Water

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Protecting freshwater resources can no longer be regarded as an issue for individual countries or regions. Consider Australia as an example. Australia is currently using a substantial amount of its water resources in making export products. Freshwater scarcity in Australia cannot thus be understood as being related to demands from Australian consumers alone. The total volume of water consumed in Australia within the various economic sectors amounts to about 90 billion cubic meters per year. The water footprint of Australian consumers amounts to no more than one-third of that (Hoekstra & Chapagain 2008). By exporting huge volumes of water-intensive commodities, Australia and the Americas are the big "water suppliers" to the rest of the world, especially Europe and Japan.

Europe is a large importer of crops like sugar and cotton, two of the most thirsty crops. Europe also imports large volumes of feed, like soybean from Brazil. European consumption strongly relies on water resources available outside Europe. Although in many countries – including China and India – most of the food still originates from the country itself, substantial volumes of food and feed are internationally traded. There is a growing demand for biofuels as well. As a result, all countries import and export water in virtual form, that is, in the form of agricultural commodities. Worldwide, trade in agricultural products results in international virtual water flows that add up to 1250 billion cubic meters per year, equivalent to more than twice the annual runoff of the Mississippi (Hoekstra & Chapagain 2008). Countries that import water-intensive commodities save their own water resources, which can be attractive when domestic resources become scarce. At the same time, however, reliance on external water resources makes a water-scarce country dependent on other nations, in a similar way as countries without oil depend on oil-exporting countries.

From an economic point of view, it makes sense that water-intensive commodities are produced in those regions of the world where water is most abundant and can be made productive in the most efficient way. However, the current global economic regime provides few incentives for using water efficiently, because water is generally not priced, or very poorly priced, particularly in the agricultural sector, which consumes most water within most economies. In many places on earth, rivers and aquifers are being depleted beyond what is considered ecologically sustainable, and water bodies are unnecessarily polluted. Most national regulatory frameworks are insufficient to effectively avoid water depletion and pollution; even in the developed world, like the United States and Europe, examples of river and groundwater depletion and water pollution are widely available. Water scarcity and pollution are not properly priced anywhere in the world. Other means of transmitting information about unsustainable water use to the final consumers of water-intensive commodities do not exist either. These factors are unfavorable to good water governance, because producers and consumers lack incentives to make choices in production or consumption that are sustainable. Improving the situation is a challenge at the national level, but the fact that many water-intensive commodities are intensively traded internationally makes it a true global challenge as well.

Water-scarce countries that import food and other water-intensive commodities relieve the pressure on their own domestic water resources. The imported products contain water in a virtual sense. The virtual water content of a product is the volume of water used to produce it, measured at the place where it was actually produced. The adjective "virtual"

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refers to the fact that most of the water used in the production is in the end not contained within the product. The real water content of products is generally negligible compared to the virtual water content. The virtual water content of wheat for instance is in the order of 1000–2000 m^3/ton, while the real water content is obviously less than 1 m^3/ton. While the transfer of real water over long distances is very costly and therefore generally not economically feasible, transfer of water in virtual form can be an efficient way of obtaining water-intensive products in places where water is very scarce.

An increasing number of water-short countries, most particularly in North Africa and the Middle East, seek to preserve their domestic water resources through the import of water in virtual form, by importing water-intensive commodities (those with a relatively high water input per dollar of product) and exporting commodities that are less water-intensive. Jordan, for example, imports about five to seven billion cubic meters of virtual water per year, which is much more than the one billion cubic meters of water annually withdrawn from its domestic water sources. Even Egypt, with water self-sufficiency high on the political agenda and a total water withdrawal within the country of 65 billion cubic meters per year, still has an estimated annual net virtual water import of 10 to 20 billion cubic meters.

During the past few years various global studies have been carried out to quantify the actual virtual water flows between nations. All studies show that North and South America, Australia, and most of Asia and Central Africa have a net export of virtual water. The reverse, a net import of virtual water, can be found in Europe, Japan, North and Southern Africa, the Middle East, Mexico, and Indonesia. Obviously, the import of virtual water in, for instance, Europe should be understood in a different context than the import of virtual water in North Africa and the Middle East. In the latter case, the virtual water import can be explained – at least partially – by the actual water scarcity situation in the countries of this region. The water availability in most of the countries in North Africa and the Middle East falls below a threshold of about 1500–2000 m^3/yr per capita, below which net cereal import grows exponentially with decreasing water availability per person. It is not suggested here that all countries with a net import of water in virtual form do this because they intend to save domestic water resources. By importing virtual water they will indeed save domestic water resources, but this does not imply that saving water was necessarily the main driving force behind the virtual water imports. International trade in agricultural commodities depends on many more factors than water, such as the availability of land, labor, knowledge, and capital, the impossibility of growing certain crops or crop varieties in certain places, competitiveness (comparative advantage) in certain types of production, domestic subsidies, export subsidies, and import taxes. As a consequence, the international trade in virtual water trade cannot in most cases be explained at all, or only partly, on the basis of relative water abundance or shortage.

As shown in Table 1, the (intended or unintended) national water saving as a result of international trade in agricultural products can be substantial. In Algeria, water use would triple if the Algerians had to produce all imported products domestically.

With people increasingly consuming imported water-intensive goods, the "water footprints" of people become more global. The water footprint of an individual or community is defined as the total volume of freshwater that is used to produce the goods and services consumed by that individual or community (Hoekstra et al. 2011). The water footprint of the people in a country shows not only water use within the country, but also water use outside its borders. The water footprint of the Dutch community, for example, also includes the use of water for cotton production in China and for producing citrus fruits in Spain, insofar as these commodities are exported to and consumed within the Netherlands. Given the increase in international trade flows, the water footprints of people are increasingly being externalized to other parts of the world.

Table 1 Examples of nations with net water saving as a result of international trade in agricultural products (1997–2001).

Country	*Total consumption of domestic water resources in the agricultural sector*[a] *(10^9 m^3/yr)*	*Water saving as a result of import of agricultural products*[b] *(10^9 m^3/yr)*	*Water loss as a result of export of agricultural products*[b] *(10^9 m^3/yr)*	*Net water saving due to trade in agricultural products*[b] *(10^9 m^3/yr)*	*Ratio of water saving to water use*
China	733	79	23	56	8%
Mexico	94	83	18	65	69%
Morocco	37	29	1.6	27	73%
Italy	60	87	28	59	98%
Algeria	23	46	0.5	45	196%
Japan	21	96	1.9	94	448%

[a] Hoekstra & Chapagain (2008).
[b] Chapagain et al. (2006). Agricultural products include both crop and livestock products.

Consumers do not generally pay for the negative effects of their water footprints because water supply is mostly heavily underpriced, and the negative effects of pollution are not taken into account in the price of the products. Local water problems are thus strongly related to cheap consumption elsewhere, where "cheap" refers to the fact that prices of water-intensive consumer goods generally include neither a water scarcity rent nor externalities that occur during production.

Global water use, including both green and blue water, is estimated to be 7450 billion m^3/yr. The global volume of virtual water flows relating to the international trade in commodities is 1625 billion m^3/yr, of which 1200 billion m^3/yr relates to the export of home-made products; the remainder concerns re-exports of imported goods (in the same form as imported or after processing) (Hoekstra and Chapagain 2008). From these figures it follows that (1,200/7,450 =) 16 percent of global water use is not for producing domestically consumed products, but for products for export. Assuming that, on average, agricultural production for export does not significantly cause more or fewer water-related problems (such as water depletion or pollution) than production for domestic consumption, this means that one-sixth of the water problems in the world can be traced back to production for export.

The physical distance between production and consumption and the fact that much of the consumer information on product origin and production circumstances is generally at best limited to information about the country of origin and some data on the main ingredients mean that there is a disconnection between consumption decisions and the detrimental impacts of production. Consumption can only be reconnected with the effects of production through a global approach. Local or national measures to include externalities and a water scarcity rent in water-intensive products will not work satisfactorily because such local products run the risk of becoming too expensive in the global market, which is dominated by others who have not yet taken such measures.

Overexploitation of the soil in some places, excessive use of fertilizers in others, long-distance transfers of food and animal feed and concentrated disposal of nutrient-rich wastes in densely populated areas of the world cause disturbances in the natural cycles of nutrients, such as nitrogen and phosphorus. This has already led, and will further lead, to depletion of the soil in some areas and eutrophication of water elsewhere. For example, the surplus of nutrients in the Netherlands is partially related to deforestation, erosion, and soil degradation in those areas of the world that export food and feed to the Netherlands – for example, in Brazil from where a lot of soybeans for the Dutch pigs and chickens are imported. This implies that the nutrient surplus in the Netherlands is not an issue that can simply be handled by the Dutch in isolation. Dutch water pollution is part of the global economy.

The disturbance of nutrient cycles is not the only mechanism through which the global economy influences the quality of water resources worldwide. Other substances are also dispersed into the global environment and change the quality of the world's rivers (Meybeck 2004). The regular publication of reports on global pollution shows that this phenomenon in itself is no longer news; what is now gradually being uncovered, and is therefore relatively new, is the fact that pollution is not simply "global" because pollution is so "widespread," but that it is interlinked with how the global economy works and is therefore a true global problem. Water pollution is intertwined with the global economic system to such an extent that it cannot be dealt with independently from that global economy. Indeed, pollution can be tackled by end-of-pipe measures at or near the location of the pollution, but a more cause-oriented approach would be restructuring the global economy, with the aim of the closure of element cycles. Making adjustments to the organization of the global economy would obviously require international coordination.

Local precipitation and thus local water availability and peak flows depend on local climate conditions, which in turn are influenced by global climate conditions. Evidence is available that humans have played, and will continue to play, a role in changing climate by contributing to the emission of greenhouse gases and aerosols and through changing land use. Whereas the effects of land use changes are often still limited to the climate at (sub)continental level, the effects of aerosols and greenhouse gases are very much global. Good governance of local water systems can thus be hampered or impaired by mechanisms that go beyond the governance domain of water managers who operate at the local, national, or river basin level. They can use their power to influence water use, but not land or energy use, to say nothing about the fact that their power does not surpass the scale of the river basin. Arrangements for good water governance would include institutions that coordinate efforts to manage water with efforts to manage the land in the wider surroundings as well as the globe's energy resources. Overlooking this external component of water governance can result in a situation where the good work of local water managers is completely nullified by external, global developments. Consider the case of the Dutch river delta, where the work of water managers in the coming decades will be continuously challenged by sea level rise, a changing local climate, and growing peak river discharges (all three due to global climate change), as well as subsidence of the land (due to land use and gas extraction). Similarly, dedicated water demand strategies in the Mediterranean will have little effect in closing the gap between demand and supply if gains in reducing water demand are accompanied by climate-change-driven reductions in water availability.

The past decade has shown a growing presence of transnational corporations in the drinking water sector. An increasing number of municipalities are served by private companies that often run water services across the globe. At the same time, production of bottled water is steadily increasing. Barlow and Clarke (2002) have argued that drinking water is gradually turning from a public resource into a commercial commodity with global players. This has also been called the "commodification of water." Questions such as whether water should be treated as a resource or a commodity, and whether or not water should come under the regulations of the World Trade Organization, are nowadays hot topics at international water forums.

As a result of the process of privatization in the water supply sector during the past two decades in several countries, water supplies have fallen to an increasing degree into the hands of large multinationals. Stimulated and made possible by the loan practices of the World Bank, 70 percent of the private water supply systems in the world are currently owned by the three largest water companies – Veolia, Suez, and RWE Thames Water. Some consider this an obvious development, which will ensure that through enlargement of scale water supplies will become more efficient and that the standard of water supplies in developing countries will be pushed up towards levels that are more common in the north. Others instead see a frightening picture, in which water, a basic need for everyone, becomes a tradable commodity that can be obtained only by those who can afford to pay. Shiva (2002) further argues that in many cases the privatization of water leads to a situation in which companies profit from overexploitation of water resources because scarce water resources can still be freely obtained and exploited without covering the cost of negative externalities.

The increasing demand for freshwater and the limited possibilities of raising supply lead to the need for a greater efficiency in water use, that is: produce the same volume of goods and services with less water. Fortunately there are ample opportunities to increase water use efficiency. Greater water use efficiency can be achieved at three different levels: the local, basin and global levels (Hoekstra & Hung 2005). At the local level, that of the consumer, water use efficiency can be improved by: charging prices based on full marginal cost; stimulating water-saving techniques in farming such as water recycling, drip irrigation, and the use of drought-resistant crop varieties; promoting the use of water-saving appliances in industries and households; and creating awareness among water users of the possible detrimental impacts of water use. At the catchment or river basin level, water use efficiency can be enhanced by reallocating water to those purposes with the highest marginal benefits, which can imply the reallocation of water from the agricultural to the domestic or industrial sectors or from water-inefficient crops to more efficient types or varieties. At the global level, water use efficiency can be increased if nations use their comparative advantage or disadvantage in terms of water availability to encourage or discourage the use of domestic water resources for producing export commodities. Virtual water trade between nations – provided that trade goes in the right direction (from places with high to places with low water productivity) – can thus be a means of increasing the efficiency of water use in the world.

Recent studies indicate that global water saving as a result of international trade can be substantial when compared with the total water use in agriculture. According to Chapagain et al. (2006), global water saving through trade in agricultural products during the period 1997–2001 was equivalent to 6 percent of the global volume of water used for agricultural production. Global water saving as a result of international trade in all agricultural products, including both crops and livestock, was estimated to be 350 billion m^3/yr, of which 63 percent related to international trade in cereals and cereal products, 19 percent to oil crops, 13 percent to livestock products and 5 percent to pulses and other crops.

Although it is clear that global trade and water use efficiency are connected issues, there is no international agency that has ever included this connection in either trade policy or water policy considerations. The growing scarcity of freshwater in the world and the fact that water could possibly be saved by producing water-intensive commodities in places where water is comparatively abundant and trading them to places where it is not demand international research and policy coordination in this field.

Some people around the world have comparatively large water footprints, which raises the question of whether this is fair and sustainable. Under current production conditions it would be impossible for all world citizens to develop a water footprint of the same size as the present water footprint of the average US citizen. People in the United States have, on average, the largest water footprint per capita in the world, viz. 2480 m^3/yr. China has an average water footprint of 700 m^3/yr per capita, while the world average is 1240 m^3/yr (Hoekstra and Chapagain 2008). Currently, about one billion people do not have sustainable access to an improved water source, while others water their gardens, wash their cars, fill their swimming pools, and enjoy the availability of water for many other luxury purposes. In addition, many people consume a lot of meat, which significantly enlarges their water footprint. The average meat consumption in the United States, for instance, is 120 kg/yr, more than three times the world average. This partially explains the fact that the average American citizen has the largest water footprint in the world. The water used to produce the feed for the animals that provide the meat for the rich cannot be used for other purposes, for example, to fulfill the more basic needs of people who cannot afford to pay. The answer to the question of whether the current distribution of water footprints is fair is a political and, furthermore, a global one. Redistribution of welfare among individuals is normally done within the borders of the nation-state, but since the distribution of water and water-intensive products is very uneven across the globe, the redistributive question becomes a global one as well. The normative question at global level is whether wealthy water-rich nations should play a role in supporting developing water-poor nations, for instance, by helping them to efficiently and sustainably use their scarce water resources.

What is a "sustainable water footprint," given that the earth has seven billion inhabitants and total water availability in the world is limited? The current global water footprint leads to unsustainable conditions in many places, as witnessed by the reported cases of water depletion and pollution (CAWMA 2007; UNESCO 2009). Although the annual volume of precipitation over land is roughly known, it is difficult to give a global figure for the maximum "sustainable water footprint" as an upper limit to global water use. There are various reasons for this. One is that not all precipitation can be used productively, because its fall is unevenly spread in time and space, so that there are places and times at which the water will inevitably flow to the oceans. According to Postel et al. (1996), about 20 percent of total runoff forms remote flows that cannot be appropriated and 50 percent forms uncaptured floodwater, so that only 30 percent of runoff remains for use. Although research in this direction has been done, it is not yet clearly established which fraction of this remaining flow should remain untouched in order to fulfill environmental flow requirements. It has also not been established what fraction of the total evapotranspiration on land may be counted as potentially productive. Finally, what would count as the maximum "sustainable water footprint" at global level depends on what assumptions are made regarding the level of technology. One could take water productivities as they are at present (which differ from location to location), or work with potential water productivities based on existing technology.

Nations can be "water-dependent" in two different ways: dependent on water that flows in from neighboring countries, or dependent on virtual water import. The first type of dependency follows from the ratio of external resources to the total renewable water resources of a country. The total renewable water resources of a country are the sum of internal and external water resources. Internal renewable water resources comprise the average annual flow of rivers and the recharge of aquifers generated by endogenous precipitation. External renewable water resources include inflows from upstream countries (of groundwater and surface water) and a proportion of the water in border lakes or rivers. For a country like Egypt, dependency on external water resources is extremely high, because the country receives hardly any precipitation and thus mostly depends on inflowing Nile water. Similarly, but to a lesser extent, Pakistan strongly depends on the water of the Indus, Cambodia on the water of the Mekong, and Iraq on that of the Tigris and Euphrates. In all these cases water is an important geopolitical resource, affecting power relations between the countries that share a common river basin. In a country like the Netherlands, external water resources dependency is high but less important, because water is less scarce than in the previous cases. Nevertheless, here too there is a dependency, since activities within the upstream countries definitely affect downstream low flows, peak flows, and water quality.

The political relevance of the dependency of nations on external water resources makes water a regional geopolitical resource in some river basins. The other type of water dependency, virtual water import dependency, makes water a global geopolitical resource. The fundamental reason is the combination of the increasing scarcity of water, its unique character that precludes substitution, and its uneven distribution throughout the world. Where water-abundant regions have not fully exploited their potential in the past, they now increasingly do so by exporting water in virtual or even real form. The other side of the coin is the increasing dependency of water-scarce nations on the supply of food or water, which can be exploited politically by those nations that control these resources.

From a water resources point of view, one might expect a positive relationship between water scarcity and virtual water import dependency, particularly in the ranges of great water scarcity. Water scarcity can be defined as the country's water footprint – the total volume of water needed to produce the goods and services consumed by the people in the country – divided by the country's total renewable water resources. Virtual water import dependency is defined as the ratio of the external water footprint of a country to its total water footprint. Countries with a very high degree of water scarcity – like Kuwait, Qatar, Saudi Arabia, Bahrain, Jordan, Israel, Oman, Lebanon, and Malta – indeed have a very high virtual water import dependency (>50 percent). The water footprints of these countries have largely been externalized. Other water-scarce countries with high virtual water import dependency (25–50 percent) are, for instance, Greece, Italy, Portugal, Spain, Algeria, Libya, Yemen, and Mexico. Table 2 presents the data for a few selected countries. Even European countries that do not have an image of being water-scarce, such as the United Kingdom, Belgium, the Netherlands, Germany, Switzerland, and Denmark, have a high virtual water import dependency. In those cases where large virtual water imports go together with national water abundance, the import is obviously not related to water scarcity but must be explained by other factors.

In most water-scarce countries the choice is either (over)exploitation of domestic water resources in order to increase water self-sufficiency (the apparent strategy of Egypt) or virtual water import at the cost of becoming water-dependent (Jordan). The two largest countries in the world, China and India, still have a very high degree of national water self-sufficiency (93 percent and 98 percent respectively). However, they have relatively low water footprints per capita (China 700 m^3/cap/yr and India 980 m^3/cap/yr). If the consumption patterns in these countries changed to match those of the United States or some Western European countries, they will face severe water scarcity in the future and will probably be unable to sustain their high degree of water self-sufficiency. A relevant question is how China and India feed themselves in future. If they were to decide to partially obtain food security through food imports, this would put enormous demands on the land and water resources in the rest of the world.

The fact that oil is generally seen as a global resource and water as a local one can be understood but not justified. The oil of the Middle East is "owned" by the countries in the Middle East to the same extent that the water in Brazil is "owned" by Brazil. In that sense, both resources are local. At the same time, both oil in the Middle East and water in Brazil are critically relevant for the global community as a whole. In that sense, both resources are global. The countries in the Middle East export oil; Brazil exports water (in virtual form).

The various recent studies on international virtual water trade show that water should be regarded as a global resource (demand and supply match at global level), rather than as a river basin resource (demand and supply

Table 2 Virtual water import dependency of some selected countries. Period: 1997–2001.

Country	*Internal water footprint*[a] *(10^9 m^3/yr)*	*External water footprint*[a] *(10^9 m^3/yr)*	*Virtual water import dependency*[b] *(%)*
Indonesia	242	28	10
Egypt	56	13	19
South Africa	31	9	22
Mexico	98	42	30
Spain	60	34	36
Italy	66	69	51
Germany	60	67	53
Japan	52	94	64
UK	22	51	70
Jordan	1.7	4.6	73
Netherlands	4	16	82

[a] Hoekstra and Chapagain (2008).
[b] Defined as the ratio of the external to the total water footprint.

match within the basin). Effective governance of the world's water resources will require some type of regulation of the global "water market," for example, in the form of agreements on area-specific "sustainable levels" of water consumption and on water pricing structures.

SEE ALSO: Oil (Petroleum); Pollution, water; Sustainability; Sustainable consumption; Water crisis.

REFERENCES

Barlow, M. & Clarke, T. (2002) *Blue Gold: The Battle against Corporate Theft of the World's Water*. The New Press, New York.

CAWMA (Comprehensive Assessment of Water Management in Agriculture) (2007) *Water for Food, Water for Life: A Comprehensive Assessment of Water Management in Agriculture*. Earthscan, London / International Water Management Institute, Colombo.

Chapagain, A.K., Hoekstra, A.Y. & Savenije, H.H.G. (2006) Water saving through international trade of agricultural products. *Hydrology and Earth System Sciences* 10 (3), 455–468.

Hoekstra, A.Y. & Chapagain, A.K. (2008) Globalization of water: Sharing the planet's freshwater resources, Blackwell Publishing, Oxford, UK.

Hoekstra, A.Y. & Hung, P.Q. (2005) Globalisation of water resources: international virtual water flows in relation to crop trade. *Global Environmental Change* 15 (1), 45–56

Hoekstra, A.Y., Chapagain, A.K., Aldaya, M.M. et al. (2011) *The Water Footprint Assessment Manual: Setting the Global Standard*. Earthscan, London.

Meybeck, M. (2004) The global change of continental aquatic systems: dominant impacts of human activities. *Water Science and Technology* 49, 73–83.

Postel, S.L., Daily, G.C. & Ehrlich, P.R. (1996) Human appropriation of renewable fresh water. *Science* 271, 785–788.

Shiva, V. (2002) *Water Wars: Privatization, Pollution, and Profit*. South End Press, Cambridge, MA.

UNESCO (2009) *Water in a Changing World: The United Nations World Water Development Report 3*. UNESCO Publishing, Paris / Earthscan, London.

FURTHER READING

Gerbens-Leenes, W., Hoekstra, A.Y. & Van der Meer, T.H. (2009) The water footprint of bioenergy. *Proceedings of the National Academy of Sciences* 106 (25), 10219–10223.

Shiklomanov, I.A. & Rodda, J. (eds.) (2003) *World Water Resources at the Beginning of the Twenty-first Century*. Cambridge University Press, Cambridge.