Chapter 10
The Italian Virtual Water Trade and Water Footprint of Agricultural Production: Trends and Perspectives

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Abstract The purpose of this chapter is to contribute to the knowledge about the water-food-trade nexus in Italy by introducing the concepts of water footprint and virtual water trade. Virtual water is the water "embedded" in the production of agricultural and industrial goods and services, whereas virtual water trade refers to the exchange of such embedded water that takes place as a result of the international commodity trade. The chapter aims at outlining the Country's green and blue water footprint of agricultural production, as well as providing a comprehensive overview of virtual water trade embedded in the agricultural commodity trade, over the period 1985–2016. The quantitative analyses are complemented by a policy-relevant discussion detailing the practical causes and implications of the results.

Keywords Virtual water · Water footprint · Agricultural production · Food trade · Water-food-trade nexus

10.1 Introduction

Challenges and issues related to the water-food-trade nexus can be well described by taking the perspective of water footprint and virtual water trade. The two concepts are closely interrelated, being rooted in the key role of water as a primary input for agricultural production. Virtual water (VW) is the water used for the production of agricultural and industrial goods and embedded as a factor of production

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when goods are traded (Allan 1993). Accordingly, VW trade refers to the exchange of embedded water that takes place as a result of the international commodity trade. The concept was introduced to explain how water-scarce countries could survive through food imports, without depending on scarce local water resources but importing water embedded in agricultural products (Allan 1993, 2001). Water-scarce countries thus rely on VW trade as an adaptation strategy to overcome the local limits to population and wealth growth (Distefano and Kelly 2017), while enabling a global water saving when food is imported from water-use efficient countries (Hoekstra and Chapagain 2008). VW trade may help explain the absence of wars explicitly related to water in water-scarce regions, such as the Middle East and North Africa (Allan 2001, 2003), although the public discourse on water security and policy in these countries has been downplayed (Antonelli and Allan 2019). However, VW trade implies a dependency of countries on foreign resources, a corresponding vulnerability to external crises, as well as an externalisation of pollution, costs and water-management problems. An extensive review of details and impacts of the global VW trade can be found in D'Odorico et al. (2019).

The concept of VW has been complemented by that of water footprint (WF), defined as an indicator of direct and indirect use of freshwater resources (Hoekstra et al. 2011). The WF may be referred to the production of agricultural and industrial goods and services or to their consumption by individuals or countries. When referred to a country's consumption, a WF assessment also includes the imported and exported goods of the nation and, thus, the corresponding VW trade (Hoekstra and Chapagain 2008). The WF has three components: green water (rainfall), blue water (from surface- and ground-water bodies) and grey (freshwater required to assimilate loads of pollutants discharged into a receiving body based on existing water quality standards) (Hoekstra and Mekonnen 2012). Studies have shown that agricultural goods contribute with an overwhelming 92% to the WF of humanity and that many countries have externalised their WFs by relying on trade (e.g. Hoekstra and Mekonnen 2012). The concept proved to be useful to raise public awareness on the role of water in the production of goods of daily use, to shed light on the environmental consequences of consumers' choices, and to highlight the role of different dietary regimes in shaping our impacts on water resources. For example, it has been proved that meat products are relatively water-intensive if compared to crops (Hoekstra 2015). An abandonment of the Mediterranean diet – which is widely recognised as a healthy and sustainable dietary pattern – may thus have an environmental impact, while a shift towards a healthier diet with reduced meat content can limit the WF of current European diets (Vanham et al. 2018). Therefore, an increasing awareness and appropriate actions can have the potential to reduce WFs, at the same time pursuing nutrition- and sustainability-related goals.

The VW fluxes associated to the international trade of agricultural goods have been assessed at various scales and with different approaches since the early 2000s (e.g. Hoekstra and Hung 2005; Dalin et al. 2012; Tamea et al. 2013), as extensively detailed in a recent review by D'Odorico et al. (2019). From 1986 to 2007, the number of trade connections and the total volume of water associated to global food trade more than doubled. The Asian region increased its VW imports by more than

170%, especially from North America and South America. At the same time, North America shifted to an increasing intra-regional trade (Dalin et al. 2012). Over the same period, the Middle East increased dramatically VW imports, while the Central African region and China shifted from being VW exporters to net importers (D'Odorico et al. 2019). Domestic political economy changes in the agricultural sector affect global VW trade and have environmental consequences. For example, increased soy imports in China, due to a domestic policy shift in the 2000s, translated into an increased Chinese VW import and a water saving process in the global soy market. However, it is also associated to an augmented soy production in Brazil with probable negative effects on deforestation (Dalin et al. 2012). Global VW fluxes are dominated by cereal grains, followed by soybeans, vegetable oils and luxury goods such as coffee and chocolate. Many developing countries are net exporters of VW related to luxury goods, but they are net importers as far as food crops are concerned (D'Odorico et al. 2019).

The diffusion of both VW trade and WF assessments for agricultural products has been facilitated by an open-access database of WFs provided by the Water Footprint Network (Mekonnen and Hoekstra 2010a, b). The database includes sub-national and national scale values of WFs of single crops and agricultural products, averaged over the period 1996–2005. Data are based on a global-scale model of crop growth coupled to hydro-climatic variables (rainfall, temperature) through a soil water balance, and values for derived products are obtained from their supply chains. Recently, significant progresses have been made in WF and VW trade assessment. For example, Tuninetti et al. (2017) validated a simplified approach to account for the temporal variability of WF of crops, showing the role of the yield increase as the leading factor of the interannual WF changes. Regarding the spatial dimension, trade data are usually aggregated at the country scale, e.g. in United Nations or Food and Agriculture Organisation data (FAO 2018) or in input-output tables (Arto et al. 2016). Commodity flow analyses at sub-national level have been used in studying the VW trade for the United States of America and few other countries (D'Odorico et al. 2019 and references therein), although scarcity of small-scale (sub-national) trade data is a major limiting factor for the application of the advances in WF estimation to VW trade analysis (Hoekstra 2017). VW trade studies are attempting to introduce the watershed unit as a base dimension of assessment, beside the common country or regional levels of analysis. The attempt is motivated by the purpose of developing policies informed by high-quality data linked to the local context of agricultural production, accounting for the heterogeneity of climatic and geographical conditions within countries (Vanham 2013; D'Odorico et al. 2019). These spatially and temporally refining efforts make the evaluation of the links between water scarcity, water resources sustainability, and complex supply chains even more opportune.

The VW trade has also been studied through the lens of economics (e.g. Duarte et al. 2016; Reimer 2012; Fracasso 2014). It has been highlighted that analyses of VW trade have the advantage of providing new significant information with respect to traditional price-based analysis of food trade. Indeed, global food prices are only weakly correlated with physical commodity flows and VW flows (Distefano et al.

2018). Scholars have analysed VW trade by applying both network analysis techniques and gravity models, focusing in particular on its determinants (e.g. Fracasso et al. 2016). Interesting applications of the VW trade concept are also in the field of food crisis propagation and country vulnerability (Tamea et al. 2016; Sartori and Schiavo 2015).

Within the literature, the VW trade of Italy has been analysed with reference to both global and bilateral trade (Tamea et al. 2013; Winter et al. 2014; Miglietta and Morrone 2018 on wine; Lamastra et al. 2017 on olives) utilising, among other tools, also the input-output tables approach (Ali et al. 2018). Italy is placed among the largest importers of VW worldwide. Only 1% to 3% of the world population exhibits its per-capita net import higher than Italy. Moreover, the dependence on imports has increased over the last years and it has overcome the reliance on internal production (Tamea et al. 2013). With respect to the rest of the world, Italian VW import and export have grown by 82% and by 208%, respectively, from 1986 to 2010. This growth rate is coherent with the general behaviour of the global network, and trade fluxes are shown to connect Italy to almost all countries in the world. In particular, Italy trades VW to/from distant countries, with a mean travelled distance per cubic meter estimated to be about 3800 km for imported products and 2500 km for exported ones – with distances which have increased significantly in the last decades (Tamea et al. 2013). The water footprint of production and consumption in Italy has been assessed at the national level (Hoekstra 2015; Antonelli and Greco 2014), applied to specific sectors (Nicolucci et al. 2011), crops and products (e.g. Bocchiola 2015; Bocchiola et al. 2013; Amicarelli et al. 2011), as well as companies (Ruini et al. 2013). At the level of intra-EU agricultural trade, Italy has also emerged as one of the largest VW importers over the period 1993–2011, and one of the major blue VW exporters in the region, despite being close to water stress thresholds (Antonelli et al. 2017).

Within this context, this chapter provides a state-of-the-art assessment of Italy's WF of agricultural production and engagement in VW trade, explicitly taking into account the temporal variability of the WF of agricultural goods. The chapter closes with some considerations about the importance of these indexes for policy and management.

10.2 Data and Method

The quantification of the WF and VW trade is based on two main data sources: FAOSTAT, i.e. the Food and Agriculture Organisation database (FAO 2018), and WaterStat, i.e. the Water Footprint Network database (Mekonnen and Hoekstra 2010a, b). FAOSTAT is the source of bilateral trade data of agricultural goods from 1986 to 2016, of export data from 1961 to 2016, as well as data about production and yield from 1961 to 2013. Countries considered in the present analysis include all countries active for at least one year in the considered period, for a total of 255 countries. Goods considered in the present analysis include primary crops, processed crops (such as juices or bread), livestock primary goods (e.g. meat and milk), and livestock processed goods (e.g. cheese), with data for 345 traded or produced goods. Goods are aggregated into categories, namely cereals, fruits (including olives), vegetables, seeds and oils, animal meat, dairy products and eggs, luxury foods such as sugar and coffee, and non-edible products (such as fibres and tobacco).

The quantification of the WF for each good is obtained by multiplying the quantity, X, of the produced or traded good (FAO 2018) by the WF per unit weight of the good, or unit WF (uWF), in the country and year of production, i.e.

$$WF = X \cdot uWF. \tag{10.1}$$

For crops, the unit WF is defined as the ratio between the water used by the crop during the growing season and lost through actual evapotranspiration (ET in mm), and the crop yield, Y (in ton/ha), i.e.

$$uWF = 10 \cdot ET / Y, \tag{10.2}$$

where the factor 10 converts the units of uWF into m^3/ton. The unit WF thus expresses an inverse measure of efficiency, because the lower is the value, the more efficient is the use of water resources in the crop production. The water evapotranspired may be originated from rainfall, in which case it is called green water, or from irrigation, in which case it is called blue water. Blue water may also include additional volumes used in the processing phase of the good and usually withdrawn from surface water or groundwater bodies (for methodological details, see Hoekstra et al. 2011). In the present analysis, only the consumptive WF is considered, thus blue and green WF, but not grey water.

Previous studies about the WF and VW trade of Italy (e.g. Tamea et al. 2013; Antonelli and Greco 2014) were based on the use of a constant uWF provided by the WaterStat database (Mekonnen and Hoekstra 2010a, b), which reports green and blue unit WF of a large number of goods, per country of production, averaged over the period 1996–2005 (uWF_0). However, the unit WF of crops changes over time due to climatic and anthropic factors, including mechanisation, fertilisation, irrigation, and technical advancements. In order to account for the temporal variability, the method proposed by Tuninetti et al. (2017) is adopted in the present analysis, which computes the total (green plus blue) uWF in a generic year, t, as

$$uWF(t) = uWF_0 \cdot (Y_{96-05} / Y_t) \tag{10.3}$$

where uWF_0 is the (green plus blue) value reported in WaterStat, Y_{96-05} is the average crop yield in the period 1996–2005, and Y_t is the crop yield in year t. This method does not account explicitly for climate-driven oscillations of actual evapotranspiration, but reproduces well the statistically significant trends introduced by anthropic factors (Tuninetti et al. 2017).

The role of the temporal variability of the unit WF is expressed in Fig. 10.1, showing the unit WF of some crops in Italy from 1961 to 2016. The crops are chosen for having the largest production (in terms of weight) and the largest economic value of production in Italy in the most recent years. The marked decreasing trend is evident in all crops: it dominates over the interannual fluctuations and is statistically significant at the 5% level. Olive production, shown only in the figure inset, is characterised by large biennial fluctuations in the unit WF, motivated by the yield fluctuations reported in FAO (2018) and likely caused by the biological cycle of olive plants which alternates rich and poor production years (a phenomenon named alternate – or biennial – bearing). The recent increase in the unit WF of olives is motivated by the reduction of yield as olive production is threatened by climate change and pests (e.g. *Xylella fastidiosa*). It is worth noticing that, when green and blue water are considered together (as in Fig. 10.1), the unit WF of rice is comparable to other cereals and even lower than wheat, whereas when separating the two components, the blue water required for rice overtops the other crops.

For processed crops, the production can use local or imported primary goods. For this reason, the unit WF is taken as a weighted average of the unit WF in Italy and in countries from which primary crops are imported, using production and import quantities as weights. As opposed to crops, the unit WF of goods with animal origin is currently kept constant in time and equal to the WaterStat value, for the lack of sufficient data allowing to quantify its temporal variability. Details about the computation of WF data can be found in Tamea et al. (2021). The blue unit WF variable in time is computed through Eq. (10.3), substituting for uWF_0 the blue unit WF

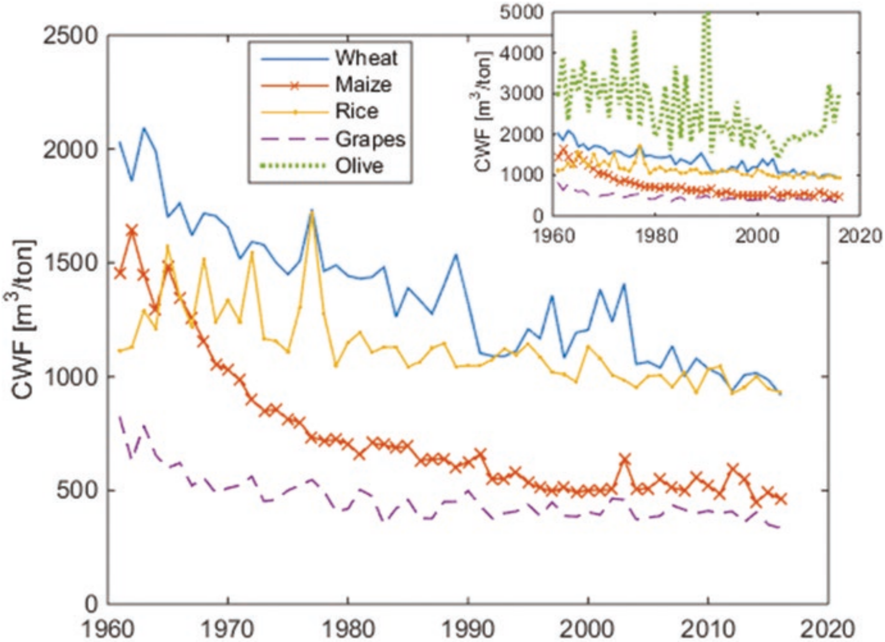

Fig. 10.1 Unit water footprint (green plus blue water) of major agricultural products in Italy, from 1961 to 2016 (in m^3/ton)

from WaterStat, implicitly assuming a constant-in-time ratio of blue-to-total unit WF.

The total WF of Italy's production is obtained by summing the WF (from Eq. 10.1) of all goods produced in the Country. Processed goods, having crop or animal origin, are not considered in the sum in order to avoid the double counting of water volumes required to produce primary and derived goods. Goods used both as food and feed for animals, that in turn produce goods which are further included in the sum, would be subject to double counting of water volumes. For this reason, the fraction of goods being used as feed is omitted from the sum, by multiplying their WF by a factor $(1-f)$, where f is the ratio between feed and total supply of each good, obtained from the Food Balance Sheet of Italy (FAO 2018).

As explained, the VW trade is the WF of agricultural goods that are traded internationally. Quantification of the VW flows is based on Eq. (10.1), where X identifies the quantity of a good traded between two countries in a given year. Bilateral trade data from FAO (2018) are arranged in trade matrices connecting exporting and importing countries, per each good and year in the period 1986–2016. The associated WF is computed by multiplying each flow by the good's unit WF, considering the country of origin of the trade flow as the producing country. Similarly, VW exports are also computed from export data available from FAO (2018) for the period 1961–2016 (for details, Tamea et al. 2021).

10.3 Trends in the Water Footprint of Agricultural Production in Italy

Italy is a country with spatially heterogeneous water endowment.[1] The average annual volume of precipitations is 241 km^3, corresponding to an average precipitation depth of 800 mm, but the spatial distribution has a marked gradient from North to South, with regions receiving from 505 to 1145 mm per year (ISTAT 2015). The water returning to the atmosphere through actual evapotranspiration (evaporation from soil and open water plus transpiration from plants) has been estimated to have an average annual volume of 156 km^3 (ISTAT 2015), lost from cultivated, non-cultivated and non-vegetated areas.

Regarding general considerations on the evolution of the agricultural sector in Italy, we notice that cultivated areas (or cropland) represent about 30% of the Country's surface. Such area has been decreasing markedly over time, from 124,000 km^2 in 1971 to 90,000 km^2 in 2016 (FAO 2018). The temporal evolution of cropland area is depicted in Fig. 10.2, together with other variables, expressed as a relative change with respect to the base year 2005. It appears that cropland area has

[1] A detailed description of Italy's water resources is provided by Benedini and Rossi in Chap. 1 of this volume.

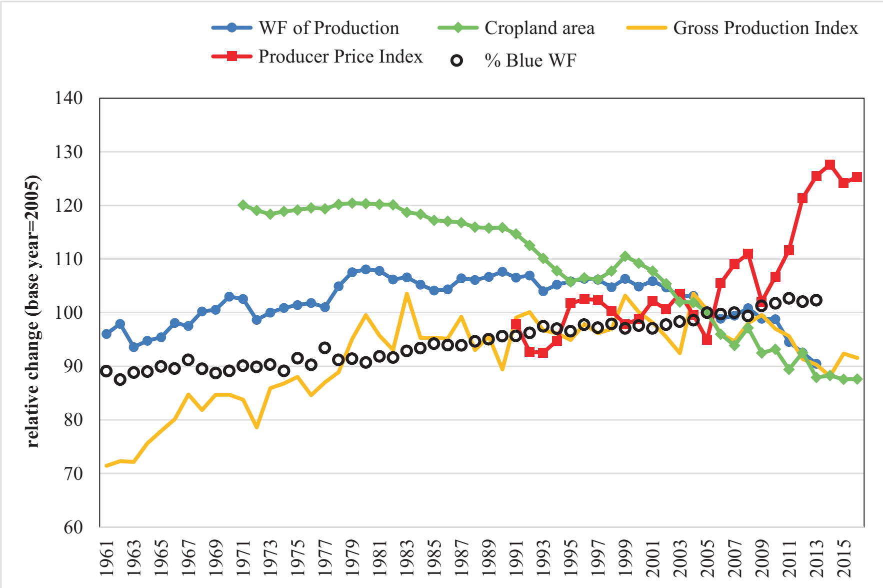

Fig. 10.2 Evolution of variables related to the agricultural production in Italy, from 1961 to 2016, normalised by the value in 2005

evolved differently from, for example, the Gross Production Index,[2] which quantifies the overall agricultural production of Italy. In the 1970s, the cropland area remained constant while the production increased, indicating a strong improvement in agricultural yields. Then, up to the mid-1990s, the area decreased significantly, while the production fluctuated around a plateau, suggesting a reduction of low-efficiency areas which did not compromise the overall production. In the last two decades both area and production, as well as water use, decreased, reflecting the declining share of the agricultural sector as relative contribution to the total Gross Domestic Product. However, the fact that the production decreased less than the cropland suggests an overall increase in agricultural productivity that occurred in the same period (Romano 2012).

The decrease in production quantity has occurred simultaneously with the increase of producer prices, with a mirror dynamic of the two indices. The Italian agricultural Producer Price Index[3] reflects the general dynamics of the whole economy, as it falls during recessive phases and it increases during expansionary periods.

[2] The Gross Production Index is obtained with production quantities of each commodity weighted by 2004–2006 average international commodity prices in International Dollars and summed for each year. To obtain the index, the aggregate for a given year is divided by the average aggregate for the base period 2004–2006 (FAO 2018).

[3] The Producer Price Index measures the average annual change over time in the selling prices received by farmers (prices at the farm-gate or at the first point of sale). The indices are constructed using the Laspeyres formula with price data in Standardised Local Currency (FAO 2018).

Moreover, it follows also agricultural price trends worldwide, as it is observable in fluctuations around 2008 and 2010 (Romano 2012). In particular, the last change may be related to the peak in cereal prices that occurred in 2010–2012 on the international markets.[4] Although this chapter focuses on the water embedded in the quantities of food produced and traded, considering the price trends of the agricultural sector is useful since prices provide crucial incentives for production and commercial decisions on food quantities and consequently on the volumes of VW utilised. Moreover, statistics on agricultural production are usually expressed in monetary terms, and it is informative to observe differences with respect to the trends of more environmentally-oriented variables, such as virtual water (Distefano et al. 2018). Finally, given the increasing globalisation over time, prices are the channels through which shocks propagate to the domestic agricultural market, and represent the variables that encounter early changes, due to rigidities in changes in produced quantities (Romano 2012).

Figures on the WF of crops provide a more environmentally-oriented information on agricultural dynamics. They are therefore useful to complement the data derived from the variables that are more commonly used in the evaluation of agricultural performance, which are quantities and prices. The WF of agricultural production in Italy, accounting for all primary goods and explicitly avoiding double counting of food and feed, has an annual average volume of about 75 km^3 (considering green plus blue water). The temporal dynamics of the WF of production, indexed at year 2005, is also shown in Fig. 10.2 and compared to the other variables. The comparison with the Gross Production Index reveals that in the 1970s the WF of agriculture in Italy was similar to 2005, but production was much smaller, indicating a lower efficiency in the use of water because larger (green and blue) water volumes were necessary for the same agricultural production. This confirms the trends observed in Fig. 10.1 for the unit WF of single crops, and extends to the whole agricultural production our previous consideration about an improved efficiency. In most recent years, the overall WF has been decreasing partly thanks to the decreasing unit WF (corresponding to an increased efficiency), but also because of a decrease in production quantities and cropland area. In contrast, the ratio of blue-to-total WF of agricultural production of Italy has been increasing constantly over time, indicating a growing relevance of irrigated crops in the Italian agriculture. Of the total cultivated area in Italy, more than 20% is irrigated, with a percentage that is among the largest in Europe. In irrigated areas, the evapotranspiration of crops is contributed by both precipitation and irrigation, and the blue WF is mostly originated in these areas. Blue water is provided by withdrawals from streams, lakes and groundwater. The annual volume of freshwater withdrawn for irrigation in Italy equals 16 km^3, whereas the total annual freshwater withdrawals for agricultural, industrial and municipal uses amount to 34.2 km^3 (FAO 2016).

[4] The 2010–2012 peak in food prices was due to diverse factors. An increase in oil prices led to increased production of corn for ethanol. Rise in global population jointly with changes in dietary habits increased the cultivation of corn for animal feed. The consequent decrease in supply of cereals for human consumption led to a peak in its prices (Coulibaly 2013).

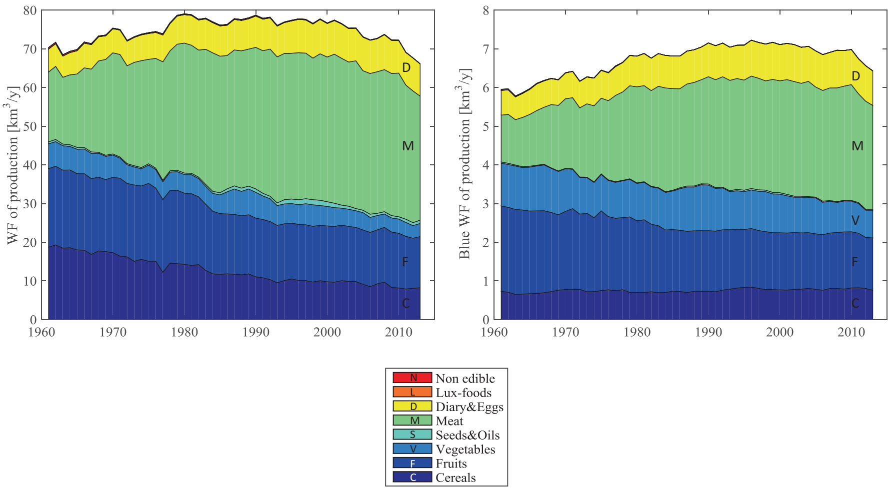

Fig. 10.3 Temporal variability of water footprint of agricultural production in Italy, per category, from 1961 to 2016, in terms of total (left) and blue water (right) in km^3/year

The WF of agricultural production in Italy is detailed in Fig. 10.3, where total and blue water volumes are shown (left and right panels, respectively) for different categories of goods. Only primary products are included in the sum, in order to avoid double counting of water volumes; thus, for example, olive oil is not included, but olives are included in the "fruit" category. Currently, the largest total WF is generated by the production of meat, followed by fruits, cereals, diary and eggs, and vegetables. The most dynamic category is "meat", whose WF (total and blue) has grown significantly in the first three decades, then became more constant to finally shrink in the most recent years. Since in this category the unit WFs are kept constant in time, the temporal dynamics of WF mirrors the production quantities without reflecting efficiency variations. With respect to the past, cereal production shows a decreasing trend in WF, justified by the decrease in the cereal-cultivated area, which has halved during the studied period (FAO 2018). This can be made explicit considering that in computing the WF of production of a crop, the produced quantity (*X* in Eq. (10.1)) can be obtained from the crop yield and the harvested area, *A* (in ha). In such case, Eq. (10.1) becomes

$$WF = (Y \cdot \mathrm{A}) \cdot (10 \cdot ET / Y) = 10 \cdot \mathrm{A} \cdot ET \tag{10.4}$$

and the WF equals the volume of water, computed from the actual evapotranspiration depth (*ET* in mm) and the harvested area. Since in our approach the temporal variability of *ET* is neglected, *WF* reflects the temporal variability of harvested areas, or the changing composition of agricultural production, when the WF of different goods are summed.

The blue WF of overall agricultural production (marked by the upper line in the sequence of categories in Fig. 10.3) increased significantly from 1960 to 1990, then remained more constant and finally decreased in the last years. With respect to total (green plus blue) WF, the volumes increased for a longer time and more markedly in the first three decades. The share of categories in the blue WF is similar to that of total WF, even though goods with greater associated volumes are different between total and blue WF. The increase of blue WF over time is ascribable again to meat, while other categories behave differently. For example, the "cereals" category, which for the blue WF is dominated by rice, has a constant WF because the rice-cultivated area has not varied much. On the contrary, fruits have decreased their blue WF to a greater extent than the reduction of total WF.

10.4 The Virtual Water Trade of Italy

The agricultural production of Italy (and the associated use of water resources) is connected with the rest of the globe by international trade, because part of the local production is exported to other countries. Moreover, a relevant share of agricultural goods is imported from abroad, connecting Italy to external water resources and motivating the so-called water-food-trade nexus. According to the present analysis, Italy exported 24 km^3 of (green and blue) VW in 2013, which represents the 36% of the WF of agricultural production (66 km^3 in the same year). The enlargement of foreign demand has played a central role in the increase in the Italian export of agricultural products. The export from Italy toward extra-European countries doubled in the last ten years, while the one toward EU-28 increased by 70% (ITA 2017).

Figure 10.4 presents a description of Italian exports of agricultural goods by an economic and VW perspective, comparing variables indexed at year 2005. As explained in the previous section, it is useful to insert value trends in the overall description, because of its complementarity with the other metrics. In Fig. 10.4 it is possible to observe that export steadily increased from the 1960s to 2016. The Export Quantity Index, the Export Value Index[5] and the total VW associated to crop export show a constant positive trend. However, the price trend followed the other two metrics only until the late 1990s, whereas afterwards we observe a decoupling of the metrics evolution. The Export Value Index slightly decreased from 1997 to 2002, while the quantities exported were increasing. It later experienced a strong peak, with a growth rate of about 20 points per year, overcoming sharply the growth of the Quantity Index and the related VW content. This constant increase fully reflects the global trend of food prices. However, while the Italian agricultural export prices peak of 2008 coincides with the worldwide figure, the second peak that is globally registered around 2011 reached Italy only in 2014 (Bellmann and Hepburn 2017). According to ITA (2017), the export value of the Italian agro-food

[5] The Export Quantity and Export Value Indices represent the changes in the price-weighted sum of quantities and of values of agricultural products traded between countries. The weights are the unit value averages of 2004–2006. These indices are calculated using a Laspeyres-type formula with price data in International Dollars (FAO 2018).

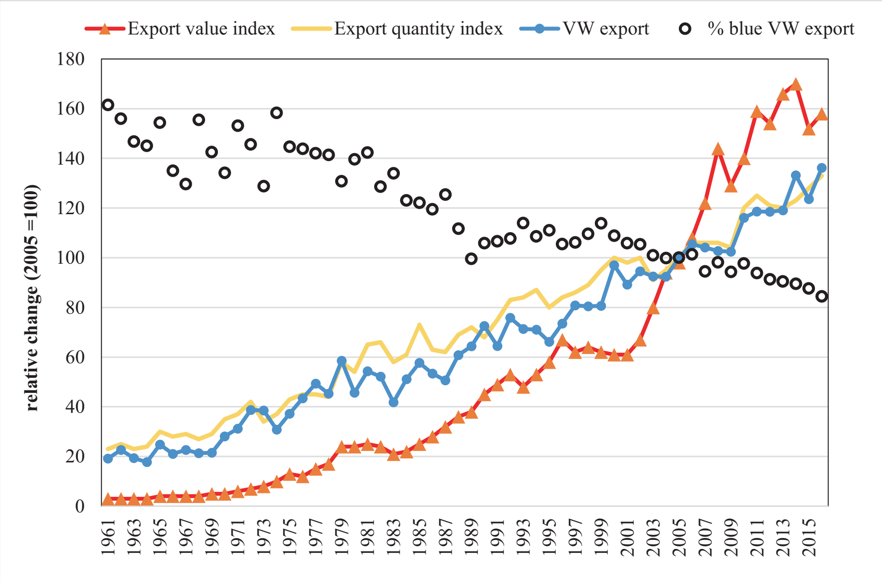

Fig. 10.4 Evolution of variables related to the export of agricultural goods from Italy, from 1961 to 2016, normalised by the value in 2005

sector increased by 79% in the decade 2006–2016, as compared to the 47% of the total Italian exports. With reference to Fig. 10.4, this sharp increase seems to have been driven more by the increase in the agricultural prices than by the increase in quantity.

The trends relating to VW and quantity are very similar, with the exception of some selected periods: the 1980s and the 1990s. In such periods, the composition of export could have changed, with the share of water-intensive goods (such as meat, dairy and luxury food) growing at an irregular pace within the export basket, as it can be observed in Fig. 10.5 (left). A correspondingly variable Export Value Index confirms that in early 1980s and early 1990s the value dropped, to recover again in few years. Another possible explanation of the quantity/VW gap of the early 1990s could be related to an increase in production efficiency, reflected in a lower amount of water used per ton. The blue VW export of Italy, as well as its total VW export, increased significantly over time and almost doubled from 1986 to 2016. However, as opposed to what happened to the WF of production, the share of blue water over total VW export constantly decreased over time (Fig. 10.4), first with fluctuations, then more regularly, with a period of relative stability during the 1990s. The product associated to the greatest blue VW export is rice, with an average blue VW export of 1 km^3/year, which has been roughly constant over time. The increase of blue VW export is due to the increase for all other categories, which amounted to 0.4 km^3 in 1986 and went up to a maximum of 1.5 km^3 in 2016. Such rate of increase is small with respect to the increase of green VW export, thus leading to a decreasing share of blue-to-total VW export. A role is also played by the improving agricultural techniques and a more efficient use of blue water (decreasing blue unit WF), which limited the inflating effect of export increase on the draining of Italy's water resources.

Figure 10.5 shows that the total amount of agricultural VW imports, from 1985 to 2015, is higher than the exports. However, in the last decade VW exports increased more than imports, and with less fluctuations. This figure reflects the findings of ISMEA (2018), that noted that the trade balance of the Italian agro-food sector is in structural deficit, but also that this deficit recently decreased thank to an increase in the export value more robust (+18% from 2013 to 2017) than the increase in the import value (+14% in the same period). With respect to the partition of exports among product categories, we observe a larger role of luxury crops, seeds and oils, meat, dairy products and eggs (listed in order of magnitude of the share increase). The shares of cereals, fruit and vegetables did not increase in the same period. Overall, we observe that while in 1985 the highest percentage of VW export was related to cereals, in 2015 it was dominated by the role of luxury foods and of seeds and oils. VW imports have followed similar trends than exports, but with a stronger presence of vegetables and non-edible products.

It is interesting that, from a VW perspective, although overall volumes of water imports overcome exports, the weights of categories in both fluxes are similar. This seems to suggest that Italy's food trade, especially the import, is not driven by the impossibility of producing goods locally due to domestic water deficits that must be rebalanced through foreign water resources, such as in the case of the Middle East and North Africa region (Antonelli and Tamea 2015; Antonelli and Allan 2019). This is not surprising, because water is not a major determinant of trade patterns (Reimer 2012) as it generally accounts for a share of production costs which is very

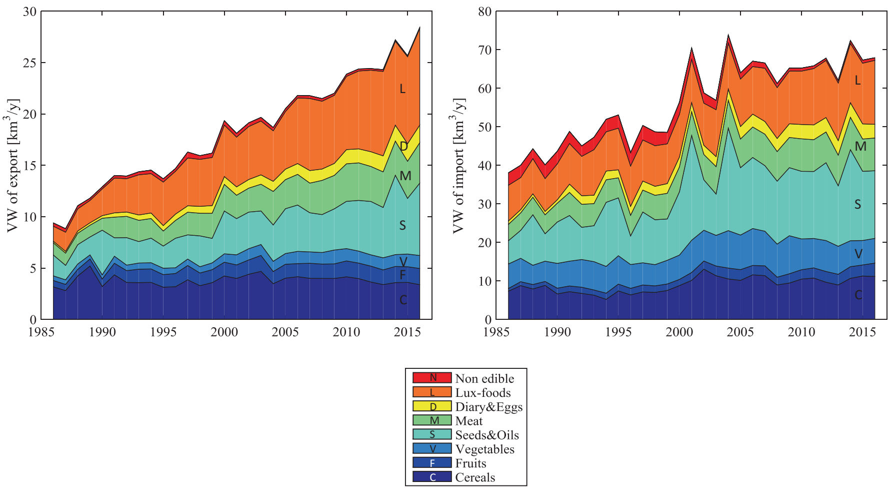

Fig. 10.5 Temporal variability of VW trade (total: green plus blue water) of Italy, per category, from 1986 to 2016: export (left) and import (right) in km^3/year

small or often close to zero. Patterns of trade are therefore driven largely by which country can be the low-cost producer to a given destination. For agricultural products, this is greatly affected by distance (freight costs) as well as tariff and non-tariff barriers to trade, which are also quite high in this sector (Reimer and Li 2010). As water resources account for a tiny share of overall costs of production, the international trade system is not necessarily organised to achieve maximum water savings, but it is driven rather by costs and consumer preferences (Reimer 2012). If observed from the perspective of the economic value instead of that of VW, we realise that the main Italian food imports and exports are dominated by different categories (FAO 2018), which shows that more complex economic reasons, such as dynamics along the value chain, may be stronger determinants of food exchange. For example, raw products like cereals and coffee beans are among the most imported crops in terms of economic value, while processed food, such as pasta and roasted coffee are among the most exported (FAO 2018). Moreover, fresh fruits are among the top Italian exports with respect to value, but from a VW perspective they play a minor role.

10.5 Blue Water and the Euro-Mediterranean Context

Analyses about total (green plus blue) WF or VW trade are sometime misinterpreted, unless the accounting of rainfall (green) water is made explicit. Green water and blue water have different sources, the latter being withdrawn from surface- and ground-water bodies, but they both contribute to crop evapotranspiration during the growing season, with blue water provided as irrigation. A careful planning and management of green water can indeed save blue water, as well as process optimisation can save blue water along the production chain.

A focus is here presented about the blue water imported and exported by Italy, averaged over the period 2012–2016. Indeed, Italy imports more blue water (around 4.7 km^3/year) than it exports (around 2 km^3/year), as shown in Fig. 10.6. In exports, the share of blue water among product categories seems to be more uniformly distributed than for imports. Blue VW export is dominated by cereals (rice), followed by seeds and oils (olive oil) and meat (ham and other preparations). Blue VW import is dominated by luxury goods (sugar) and seeds and oils (olive oil), followed by fruits (dried fruits, olives and many other), cereals and meat (pig meat).

Comparing the Italian VW trade with that of a few Mediterranean countries in the same period highlights that Italy is the only net importer of blue VW among them, with imports larger than exports. Italy shows the largest blue VW imports compared to Spain, Greece and France, while Spain plays the strongest role in blue VW export (>9 km^3/year), followed by France, with Italy and Greece being overall into a lower position (<2.5 km^3/year). Spain's blue VW exports are related to trade in seeds and oils, meat and fruits, while in France they are strongly led by luxury goods (mostly sugar). Only Greece and Spain show a considerable share of blue water export associated to non-edible products. Blue VW import in seeds and oils is

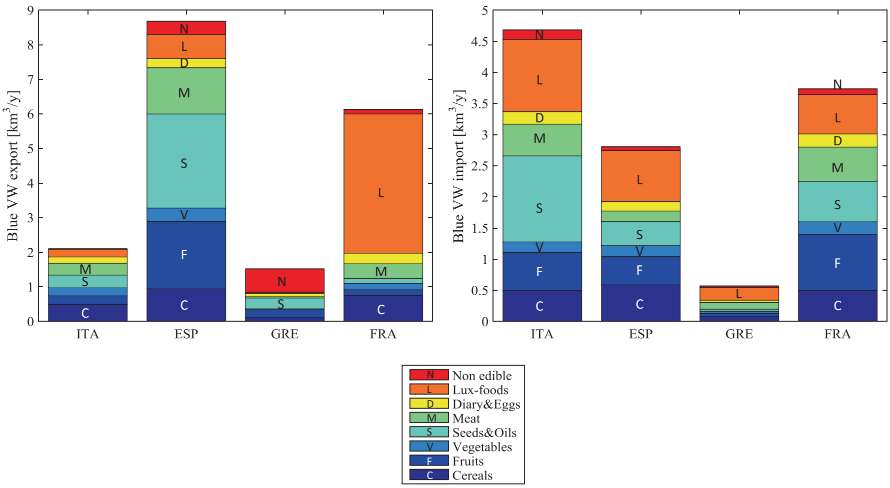

Fig. 10.6 Blue VW trade of different countries averaged in the period 2012–2016: export (left) and import (right) of Italy (ITA), Spain (ESP), Greece (GRE) and France (FRA), in km^3/year. Vertical axes are different to optimise categories visibility

large for Italy, and lower in Spain and France. The volume of blue VW export associated to cereals is similar among the three countries, but different in products, because it is dominated by rice in Italy and Spain and by maize in France. Blue VW imports for luxury goods are present in all the four countries, with a concentration in Italy and Spain, mainly due to sugar products. In general, luxury goods and oils and seeds are the most represented categories in the blue VW trade of these four countries, followed by cereals.

The main trade partners of Italy for blue VW imports are Spain (1.5 km^3/year), France (0.5 km^3/year) and Greece (0.2 km^3/year), while for exports are the United Kingdom (0.11 km^3/year), then Germany and other countries in Central Europe. VW flows in the EU market are intense (Antonelli et al. 2017). Spain, France and, to a lower extent, Greece are net exporters of VW, both towards Italy and globally, as confirmed by Fig. 10.7, which shows the net importing and exporting countries in the area for blue VW. Italy is confirmed to behave differently than the surrounding countries, and more similarly to others in Central Europe, the United Kingdom, or Turkey. It is well-known that blue water plays an important role in Egypt, due to irrigation fed by the Nile river, leading to high figures in blue water use in both production and export. Other countries, such as Greece, Morocco and Tunisia, show a peculiar figure, resulting in a net blue VW export, despite being net importers of total (green plus blue) VW. Their net blue VW export indicates that they are able to sell abroad the food produced through irrigation, demonstrating positive economic impacts of investments in water management. On the other hand, it may be surprising that Israel is a net blue VW importer, despite having an advanced level of water management and control for irrigation and thus a comparative advantage in self-producing water-intensive goods. The figure is probably due to a general tendency

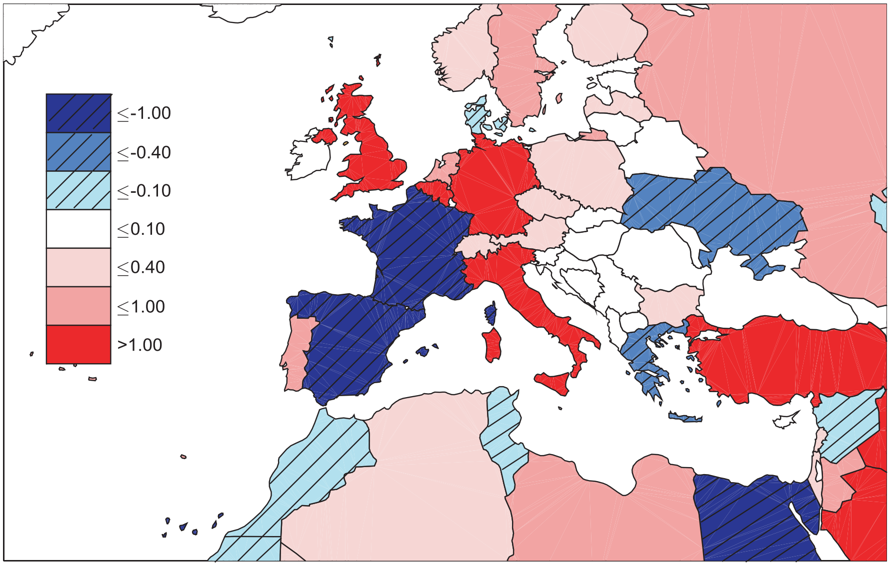

Fig. 10.7 Map of net blue VW import, averaged in the period 2012–2016 in km³/year. Blue (striped) countries are net exporters and red (solid) are net importers

of wealthy countries to import large amounts of food, derived from both rainfed and irrigated cultivations.

10.6 Italian Excellence: Olive Oil and Wine

Olives and wine are analysed here as they represent two of the most strategic exported agricultural products for Italy. Both are highly reputed internationally for their Italian origin, and are also generally associated with the typical diet of the Country. Over the period 2012–2017, the EU produced 67% and consumed 55% of global olive oil production and exported 67% of worldwide export (European Commission 2019a). Italy is the second largest exporter of olive oil in the world, after Spain and before Tunisia and Greece, and it contributes to about 20% of all EU production, two thirds of which is extra-virgin olive oil (Carbone et al. 2018). Currently, Germany, France, and the United Kingdom are the main importers of olive oil from Italy, while Italy is itself a net – and the largest – importer worldwide (FAO 2016). The price of olive oil from Italy is by far higher than the price from Spain and Greece, which are net exporters, and its national average for the years 2018/2019 stands at 5.30 Euro/kg for extra-virgin olive oil (European Commission 2019b). Both the profile of the producer and the production area affect the price (Carbone et al. 2018). Since 2008, the olive oil regime is part of the EU Single Common Market Organisation (CMO) (European Commission 2019a).

Most of olive production in Italy is non-irrigated (about 80%), with southern-insular regions of Sicily, Sardinia, Calabria, Puglia and Basilicata being the largest in terms of production areas (European Commission 2012). Yields vary depending on the year, climate, growing practices and planting density, as well as the above-mentioned alternate bearing, but low and erratic rainfall is often a cause of a reduction in production levels (European Commission 2012). As shown by Amicarelli et al. (2011), the WF of olive oil production in Italy ranges between 3.6 and 6.7 km^3/year, comprising both internal and external WFs. Previous studies, for example on Spain, have shown that most of the water use in olive oil production occurs as evapotranspiration in olive fields (Salmoral et al. 2011). Pellegrini et al. (2016) have demonstrated that the high-density olive cropping system is the most water-saving and produces the lowest aggregated WF compared to other agronomic cropping schemes in Italy.

As shown in Fig. 10.8, Italy's olive oil exports corresponded to 1.27 km^3 of exported water in 1985 and 5.39 km^3 in 2016. Olive oil export has reached, in the most recent years, the 60% of the national production of olives, in terms of VW. VW export of olive oil varies across years and mostly depends on green water, which is therefore the main component of VW trade. Green water accounts for an average 88% of the total exports associated to olive oil between 1985 and 2016. The difference between olive oil production and exports depends on the final stock resulting from each season, meaning that a fall of production in one year may be reflected in a reduction of exports in the following year (such as in the case of Spain after the fall in olive oil production in 2002: Salmoral et al. 2011). As mentioned, Italy is a net importer of olive oil, in terms of both quantity and embedded VW, with an import-to-export ratio of about 2.

As concerns wine, the EU represents 45% of global vineyard areas, 65% of global production, 57% of consumption and 70% of worldwide exports (European Commission 2019a). Italy is the top wine producer in the world, accounting for 19% of global production, and is followed by France (16%) (Miglietta and Morrone 2018). Figure 10.8 shows that the production of wine has decreased in quantity by 37% over the period 1986–2013; however, the 1980s were characterised by a peak of wine production in Italy, that was lower (6 million tons) in 1961 (FAO 2016). The wine sector in Italy experienced a number of changes over these decades, such as a shift in wine consumption towards lower per-capita volumes but higher average quality, as well as the entering of newcomers in the international wine market. Between 1980 and 2005, the total production decreased, while controlled denomination grew from 10.7% to 25.3% of total production (Corrado and Odorici 2009). Consistently with what found by Miglietta and Morrone (2018), green water is the largest WF component of wine production. Lamastra et al. (2014) also developed a specific methodology to analyse the WF components of different grape-wines production of one winery in Sicily. In all cases, green water was the largest contributor to the WF. The study has also shown that the factors determining the largest differences in terms of WF included the distance from the water body, the degree of fertilisation and the eco-toxicological behaviour. VW exports from Italy rose from 0.41 km^3 in 1986 to 1.02 km^3 in 2016, with a limited blue water component. Italy is

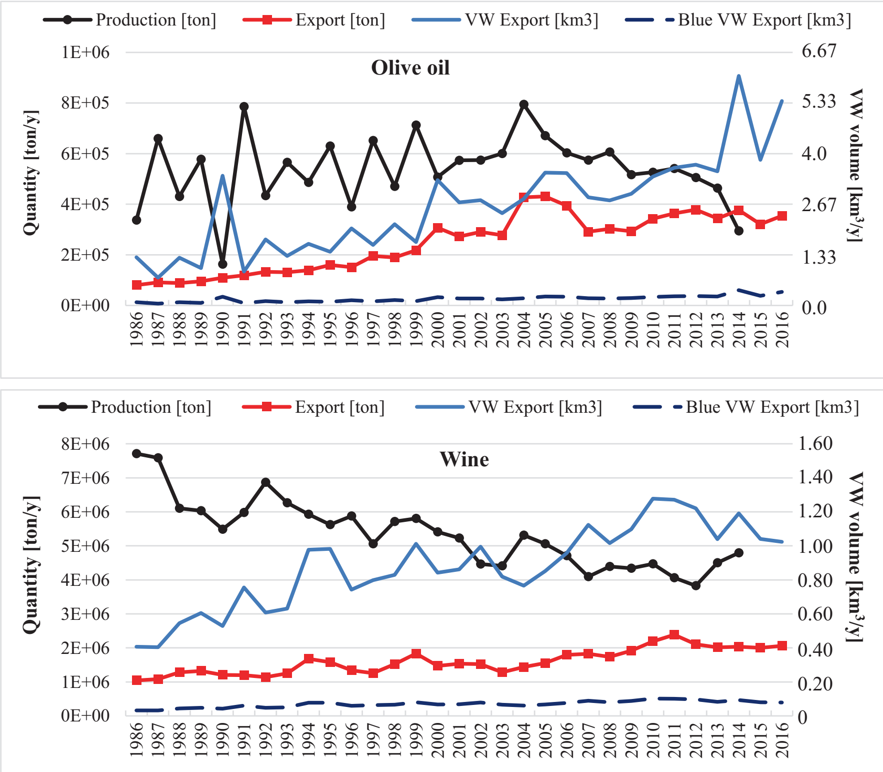

Fig. 10.8 Production, export, VW export and blue VW export of olive oil (above) and wine (below) in Italy, in 1986–2016

a net exporter of wine both in terms of quantity and of embedded VW, with very small import with respect to export.

10.7 Discussion on the Policy Relevance of Water Footprint and Virtual Water Trade

Since their inception, a number of authors have highlighted that the concepts of WF and VW trade can be considered as effective tools for contributing to better water use, management and policy (e.g. Aldaya et al. 2009, 2010; Velázquez 2007; Ma et al. 2006). These concepts can be applied to identify challenges and criticalities related to local and global water resources and to address issues related to the water-food-trade nexus (Allan 2003). By assessing the origin and destination of water resources associated to goods and services, the two concepts enable quantifications of water volumes, which can support analyses of impact and sustainability as well as preparation of multiple scenarios.

At the global scale, WF and VW trade can be applied to evaluate the human pressure on freshwater resources (Hoekstra and Mekonnen 2012) as well as to appraise the impacts of final consumption (also associated with imports) and production (also associated with exports). At the national or regional level, they can explain the balance between imported and exported water with respect to local water endowments (Zhang et al. 2017). They can show the major role of agricultural export from dry areas in exacerbating the pressure on water resources, with consequences for the health of ecosystems and access to water of local communities (e.g. Dalin et al. 2017; Lenzen et al. 2013). In this vein, the WF and VW perspective allows to detect the presence of paradoxes, such as the fact that a number of countries with water deficits like India and China are VW net exporters, whereas countries like the Netherlands and the United Kingdom, are net importers (Vos and Boelens 2016). The WF argument reveals much about the dependency of nations or regions on water resources, and whether it is a local or foreign dependency (Delbourg and Dinar 2020). In many regions, such a perspective has allowed to recognise that VW fluxes successfully replaced costly real water transfers (Antonelli and Sartori 2015), or to alleviate local water deficits such as in the case of the Middle East and North Africa region (Antonelli and Allan 2019).

Some authors suggested that water-scarce nations can gain from international trade by importing VW from nations with larger water endowments and higher water productivity (Yang and Zehnder 2002; Shuval 2007; Velázquez 2007; Chapagain and Hoekstra 2008), thus engendering positive consequences for local food availability (Antonelli and Sartori 2015). The adoption of a WF and VW trade perspective in this context has enabled and enriched the discussion on the relationship between water resources and food security.

It has been argued that VW trade metrics provide new information with respect to price-based analyses, traditionally used to analyse food production and trade (Distefano et al. 2018). The VW dimension, together with the economic value and the caloric equivalent of food, give a multidimensional description of international trade of agricultural goods.

The WF assessment allows to appraise the sustainability of all social actors' behaviour, including that of corporations. Namely, it enables us to account for both direct and indirect water use in a process, product, company or sector. This can usefully be applied also to the case of corporate water use and can inform business reporting as well as risk management throughout the full production cycle, from the supply chain to the consumer (Ruini et al. 2013). A few authors have also recognised that the concept is helpful in generating public awareness regarding the volume of water required to support production and consumption, as producers and consumers are currently very disconnected from one another (among others, Roth and Warner 2008). In addition to that, appraising the spillover effects of agricultural trade and VW trade can be usefully applied for the purpose of monitoring the Sustainable Development Goals of the 2030 Agenda of the United Nations (Hoekstra et al. 2017).

A few controversial issues regarding the use of the WF and VW metrics for informing policy-making deserve attention and further research. For example, comparing WF figures sheds light on differences in the productivity of water use across regions and countries, but these figures remain difficult to interpret because of the diversity of inputs and local conditions. For a more comprehensive and policy-relevant interpretation, one should place WF and VW trade figures into a larger physical, economic, political, and historical context. A given amount of water required per unit of crop production may or may not be sustainable, depending on local water conditions (Dalin et al. 2017; Tuninetti et al. 2019; Delbourg and Dinar 2020). Decisions on trading in specific goods are influenced by multiple factors that, besides water endowments, include the availability of land and capital, and trade agreements and policies (Antonelli and Sartori 2015). It has also been pointed out that the policy relevance of the VW perspective can be greater where scarcity values – that is, opportunity costs – are substantial (Wichelns 2010).

Then, one should not confuse WF with environmental impact. For example, a higher use of fertilisers leads to increased yield and to lower WF, but with harmful consequences in terms of land and water quality. A strategy that takes into account VW issues must form part of a comprehensive system for water resource management and needs to be overall ecologically acceptable (Horlemann and Neubert 2006).

Water scarcity issues, which involve the imbalance between supply and demand, are regional and local, rather than international. Reducing the WFs of residents in one city will not enhance water availability in another town (Wichelns 2015). However, the development of stewardship programmes, compensation measures or optimisation strategies can enhance the efficiency of water use at larger scales and increase water availability for local and downstream communities and the environment.

Also, practices that lead to a lower WF are highly dependent on other critical dimensions linked to agriculture, like capital, technology, labour and energy (Antonelli and Sartori 2015). These dimensions as well should be included into the WF discourse. Examples of the need of broadening the view are given by the coexistence of groundwater depletion and the Green Revolution in India, or the role of capital-intensive technologies in the decrease of the WF of Singapore and Israel (Delbourg and Dinar 2020).

To conclude, despite the acknowledged limitations, we argue that VW trade and WF methodologies can contribute to build a comprehensive framework for better water management, use and policy at the national level. A number of examples can be provided on the potential of these indicators to inform sound water policies. For example, they can contribute to comply with the EU Water Framework Directive (WFD).[6] As pointed out by Serrano et al. (2016), the WFD targets only part of the "real water" use in the EU, namely, blue water, while omitting the green water component and VW trade. Spain is the first country in the EU that has decided to include WF analysis into governmental policy making in the context of the WFD. Another

[6] For further information on the WFD, see Part IV of this volume.

example is that WF and VW trade can help choose between the production of water-intensive crops and their import, stressing that the latter option may be a strategy to achieve national water savings and release blue water resources to be used for higher-value irrigated crops. Understanding the interlinkages between green and blue water and unlocking the full potential of green water in rainfed farming can lead to local water savings and therefore deserve consideration, also in view of climatic and socio-economic changes and the need to adapt to them.

WF and VW trade can help us understand the implications of the production of goods for export, in terms of water withdrawal and pollution in the producing area or country. However, in order to enhance the usefulness of VW as a tool to support policy making it is important to integrate it in multidisciplinary assessments of the national socio-economic and political conditions that influence or are influenced by water use and management. Currently, an increased integration of VW into broader environmental and economic studies in water management is needed.

Finally, although WF and VW trade have been presented as tools for enhancing food security, and optimal strategies related to local production or trade of agricultural goods, public policy objectives should consider also other social, economic, and environmental dimensions. In some situations, when conditions for effective food trade (driven by food lack) are missing (Horlemann and Neubert 2006), improvement of management of local water resources would be more helpful than implementing VW trading strategies, while under other circumstances the opposite may be true (Wichelns 2010; Antonelli and Sartori 2015). Finally, one should be aware that, since the VW trade is deeply linked to dynamics of commercial strategies and international land transactions, the governance of global fluxes of VW goes beyond the sphere of water management and enters other realms of political economy (D'Odorico et al. 2019).

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