Virtual water trade between nations: a global mechanism affecting regional water systems

by A.Y. Hoekstra

How can people in Japan affect the hydrological system in the United States? And how do people in the Netherlands affect regional water systems in Brazil? The obvious answer is: through contributing to changes in the global climate system. We know that local emissions of greenhouse gasses contribute to the predicted change of the global climate, thus affecting temperature, evaporation and precipitation patterns elsewhere. There is however a second mechanism through which countries affect water systems in other parts of the world. There is a direct link between the demand for water-intensive products (notably crops) in countries such as Japan and the Netherlands and the water used for production of export goods in countries such as the United States and Brazil. The water used for producing export goods for the global market significantly contributes to the change of regional water systems.

Japanese consumers put pressure on water resources in the US, contributing to the mining of aquifers, emptying of rivers and increased evaporation in North America. We know the examples of the mined Ogallala Aquifer and emptied Colorado River. Dutch consumers contribute, to a highly significant degree, to the water demand in Brazil. The question put here is: how significant are these tele connections in the global water system via the mechanism of global trade? Recent research [1,2] shows that the impact of global trade on regional water systems is at least as important as the impact of climate change on regional water systems. Although a large part of the impacts of climate change are yet to come, the impacts of global trade on water systems are visible and already occurring today.

Producing goods and services generally requires water. The water used in the production process of an agricultural or industrial product is called the 'virtual water' contained in the product. About ten years ago, Tony Allan, from the University of London, introduced this concept. For example, in order to produce 1 kg of grain we need 1-2 m^3 of water. Producing 1 kg of cheese requires 5 m^3 of water and for 1 kg of beef we need 16 m^3 of water on average. If one country exports a water-intensive product to another country, it exports water in virtual form. In this way some countries support other countries in their water needs. Trade of real water between water-rich and water-

Virtual Water Pilot Project

Earth System Science Partnership

The new Global Water System Project (www.gwsp.org) analyses the impacts of human activities on the Global Water System, emphasising the interactions and feedback between the global and the regional scale. Virtual water provides a teleconnection in the Global Water System, linking through global trade water resources in different regions. Virtual water trade also illustrates the interactions in the coupled human-environment system, a key aspect of the Earth System Science Partnership. It has biophysical dimensions, such as climate induced water scarcity as a driver or water savings through production in more humid regions, but also socio-economic dimensions, such as allocations of water at different scales, opportunity costs of water used in export agriculture etc. The GWSP has initiated a Virtual Water Pilot Project, synthesising information on current virtual water fluxes and outlining relevant research questions as a fast track activity. It may address questions of environmental or socio-economic impacts of virtual water trade, or the usefulness of virtual water trade as a tool in an integrated water resources management context, or the potential for compensation mechanisms for the water footprint that countries leave in other regions.

poor regions is generally impossible due to the large distances and associated costs, but trade in water-intensive products (virtual water trade) is realistic.

In order to assess the virtual water flows between nations, the basic approach has been to multiply international trade volumes (ton / yr) by their associated virtual water content (m^3 / ton). Trade data have been taken from the United Nations Statistics Division in New York. The virtual water content of crops has been estimated per crop and per country on the basis of various FAO databases (CropWat, ClimWat, FAOSTAT). The virtual water content of livestock products has been calculated along

Potatoes	160
Maize	450
Milk	900
Wheat	1200
Soybean	2300
Rice	2700
Poultry	2800
Eggs	4700
Cheese	5300
Pork	5900
Beef	16000

Table 1. Virtual water content of a few selected products in m^3/ton. Source: [3,4].

the lines of 'production trees' that show different product levels [3]. The virtual water content of meat for instance depends on the virtual water content of the animal carcass, which in turn depends on the virtual water content of the live animal. If the carcass of the live animal provides skin for leather as well, the virtual water content of the live animal is divided over carcass and skin according to the economic value ratio. The virtual water content of a live animal largely depends on the virtual water content of the feed consumed during the lifetime of the animal. Added to that is the drinking water required during the lifetime of the animal and if relevant other water requirements such as for cleaning stalls.

Table 1 gives the estimated virtual water content for a number of products. The given figures represent global averages. There are very significant differences between countries, mainly relating to differences in climate conditions, but in the case of livestock products also relating to differences in animal diets in different countries.

The global virtual water trade is estimated to be $1+10^{12}$ m^3 / yr in the period 1995-1999, of which 67% relates to international trade of crops, 23% to trade of livestock and livestock products and 10% to trade of industrial products [1,3,4]. Other global studies of global virtual water trade show estimates in the same order of magnitude [5,6]. For comparison: the global water withdrawal for agriculture (water use for irrigation) in the same period was about 2500 Gm^3 / yr. Taking into account the use of rainwater by crops as well, the total water use by crops in the world has been estimated at 5400 Gm3 / yr. The total water use in the world for domestic and industrial purposes has been estimated at 1200 Gm3 / yr. This means that about 15% of the water used in the world for human purposes is not used for domestic consumption but for export (in virtual form).

The world's nations do not have comparable shares in global virtual water trade. Dominant virtual water exporters are the USA, Canada, Australia, Argentina and Thailand. Countries with a large net import of virtual water are Japan, Sri Lanka, Italy, South Korea and the Netherlands.

Based on the estimated global virtual water trade flows, we can draft national virtual water trade balances. The balance is calculated by adding all virtual water

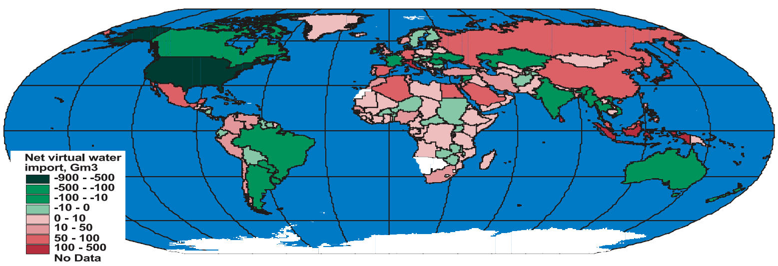

Figure 1. National virtual water trade balances over the period 1995-1999. Red represents net import, green net export.

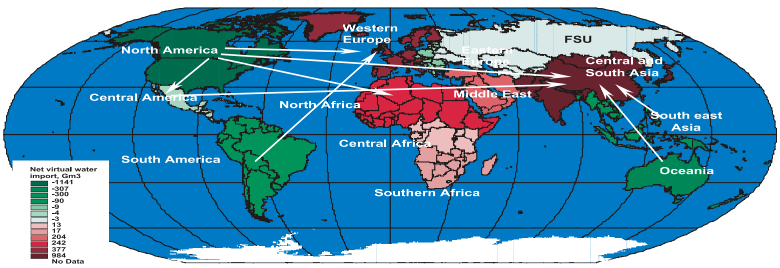

Figure 2. Virtual water trade balances of thirteen world regions over the period 1995-1999. The arrows show the largest net virtual water flows – the most important tele-connections – between regions (virtual water flows>100 Gm^3).

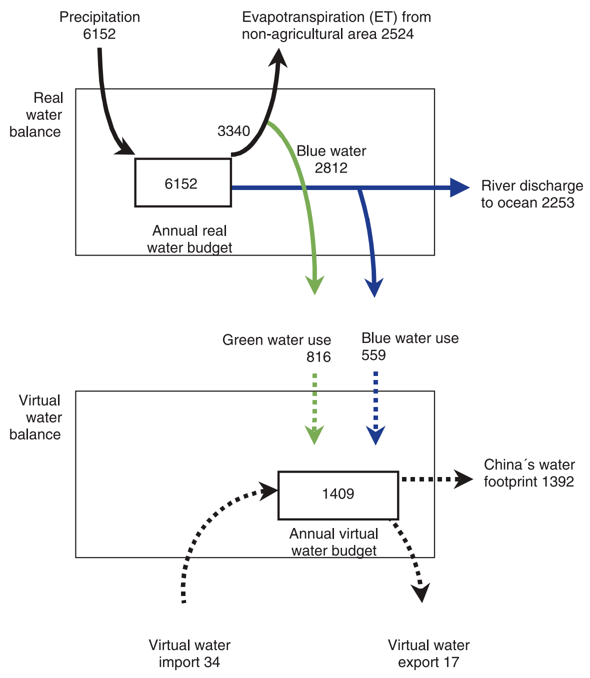

Figure 3. The real and the virtual water balance of China in 1999 (data in Gm^3/yr).

imports and subtracting all virtual water exports. The national virtual water trade balances over the period 1995-1999 are shown in Figure 1. Countries with net virtual water export (a negative balance) are shown in green colour and countries with net virtual water import (a positive balance) in red colour. Figure 2 shows the virtual water trade balances for thirteen world regions and also shows the largest virtual water trade flows between these regions.

The virtual water concept offers the possibility to analyse the impacts of consumption patterns on water use. Per country, we have calculated the cumulative virtual water content of all goods and services consumed by the individuals of the country [1]. In this way we have calculated what we call the 'water footprint' of a nation, a term chosen in analogy of the ecological footprint [7]. The water footprint of a nation is equal to the use of domestic water resources, minus the virtual water export flows, plus the virtual water import flows. Generally, the water footprint of a nation partly weighs upon their own domestic water resources and partly on foreign water resources (i.e. the water resources of the countries from which water-intensive products are imported). Import of virtual water can thus be seen as an alternative source of water, relieving pressure on the resources of importing countries.

As an example of how the real water balance and the virtual water balance of a country link to each other, Figure 3 shows both balances for China in the year 1999. The total use of domestic water resources in China is 1375 billion m^3/yr (59% 'green' water, 41% 'blue' water), of which 1.2% is used for export. The water footprint in China is 1392 billion m^3/yr, pressing on domestic resources for 97.6% and on foreign water resources for the remaining 2.4%. This is not so much, but is likely to increase in the future. China is just one example in the whole spectrum of cases. Some countries, such as the United States, Canada, Australia, Argentina and Thailand, have net export of virtual water, so they do not depend on foreign water resources. However, an extreme example at the other end of the spectrum is Jordan, which depending on the year considered, relies on foreign water resources to satisfy 60 to 90% of its domestic water need.

The overall picture is that 15% of the world water use is not for meeting domestic demands, but for meeting foreign demands, often located on other continents. In other words, roughly speaking, 15% of the disturbances of regional water systems that have been widely reported are linked to demands for water-intensive products in other parts of the world. Given the ongoing process of globalisation, these tele connections are likely to become increasingly important.

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