Springer Water

Marta Antonelli
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The Water We Eat

Combining Virtual Water and Water Footprints

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Foreword

Food and Agriculture Organization of the United Nations (FAO)

The most recent world summit on sustainable development, held in Rio de Janeiro in June 2012 (Rio +20), clearly stated the central role of water in all human activities and in nature as a whole. Over the next 40 years, our planet will have to develop facing an unprecedented and increasing scarcity of natural resources, such as first and foremost water.

The main driver of this difficult future is the growing world population, which will quickly go from today's nearly seven billion people to over nine billion people in 2050; at that point, mere basic drinking and nutritional needs will put natural resources under extraordinary pressure, further exacerbated by the impact of climate change.

Food production will be the activity that will cause the biggest increase in water consumption, hence the FAO's slogan "The world is thirsty because it is hungry", coined for the 2012 World Water Day, dedicated precisely to water and food security. However, this close connection between water consumption (through crop's transpiration) and food production (through photosynthesis in plants) escapes most people. Many do not realize they may contribute to the reduction of water consumption through their eating habits. Lack of awareness of the damages and benefits to which different diets may lead is one of the main obstacles to sustainable development and to being respectful of future generations, from which we are borrowing extremely scarce natural resources such as water.

The Water We Eat comes at an important time in our journey towards gaining deeper knowledge about sustainable development. By means of the concept of "virtual water"—i.e., the water we consume to produce any kind of "product", and in particular to produce food—the book allows us to acquire and expand our knowledge of water issues, with the exciting potential outcome of significantly changing our eating behaviors. This is extremely relevant at the turn point of the post 2015 agenda for the achievements of what will be the *Global Development Goals*.

Moreover, we must note that *The Water We Eat* was published in 2013, the United Nation's International Year of Water Cooperation, which is another important event considering the fact that many nations will never be self-sufficient in the production of the food they need. Thus, satisfactory water (and subsequently food) security objectives can be achieved only through international cooperation.

Raising awareness about the fact that we can (and should) curb the "demand" for water by reducing food waste and following a balanced, low-water, diet is a prerequisite to accomplishing sustainable development, and one to which all individuals and governments have the opportunity to contribute.

No better venues could be selected for presenting the translated version of this book at the Expo Milan 2015 'Feeding the Planet, Energy for Life'.

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Fondazione Eureka was established in 2014 and is based in Milan; its objective is to develop and propose models of sustainable consumption of resources to reduce the impact that daily consumption habits have on the planet and, therefore, in our lives.

The Foundation develops research projects in partnership with prestigious Italian universities and research centers for rigorous and scientific analysis as well as numerical quantifications of environmental, economic, and social impacts of the consumption of resources, such as water.

The activities of the Foundation are addressed to the general public by providing user-friendly software applications to promote consciousness of citizens and to networks and study groups for the distribution of researches and the sharing of effective solutions.

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Part I
To Begin: Virtual Water and the Water Footprint

Not All Drops of Water Are the Same

Francesca Greco and Marta Antonelli

Where does the food we eat come from? Is it good for me? And am I doing the right thing in consuming it? In a world of limited resources, questioning ourselves about our lifestyles and our consumption patterns is not only desirable but also necessary. For this reason, we will introduce here the concept of "virtual water", namely the water required to produce the food, goods and services that we consume daily (Allan 1993, 1994, 1998). Thanks to the application of this concept, we will discover that we consume much more water than that we effectively see "running" before our eyes; we will highlight that the data showing Italian water consumption being 152 cubic litres a year per capita only reflects a partial consumption, referring only to the water used for our domestic purposes (drinking, cooking, washing, etc.).[1] The water we consume is actually much more than that. We are not able to perceive it as such because it is water that we literally "eat", embedded in an invisible way in the food we consume.

The purpose of this contribution is to unveil the consumption of virtual water, that is the volumes and the different typologies of water used in the production phases of goods and services of daily use. The study will focus on food products as they require far more water resources than any other good.[2] We will discover that

Both authors contributed equally to this work

[1]ISTAT data released for the World Water Day, 21 March 2011.
[2]2013 AQUASTAT data show the global percentages of use by sector: 70 % agriculture, 19 % industry and 11 % domestic use. Data available at: http://www.fao.org/nr/water/aquastat/water_use/index.stm

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the water used for the production of food follows quite alien and remote paths to our awareness as consumers.

1 Virtual Water, the Real Impact

The fact that water is a basic good and a human right, as proclaimed by the United Nations,[3] is now a part of our general thinking and accepted by all. Among the threats to water security in many countries of the world, we can include, above all, increases in population, climate change, economic development and the growth of consumerism, the general increase in the consumption of animal products and, finally, the asymmetrical availability of this precious resource for both economic and geographic reasons (see the map of physical and economic water scarcity in Fig. 2).

Water is a renewable resource but with very particular characteristics. Above all, it is a "primary good" essential for human and any other form of life. Water is an irreplaceable good, and its scarcity can be conditioned by physical or economic factors. Its scarcity, relative or absolute, is subject to natural processes which influence not only its geographical distribution, but also its access by humans in many parts of the world. Moreover, water is difficult to transport. It can be costly due to the use of expensive hydraulic works and can often be to the detriment of conserving and preserving natural environments and local populations. Even if it is a scarce and irreplaceable resource, water and its trade enjoy an extremely inflexible demand curve, and therefore, it is hardly influenced at all by market price increases (Savenijie and van der Zaag 2002). Furthermore, the exploitation of water by different production sectors involves significant environmental costs which, in many cases, lead to negative externalities for societies, not being "internalized" by those who produce them. This, in many cases, encourages the intensive use of the resource, well over its levels of sustainability, and consequently contributes to creating a very low efficiency in resource management.[4]

The awareness of our dependence on the ecosystems and the impact that our daily lives have on natural resources is, however, only partial. Indeed, most of us are ignorant of the fact that enormous volumes of water are involved in our daily

[3]On 28 July 2010, the United Nations General Assembly adopted Resolution A/64/L.63/Rev.1 stating the right to safe clean drinking water and to sanitation services as a human right essential to the full enjoyment of life and all other human rights.

[4]Different tools exist in the attempt to limit the externalization of environmental costs regarding the use of water for society. These include the following: sanctioning illegal water connections, setting up a pricing system for the distribution of water for irrigation and establishing a tax on groundwater pollution based on the principle "those who pollute pay". There is also a proposal for a tax on the use of agricultural land for building purposes that would place sanctions on the loss of agricultural land "sealed" by cement (see *Ambiente Italia 2012*, edited by D. Bianchi and G. Conti, *Edizioni Ambiente 2012*) (Bianchi and Conte 2012).

activities, often not actually being seen. In fact, the withdrawal and use of water by humans is not only limited to domestic use. Most of the water we use is the water we "eat", that is the water contained (even if we cannot see it) in the food that arrives on our table after having gone through the various phases of production, transformation and distribution (for more detailed information on the agri-food supply chain, see "Water and Food Security" by J.A. Allan in this book). In each of these three phases, water plays a fundamental role, both directly and indirectly, as a production input, destined, respectively, for a final or intermediate use (Antonelli et al. 2012). Some examples: a cup of coffee hides 140 liters of water, 135 in an egg and 2400 in a hamburger [data from the Water Footprint Network in Allan (2011), FAO (2012), Fig. 1]. As already mentioned, the water we consume is, therefore, much more than what we actually see. The virtual water content (measured in litres of water in the production of goods or services) is higher in food products, especially those of animal origin[5]. Therefore, the concept of virtual water is fundamental, not only in understanding our dependence on hydrologic systems, even those far away, but it also helps in understanding the impact of our lives, our daily activities and choices have on them.

2 Why Water is not All the Same

This contribution focuses on agriculture, as it is the major user of water resources at a global level (WWAP 2012). Contrary to our common understanding, the water that reaches our table in the form of food is not all the same. The different types of water involved in the production of agri-food goods can be divided into two categories—"blue" water and "green" water.[6]

"Blue" water is defined as surface water (found in rivers and lakes) or underground water (groundwater). It is easy to access and transport. It can be measured, stored in dams, conserved or pumped into water systems to meet the needs of different sectors (agricultural, industrial and domestic). Worldwide, according to FAO estimates (AQUA-STAT 2013), 70 % of this water is used in agriculture. In some countries, even very arid ones, the figure is even much higher than the world average, reaching more than 90 % of total water consumption. An example of this are the countries in the Middle East and North Africa, the most arid region in the world. Instead, "green" water is rain or snow water which falls to earth but does not become blue water (neither reaching the groundwater nor becoming a part of rivers, lakes or glaciers). This precipitation ends up evaporating or being transpired through plants. Its volume is equal to the volume of rainwater found in the body of the plant, to the water that produces natural soil moisture and that evaporates

[5]FAO 2010 AQUASTAT, http://www.fao.org/nr/water/aquastat/water_use/index.stm

[6]The theorizing of the concepts of blue and green water is the work of Malin Falkenmark (1989), a Swedish hydrologist and member of the Stockholm International Water Institute (SIWI).

Fig. 1 Virtual water in the more common foods. *Source* FAO 2012; edited by FAO WATER

naturally from plants during their life cycle. Green water cannot be transported nor withdrawn using pumps nor channelled. It is an intrinsic part of the plant–rain–soil system and cannot be appropriated from this.

To distinguish another type of water, we need to make a further breakdown in blue water: water originating from renewable or non-renewable sources. Surface water or groundwater belongs to the first group, being replenished by rainwater or snowmelt, where the exploitation threshold can be measured by calculating how much is naturally replenished by annual percolation. If the exploitation exceeds the natural replenishment threshold, we are speaking of the "non-sustainable exploitation" of a renewable source. Instead, the second type, non-renewable blue water refers to water extracted from groundwater, the so-called fossils, with a minimal replenishment percentage. This involves a stock of water that has been there for thousands of years and which, if consumed, will not be replaced for at least the same number of years. Even if not actually "non-renewable", this second type of water is considered to all effects as such because its total exploitation would result in certain water scarcity for hundreds of future generations (UNEP-DEWA 2003).

Returning to our earlier distinction between blue and green water, let us now explore how the latter has played an important role in global food production. Green water, that is rainwater evaporated from the ground during periods of crop growth, including evapotranspiration, allows for the growth of crops (non-irrigated agriculture) and the growth of vegetation and biodiversity conservation. While this type of water, differently to blue water, is completely invisible to the eye and relatively more complicated to measure, it accounts for about 84 % of the water used in agriculture (Fader et al. 2011) and its use has a less invasive impact on environmental balances (Aldaya et al. 2010). In an economic analysis, the opportunity cost of green water would be, moreover, very low, in some cases almost zero,[7] as it can only be used in agriculture and/or environmental conservation, and not in other sectors. Furthermore, its use does not affect the availability of blue water which, given it can be used in other sectors, has, instead, a high opportunity cost and needs to be protected as much as possible. In Italy, the yearly blue water volume per capita is 982 m^3, 61 % of total water availability, whereas green water amounts to 632 m^3 or 39 % of total availability (Gerten et al. 2011). As these figures show, green water is a very precious resource and plays a key role in water security and global food production (Aldaya et al. 2010; Allan 2011; Chatterton and Chatterton 1996). Therefore, the virtual water content of an agricultural product is the sum of the green water volume evaporated during the growth phase of a crop and the blue water volume withdrawn and used to grow the crop in a cultivated area. To this figure (the sum of green and blue water), we must also add the water needed to dilute the polluting agents during the production process, defined as "grey" water (Hoekstra et al. 2011). The different food products have a set virtual

[7]Different authors refer to green water as having a very low or zero cost opportunity. Some have suggested that green water could be considered as a "gift" (Chatterton et al. 2010; Chapagain and Orr 2009).

water content, generally expressed in litres or cubic metres, which can be broken down, in turn, into green water (from non-irrigated agriculture), blue water (irrigated agriculture) and grey water (polluted during the production phases). Therefore, a tomato irrigated with renewable water will have a lower environmental impact than one irrigated with non-renewable water. Moreover, the virtual water content of products of animal origin, such as eggs, milk and meat, is much higher than products of plant origin (Chatterton et al. 2010). However, the water sustainability of the production of a foodstuff will not derive only, as it would be easy to think, from the mere volume of the good's virtual water content[8] but, instead, will depend on the type of water used in its production (green or blue, renewable or non-renewable). Food produced by rainwater agriculture will have a lower impact compared to food produced using irrigated means, even more so in conditions of scarcity. This means that despite the fact that, on an average, 15,500 liters of water is needed to produce one kilo of beef, the meat produced by grazing livestock (non-irrigated) has a markedly lower water impact than meat from animals fed on fodder grown by irrigated methods (for more detail, see "The Water Footprint–a Tool to Compare our Consumption with the Use of Water" by A.Y. Hoekstra in this book).

In conclusion, not all drops of water are the same. The water found in everything we eat can have positive or negative effects on humans and the environment, in different countries, whether they be near or far from us, depending on the intrinsic characteristics of its original source.

3 The Origin of Virtual Water

Besides distinguishing between the different types of water contained in a product, another important step in understanding the water–food relationship is to identify the geographical origin of the virtual water contained in food products. In fact, the same product will have a different environmental impact depending on whether it is cultivated in a water-rich or water-scarce area. The surface areas of the earth can be subdivided into more or less wet zones, characterized by different climates and water availability—blue and green. The International Water Management Institute has divided the world zones into two macro-areas (Fig. 2): those where resources are plentiful (blue areas) and those where resources are scarce (orange, red and purple areas). It is interesting to note that water scarcity is not only assessed from a physical–natural viewpoint but also from an economic one (in cases where scarce economic means hinder the exploitation of naturally existing resources). Therefore,

[8]Note that the volume of water required to produce the same foodstuff can vary considerably depending on the production site—the productivity of water is, in fact, conditioned by the soil characteristics and climatic factors, by the technologies used and by the resource management methods. This means that the volume of water required to produce a tomato in temperate areas will be different from the virtual water contained in the same product coming from arid or semi-arid regions.

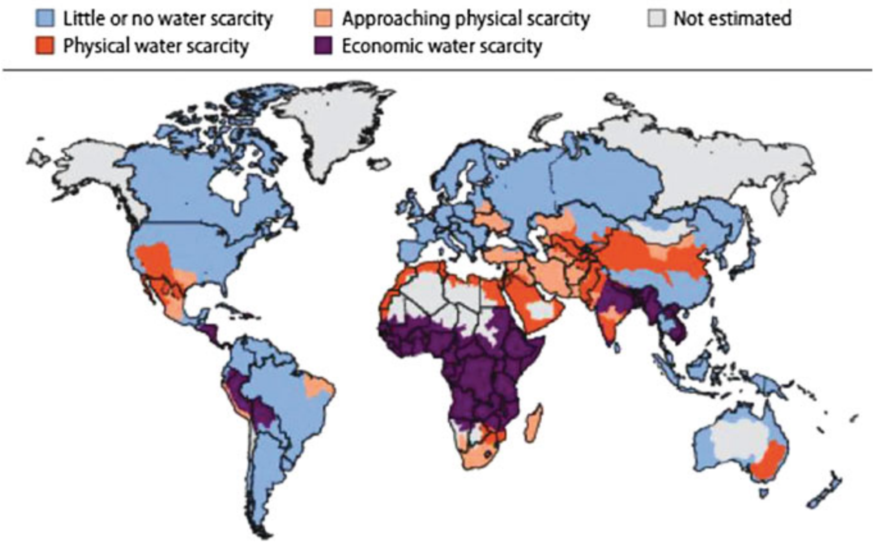

Fig. 2 Map of water scarcity. *Source* International Water Management Institute (2007)

water withdrawal and virtual water trade will weigh more heavily in local impact assessment depending on geographical origin. Looking at the map in the Figure, it is clear that exporting irrigated products from north-east America are quite different to exporting products from North Africa.

As far as the origin of virtual water from Italy is concerned, the production of agricultural products, both for internal consumption and export, presents a potential risk for local water resources in different areas, the so-called "hot spots". These are obviously found in the more arid areas of the country—in the south and on the islands—and involve south–north and south-external trade. From reading the hydro-geographical map of Italy, where most irrigation overlaps with the over-exploitation of groundwater and thus raises the risk of desertification, it is possible to identify the "risk zones", that is those zones where irrigated agricultural production results in a high environmental impact on the more critical water resources. These areas are found in Sicily, Apulia, Basilicata, Calabria and Sardinia. Moreover, in these areas, due to the intensive, and often unsustainable, use of groundwater (both renewable and non-renewable), the risk of desertification has increased. In Sicily, Sardinia and Calabria, the most exploited groundwater zones also coincide with the most intensely irrigated zones, while in Apulia we find in the most intensely irrigated zones less groundwater exploitation. This difference is due to the presence of a large canalization work, the *Acquedotto Pugliese*, using surface water for irrigation originating from outside the region.

Summing up, it is in those zones identified as “at risk” that goods are produced with a higher environmental impact on water.[9] If we add to these considerations those relevant to the social conditions of the migrant workers who work in these areas (FLAI-CGIL 2012), constantly reported by the Italian media, the general picture would be even worse. The phenomenon of “waste in the fields” (Segré and Falasconi 2012), very common in these areas, is another example of how controversial the methods of food production and distribution are in Italy. However, with the examples presented up to now, we do not want to claim that all virtual water trade is damaging. Indeed, it is a benefit where it contributes to relieving entire areas from the problem of food security, or simply, where it contributes to creating well-being for the locals and consumers without harming the environment. This occurs, for example, in cases where food products are exported by countries rich in water or in cases where products have a high green virtual water content. Virtual water trade becomes damaging in cases where it impoverishes the local water resources, the environment and the relevant populations, and therefore should be analysed concerning its full potential and all its benefits and implications. Considering that the biggest risks are linked to the negative impact of water use on the environment and on humans, this paper proposes to raise a point for reflection and bring to light some of the most hidden aspects of this phenomenon.

4 The Water Footprint of Italy

The concept of virtual water underlies the development of the so-called water footprint, an indicator for water consumption introduced by Arjen Hoekstra in 2003 similar to the “ecological footprint” developed in the mid-1990s by Mathis Wackernagel and William Rees. The water footprint of a person, a community or a company is defined as the total volume of water used to produce goods and services consumed by that person, community or company (Hoekstra et al. 2011). Water consumption is measured as the total water volume used and/or polluted in the production steps of a given good or service. The water footprint can be calculated for different types of subjects and groups of consumers (whether they be an individual, community, city or state) or producers (economic sectors or private companies). At a national level, we distinguish the water footprint of national consumption from the water footprint of national production. The former corresponds to the total of the internal water footprint (the water consumption in a given geographical area for a given period of time) and the external water footprint (water consumption originating from source external to the geographical area in consideration following the importation of virtual water involved in the international trade

[9]Further studies are being carried out to also identify all the cases involving over-exploited water used to irrigate products in Italy marked for exportation, both internally (south–north) and for foreign markets, at King's College London, London Water Research Group, Francesca Greco.

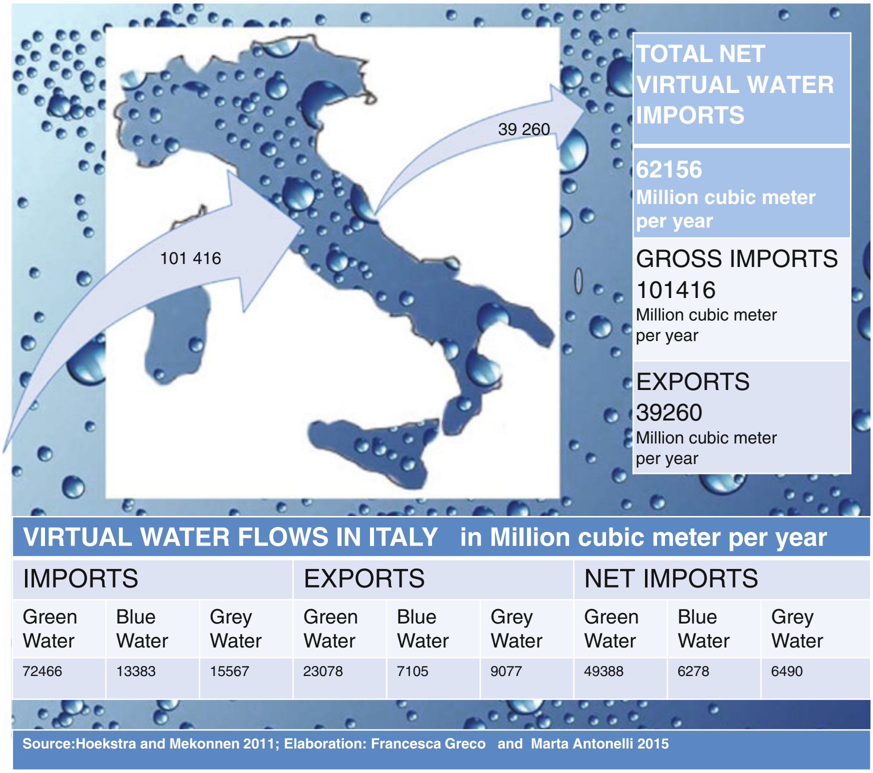

Fig. 3 Map of annual virtual water flows in Italy (1996–2005; mill. of m^3). *Source* Mekonnen and Hoekstra data, (2011); edited by authors

of goods and services). Instead, the national production water footprint is defined as the total of the internal water footprint and the water consumption for the production of goods for exportation (and, therefore, represents a water footprint external to the importing state).

Italy has a water footprint consumption per capita of 2330 m^3 per year, compared to an average of 1240 m^3, and it is the third net importing country of virtual water in the world after Japan and Mexico (Hoekstra and Mekonnen 2012, p. 3232–3237). Figure 3 shows the entry flows (import) and the exit flows (export) of virtual water for Italy linked to the international trade in agricultural goods, of animal and industrial origin.

What causes a high water footprint? There are four main factors that condition a country's virtual water footprint:

- water demand volume;
- demand composition which is mainly linked to the country's dietary habits. For example, as products of animal origin are more water demanding, the highest water footprint is found in the USA, followed by Greece, Italy and Spain;

- climatic conditions, which influence plant growth;
- agricultural practices, the management and efficiency of water use in the agricultural sector.

It is estimated that for every kilo of dry pasta produced in Italy, on an average, 1924 liters of water is required. The water footprint for a pizza weighing about 750 g is a little less at 1216 liters of water (Aldaya and Hoekstra 2010). It is important to underline that the environmental impact of the production of food goods such as these does not depend so much on the volume of water withdrawn and then incorporated in the final product, but rather on the context in which the water was withdrawn and used. The impact will be higher, for example in cases where the water withdrawn originates from over-exploited groundwater, as occurs in Sicily in the irrigation of durum wheat (*ibidem*). Instead, the cultivation of non-irrigated rice in Piedmont will have a much lower environmental impact (in fact, almost zero). The advantages arising from the introduction of water footprinting as an indicator of water consumption are varied. First of all, the water footprint is a recognition of the impact that human consumption has on the water resources by directly quantifying the volume of water incorporated in goods and services of common use. Secondly, the concept results in integrating a broader perspective into the traditional "basin vision" (interregional, interstate and international). The study of water footprints (internal and external) of different countries in the world has shown, for example, that many countries have, in fact, externalized their water footprint by importing from other countries those goods they need which require huge quantities of water in their production. This "movement" of virtual water between countries—as occurs in the trading of goods, especially agricultural ones—results, on the one hand, in satisfying the water–food needs of arid and semi-arid countries [first among these, the Middle East and North Africa, as shown by Allan (2001)], but on the other hand, gives rise, in some cases, to pressure being placed on the water resources of the exporting countries, in cases where they themselves can be exposed to a situation of water scarcity, both physically and economically.

4.1 Why Do We 'Eat' the Water of Other Countries?

The logic behind food production and trade is linked to political and economic reasons that are quite divorced from any considerations of an environmental nature. It is impossible to impose on any one country what they must or must not produce as the choice of agricultural policies lies solely under the control of that country. Therefore, the logic of production is quite external to the idea of maximizing the water resource use (for a study on water resource use in Italy, see "An economic approach to water scarcity" by A. Massarutto in this volume).

If the "good" use of water would fall under a moral, ethical code, a type of ecological conscience—similar to an animalistic conscience—then consumers choice could influence the market logic, which presently follows other codes.

Developing a "water conscience" could trigger a virtual circle of good practices on the part of consumers and companies that could make an investment and create an added value for products in the market (for how Italy could develop a national and global water conscience, see "Mobilisation for public water in Italy: a moral economy and virtual water" by E. Fantini in this volume).

A successful example of awareness raising on these issues has been provided by the experience of the WWF-Great Britain, which together with the Water Footprint Network, is working on drawing up international standards aimed at understanding how to improve the water footprint in the private sector of some of the largest global multinationals in order to decrease their products' footprint and create a guarantee for safeguarding water which would be recognized and included in their product brands (the so-called *water stewardship*). Water stewardship, that is the "safeguarding or good governance of water resources", includes the annual publication of a report on the water footprint of products, their labelling, certification of their business, comparison with other producers of similar products and reaching the quantitative targets in reducing their annual water footprint [10] (the opportunities and the challenges involved in introducing a sustainable water labelling for food products is the subject of a study "Aware eaters of water: an hypothesis for water labelling" by F. Greco and M. Antonelli (2012) in this volume).

5 Conclusions

This chapter has contributed to introducing concepts on virtual water and water footprint and has provided a preliminary analysis of the problems linked to the water we unconsciously consume through food with particular reference to the Italian case. We have seen how not all drops of water are the same since agriculture may use rainwater, with a very low or near zero environmental impact, or water originating from surface water bodies or from underground which is pumped and used for irrigation, whether it be renewable or non-renewable in nature. Consequently, despite appearances, not all tomatoes are the same. 70 % of all the world's fresh water is used in agriculture. The more negative implications of this occur when, for example, blue water is denied to poorer populations, in conditions of scarcity, or when non-renewable sources are used exceeding sustainability levels, in order to benefit the global market of food consumers.

The need to integrate the qualitative and quantitative (the volumes of water used) aspects has been recognized by the Water Footprint Network which has quantified, firstly, the water footprint of the different players (countries, companies, etc.). Opening up this debate in Italy, the third largest importer in the world of virtual

[10] Aldaya and Hoekstra (2010), "Analyzing International Virtual Water Trade and Water Footprint of Products" presented during the Corporate Water Footprinting and Managing Water Resources Meeting, London, 28–29 May.

water is therefore fundamental. Despite the fact that we are all informed about the origin of the water that runs from our taps and that this only makes up a small part of our total consumption, the information gap concerning the water contained in the food we eat, and which is the most important part of our needs, is still very general. This water often comes from far away with significant implications that we are not aware of (for further details on the issue of the de-socialization of water, see "Virtual water, H2O and the de-socialization of water. A brief anthropological overview" by M. Van Aken in this volume). Moreover, 90 % of the water used in food production is entirely managed by the private sector, specifically by a rather small number of multinationals (the so-called ABCD[11]) which operate in the international market and, thus, in conditions of "hegemony" (Sojamo et al. 2012). In conclusion, we believe that awareness is the underlying factor for change. Who would eat a strawberry knowing that its irrigation had denied drinking water to a village of Bedouins in the Arabian desert? If we could know, and choose, we would choose what is right.

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[11]The reference is to the companies Archer Daniels Midland, Bunge, Cargill and Louis Dreyfus.

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Water and Food Security: Food-water and Food Supply Value Chains

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Abstract The purpose of this chapter is to highlight the importance of food supply chains in understanding water security. Food supply chains are important because about 90 % of the water needed by an individual or a national economy is embedded in their food consumption. This water will be called food-water in this analysis. Food requires water to produce it. This water can be either green water—that is the water that is held in the soil profile after rainfall. Crops and vegetation can use this water for consumptive transpiration. Food-water can also be blue water, usually called freshwater. Such water can be diverted from rivers or pumped from groundwater. Globally, green water accounts for about 80 % of the water used for crop and livestock production. Over 20 % is blue water which is the water used consumptively in full and supplementary irrigation. The food supply chain is also important because farmers and other agents in this supply chain allocate and manage the vast volumes of water used consumptively. Farmers are helped by ag-industries which breed seeds and provide fertilizers, equipment and pesticides. All of these inputs plus science and many government subsidies have enabled farmers to increase their water productivity. Farmers manage about 90 % of the food-water resources in the food supply chain. The other 10 % of food-water is handled by corporations and other private sector entities that trade, transport, process and market food for consumers. The volumes of food-water in this non-farm part of the supply chain are therefore relatively small. (Note the analysis in this chapter does not address the water resources devoted to the production of fibre and energy. The author recognises the role of water in these economic activities but there is no space to address the nuances that these consumptive and non-consumptive demands place on the consumptive use of water.)

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1 Introduction—Hydro-system Fundamentals and Food Supply Chain Shaped Food-water Demands

> There are no water wars because food wars are not judged to be necessary.

> Society, politics and market players have conspired to put in place - globally and nationally - highly politicised global food regimes and food supply chains that have no reporting or accounting rules for water resources.

The purpose of the chapter is to highlight the importance of food supply chains in understanding water security. It will highlight both the politicised relationships, as well as the inescapable bond, between sustainable food security and sustainable water security. Sound food policies as well as sound water resource allocation and management will depend on the recognition of this connection.

The relationship between water and food is exceptional. No other supply chain needs or consumes a natural resource in the proportions that the world's food supply chains use water resources consumptively. The water used to produce food will in this analysis be called food-water.

Agents in the food supply chain have, since the beginning of farming about 13,000 years ago—usually unwittingly—been adapting and mainly enhancing the efficiency of the ways they mobilise the invisible rainfed green water in the root zone for food production. During all of this pre-industrial era, almost all the food-water consumed in crop transpiration was Nature's rainfed green water. Blue water—surface and groundwater—has been used in different modes of irrigated agriculture for the past five millennia. But very small volumes of blue water were consumed in irrigation until the beginning of industrialisation two centuries ago. The scale of the negative impacts on water resource ecosystems of humanity's industrial and post-industrial food supply chains has no precedent.

The analysis that follows will include the consideration of two major systems that bind together water resources and food production and consumption. First, there will be a very brief review of the significant characteristics of the hydro-systems that underpin the supply chains on which societies depend for their food security. It will be concluded that farmers are the major professionals that allocate and manage natural and engineered water resources. Secondly, there will be a very brief review of the history of global and other *food regimes* and *food supply chains*. The brief history of the world's food regimes shows that recent market volatility has exposed some dangerous features of the power asymmetries of the current global food regime. This regime emerged after the Cold War food regime of the 1950–1989 era. Thirdly, it will be shown that there exist many enduring sub-national food systems. These feed over 80 % of the world's populations (Hoekstra and Mekonnen 2012). Global food *trading* systems only ensure the food security of about 15 % of the global population (Hoekstra and Mekonnen 2012). This low proportion, however, belies its significance. The successful servicing of this international demand for traded food, driven by food consumption in water and food deficit economies, keeps the world at peace. It must be emphasised that it is normal to live in a food