Hydrol. Earth Syst. Sci. Discuss., 9, C6729–C6738, 2013
www.hydrol-earth-syst-sci-discuss.net/9/C6729/2013/

Hydrology and Earth System Sciences Discussions

Interactive comment on "Local and global perspectives on the virtual water trade" *by* S. Tamea et al.

S. Tamea et al.

stefania.tamea@polito.it

Received and published: 13 February 2013

We thank both reviewers for their comments and suggestions. In the following we detail our replies following the relevant points of each review, starting from the Anonymous Referee 1 to which we are grateful for interesting suggestions (quoted below) allowing for manuscript improvement.

« RIVER NETWORKS AND RIVER DELTAS OF VIRTUAL WATER. While I think that the river networks and river deltas are aesthetically pleasing (which I really like) and potentially useful GRAPHICAL representations of virtual water trades, they are NOT appropriate NETWORK representations of them. [. . .] This is all fine, but it must be explained and emphasized more

explicitly as to avoid misleading the casual reader of the manuscript. »

The reviewer is right in emphasizing that graphical representations of virtual water flows in the form of rivers/deltas do not refer to a proper "network" representation, in that flows to/from Italy are associated to food trading which connects directly this country with each of the trading partners. However, the river network representation allows one to visualize aggregated flows to/from nearby countries and different geographical areas, and it is particularly useful for an immediate comparison of contributions from different continents (e.g., are flows from Africa and Asia –as a whole- very different?). Such aggregation also enables a direct comparison with numerical data provided in Table 1 of the manuscript which would be missed in a representation with one-to-one country connections. Thus we will add a specification in Section 3.1 of the revised manuscript to better clarify this point and to prevent misunderstanding to the readers.

« VIRTUAL WATER BALANCE (SECTION 3.2). Part of this analysis is based on ranking of the volumes of virtual water in trade. I believe that such ranking, or something very similar, has been conducted somewhere in the existing literature. »

There are two points in the manuscript where rankings are discussed. One is Table 2, which shows the country ranking with respect to the virtual water flows exchanged with Italy; such rankings are new as they are part of the country-based analysis developed in this manuscript. The second point about ranking is in the text at page 12968-12969, with indication of the position occupied by Italy in the world sorting of net import and net per-capita import. This is probably the objective of reviewer's mention but a specification is needed. We are aware that extensive computations of virtual water volumes/flows by country can be found in Mekonnen and Hoekstra (2011), which is also cited in the manuscript, and a form of sorting is deductible from some of their results, e.g. Figure 11, here reported as Figure 1. However, such sorting does not refer to net import (import minus export) nor to per-capita values of the virtual water flows, and we are not aware of explicit ranking of such kind published in the literature.

HESSD
9, C6729–C6738, 2013
Interactive Comment

« DISTANCE-BASED ANALYSES. To my knowledge, this section is quite novel and should be emphasized more. For one thing, it opens the possibility of linking virtual water to energy consumption required to transport it, which would then allow for an even more comprehensive analysis of the effects of trade on the environment. I believe there is a trend among a number of scientists to move toward such analyses, and the authors' analysis could contribute to that development. This is something the authors may wish to include in their discussion, as it broadens the impacts of their work. »

We thank the reviewer for emphasizing the novelty of the proposed "distance-based analysis" and we agree that such part might set the basis for new insights into the characteristics of the virtual water trade network. In light of possible future developments, another piece of information can be given to complement the country-based weighted distances shown in Figure 5 of the manuscript (and corresponding figures in the Supplementary Material). This is the plot of average weighted distances travelled by a generic unit of virtual water exchanged on the international trade network, defined as

$$d_{vw} = \sum_{i,j=1}^{253} \frac{VW(i,j)}{VW_{tot}} \cdot d(i,j) \tag{1}$$

where $VW(i,j)$ is the virtual water exchanged from country i to country j in a given year, $d(i,j)$ is the distance between countries i and j, and VW_{tot} is the total volume of virtual water exchanged worldwide in the same year, i.e. $VW_{tot} = \sum_{i,j=1}^{253} VW(i,j)$, with 253 being the total number of countries considered. Notice that $VW(i,j)$ identifies the elements of the non-symmetrical trade matrix, having null elements on the diagonal, i.e. $VW(i,j) \neq VW(j,i)$ and $VW(i,i) = 0$. Figure 2 in this post shows that the average distance travelled worldwide by virtual water has markedly decreased in time, as a result of strengthening of closer connections to the detriment of farther connections. This figure will be added to the revised manuscript in Section 3.3 together with a brief

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper

explanation.

In order to investigate the rationale behind the global trend shown in the figure above or the sharp drop in the early 1990s, one could focus on the contributions given by each trade link to the average distance travelled by virtual water. Contributions can be quantified by country and separated by the points of view of import and export using the variables

$$d_{vw,imp} = \sum_{i=1}^{253} \frac{VW(i,n)}{VW_{tot}} \cdot d(i,n)\ , \quad d_{vw,exp} = \sum_{j=1}^{253} \frac{VW(n,j)}{VW_{tot}} \cdot d(n,j) \tag{2}$$

whose sums over all countries are both equal to the overall average weighted distance, i.e. $\sum_{n=1}^{253} d_{vw,imp} = \sum_{n=1}^{253} d_{vw,exp} = d_{vw}$.

Considering first the sharp drop in the early 1990s, Figure 3 here shows the largest contributions, in terms of $d_{vw,imp}$ and $d_{vw,exp}$, to the change of overall weighted distance between 1990 and 1992, and the corresponding change in virtual water volumes imported and exported by the same countries. The drop (485 km) is partially justified by the geopolitical change of former URSS, but other major contributions are the decrease in Australian export (in both distances and volume of virtual water), the decreased distance of exports of Argentina and Brazil, the decreased distance of imports (but not in virtual water volume) of Japan and Netherlands and the decreased distance and volumes of imports of China and Iran. Other minor contributions are not shown.

With a similar analysis one can also evaluate the largest contributions to the change between 1986 and 2010 of the overall weighted distance (849 km in total), shown in Figure 4 in this post. A major contribution is given by the decrease of trading distances of the United States, in both import and export; other contributions to the decrease of export distances is given by Australia and Cuba, while Brazil and Argentina had the opposite tendency to increase export distances while increasing also the virtual water volumes exported. As of import, apart from the cessation of URSS trade, Japan, USA and Netherlands have decreased their distances while increasing the virtual water volume imports, whereas China has given the greatest positive contribution to the average distance traveled by virtual water worldwide. As anticipated by the results above, the distance-based analysis has many implications and opens new scientific questions, therefore a paragraph will be added in the revised manuscript in Section 3.3 as suggested by the reviewer.

« Some additional specific comments: P12962, 1st par: Regarding the exponential distributions of the node degrees, please note that while Konar et al. (WRR 2011) reported that they follow exponential distributions, a more recent work by Shutters and Muneepeerakul (PLoS ONE, 2012) questioned this claim. »

We thank the reviewer for pointing out the interesting work by Shutters and Muneepeerakul (2012): we will modify the sentence regarding the exponential distributions of nodes and the corresponding references.

« P12962, 2nd par: "previous country-based works": :it would be good to provide some references of these works. P12963, Methods: Brief definitions of grey, blue, and green waters would be helpful for the reader who is not familiar with these terms. »

A sample of country-based works about virtual water balance is already mentioned in the text and we will make explicit reference to them, as requested. We will also add the required definitions in Section 2.

Finally we also want to thank Maria Cristina Rulli (Referee 2) for her comment:

« Some points could be better addressed: Page 3 line 77 the authors talk about the gray

HESSD

9, C6729–C6738, 2013

Interactive Comment

component of the water footprint, but they do not define the three components (green, blue and grey) of the WF. Page 7 Lines 224-227 Please explain better the concept. »

A brief introduction to the three components of water footprint will be added in the first paragraph of Section 2.

REFERENCES:

Mekonnen M.M., Hoekstra, A.Y. (2011) National water footprint accounts: the green, blue and grey water footprint of production and consumption, *Value of Water Research Report Series No. 50*, UNESCO-IHE, Delft, the Netherlands.

Shutters S.T., Muneepeerakul R. (2012) Agricultural Trade Networks and Patterns of Economic Development, *PLoS ONE*, **7**(7), e39756, doi:10.1371/journal.pone.0039756.

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 9, 12959, 2012.

HESSD

9, C6729–C6738, 2013

Interactive Comment

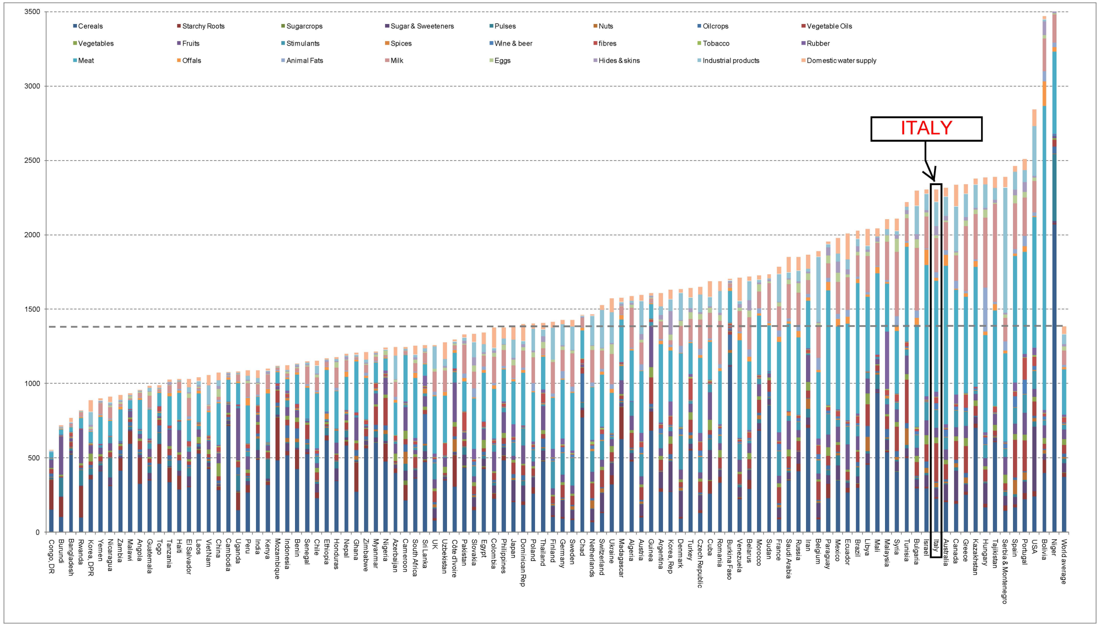

Figure 11. Water footprint of national consumption for countries with a population larger than 5 million, shown by product category (m^3/yr/cap) (1996-2005).

Fig. 1. Example of ranking/sorting from the litterature: Figure 11 in Mekonnen and Hoekstra (2011).

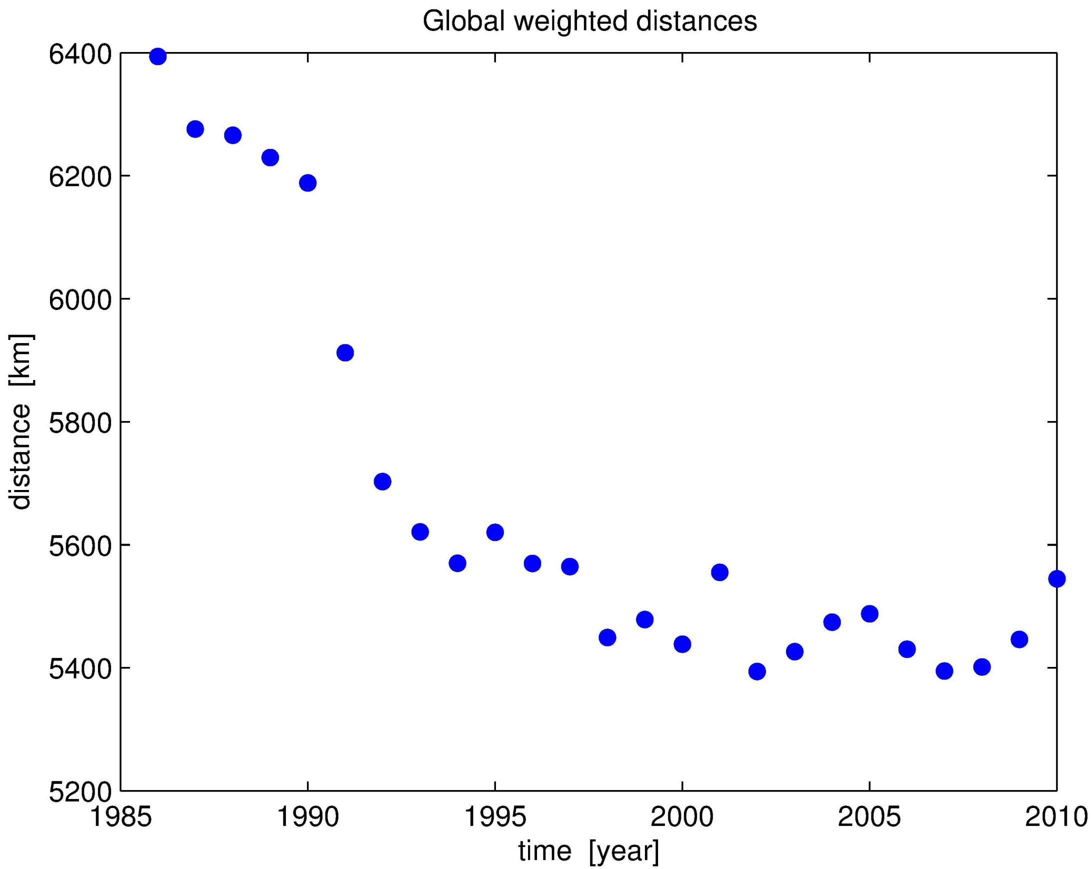

Fig. 2. Plot of average weighted distances travelled worldwide by a generic unit of virtual water exchanged on the international trade network.

HESSD
9, C6729–C6738, 2013

1992-1990	country	contribution to distance change [km]	change in VW volume exchanged [km3]
TOTAL	-	-485	+179.6
EXPORT	Argentina	-84	+7.10
($\Delta d_{vw,exp}$)	Australia	-184	-12.5
	Brazil	-84	+0.21
IMPORT	China	-89	-3.17
($\Delta d_{vw,imp}$)	Iran	-63	-3.32
	Japan	-110	+0.96
	Netherlands	-80	+0.43
	Russian Federation	+209	+54.8
	USSR	-302	-50.8

Fig. 3. Table of largest contributions to the change of average weighted distance between 1990 and 1992, and the corresponding change in virtual water volumes imported and exported by same countries.

2010-1986	country	contribution to distance change [km]	change in VW volume exchanged [km3]
TOTAL	-	-849	+1705
EXPORT	Argentina	+171	+102.7
($\Delta d_{vw,exp}$)	Australia	-451	+15.8
	Brazil	+460	+161.2
	Cuba	-195	-20.3
	USA	-447	+123.0
IMPORT	China	+792	+243.2
($\Delta d_{vw,imp}$)	Japan	-476	+6.67
	Netherlands	-206	+60.5
	Russian Federation	+144	+65.7
	USSR	-510	-71.5
	USA	-316	+54.7

Fig. 4. Table of largest contributions to the change of average weighted distance between 1986 and 2010, and the corresponding change in virtual water volumes imported and exported by same countries.