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The water needed for Italians to eat pasta and pizza

M.M. Aldaya *, A.Y. Hoekstra

Twente Water Centre, University of Twente, 7500 AE Enschede, The Netherlands

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ABSTRACT

Water resources use in agriculture is generally quantified in relation to the harvest. In contrast, this paper takes a consumer perspective by assessing water use in relation to the final consumer product. The paper analyses the water use related to two products that are typical to Italian consumers: pasta and pizza margherita. We use the water footprint concept as a tool to quantify and localise this water use. The water footprint of a product is the volume of freshwater used to produce the product, measured over the various steps of the production chain. We find that the water footprint of dry pasta made in Italy amounts to 1924 l of water per kilogram of pasta. The water footprint of a 725 g pizza margherita is 1216 l of water. The impacts of the water footprints of pasta and pizza depend on the vulnerability of the water systems where the footprints are located. The impact of the water footprint of pasta is most severe in Puglia and Sicily, where groundwater overexploitation for durum wheat irrigation is common. The impact of the water footprint of pizza is more diverse. It is concentrated in the first step of the supply chain of tomato puree and mozzarella, i.e. in the cultivation of tomatoes and the feed crops of dairy cows. The bread wheat used for the pizza base does not have large impacts. The water footprint impact of the tomato puree on the pizza is concentrated in Puglia (groundwater overexploitation and pollution related to tomato cultivation) and Emilia-Romagna (water pollution). The water footprint impact of mozzarella lies mostly in the effects of water use for producing the feed ingredients for the dairy cows. Mozzarella production further poses a potential threat to water quality, mostly in the Po valley, but this problem seems to be properly regulated, although possibly not fully controlled.

1. Introduction

Problems of freshwater scarcity and pollution relate to water use by farmers, industries and households. The term 'water users' has always been interpreted as 'those who apply water for some purpose'. As a result, governments responsible for water resources management have traditionally targeted their policies towards those water users. Recently, however, it has been shown that this approach is limited (Hoekstra and Chapagain, 2007, 2008). Final consumers, retailers, traders and all sorts of businesses active along the supply chains of final consumer goods remain out of the scope of governmental policies aimed at mitigating water scarcity and pollution. All water use in the world, however, is ultimately linked to final consumption by consumers. It is therefore interesting to know the specific water requirements and impacts of various consumer goods, particularly for goods that are water-intensive, like food items, beverages, bio-energy and materials from natural fibres. This is relevant information not only for consumers, but also for retailers, traders and other businesses that play a central role in supplying those goods to the consumers.

The concept of the 'water footprint' has been proposed as an indicator of water use that looks at both direct and indirect water use of a consumer or producer (Hoekstra, 2003). A water footprint can be calculated for any well-defined group of consumers (e.g. an individual, family, village, city, province, state or nation) or producers (e.g. a public organization, private enterprise or economic sector). The water footprint of a product is the volume of freshwater used to produce the product, measured at the place where the product was actually produced (Hoekstra and Chapagain, 2008). It refers to the sum of the water use in the various steps of the production chain. Water use is measured in terms of water volumes consumed (evaporated) and/or polluted per unit of time.

The water footprints of various commodities have been studied in more or less detail, including cotton, coffee, tea, tomatoes, bioethanol and biodiesel (Chapagain et al., 2006; Chapagain and Hoekstra, 2007; Chapagain and Orr, 2009; Gerbens-Leenes et al., 2009). The work here addresses two specific consumer products not studied before: pasta and pizza. The study focuses on Italy, origin of both products and still a huge producer and consumer.

When expressed per capita, the Italian consumers have one of the largest water footprints of the world, together with other south European countries and the US. The water footprint of the average Italian consumer is 2330 m^3/yr, while the global average amounts

* Corresponding author. Tel.: +31 53 4894464; fax: +31 53 4895377.
E-mail address: m.m.aldaya@ctw.utwente.nl (M.M. Aldaya).

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to 1240 m^3/yr (Hoekstra and Chapagain, 2008). Within Italy, agriculture is the main water consuming sector, adding up to more than 70% of the total water demand, with its consequent pressure on Italian surface and groundwater resources (ibid). Furthermore, Italy is one of the main wheat consuming countries in the world (FAO, 2008), probably due to the fact that pasta and pizza are the most popular dishes in Italy.

This study analyses the water footprint of Italian pasta and pizza margherita. Disclosing this type of information could increase awareness among consumers, which is a precursor to improving water governance.

The study considers the so-called 'green water footprint' (consumptive use of rainwater stored in the soil) (Falkenmark and Rockström, 2004), 'blue water footprint' (consumptive use of ground- or surface water) and 'grey water footprint' (volume of polluted water that is associated with the production of goods and services). In water-scarce areas, knowing the water footprint of a good or service can be useful for determining how to make best use of the scarce water available. It is important to establish whether the water used proceeds from rainwater evaporated during the production process ('green water') or surface or groundwater evaporated as a result of the production of the product ('blue water').

First of all, we have analysed – per region – the water footprints of the three primary crops involved: durum wheat (*Triticum durum* Desf.), bread wheat (*Triticum aestivum* L.) and tomato (*Solanum lycopersicum* L.). Subsequently, we estimated at a national scale the water footprints of the direct pasta and pizza ingredients (i.e. durum wheat flour, bread wheat flour, tomato puree and mozzarella). Then, the water footprints of the different ingredients were added to arrive at overall estimates for the water footprints of pasta and pizza margherita. Finally, an impact assessment of the water footprint of pasta and pizza margherita production in Italy was carried out, identifying the hotspots or high risk areas.

2. Method and data

2.1. Water footprint of primary crops

The green, blue and grey water footprints of primary crops are calculated using the methodology described in Hoekstra and Chapagain (2008) and Hoekstra et al. (2009). The total crop water requirement, effective rainfall and irrigation requirements per region have been estimated using the CROPWAT model (Allen et al., 1998; FAO, 2003a). The calculation has been done using climate data for the major crop-producing regions and a specific cropping pattern for each crop according to the type of climate. The climate data have been taken from the CLIMWAT database (FAO, 2003b) for the most appropriate climatic stations located in the major crop-producing regions (ISTAT, 2008). For regions with more than one climate station, the data for the relevant stations have been equally weighed assuming that the stations represent equally sized crop producing areas. The actual irrigation water use is taken to be equal to the irrigation requirements as estimated with the CROPWAT model for every region.

The 'green' water footprint of the crop (m^3/ton) has been estimated as the ratio of the green water use (m^3/ha) to the crop yield (ton/ha), where total green water use is obtained by summing up green water evapotranspiration over the growing period. Green water evapotranspiration is calculated with a time step of 5 days, as the minimum of effective rainfall and crop water requirement. The 'blue' water footprint of the crop has been taken to be equal to the ratio of the volume of irrigation water used to the crop yield. Since data on irrigated and rain-fed production per crop were not available, crop water requirements are assumed to be always fully satisfied. Both green and blue water footprints have been estimated separately by region. Then, national average green and blue water footprints have been calculated on the basis of the respective share of each region in national production. The major crop-producing regions combined accounted for more than 99% of the total national production. Data on average crop yield and production by region are taken from the Italian National Institute of Statistics (ISTAT, 2008). Crop coefficients for different crops are taken from FAO (Allen et al., 1998; FAO, 2003a).

The 'grey' water footprint of a primary crop (m^3/ton) is calculated as the load of pollutants that enters the water system (kg/yr) divided by the maximum acceptable concentration for the pollutant considered (kg/m^3) and the crop production (ton/yr) (Hoekstra and Chapagain, 2008). In this study, nitrogen was chosen as an indicator of the impact of fertiliser use in the production systems. The total volume of water required per ton of N is calculated considering the volume of nitrogen leached (ton/ton) and the maximum allowable concentration in the ambient water system. The quantity of nitrogen that reaches ground or surface water has been assumed to be 10% of the applied fertilization rate (in kg/ha/yr) (following Hoekstra and Chapagain, 2008). The standard recommended by the European Nitrates, Groundwater and Drinking Water Directive for nitrate in water is 50 mg/l (measured as NO_3^-). This is very similar to the drinking water standard recommendation by the US Environmental Protection Agency (EPA, 2005), which is 10 mg N/l, equivalent to about 45 mg NO_3^-/l. The standard of 10 mg N/l was used to estimate the volume of water necessary to dilute polluted leaching flows to permissible limits. This is a conservative approach, since the natural background concentration of N in the water used for dilution has been assumed to be negligible. In the absence of more detailed information, data on the application of nitrogen fertilisers have been obtained at the national level from the FERTISTAT database (FAO, 2007). Grey water footprint estimations based on more localised information would have been preferred. Providing spatiotemporally explicit grey water footprint information is crucial in order to identify hotspots and assess the local impacts of the grey water footprint. We have no indications, however, that fertilizer application strongly varies within Italy.

The effect of the use of other nutrients, pesticides and herbicides on the environment has not been analysed, mainly because of three reasons. First, for many chemicals data on application rates per crop are not available. Second, good estimates on the fractions that reach the water bodies by leaching or runoff are very difficult to obtain. The problem for a substance like phosphorus, for instance, is that it partly accumulates in the soil, so that not all P that is not taken up by the plant immediately reaches the groundwater, but on the other hand may do so later. Finally, there do not exist broadly agreed water quality standards for all substances.

2.2. Water footprint of crop and livestock products

The water footprint of crop and livestock products (like wheat flour, pasta, tomato puree and mozzarella) is calculated by dividing the water footprint of the root (input) product by the product fraction (Hoekstra and Chapagain, 2008). The latter is defined as the quantity of the processed product obtained per quantity of root product. If the root product is processed into two or more different products, the water footprint of the root product is distributed across its separate products, which is done proportionally to the value of the resultant products. The value fraction for a processed product is defined as the ratio of the market value of the product to the aggregated market value of all the products obtained from the root product. If processing involves some water use, the process water use is added to the water footprint of the root product before the total is distributed over the various processed products. The product fractions for various crop and livestock products are derived from different commodity trees as defined in FAO (2003c) and Chapagain and Hoekstra (2004).

In order to calculate the water footprint of livestock products (e.g. mozzarella from cow milk) the water footprint of the animal has to be estimated. The water footprint of live animals can be calculated based on the water footprint of their feed and the volumes of drinking and service water consumed during their lifetime (Hoekstra and Chapagain, 2008). Obviously, one will have to know the age of the animal when slaughtered and the diet of the animal during its various stages of life. The type and quantity of feed of cows during the various stages of life were taken from Chapagain and Hoekstra (2004). The milk yield and live weight of an adult cow in Italy were obtained from FAO (2003c).

3. The national context

The agricultural sector in Italy, when considering both green and blue crop water consumption, represents more than 72% of the total water use (Hoekstra and Chapagain, 2008). Domestic water use adds up to 10% of the total water used, whereas the industrial sector represents 19% of the total water use. In economic terms, in 2000, the agricultural sector represented about 3% of the Gross Domestic Product (GDP), the industrial sector 30% and the service sector 68%. The agricultural sector employs about 5% of the economically active population while the industrial sector employs 30%.

In Italy, the consumptive water use for growing wheat and tomato constitute about 30% and 1% of the total agricultural water use respectively. Improved water management within the wheat sector, therefore, seems to be key for Italian water resources planning and management. Even though Italy is one of the major wheat importing countries (largely from France, the USA and Canada), the present study focuses on the water consumption within Italy.

In Italy, the availability of water varies considerably across regions. As in all Mediterranean countries, the seasonal and regional variability of rainfall is extremely high. Northern regions can enjoy a regular and relatively abundant water endowment, whilst southern regions show a considerably lower availability of water resources, characterized by an extremely high seasonal variability of runoff.

Considering water quality, the situation is again differentiated throughout the country. In general, the biological and chemical quality of the largest rivers is poor, and the number of polluted sites has increased, spreading even outside highly urbanized areas. Pollution in the north and the centre is mostly due to industrial and agricultural activities (Goria and Lugaresi, 2002). Nitrate concentrations over the acceptable threshold established by the European Directives (50 mg/l) are recorded in several cases, mainly in the coastal plains of the rivers Tevere and Po. In other regions, particularly in the southern part of Puglia, or in the coastal plains of Campania, Calabria and the island of Sardinia, the main problem is salt intrusion. In these cases the over-abstraction can be attributed to private abstractions for agriculture and, in some cases, to public water supplies.

Most of these problems have been exacerbated by a lack of attention and awareness (Goria and Lugaresi, 2002). Water has constantly been perceived as an infinite, non-exhaustible resource, to be made available at a very low price. Wasteful behaviour has therefore been common and accepted. Water pricing policies have not been able to support investments in the water sector. Over time, the management and utilisation patterns of water resources have appeared to be unsustainable (ibid).

4. The water footprint of pasta

4.1. The water footprint of durum wheat

The basis for pasta is durum wheat, an annual grass very similar to bread wheat but differing in the larger, harder grains, higher protein content and different chromosome number (Van Wyk, 2005). It is cultivated in relatively dry regions and harvested in the same way as wheat and other cereals (ibid). Italian durum wheat is cultivated mainly in southern Italy (ISTAT, 2008). The national average green water footprint of durum wheat is 748 m^3/ton; the blue water footprint is 525 m^3/ton. Regional differences in both total water consumption and the green–blue ratios, however, are substantial (see Fig. 1). Puglia and Sicily are particularly

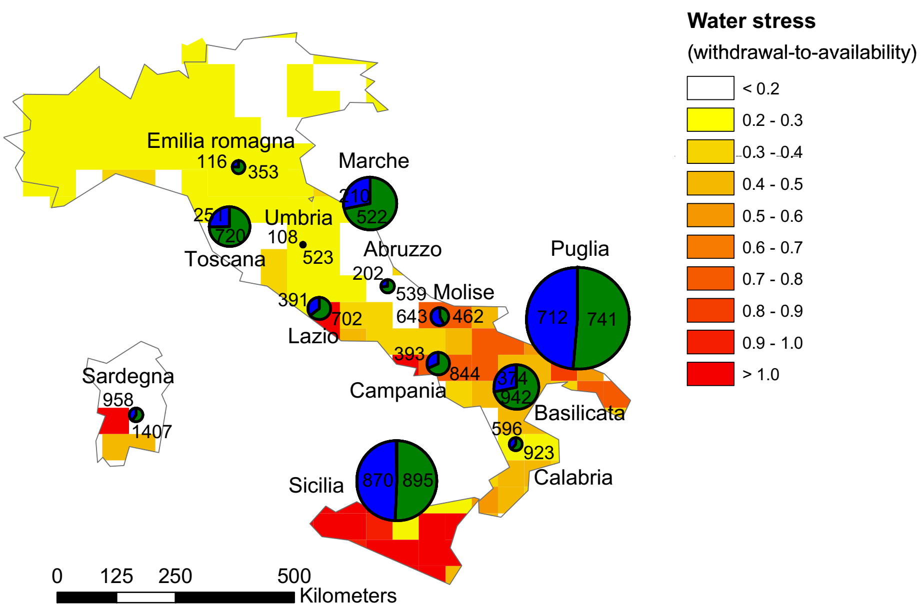

Fig. 1. Green and blue water footprint for Italian durum wheat production by region plotted on a water scarcity map of Italy. The size of each pie reflects the regional contribution to the national production. The numbers shown in the pies refer to the water footprint per ton (m^3/ton). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.) *Source*: Alcamo et al., 2003a,b.

Table 1
Nitrogen application and the associated grey water footprint for the production of durum wheat, bread wheat and industrial tomato in Italy.

	Average N fertiliser application rate (kg/ha)	Area[a] (ha)	Total N fertiliser applied[b] (ton/yr)	Nitrogen leached to the water bodies (ton/yr)	EPA (2005) standard (mg/l)	Volume of dilution water required (10^6 m^3/yr)	Production[a] (ton/yr)	Grey water footprint (m^3/ton)
Durum wheat	82	1,612,706	132,242	13,224	10	1322	4,387,863	301
Bread wheat	82	629,778	51,642	5164	10	516	3,111,352	166
Industrial tomato	110	95,721	10,529	1053	10	105	5,675,751	19

[a] ISTAT for the year 1999–2007 (ISTAT, 2008).
[b] FAO (2007) for the year 1999/2000.

strong in the production of durum wheat; the blue water proportions in these regions are relatively large (nearly 50%).

The grey water footprint of durum wheat was estimated at country level. Only water pollution through the leaching of nitrogen fertiliser was considered. Nitrate is essential for plant growth but excessive amounts in water represent a major pollution problem. The grey water footprint shows the volume of water required to assimilate the fertilisers that reach the water system. Based on the average N fertiliser application rate, an assumed leaching percentage of 10% and a nitrogen water quality standard of 10 mg/l, the grey water footprint of durum wheat is estimated to be 301 m^3/ton (Table 1).

Summing up the green, blue and grey water footprint of durum wheat, we arrive at an estimated total water footprint of 1574 m^3/ton (Table 2). For pasta, the durum wheat grains need to be processed into flour. About 72% of the original durum wheat weight becomes flour (semolina); the rest consists of the wheat bran and germ. The semolina constitutes 88% of the total value of the two separate products. Given a total water footprint of durum wheat of 1574 m^3/ton, we can calculate that the water footprint of semolina is (1574 × 0.88/0.72=) 1924 m^3/ton.

4.2. The water footprint of pasta

Durum wheat has a very hard grain with a low gluten content, which makes it unsuitable for bread but ideal for pasta, gnocchi, couscous and bulgur. The wheat is milled in such a way that the grain is separated into bran, germ and semolina. Authentic pasta is simply durum semolina to which various liquids (water, milk or eggs) are added. Pasta can be found in dried and fresh varieties depending on what the recipes call for. Pasta is dried in a process at specific temperature and time. Traditional pasta is allowed to dry slower, up to 50 h at a much lower temperature than mass-produced pasta, which is dried at very high temperatures for a short time.

For the purpose of this study we have assumed that pasta is made from semolina (1 kg), water (0.5 l) and salt. The water is removed when drying the pasta. The water footprint of dry pasta is equal to that of the semolina it is made from, i.e. 1924 l/kg. The green component in this total figure is 48%, the blue component 33% and the grey component 19%. Taking into account that each Italian eats on average 28 kg of pasta every year (BBC, 2007), the water footprint of pasta consumption by an Italian inhabitant is 54,000 l/yr. In relative terms, this is about 2% of the average Italian water footprint (2330 m^3/cap/yr).

Given an Italian population of almost 60 million people, the water footprint of Italian pasta consumption amounts to about 3200 million m^3/yr. This quantity is equivalent to the volume of water required to fill more than one million swimming pools (one Olympic size swimming pool contains 2500 m^3 of water).

Table 2
The water footprint of pizza and pasta ingredients made in Italy.

	Water footprint (m^3/ton)			
	Green	Blue	Grey	Total
Durum wheat	748	525	301	1574
Durum wheat flour (semolina)	914	642	368	1924
Bread wheat	495	125	166	786
Bread wheat flour	605	154	202	961
Industrial tomato	35	60	19	114
Puree from industrial tomato	117	200	63	380

5. The water footprint of pizza margherita

5.1. The water footprint of bread wheat

The base of a pizza is made from bread wheat flour. Bread wheat (soft wheat) has a very high nutritive value and contains 60–80% carbohydrates (mainly starch), 8–15% protein (all the essential amino acids except lysine, tryptophane and methionine) and various vitamins (especially B and E) (Van Wyk, 2005). According to our calculations, the green water footprint of Italian bread wheat is 495 m^3/ton on average, while the blue water footprint is 125 m^3/ton. Compared with the water footprint of durum wheat, bread wheat consumes half of the amount of water per ton. This difference is mainly due to the different yields and production conditions of bread and durum wheat. Bread wheat is an annual crop adapted to a wet winter and rain-free summer (Van Wyk, 2005) and is mainly produced in the northern part of Italy (Fig. 2), whereas durum wheat is essentially produced in the southern regions (Fig. 1). In the north of Italy, yields are higher due to different weather and soil conditions (Bianchi, 1995).

The grey water footprint of bread wheat was estimated at country level in the same way as the water footprint of durum wheat (see Section 4.1). The results are shown in Table 1. When looking at bread versus durum wheat, the grey water footprint related to nitrogen pollution is notably lower for bread wheat, amounting to 166 instead of 301 l/kg.

Adding the green, blue and grey component of the water footprint gives a total water footprint of bread wheat of 786 m^3/ton (Table 2). When the grains are ground into flour, 72% of the original wheat weight becomes flour, the remaining 18% are the wheat pellets. The wheat flour constitutes 88% of the total value of the two different products. Given a total water footprint of bread wheat of 786 m^3/ton, we can calculate that the water footprint of bread wheat flour is (786 × 0.88/0.72=) 961 m^3/ton. The total water footprint is composed as follows: 63% green, 16% blue and 21% grey.

5.2. The water footprint of tomato

In this study, we assume that pizza is cooked with puree from industrial tomatoes. Italy is one of the main producers of industrial and processed tomato worldwide (FAS, 2001).

Industrial tomatoes are primarily produced in Emilia-Romagna and Puglia (Fig. 3). The national average green water footprint of tomatoes is 35 m^3/ton; the average blue water footprint is 60 m^3/ton.

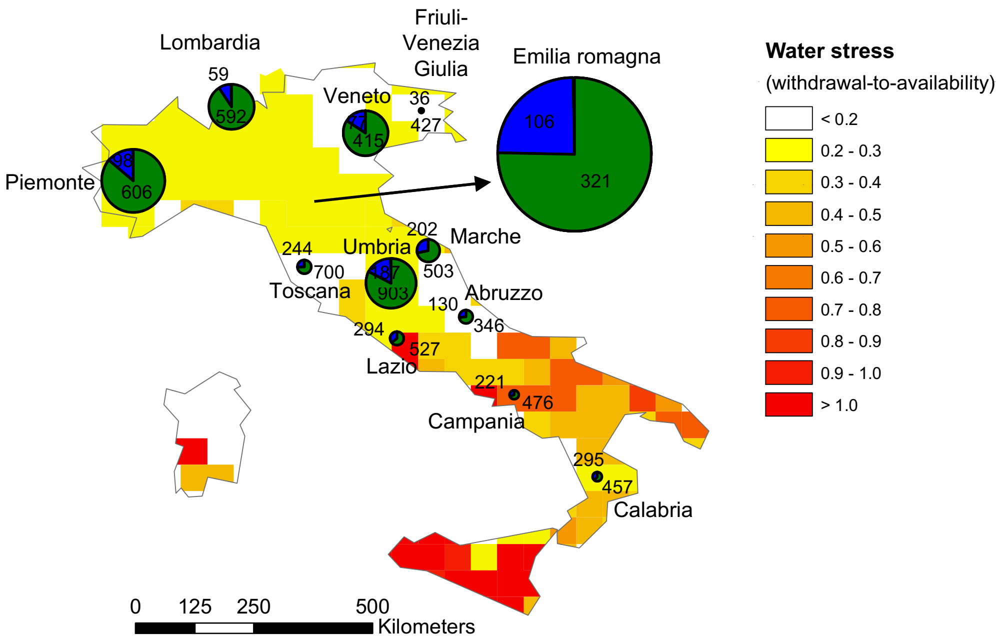

Fig. 2. Green and blue water footprint for Italian bread wheat production by region plotted on a water scarcity map of Italy. The size of each pie reflects the regional contribution to the national production. The numbers shown in the pies refer to the water footprint per ton (m^3/ton). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.) *Source*: Alcamo et al., 2003a,b.

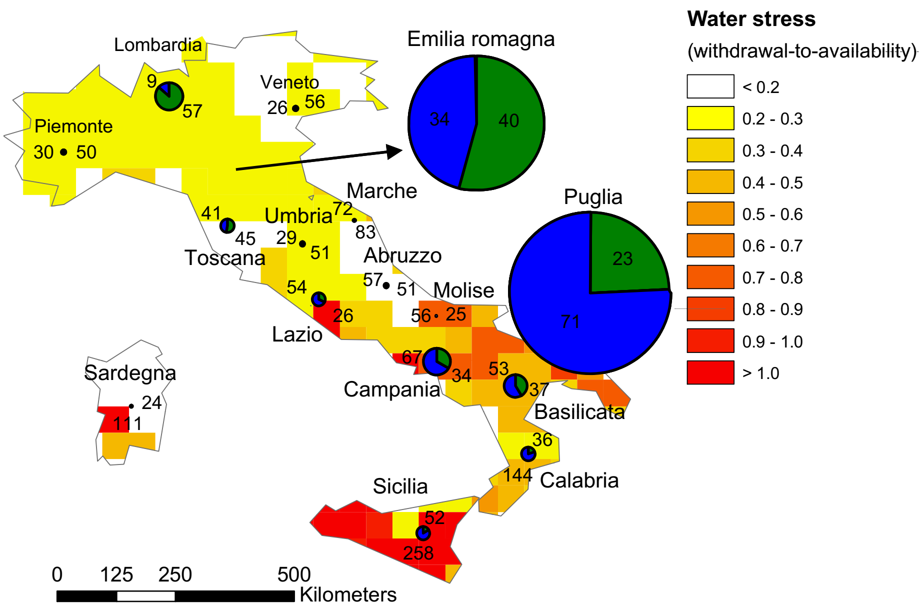

Fig. 3. Green and blue water footprint for Italian industrial tomato production by region plotted on a water scarcity map of Italy. The size of each pie reflects the regional contribution to the national production. The numbers shown in the pies refer to the water footprint per ton (m^3/ton). *Source*: Alcamo et al., 2003a,b. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

The grey water footprint of tomatoes was estimated at country level. We only considered water pollution as a result of the use of nitrogen fertiliser. The grey water footprint of tomatoes shown in Table 1 refers to the volume of water required to dilute the nitrogen flow that enters the water system. Contrary to what one might expect, the grey water footprint, in terms of m^3/ton, is noticeably lower for tomatoes (19 m^3/ton) than for wheat (166–301 m^3/ton, see Table 1). For wheat, fertiliser application rates are on average 25% lower than for tomatoes, but wheat yields per hectare are on average fifteen times less than tomato yields. In the case of tomatoes, Chapagain and Orr (2009) obtained even smaller grey water footprint figures when looking at tomato production in Spain: 8 m^3/ton for open production systems and 4 m^3/ton for covered systems. It is widely known, however, that tomato production is a very intensive form of agriculture in terms of water use and chemical inputs (Rinaldi et al., 2006). This becomes clear when one considers the nitrogen load per hectare: the average fertiliser application rate in terms of kg/ha is higher for tomatoes than for wheat (110 versus 82 kg N/ha, respectively). One can thus see that the grey water footprint of tomatoes compared to wheat is low when expressed per ton but high when expressed per hectare. The same can be observed for the blue water footprint: relatively low for tomatoes when expressed per ton, but relatively high when expressed per hectare.

Table 2 shows the total water footprint of industrial tomatoes, adding the green, blue and grey components. The total water footprint of industrial tomatoes is 114 m^3/ton. The table also shows the water footprint of tomato puree, made from industrial tomatoes. In order to produce tomato puree, ripe tomatoes are cooked until soft and broken down into a mushy pulp. Afterwards, the pulp is passed through a sieve to extract the skins and some seeds. Finally, the tomato puree is poured into jars and boiled (BBC, 2008a). Since 1 kg of tomatoes on average gives 0.3 kg of tomato puree, the total water footprint of tomato puree is (114/0.3=) 380 m^3/ton.

According to the Mediterranean International Association of the Processing Tomato (AMITOM, 2006), tomato processing enterprises are not always located in the tomato-growing regions. In the Puglia region, in southern Italy, only a few factories have been set up, so tomatoes have to be transported by lorry to processing plants in Campania, 200–300 km away. The main production zone in Puglia is around Foggia, but processing tomatoes are also grown further south around Bari and Brindisi (ibid). The Foggia area is a large plain with soils alternating between a predominance of clay and a predominance of sand. In the north of Foggia, tomatoes are mainly produced for paste, whereas in the south they are grown primarily for canned peeled tomatoes. Drip irrigation is particularly developed in this zone, sprinklers being the most common alternative to drip systems (AMITOM, 2006).

Concerning industrial tomato production in the north of Italy, processing tomatoes are mainly grown around Parma and Piacenza, but also in small areas around Ferrara and north of the Po. Soils near Parma and Piacenza are predominantly clay, with sandy-clay in Ferrara and silt north of the Po. The climate is ideal for tomato cultivation with notably a big difference between day and night-time temperatures, producing a good colour in the fruit. There is a risk of late drought and hail storms. Irrigation is still partly applied by sprinklers, with coiled hose water guns, but drip irrigation is becoming widespread.

5.3. The water footprint of mozzarella

Mozzarella made from fresh cow milk is the most common in Italy. The average water footprint of the Italian milk is estimated to be 1308 l/kg, based on a total milk production during the 7-years life time of the cow of 33.5 ton and a total water footprint of the cow of 44,000 m^3. The latter figure refers to the water footprint of all feed consumed during the lifetime of the cow (contributing more than 99% to the total) plus the water consumed for drinking by the cow and for cleaning cow facilities (contributing less than 1% to the total).

About 10% of the milk weight becomes mozzarella. Apart from mozzarella, the process provides whey. The mozzarella forms 54% of the total value of the two separate products. Given a water footprint of milk of 1308 l/kg and an estimated processing water requirement of 10 l/kg, we can calculate that the water footprint of mozzarella is (1318 × 0.54/0.1=) 7117 l/kg.

5.4. The water footprint of pizza margherita

The basic ingredients for cooking a pizza margherita are bread wheat flour, tomato puree and mozzarella from cow milk. There are different recipes for cooking the pizza margherita. We have used a traditional recipe for two people following BBC (2008b). There are other potential additional ingredients such as basilica or olive oil which have not been included in the present study. Based on the average figures for its ingredients, we estimate that the water footprint of a pizza margherita is 1216 l (Table 3). The largest contribution to the total comes from the mozzarella.

Table 3
The water footprint of a pizza margherita.

Ingredients	Weight (kg)	Water footprint per kilogram (l/kg)				Water footprint (l) of 1 pizza of 725 g
		Green	Blue	Grey	Total	Total
Bread wheat flour	0.300	605	154	202	961	288
Tomato puree[a]	0.100	117	200	63	380	38
Mozzarella	0.125	n.a.	n.a.	n.a.	7117	890
Water	0.2	0	1	0	1	0.2
Total	0.725					1216

[a] From industrial tomatoes.

6. Water footprint impact assessment and response options

Understanding the environmental, social and economic impacts of the water footprints of pasta and pizza margherita is particularly important in Italy since the production and consumption of wheat, tomato and mozzarella, their main ingredients, is widespread in this country. Wheat and tomato are two of the main Italian crops, both in terms of production and consumption – with 7.4 and 6.8 Mton/yr produced and 150 and 62 kg/cap/yr consumed, respectively (FAO, 2008) – whereas mozzarella cheese plays an essential role: 77% Italian families eat mozzarella, and 58% at least once a week (Pagliarini et al., 1997).

In the present paper the environmental impacts of the water footprint are analysed differentiating between the effects of the blue, green and grey water footprint. The impact of the water footprint spatially varies along with the vulnerability of the local water systems where the footprint is located, the actual competition over the water in these local systems and the negative externalities associated with the use of the water (Hoekstra, 2008).

The water footprint of bread wheat, durum wheat and tomato in the different regions is compared with the water scarcity map. As an indicator of water scarcity we used the withdrawal-to-availability ratio as given by Alcamo et al. (2003a,b). The water scarcity map of Italy based on data from Alcamo (Fig. 1) shows the same pattern as the water scarcity map by Smakhtin et al. (2004a,b), which takes into account the environmental water requirements. In this way the high risk areas or hotspots were identified.

In the case of pasta production, most of the water is used in the stage of durum wheat cultivation. The water used in the pasta processing is very small if compared with the quantity used in the durum wheat production (0.5 m^3/ton and 1557 m^3/ton, respectively). The durum wheat water footprint thus adds up to almost 100% of the total water used. The cultivation of durum wheat, is the sub-process that accounts for most of the water footprint during the production of pasta. These results can be useful for practitioners in the agri-food industry who wish to improve the environmental performance of their final product over its full supply chain. This could be done through working with and influencing durum wheat suppliers to promote traditional rainfed farming and organic production. Organic production, which relies on green manure, compost, biological pest control, and mechanical cultivation to maintain soil productivity and control pests, excluding or strictly limiting the use of synthetic fertilizers and pesticides, could reduce soil evaporation and minimize the grey water footprint. Since the late 1990s, the Italian producers of pasta have been striving to improve the environmental performance of their own operations and, nowadays, this effort is being extended to the whole supply chain (Bevilacqua et al., 2007).

As shown in Fig. 1, Puglia and Sicily are the regions with the highest durum wheat water footprints along with the highest water scarcity levels. Basins with water stress values above 0.4

may be classified as severely water stressed (Cosgrove and Rijsberman, 2000). According to Smakhtin et al. (2004a), in these heavily exploited basins the current water use is tapping into the environmental water requirements. Both Puglia and Sicily can be considered as high-risk regions or hotspots, where the high water use may be in conflict with the environmental water requirements and consequently, there is a higher risk of environmental water scarcity. The minimum flow needed for water ecosystems cannot be guaranteed in these regions.

As shown in Fig. 4, groundwater abstraction is widespread in both Puglia and Sicily (OECD, 2006). Actually, the most serious water problem in Italy is the increase of groundwater use (National Environment Protection Agency, 2004), which represents the prevailing source of irrigation supply in this country. In particular, in Puglia and in the coastal plains of Sicily pervasive aquifer overdraft and water quality problems exist (OECD, 2006). Several aquifers in Sicily are claimed to be overexploited, such as the case of the Catania plain in eastern Sicily, with negative consequences on its hydrodynamic equilibrium and water quality (Ferrara and Pappalardo, 2004). Furthermore, the development of groundwater extraction is carried out by private users, who are largely outside the control of the water administration (OECD, 2006). In Italy, there are an estimated 1.5 million illegal wells. In eight regions (Abruzzo, Molise, Puglia, Campania, Basilicata, Calabria, Sicily and Sardinia) about 830,000 ha are irrigated legally while the total of irrigated area reaches about 1.6 million ha. In the Puglia region alone, there are an estimated 300,000 illegal wells, which provide for one third of the total irrigated area in that region (WWF, 2006). On the other hand, aqueducts are also common in these regions. The aqueduct serving Puglia, however, is riddled with so many holes that it leaks more water than it delivers according to a study by the Italian investment bank Mediobanca. The 102-years-old Acquedotto Pugliese, Europe's largest aqueduct with about 16,000 km of conduits loses 50% of the water it carries.

In southern regions, such as Puglia and Sicily, the water footprints of durum wheat are higher than in more northern regions,

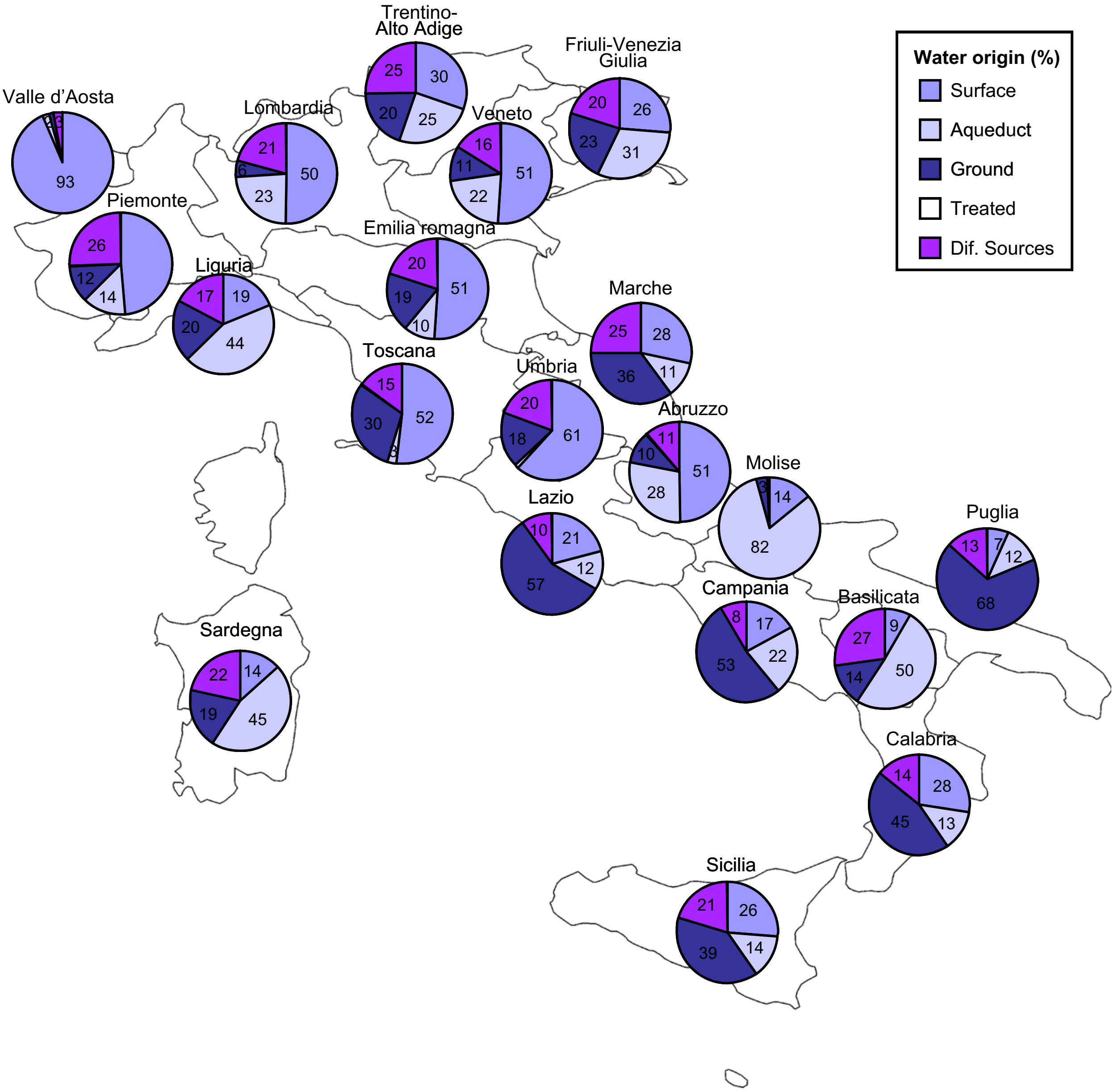

Fig. 4. Percentage of the different sources of blue water use by region. *Source*: ISTAT (2008). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

probably due to the high evapotranspiration and lower yields in these regions (Fig. 1). The large differences in average yield among the regions are mainly due to the different soil and climatic conditions (Bianchi, 1995). The northern parts of Italy are more adequate for the cultivation of durum wheat from the perspective of soil fertility but also because of the greater availability of water.

Water scarcity can also emerge from water quality deterioration (e.g. by diffuse pollution from fertilisers). The grey water footprint related to the use of nitrogen fertiliser in durum wheat production in Italy amounts to 301 m^3/ton. According to the OECD (2006), water quality problems exist in both Puglia and in the coastal plains of Sicily.

The water footprint of an Italian pizza margherita is 1216 l (assuming a pizza of 0.725 kg). Mozzarella represents about 73% of the total water use, bread wheat flower 24% and tomato puree about 3%. Concerning the wheat flour water footprint, most of the water use is for the cultivation of bread wheat. The bread wheat water footprint, however, does not seem to represent a problem since it is produced using mainly green water resources (495 m^3/ton of green water versus 125 m^3/ton of blue water) in the northern part of Italy where the water scarcity is low (Fig. 2).

With regard to the tomato puree water footprint, most of the water use is for the cultivation of industrial tomatoes mainly grown in Puglia and Emilia-Romagna (Fig. 3). The tomato water footprint represents an additional source of pressure to the already scarce water resources in the Puglia region. Highly profitable tomato production takes places mainly in the Po basin in Emilia-Romagna. In this region, the problem is not so much water scarcity but water quality. According to UNEP/DEWA/GRID-Europe (2008), the main environmental problems in the Po basin are related to chemical and organic fertiliser input, and to the use of pesticides. According to our results, the nitrogen grey water footprint related to tomato production, even though it is not the highest among the studied crops, can contribute and perhaps aggravate the already existing problem. The promotion of organic tomato production could mitigate this problem.

Finally, in the case of the mozzarella, most of the water footprint comes from the indirect water required to produce milk, namely the water required to produce the various ingredients of dairy cow feed. The impact on water resources, thus, will depend on the type and origin of dairy cow feed. Italy is the principal producer of stretched curd cheeses of which Provolone, Caciocavallo and Mozzarella are the best known (Fox, 1993). These cheeses were, traditionally, produced mainly in southern Italy and Sicily, mostly from buffalo milk. At present, however, both mozzarella and milk production are concentrated in the Po valley, often on big dairy farms (Fox, 1993). The milk production in this region amounted to 79% of total national production in 2004 (FAO, 2009). We were not able to trace the origin of the feed ingredients applied in this region.

Concerning the mozzarella production, the disposal of the dairy liquid waste (whey or stretching water – water in which the mozzarella has been stretched), represents a significant problem for the dairy industry from the environmental point of view, if we consider the great quantity produced (Faccia, 2008). According to Faccia (2008), processing of 10 kg of milk gives an average of 1–2 kg of cheese and 8–10 kg of liquid waste. A small cheese-factory – that produces about 20 m^3 of liquid waste per day – causes pollution that can be compared with that of a town with a population of about 10,000 inhabitants. Therefore, despite the important substances the whey contains, according to the current legislation (Ministerial Decree 125/06) it is considered a special waste because of its high pollution load, and the uncontrolled deposit on the soil or the discharge into superficial or underground waters is prohibited (art. 192 paragraphs 1 and 2). Although the wastewater from mozzarella processing contains valuable ingredients for making derived products with a high added value, the costs for this are considerable. In some cases, the regulations on toxic waste are ignored and toxic material is disposed in the countryside and rivers (e.g. Campania). In order to avoid serious environmental impacts, it is therefore necessary, when there are no possibilities of disposal at contained costs, to subject whey to treatment before disposal (Faccia, 2008).

In summary, the water footprint impact of pasta is most severe in Puglia and Sicily, where groundwater overexploitation for durum wheat irrigation is common. The impact of the water footprint of pizza is more diverse. It is concentrated in the first step of the supply chain of tomato puree and mozzarella, i.e. in the cultivation of tomatoes and the feed crops of dairy cows. The bread wheat used for the pizza base does not have large impacts. The water footprint impact of the tomato puree on the pizza is concentrated in Puglia (groundwater overexploitation and pollution related to tomato cultivation) and Emilia-Romagna (water pollution). The water footprint impact of mozzarella lies mostly in the effects of water use for producing the feed ingredients for the dairy cows, but we were unable to locate those impacts due to the absence of good statistics on feed origin. Mozzarella production further poses a potential threat to water quality, mostly in the Po valley, but this problem seems to be properly regulated, although possibly not fully controlled.

Water demand in Italy has been stimulated by a number of factors, such as inadequate pricing systems, lack of compliance with water related legislation as well as lack of control by the competent River Basin Authorities, mainly in relation to illegal groundwater withdrawal (WWF, 2006; Bartolini et al., 2007). The price of water in Italy does not reflect its value since it does not reflect the opportunity cost of water and environmental externalities of its use (Goria and Lugaresi, 2002; Rogers et al., 1998) and subsidies hinder the move towards new technologies. The prices of the commodities used as ingredients for pasta and pizza do not reflect water scarcity in Italy, so that there is little incentive to prevent excessive consumption or waste or to encourage the efficient allocation of water resources. Raising water tariffs and levying effluent or pollution charges can play significant roles in improving economic efficiency and environmental sustainability of water use (Rogers et al., 1998). Improving Italian irrigation schemes and water collection technology is crucial to limiting the use – and waste – of water. Concerning the lack of compliance with water related legislation, Italy has been found not to comply with the EU Water Framework Directive, by inadequate or lack of reporting of water pollution, inadequate or lack of wastewater treatment (e.g. mozzarella), insufficient designation of sensitive areas and national nitrogen surpluses in regions of Italy of the order of 100–150 kg N/ha yr (e.g. industrial tomato 110 kg N/ha) (EC, 2010). In Italy (north–east) a significant proportion of measured concentrations in ambient water bodies were between 10 and 25 mg NO_3^-/l, which points at a serious risk of eutrophication (ibid).

There are agricultural subsidies that support production and/or the development of irrigation systems, regardless of water availability. The EU Common Agricultural Policy (CAP) has led to increased water consumption through production-related subsidies which provoked a shift from traditional rain-fed crops, such as wheat, to irrigated cultivation in Italy and other southern EU member states (Brouwer et al., 2003). Although the CAP reforms in the last few years have introduced some regulations (CE 1782/2003, CE 796/2004, CE 1698/2005) towards new approaches for EU agricultural funding (decoupling subsidies and production volume, compliance), in practice national implementations are weakening these changes. It remains to be seen if and how the regulations will be implemented by the member states over the long run.

Businesses can play a role in reducing the water footprint impact of pasta and pizza, not only by reducing the water consumption and pollution in their own operations, such as in the case of the mozzarella waste disposal, but mainly through influencing and engaging with wheat, tomato and milk suppliers that for example promote rainfed and organic agriculture. Businesses can also change to other suppliers (for instance to tomato producers in the north) or transform their business model in order to incorporate or better control their supply chain. They can disclose their water footprint, management strategies and actions (e.g. through a water label or by making annual business water footprint accounts and setting measurable reduction targets) so that the other stakeholders, such as governments and consumers are informed.

Product transparency is a precondition for consumers to be able to make well-informed decisions on what to buy. Information on the water footprint can increase awareness about the huge volume of water used to produce different food items and about related environmental impacts. Hitherto consumers have generally dealt with their direct water footprint (home water use) by installing water saving toilets, applying a water-saving showerhead, closing the tap during teeth brushing, using less water in the garden and by not disposing of medicines, paints or other pollutants down the sink. However, it is a fact that the indirect water footprint of a consumer is generally much larger than the direct one. In Italy the awareness of the water footprint of pasta and pizza can help address the water scarcity problem. Informed consumers can reduce the impacts of their consumption through selecting the commodities that have a relatively low water footprint impact or that have a footprint in an area that does not have high water scarcity. Since adequate product information is generally not available in the world of today, an important thing consumers can do now is ask for product transparency from businesses and regulation from governments.

7. Conclusion

On average, every Italian uses about 380 l of water a day for domestic purposes, but actual consumption is 17 times higher if we take into account the water footprint used to make the food Italians eat and the clothes they wear. The total comes to some 6400 l of water per capita every day (Hoekstra and Chapagain, 2008). This is nearly double the world average and among the highest figures in the world. The water footprint of Italian pizza margherita is about 1216 l. The water footprint of pasta is about 1924 l/kg.

Water mismanagement is still a widespread issue in Italy. Illegal water users are common in Puglia and Sicily where the water footprint of durum wheat and tomato is high and water is scarce. Illegal water abstraction is a major issue for Italy, with estimates of about 1.5 million illegal wells (300,000 in the Puglia region alone). Furthermore, Italy's south and islands have scant resources, as well as very high leakage rates in the supply system. The price of water does not reflect its value and subsidies hinder the move towards new technologies. The prices of the commodities used as ingredients for pasta and pizza do not reflect water scarcity in Italy, which means that there is little incentive to prevent excessive consumption or to encourage the efficient allocation of water resources. Improving Italian irrigation schemes and water collection technology is crucial to limiting the use – and waste – of water. Raising awareness among consumers on the water footprint of the different types of commodities and sources could have an equally significant impact.

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