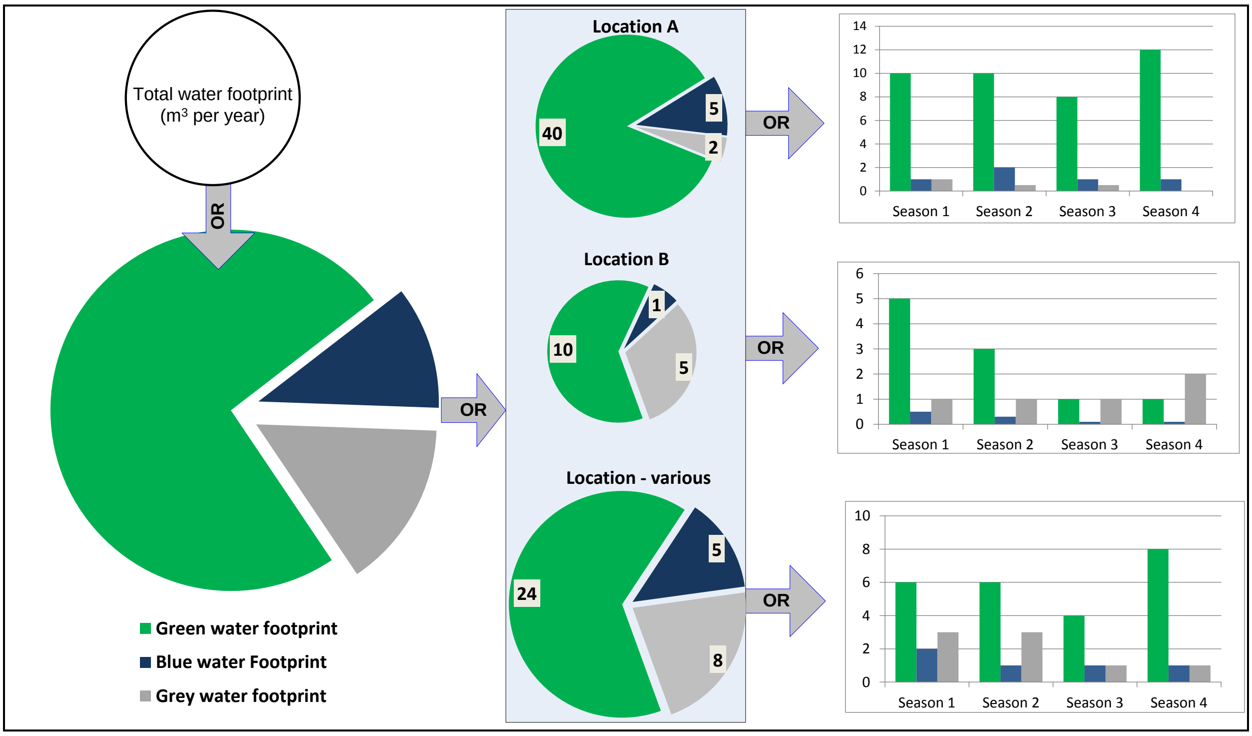
THE EVOLUTION OF WATER FOOTPRINT APPLICATIONS

Water footprint analyses have been deployed in a number of different applications in recent years. Major applications, and exemplar studies, are summarised in table 1.

National water footprints

Most national water accounts provide data only on blue water withdrawal for three main sectors: agricultural, industrial and household, e.g. AQUASTAT (FAO, 2011), The World's Water (Pacific Institute, 2011) and the Key Water Indicator Portal (UN Water, 2012). While these data aid understanding of pressures on surface water and groundwater resources within a country, they provide limited information about the impacts of water-related risks on the food security and economic development of a nation, especially where countries import and/or export substantial volumes of agricultural produce. Moreover, such accounts take little or no account of green water use in agriculture. The development of national, or sometimes regional, water footprint accounts has emerged from attempts to address these gaps.

Figure 2. Four different ways of presenting water footprint accounts.



The first preliminary assessment of the WF of nations was presented by Hoekstra and Hung (2002) who added the net virtual water import of selected crop products to the volume of blue water withdrawal to calculate the average WF of a nation. In this prototype analysis, no account was taken of the international trade of livestock products or of green water use in crop production (the latter shortcoming was later rectified by Chapagain and Hoekstra [2004]). In common with other early investigations (Chapagain and Hoekstra, 2003, 2004; Chapagain and Orr, 2008; Hoekstra and Hung, 2005), Hoekstra and Hung also took little account of specific local climatic and hydrological conditions. For instance, country average data were used to calculate crop evaporation even in countries where spatial variation in such parameters is huge, such as the USA, China or India. Furthermore, the assumption was made that potential crop evaporation was fulfilled in all cases, implying that deficit crop water requirements were always met by supplementary irrigation. In reality, only 22% of global arable land is irrigated (FAOSTAT, 2012) and these studies overestimated the WF of crops and livestock products, a shortcoming highlighted by Chapagain et al. (2006) who analysed the WF of cotton using local climatic data. WF accounting methodologies were further developed by Chapagain and Orr (2009) by including covered cropping systems and by taking account of seasonal climatic variability in production. Mekonnen and Hoekstra (2010; 2012) updated the statistical basis for WF accounts by using climate and irrigation data at much finer resolution (to 5 by 5 arc minutes) rather than using country average data. They also used crop-specific irrigation data to correct overestimations of crop water use.

Table 1. Major applications of water footprint analysis.

Application type	Typical question(s) addressed	Example data	Selected references
National water footprint accounts	How reliant is the import and consumption of goods within a country on water resources within that country and elsewhere? What is the vulnerability of a nation to global water-scarcity risks?	Of UK's agricultural water footprint 62% is through virtual water embedded in imported goods*	Hoekstra and Hung, 2002 *Chapagain and Orr, 2008 Mekonnen and Hoekstra, 2012
River basin water footprint accounts	What is the true picture of water stress or scarcity in river basins? What are the political-economic implications of different water management scenarios in water-stressed basins?	The construction of 11 main stem dams along the Mekong river, and consequent impacts on freshwater fisheries, could result in a 4-7% increase in water use for food production throughout the basin, with much higher estimations for countries entirely within the basin: Cambodia (29-64%) and Lao PDR (12-24%).*	WWF and Pegasys Strategy and Development (Pegram, 2010) Hoekstra et al., 2012 *Orr et al., 2012
Product water footprints	What is the water footprint of a specific product? What is the water footprint of an individual who uses a range of different products? What is the connection between product-specific and personal water footprints and ecosystems or other water users?	A litre of beer brewed in South Africa has a water footprint of 155 litres per litre of beer (47.1% net green water, 34.3% blue water, 18.6% grey water); a litre of beer brewed in the Czech Republic has a water footprint of 45 litres (91.7% net green water, 5.9% blue water, 2.4% grey water).*	*SABMiller and WWF, 2009 Water Footprint Network, 2012
Business water footprints	Where and when in the value chain might a business potentially have adverse impacts on the environment and/or on other water users? What is the strategic water-related risk (reputational, physical, regulatory or other) to a business, and in which parts of the world does this risk arise? Where might be the priorities for action to manage water-related business risk?	Based on the analysis of 1600 products representing 70% of its sales volume, Unilever found that 44% of its total domestic water footprint in water-scarce countries was associated with the manufacture and use of personal care products.*	SABMiller et al.2010 The Coca-Cola Company and The Nature Conservancy, 2010 Gerbens-Lees and Hoekstra, 2008 *Unilever, 2012

The water footprints of nations have been calculated using both 'top-down' and 'bottom-up' approaches. Top-down approaches are predicated on assessments of total global virtual water flows and allocating these flows to economic sectors within a country using environmental input-output analysis frameworks (Velázquez, 2006; Dietzenbacher and Velázquez, 2007; Guan and Hubacek, 2008; Zhao et al., 2009; Feng et al., 2011). Input-output analysis focuses on final consumption of a product and the water used in production is assigned to end-product consumers. The results are aggregated by economic sectors rather than by specific products, so it is difficult to separate major water-intensive processes from the results. As agriculture is a dominant water user globally, aggregation in this sector is a major shortcoming of the approach. In contrast, bottom-up approaches calculate the national WF by summation of the WF of individual products used in a country (Chapagain and Hoekstra, 2004; Hoekstra and Chapagain, 2007; Chapagain and Orr, 2008; van Oel et al., 2008). This makes the bottom-up approach a laborious process in which the scope for significant truncation errors is increased, i.e. if the parameters of a WF analysis are drawn too tightly, key water-intensive processes may be left out. For example, in the calculation of the indirect WF of a tomato, the water uses in producing the fertiliser, tools and other machinery used in the field may be included or excluded. In most instances, if water use in fertiliser production is not accounted for, the final WF number will be an underestimate of the true WF.

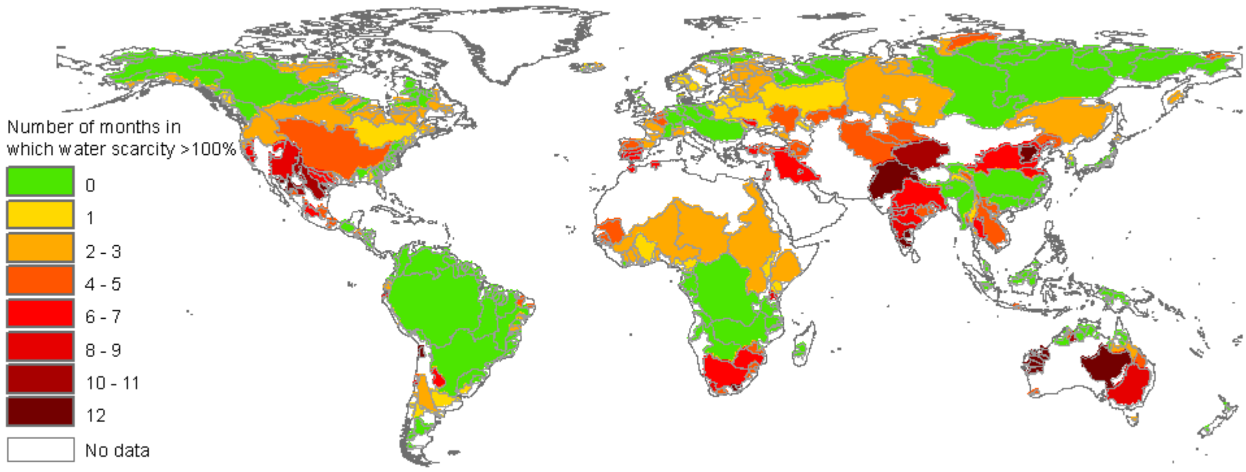
River basin water footprints

Conventional water stress or scarcity calculations at the river-basin scale have largely been based on annual estimates of blue water withdrawal as a proportion of mean annual run-off and on an assumption that 100% of the water withdrawn from surface water and groundwater bodies is lost to the system (Alcamo et al., 2000; Oki et al., 2001; Smakhtin et al., 2004). A more accurate picture of the pressure on blue water resources would take account of environmental water requirements; of seasonal variations in rainfall and river flows; and of return flows to blue water sources from agricultural, industrial and household water uses.

To this end, Hoekstra et al. (2012) analysed the monthly blue WF of 405 major river basins (figure 4), taking account of river flows needed to sustain critical ecological functions. The darkest red shading indicates river basins where more than 20% of water available in the basin was being used throughout the year. (The 20% ratio reflects a recently proposed presumptive standard that depletion beyond this proportion of a river's natural flow increases risks to ecological health and ecosystem services, after Richter et al., [2011]). Some of these basins are consistent with previous attempts to map global water scarcity, including arid regions (such as central Australia) and regions where significant amounts of water within these basins are being channelled into agriculture (e.g. the Indus basin). However, unlike maps based on water withdrawal, the monthly blue WF analysis suggests that even in basins such as the Mississippi and those of several small Western European rivers, water scarcity presents a risk during at least part of the year. Whereas the Comprehensive Assessment of Water Management in Agriculture (2007) estimated that 1.2 billion people lived in river basins where the physical scarcity of water was absolute, with a further 500 million living in basins approaching this state, the analysis based on monthly blue WF (Hoekstra et al., 2012) suggested that at least 2.7 billion people live in river basins that experience severe water scarcity during at least one month of the year.

Basin-scale data on trade and production are scarce and, as a result, relatively few investigators have used WF approaches to explore water stress or scarcity and related management issues for specific river basins. In light of proposed dam construction in the Mekong basin, a land and water footprint study by Orr et al. (2012) sought to quantify potential pressures on land and water resources as a result of communities seeking to replace lost freshwater fish protein with that from livestock products. In the Lake Naivasha basin, Kenya, a combination of WF analysis and economic data has been utilised to compile a situation assessment of water use and the horticulture and agriculture sectors (Pegram, 2010). This assessment suggested that there were clear distinctions between the socio-economic contribution of different water uses in the basin, in terms of dollar revenue and/or numbers of jobs per m^3 of water use.

Figure 3. Blue water scarcity in 405 river basins between 1996 and 2005.



Source: Hoekstra et al., 2012.

Product water footprints

In many parts of the world, consumers and companies are becoming increasingly concerned with issues of sustainability and natural resource use. In this context, and as noted above, water scarcity is rising up the public agenda and water footprints of specific products have been developed to aid understanding of potential direct and indirect impacts on rivers, lakes and wetlands and on the communities which depend on them. For example, the Water Footprint Network website (WFN, 2012) cites the water footprint of a cup of coffee as 140 litres and that of a cotton T-shirt 2500 litres. Such data have entered into the public domain (e.g. Lawrence, 2008) and have probably helped to raise awareness of the links between lifestyles, material consumption and potential impacts on water resources. Volumetric accounting such as this does not in itself illuminate the actual impacts (positive and negative) of consumer choices; as noted above, these are strongly influenced by a complex array of local factors. In response to the challenge of linking material consumption to environmental impact, attempts have been made to develop weighted water footprint accounts. These efforts draw on Life Cycle Assessment (LCA) methodologies and measures of water stress to distil the impact of product water footprints to a single quantifiable indicator (Ridoutt et al., 2009a, b; Ridoutt and Pfister, 2009). The underlying philosophy of such accounting frameworks is that better consumer choices and business management decisions can be facilitated by providing simple and communicable impact indicators, harmonised across products.

Business water footprints

Companies in the food and beverages sector were the first to explore the utility of WF approaches to aid understanding of corporate water-related risks Chapagain and Orr, 2010; SABMiller and WWF, 2009; The Coca-Cola Company and The Nature Conservancy, 2010). After initial exploration of the potential for simple volume-based measures (generally expressed in cubic meters of water per unit of time), at least some of these companies realised that the geo-spatial complexity of water risks and impacts necessitated the use of more sophisticated risk assessment tools and approaches (e.g. SABMiller and WWF, 2009; WWF and M&S, 2010). Nevertheless, business WF accounts have often drawn on a range of specific product water footprints to show that significant elements of business impact and risk relating to water resources lie beyond the factory fence, especially in agricultural supply chains (e.g. The Coca-Cola Company and The Nature Conservancy, (TCCC and TNC, 2010; Unilever, 2012)).

Driven by partnerships between businesses and NGOs, corporate water-risk assessment tools have evolved rapidly in recent years to the point that it is now possible for a complex multinational company or investor to undertake rapid high-level global risk assessment for a range of business units cutting across different economic sectors (WWF and DEG, 2012). At least one company, Puma (a sports clothing manufacturer) has sought to combine analysis of its water-related impacts with a profit and loss methodology as part of an effort to measure, value and report environmental externalities, although it is not clear from the available literature whether this was achieved through standard WF accounting techniques or through an alternative methodology (PUMA, 2012).

Partly as a result of water footprint analyses, and of a better understanding of water-related business risks, some multinational companies have established risk-management initiatives that seek to address practical water resources management challenges which are of wider relevance. For instance, SABMiller (a global brewing company), in partnership with WWF and GIZ (Deutsche Gesellschaft für Internationale Zusammenarbeit, on behalf of the German Federal Ministry for Economic Co-operation and Development) instigated the Water Futures partnership, which aimed to develop a business case for private-sector engagement in promoting the sustainable management of water resources. This ongoing partnership has attempted to stimulate local action to improve water resources management in order to address risks shared by businesses, local communities and ecosystems (SABMiller et al., 2010).

THE POSITIVES AND PITFALLS OF WATER FOOTPRINT APPLICATIONS

As experience of using WF applications has increased, so has the discourse about their advantages and disadvantages. While some of this debate can be found in peer-reviewed literature (e.g. Wichelns, 2010a, b, 2011), informal conversations in conference halls, meeting rooms and bars have also been important. The discourse can be classified into four questions:

1. Is it possible to develop robust *WF accounting standards*?
2. How useful and responsible is it to use results from a *WF analysis as a communications tool* to facilitate conversations with different audiences about water issues?
3. What are the benefits and dangers of using *WF as a business-risk assessment tool*?
4. What case is there for shifts in *public policy in light of WF analyses*?

With the exception of the first question, which reflects the ongoing methodological evolution of WF, debate has focused on the merits and utility (or lack thereof) of WF applications and business responses in the broader context of water resources management and the development of public policy. A common theme has been the need for the results of WF analyses to be placed in context, taking account of local environmental, social, economic and political situations.

Water footprint accounting standards

The science behind WF analysis has continuously evolved since the first publications appeared in the literature, and the number of experts publishing WF assessments has increased rapidly. Underlying climatic and hydrological databases have been improved to take better account of local conditions (e.g. Chapagain et al., 2006); data on flows of agricultural and other trades have been updated (Chapagain and Hoekstra, 2004; Mekonnen and Hoekstra, 2010, 2012); and conceptual refinements have been introduced such as 'net green WF' which distinguishes between the green WF of a crop and that of the natural or semi-natural land cover prior to cultivation (SABMiller and WWF, 2009). In an attempt to consolidate a robust and standardised analytical approach, the Water Footprint Network published a Water Footprint Assessment Manual (Hoekstra et al., 2011).

Nevertheless, methodological obstacles remain. For instance, a standardised approach to grey WF accounting has yet to be developed. This is partly because of variation in standards of water quality and in the pre-existing quality of receiving waters in different parts of the world (and hence differences in the volume of dilution water which would be required, hypothetically, to bring polluted return flows to acceptable levels). Moreover, by definition, grey water remains within the local hydrological system, ready to be used repeatedly if it is subject to adequate treatment (which is only sometimes the case). Whether or not to treat such water as effectively 'lost' from the local system, in the same way that evapo-transpired blue or green water is considered lost, is a tricky conceptual question.

A significant methodological cloud also hovers over the concept of weighted WF. One of the perceived merits of a WF analysis is that it enables users to disaggregate components of water footprint into different components (blue, green, grey; direct, indirect). Even so, critics (e.g. Wichelns, 2010a) have highlighted the danger that a simple combined volumetric WF indicator can be misunderstood to be a proxy for the actual impacts of water use, in the same way that the atmospheric impacts of carbon footprints can be interpreted from a single volumetric indicator (kg of CO_{2e}). Understanding of WF impacts necessitates not only disaggregation into component WF elements but also consideration of contextual issues at the point of water use, involving substantial spatial and temporal variability in environmental, social, economic and political factors. The corollary of this is that interpretation of WF analyses is more complex than interpretation of carbon footprints. Weighted WF assessment is an attempt to reduce this complexity and to aid communicability through harmonisation of WF indicators across geographies and sectors. However, weighting factors have largely been predicated only on physical indicators such as water stress; socio-economic and political issues, including the opportunity costs of water uses, have been more difficult to incorporate and can only be weighted in a qualitative (and therefore subjective) way. There are technical, as well as conceptual, hazards in such a reductive approach. For example, the use as a weighting factor of water stress measures based on average annual blue water availability (e.g. mean annual run-off) masks seasonal variability in annual river hydrographs and may fail to take account of the need to maintain environmental flows.

Water footprint analysis as a communications tool

It has been recognised that water experts increasingly need to communicate 'out of the box' so that decision makers in government, the private sector and civil society better understand how better water management can support attainment of economic, social and environmental outcomes (World Water Assessment Programme, 2009). In comparison with peer-to-peer communication (through academic journals, for instance, or using concepts such as Integrated Water Resources Management) this necessitates telling new stories, using compelling data and language and mobilising a range of media. The results of WF analyses have found their way to the front pages of newspapers (e.g. Lawrence 2008) and anecdotal evidence from conversations with a variety of external audiences has suggested that scientifically-based volumetric water footprint statistics have been a powerful tool for engaging new audiences. In short, ostensibly shocking facts – such as the fact that the average per capita water footprint in the UK is 4645 litres per day, a 30-fold increase on simple measures of direct water use (Chapagain and Orr, 2008) – have helped non-expert decision makers and consumers to understand how global water security underpins national food security, especially in relation to imported agricultural products. The fact that such audiences have normally been familiar with the concepts and language of carbon and/or ecological footprints means that this has been an easily understandable story.

Care is needed using WF analysis in this manner. As discussed, volumetric WF results cannot tell the whole story of costs and benefits of water use. Even specialists have fallen into the trap of calling for a simple reduction in WF as a step towards sustainability, rather than focusing on addressing adverse impacts of WF (e.g. ICE, 2010). Moreover, messages based solely on volumetric WF measures may be perceived – accurately or not – as attributing blame for water scarcity in an exporting country to those in another country who sell or consume such goods (Wichelns, 2010a, 2010b, 2011). The reality is likely to be far more complex and such perceptions may lead to unintended socio-economic or environmental consequences. Most companies in the forefront of WF analyses have understood this complexity and, as a result, have steered clear of developing volumetric WF labelling schemes for consumer goods. Even in the popular press, the need for nuanced interpretation of WF analyses results is beginning to be recognised e.g. Burrows, 2011. Nevertheless, the danger of companies using oversimplified messaging remains and will increase as more companies become aware of water-related risks and undertake WF assessments. The roll-out of weighted WF assessments is likely to exacerbate this risk.

Water footprint as a business-risk assessment tool

The rapid and increasingly widespread uptake of WF analyses by multinational companies suggests that it can be a useful tool for mapping and understanding water-related business risks and impacts. Working in partnership with NGOs and researchers, companies have experimented with WF analyses to understand how best to use it. For instance, M&S (a UK-based food and clothing retailer) originally set out to assess the WF of all of the food products on its shelves. However, the company has worked with WWF to deploy the Water Risk Filter ((WWF and DEG, 2012)) tool to gain a more strategic view of where priorities are for investment in risk mitigation actions. This has resulted in a more beneficial understanding of the strategic risks and impacts across the business and significantly less time consuming and resource intensive than assessing all food products. (Mike Barry, personal communication). The experience of SABMiller with WF analyses has demonstrated that it can be useful in helping operational managers within the company to understand that a significant proportion of the water risks to the business lie beyond the factory fence. In the case of SAB Ltd. (the company's South African subsidiary) a WF analysis of beer production illustrated that 98.3% of the total WF was related to crop growth in South Africa (SABMiller and WWF, 2009). This new understanding helped to motivate SAB Ltd. to enter into new stakeholder partnerships which aimed to address water scarcity issues in the Gouritz Water Management Area that presented risks to the company's hop supply chain as well as to other water users and to freshwater ecosystems (David Grant, SABMiller, personal communication).

While WF analysis can help companies to understand water-related risks, it offers no information on potential courses of action to address these risks. From this perspective, companies need to understand that benefits to their business and assessment of their impacts will be measured more by their responses to water-related risks than by the simple fact that they may have undertaken and published a WF assessment. Other tools and guidance have been developed to help companies understand how to engage with a range of stakeholders in order to promote and resource context-specific water management initiatives that can benefit communities and ecosystems as well as reducing business risks (e.g. UN Global Compact, 2012). A key concept is that of 'shared risk', which reflects the fact that, for governments, communities, ecosystems and businesses, all water-related risks ultimately stem from physical risks related either to stress in the water resources (quantity and quality) or to failure of supply systems. Thus there are areas of shared risks that provide opportunities for cooperation and partnership in the effective and sustainable management of water resources (Pegram et al., 2009). This is particularly relevant when both government and business managers take a longer-term perspective of their respective imperatives. Only a small number of so-called 'water stewardship' initiatives currently exist, addressing shared water-related risks through action beyond the business boundary. To date, there is little published evidence of outcomes of these initiatives in terms of changes in water resources management policy and practice as a result of business engagement. This may change in time as more companies engage to address such shared risks and as initiatives mature. If so, it will be important that any such outcomes, and the role of companies in bringing them about, will be subjected to critical review.

Public policy in light of water footprint analysis

The connections between WF assessments, water policy and policy on related issues such as trade, economic development and agriculture have been the subject of discussions at major conferences in recent years.[3] The Water Footprint Network has also begun to consider the policy implications of WF more systematically (Stuart Orr, personal communication). But despite this discourse, and despite the proliferation of national WF assessments, there have been few examples to date of WF analyses stimulating shifts in water policy at the country or regional level. In Spain, the national government has made it mandatory to include a WF analysis for any new development project, and linked this to implementation of the EU Water Framework Directive (Aldaya et al., 2010). UK government bodies have shown interest in WF approaches, but substantive action has so far been limited to commissioning research and convening stakeholders (Defra, 2009, 2012) and publishing guidance notes (Wentworth, 2011). The limited traction of WF at the policy level may be partly because it is a new tool whose utility has yet to be fully explored. In addition, governments are normally quite aware of the state of national or regional water resources (especially blue water), and in many countries where these resources are under pressure water policy has already been amended to set a framework for better management. The value of using WF to inform further revisions to water management approaches may be limited. In such places, the larger challenge is often implementation of existing water policy (Le Quesne et al., 2010). Suggestions that water policy should be re-framed in light of WF analyses may even in some instances distract from – or in the worst case, hinder – current implementation efforts.

A different role for WF analysis in policy definition is illustrated in the analyses of economic water-related risks around Lake Naivasha, Kenya (Pegram G. 2010) and the Western Cape, South Africa (Guy Pegram, Pegasys Strategy and Consulting, personal communication). These assessments use WF analyses in combination with economic tools to assess the implications of water scarcity for economic development scenarios, especially as they relate to agriculture, energy production and trade. The hypothesis underpinning both studies is that decisions about economic development policy, food and energy security and trade are often made by political and business leaders in the absence of adequate information on the implications of local hydrological constraints. To this end, the analyses seek to describe opportunities to deliver economic and social outcomes which are sustainable in terms of the available water resources; to set out choices that may need to be made between different water uses within the local political-economic context; and to illustrate some of the medium to long-term social and economic consequences of using water resources unsustainably. This has been described as a 'water in the economy' analytical approach, distinguished from the 'water for the economy' approach traditionally taken by water managers primarily concerned with enhancing water-supply options in response to economic development plans (Stuart Orr and Guy Pegram, personal communication).

Some commentators have gone further and suggested that WF analyses – and the illustrations they provide of links between economic development, global trade and water use – point to the need to develop and/or amend international policy frameworks and governance arrangements such that they facilitate more hydrologically sustainable global consumption patterns (e.g. Hoekstra, 2006). Such aspirations are understandable: current international frameworks governing trade and development

[3] In 2010, the World Water Week conference in Stockholm included a seminar, convened by the Water Footprint Network and UNEP, entitled *Water footprint and public policy: what can governments do to reduce humanity's water footprint*? (see programme, page 53, at www.worldwaterweek.org/documents/WWW_PDF/2010/Final_programme_2010_web.pdf). In 2012, the Planet under Pressure conference in London included a session, convened by the WFN, the University of Twente and WWF, entitled *Solving the water crisis: common action towards a sustainable water footprint*" (see www.planetunderpressure2012.net/pup_session.asp?19064).

arguably take too little account of a range of environmental concerns and constraints, including those linked to water resources (Biermann et al., 2012). But arguments for reformation of the global governance of trade flows based on WF analyses have been made in isolation of concerns for other environmental impacts of trade (such as carbon emissions or biodiversity impacts) and of social equity considerations and have not acknowledged the complex, imperfect and intrinsically political nature of international negotiations. Consequently, they have not yet been sufficiently compelling to gain traction.

CONCLUSIONS

Strategic decisions which affect water use are often made by political leaders and captains of industry who are not water experts and who are primarily concerned with economic and social, rather than hydrological or environmental, priorities. Their decisions should be informed by robust analyses of consequences and constraints linked to water resources and freshwater ecosystems (among other issues). To this end, tools are needed which can shed analytical light on the profound connections between hydrological sustainability and policy priorities relating to trade, economic development and social welfare. WF analysis is such a tool, alongside others, such as IWRM-related applications, that water resource managers already use. Importantly, WF tools are potentially helpful not only for water experts; business analysts, communications experts and policy makers may also find them useful.

All tools are designed to help with certain tasks. WF is no exception. WF analysis has helped to improve understanding of the hydrological interdependence of nations, linked to agricultural trade. As a metaphor and as a set of metrics, WF has proven to be a powerful aid to communication 'outside the box' to political stakeholders, a wider range of policy makers and the public. It has been particularly useful for strategic business risk assessment and, from this, for motivating CEO and Board-level engagement in efforts to address water-related risks, including those shared with other water users and ecosystems. The scenario analyses for Lake Naivasha and the Western Cape suggest that WF, combined with economic analyses, may prove to be a useful tool for development planning.

A WF analysis is not a silver bullet and there are many water policy and water resources management tasks which are beyond its scope. Methodologies are imperfect and evolving. Results from WF analyses can help to highlight interconnections and risks but do not provide solutions (other tools are more useful for this). These shortcomings have at times been exacerbated by some WF 'evangelists' who have failed to contextualise WF results or to recognise explicitly that WF can provide only one part of the analytical puzzle. An emphasis on development of new water resources management policies in light of WF analysis may even distract from the existing, and important, challenge of implementation of existing, largely sensible, water policy in some parts of the world. Responses to WF analyses need to be nuanced in order to take account of broader environmental, social and economic issues, including local hydrological contexts and the opportunity cost of water use. Equally, sceptics in the water expert community who dismiss WF tools because methodologies are imperfect or because analyses take account of only a hydrological subset of sustainability indicators may misunderstand the primary value of WF: to strengthen the foundation of risk and sustainability assessments and to motivate better decisions by business and government leaders. Sceptics' concerns about volumetric WF measures as oversimplified indicators of sustainability are technically justified; but a narrow focus on this issue omits consideration of the benefits of careful communication of WF data to important audiences 'outside the box'.

In light of this review, and of the lessons taken from the application of WF in the private sector and public policy arena, it is possible to derive a set of 'golden rules' that might be helpful to further the debate and to guide the deployment of WF applications. These should be subject to further critical reflection, debate and amendment as experience in the deployment of WF tools increases and as the literature on the issue expands:

1. WF analysis has already led to better understanding of the true picture of water scarcity at the global, regional and national levels and of the link between water security challenges and food security. Researchers should prioritise the development and refinement of applied tools for use by businesses, policy makers and stakeholders as they seek to address such challenges. Further critical examination of the response of the businesses to risks highlighted in WF assessments is needed.
2. WF assessments should be used by stakeholders for communication to wider audiences beyond the expert community. Scientific analysis, and visual tools such as virtual water flow maps, can quickly build awareness of the links between global water security, trade, national food or energy security and social or economic development goals.
3. Such communication should be carefully planned. An emphasis on the total volumetric WF indicator can grab the headlines, but without explanation and contextualisation it can lead to misinterpretation of the issue and, potentially, to perverse responses. Messaging should incorporate at least a minimum of explanation about the environmental *impacts* of water footprints and about social and economic benefits of water use.
4. Because of this need for contextualisation, extreme care should be taken in interpretation of weighted WF data. Similarly, use of 'single number' WF indicators to label consumer goods is seldom appropriate or helpful and businesses should be wary of their use.
5. Businesses should use WF analysis to understand strategic corporate risk related to water. There is a range of WF tools available to guide companies in this endeavour. Many are freely available online and increasingly straightforward to use. Companies should also draw on tools which provide guidance on appropriate responses to WF-based risk assessments, including those which advise on stakeholder engagement, partnership development and dialogue with governments about public policy.
6. Governments and the research community should further explore the use of WF tools to improve understanding of the links between water resources and economic development planning. Combining WF applications with economic and social analytical tools has the potential to aid development of more sophisticated and hydrologically sustainable options in pursuit of social and economic outcomes.
7. Although WF analysis may not be useful to stimulate development of new public policy on water management, governments and other stakeholders (such as NGOs) should target communication of WF data to encourage involvement of new political and economic actors in dialogue to support implementation of existing water policy. For instance, a broader cross-section of the business community might be motivated to contribute to water resources management efforts, including hydrological monitoring, if they are shown data which link supply chain risks to increasing water scarcity or pollution in catchments from which they source goods or services.
8. Use of WF data to call for more sustainable global trade and economic development frameworks may be helpful but calls to action should take account of (or at least acknowledge the need to take account of) a wider set of environmental, social and economic issues linked to water use. They should also recognise the necessity and inevitability of political trade-offs between these issues.
9. Any organisation considering undertaking a WF analysis should be clear on *why* it is doing so, and on *how* it will use the results. The purpose might be exploratory (to understand WF approaches and to help decide whether they can be useful, for instance) or applied. A water footprint analysis for its own sake is seldom useful.

10. Finally, remember that WF analysis is a tool. Like all tools, it has a defined utility. The generation of appropriate responses by businesses and others to WF analyses will require other tools, especially those which contextualise WF data.

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