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Analysis

Sustainability of national consumption from a water resources perspective: The case study for France

A. Ertug Ercin *, Mesfin M. Mekonnen, Arjen Y. Hoekstra

Twente Water Centre, University of Twente, P.O. Box 217, 7500 AE Enschede, The Netherlands

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ABSTRACT

It has become increasingly evident that local water depletion and pollution are often closely tied to the structure of the global economy. It has been estimated that 20% of the water consumption and pollution in the world relates to the production of export goods. This study analyzes how French water resources are allocated over various purposes, and examines impacts of French production in local water resources. In addition, it analyzes the water dependency of French consumption and the sustainability of imports. The basins of the Loire, Seine, Garonne, and Escaut have been identified as priority basins where maize and industrial production are the dominant factors for the blue water scarcity. About 47% of the water footprint of French consumption is related to imported agricultural products. Cotton, sugar cane and rice are the three major crops that are identified as critical products in a number of severely water-scarce river basins: The basins of the Aral Sea and the Indus, Ganges, Guadalquivir, Guadiana, Tigris & Euphrates, Ebro, Mississippi and Murray rivers. The study shows that the analysis of the external water footprint of a nation is necessary to get a complete picture of the relation between national consumption and the use of water resources.

1. Introduction

In recent years, it has become evident that local water depletion and pollution are tied to the structure of the global economy (Hoekstra and Chapagain, 2007). It has been estimated that about twenty percent of the water consumption and pollution in the world relates to the production of export goods (Hoekstra and Mekonnen, 2012). International trade in commodities implies long-distance transfers of water in virtual form, where virtual water is understood as the volume of water that has been used to produce a commodity and that is thus virtually embedded in it (Chapagain and Hoekstra, 2008). Knowledge about the virtual-water flows entering and leaving a country can cast a new light on the actual water scarcity of a country. For developing a responsible national water policy, it is also relevant to consider the linkages between consumed goods in a country and impacts on freshwater systems where the goods are produced.

The water footprint is an indicator of freshwater use that looks not only at direct water use of a consumer or producer, but also at the indirect water use. The water footprint can be regarded as a comprehensive indicator of freshwater resources appropriation, next to the traditional and restricted measure of water withdrawal (Hoekstra et al., 2011).

The objective of this study is to carry out a water footprint assessment for France from both a production and consumption perspective. The aim of the assessment from the production perspective is to analyze how French water resources are allocated over various purposes, and examine where the water footprint of production within France exceeds local environmental flow requirements and ambient water quality standards. Additionally, the aim is to quantify which volumes of French water resources are allocated for making products for export and to assess the impact related to this water footprint for export. The assessment from the consumption perspective focuses on the analysis of the external water footprint of French consumption, to get a complete picture of how national consumption translates to water use, not only in France, but also abroad, and to assess French dependency on external water resources and the sustainability of imports. The sustainability is addressed from environmental perspective; social and economic aspects are not taken into account.

The study starts with a quantification and mapping of the water footprint of the agricultural and industrial sectors and of domestic water supply within France. Next, virtual water imports into France and virtual water exports leaving France are quantified, by traded commodity. Subsequently, the internal and external water footprints of French consumption are analyzed. Finally, it has been analyzed which components of the French blue water footprints of production and consumption contribute to blue water scarcity in specific river basins and which products are responsible herein.

From a methodological point of view, this study improves upon the previous country-specific water footprint studies in three ways, following the global study by Mekonnen and Hoekstra (2011b). First, the water footprints of production and consumption are mapped at a high level of spatial detail. Second, the analysis explicitly

* Corresponding author. Tel.: +31 534854466; fax: +31 534855377.
E-mail addresses: a.e.ercin@utwente.nl (A.E. Ercin), M.M.Mekonnen@utwente.nl (M.M. Mekonnen), a.y.hoekstra@utwente.nl (A.Y. Hoekstra).

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includes green, blue and gray water footprints. Finally, we make a substantial step beyond quantifying and mapping the country's water footprint of production and consumption by analyzing how different components in the water footprint may contribute to blue water scarcity in different river basins and identifying which products are behind those contributions.

2. Method and Data

2.1. Water Footprint Accounting

This study follows the methodology and terminology of water footprint assessment as described in the Water Footprint Assessment Manual (Hoekstra et al., 2011). A water footprint has three components: green, blue and gray. The blue water footprint refers to consumption of blue water resources (surface and ground water). The green water footprint is the volume of green water (rainwater) consumed, which is particularly relevant in crop production. The gray water footprint is an indicator of the degree of freshwater pollution and is defined as the volume of freshwater that is required to assimilate the load of pollutants based on existing ambient water quality standards.

The water footprint of national production is the total freshwater volume consumed or polluted within the territory of the nation. This includes water use for making products consumed domestically but also water use for making export products. It is different from the 'water footprint of national consumption', which refers to the total amount of water that is used to produce the goods and services consumed by the inhabitants of the nation. This refers to both water use within the nation and water use outside the territory of the nation, but is restricted to the water use behind the products consumed within the nation. The water footprint of national consumption thus includes an internal and external component. The internal water footprint of national consumption is defined as the use of domestic water resources to produce goods and services consumed by the national population. It is the sum of the water footprint within the nation minus the volume of virtual-water export to other nations insofar as related to the export of products produced with domestic water resources. The external water footprint of national consumption is defined as the volume of water resources used in other nations to produce goods and services consumed by the population in the nation considered. It is equal to the virtual-water import into the nation minus the volume of virtual-water export to other nations because of re-export of imported products.

The water footprint of crops and derived crop products produced in France or elsewhere were obtained from Mekonnen and Hoekstra (2010a, 2011a), who estimated the global water footprint of crop production with a crop water use model at a 5 by 5 arc minute spatial resolution. The water footprint of animal products that are produced in France was taken from Mekonnen and Hoekstra (2010b, 2012). The data related to the water footprint of production and consumption in France and the virtual water flows to and from France were taken from Mekonnen and Hoekstra (2011b). In all cases, data refer to the period 1996–2005.

2.2. Identifying Priority Basins and Products

For the blue water footprint of French production and consumption, some additional analysis was carried out in order to identify river basins of concern. After we quantified and mapped the blue water footprints of French production and consumption, we estimated which parts of both water footprints are situated in river basins with moderate to severe water scarcity during part of the year. Monthly blue water scarcity values for the major river basins around the world were taken from a recent global water scarcity study (Hoekstra and Mekonnen, 2011; Hoekstra et al., 2012). The blue water scarcity values in that study were calculated by taking the aggregated blue water footprint of production per basin and per month over the blue water availability in that basin and month. The latter was taken as natural runoff in the basin minus a presumptive standard for the environmental flow requirement in the basin. They classified blue water scarcity values into four levels:

- low blue water scarcity (<100%): the blue water footprint is lower than 20% of natural runoff and does not exceed blue water availability
- moderate blue water scarcity (100–150%): the blue water footprint is between 20 and 30% of natural runoff
- significant blue water scarcity (150–200%): the blue water footprint is between 30 and 40% of natural runoff
- severe water scarcity (>200%): the monthly blue water footprint exceeds 40% of natural runoff.

The following three criteria have been used to identify priority basins regarding the various components of the blue water footprint of French production or consumption: level of water scarcity over the year in the basin where the water footprint component is located, the size of the blue water footprint of French production or consumption located in the basin (agricultural and industrial products separately), and the significance of the contribution of a specific product to the total blue water footprint in the basin in the scarce month.

A specific river basin is identified as a 'priority basin' related to France's water footprint of production or consumption of agricultural/industrial products if three conditions are fulfilled: (a) the river basin experiences moderate, significant or severe water scarcity in any specified period of the year; (b) the French blue water footprint of production or consumption of agricultural/industrial products located in that basin is at least 1% of total blue water footprint of production or consumption of agricultural products; and (c) the contribution of any specific agricultural commodity to the total blue water footprint in that specific basin in the period of scarcity is significant (more than 5%). In addition, a river basin is also identified as a priority basin if the following two conditions are met: (a) the water scarcity in the river basin is severe during any month of the year; and (b) the contribution of any specific agricultural commodity/industrial product produced or consumed in France to the total blue water footprint in that specific basin in the period of scarcity is very significant (more than 20%). Fig. 1 shows how basins are identified as a "priority basin".

3. Water Footprint Calculations

3.1. Water Footprint of Production

The total water footprint of national production in France is 90 Gm^3/year for the period 1996–2005, which is 1% of the total water footprint of production in the world (Hoekstra and Mekonnen, 2012). The largest part of this water footprint is green (76%), followed by gray (18%) and blue (6%) (Table 1). Crop production constitutes the largest share (82%) in the water footprint of national production in France, followed by industrial activities (8%), grazing (6%), domestic water supply (3%) and livestock production (drinking and service water) (1%). Among the crops, cereals contribute 47% to the total water footprint. Fodder crops (15%), oil seed crops (9%) and fruits and nuts (6%) are the other major crop groups with a significant share in the total water footprint. Crop production contributes 50% to the total *blue* water footprint within France. The shares of industrial production, animal water supply and domestic water supply in the blue water footprint are 26, 14 and 11% respectively. In France, the gray water footprint is largely due to crop and industrial production.

The spatial distributions of the green, blue and gray water footprints of national production in France are shown in Fig. 2. Center region has the largest water footprint with 9.6 Gm^3/year (12% of the total). Other