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Water, Scarcity of

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Introduction

Overexploitation of water has resulted in reduced river flows, declining groundwater tables, shrinking lakes, and heavily polluted waters (Pearce, 2006). About 4 billion people live in areas that face severe water scarcity during at least one month per year (Mekonnen and Hoekstra, 2016). Increased competition has already led to various local and international conflicts over water. Water scarcity (WS) will continue to grow as a result of population and economic growth, increased demands for animal products and biofuels, and climate change. The World Economic Forum has listed WS as one of the global systemic risks of high concern. Water use efficiency improvements may slow down the growth in water demand, but, particularly in irrigated agriculture, such improvements will most likely be offset by increased production (Hoekstra, 2014). Similarly, water storage and transfer infrastructure improve water availability but allow further growth in demand as well. The expected increase in climate variability will exacerbate the WS problem in dry seasons through reduced water availability and increased demand (Haddeland *et al.*, 2014).

WS results from the competition between different water users to get access to limited water resources. This is not be confused with “aridity” or “drought.” Aridity refers to conditions of low water availability: little precipitation compared to potential evaporation. Drought refers to a prolonged period in which rain is substantially below the long term average for that part of the year. WS often occurs in arid and semiarid regions, but also in humid regions, as a result of high population densities and related water demands. WS is different from place to place and shows great intra- and interannual fluctuations, peaking when water availability is relatively low while demand is high. Many areas in the world face WS during part of the year and flooding during another part. The growing WS during the past century can largely be attributed to rising demands for water, which in turn are due to population growth and changing consumption patterns. An important reason for an increasing water demand per capita is the growing fraction of animal products in people's diets, which require more water per unit of energy or protein than nutritionally equivalent crop products (Mekonnen and Hoekstra, 2012). Another factor that will likely contribute to increasing water demands is the switch to biofuels (Gerbens-Leenes, Hoekstra, and Van der Meer, 2009). The water demand of societies mostly relates to water use in agriculture, even in industrialized countries. The amount of water needed to fulfill basic water requirements at home – in the kitchen and bathroom – is small compared to the volumes of water required to grow crops. Inadequate access to safe water and sanitation services – according to the World Health Organization and UNICEF, 748 million people lacked access to safe drinking water and 2.5 billion people had no proper sanitation facilities in 2012 – is not related to WS, but to poverty, lack of infrastructure, and the absence of good institutional arrangements.

Measuring Water Use

Traditionally, water use is measured as the gross water abstraction from surface and groundwater sources. A more comprehensive indicator is the water footprint (WF), a measure of freshwater appropriation underlying a certain product or consumption pattern (Hoekstra *et al*., 2011). Three components are distinguished: the blue, the green, and the grey WF. The blue WF measures net abstraction from surface and groundwater ("blue water"). It thus refers to water evaporated or water incorporated into a product. The blue WF considers net rather than gross water abstraction, because return flows can be reused within the catchment and thus do not contribute to WS. In irrigated agriculture, about 40 percent of water abstractions typically return to local rivers and aquifers; in industries and households this is even 90–95 percent. The green WF is particularly relevant in agriculture and forestry and refers to the rainwater evapotranspiration from fields and plantations and to the rainwater incorporated into biomass. The grey WF measures freshwater pollution and is defined as the freshwater volume needed for the assimilation of a load of pollutants, given the difference between natural background and maximum allowed concentrations.

WS Indicators

A classic WS indicator is the population divided by annual runoff in an area; this is called the water competition level (Falkenmark, Lundqvist, and Widstrand, 1989) or the water-crowding indicator (Falkenmark and Rockström, 2004). Many authors take the inverse ratio: water availability per capita. Regions with more than 1,700 m^3/yr per capita are considered "water sufficient." The threshold is based on the idea that this amount is sufficient to produce the food and other goods and services consumed by one person. The indicator provides limited information, because it only depends on population size and runoff; the indicator does not relate to the actual consumption of the people, the efficiency of water use, or the way in which water-intensive goods are obtained (through self-production or import). When water-intensive goods, particularly food items, are imported, a country with much less than 1,700 m^3/yr per capita may do fine.

Another classic WS indicator is the ratio of annual gross water abstraction to annual runoff in an area, which is called the water utilization level, the water use-to-availability ratio, or the water use-to-resource ratio (Vörösmarty *et al*., 2000). Usually regions with a water utilization level exceeding 40 percent are classified as facing "severe WS." By looking at the actual water use of a population rather than just at the population size, this indicator responds to changes in a population's actual consumption patterns and to associated alterations in water use, improvements in water use efficiency, and shifts in imports and exports of water-intensive commodities. Still, weaknesses of this indicator are that (1) WS typically gets manifest during part(s) of the year and cannot adequately be captured on an annual basis; (2) it would be better to measure water use in terms of net rather than gross water abstraction, because return flows can be reused and thus don't contribute to WS; and (3) water availability is measured as total runoff, while it would be better to subtract environmental flow requirements – the water needed to sustain life and water-dependent socioeconomic activities along the river.

To repair the weaknesses of the classic water use-to-availability ratio, Hoekstra *et al*. (2011) define blue WS as the ratio of blue WF to blue water availability, whereby blue WF refers to net abstraction of surface and groundwater and blue water availability to natural runoff minus environmental flow requirements. Blue WS is to be measured at river basin or subcatchment level with a time step that can adequately capture variations within the year. Hoekstra *et al*. (2012) applied this indicator at a monthly scale and considered, for the world's major river basins, the number of months per year in which the blue WF exceeds blue water availability (Figure 1).

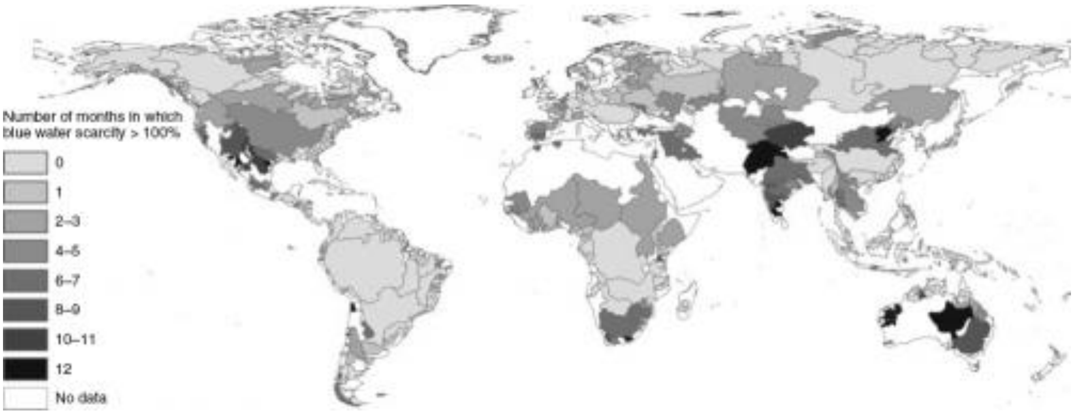

Figure 1 Number of months per year in which the blue water footprint exceeds blue water availability for the world's major river basins. Period 1996–2005. Source: Hoekstra *et al*. (2012).

Another critique of existing WS indicators is that no separate analysis is made of groundwater and river depletion. Recent developments – as new data and models are becoming available – show that it is possible to estimate water abstractions from ground and surface water separately, as well as water availability in both systems, enabling specific groundwater depletion studies (Wada *et al*., 2010). It is further to be noted that WS is not only a matter of quantitative depletion of natural groundwater and river flows but also an issue of deteriorating water quality. Finally, a focus on ground and surface WS is too narrow, because it disregards scarcity of rain and soil water, which is key in agriculture. Therefore Falkenmark (2003) has proposed to look beyond the use and availability of water in the surface–groundwater system (blue water) by also considering the use and availability of rainwater stored in the soil for plant growth (green water). Indicators of green water scarcity are still under development (Schyns, Hoekstra, and Booij, 2015).

Mitigating WS

Blue and green WS and pollution form a societal risk, since water is a vital input in food and energy production. Even consumers and companies in water–abundant places become vulnerable to the effects of water depletion and deterioration, because supply chains of most commodities nowadays stretch across the globe. An estimated 22 percent of water consumption and pollution in the world relates to producing export commodities (Hoekstra and Mekonnen, 2012). Countries like the United States, Brazil, Argentina, Australia, India, and China are big “virtual water exporters,” which means that they intensively use domestic water resources for producing export commodities. Reversely, countries in Europe, North Africa, and the Middle East, as well as Mexico and Japan, are dominated by “virtual water import,” which means that they rely on import goods produced with water resources elsewhere. The water use behind those imported goods is often not sustainable, because many of the export regions overexploit their water resources.

Water is a public good, vulnerable to free–rider behavior, and WS and pollution remain unpriced. In many countries water use is subsidized, either through direct governmental investments in water supply infrastructure or indirectly, through agricultural subsidies, promotion of crops for bioenergy, or fossil energy subsidies provided to pump water. There is an urgent need for governmental regulation and international cooperation. Governments should develop monthly WF caps for all river basins in the world, in order to ensure sustainable water use within each basin (Hoekstra, 2013). The total volume of WF permits to specific users in a basin should remain below the maximum sustainable level. In addition, WF benchmarks need to be established for water–intensive products like food and beverage products, cotton, cut flowers, and biofuels. The benchmark for a product will depend on the maximum reasonable water consumption in each step of the product's supply chain, as based on best available technology and practice. In this way producers who use water, governments that allocate water and manufacturers, retailers and final consumers at the lower end of the supply chain share information about what are “reasonable WFs” for various process steps and end products. Finally, users should pay for their pollution and consumptive water use with a differentiated price in time and space, which should be based on water vulnerability and scarcity.

SEE ALSO: Consumption, Green/Sustainable; Environmental Problems; Population and the Environment

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