Papeles de Agua Virtual

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SUMMARY

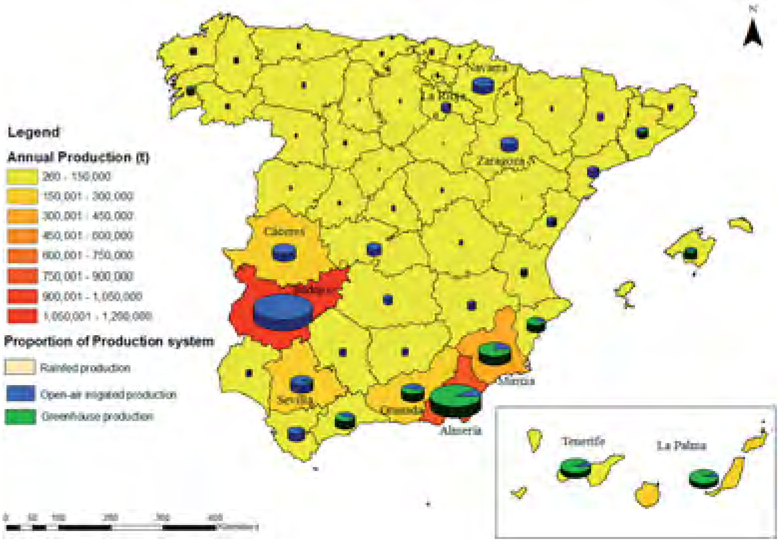
The water footprint is an indicator of water use that looks at both direct and indirect water use of a consumer or a producer. The present study analyses the green, blue and grey water footprint of tomato production in Spain. It assesses the water apparent productivity between different production systems and seasons. It also compares the productivities of surface and groundwater and evaluates the virtual water of tomato exports. The total water footprint of 1 kilogram of tomatoes produced in Spain is about 236 litres per kilogram as a national average, ranging from 216 to 306 litres per kilogram. The water footprint of fresh tomatoes varies in the different locations mainly depending on the local agro-climatic character, total tomato production volumes and production systems. The Spanish average green water footprint component amounts to about 5%, the blue component 36% and the grey component 59%. The differences in the water footprint between production systems are notable (open-air - rainfed or irrigated- versus greenhouse). Rainfed open-air tomato production has by far the highest water footprint with 966 l/kg, of which 84% is grey water footprint. The grey footprint of irrigated systems is, in comparison to that of rainfed systems, much lower, mainly due to the higher yields of these production systems. The major producing provinces in Spain have in general low water footprints in terms of l/kg compared to the average of the rest of the provinces, but a much higher total water footprint in absolute terms (hm ^{3}). This is because these provinces produce overwhelmingly the most part of the national production. The green and blue water apparent productivity of the tomato production ranged from 2.1 €/m ^{3} for rainfed systems to 3.1 €/m ^{3} of open-air irrigated systems and 7.8 €/ m^3 for greenhouse production. By season, tomato produced in the middle season (June to September) rendered the lowest apparent water productivity with 2.7 €/m^3. By contrast, tomatoes produced in early (January to May) or late season (September to December) rendered higher apparent water productivities, 7.5 and 9.5 €/l respectively. In relation to the origin of water, groundwater production presented a higher blue water apparent productivity than that of open-air irrigated production, around 7 €/m^3 compared to 3 €/m^3. When analysing the exports of tomato the yearly amount of virtual water exported through the tomato exports is 4, 88 and 134 hm^3 of green, blue and grey water respectively, with an average water apparent productivity of 8.81 €/m^3.

1. INTRODUCTION

In a context where water resources are unevenly distributed and, in regions where flooding and drought risks may become more severe, enhanced water management is a major challenge not only to water users and managers but also to final consumers, businesses and policymakers in general. From a global perspective, about 86% of all water is used to grow food (Hoekstra and Chapagain, 2008). Parallel to this, food choices can have a big impact on water demand. From the production perspective, agriculture has to compete with other water users like the environment, municipalities and industries (UNESCO, 2006).

In Spain, tomato production represents 5% of the gross national agricultural production with a yearly average production of about 4 million tons in 62,939 ha. In economic terms, tomato production represents a 6.6 % of the gross national agricultural production in the study period (MARM, 2010b). Of this production, around 25% is exported each year, mainly to the European Markets as fresh tomato (Reche, 2009). Tomato production in Spain represents 1.5% of the total Spanish water footprint (Garrido *et al.,* 2010). The main producing areas are the Guadiana Valley in southwest Spain, and the southeast corner in the provinces of Almería, Murcia and Granada (Figure 1). These two regions are quite different in their production methods. The Guadiana valley produces almost exclusively open-air, irrigated tomatoes (Campillo, 2007) for the food industry (i.e. input for tomato sauce and powder transformation), using surface water from the Guadiana valley (CHG, 2008; Aldaya and Llamas, 2009), whereas the southeast region, mainly the coastal plain of Almería province, has developed the highest concentration of greenhouses in a particular area of the world (Castilla, 2009). Its dynamic production has evolved from primary greenhouses to more complex and developed growing systems that produce high quality horticultural crops for export throughout the year (García 2009), almost exclusively out of groundwater (Regional Government of Andalusia 2003). Along these two regions, tomato production was traditionally significant in other parts of the country, where, although declining, tomato production is still impor-

FIGURE 1. *Tomato producing provinces with the proportion of production and system in each province. The size of the pie charts is proportional to the annual production of the province*



Source MARM (2009).

tant. These regions include the Canary Islands, the Mediterranean coast (Alicante, Valencia, Castellón and Baleares provinces) and the Ebro valley. In these areas, especially in the Canary Islands and the Ebro valley, this crop has a significant importance for the regional economy (Maroto, 2002; Suárez, 2002).

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). The water footprint is a comprehensive indicator of freshwater resources use, complementary to measures of direct water withdrawal. The water footprint of a product is the volume of freshwater used to produce the product, measured along the full supply chain. It is a multi-dimensional indicator, showing water consumption volumes by source and polluted volumes by type of pollution; all components of a total water footprint are specified geographically and temporally (Hoekstra *et al.*, 2009). The blue water footprint refers to consumption of blue water resources (surface and groundwater) along the supply chain of a product. 'Consumption' refers to loss of water from the available ground-surface water body in a catchment area. This fraction that evaporates is incorporated into a product, or returns to another catchment area. The green water footprint refers to consumption of green water resources (rainwater stored in the soil as soil moisture). The grey water footprint refers to pollution and is defined by the volume of freshwater that is required to assimilate the load of pollutants to meet existing ambient water quality standards.

The present study analyses the water footprint of tomato production in Spain. In particular, it focuses on the green, blue (surface and groundwater) and grey water footprint of tomato production in the different Spanish provinces. Different types of tomato production systems are analysed: open-air (irrigated and rainfed) and greenhouse. For each of them, the respective water footprint was studied in the different times of the year; early, middle and late season. To complete the analysis of the tomato sector with a socio-economic perspective, evaluations of apparent water productivity (€/m^3) and virtual water exports of tomato are also reported.

2. METHOD AND DATA

The present study estimates the green, blue and grey water footprint of 1 kilogram of tomato fruit produced in Spain following the method described by Hoekstra *et al.* (2009). In the study, the tomato production in the different Spanish provinces was considered, distinguishing production throughout the year as well as between growing systems. The study focuses on the production stage, that is, the cultivation of the product, from sowing to harvest. The study period selected was 1997-2008. The water footprint was calculated for each year distinguishing the green, blue and grey water components.

This study distinguishes the three water footprint components: green, blue and grey.

$$WF = WF_{green} + WF_{blue} + WF_{grey} \qquad E\ [1]$$

in which:

WF = the water footprint (litres/product).

WF_{green} = the green water footprint (litres /product).

WF_{blue} = the blue water footprint (litres /product).

WF_{grey} = the grey water footprint (litres /product).

Due to the differences in growing system (open-air and covered), the methodology for calculating the green and blue water footprint will be presented separately. The methodology for calculating the grey water footprint was common to both production systems.

2.1. Water footprint calculation of tomato production in open-air systems

The water footprint of open-air tomato (rainfed or irrigated) has been calculated distinguishing the green and blue and grey water components. The green and blue water evapotranspiration has been estimated using the CROPWAT model (FAO, 1998; FAO, 2009a). Within this model, the 'irrigation schedule option' was applied, which includes a dynamic soil water balance and keeps track of the soil moisture content over time. The calculations have been done using climate data from representative meteorological stations located in the major crop-producing provinces, selected depending on data availability. Monthly reference evapotranspiration (ET_o) and precipitation for each of the provinces was obtained from the National Meteorological Agency (AEMET, 2010). When data were missing, it was completed with the Integral Service Farmer Advice (MARM 2010a). The total crop area and production for each province were obtained from the Agricultural and Statistics Yearbook for each of the studied years, distinguishing growing systems and growing periods (MARM, 2010b). In the case of the year 2008, since data on seasonal production was not available, the same distribution as in 2007 was used. Data on planting dates and growing length was taken from the "sowing and harvesting calendar" from the Ministry of the Environment and Rural and Marine Affairs of Spain (MARM, 2002). This database includes open-air and greenhouse production. However, when the data was markedly biased towards short growing length, or was missing, the data was adjusted from that of the nearest, agronomically similar province (Appendix I).

Crop parameters required for the evapotraspiration calculation were based on FAO (1998), adjusted when more local information was found (Campillo, 2007) (Table 1).

Data on soil types was taken from the EUROSTAT soil map (CEC, 1985) at 1:1,000,000 scale. Textural classes were used to determine the soil characteristics and were classified in four categories: Sandy-Loam, Loam, Clay-Loam and Clay. Canary Islands' textural classes are based on the Dig-

TABLE 1. *Crop parameters used for the estimation of the tomato evapotranspiration in Spain*

	Initial Stage	*Development*	*Middle stage*	*Final stage*
Kc	0.6	1.25	0.8	
Root depth (m)	0.1		0.5	
Critical Depletion		0.3		
Crop height		2 m		

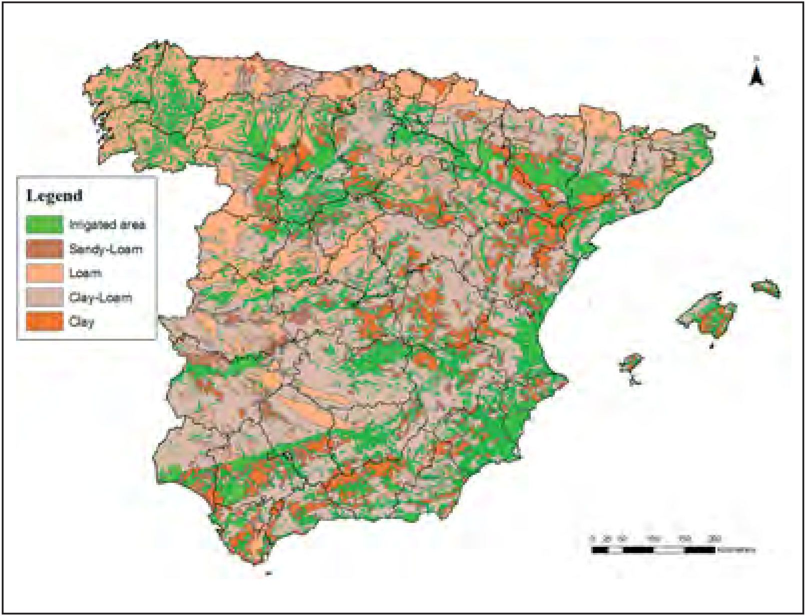
Source: FAO (1998), Nuez (1995).

ital Soil Map of the World (FAO-UN, 2007) at 1:5,000,000 scale. For each province the most frequent soil texture was applied, which was obtained by overlaying the map of irrigated areas and the soil texture map (Figure 2). The map of irrigated areas was taken from the GIS service of the Ministry of Environment and Rural and Marine Affairs of Spain (MARM, 2010c), which was contrasted with the main tomato producing regions in each province (Hoyos, 2005; Maroto, 2002; Nuez, 1995).

In the case of irrigated production, crop blue water use (mm) was obtained selecting the "irrigate at fixed interval per stage" and "refill soil to field capacity"options in the CROPWAT model considering thus an irrigation scheme that completely satisfies the crop water demand. The actual evapotraspiration (Et_a) during the entire growing period is partly fulfilled by the rain and partly by irrigation. The blue water evapotranspiration (ET_{blue}) is equal to the 'total net irrigation' as specified in the model. The green water evapotranspiration (ET_{green}) of the crop is equal to the difference between the total actual evapotraspiration and the net irrigation.

$$\begin{aligned} &ET_{blue}(irr=1)=Total\ net\ irrigation \\ &ET_{green}(irr=1)=ET_a(irr=i)-ET_{blue}(irr=1) \end{aligned} \qquad E\ [2]$$

FIGURE 2. *Soil map of Spain with the different textural classes and irrigated areas s*



Source: Own elaboration based on EUROSTAT soil map (CEC, 1985) and MARM (2010b).

Over the growing period, the blue water evapotranspiration is generally less than the actual irrigation volume applied. The difference refers to the irrigation water that percolates to the groundwater or runs off from the field.

Rainfed conditions can be simulated in the model by choosing to apply no irrigation. In the rainfed scenario (irr = 0), the green water evapotranspiration is equal to the total evapotranspiration as simulated by the model and the blue water evapotranspiration is zero:

$$ET_{blue}(irr=0)=0 \qquad E\ [3]$$

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). The blue water footprint of the crop is assumed equal to the ratio of the volume of irrigation water consumed to the crop yield.

$$WF_{green\,ijkl} = \frac{10 \times ET_{green\,ijkl}}{Y_{ijkl}}$$
$$WF_{blue\,ijkl} = \frac{10 \times ET_{blue\,ijkl}}{Y_{ijkl}} \qquad E\ [4]$$

In which:

i = year season (early, middle or late season).

j = production system (rainfed, open-air irrigated or covered).

k = province of the country.

l = year of the study period (1997-2008).

$ET_{green\ ijkl}$ = Green water evapotraspiration of the province k, under the production system j in the year season i in the year l (mm).

Y_{ijkl} = Yield of the province k, under the production system j in the year season i in the year l (t/ha).

$ET_{blue\ ijkl}$ = Blue water evapotraspiration of the province k, under the production system j in the year season i in the year l (mm).

Finally, the grey water footprint of a primary crop is an indicator of freshwater pollution associated with the production of the crop (Hoekstra *et al.*, 2009). It is defined as the volume of freshwater that is required to assimilate the load of pollutants based on existing ambient water quality standards. The grey water footprint is calculated by dividing the pollutant load (L, in mass/time) by the difference between the ambient water quality standard for that pollutant (the maximum acceptable concentration c_{max}, in mass/volume) and its natural concentration in the receiving water body (c_{nat}, in mass/volume).

$$WF_{blue\,ijkl} = \frac{10 \times ET_{blue\,ijkl}}{Y_{ijkl}} \qquad E\ [5]$$

As it is generally the case, the production of tomato concerns more than one form of pollution. In our case though, the grey water footprint was estimated only for Nitrogen. The total volume of water required to assimilate a ton of Nitrogen was calculated considering the surplus Nitrogen, which ends up leaching. The natural concentration of Nitrogen in the receiving water body was assumed negligible whereas the maximum allowable concentration in the ambient water system considered was 50 $mgNO_3^-/l$, as the concentration stated in the EU Nitrates Directive (91/676/EEC). The pollutant load considered was the excess Nitrogen based on data from the Ministry of the Environment and Rural and Marine Affairs of Spain (MARM, 2008) (Annex IV). This excess Nitrogen available for leaching or run-off (kg/ha) was then multiplied by the corresponding area in order to obtain the total load of Nitrogen (kg) reaching the surface or groundwater systems. This was divided by the ambient water quality standard and the corresponding crop yield (ton/ha) to obtain the grey water content in terms of m^3/ton. Thus, a grey water footprint was obtained for each year period and type of production system.

$$WF_{grey\,ijkl} = \frac{ExcessN_k}{LimitN \times Y_{ijkl}} \qquad E\ [6]$$

In which:

i = year season (early, middle or late season).

j = production system (rainfed, open-air irrigated or covered).

k = province of the country.

l = year of the study period (1997-2008).

$WF_{grey\ ijkl}$ = the grey water footprint of the province k, under the production system j in the year season i in the year l (l/kg).

$ExcessN_k$ = Nitrogen excess of the Nitrogen balance in the province k (kg N/ha).

Limit N = limit concentration of NO_3^- in the receiving water body according to the EU Nitrates Directive (91/676/EEC) (kg NO_3^- /l).

Although this approach is based on some assumptions, it allowed us to have a preliminary estimate of the grey water footprint for each type of production. A more local approach would be desirable if a more accurate quantification is searched.

2.2. Water footprint calculation of tomato greenhouse production

In the case of tomato production under greenhouses, the methodology was similar to that followed for the open-air systems but differed in some points. In this case, since the planting dates and crop growing period vary significantly, being decided by the producer based on climatic, agronomical and economical reasons (Reche, 2009), these two parameters were provided at the national level. The crop parameters were assumed to be the same for all the provinces and different from those of the calculus of open-air production (Table 4).

TABLE 2. *Crop parameters used for the greenhouse production*

	Initial Stage	*Development*	*Middle stage*	*Final stage*	*Total*
Period length (days)	30	35	40/155 [1]	20	125/240 [1]
Kc	0.2		1.6 [2]	0.8 [1]	
Root depth (m)	0.1		0.5		
Critical depletion			0.4 [3]		
Crop height			3 m [3]		

Source: FAO 1998; [1]Hoyos, (2005); [2]Fernandez et al, (2001); [3]Castilla (2009).

In the tomato greenhouse production, there are four main production periods (Hoyos, 2005):

— Spring short period: the plant is transplanted in January-February. The harvest period ranges from late April to early June. For the calculations the planting date was assumed to be the 1st of January. This cycle was applied to the early greenhouse production in most of the provinces.

— Spring-Summer cycle: The crop growing period ranges from early March until late summer, being the harvest period from early June until late August. The planting date was assumed to be the 1st of March. This cycle was applied to the production in the middle part of the year.

— Short autumn cycle: The plant is transplanted in late August early September and harvested from late November to February. The planting date was 1st of September.

— Long cycle: this special cycle is the most common in Almería province (Reche, 2009). The plant is transplanted in early September and harvested from December until May or June. For the calculations the planting date was assumed to be the 1 st of September with a growing period of 240 days (Table 2).

The soils used in the case of greenhouse production where assumed to be the same as in open-air production, except for the cases of Almería, Granada and the two provinces in the Canary Islands, since in these provinces, most of the greenhouse production is done on artificial soils. These soils are constructed by extending a layer of 2 cm deep of manure, clay and sand mulch above them. The parameters of these soils were obtained from the study of F.I.A.P.A. Foundation (Foundation for Agricultural Research in eh Province of Almería) on the soils of greenhouses in the Poniente region of Almería province (Gil de Carrasco, 2001), and from Bertuglia (2008) for the province of Granada. In the Canary Islands, the production is carried out also in a wide range of soils: natural, (local or transported) modified natural soils or artificial (Nuez, 1995).

The atmospheric demand inside the greenhouse was considered 70-80% of that outside (Orgaz *et al.*, 2005) and no precipitation was taken into account. Many of the greenhouses have rainwater collectors (Fernández, 2001). Mostly, rainwater harvesting refers to the collection of rain that otherwise would become runoff. Since consumptive use of harvested rainwater will subtract from runoff, we consider such water use as a blue water footprint.

2.3. Calculation of the water apparent productivity and exported virtual water

The water apparent productivity was calculated using the monthly tomato prices from the Agricultural and Statistics

Yearbook of the Spanish Ministry of the Environment and Rural and Marine Affairs for the corresponding months in each year period (MARM, 2010). The prices taken include the price of tomatoes intended for fresh consumption as well as those intended for the industry. Then, the average price for each year period ($P_{i\cdot k}$, €/t) was divided by the corresponding water footprint (WF_{ijk}, m^3/t) to obtain the water apparent productivity for each production system and year period (€/m^3).

$$WAP_{ijkl} = \frac{P_{i.kl}}{WF_{ijkl}} \qquad E\ [7]$$

In which:

i = year season (early, middle or late season).

j = production system (rainfed, open-air irrigated or covered).

k = province of the country.

l = year of the study period (1997-2008).

WAP_{ijkl} = Apparent water productivity of the province k, under the production system j in the year season i in the year l (€/m^3).

$P_{i.kl}$ = Price of the production of the province k, in the year season i in the year l (€/t).

WF_{ijkl}= Green and/or blue water footprint of the province k, under the production system j in the year season i in the year l (m^3/t).

Virtual water exports were calculated by multiplying the exported quantity (ton/yr) with its associated water footprint (m^3/ton). The province-specific tomato water footprint was estimated. Since the location of origin of traded tomatoes within Spain was not known, the amount of exported tomatoes was assigned to each province proportionally to their share of the national production. The tomato export data, in tonnes and value, was taken from the international trade database (DataComex) of the Spanish Ministry of Industry, Tourism and Commerce (MITYC, 2009).

3. THE WATER FOOTPRINT OF 1 KILOGRAM OF TOMATOES

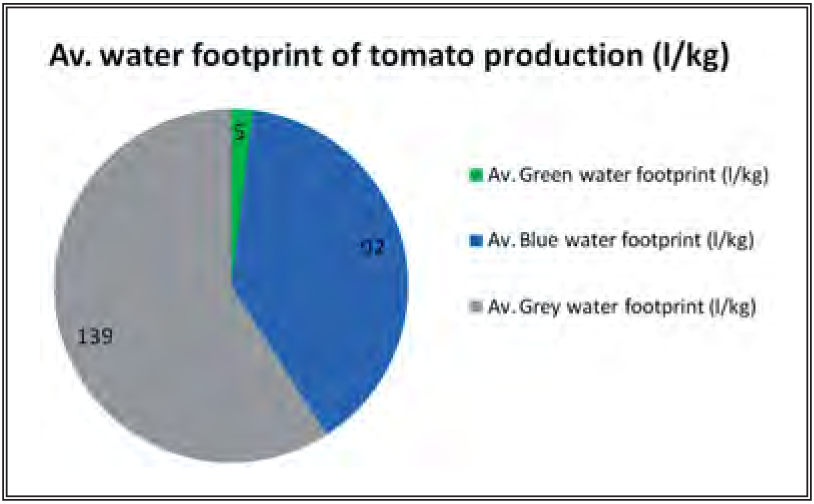
3.1. Aggregated water footprint

This section includes the analysis of the green, blue and grey water footprint of Spanish tomatoes both at national and provincial scale.

At the national level, the main component of the water footprint of Spanish tomatoes in terms of l/kg is the grey water footprint, being around 60% of the total water footprint (Figure 2). The green component was less than 2% of the total. The average green and blue water content obtained was 97 m^3/ton.

As shown in Figure 4, there are important differences when analyzing total green, blue and grey water footprints in different years at the national level. The green water component is always significantly smaller than the blue one, ranging from 15 to 25 and from 252 to 457 hm^3, respectively, while the national grey water footprint ranged from 473 to 706 hm^3 during the study period. The water footprint is directly related to the yields obtained, the water use and the total production. Thus, variation in these factors implies a variation in the water footprint, as can be seen in figure 4. These differences can be explained by the variations on the proportion of each production system, which differ significantly as will be explained in the following section.

FIGURE 3. *Average green, blue and grey water footprint of Spanish tomato (l/kg)*

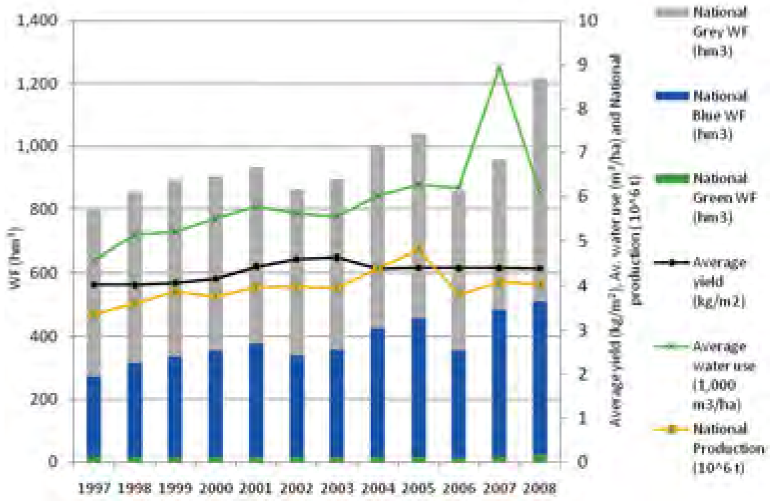


Source: Own elaboration.

There are important differences in the volume, type, and purpose of the production between the different production provinces which derive in different water footprint of tomato. Figure 5 summarizes the average green, blue and grey water footprint (l/kg) in all the Spanish provinces in decreasing order.

As shown, the water footprint varies significantly between the different provinces, and so does the proportion of the green, blue and grey components. These differences may be due to the predominant production system (open-air rainfed or irrigated vs. covered) in the province, yields obtained and climate parameters (precipitation and atmospheric evapotraspiration demand). In general, we can see that the grey water footprint is the main source of variability, whereas the green water footprint is in general terms rather low.

FIGURE 4. *National green, blue and grey water footprint (WF) (hm ^{3}, left axis), average yield (t/ha), national tomato production (1,000,000 t) and weighed water use (1,000 m ^{3}/ha) (right axis)*

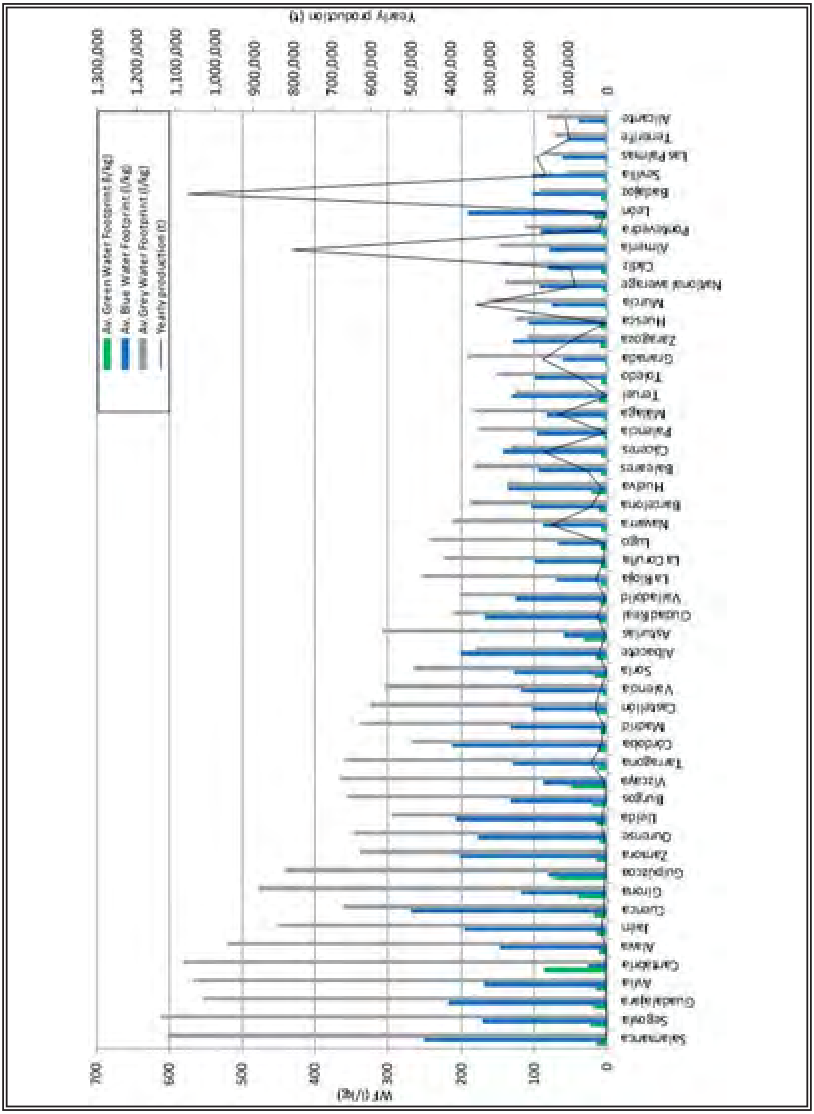


Source: Own elaboration.

As illustrated in figure 5 most of the main producing provinces have a total water footprint below the national average. This may be related to the high yields achieved in these provinces. In Figure 6 the total water footprints in hm^3 of the main producing provinces are represented, along with the average annual water footprint of all the provinces as a reference point and the percentage of national production each province represents.

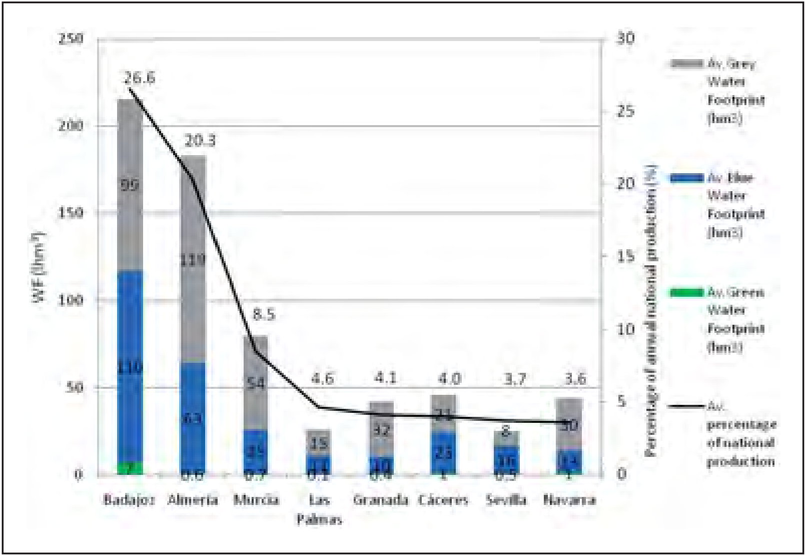
Again, we observe that the relative differences between the green, blue and grey water footprints are maintained, being the grey water footprint the most important component. The high production of Badajoz and Almería makes

FIGURE 5. *Average green, blue and grey water footprint (WF) (l/kg) in the different Spanish provinces (l/kg, left axis) and annual production (t, right axis)*



Source: Own elaboration.

FIGURE 6. *Annual green, blue and grey water footprint (hm ^{3}) of Spanish tomatoes for the main producing provinces and average percentage of national production*



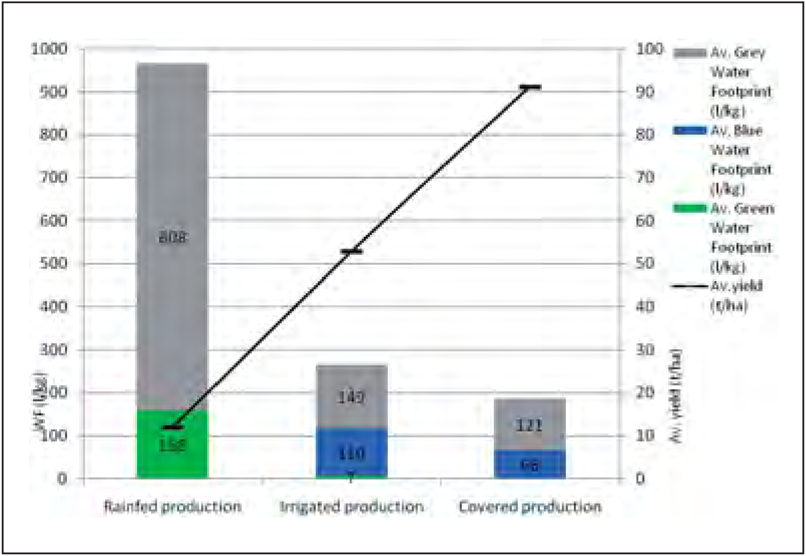
Source: Own elaboration.

the total water footprint soar, although both provinces have relatively small water footprints in terms of l /kg and high efficiencies (Figure 5). In the province of Almería most of the water bodies are at risk of no compliance with the European Water Framework Directive (Andalusian Water Agency, 2010), as so are in Badajoz the groundwater bodies and the Guadiana river itself (CHG, 2009).

3.2. Disaggregated water footprint: Analysis between production systems

The main components of the water footprint are very dependent on the production system and actually vary signif-

FIGURE 7. *Average green, blue and grey water footprint (WF) of open air (rainfed and irrigated) and greenhouse production (l/kg)*

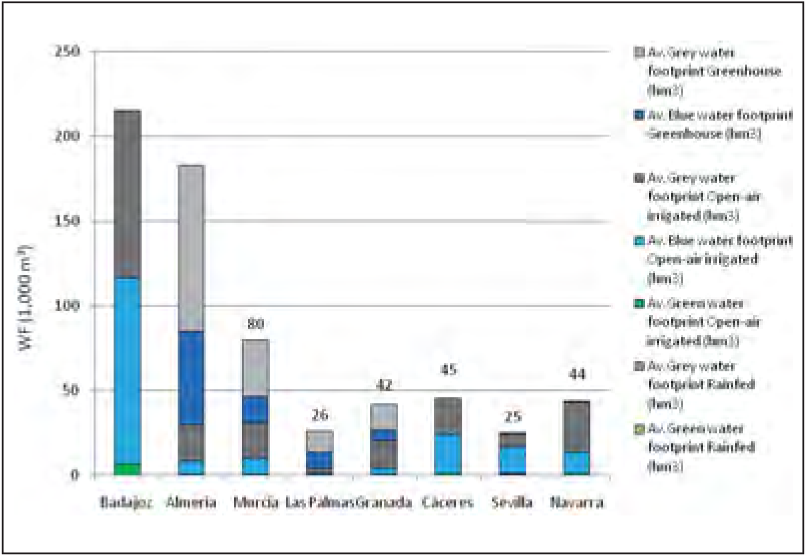


Source: Own elaboration.

icantly even within the same province. Moreover, tomato and in general horticultural crops may be grown within a wide range of production systems in mild climates. In the Spanish case, this whole range is covered, with production (albeit small) of rainfed tomato, low intensity traditional tomato, highly productive intensive open-air tomato and the most intensive, even technology-driven greenhouse production (Maroto, 2002; Nuez, 1995).

As already mentioned, there are sharp differences in the water footprint across production systems. Rainfed tomato production has by far the highest water footprint with 966 l/kg. The grey water footprints of open-air irrigated and greenhouse production systems are small in comparison to it, partly due to their much higher yields. The Nitrogen bal-

FIGURE 8. *Yearly average green, blue and grey water footprint (WF) per production system of the main producing provinces (hm ^{3})*



Source: Own elaboration.

ance data used for the calculation of the grey water footprint did not distinguish between the different production systems, being the resulting grey water footprints therefore inversely proportional to the yield. It must be noted that these results are given in terms of l/kg.

When analysing the water footprint in terms of total cubic meters, the tomato water footprint is very concentrated in a few productive areas. Figure 8 represents the green, blue and grey water footprint of the eight most productive Spanish provinces per production system and their average annual water footprint. In accordance with Figure 6, Badajoz and Almería are the two provinces with the highest total water footprint (hm ^{3}).

Table 3. *Percentage of green, blue and grey water footprint per production system of the most productive provinces (1,000 m ^{3})*

Province	*Av. Green water footprint Rainfed*	*Av. Grey water footprint Rainfed*	*Av. Green water footprint Open-air irrigated*	*Av. Blue water footprint Open-air irrigated*	*Av. Grey water footprint Open-air irrigated*	*Av. Blue water footprint Greenhouse*	*Av. Grey water footprint Greenhouse*	*Total Water Footprint (hm^3)*
Badajoz			3	51	46			215
Almería			0.3	4	12	30	54	183
Murcia			1	11	26	20	42	80
Las Palmas	0.1	0.5	0	6	10	35	48	26
Granada			1	9	39	15	37	42
Cáceres			2	51	47			45
Sevilla	0.2	1	2	64	32	0.1	1	25
Navarra			3	28	68	0.5	1	44

In all cases the green water footprint is practically negligible. It should also be noticed that the grey water footprint of both Badajoz and Almería is similar, even if the production is greater in Badajoz. This is related to the higher excess of Nitrogen in Almería, 139 kg N/ha as compared to 68 kg/ha of Badajoz (MARM, 2008) (Appendix IV).

However, different green, blue and grey water footprint proportions are found across production regions. In this regard, we see that the main component of the water footprint in Badajoz is the blue one (of the open-air irrigated production) whereas in Almería it is the grey one. Something similar happens in the rest of the provinces.

If the water footprint is an indicator of the water appropriation of a product (Hoekstra et al., 2009), its composition may help us identify the main areas of impact of its production. The main primary impact of the tomato production in Badajoz, (also in Cáceres or Sevilla) would be the high volume of blue water consumed, whereas in Almería (and Murcia, Navarra or Granada) would be the pollution of water resources. It is through this type of analysis where the water footprint reveals itself as a powerful indicator.

4. APPARENT WATER PRODUCTIVITY AND VIRTUAL WATER EXPORTS OF TOMATO PRODUCTION

4.1. Water apparent productivity of tomato production

The apparent water productivity (WAP) is an indicator of the economic performance of the water use. As shown in Tables 4 and 5 the water apparent productivity of tomato production varied from 0.025 to 36 €/m ^{3}, depending on the production system, type of water (green or blue) and on the

Table 4. *Proportion of green and blue water footprint (WF) in open-air irrigated systems and average apparent water productivity (WAP) of the main producing provinces under different production systems (€/m ^{3})*

Prov.	*Proportion of Green WF vs. Total WF*	*WF Proportion of Blue WF vs. Total WF*	*WAP of rainfed systems (€/m^3)*	*WAP of open-air irrigaton systems (€/m^3)*	*WAP of greenhouses (€/m^3)*
Badajoz	5.9	94.1		3.1	0.03
Almería	6.0	94.0		3.9	7.1
Murcia	6.8	93.2	3.8	3.9	8.8
Las Palmas	4.2	95.8	18.1	4.6	9.3
Granada	9.0	91.0		7.3	7.2
Cáceres	4.7	95.3		2.2	
Sevilla	3.1	96.9	2.6	3.1	127.4
Navarra	7.4	92.6		3.4	6.3
National average	8.7	91.6	2.1	3.1	7.8

season of the year. On average, the WAP of tomato was about 5 €/m^3. In the tomato production, the prices vary significantly depending on the time of the year, being a stimulus for off-season productions (autumn and winter) where it is possible. Tables 4 and Table 5 show the apparent productivity of water over the different production periods of the year and production systems for the main producing provinces.

As shown in table 4, greenhouse production has much higher productivity compared to open air, irrigated. The relatively low productivity of rainfed production leads to a higher water footprint of this production system. As shown in Table 5 the productivity of tomatoes in the early and late season is much higher than that of the middle season. In the Spanish case, these productions correspond mainly to greenhouse production.

However, some of the values obtained seemed to be too high to be realistic (e.g. apparent water productivity of Sevilla province under greenhouses). Apparent water productivity is calculated at market price and in correspondence with

TABLE 5. *Proportion of green and blue water footprint (WF) and average apparent water productivity of the main producing provinces in relation to the year season (€/m ^{3})*

Province	*Prop. of Green WF vs. Total WF*	*Prop. of Blue WF vs. Total WF*	*WAP (€/m^3)*	*Prop. of Green WF vs. Total WF*	*Prop. of Blue WF vs. Total WF*	*WAP (€/m^3)*	*Prop. of Green WF vs. Total WF*	*Prop. of Blue WF vs. Total WF*	*WAP (€/m^3)*
Badajoz	3	97	5.7	5	95	3.8	2	98	10.4
Almería	6	94	9.3	22	78	2.1	3	97	7.9
Murcia	28	72	9.2	24	76	3.4	24	76	10.4
Las Palmas	5	95	11.8	5	95	3.8	3	97	11.1
Granada				5	95	2.2			
Cáceres	1	99	22.7	39	61	3.0	1	99	24
Sevilla				5	95	3.3	6	94	4.7
Navarra	20	80	7.5	24	76	2.7	15	85	9.5
National average	3	97	5.7	5	95	3.8	2	98	10.4

the water footprint. In these cases, the small share of a particular production system and/or season of the provincial production is probably a source of bias. For example, in the case of Sevilla province, the average area under greenhouse is 33 ha compared to 2196 ha of tomato production or 13 ha of rainfed tomato in Las Palmas province compared to 2031 ha cultivated annually for tomato production. These small surfaces, together with recorded yields, as shown in the statistical databases should probably be reviewed.

4.2. Water apparent productivity of surface or groundwater

In this section, the water apparent productivity is analysed depending on the origin of water; ground or surface water. Information on the origin of irrigation water specifically for horticultural production in each province is not directly available. However, in some of the main productions provinces, the water is overwhelmingly of a specific origin; surface in the case of Badajoz, Cáceres and Navarra provinces (CHG, 2008) and groundwater in the case of Almería (Regional Government of Andalusia 2003) and Canary Islands (Las Palmas and Tenerife provinces). These six provinces represent 61% of the yearly national production.

The origin of the water is related to the production system. In these cases, the provinces using surface water produce around 98% of their production in open-air systems while the two provinces accounted for with groundwater produce over 90% of their tomatoes in greenhouses. As seen in Table 4 the groundwater apparent productivity is notably higher than surface water productivity. It clearly exceeds the average productivity of blue water used in irrigated agriculture in Spain, which is about 0.44 €/m^3 according to the Spanish Ministry of the Environment and Rural and Marine Affairs (MARM, 2007).

TABLE 6. *Water apparent productivity of surface and groundwater irrigation (€/m ^{3})*

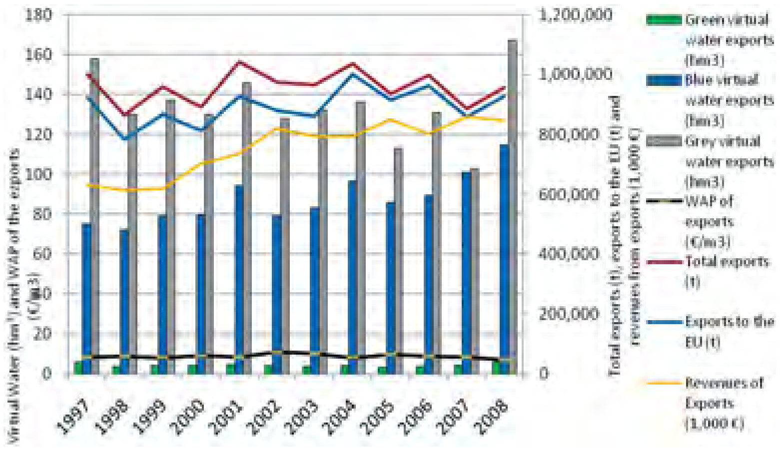
	Open-air irrigated WAP (€/m^3)	*Greenhouse WAP (€/m^3)*	*Early season WAP (€/m^3)*	*Middle season WAP (€/m^3)*	*Late season WAP (€/m^3)*	*Av. WAP €/m^3)*
Surface	3.0	6.4		2.8	4.7	3.0
Groundwater	4.1	7.6	6.5	3.7	10.5	7.2

4.3. Virtual water exports

As explained above, the production of tomatoes in Spain is to a high degree intended for export, especially in the southeastern Mediterranean provinces. In this case, the production is highly dependent on international markets and competition from other areas (García Martínez, 2009; Colino, 2002).

As an average of the study period, the yearly amount of virtual water exported through the tomato exports is 4, 88 and 134 hm^3 of green, blue and grey water respectively. Spanish tomato exports are to a very high degree directed towards

FIGURE 9. *Virtual water exports (hm^3, left axis), exported tonnes of fresh tomatoes to the world and to the EU, apparent water productivity of the exported production (€/m^3, right axis) and revenues of the tomato exports (1,000 €, right axis)*



Source: Own elaboration.

the European Union, being the UK, Germany and the Netherlands the main importers (MITYC, 2009). As an average, 93% of the virtual water exports correspond to the EU.

The average water apparent productivity of the exported production in the period was 8.8 €/m^3. This productivity is higher than the average WAP of 5 €/m^3, and closer to 7.1 €/m^3 of greenhouse production and to 7.2 €/m^3 corresponding to production using groundwater. These results are actually closely related, since the main exporting provinces, Almería, Murcia and Las Palmas, have a production mainly under greenhouses conditions, using groundwater and in early and late season (MARM, 2010b; Suárez, 2002 García, 2009). Together they represent more than 60% of the annual exports (MICYT, 2009).

5. DISCUSSION

This study provides a detailed analysis of the green, blue and grey water footprint of tomato production in Spain, both in l/kg and hm^3, for all the Spanish provinces during the period 1997-2008.

The results obtained for the average green and blue water footprint in terms of l/kg were in the range of those from other studies, whereas the values obtained for the average grey water footprint were much higher. For tomato production in Spain, Chapagain and Orr (2009) obtained values of about 14, 60 and 7 l/kg for the green, blue and grey water footprint respectively. In their study of the water footprint of tomato production in Italy, Aldaya *et al.* (2010) calculated values of 35, 60 and 19 l/kg for green, blue and grey water footprint respectively. These differences with the study of Chapagain and Orr may be related to the different data sources and assumptions made. We followed the Nitrogen

Balance of the Spanish Ministry of the Environment and Rural and Marine Affairs, which presents rather high values for excess Nitrogen (MARM, 2008), 112 kgN/ha as a national average. In the case of Chapagain and Orr, they considered the leaching Nitrogen to be 25kg/ha from open and 15 kg/ha from covered systems following Mema *et al.* (2005). As for the study of Aldaya *et al.* used an estimated leaching of 10 % of the estimated applied rate of 110 kg/ha from Fertistat database (FAO, 2010).

The main producing provinces (Badajoz, Almería and in a lesser extent Murcia, Las Palmas, Granada, Sevilla, Cáceres and Navarra) are among the most effective in terms of l/kg, having achieved large yields and productivities thanks to intensification (García, 2009; Suárez, 2002). However, due to their huge cumulative total productions their water footprints are also significantly higher than the rest. This shows the pressure on the water resources in these provinces. For instance, in Almeria most of the aquifers in the province are at risk of non-compliance with the objectives by the EU Water Framework Directive (Andalusian Water Agency, 2010), so are in Badajoz the groundwater bodies and the Guadiana river itself (CHG, 2009). As expected for a horticultural crop, the green water footprint is almost negligible, both for rainfed and for irrigated open-air production. An interesting analysis would be the study of the social revenues of this pressure.

As explained above, one of the reasons for the different water footprint results from other studies may be related to the different data used and assumptions taken to model the crop water use. A change in, for example, the length of the growing period may notably vary the crop water use and thereafter the green and blue water footprint obtained. Despite this, the values obtained here were in the same scale as those from other authors for the green and blue water footprint of tomatoes in Spain (Chapagain and Orr, 2009; Madrid and Velázquez, 2008; Aldaya and Llamas, 2009). Chapagain and Orr (2009) obtained an average green and blue water footprint of 74 m^3/t, compared to our 92 m^3/t. Madrid and Velázquez (2008) studied the Andalusia region, obtaining blue water values of 80 m^3/t, which in our case was 58 m^3/t as an average for this region. Aldaya and Llamas (2009), in their study of the Guadiana river basin calculated 6 and 115 m^3/t for the green and blue water footprint in open air irrigated tomato of the middle Guadiana basin, which corresponds to Badajoz province. In our case, the average water footprint for this production system was very similar; amounting to 6 and 103 m^3/t. Garrido *et al.* (2010) calculated an average green and blue water footprint of tomato production of 95 m^3/t.

The estimation of leached Nitrogen is a very context specific factor. With this in mind, we tried to make an approximation, based on the Nitrogen balances. The values obtained should be taken as a first approximation, by no means we consider it a definitive measurement. With this methodology, we made a number of assumptions in order to calculate the grey water footprint. First, the excess Nitrogen from the N balance data of the Spanish Ministry of the Environment and Rural and Marine Affairs are provided for the year 2006 (MARM, 2008). Excess Nitrogen therefore was assumed to be constant throughout the years for each province and between production systems. The resulting grey water footprint thus mainly depends on the yields used. Besides, the excess Nitrogen data does not distinguish between rainfed and irrigated farming. Since the rainfed production has a very limited area, its weight in the Nitrogen balance calculation is limited and may not be representative. Secondly, no temporal calculation less than a year was taken into account. Lixiviation occurs on early stages of the crop and is sharply dependent on precipitation

(Vázquez *et al.,* 2003). In their study of the N lixiviation from open air, drip irrigated tomatoes in Ebro valley, Vazquez *et al.* (2003) measured leaching N values of 155-421 kg N /ha, which were very dependent on the irrigation schedule, available N at the beginning of the season and precipitation. The value taken here for La Rioja was 161 kg N /ha. Within our scope, it was impossible to account for site- and management- specific factors, so further refinements are clearly necessary.

As for the case of the Almería province (and this can probably be generalized to production in greenhouses in southeast Spain), the N pollution may also be a consequence of large irrigation prior to transplanting and during the first 6 weeks of the crop. This irrigation, combined with large manure applications (as part of the artificial soils) and generous fertilizations may lead to high Nitrogen lixiviation (Thompson, 2007). In our case, this was indirectly reflected through the N balance data of the Spanish Ministry of the Environment and Rural and Marine Affairs, with values of about 139 N/ha. This balance however may be underestimating the amount of N available for leaching. Thompson *et al.* (2002) observed a mean value of 527 kg N /ha at 60 cm depth in greenhouses in Almería. They mentioned the variability of the data, reassuring the difficulty of making accurate estimations.

Another limiting factor of our study is that many of the main producing provinces developed and changed significantly their irrigation techniques during the study period. Irrigation technologies, schemes and applications have evolved since 1997. So have the growing technologies, such as plastic mulch in open-air production (Campillo, 2007; Macua and Lahoz, 2005), or greenhouses' technological change (García, 2009; Céspedes, 2009), which could have led to different soil moisture balances and thereafter to different crop water uses. This factor was not taken into account, so the analysis of the temporal evolution of the provinces could be improved. In any case, the scope of this study is different as we intended to cover the whole country and for a relatively long period.

The apparent water productivity (€/m^3) varied significantly not only between production systems, but also between periods of the year. The productivities were significantly higher for greenhouse production and for early and late season productions. These results are related since production in early (January to May) and late (October to December) seasons are done mainly in greenhouses, which compensates the adverse climatic conditions of these periods. Along with this, these productions are to a high degree intended for export markets and consumed in other countries (García, 2009) and therefore focus on a high-quality valuable product (Castilla, 2007). This way, Spanish water resources are virtually exported away from the country in exchange for revenues.

The differences in the apparent water productivity would probably have been sharpened if we had distinguished the prices of the tomatoes for provinces and growing systems, specially separating production for fresh consumption from production for the industry as the price of both products is very different. Still, this is reflected to a certain degree in our work. In general terms, the production areas (and the provinces) “specialise” themselves in specific productions for agronomical and socio-economical reasons.

The analysis of the apparent water productivity in relation to the origin of water did show clearly that groundwater is more productive than surface one. This is also reflected in the type of production in which each of them is used. Surface water is predominantly used in areas where the main production system is open-air irrigation. In many cases (though not exclusively) this type of production is intended for processing tomato, as in the Middle Guadiana and Ebro Valleys, which has a lower market price. Groundwater is generally used in areas where the production is intended for export and has higher prices. These results confirm previous studies that claim that agriculture using groundwater is economically more productive that using surface water (Hernández-Mora *et al.*, 2001; Llamas and Martínez-Santos, 2005). This difference can be attributed to several causes: the greater control and supply guarantee that groundwater provides, which in turn allows farmers to introduce more efficient irrigation techniques and more profitable crops; the greater dynamism that has characterized the farmer that has sought out his own sources of water and bears the full costs of drilling, pumping and distribution; and the fact that the higher financial costs farmers bear motivates them to look for more profitable crops that will allow them to maximize their return on investments (Hernández-Mora *et al.*, 2001).

Finally, as for the water footprint of tomato exports, they were assigned to each province proportionally to their share of the national production. The international trade database (DataComex) of the Spanish Ministry of Industry, Tourism and Commerce reflects where the amount of tomatoes left the country, not where they were produced. Had we applied the water footprint of the exporting province to the tomatoes exported, it would have meant an overestimation of the water footprint of the exports of the provinces with intensive international commerce while ignoring those producing the tomatoes. In any case, a more detailed analysis of the export character of particular provinces would be advisable to better quantify the water footprint other nations have in Spain.

6. CONCLUSION

The total water footprint of 1 kilogram of tomato produced in Spain is about 236 litres per kilogram, ranging from 216 to 301 litres per kilogram. The colours of the total average water footprint are as follows: 3% green, 36% blue and 58% grey. Still, these averages vary greatly depending on the crop and water management systems, location and climate.

Total largest footprints (hm^3) correspond, logically, to the two main producing provinces; Badajoz and Almería. They are well ahead of the rest of the provinces with an average of 215 and 182 hm^3 per year. In contrast, these two provinces show a high efficiency in terms of water use (l/kg), standing below the national average of 235 l/kg, with 201 l/kg for Badajoz and 228 l/kg for Almería.

The large differences of water footprints across provinces, years and production systems, indicate the relevance of evaluations carried out at the lowest possible scale. The national annual average water footprint in terms of l/kg for rainfed, open-air irrigated and greenhouse production systems was 73, 331 and 74 l/kg respectively. Greenhouse production obtains very high yields that compensate their water use.

The average water apparent productivity of tomato production was about 2, 3 and 8 €/m^3 for rainfed, open-air irrigated and greenhouse production systems respectively. We note also the important differences in the apparent water productivity throughout the year, which may be related to the much higher price of off-season productions.

Groundwater production presented a higher blue water apparent productivity than that of open-air irrigated production, around 7 €/m^3 compared to 3 €/m^3. In any case, the study in this field included only some provinces with specific and different productions. While the provinces irrigated with surface water produce mainly tomatoes intended for the industry in open-air systems, those accounted for as irrigated with groundwater produce fresh tomato for export, more valuable.

Virtual water exports related to tomato exports represent about 2.5% of total Spanish water exports, without considering grey water (Garrido *et al.*, 2010). However, in economic terms (€/m^3) tomato exports are 350% larger than the average exports (Garrido *et al.*, 2010), with 8.81 €/m ^{3} compared with the average 2.5 €/m ^{3} of the average exports. Reducing the blue and green water footprint of tomato production will not be easy because of plant physiology restrictions, but the grey water component can be significantly reduced. Should this be achieved by optimizing the timing and technique of Nitrogen applications, so that less is needed and/or less leaches or runs off, Spanish tomato exports's sustainability would significantly improve. Water footprint evaluations that omit the grey component would lead to incomplete conclusions, as they may lead to increase efficiency in direct water consumption but fail to take into account the environmental pressure related to pollution.

Finally, the water footprint contextualized in space and time can provide useful information for benchmarking, indentifying best practices and achieving a more integrated water resource management. However, to obtain a comprehensive picture, not only the (eco) efficiency in terms of m^3/ton should be considered, but also the context-specific total cumulative water footprint.

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10. APPENDIX

APPENDIX I. *Planting and harvesting dates for each season and type of soil in relation to tomato production in the different Spanish provinces*

Provinces	*Soil texture*	*Early season*		*Middle season*		*Late season*	
		Planting date	*Harvesting date*	*Planting date*	*Harvesting date*	*Planting date*	*Harvesting date*
La Coruña	Loam			May-01	Sep-01	Jun-01	Oct-01
Álava	Loam			Apr-01	Aug-01	May-01	Oct-01
Albacete	Clay-Loam			May-01	Sep-01		
Alicante	Loam	Dec-01	Apr-01	Apr-01	Aug-01	Jul-01	Dec-01
Almería	Clay-Loam	Jan-01	Apr-01	Jan-01	Jun-01	Aug-01	Dec -01
Asturias	Loam			May-01	Sep-01	Jun-01	Oct-01
Ávila	Clay-Loam			May-01	Aug-01	Jun-01	
Badajoz	Loam			Mar-01	Aug-01		
Baleares	Clay-Loam	Dec-01	May-01	Apr-01	Aug-01	May-01	Oct-01
Barcelona	Loam			Apr-01	Aug-01	Apr-01	Oct-01
Burgos	Loam			May-01	Aug-01	Jun-01	
Cáceres	Loam			May-01	Sep-01		
Cádiz	Loam	Nov-01	Mar-01	Mar-01	Aug-01	Aug-01	Nov-01
Cantabria	Loam			May-01	Sep-01	Jun-01	Oct-01
Castellón	Loam	Jan-01	May-01	Mar-01	Jul-01	Jul-01	Oct-01
Ciudad Real	Clay-Loam			May-01	Sep-01	May-01	Sep-01
Córdoba	Loam			Apr-01	Aug-01		
Cuenca	Loam			Jan-01	Aug-01		

Appendix I. *Planting and harvesting dates for each season and type of soil in relation to tomato production in the different Spanish provinces.* (Cont.)

Provinces	*Soil texture*	*Early season*		*Middle season*		*Late season*	
		Planting date	*Harvesting date*	*Planting date*	*Harvesting date*	*Planting date*	*Harvesting date*
Girona	Loam			Apr-01	Aug-01	Jun-01	Oct-01
Granada	Clay-Loam	Dec-01	Apr-01	Mar-01	Jul-01	Aug-01	Dec-01
Guadalajara	Clay			May-01	Sep-01		
Guipúzcua	Loam			Apr-01	Aug-01	May-01	Oct-01
Huelva	Clay-Loam	Dec-01	Apr-01	Apr-01	Aug-01	Jul-01	Nov-01
Huesca	Clay			Apr-01	Sep-01	May-01	Oct-01
Jaén	Loam			May-01	Aug-01	Aug-01	Nov-01
La Rioja	Loam			May-01	Sep-01	May-01	Oct-01
Las Palmas	Loam	Oct-01	Feb-01	Apr-01	Jul-01	Aug-01	Dec-01
León	Loam			Jun-01	Sep-01		
Lérida	Loam			Feb-01	Aug-01	Jun-01	Oct-01
Lugo	Loam			May-01	Sep-01	Jun-01	Oct-01
Madrid	Loam			Apr-01	Jul-01		
Málaga	Loam	Dec-01	Apr-01	Mar-01	Jul-01	Jul-01	Dec-01
Murcia	Clay-Loam	Oct-01	Mar-01	Apr-01	Aug-01	Jul-01	Nov-01
Navarra	Loam			Apr-01	Sep-01	May-01	Oct-01
Orense	Loam			May-01	Sep-01	Jun-01	Oct-01
Palencia	Loam			May-01	Aug-01		
Pontevedra	Loam			May-01	Sep-01	Jun-01	Oct-01
Salamanca	Loam			Jun-01	Sep-01		
Segovia	Clay-Loam			May-01	Sep-01		

APPENDIX I. *Planting and harvesting dates for each season and type of soil in relation to tomato production in the different Spanish provinces.* (Cont.)

Provinces	*Soil texture*	*Early season*		*Middle season*		*Late season*	
		Planting date	*Harvesting date*	*Planting date*	*Harvesting date*	*Planting date*	*Harvesting date*
Sevilla	Loam	Mar-01	Jun-13	Apr-01	Aug-01	Aug-01	Nov-01
Soria	Loam			May-01	Aug-01		
Tarragona	Loam	Feb-01	May-01	Apr-01	Aug-01	Jul-01	Oct-01
Tenerife	Loam	Oct-01	Feb-01	Apr-01	Jul-01	Aug-01	Dec-01
Teruel	Clay			Apr-01	Aug-01	May-01	Oct-01
Toledo	Loam			Apr-01	Jul-01	Jun-01	
Valencia	Loam	Mar-01	Jun-13	Mar-01	Jul-01	Aug-01	Nov-01
Valladolid	Loam			May-01	Aug-01		
Vizcaya	Loam			Apr-01	Aug-01	May-01	Oct-01
Zamora	Loam			Apr-01	Sep-01		
Zaragoza	Loam			Feb-01	Aug-01	May-01	Oct-01

* Source MARM (2010) and MAPA (2002).

Appendix II. *Average green, blue and grey water footprint of tomato production in the different Spanish provinces*

Province	*Average green water footprint (m^3/t)*	*Average blue water footprint (m^3/t)*	*Average grey water footprint (m^3/t)*
Alava	10.9	148.4	438.8
Albacete	14.6	207.4	170.8
Alicante	0.6	36.6	81.5
Almería	0.7	67.1	129.3
Avila	15.2	164.6	536.0
Badajoz	6.4	102.2	94.3
Baleares	7.6	94.0	150.7
Barcelona	10.1	103.2	156.6
Burgos	18.9	135.3	346.7
Cáceres	7.1	142.3	134.0
Cádiz	7.8	86.8	172.2
Castellón	13.8	108.2	342.7
Ciudad Real	8.6	166.5	213.0
Córdoba	11.3	205.3	271.7
La Coruña	14.4	108.9	213.6
Cuenca	15.1	275.8	349.6
Girona	41.2	128.6	439.0
Granada	2.5	55.0	158.8
Guadalajara	16.4	199.5	560.0
Guipúzcoa	89.1	80.7	402.2
Huelva	149.3	139.7	127.4
Huesca	8.6	109.8	128.2
Jaén	13.8	200.6	456.9
León	16.5	204.9	-21.7
Lleida	13.8	208.6	303.4
La Rioja	6.2	72.4	242.4
Lugo	39.6	80.5	436.5
Madrid	8.8	134.1	311.6
Málaga	3.4	78.7	156.0
Murcia	2.1	70.3	156.2
Navarra	7.9	88.7	215.6
Ourense	14.7	213.7	380.9
Asturias	28.0	58.8	226.5
Palencia	5.6	96.4	121.9
Las Palmas	0.5	58.1	76.9
Pontevedra	5.0	102.6	75.7
Salamanca	16.4	271.1	633.3

Appendix II. *Average green, blue and grey water footprint of tomato production in the different Spanish provinces.* (Cont.)

Province	*Average green water footprint (m^3/t)*	*Average blue water footprint (m^3/t)*	*Average grey water footprint (m^3/t)*
Tenerife	0.6	52.5	64.5
Cantabria	95.4	26.9	546.9
Segovia	19.1	188.1	563.4
Sevilla	3.4	104.7	58.3
Soria	16.1	159.6	315.2
Tarragona	11.4	130.8	361.8
Teruel	10.4	152.5	139.8
Toledo	6.3	100.5	152.7
Valencia	5.1	120.6	240.7
Valladolid	9.4	119.3	167.0
Vizcaya	51.1	83.8	294.0
Zamora	14.4	179.6	323.1
Zaragoza	8.1	130.9	110.6

* Source: Own elaboration.

APPENDIX III. *Average green, blue and grey water footprint of tomato production per province and production system (l/kg)*

Province	*Rainfed production water footprint (1/kg)*			*Open-air irrigated production water footprint (1/kg)*			*Greenhouse production water footprint (1/kg)*		
	Green	*Blue*	*Grey*	*Green*	*Blue*	*Grey*	*Green*	*Blue*	*Grey*
Alava				15	173	620		89	294
Albacete	206		638	12	208	176		133	100
Alicante	58		951	3	59	147		33	63
Almería				10	125	343		75	132
Avila	106		562	17	126	431		63	154
Badajoz	143		1,773	21	208	698		93	289
Baleares				6	103	92		0	14
Barcelona	123		691	10	111	221		79	124
Burgos	225		986	12	126	222		68	106
Cáceres	140		737	15	142	356		101	243
Cádiz	160		940	33	121	534		53	173
Castellón	121		846	8	113	313		90	222
Ciudad Real				9	167	211			
Córdoba	343		2,154	8	277	319		0	176
La Coruña				7	143	132		0	30
Cuenca				7	81	151		65	89
Gerona	116		768	9	216	258			
Granada	216		1,512	50	140	524		72	306
Guadalajara				6	54	235		65	161

Appendix III. *Average green, blue and grey water footprint of tomato production per province and production system (l/kg).* (Cont.)

Province	*Rainfed production water footprint (1/kg)*			*Open-air irrigated production water footprint (1/kg)*			*Greenhouse production water footprint (1/kg)*		
	Green	*Blue*	*Grey*	*Green*	*Blue*	*Grey*	*Green*	*Blue*	*Grey*
Guipúzcoa	474		2,767	13	219	533			
Huelva	253		831	10	125	384		99	221
Huesca	251		618	10	172	122		7	62
Jaén				9	106	126			
León	221		2,303	12	199	441		93	163
Lérida	117		596	18	181	416		82	163
La Rioja				7	70	258		48	155
Lugo	30		271	4	97	165		56	76
Madrid	261		0	17	194	0		137	0
Málaga	288		1,253	14	209	295		77	138
Murcia	167		1,111	14	131	442		49	146
Navarra	38		1,414	9	133	339		113	230
Ourense	130		4,297	9	119	272		61	128
Asturias	85		1,040	9	97	256		73	143
Palencia				8	89	214		54	136
Las Palmas	95		1,843	22	278	520		93	199
Pontevedra	17		190	12	131	259		75	129
Salamanca	83		265	12	113	159		81	85

APPENDIX III. *Average green, blue and grey water footprint of tomato production per province and production system (l/kg).* (Cont.)

Province	*Rainfed production water footprint (l/kg)*			*Open-air irrigated production water footprint (l/kg)*			*Greenhouse production water footprint (l/kg)*		
	Green	*Blue*	*Grey*	*Green*	*Blue*	*Grey*	*Green*	*Blue*	*Grey*
Tenerife	204		2,126	14	254	610		244	439
Cantabria	296		2,307	16	184	594		100	326
Segovia	140		500	3	107	54		3	38
Sevilla	63		304	16	129	265			
Soria	239		1,636	11	131	357		64	191
Tarragona				5	71	134		52	66
Teruel				12	153	148		31	28
Toledo	337		1,277	6	98	151			
Valencia	142		1,127	8	139	372		90	215
Valladolid				15	153	251		66	97
Vizcaya	199		728	18	145	376		92	196
Zamora	116		1,001	18	247	404		51	106
Zaragoza				8	129	109			
National average	172.27		1,176.76	12.35	145.94	300.23		71.35	152.39

* Source: Own elaboration.

Appendix IV. *Excess Nitrogen per province in horticultural crops*

Province	*Excess N*		
	t	*kg/ha*	*% input*
La Coruña	624	94.6	42.8
Alava	127	165	21.9
Albacete	1032	60.8	36
Alicante	1189	106.8	34.9
Almería	6414	139.5	34.4
Avila	132	172.7	56.7
Baleares	247	108.9	38.7
Badajoz	1542	63.3	24.5
Barcelona	535	97.6	37.8
Burgos	92	104.2	41.9
Cantabria	76	156.7	49.6
Castellón	714	149.6	50.3
Ciudad Real	1476	100.4	40.4
Cuenca	470	104.1	45.4
Cáceres	387	76.2	30.9
Cádiz	1033	81.2	26.9
Córdoba	914	101.2	42.5
Girona	295	195.9	54.3
Granada	2959	168.3	48
Guadalajara	77	155.5	58.1
Guipúzcoa	67	108.1	67.2
Huelva	1240	44.4	31.8
Huesca	174	82.2	39.4
Jaén	490	147.3	53.6
La Rioja	1137	161	51.2
Las Palmas	332	84.1	27.3
León	–2	–5.6	–4.3
Lleida	235	116.7	40.1
Lugo	557	136.9	44.5
Madrid	715	159.6	57.8
Málaga	1432	127.2	39.8
Navarra	2279	140.2	47.3
Ourense	313	107.5	40.3
Asturias	109	119.9	45.2
Palencia	44	118.2	45.2
Pontevedra	162	57.9	22.8
Murcia	6662	124.2	42.1

APPENDIX IV. *Excess Nitrogen per province in horticultural crops.* (Cont.)

Province	*Excess N*		
	t	*kg/ha*	*% input*
Tenerife	187	69.2	29.6
Salamanca	52	128.9	57.7
Segovia	772	208.4	42.9
Sevilla	451	43	18.1
Soria	54	85.8	34.7
Tarragona	718	154.2	48.1
Teruel	6	53.6	22.4
Toledo	727	86.5	40.2
Valencia	1402	157.1	45.1
Valladolid	577	102.5	33.7
Vizcaya	130	104.8	45.3
Zamora	106	124.3	47.1
Zaragoza	286	70.5	32.1

* Source: MARM (2008).

Appendix V. *Average monthly prices for fresh tomatoes (€/t)*

	€/t											
	1997	*1998*	*1999*	*2000*	*2001*	*2002*	*2003*	*2004*	*2005*	*2006*	*2007*	*2008*
January	314	536	595	566	465	758	510	431	901	345	758	378
February	251	543	424	538	421	832	563	486	755	305	569	386
March	448	545	437	943	434	1290	741	664	769	449	748	569
April	476	508	528	817	496	888	805	480	1271	945	908	606
May	380	395	396	298	369	472	639	469	896	617	346	583
June	236	313	366	472	643	287	371	452	406	302	493	267
July	275	284	335	366	432	258	234	397	394	548	498	189
Augoust	176	154	166	229	156	207	246	159	358	568	418	218
September	179	159	172	215	157	231	448	184	266	569	437	277
October	274	371	343	373	295	609	779	336	398	470	691	456
November	599	553	519	862	492	492	681	784	350	446	759	633
December	850	748	528	826	720	596	674	844	537	642	634	723
Earlyseason	374	505	476	632	437	848	652	506	918	532	666	504
Middle season	216	227	260	320	347	246	324	298	356	497	461	238
Late season	574	557	464	687	502	566	711	655	428	519	694	604

* Source MARM (2010).

APPENDIX VI. *Exported tonnes of raw tomatoes from Spain (t) and value of the exports (€)*

Year	*1997*	*1998*	*1999*	*2000*	*2001*	*2002*	*2003*	*2004*	*2005*	*2006*	*2007*	*2008*
Exported tonnes	996,748	877,264	958,418	891,750	1,041,114	973,913	965,655	1,036,606	936,848	997,503	884,244	957,600
Value of exports (€)	628,898	614,214	621,112	704,398	737,254	822,222	794,106	796,036	850,271	804,095	859,764	848,800

* Source: MITYC (2009).

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