The Globalisation of Food and Water: The Italian Case

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Food security, intended as the agricultural production capacity to satisfy the nutritional needs of the world’s population, is closely tied to water availability, the latter being essential for the production of any type of food. The water volume required to produce an established quantity of food is called the “virtual water content” and is the amount of water virtually embedded in the good, though not physically present in it. Italy is an exemplary case of high virtual water consumption and dependence on food imports. It is among the leading countries in the world for net virtual water importation, with a high per capita consumption and a persistent reduction in land surface used for agricultural production. Local contradictions arising from the global food supply model are the issue dealt with in this contribution, with particular reference to Italy. Agriculture, often neglected in press campaigns on water saving, is, instead, the main consumer of water; the production of food goods corresponds to a global consumption of about 80–90 % of the total water used to satisfy anthropic demand (Falkenmark and Rockström 2004). The water volume required to produce an established quantity of food is called the “virtual water content” and is the amount of water virtually embedded in the good, though not physically present in it (Allan 1993). For example, it is calculated (Hoekstra and Chapagain 2008) that 1600 l of water are required to produce one kilo of bread and 15,400 l for 1 kg of beef. An individual consumes, on average, 2000 l of water a day, about one thousand times the daily per capita need for drinking water.

Apart from some rare exceptions, in past traditional economies, most food was produced and consumed locally and, consequently, there were no great transfers in virtual water. In these systems, the population growth in a given geographic region was limited by the local water resource availability, tempered by the level of efficiency reached in managing this resource. In recent times, however, the global market trade in food has allowed local populations to be free from the restrictions of local water resource availability, allowing some populations to exceed the food

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need limitations imposed by the water available in loco (Allan 1998). International trade results in the virtual transfer of water from food production areas to importing regions, resulting in a disconnection between demographic expansion and locally available natural resources (Carr et al. 2012).

Scientific research and debates on policies regarding the virtual water trade have shifted towards the idea that, by importing virtual water, countries relatively scarce in water could preserve or use their water reserves quite efficiently (Hoekstra and Chapagain 2008). Not only does international trade lead to a more efficient allocation of goods production with a high water content, but it also contributes to decreasing the use of water at a global level. Thanks to the production specialisation imposed by trade, a growing part of high water content goods can be produced in countries with a more efficient water use and exported to less efficient countries. Indeed, according to most studies on the issue, the net effect of the world virtual water trade appears to reduce the overall use of water (De Fraiture et al. 2004; Oki and Kanae 2004; Hoekstra and Chapagain 2008).

However, in certain cases, the empirical evidence clashes with this theory. The studies on virtual water flows highlighted, for example, that major trade occur from relatively water-short regions to regions with abundant water resources. Well-known examples include China (Hoekstra and Chapagain 2008) and India (Verma et al. 2009), but also Africa emerges as an exporter of virtual water to Italy, despite the limited water availability of many African countries. This can be explained by the fact that the cost of water represents only a small part of the production cost, together with the fact that water is not generally traded at market prices (Hoekstra and Chapagain 2008). This situation derives from various "externalities", that is situations where the value of the traded goods does not take into account all the actual costs involved in their production, and in these circumstances, a water resource use results in being incompatible with its availability. The absence of a suitable and common system of rules to define water resource economic value leads to difficulties in assessing the possible over-exploitation of the resource in fragile contexts from socio-economic and environmental perspectives. This phenomenon tends being exacerbated by world demographic pressures, which result in an increasing water resource demand, with water becoming a key factor for food security and community well-being (Rosegrant et al. 2002; World Economic Forum 2011); Hoekstra and Mekonnen 2012). Scientists, politicians, decision-makers are increasingly realising that the development of the right strategies to meet ecosystem water requirements on the one hand, and world's population demand on the other, is one of the main environmental challenges of this millennium (Falkenmark and Rockstrom 2006; Hanjra and Qureshi 2010; Vörösmarty et al. 2010). Within this framework, it is crucial to understand the globalisation of water (Hoekstra and Chapagain 2008) induced by the trade in virtual water. Furthermore, even though the problem is intrinsically global, due to the increase in the trade in food goods, there can be very different implications for individual countries. Italy is an exemplary case of high virtual water consumption and dependence on food imports. It is among the leading countries in the world for net virtual water importation, with a high per capita consumption and a persistent reduction in land surface used for agricultural production. Local contradictions arising from the global food supply model are the issue dealt with in this contribution, with particular reference to Italy.

1 General Context

The final objective of the analyses which we will present in the following is to reconstruct, on a single country level or global level, the terms of the virtual water balance, that is the total virtual water volume involved in production, consumption, importation and exportation. Three types of data are required to obtain the virtual water volumes. The first concerns the world trade in goods where the data are updated every year for hundreds of products and refer to each country's imports and exports. The second type, instead, refers to the internal production of the same goods (also here the quantity produced in each country and for each year is available). The third type of data pertains with the virtual water volume contained in one unit of each good (for example, a tonne of wheat or milk) for each considered country. This detail is necessary as the virtual water content depends on many factors, such as climate, soil features, agricultural methods used and the irrigation infrastructures in the production regions. Moreover, it is necessary to know both the origin of the water used in producing the goods, so as to differentiate the so-called green water (rainwater) and blue water (irrigation water), and the pollutant load involved in producing the goods to estimate the grey water (the water required to maintain the concentration of fertilisers and pesticides under the legal thresholds). Therefore, it is easy to understand that assessing the water content of a good is a somewhat delicate operation. Once these three types of information are known, each good's weight can be converted, be it produced, exported or imported, into its corresponding water content, and then, the global virtual water flows and the relative balances for each country can be reconstructed, from which the corresponding water footprint can be obtained (Hoekstra and Mekonnen 2012). The most used databank (which we will refer to) is managed and made available by FAO (UN Food and Agricultural Organisation, www.faostat.fao.org). Specifically, it provides information on 309 agricultural products surveyed over the period 1986–2010. This period, apart from cases where literature data are reported, will be the one considered in the following analyses.

In studying the recent history of virtual water trade, some figures will help us in providing an immediate picture of the phenomenon. The temporal evolution of the traded volumes among all the countries of the world (Fig. 1) highlights both the large volumes of water traded, thousands of cubic kilometres, and their marked increase over the last decades. To appreciate the actual volume involved, it must be taken into account that, in 2008, it corresponded to about 50 times the water volume of the Po River annual flow at the mouth. The increase in time is also extremely relevant, as seen by the volume doubling over a span of 23 years. Since in the same period the world population did not increase at the same rate, it can be concluded that the

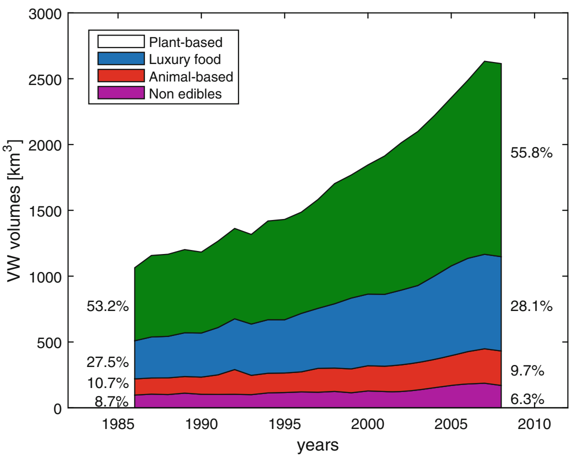

Fig. 1 Temporal evolution of virtual water volumes exchanged worldwide, subdivided into the four main categories. *Source* Carr et al. (2013)

average volumes per capita of traded virtual water clearly increased from about 210 to 320 m^3/year. The same figure also shows the contribution of different product macro-categories, from which it is seen that more than a half of virtual water is traded through basic food plant products (such as cereals), a little more than 28 % regards agricultural goods non-essential for nutrition (e.g. coffee, cocoa, etc.), while a little less than 10 % regards meat and animal-origin products. Concerning the latter, it can be noted that even if the different percentages remained substantially unchanged over the years, the percentage regarding meat tended to slightly decrease.

A recent study conducted by Carr et al. (2013) has shown how the geography of net virtual water flows has changed over time (1986–2006). The basic data emerging from the study is that there are only a few main exporters that have substantially remained unchanged (Canada, USA, Australia, Argentina, Brazil, Indonesia, etc.), with the appearance of Ukraine during the last decade, while most countries are net importers—among these the Mediterranean and European countries emerge. The larger surface areas of some net exporter countries (e.g. Canada and Australia) do not betray the fact that only a minority of the population holds positive net flows in exportation. This involves about 6–8 % of the world population with this percentage having remained more or less constant in time. Moreover, by clear demographic weight, China especially deserves to be noted as it has increasingly become a virtual water importer; also India is worth being mentioned, where importation/exportation has tended to become balanced, however, at the cost of a marked over-exploitation of “blue water” reserves (groundwater).

Observing that each good traded between two countries corresponds to a virtual water flow, it is easy to imagine how virtual water trade gives rise to a very complicated global network. The evidence is in the large number of connections, about 15,700, compared to the number of hubs (i.e. the countries), about 200. It is interesting to note that, also from this perspective, there has been a marked increase in globalisation. Carr et al. (2013) showed that the degree of connections among countries has markedly increased over time and that countries initially quite marginalised, particularly in Africa, have begun to be more connected. The increase in the number of connections should not convey the image of a network increase due to accumulation, that is a network where each time new links are added without changing the pre-existing ones. On the contrary, the network displays a high plasticity; that is, many of the existing connections disappear, while others emerge again.

The information reported above unequivocally demonstrates that international virtual water trade is becoming increasingly important in the water balance of single countries, making water resource management an issue which is becoming less local and more global.

2 The Italian Case

Italy is a prototypical case of high virtual water consumption and heavy dependence on food imports, being one of the main countries in the world for net virtual water importation. Therefore, it is interesting to analyse the country's balance of virtual water flows and their composition regarding the agri-food product categories generating them. Moreover, it will be possible to outline the geography of the virtual water flows and the globalisation of water, describing the international trade networks which have their origin or destination in Italy.

2.1 The Virtual Water Balance

In 2010, Italy traded almost 130 km^3 of virtual water abroad, importing 91.4 km^3 and exporting 36.8 km^3, with local agricultural production use of 65.9 km^3. The ratio between the volumes traded and those produced in loco is, therefore, slightly less than two, evidence of an intensive commercial activity associated with a less important productive activity. And this is not a peculiarity for year 2010 only. The ratio between volumes traded and produced in loco has in fact increased over the last 25 years. A more complete picture of the situation is found in Fig. 2, which shows the annual volumes of virtual water imported to and exported from Italy in the period 1986–2010, together with the amount consumed by the population and that used for the internal production of agri-food goods.

It can be seen that the volumes of virtual water traded abroad have significantly increased over the last decades. The increase in exports has been continuous and steady over time, and the volume traded tripled in the 25 years under study. Imports also markedly increased but with some fluctuations in the more recent years, with a total increase of 80 %. During the period considered, Italy greatly increased its dependence on the international market, to the extent that imports exceeded the volume used for internal production, almost reaching the virtual water volume consumed by the Italian population.

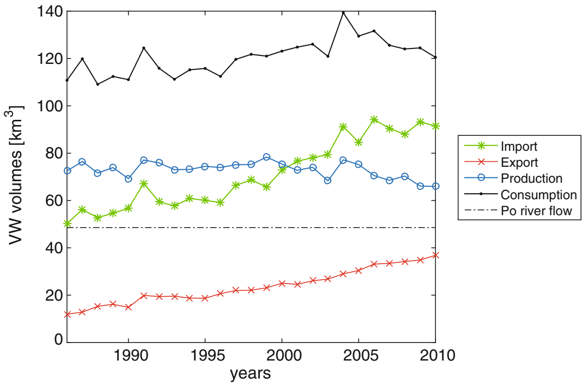

Fig. 2 Virtual water balance of Italy in the period 1986–2010, and comparison with the total annual flow of the River Po at the mouth. *Source* The authors

The virtual water used in agri-food production remained almost constant during the period, with only a slight reduction. This trend is due to three combined factors: the cultivated area in Italy has reduced by more than 20 % in the period 1986–2010 (from 127,000 to 97,000 ha, according to FAOSTAT data); an increase in crop yield (agricultural production per unit of area) occurred along witha shift to crops requiring more water. The outcome of these three factors results, as mentioned, in a slight decrease in the water volumes used in agriculture. Still referring to Fig. 2, it is interesting to note that the virtual water relating to internal consumption, obtained from the difference between net importation (import minus export) and the use in production, in the 25 years studied, shows a growing trend, to a large extent due to the increase in the Italian population.

Comparing the virtual water volume with the total annual flow of the largest Italian river, the Po River (1540 m^3/s or 48.6 km^3/year), it is observed that, in 2010, Italy used in food production a water volume which is about 1.5 times the annual volume flowing from the Po into the Adriatic Sea, while, in 2010, Italian virtual water importation was almost double the total annual flow of the Po. To integrate and better understand the comparison of virtual water flows with the Po River, it should be taken into account that the Po's basin covers almost a quarter of the Italian surface and that 48.6 km^3/year of water corresponds to almost half the total flow theoretically available in all Italian rivers, estimated at about 104 km^3/year. This total was estimated using a simplified model which, through a global inflow/outflow ratio, provides an estimate of the total surface water resources available for the Italian area. The model is based on a multiple regression analysis using rainfall and the Budyko Index (the ratio between potential evapotranspiration and the average annual precipitation) as the runoff explicative variables and is based on about 300 catchment basins considered under the CUBIST project (project funded by the Ministry for Education, Universities and Research, www.cubist.polito.it) which cover almost all Italian land surface. By applying the regression analysis model for all of Italy, it is estimated that the average annual runoff is about 352 mm (that is, 104 km^3), for an average annual precipitation of about 848 mm (that is, 252 km^3). Based on these estimates, the approximate 90 km^3 of imported water appears to be an extremely high figure, which raises serious questions about the long-term sustainability of Italian water consumption.

2.2 Analysis Per Category

Up to now we have considered the virtual water flows independently from their associated agri-food goods. However, interesting aspects emerge if we take into account the product typologies which are involved in virtual water trade. For this reason, four categories were individuated, including those products exported from Italy to other countries. The categories are (see Carr et al. 2013) as follows: edible plant-origin goods, animal-origin goods, luxury goods (such as coffee, cocoa, spices, etc.) and non-edible commodities (such as natural fibres). The main findings of this analysis can be seen in Fig. 3, which shows the temporal evolution of virtual water volumes for each category for the period 1986–2010.

Some general characteristics are evident: firstly, the plant-origin products represent the main goods for virtual water imports for all the period under study, up to 50 % of the total imported volume in 2010. Instead, the imports of animal-origin products

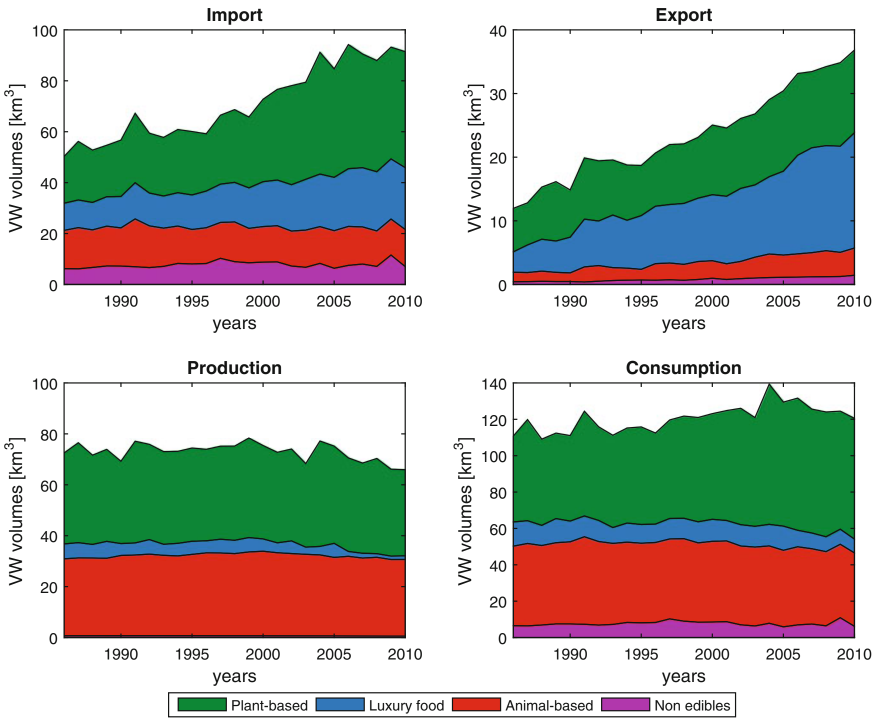

Fig. 3 Composition per category of the terms of the virtual water balance of Italy in the period 1986–2010. *Source* The authors

remained stable, despite the marked increase in total imports, which led to a reduction in the animal-origin importation percentage, possibly due to changes in commercial and eating trends. In the last years, the second main contribution to virtual water importation was linked to luxury goods, which increased significantly—from 21 to 26 % of total imports.

As for exportation, there are some basic differences compared to importation. The plant products dominated virtual water exports at the beginning of the period, whereas the luxury products took the lead after year 2000, reaching about 50 % of exports. The behaviour of this category evidences the importance offood processing industry in Italy (e.g. wine, coffee, pasta and baked goods). The animal or non-food products are a minor part of Italian virtual water exports compared to plant and luxury products and show a weak growth trend.

Finally, the use of virtual water in internal production mainly concerns plant- and animal-origin goods, which maintained quite constant volumes, while luxury goods underwent a recent decline. The use of water for non-food production is quite modest, with a consumption of 7–8 km^3/year which is satisfied by imports. A significant increase in virtual water linked to plant goods can be noted, from 47 to 66 km^3, while the other categories remained steady.

2.3 The International Trade Network

A geographic representation of virtual water flows which originate and end in Italy can be illustrated in a map showing the volumes traded with other countries. The volumes imported by Italy per year from each country are represented as river branches showing the country of origin from where the goods were imported. All the branches are then linked up in a hydrographic network grouping them into a single direct flow towards the importer country—Italy. A representation of this "virtual river" can be seen in Fig. 4 for 2010, where line thicknesses and colours indicate the ranking of the flow sizes. For a detailed assessment of the virtual water flows, Table 1 shows the imported and exported volumes in 1986 and 2010.

In 2010, Italy imported 91.4 km^3 of virtual water from all continents, but mainly from Europe, as can be seen by the thickness of the line grouping the European contributions in Fig. 4. The total virtual water flow imported by Italy increased by 82 % from 1986 (when it was only 50.3 km^3); however, the trend was not the same in all regions of the world. For example, North America (which also includes Central America) is the only region to have decreased its virtual water contribution (−28 %), while the flow from South America and Asia more than doubled. Instead, the import flows from Africa and Oceania saw an increase less than the average growth in the reference period.

As for Italy's exportation of virtual water to the rest of the world, in 2010 it was 36.8 km^3, with more than 70 % of this direct flow to European countries. The trend in exported virtual water was still more significant than for imports—the total flow in 1986 was a third of the 2010 flow. Also in this case, the variations of the different

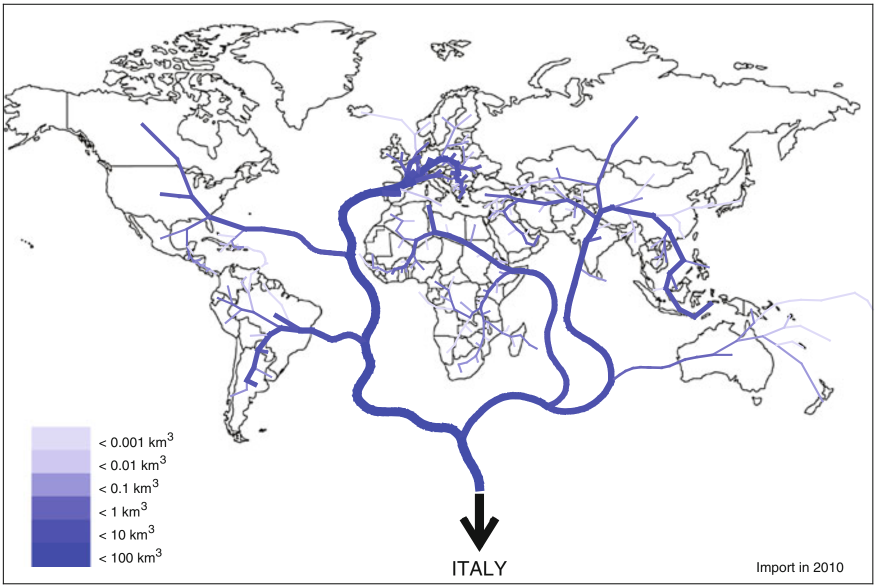

Fig. 4 The virtual water river flow towards Italy in 2010. *Source* Tamea et al. (2012)

Table 1 Origin and destination of Italian virtual water import and export in 1986 and 2010 (km^3/year)

	Import				Export			
	1986		2010		1986		2010	
Europe	28.2	56 %	54.6	60 %	6.7	56 %	26.5	72 %
Asia	4.5	9 %	11.7	13 %	1.2	10 %	5	13 %
Africa	5.9	12 %	8.2	9 %	2.7	23 %	1.5	4 %
North America	6.6	13 %	4.8	5 %	0.9	7 %	3	8 %
South America	4.5	9 %	11.4	12 %	0.4	4 %	0.3	0.90 %
Oceania	0.58	1.20 %	0.87	1.00 %	0.06	0.50 %	0.55	1.50 %
Total	50.3	100 %	91.4	100 %	12	100 %	36.8	100 %

Percentages are calculated based on the total in the last line
Source Tamea et al. (2012)

regions of the world were not the same—Africa and South America reduced their virtual water imports (−45 and −24 %, respectively), while the other continents more than tripled their flows. In particular, exports to European countries quadrupled, from 6.7 to 26.5 km^3. This increase was a consequence of the enlarging and strengthening of the Common European Market during the period studied.

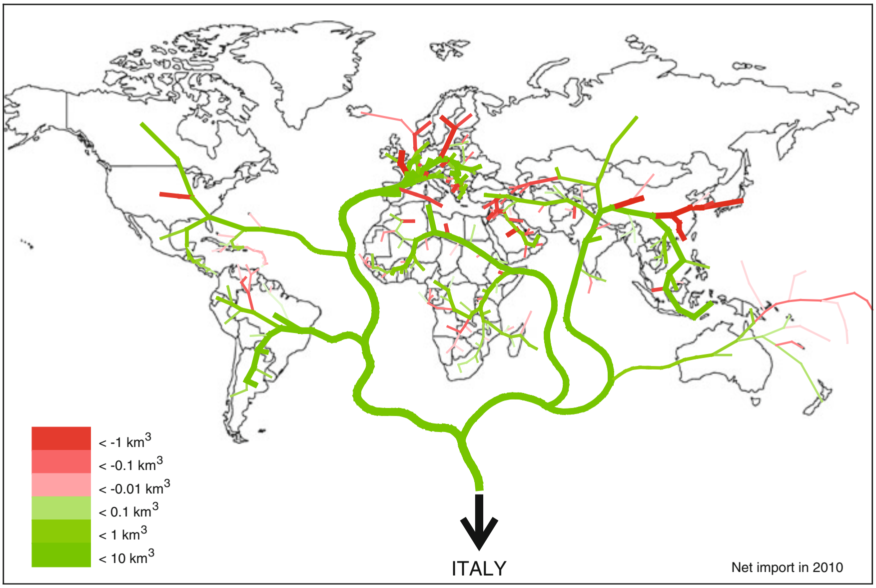

Fig. 5 Italian net import (import–export) of virtual water in 2010. *Green lines* indicate a net import and *red lines* indicate a negative net import (thus a net export) of Italy. *Source* The authors

The net import flow (import minus export) can be estimated by combining the imported and exported volumes from Italy in relation to each country for one year. Analogously to the geographic diagram in Fig. 4, the net virtual river can be constructed, where the positive or negative sign of the flows is identified by colour (Fig. 5). One can see how the net flow from all the continents is positive; that is, Italian virtual water imports exceed its exports, but there are also important negative flows (i.e. exports dominate) towards single countries such as the USA, UK, Northern European countries, China and Japan, where the line thicknesses show a very high volume of exported virtual water.

In the years between 1986 and 2010, there was an evolution in the trends of imports and exports. The network underwent only small changes, with a slight increase in the number of supplier countries and a more conspicuous increase in countries receiving exports. Some modifications occurred due to political/administrative changes in countries such as the ex-Soviet Union and ex-Yugoslavia, while other links, for example with the remote islands of the Pacific Ocean, were intermittent. The most significant variations compared to 1986 include the marked decline in net imports by (or the increase in Italian export towards) the USA, China, Japan, Oceania, the countries of southern African and Europe (even if the net European flows increased during the time, that is imports increased more than exports). Figure 6 shows the import and net import flows only concerning the European and Mediterranean area, in order to highlight the contribution of countries

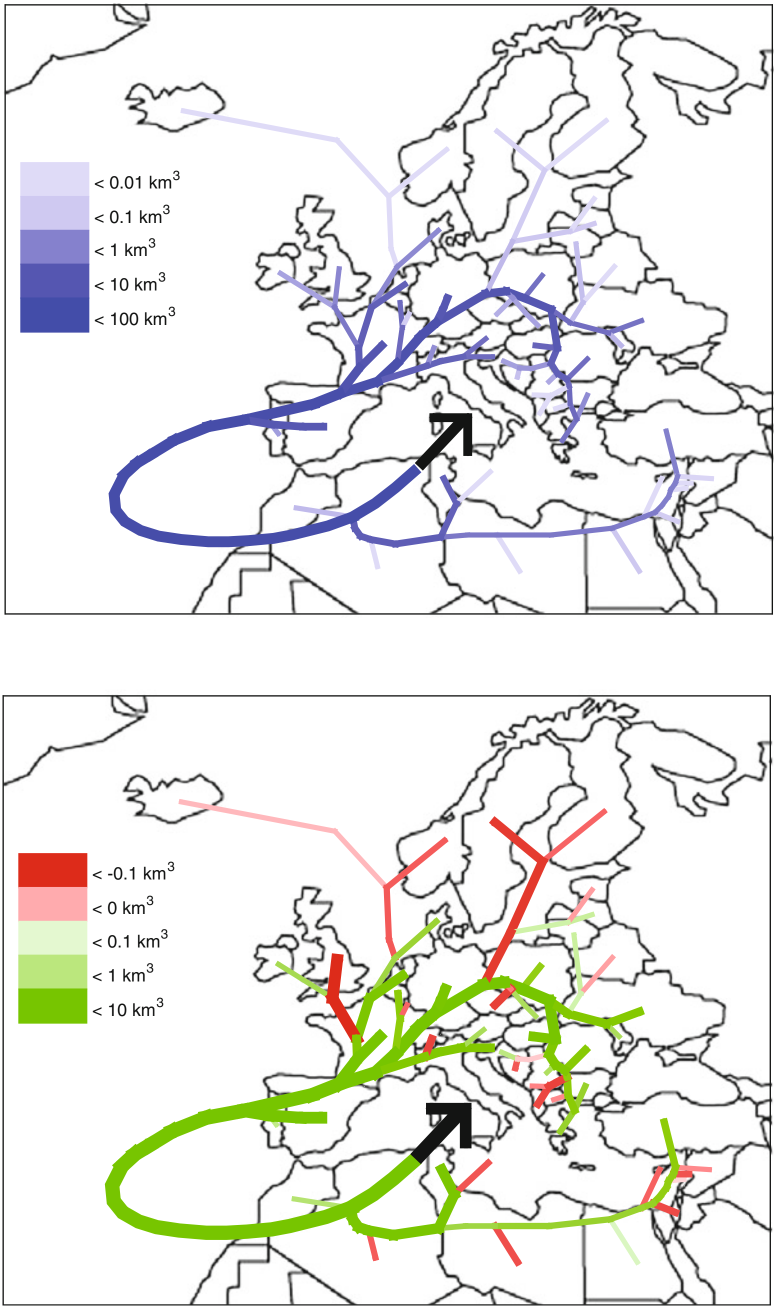

Fig. 6 Contribution of European and Mediterranean countries to Italian imports (*above*) and net imports (*below*) of virtual water in 2010. *Source* The authors

Table 2 Virtual water import (towards Italy) and export (from Italy) in 1986 and 2010 of some countries (in km^3/year)

	Import 1986		Import 2010		Export 1986		Export 2010	
Brazil	2.37	*# 5*	4.37	*# 4*	0.4	*# 8*	0.13	*# 39*
China	0.47	*# 26*	0.21	*# 49*	0.05	*# 32*	0.8	*# 13*
France	8.94	*# 1*	10.82	*# 1*	1.96	*# 1*	5.23	*# 2*
Germany	3.7	*# 4*	9.02	*# 3*	1.63	*# 2*	5.44	*# 1*
United States	4.89	*# 2*	1.98	*# 12*	0.74	*# 4*	2.19	*# 3*

In italics is the position of each country in the ranking for volumes traded with Italy
Source Tamea et al. (2012)

geographically closer to Italy. It can be seen that most of the virtual water imports within Europe originate from France, Spain, Germany and the net export flows concern countries such as the UK and the Nordic countries. In the Mediterranean area, Turkey and especially Tunisia move huge volumes of virtual water towards Italy, comparable to the main European countries, and explainable by the intense commercial trade and by the high water content of the traded products.

If the trade flows from Italy to some countries of particular interest are considered (Table 2), France remains the preferred partner for Italian imports, even if the increase in the import flow over the period is weaker compared to the world average (21 % compared to the average of 82 %). The USA has been reducing their contribution to Italian imports while, on the contrary, Brazil is taking on a leading role, with high growth rates over the last years. When exports are considered, Germany and France emerge as the main partners, with Germany in the last years tripling its contribution. Italy strongly increased its virtual water exports to the USA, with a total flow (1.98 km^3 in 2010) exceeding the corresponding import flow (see Fig. 5). Italy also significantly increased its penetration into the Chinese market, while flows towards Brazil significantly decreased in the period.

Finally, to better compare Italy and the other countries of the world, it is useful to consider the net virtual water flows traded by all countries during 1986 and 2010. Ranking the countries by decreasing net imports, it emerges that Italy was in 3rd position in 1986 and 5th in 2010, confirming the fact that Italy was among the main world net importers of virtual water. If the ranking is repeated based on the net per capita flow, it is noticed that Italy drops to 48–49th position, as in this case some smaller countries tend to register higher net per capita imports, thus making the interpretation of the results difficult. However, by totalling the population living in countries with a net per capita importation higher than Italy's (47 and 48 countries in the two cases), we obtain 1 and 3 %, respectively, of the world population. This shows that most of the world's population has a net per capita virtual water importation lower than the Italian average.

3 Conclusions

The concept of virtual water is a new paradigm for the understanding of the complex dynamics relevant to the use of water resources by humans. In particular, the use of this indicator results in highlighting the main role agriculture plays in the resource's consumption and, as well, in recognising how water resource management has now become an issue to be tackled on a planetary level, and not only locally as often occurred in the past. Indeed, as highlighted in this contribution, the trade in food commodities between countries and the different continents leads to a corresponding virtual water movement throughout the globe, with very significant and, sometimes, predominant flows concerning the water volumes consumed in agri-food production. This is the case for Italy where, over the last 25 years, there has been a progressive reduction in areas used for agriculture, a reduction only partially compensated for by an increase in crop yields. There followed a slight decline in the virtual water volumes used for agricultural purposes (from 72 km^3 in 1986 to 66 km^3 in 2010), accompanied by a growth in national virtual water consumption (from 111 to 121 km^3 in the 25 years considered), to a large extent, due to population growth. Summing-up, the gap between internal virtual water supply/demand widened from 39 to 55 km^3 and the differences were compensated for by a very important growth in agri-food good imports. More generally, the volumes of virtual water traded from Italy toward the other countries more than doubled from 1986 to 2010. Using virtual water as an indicator, a rather well-defined picture can be drawn. Italy appears to be a country which is increasingly abandoning its agricultural-productive role and is instead increasing its commercial one. In the near future, water resource management in Italy, just as for agricultural and land protection policies, will have to duly take into account, as much for water as for other resources, the understanding of the phenomenon and its correct interpretation, increasingly moving towards recognising the global scale of these issues. In other words, the globalisation of water has become an unavoidable fact.

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