**Virtual water supply chains multeity buffers cities against droughts episodes and climate strikes**

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**Abstract**

Water had a great influence on the rise and collapse of ancient civilizations. Nowadays, mankind faces related water problems exacerbated by intensive farming, rapid urbanization, and climate change strikes.

The world’s population is becoming increasingly dependent on water resource. However, most of the water humanity is currently consuming is invisible, and we know less how this virtual water is circulating across via the economic exchanges channels.

To compute and decompose cities’ virtual water (Bleu and Grey) of the global South, we used Extended Environmental Input-Output Analysis (EE-IOA) coupling global supply chain database of a multi-region input-output (MRIO) tables and cities’ final demand vectors (in form of consumers expenditures surveys). Results showed that

To put the climate-induced uncertainties in perspective, it is better to act in a pro-active approach and to spread consciousness regarding the selection of products and services that are associated with less virtual water footprints.

**Keywords**

Virtual water; cities; water security; urban sustainability; input-output analysis; global south

**Graphical abstract**



1. **Introduction**

**The status of water and the role of global warming**

Water is a finite resource and plays a major role in urban development and ecosystems sustainability. Thorough history, the first mankind’s revolutions testifies on the relevance and the safety of water as resource (e.g., ancient human civilizations Mesopotamia, Egyptian, Greek and Roman). 97% of the water on Earth is saltwater, leaving only 3% as freshwater, only 1% of which is readily available for human consumption including power generation, irrigation, industrial activities, and daily use.

The world’s population is becoming increasingly dependent on this valuable resource. Water is considered to be a *“human right”* that is currently under sever strikes. The Millennium Development Goal defined *water security* as *“access to safe drinking water and sanitation”*.

Health problems and environmental risks can be abstained.

Unfortunately, we’re living in a changing climate, climate change is currently effecting water planning include changes in precipitation events, runoff patterns, and droughts. Despite recent advancements in climate research, there is still a lot of uncertainty about how and when the climate will change, and how these changes will affect water availability within an increasing demand for water, worldwide.

Many areas around the world are facing water-related issues such as Cape Twon in 2018 where the city experienced the Day-Zero.

**Virtual water, what does it means?**

However, virtual water (also including virtual carbon, energy, nitrogen, phosphorus, human approrition …) is not yet regulated by any national or international protocol.

**The role of water in urban development and sustainability future (urban metabolism approach)**

Supply and demand for water encompasses other non-climatic factors that might have a considerable effect on water including demographic growth, economic growth, affluence, and geopolitics. Cities are hyper-complex system that require inputs from the national and international markets to satisfy their development needs.

In addition, water pollution is increasing across the world which further shrink the available water for anthropogenic activities.

Water supply is bound with time, geography and climate hazards, therefore, societies of the global south should innovate new lifestyle patterns and

Developing economies are trying to grow so fast, without paying attention to the environmental degradation generated during this process.

**The novelty of this article**

The novelty of this study is that it computes the different types of virtual water namely blue and grey water for 197 cities belonging to the Global South and decomposes each water footprint by major final consumptions categories (Food, Goods, Services, Transport, and Others) in order to allocate responsibilities to final demand sectors and trigger potential policy leverages.

1. **Methods and Materials** 
   1. **Data collection**

To answer our research questions, we needed two types of data. The first is urban expenditures surveys (UES) or consumers expenditures surveys (CES) (also denoted as city final demand vector - -) following COICOP-categorization of the 186 selected cities belonging to 24 Middle-Income Countries (MICs), see electronic supplementary information (ESI) file for further details. Data were retrieved from the office of statistics of each host-country. Notice that data collection methods and quality may vary from a country to country, hence, from a city to city (took as-is). Because of data scarcity in the Global South, cities final demand vectors - - were not taken at the same year because of the internal protocol of each host-country to establish and deploy the consumer expenditures surveys, some countries establish them annually, while others quinquennial as such several limitations are to encounter while comparing results among selected cities. The second data constitutes of global Multi-Regional Input-Output (MRIO) tables which were retrieved from Eora global supply chain database (Lenzen et al., 2013, 2012). Eora provides multi-region input-output table (MRIO) model that provides a time series (from 1990 to 2021) of high-resolution Input-Output (IO) tables (capturing the inter-sectoral transfers amongst 15,909 sectors) with corresponding environmental and social satellite accounts () for 190 nations. We used Input-Output tables (version 199.82) harmonized to 26 sectors to enable a transparent and an accurate comparison across selected cities.

* 1. **Method**

For this study we used Environmental Extended Input-Output Analysis (EE-IOA). Our analysis process is divided into two parallel phases (Fig.1). The first in which we collected cities final demand vectors () in local currencies, next we aggregated the values (via a distributive process) to match Eora 26 sector classification, after we converted the final demand arrays from local currencies into $US using the World Bank exchange rates (World Bank, 2021). In the second phase, we computed the direct intensity vectors () as shown in Eq.1 (for each year corresponding the selected city’s final demand vector) for each virtual water category (Grey, and Blue water), after we computed the final demand vector () using the Leontief inverse as shown in Eq.2.

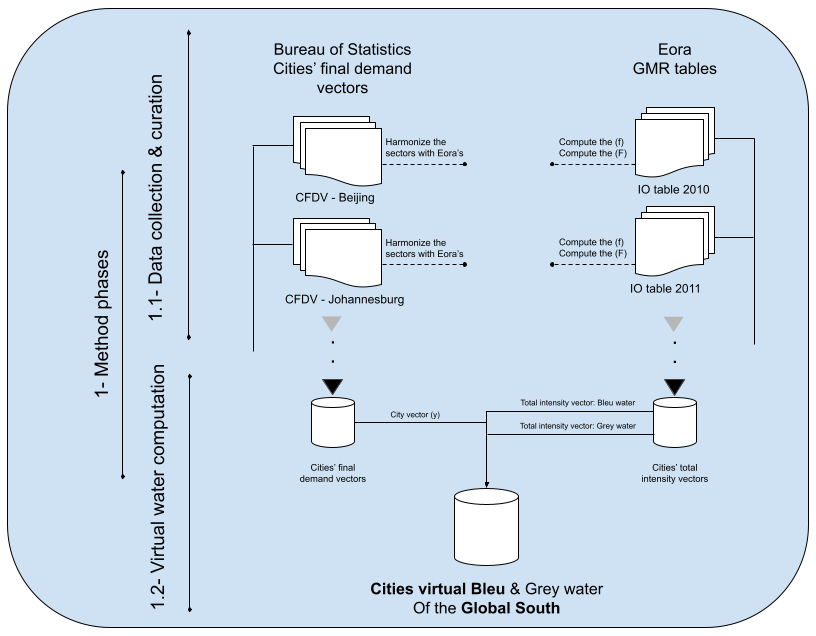
…(Eq.1)

… (Eq.2)

Next, cities final demand vectors - - were converted from purchases price (PP) to base price (BP) on a sector by sector basis using national BP/PP ratios computed from Eora’s Multi-Regional Input-Output tables (as implemented in (Pichler et al., 2017)). To compute cities’ virtual water footprints (for each sector), we multiplied element wise the total demand vector (f) with the city final demand vector () as shown in Eq.3.

... (Eq.3)

Where is the virtual water per capita quantities (m3/year), is the total intensity vector, and is the city final demand vector.

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**Figure 1:** Method utilized to compute cities’ virtual water of the Global South.

1. **Results and discussions**
   1. **Urban virtual water of the Global South: Learning from contexts**

Results (Fig.02) for the Bleu water category shows that Asian and North African cities are the among the highest Global Southern cities that imports fresh water from the global economic market. For Asia, three Chinese’s cities have the highest quantities of imported water embedded within goods and services namely Beijing with 328.45 liters per capita/yr, followed by Guangdong with 267.42 liters per capita/yr, and Jiangsu with 248 liters per capita/yr. From North African region, we find Tunis (Tunisia) is associated with 314.65 liters per capita/yr, while Casablanca, Tangier and Laayoun (Morocco) are associated with the respected total embedded fresh water 301.1, 285.6, and 251.65 liters per capita/yr.

On the other hand, results for the Grey water category, we found that Atolls (Maldives) have the highest virtual water consumption across all the selected cities with value estimated to 667.99 liters per capita/yr, followed by the three Chinese’ major cities Beijing with 622.8 liters per capita/yr, followed Montenegro with 576.64 liters per capita/yr. Chinese cities represent a share of the top Global Southern cities’ fresh water footprint Guangdong with 516.64 liters per capita/yr, and Tianjin with 486.80 liters per capita/yr.

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**Figure 2:** Top 20 Global Southern cities’ with highest values of virtual water.

A deeper look to Fig.02 regarding the sectoral composition of the fresh/Bleu water footprint we found that

North African cities are collecting water/ while major cities are causing water pollution.

* 1. **Urban virtual water policy: Hotspots and architectures of handicaps**

1. **Conclusions**

Water is not unequally distributed across countries and regions, and it’s availability is highly dependent on the future pathways of Earth’s climate system. Moreover, most of the water humanity is currently consuming is invisible by nature. It is embedded within goods and services purchased from the global economic market. Hence, it is also vital to be prepared to manage the virtual part of water while making fundamental decisions or evaluating future choices and strategies.

Cities of the Global South can import goods and services that require massive water input from the global economic market in order to amortize the current and future climate impacts on the local water sources.

1. **References**

Lenzen, M., Kanemoto, K., Moran, D., Geschke, A., 2012. Mapping the structure of the world economy. Environmental science & technology 46, 8374–8381.

Lenzen, M., Moran, D., Kanemoto, K., Geschke, A., 2013. Building Eora: a global multi-region input–output database at high country and sector resolution. Economic Systems Research 25, 20–49.

Pichler, P.-P., Zwickel, T., Chavez, A., Kretschmer, T., Seddon, J., Weisz, H., 2017. Reducing Urban Greenhouse Gas Footprints. Sci Rep 7, 14659. https://doi.org/10.1038/s41598-017-15303-x

World Bank, 2021. Official exchange rate (LCU per US$, period average) | Data [WWW Document]. URL https://data.worldbank.org/indicator/PA.NUS.FCRF (accessed 11.1.21).