The Virtual Water in a Bottle of Wine

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Every form of life on the Earth depends on water, and it is in water that billions of years ago the first life forms appeared. Also today, the almost 9 million living species found on our planet base their existence on water, a resource which is, therefore, not only essential but also very precious. Despite it being a renewable resource, it still, however, remains limited and vulnerable. Even if our planet viewed from afar appears as a prevalently blue sphere, with 71 % of the surface covered by water, we know very well that not all this water is actually available to humans. First of all, 97 % of the water is salt water found in the seas and oceans and only 3 % is freshwater, of which, however, most (68.6 %) is locked up in ice and glaciers, 30.1 % in groundwater and 1.3 % in surface water. The liquid water on the land surface is mainly found in the large lake basins, such as the North American Great Lakes or Lake Baikal in Russia, which contain 20.1 %, equal to 0.26 % of total freshwater, and in the swamps which make up 2.53 % (0.03 % of total freshwater). The atmosphere contains 0.04 % of total freshwater in the form of water vapour and the land 0.05 %, while the river systems contain a relatively low portion (0.006 %) (Fig. 1). Moreover, the geographic distribution of water is not homogenous—Brazil has 15 % of the global reserves and 64.4 % of the total water found on the Earth is found in only 13 countries (http://ga.water.usgs.gov/edu/earthwherewater.html; Shiklomanov 1999). For this and for reasons of economic inequality, despite only 54 % of the world's freshwater reserves presently used being accessible, a billion people do not have access to drinking water and 2 billion people do not have sufficient water for hygiene-sanitary services (Prüss-Üstün 2008; IWMI 2007).

The term water stress was coined by the World Resources Institute (WRI) to indicate when, in a delineated zone, there is not sufficient water to meet agricultural, industrial or domestic needs (Revenga et al. 2000). Therefore, we say a zone is suffering water stress when the annual freshwater availability is less than 1700 m^3

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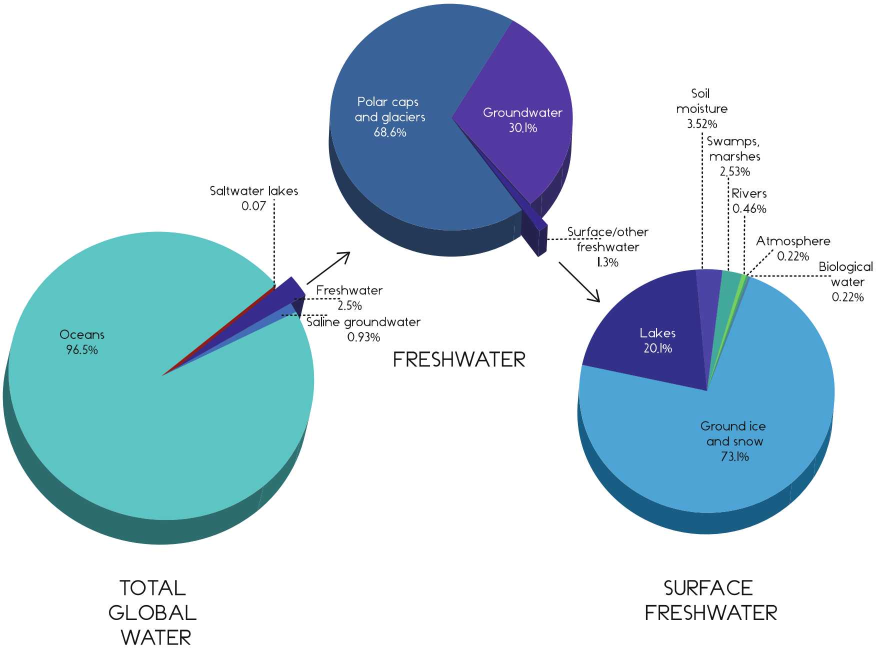

Fig. 1 The distribution of water on the planet. *Source* Shiklomanov (1993)

per year per capita. Instead, we say there is a chronic water scarcity when the availability falls between 500 and 1000 m^3 a year per capita, while absolute water scarcity is when the quantity falls below 500 m^3 a year per capita. Corresponding to these levels, there are profound economic impacts on development and serious risks to human health (Rijsberman 2006; Falkenmark 1992). The present estimates indicate that, by 2025, water stress will be a reality for almost half of the world's population. This, in turn, will lead to the price of water, which reflects the supply scarcity and competition, continuing to increase and thus changing the water allocation to the different production sectors and user groups (Rosegrant 2002; UNDP 2006). Added to the problems of local and regional water shortages, there is the problem of pollution which renders enormous volumes of water unsuitable for civil and non-civil use. Pollution threatens the quality of water resources and is also linked to demographic growth and the access to the market of large swathes of populations previously excluded from mass consumption, which has resulted in an increase in production and in the management of its waste. For example, it is estimated that 2 million tonnes of waste generated from human activities are returned to water courses with direct consequences on their quality. In fact, in developing countries, 90 % of effluent water and 70 % of industrial water are released into water bodies without being subjected to any kind of treatment, polluting the freshwater resources available for humans. Moreover, the water cycle is also affected by the climate change, the acidification of the oceans, the melting of the ice caps, the increase in the average sea level, the shifting of tropical storms towards the poles, with significant effects on the winds, rainfall and temperatures, and an increase in the frequency of "extreme" phenomena, such as flooding and heat waves (UNESCO 2009).

1 Impacts and Footprints: The Sign on Water

As far as the allocation of water resources is concerned, it should be remembered that most freshwater is employed by agriculture (more than 70 %), 23 % by industry and 7 % by domestic use (FAO 2012).

These factors have led academics in the environmental sciences to look for a way to express the impact on the water resources of each production process and consumer good with the objective to guide and urge for the most sustainable resource use possible. Consequently, in the last ten years, the calculation of the water footprint has spread. The term "footprint", common to carbon footprint and ecological footprint, sets a quantitative measurement of the appropriation of natural resources by humans (Galli et al. 2012). Consequently, as for other footprints, the water footprint is also being increasingly applied in companies and is receiving more and more attention from consumers, setting underway an awareness of *how* and *where* water is used.

Often the terms "water footprint" and "virtual water" are used synonymously. However, some distinctions between the two should be made. Both express the volume of freshwater "contained" in a product, not really but virtually, that is, all the water used and polluted throughout the production process. However, the water footprint distinguishes itself from the virtual water content as it refines the concept —it expresses and distinguishes the different types of water used and it is spatio-temporal explicit. Therefore, it tells us what type of water was used, and how it was used, with a value changing over time and depending on the production site (Hoekstra et al. 2011). Moreover, while the concept of the virtual water content may be easily reduced to a product, it is difficult to correlate to a person or a group of people (nobody could easily understand the statement "the virtual water content of the average Italian is more than 2 million litres" (Mekonnen and Hoekstra 2011). The footprint, instead, is a concept which can be easily used also to refer to the impact on the water resources relevant to a consumer as much as to a group of people (organisation, city, region, nation, humanity).

In calculating the water footprint, three different typologies of water (green, blue and grey) have been individuated, which define the nature of the water used (Fig. 2). Green water is the volume of rainwater used by crops through evapo-transpiration and is extremely important for agricultural products. Blue water is the freshwater withdrawn from a water basin which is not then reintroduced into that basin, or it may return there but at different times. Finally, there is grey water, a new

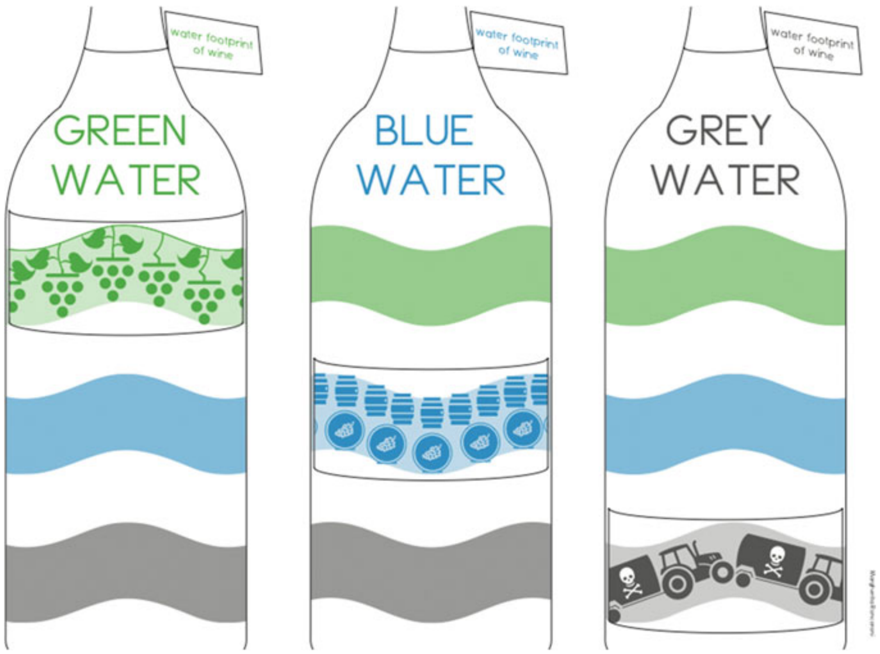

Fig. 2 The water footprint: the 3 colours of virtual water. *Source* Hoekstra et al. (2011)

and intuitive way to describe water body pollution in terms of volume, and therefore, this quantity can be added to the previous other two to obtain a total index. Grey water expresses the "imaginary" water volume required to dilute the pollution possibly produced below established legal and/or ecotoxicological end points. It is not actually a quantity of water used, but is the quantity of water which would be necessary to cancel the pollution resulting from the process being analysed (Hoekstra et al. 2011).

Therefore, the water footprint does not represent the water actually contained in a product but how much is required to produce that product. It is an indicator of the water volumes used in the production process, considering as well the water required to neutralise the resulting eventual impacts (if we think, for example, that a 0.33 l can of Coca Cola has a water footprint of 35 l, it is quite clear that this volume does not exclusively reflect its actual content; Coca Cola Europe 2011).

Consequently, the theme of the virtual water concept brings to the fore the water consumption and pollution which can be verified throughout the entire supply chain, highlighting the volumes actually contained in the product though usually "hidden". It is because they are "hidden" that this consumption is often ignored and even today, there is a lack of awareness of how much production and supply chain aspects can affect the volumes of water consumed, on the spatiotemporal distribution of its use and on the resulting types of pollution. Very often, we could almost say always, these impacts on the water resources which occur along the supply chain greatly exceed the volumes regarding the product's actual water content and its direct water consumption (Molden 2010).

2 From the Field to the Table: The Virtual Water of Agri-Food Products

Over the last years, the growing interest in the question of water has led companies, institutions and individuals to look more carefully at the issue of virtual water and the water footprint and to tackle the calculation of its relative volumes. All the studies carried out have highlighted that the virtual water of agricultural products and their derivatives always corresponds to high volumes, and for the product derivates, the most important phase is always the agricultural one. We have already mentioned that 70 % of freshwater withdrawal is due to water use in agriculture, especially regarding irrigation practices which are increasingly spreading worldwide, and which are a factor of climate change and production intensification. Mekonnen and Hoekstra in the report, "National Water Footprint Accounts: the green, blue and grey footprint of production and consumption", published in 2011, show that agriculture is responsible for about 92 % of the global water footprint (9087 Gm^3/year for the period 1996–2005; Mekonnen and Hoekstra 2011). However, it is necessary to make a distinction here. Clearly, each crop and each transformation process of agricultural products will have intrinsic characteristics which will make them, always depending on spatiotemporal dimension (the where and when), more or less water absorbent.

Wine is obtained from a product of agricultural origin—the grape, through a transformation process. The virtual water content of processed products originating from agricultural products, therefore, includes the virtual water content of these, as well as the quantity of water required to complete the production process. Therefore, to calculate the virtual water for a bottle of wine, it is necessary to begin with an analysis of the volumes used in the vineyard to produce the grapes, to which must be added the volumes used in the cellar to transform the grapes into wine. To this "direct" consumption, that is, the consumption the producer company is directly responsible for, in that it is a controlled consumption occurring on company premises, we need to add the indirect consumption, that is the water consumption for the production of the inputs required to produce the end product. In the case of wine, then, it would be the agri-pharmaceuticals and fertilisers used in the vineyards, enological additives and packing products used in the cellar, and the energy consumption and fuels used for the entire life cycle of the wine bottle (from the vineyard to the selling of the product). In calculating the water footprint, the water consumption for each step identified in the wine bottle's life cycle is broken down based on the type of water used to give the water footprint for each step, and from the sum of this the total, water footprint is obtained (Hoekstra et al. 2011).

3 The Virtual Water in a Glass of Italian Wine

Let us now discover the hidden water in a glass of Italian wine. Even if by adding "Italian", it can appear rather unnecessary, in reality, it is not. In fact, the water footprint is spatiotemporal explicit—the volumes of water used change depending on *where* and *how* the wine is produced. However, not everyone knows that Italian wine has a lower water footprint compared to the average global value. Very often, the information concerning this is not as clear as it should be and the water footprint appears as a number not only far from the understanding of people but also from reality. Let us try to clarify the situation a little. From the database that the Water Footprint Network began constructing in 1996, we can find the data on the water footprint values of a wide range of agricultural products and their derivatives, of biofuels, and of products originating from livestock breeding or industrial origin (Mekonnen 2010; http://www.waterfootprint.org/?page=files/WaterStat-ProductWaterFootprints). Each of these is accompanied by, in different detail, its geographic position (nation or region) and the indication of the volumes of water used subdivided by water typology. The water footprint of wine, globally, nationally and regionally, is shown in Table 1. If we compare the data, we can see how the Italian national average is more than 20 % lower than the global average.

A glass of wine requires 108 l of water broken down into 76 l of green (about 70 %), 17 of blue (about 15 %) and 15 of grey (about 15 %). If we look at the average national figures, we see how it is lower at 88 l, 67 (78 %) being green water, only 6 l (7 %) blue water and 15 l (15 %) grey water. The differences among the Italian regions reflect the different climate conditions, but also the different production strategies based on a lower or higher irrigation use, while the grey water value remains constant, practically equal to the world average. Looking at the data led us to considering the idea of studying more closely the question of the water footprint in the viniculture sector as an indicator for environmental performance. What is the significance of the green water footprint? Can the value of grey water be so unvarying in different national and international situations? Why are the blue water volumes in Italy on an average lower than the global one? An aspect that further interested us was to see how much the average data reported for statistical purposes in the database responded to the company situation, or if, instead, each company depending on its geographic and management features, distinguished itself significantly from the others.

4 Discovering Green Water

Water is an essential element for the life of plants. It is necessary for the carrying out of numerous chemical processes which occur in the plant tissue (e.g. chlorophyll photosynthesis), it allows for maintaining the cell turgor determining the

Table 1 The water footprint of wine

Liter/Liter of wine	World Average	National Average	Italian							
			Abruzzo	Basilicata	Calabria	Campania	Emilia-Romagna	Friuli-Venezia Giulia	Lazio	Lombardia
Green (l/l of wine)	607	534	536	584	583	584	502	519	568	503
Blue (l/l of wine)	138	46	33	67	74	41	57	3	43	33
Grey (l/l of wine)	124	117	120	133	139	125	108	103	120	103
WF (l/l of wine)	869	697	689	784	796	750	667	625	731	639

Liter/liter of wine	Italian									
	Marche	Molise	Piemonte	Puglia	Sardegna	Toscana	Trentino-Alto Adige	Umbria	Valle d'Aosta	Veneto
Green (l/l of wine)	569	569	505	549	565	565	430	567	406	499
Blue (l/l of wine)	20	39	17	126	28	28	0	38	0	24
Grey (l/l of wine)	121	122	104	128	123	123	103	121	103	104
WF (l/l of wine)	710	730	626	803	716	716	533	726	509	627

Liter/glass of wine	World Average	National Average	Italian							
			Abruzzo	Basilicata	Calabria	Campania	Emilia-Romagna	Friuli-Venezia Giulia	Lazio	Lombardia
Green (l/0,125 of wine)	76	67	67	73	73	73	63	65	71	63
Blue (l/0,125 l of wine)	17	6	4	8	9	5	7	0	5	4
Grey (l/0,125 l of wine)	15	15	15	17	17	16	14	13	15	13
WF (l/0,125 l of wine)	108	88	86	98	99	94	84	78	91	80
WF (l/0,75 l of wine)	648	528	516	588	594	564	504	468	546	480

Liter/glass of wine	Italian									
	Marche	Molise	Piemonte	Puglia	Sardegna	Toscana	Trentino-Alto Adige	Umbria	Valle d'Aosta	Veneto
Grey ((l/0,125 l of wine)	71	71	63	69	69	71	54	71	51	62
Blue (l/0,125 l of wine)	3	5	2	16	14	4	0	5	0	3

(continued)

Table 1 (continued)

Liter/glass of wine	Italian									
	Marche	Molise	Piemonte	Puglia	Sardegna	Toscana	Trentino-Alto Adige	Umbria	Valle d'Aosta	Veneto
Grey (l/0,125 l of wine)	15	15	13	16	17	15	13	15	13	13
WF (l/0,125 l of wine)	89	91	78	101	100	90	67	91	64	78
WF (l/0,75 l of wine)	534	546	468	606	600	540	402	546	384	468

WF glass (0.125 L)	WFN	A	B	C	D
	Italy	Centre	South	North	South
Green (l water/glass of wine)	67	60	55	69	159
Blue (l water/glass of wine)	6	6	1	1	1
Grey (l water/glass of wine)	15	63	0	1	23
Total (l water/glass of wine)	88	129	56	71	183

Source Mekonnen (2010)

rigidity and characteristic aspect of various parts of the plant, it guarantees the thermoregulation, and it allows for the transporting of nutritive substances within the plant. In fact, in the latter, the mineral elements present in the soil necessary for a normal development and growth of the plant species are dissolved. Water becomes a particularly important resource for the cultivation of arboreal and herbaceous species which make up the plant cycle in the spring–summer period, when rainfall is usually scarce. This fundamental resource is supplied to the crops, in part from the environment in the form of rain and in part by man using irrigation methods. Green water only involves the environmental part of the water required for the vines during the crop cycle (Hoekstra 2011).

The green water calculation is based on weather data, on soil and farming methods. This information is necessary to obtain the potential evapotranspiration value and from this calculate the effective evapotranspiration (from among the different methods to calculate the potential evapotranspiration, we used the Penman–Montheith modified by FAO; FAO 1998).

The assessment of the green water footprint leads to defining the quantity of rainwater held in the soil and used in the evapotranspiration processes during the crop cycle. For example, very often, rain falls during the winter, a time when the vine is dormant, while the vine itself requires water during the summer, a time when rain is generally scarce. In other words, the millimetres of water provided by winter rains do not all fall into the water footprint calculation. Indeed, only a very small part of this water quantity is effectively used by the vines as can be noted by studying the crop coefficient values for the vine during the different periods of the year (Table 2).

Table 2 Crop coefficient values of the grapevine in Italy

Month	Kc
January	0.2
February	0.2
March	0.2
April	0.48
May	0.59
June	0.68
July	0.68
August	0.68
September	0.68
October	0.59
November	0.38
December	0.2

Source FAO (1998)

Box. Water and the Vine: From Evapotranspiration to Water Stress

Evapotranspiration is the quantity of water (expressed by unit time) which from the soil-plant system passes to the vapour state due to the combined effect of transpiration, through the plant, and evaporation from the ground. Two distinct and different phenomena are involved which, however, are neither logical nor possible to separate. The evaporative part is, in fact, not closely linked to the crop, but however affects the water balance of the soil-plant system and from a practical point of view goes to determining the quantity of water effectively consumed.

The potential evapotranspiration is the maximum quantity of water which can be lost during the unit time for the evaporation and transpiration by 1 m^2 of a *Festuca arundinacea* field in an optimised and standardised condition. Therefore, the value is independent of the crop and the methods carried out, but, instead, depends on the seasons and the climate influencing the atmosphere's evaporating power. For this reason, for each crop there exists empirically determined "crop coefficients", differentiated by the phenological phases and subject to changes due to environmental factors (farming method, climatic region, etc.). The phenological phases identify the different stages of the life cycle of a plant species characterised by a morphological status to which specific physiological needs are linked. When possible, crop coefficients related to their specific climatic and geographic region should be adopted and, in the absence of the relevant documentation, reference should be made to similar environmental conditions. The crop coefficient value may be less or more than the unit and must be multiplied by the potential evapotranspiration to provide the effective evapotranspiration. Therefore, depending on the crop coefficient value, the effective evapotranspiration may be less or more than the potential evapotranspiration. In non-standard climatic and management conditions, the estimate of the effective evapotranspiration can be improved ("adjusted") by introducing a stress coefficient, *K*s. This is a water stress coefficient. In fact, while the effective evapotranspiration represents the crop's consumption when it is maintained with an optimum water supply where it can therefore transpire without limitations, in reality, the crops, even if irrigated, can encounter stress conditions which reduce their transpiration rate. Stress conditions can be verified when the soil's water content falls below the threshold value defined as "the easily usable reserve". Therefore, the crop is not in a condition of stress when the soil has a water content more than the easily usable reserve value. In these conditions, the stress coefficient will be 1 and the effective evapotranspiration value is not adjusted. Instead, the stress coefficient becomes less than 1, tending towards 0, when the soil water content falls below the easily usable reserve value. Therefore, the stress coefficient is maintained at 1 until reaching the value equal to the easily usable reserve, to then fall to 0, when the soil moisture reaches the wilting point value. The easily usable reserve value is typical of every type of soil and varies from crop to crop depending on the soil water withdrawal efficiency and the root system depth (FAO 1998).

There are those who criticise the fact that, in the virtual water volume estimates, this quantity of water naturally supplied by the environment by means of rain is also taken into account (Daniels 2011; Berger 2012). It is true that rainwater which is used by the vine would fall on the soil anyway, and it is true that any plant species would use it, but it is especially true that the vine always has a crop coefficient of less than 1, that is, it requires less water than the standard *Festuca* field, but also less water than a mixed oak forest where for 220 days (beginning from the 121st day, the 1st May), the crop coefficient value is more than 1 reaching a peak of 1.2 (INEA 2005).

The new and important point that the green water footprint raises is how much does a crop adapt or not to being cultivated in a given climate zone. When the green water footprint is high and significantly higher than the blue water footprint, then it is in a zone suitable for the production of grapes. Looking at this from an international trade perspective, the exportation of wine with a high green footprint to countries where the production of wine grapes requires a higher water volume for irrigation purposes and where, therefore, the possible or actual production of wine would be characterised by a higher blue water footprint value would be an advantage in terms of overall water resource saving!

Box. Green Water and False Myths: "The Green Water Footprint is Higher in the South!"

Often, those who approach the concept of the water footprint believe that it penalises the crops of warmer regions, where the potential evapotranspiration is higher. It is true—where the average temperatures are higher, potential evapotranspiration is higher, but this does not suffice. The green footprint does not tell us how much water the plant would require during the crop cycle to compensate for the potential evapotranspiration, but it tells us how much rainwater was held by the soil and used by the crop. Therefore, if, let us say, it rained during the year, much more than the vine required, the green water footprint would be equal to the effective evapotranspiration value and not to the quantity of rainwater which fell during the crop season. If, instead, as usually happens, the rainfall during the year was less than the water volume required to compensate for the potential evapotranspiration calculated for the crop cycle, the green water footprint would correspond to the quantity effectively used during the crop cycle provided by the difference between the effective daily rainfall and the quantity of water in excess that is not held in the soil and which percolates down (calculated in the absence of irrigation). The sum of these values during the crop period corresponds to the sum of the effective evapotranspiration values calculated under water stress conditions, and these values correspond to the green water.

Consequently, contrary to how it may seem, the green water footprint is not higher than in the south. In fact, in hotter and less wet regions, the green water footprint should be lower, whereas the blue water footprint is higher as irrigation methods are required to avoid, even for the highly resistant vine, qualitatively and quantitatively excessive and harmful water stress.

5 Discovering Blue Water

In the production of wine, the consumption of blue water occurs in different phases, beginning with the vineyard where the blue water is used for irrigation, for the dissolution and use of active principles used for protecting, and washing the agricultural machinery used, right up to the cellar where water is required in almost every step in the wine-making process.

As shown in Table 1, the blue water volumes are generally low in wine. This is due to two main reasons. As far as the vineyard is concerned, it should be remembered that the vine is a plant that has an extremely high resistance to water stress, a reason why it is often not irrigated and, even when irrigated, it tends to be an emergency irrigation using very low volumes of water compared to those required to compensate for the evapotranspiration (even less than 50 %; Pou 2011). Of the approximate 2.5 million irrigated hectares in Italy, only 7.4 % involves vineyards, about 30 % of the Italian vineyards (INES 2005). Instead, in the cellar, consumption is generally low and it is estimated around 5–8 l of water are used for each bottle of wine, highlighting how wine making is a highly technological and efficient process concerning water consumption (Winetech 2005; Di Stefano 2008).

Only the water used for irrigation methods is considered from the data, and it is in all likelihood a conservative value. In fact, where the grapevine is not irrigated, the value is significantly lower, and only includes the volumes relevant to agri-pharmaceuticals and the washing of the agricultural machinery (Table 1).

Box. Vine irrigation: Strategies and Methods

The grapevine is a traditionally non-irrigated crop able to tolerate summer season water stress, and thus, it is usually found in dry areas. In the past, the *Vitis vinifera sativa* was cultivated in low-growing rows of vines, and because of its extensive and deep root system, it never required irrigation. Modern viticulture, instead, must take into account the introduction of new more resilient hybrid grapevine varieties, growing taller and with more foliage spread, focusing more on the must quality, and finally, but not less important, the effects of the present climate change. Weather conditions can, in certain phenological phases, be insufficient to meet plant growth requirements, and if once grapevine irrigation was considered a "forced" agronomic practice that is aimed at maximising yield to the detriment of the end product quality, it is now permitted as an "emergency" practice under legislation, also of high-quality wines. Moreover, it should not be forgotten that in vine cultivation marked for wine production, an excessive artificial water input or one carried out after the maturation phase may be harmful in terms of must quality. For these reasons, the European Community has given the right to EU member states to establish their own regulations on the use or non-use of emergency irrigation in DOC and DOCG production, while specifically prohibiting along with some other methods the use of irrigation as a forced cultivation.

Among those irrigation methods widely used and able to respond to the needs of an "emergency" situation, "regulated deficit irrigation (RDI)" stands out, where irrigation must only be implemented in the most sensitive phases of the crop growth, or the flowering-setting phase and the period between the veraison and the ripening phase. A reduced or zero water input in other phases allows for reducing the plant canopy growth and increasing the "fruit to leaf" ratio, improving berry colour and quality resulting in the right skin/flesh ratio and an increase in the content of the anthocyan and phenolic elements (McCarthy 2002; Pou 2011). The irrigation methods that adapt better to this strategy are the localised ones. This is drip irrigation with drip water supply lines (above ground) or sub-irrigation (underground). These methods, which are more commonly used in viticulture, result in an efficient water resource use further justifying the low blue water footprint values (McCarthy 2002; Pou 2011).

6 Grey Water

The grey water footprint generally expresses a volume of water that has not been actually used, but the volume that would be required, if water body pollution occurred, to return the concentrations to below the legal standards or the established ecotoxicological end points. A new term coined in 2008 by Hoekstra and Chapagain, the grey water footprint, expressed a new and simple way to report pollution, generally expressed as a concentration (quantity in weight compared to volume) in units of volume and able, therefore, to be added to the green and blue footprints to provide a comprehensive water footprint (Hoekstra 2008). Thus, the grey water footprint is obtained from the pollutant load divided by the difference between the maximum acceptable concentration in the receiving water body and the natural background concentration. This because in the case where pollution had already been present in the water body, the water body's capacity to assimilate it would be consequently reduced. The maximum acceptable concentration depends not only on the pollutant but also on the water body it was found in. There are different legal and ecotoxicological standards according to the type of water and that water's use. Surface water and groundwater apart from the differences in the maximum acceptable concentrations are, instead, considered as a single water body when calculating the dilution volumes concerned. In calculating these, furthermore, the critical pollutant is used, that is the dilution volumes are not summed up but, instead, the highest is selected (that would be required for the pollutant based not only on the concentration reached in the water body but also on its toxicity as per the legal and ecotoxicological standards) as that virtual volume would also dilute the other pollutants, which would require lower dilution volumes (Hoekstra et al. 2011).

In order to calculate the grey water volumes, the manual itself proposes three types of approaches, from the simplest, to the more complex and realistic.

1. The simplest approach uses a fixed fraction to express the part of the pollutant which reaches the water body. This index depends on the type of pollutant and comes from the sector literature.
2. The second approach uses standardised and simple models to forecast the pollutant concentrations found in the water body.
3. The last approach, instead, is proposed as a refining of the second where sophisticated and complex models are used able to forecast the pollutant concentrations in the water body based on the company scenario (Hoekstra et al. 2011).

Table 1 shows the similar grey water footprint values in Italian regions compared to the world average. Why?

In order to estimate the grey water footprint, the database was actually created using a Type 1 approach which only includes nitrogenous fertilisers and estimates a nitrate leaching of 10 %.[1] The maximum acceptable concentration used is the legal standard for nitrates (50 mg/l) and assumes a natural groundwater concentration of 0. The nutritive input for a vine is considered practically the same worldwide and in the Italian situation, and thus, the grey water footprint remains constant. Moreover, it has been evaluated that the nitrogenous fertilisers are the critical pollutants, and therefore, no agri-pharmaceutical application is taken into consideration.

This mean data obviously involve many different situations. Fertilisation is not always adopted as a practice just as sometimes it is not a given that the nitrates are the critical pollutants. The generalisation can be made, but it does not always correspond to the mean value, and sometimes does not even represent the "worst case scenario". Let us look at why.

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[1] The term leaching refers to the transporting of dissolved solutes in water, such as nitrates and agri-pharmaceuticals, which penetrating beyond the root system depth reach and pollute the groundwater. The nitrates, being highly soluble and mobile in the soil, are a risk of water pollution in that the excess not employed by the plants is washed away by rainwater or irrigation water and can reach, through leaching, the deeper water bodies.

We attempted to calculate the grey water footprint of some Italian wine-producing companies different in their management strategies and their geographic position. However, firstly, we made some of our own modifications to the model:

- we decided to use as a fixed nitrate leaching percentage, not 10 % but 6 %. This is a value obtained after 15 years of studies using a lysimeter in Europe that seemed for us to respond better to the actual situation (Fank 2006);[2]
- we also considered the use of agri-pharmaceuticals, and by means of scientifically validated models, we assessed the percentage which reached the surface and groundwater bodies, applying, in the first case as the maximum acceptable value, the No Observed Effect Observation(NOEC) and, in the second, the legal standard for groundwater as established by the European Water Framework Directive (EU 2000). In addition, we also considered the possible mitigating measures adopted by the companies resulting in reducing their pollution levels.

Consequently, for each agri-pharmaceutical, we obtained a dilution volume for the groundwater and for the surface water and we considered the higher of the two. Therefore, from among all the agri-pharmaceuticals applied in the same vineyard, we took as the grey water footprint of the agri-pharmaceuticals applied, the value relative to the resulting higher dilution volume. We then compared this value with the fertilisation value, and again, we chose the highest, thus, obtaining the grey water footprint, that is the water volume that would have diluted the pollution resulting from the use of nitrogenous fertilisers and agri-pharmaceuticals.

The results change depending on the active principles used, but also on the company's location in relation to surface water bodies. For companies with vineyards more than 100 m from a surface water body, the pollution of this body becomes highly unlikely, while this becomes very significant for those vineyards found far from a water body.

The values are sometimes above and sometimes below what is reported in the database. In company A, the main differences are found in the grey footprint. This company uses irrigation and is positioned near a water body, and the latter information explains the high grey water footprint. It is considered, in fact, that a moderate amount of pollutants may reach the water body requiring a high dilution volume (more than 60 l/glass for the critical pollutant, this involves a volume that also dilutes the other pollutants) (Fig. 3).

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[2] The lysimeter is a device used to assess groundwater dynamics. It is equipped with a drainage system to collect the percolated water. The study mentioned analysed the percolated water for a period of 15 years. On the basis of the findings, it seemed opportune to reduce the fixed nitrate leaching percentage.

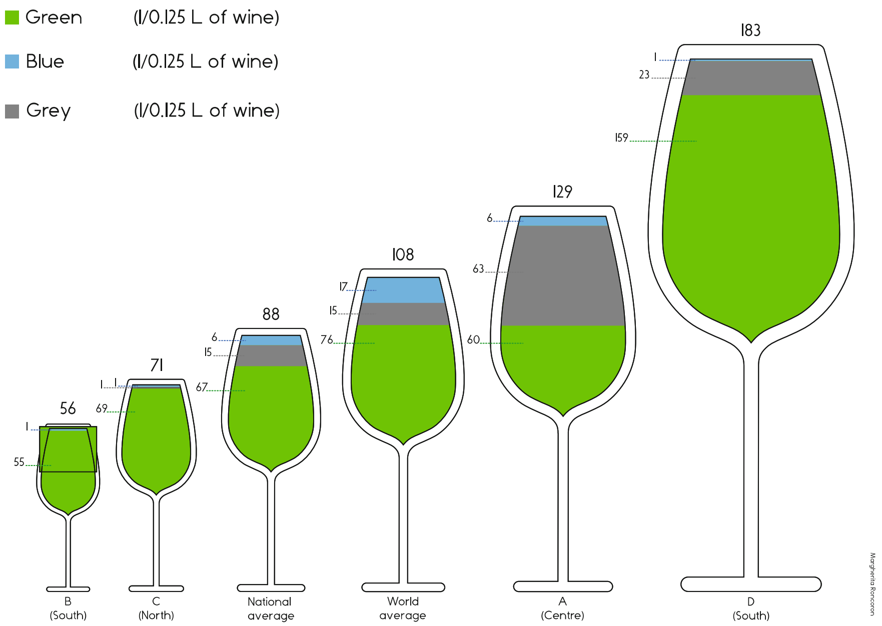

Fig. 3 The water footprint of Italian wine in 4 different situations. The results are compared with the mean data and expressed per glass of wine (0.125 l)

WF glasses (0.125 l)	NWF* Italy	A Centre	B South	C North	D South
Green (l water/glass)					
Blue (l water/glass)					
Grey (l water/glass)					
Total (l water/glass)					

* Data from water footprints of crops and derived crop products (1996-2005). Report 47, Appendix II.

In company B, irrigation methods are not used, no nearby water bodies exist, and no use of fertilisers. These factors result in markedly low blue and grey water footprint values.

In company C located in the north, irrigation and fertilisers are not used and the nearest surface water body is 200 m away. Despite this, a significant part of an active principle used in high amounts (copper oxychloride, 3.2 kg/ha) reaches the water body, thus, necessitating dilution.

The last company, D, is located in the south of Italy and shows the highest green value which, however, is due to the low production yields (50 cwt/ha). The blue value, however, remains low, while the grey water footprint results from the virtual dilution after fertiliser application.

Therefore, it is important to note how low yields penalise the products, demonstrating a low efficiency in water resource use (green, blue and grey). If, in fact, from the same planted surface area, higher grape yields were obtained and, therefore, a higher quantity of wine, the water footprint values would be lower. Therefore, using less water in production, from a water efficiency point of view, is an assumption of sustainability, even if, for qualitative reasons or due to particularly adverse environmental conditions, and it often appears to be a choice that is not always very practicable.

Box. Sustainability and Quality: Synonyms or Antonyms?

It is often believed that high-quality wines are more environmentally sustainable than those of lower quality. But the environmental indicators, including the water footprint, sometimes tell us the opposite. Why? Maybe we should take a few steps back and clarify our ideas. First of all, the water footprint of a lower quality wine could in some cases be lower to that of a higher quality wine due to differences in yields per hectare. Those who must produce a cheaper wine will try to maximise the yields in order to contain costs, on the contrary, those aiming for quality will have to select better grape clusters during the crop season to be able to reach the established qualitative standards. It is clear that those, with the same weather conditions and cultivation techniques, from the same farmed surface area and a higher grape yield and, therefore, more wine will have an overall lower water footprint. In fact, the green, blue and grey water volumes used will be distributed over a higher product quantity.

However, we should stop here to reflect if this comparison is logical and correct. The environmental impact indicators from a sustainability perspective should not lead to comparing the end products, but should be used to objectively measure product improvements from the same situation following given choices. Therefore, in the case of wine, the use of indicators should be used by the winery interested in reducing the impact on water resources to assess the initial state, to identify the critical areas, to plan effective strategies to reduce the impact in delineated critical areas and, finally, to measure the improvements achieved. Consequently, the intra-company and not the inter-company comparison becomes important. The fact itself that even hypothesising a similar management strategy in the field and in the cellar in different company situations due to geographical position, climate conditions and territorial context have quite different water footprint values, should discourage us from any attempt to compare, which, however, remains interesting for statistical purposes in creating global, national and regional databases. Lastly, but not of less importance, the fact would remain that the two wines hypothesised (quality wine obtained from low yields due to management choices in selecting better grape clusters and lower quality wine obtained from vineyards aimed at maximising yields) respond to two different needs and cannot be compared, not only for their environmental impact, but also for their intrinsic qualitative characteristics, for their economic value and their market positioning. They respond to different needs, pursue different objectives, require different management strategies and, therefore, result in products with different targets and so any comparison loses every possible significance.

Box. Communicating Virtual Water It is definitely not easy. It often involves high numbers, sometimes incredibly high. Who would not be surprised to know that for a good glass of wine, it requires, on an average, 109 l of water when we actually pour only 0.125 from the bottle (872 times less!)? We can easily imagine that there is “hidden” water, but it would be much more difficult to calculate the right weight.

For this reason, a simple number should not be delegated to carry out this task. How many times have we read 3000 l for a 200 g beef steak, but how many times have they told us that 94 % of the volume of water is green water, 4 % is blue and 3 % grey? The values should always be shown by water typology, and the different water typologies should always be explained. It is quite different knowing that of the 109 l of water required at a global level for producing one glass of wine, only 17 are of blue water, 15 grey and 76 of green water. Moreover, as we have seen, on a world average, Italian wine has an even lower water footprint, a reason why the information on the product should not only be clear, referring to the single elements of the water footprint, but also linked to the spatiotemporal explication. Thus, the water footprint would include information and not a number, far from our understanding and also from the existing reality.

7 Some Drops of the Wine Water Footprint

The virtual water and water footprint of wine express the “hidden” volumes of water, calculated from the vineyard to the cellar, required in producing the wine. The water footprint, extending the virtual water concept, distinguishes between the volumes depending on the water typology used—green water is the rainwater effectively used by the crops, blue water is the surface water and the groundwater withdrawn and used in the production processes, and grey water is the volume of water required to neutralise the resulting pollutants. In Italy, the recognised value is 88 l per glass of wine (0.125 l), but the findings of experiments conducted in different national contexts result in values varying between 56 and 183 l depending on the management and geographic aspects of the wineries involved.

Almost all the “hidden” water in a glass of Italian wine is green water (55–159 l per glass of wine corresponding to a percentage varying from 46 to 97 %). It is important to note here that a cultivation of *Festuca arundinacea* (a grass commonly used in lawns) or a wood of oak trees would require much more green water than the grapevine itself. As far as blue water in Italy is concerned, it makes up a very small percentage of the total, varying between 0.5 and 7 %. It should be recalled that the *Vitis vinifera sativa* is able to tolerate high water stress levels and that Italian cellars are equipped with a high technological efficiency in limiting the water consumption required in the processing stages.

From the general data, a certain consistency in grey water volumes appears (approx. 15 l per glass) and by trying to assess, through scientific models, the pollution levels of water bodies based on the management strategies used, and of the company scenario (also including the company carrying out mitigation measures), different values are obtained, varying from 0 to 63 l per glass of wine! These data accurately mirror the studied product's water footprint and can help companies in reducing their impact through modifying their management strategies.

For these reasons, the water footprint of a glass of wine should always be presented based on the water typology used and on the spatiotemporal position of the wine company. Indeed, the hidden volumes can often seem "enormously" high, especially to those not actually involved in the production. Being clear and transparent would help in conferring the right weight to water, especially the water we do not see!

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