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Global use of water resources: A multiregional analysis of water use, water footprint and water trade balance

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ABSTRACT

In this paper a multiregional input–output model is proposed and used to estimate time series trends for water use, water footprint and water trade balance. By using data provided by the World Input–Output Database, the water used in production, consumption and trade is quantified for 41 world regions between 1995 and 2008. Results show that global water use grew by 37.3%, with China, India and Brazil contributing most to that increase. China and India, together with the EU-27, were also responsible for the largest water footprint variations. In terms of trade, the EU-27 was the largest water importer and China and India the main water exporters. The results provided in this paper offer an overview of the main countries' responsibility for the use of water resources. They provide a good starting point for international debates and policies on sustainable water use.

1. Introduction

During the last century water use has been increasing at more than twice the rate of population growth, making water scarcity one of the most urgent challenges facing human society in the 21st century [36]. Water stress generated by pollution and climate change, a growing world population and an increasing water demand are some of the most important factors affecting the local and global availability of fresh water resources [29,37].

Despite researchers and international organizations increasingly highlighting the global dimension of water changes, most governments still manage water resources from a national perspective, focusing on the use of water within national territories, and ignoring both the large-scale impacts generated by local water use and the global dimensions of water supply. For this reason the majority of water policies are unable to address the issue in an over-national perspective and plans for water policies moving beyond the regional borders are still lacking [17,19]. The lack of data and analysis able to identify countries' responsibility on water trade and consumption is one of the main element making difficult the design of effective water policies and the consequent agreement between countries. In the present context of globalization, where different world regions are ever more integrated into global markets, large volumes of water are implicitly traded between regions, extending water responsibilities far beyond national borders.

To better investigate the existing differences between water demand, water supply and the geographical distance between them, the concepts of water footprint and virtual water trade were elaborated in the 1990s, and, since then, an increasing number of studies have been carried out to quantify these parameters. The water footprint, originally proposed by Hoekstra and Hung [20], in an analogy of the ecological footprint [27], originates from the concept of'virtual water' proposed by Allan [1], in which

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the water footprint of a nation is the total volume of fresh water used to produce the goods and services demanded by the population of the nation, wherever this water has been used. In a similar way, the virtual water trade refers to the water embedded in the products traded between countries [20,42].

Based on these concepts, a large number of studies have quantified the water footprint of countries and the water embodied in products [6–9,14,18,22,26,31,41]. In spite of the global dimension of water changes, the majority of these studies involve only a local perspective, and very few researchers have focused on a global analysis [18,20]. Recently, Hoekstra and Mekonnen [21] presented the first global estimation of water used and traded between countries. However, as their work covered an annual average for the period 1996–2005, the results do not show global water changes over time. Steen-Olsen et al. [31] use a global model to estimate the water consumption and the (blue) water footprint of the EU-27 but also for one single year (2004). More recently, Roson and Sartori [28] use a global model and the World Input–Output Database (WIOD) to decompose the change in the water footprint. In this paper we go a step beyond and provide, for the first time, complete time series data for global water use,[1] water footprint (including results by consumption category) and water trade balance for the period 1995–2008. By using a multiregional input–output model and data from the WIOD, we provide water estimations for 40 regions: the 27 Member States of the European Union (EU-27), Australia, Brazil, Canada, China, India, Indonesia, Japan, South Korea, Mexico, Russia, Taiwan, Turkey, and the United States, and for the Rest of the World (RoW) as an aggregated region. The time series data provided in this paper are essential information both for the scientific community and for the policy arena. By estimating the water use, the water footprint and the water trade balance that took place at a global level for more than a decade, this paper supplies key information to aid investigation into key drivers in the use of water, to analyze the water dependency of countries, to asses country's responsibilities in terms of hydric stress and scarcity from a global perspective, to investigate the impacts of international trade and, ultimately, to help plan policies for a global sustainable water strategy.

The paper is structured as follows. Section 2 presents the database and explains the multiregional input–output method used to quantify the water use, the water footprint and the water trade balance. Section 3 summarizes the disaggregated results for water use, water footprint and water trade balance. Section 4 concludes. Additional data and tables are reported in Appendix.

[1] Note that here the term water use refers to the total amount of water used by the different economic activities and include both the portion of water not returned to the original source (i.e. water consumption) and the volume of water returned.

2. Data and method

2.1. Data

The World Input–Output Database is composed of a set of harmonized supply, use and symmetric multi-regional I-O tables reported both at current and previous year prices, and disaggregated between 35 industries, 59 products and 5 categories of final demand. The time period covered is 1995 to 2009,[2] and it includes data for 40 countries plus the Rest of the World (RoW) as an aggregated region. The WIOD also includes socio-economic and environmental satellite accounts for energy, emissions, water, land and materials.

The water data provided in the WIOD are used in this paper to calculate, for the first time, the water use, the water footprint and the water trade balance for all the countries reported in the database (for further information see [34]). From a methodological point of view, water data in the WIOD are estimated by using the concepts of blue, green and gray water as proposed by Hoekstra et al. [19]. In addition, the agricultural water use of the WIOD has been estimated based on data on crop production and livestock provided from FAOSTAT and based on the crop and livestock water intensities proposed by Mekonnen and Hoekstra [23,24]. Similarly, the water evaporated from artificial reservoirs to produce electricity has been calculated using the world average water use per unit of electricity as estimated by Mekonnen and Hoekstra [27] and the hydropower generation from the IEA. The use of water in other economic sectors has been calculated by using the total water use in industry as reported by Mekonnen and Hoekstra [25], the shares of water use by industry in the EXIOPOL database, and the sectoral gross output at constant prices from the WIOD. Finally, water use by households is estimated on the basis of the average domestic water supply from Mekonnen and Hoekstra [25] and population data from the United Nations.

2.2. Method

Two different approaches have generally been used in literature to quantify the water footprint and virtual water trade of countries, namely: the bottom-up approach and the top-down approach (see [2,13] for a detailed description and discussion of differences). In this paper we use a top-down approach using a Multi-Regional Input-Output (MRIO) model.

MRIO models have been widely used to calculate footprints and to analyze the environmental consequences of trade [35,38,39,40]. Although these models have generally been used to estimate CO_2 emissions, some applications exist for calculating the water footprint and the virtual water trade of specific countries [13,31]. A methodology is described in this paper for the case of 3 regions (1, 2 and 3) with n sectors, and 1 type of water but it could be applied to any number of regions and sectors. In this paper, the

[2] As the 2009 figures are preliminary estimates, the time span used in this paper has been limited to the period 1995–2008.